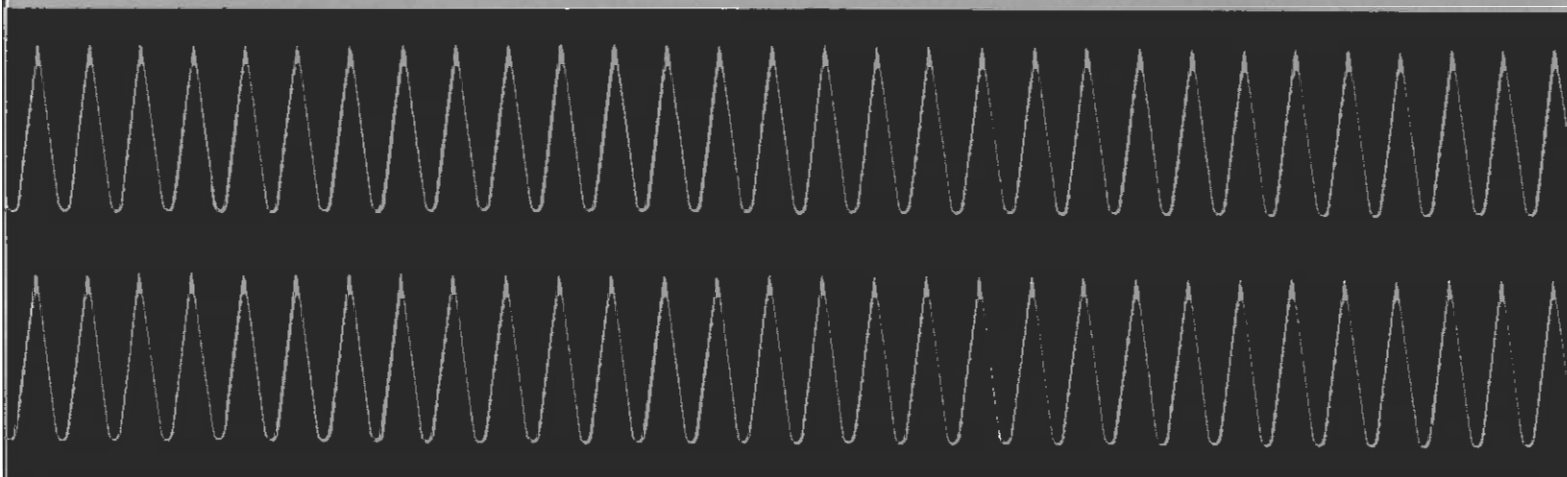


**Proceedings of the Research
Symposium on
Communication Sciences
and Disorders and Aging**



ASHA REPORTS

NUMBER 19 A PUBLICATION OF THE AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION

**PROCEEDINGS OF THE RESEARCH SYMPOSIUM ON
COMMUNICATION SCIENCES AND DISORDERS AND AGING**

Proceedings of the Research Symposium on Communication Sciences and Disorders and Aging
ISSN 0569 8553

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**PROCEEDINGS OF THE RESEARCH SYMPOSIUM ON
COMMUNICATION SCIENCES AND DISORDERS AND AGING**

Edited by
EVELYN CHEROW

ASHA Reports 19 (ISSN 0569-8553)

AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION

Rockville, Maryland

October 1990

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“There is perhaps no more fundamental issue in the life sciences than the nature of human aging. Clearly, research on aging at the applied and basic levels should be given a high priority in all developed countries, as we need to understand the facts about the relationship between age and productivity and the untapped potentials in older populations.”

James E. Birren
Productive Aging, 1985, p. 30

“... If you want to live to be over 100, you’ve got to have a positive attitude. If I say so myself, I have a positive attitude. I figure I’m 87-years-old and I’ve had a wonderful life, and I see no reason why the next half shouldn’t be as good. Anyway, I’m going to stick around and find out.”

George Burns
How to Live to Be 100 or More,
1983, p. 169

PREFACE

The facts speak for themselves and the litany is now a familiar one. By the year 2000, the population of the world over the age of 60 years will have doubled. The U.S. Congress, the Health Care Financing Administration that administers Medicare and Medicaid programs, the members of the American Association for Retired Persons (more than 30 million), professionals in health care and related fields, Madison Avenue, university faculty, and the auto industry, (the list is endless), are scurrying to assess this heterogeneous group's wants and needs in order to maximize their independence and ensure their productive aging.

Communication not only provides the vital link that keeps us connected to our individual communities and the world, but also communication reflects our humanity. Yet, predictions indicate that with the growth of the population, those persons over 65 with some degree of hearing impairment will increase by 102% and those with speech and language disorders, by 54%. The theoretical concept of "normal aging" presupposes that one can ward off or prevent specific disease processes that render us vulnerable to communication disorders. Certainly, prevention and conservation are doctrines that professionals in communication sciences and disorders promote. However, until the "elixirs" are found to eliminate all disease or restore lost communicative function, the demographic imperative urges us to investigate with vigor how better to prevent, diagnose and treat hearing, speech, and language problems associated with the aging process and related degenerative processes.

In this spirit, the Scientific and Professional Programs Board of the American Speech-Language-Hearing Association (ASHA) recommended to the Executive Board that the Association sponsor a research symposium on communication sciences and disorders and aging and publish the conference proceedings. The symposium was approved and subsequently, conducted in September, 1988 at the Capital Hilton Hotel in Washington, DC. The Symposium Planning Committee chose an interdisciplinary model for the symposium as the research questions posed in gerontology are complex and require such a multiple perspective if our research questions and answers are to be realistic and meaningful. The collective efforts of a faculty representing basic and applied researchers from hearing and speech science, neurology, sociology, psychology, exercise physiology, epidemiology, otolaryngology, and technology applications are contained here. Our goal then for this document is to inspire increased research as well as increased collaboration to further unlock the mysteries associated with human communication and "aging."

Evelyn Cherow

Acknowledgments

Communication Sciences and Disorders and Aging: A Research Symposium represented the collective planning efforts of Evelyn Cherow, Director of the ASHA Audiology Division, Cynthia Shewan, Director of the ASHA Research Division, and Barbara E. Weinstein, Chair of the ASHA Committee on Communication Problems of the Aging. Consultants to the Committee offered infinite wisdom and suggestions as to topics and speakers: Judith Cooper and Christy Ludlow from the National Institutes of Health (NIH); Leonard Jakubczak from the National Institute on Aging; and members of the ASHA Committee on Communication Problems of the Aging.

Our symposium faculty came from the ranks of “the very busy and very committed.” Scientists and clinicians volunteered to speak at the symposium as well as to author summaries of current research and their speculations about future research needs in aging and communication. Their words pose critical questions that cannot go unanswered for very long.

Representatives from the federal agencies, David Cunningham from the American Association of Retired Persons; Alfred Duncker from the Administration on Aging; Leonard Jakubczak, from the National Institute on Aging; Ralph Naunton, current Assistant Deputy Director of the National Institute on Deafness and Other Communication Disorders (NIDCD) at NIH served as members of a symposium panel on priorities in aging research. They challenged our profession to shape research directions in aging and communication science and to be ever mindful of quality of life issues.

Arnold Small, editor of *ASHA Reports*, and David Kuehn, his successor, guided the proceedings through the select peer review process to completion. Anne Watts, Sharyn Schlesinger, and Susan Karr provided ever-dependable and assiduous editing to ensure uniformity of style. Joanne Jessen, Director of ASHA’s Publications Division, expedited the publication process from budget planning to typesetting. Their knowledge and skills facilitated bringing this work to fruition.

And, on the occasion of his 80th birthday, the late Honorable Claude Pepper, rushed from a typically hectic day on Capitol Hill to address the symposium audience. He reminded us about the realities of day-to-day living for those over 65 years and for those with chronic disabilities whose access to appropriate audiology and speech-language pathology services is limited, whether through home care agencies or in long-term care settings. As he whirled into the room, he declined lunch, jumped onto the stage, delivered an emotional oratory, lauded and supported our profession and our goals, reminded us of his dependence on his hearing aids, succumbed to a round of “Happy Birthday,” blew out his candles, and away he flew. He left us with a strong impression of what’s meant by “productive aging.” His legacy as a torchbearer and, in the purest sense, as an advocate remains. Our current and future research efforts will perpetuate a similar legacy—to foster personal independence by enhancing the communication abilities of aging persons.

Evelyn Cherow

CONTRIBUTING AUTHORS

- James Bartlett, Ph.D. School for Human Development and
Callier Center for Communication Disorders,
University of Texas at Dallas, TX 75235
- Charles I. Berlin, Ph.D. Kresge Hearing Research Laboratory,
Louisiana State University Medical Center, New Orleans, LA 70112
- Fred H. Bess, Ph.D. Division of Hearing and Speech Sciences,
Vanderbilt University, School of Medicine, Nashville, TN 37232
Bill Wilkerson Hearing and Speech Center,
Nashville, TN 37212
- Robert C. Bilger, Ph.D. Department of Speech and Hearing Science,
University of Illinois, Champaign, IL 61820
- Dwight Brock, Ph.D. Biometry Office, Epidemiology, Demography and Biometry Program,
National Institute on Aging, Bethesda, MD 20892
- Harold Brody, M.D. Department of Anatomical Sciences,
State University of New York, Buffalo, NY 14260
- Scott C. Brown, Ph.D. Center for Assessment and Demographic Studies,
Gallaudet University, Washington, DC 20002
- Anthony J. Caruso, Ph.D. Orofacial Motor Control Lab
School of Speech Pathology and Audiology,
Kent State University, Kent, OH 44242
- Evelyn Cherow, M.A. Audiology Division,
American Speech-Language-Hearing Association,
Rockville, MD 20852
- Wojtek J. Chodzko-Zajko,
Ph.D. Department of Physical Education,
Kent State University, Kent, OH 44240
- Rose Dobrof, D.S.W. Brookdale Center on Aging and Hunter College,
New York, NY 10010
- Nina F. Dronkers, Ph.D. Audiology and Speech Pathology Service,
Veterans Administration Medical Center, Martinez, CA 94553
- Terese Finitzo, Ph.D. Dallas Neuroscience Associates,
Dallas, TX 75220
- George A. Gates, M.D. Washington University Medical Center,
St. Louis, MO 63110
- Aina Julianna Gulya, M.D. Department of Otolaryngology
Georgetown University Medical Center,
Washington, DC 20007
- Barry Gurland, F.R.C.P. Faculty of Medicine,
Center for Geriatrics and Gerontology,
Columbia University, New York, NY 10032

George B. Haskell, Ph.D.	Veterans Administration Medical Center, Seattle, WA 98108
Audrey L. Holland, Ph.D.	Speech Pathology Department, Eye and Ear Institute, Pittsburgh, PA 15213
Darlene V. Howard, Ph.D.	Department of Psychology, Georgetown University, Washington, DC 20057
Joel C. Kahane, Ph.D.	Department of Audiology and Speech Pathology, Memphis State University, Memphis, TN 38105
Richard C. Katz, Ph.D.	Audiology and Speech Pathology Service, Department of Veterans Affairs Outpatient Clinic, Los Angeles, CA 90013
Janice E. Knoefel, M.D.	Boston University School of Medicine, Boston, MA 02118 Geriatric Evaluation Unit/Neurology Service, Veterans Administration Medical Center, Boston, MA 02130
Michael Leung, Pharm.D., M.D.	Faculty of Medicine Center for Geriatrics and Gerontology, Columbia University, New York, NY 10032
Michael J. Lichtenstein, M.D., M.Sc.	Geriatrics Research, Education and Clinical Center, Audie L. Murphy VA Hospital, San Antonio, TX 78284
Susan A. Logan, M.Sc.	Division of Hearing and Speech Sciences, Vanderbilt University School of Medicine, Nashville, TN 37232 and Bill Wilkerson Hearing and Speech Center, Nashville, TN 37212
Lynne A. Marshall, Ph.D.	Naval Submarine Medical Research Laboratory, Groton, CT 06349
Michael A. Nerbonne, Ph.D.	Department of Communication Disorders, Central Michigan University, Mount Pleasant, MI 48859
James M. Pickett, Ph.D.	Windy Hill Lab, Surry, ME 04684
Kenneth D. Pool, M.D.	Dallas Neuroscience Associates, Dallas, TX 75220
Paul Rao, Ph.D.	Speech-Language Pathology Service, National Rehabilitation Hospital, Loyola College, Washington, DC 20010
Robert L. Ringel, Ph.D.	Audiology and Speech Sciences, Purdue University, West Lafayette, IN 47907
Barbara B. Shadden, Ph.D.	University of Arkansas and Veterans Administration Medical Center, Fayetteville, AR 72701

- Barbara C. Sonies, Ph.D. Speech-Language Pathology,
Department of Rehabilitation Medicine,
W. G. Magnuson Clinical Center,
National Institutes of Health, Bethesda, MD 20892
- Brad A. Stach, Ph.D. Department of Otolaryngology,
Baylor College of Medicine, Houston, TX 77030
- Jerry V. Tobias, Ph.D. Industrial Audiology,
Ledyard, CT 06339
- John Toner, Ph.D. Faculty of Medicine,
Center for Geriatrics and Gerontology,
Columbia University, New York, NY 10032
- Barbara E. Weinstein,
Ph.D. Department of Speech and Theatre,
Lehman College, CUNY, and Hunter/Mt. Sinai Geriatric Education Center,
New York, NY 10011
- Robert C. Wertz, Ph.D. Audiology and Speech Pathology,
Veterans Administration Medical Center, Martinez, CA 94553,
and University of California School of Medicine,
Davis, CA 95616
- Margaret A. Wylde, Ph.D. Advanced Living Systems Division,
Institute for Technology Development, Oxford, MS 38655

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OPENING REMARKS: DADDY, WHY IS IT DARK AT NIGHT? —AND OTHER MYTHS

CHARLES I. BERLIN

Louisiana State University Medical Center, New Orleans

We are witnessing a change in our population demographics. Fortunately, we are getting older; since, Peter Pan to the contrary, we can't stay young forever, we can keep our spirits young at heart. But our bodies must age. Keeping a youthful spirit and keeping alive the excitement of life for as long as we can will be easier if the quality of our lives is high.

By the year 2000, we expect that approximately one in four individuals will have significant hearing impairment requiring clinical intervention; of people over 65, it is anticipated that perhaps 10% and maybe close to 30% may have speech or language disorders related to their aging. We are at the dawn of a new age with respect to our understanding of the aging process. For years we labored under the absence of a clearcut theory, framework, or system for our understanding of aging and ontogeny—in the auditory system, for example. Now we understand that there are both morphologic and developmental changes in the auditory system that identify a continuum of normal processes from birth through death.

When scientists construct theories about things which they have not yet adequately observed or analyzed, they can often lead us in the wrong direction. They can obscure and obstruct our understanding rather than lead to better management. There are some cogent reasons that theories have this effect in these areas. As B. F. Skinner (1974) reminds us (about behaviorism):

The kind of damage caused when a theory goes wrong is especially clear in the history of medicine. Until fairly late in the 19th century, very little was known about bodily processes and health or disease from which good medical practice could be derived, yet a person who was ill should have found it worthwhile to call in a physician. Physicians saw many ill people and were in the best possible position to acquire useful if unanalyzed skills in treating them. Some of them no doubt did so, but the history of medicine reveals a very different picture. Medical practices have varied from epoch to epoch, but they have often consisted of barbaric measures — blood letting, leechings, cuppings, poultices, emetics and purgations — which more often than not must have been harmful. Such practices were not based on the skill and wisdom acquired from contact with illness; they were based on theories of what was going on inside the body of the person who was ill.

The theories were basically inaccurate.

One of the most intriguing riddles I had thought about as a 10-year-old was why the sky was dark. I asked my Dad, who calmly explained that at night the sunlight could not be seen and we were basically in a shadow, etc. My Dad, incidentally, was at the time the smartest known human in the universe and I had no need to question his wisdom. Well, as most amateur astronomers and visual psychophysicists know, the theory and hence the answer that my Dad gave me was at best misleading, and at worst so seriously flawed as to lead me to imagine a totally unrealistic universe. Because I had my question answered, at least to my 10-year-old satisfaction, I had no need to pursue a better answer. But, if you know why the sky is dark at night, then you understand exactly why a clear cut understanding of light, the human eye and the question should have led to an entirely different answer. If you think the way my Dad did, then welcome to a very large club of many bright human beings who accept what they're told with very little concern for questioning or probing the validity of the facts. At the end of the symposium, I will review the facts that taught me both that my Dad didn't know everything, but that he sure knew enough to teach his children to keep asking questions when they weren't satisfied with the answers.

I recall with warmth the common sense and wisdom that my Dad showed when

he received an unsatisfactory answer to a question from our local family physician and friend. "Irwin," he asked, "Why do I have such a miserable pain in my right shoulder?" "You have bursitis," he was told, "And it's related to your advancing age." "Nonsense," he quite rightly replied, "My left shoulder doesn't hurt, my knees and feet don't hurt, my back doesn't hurt and they're just as old as my shoulder! You'll have to come up with a better reason than that."

At the end of the symposium, I promise to come up with a better reason for the darkness of the sky at night, and I am sure that the speakers at this symposium will add more information and new postulates to the theories of aging that need new and liberating principles in order for them to generate fresh and more effective management techniques. It is time for us to realize that many infirmities like presbyopia, presbycusis, and the unfortunate non-disease called senility are semantically associated with aging, but they are no more caused by aging than high speeds in racing cars are caused by the noise their engines make.

We are gathered here today to crystallize our thinking about the aging process and communication disorders. Let us hope that our children will view our efforts as those of well-intentioned inquiring minds, working within a supportable scientific framework, which produced important new insights into the concomitants of aging. If the theories are right, and the corpus of available facts can be explained, then we can validly answer questions on aging that are not simply common sense guesses, but allow us to offer effective solutions analogous to the proper answers to the deceptively simple question, "Daddy, why is the sky dark at night?"

Finally, if you think the sky is dark at night because the light of the sun doesn't reach our sky, ask yourself how come we can see the moon at night if it's in the shadow of the earth, which in turn is supposed to be making the sky appear dark? On the last day of the symposium, a better answer will be presented. By that time you also may have heard a better answer to the question "Why do some of us lose our communication skills with age?" It should not be enough to say. . . "Because we're getting older and because Daddy said so."

A. KEYNOTE ADDRESS

Chapter 1

KEYNOTE ADDRESS. A CONCEPTUAL FRAMEWORK FOR RESEARCH IN AGING: REVELATIONS OF THE CURRENT DECADE

ROSE DOBROF

Hunter College, City University of New York

I am honored to have been selected to be a member of the faculty for the American Speech-Language-Hearing Association's research symposium on Communication Sciences and Disorders and Aging. I came to the field of aging 27 years ago when I joined the staff of the social work services department of The Hebrew Home for the Aged at Riverdale, NY, and there I learned to value deeply the work of the professions that are represented in this Association. I watched our audiologists in our very early in the morning audiology clinics engaged in systematic and skillful testing of our residents and patients, and learned of the difficulties they faced in sorting out what was real hearing impairment; what of the symptoms residents, their families, and other staff were reporting were related to hearing loss; and to what extent depression and/or dementia (which we called in those days chronic brain syndrome or organic mental syndrome) were implicated. I watched the efforts which the audiologists made to find the right hearing aid, to convince the patient that a hearing aid could help, and to teach the older person how to use it.

I watched also our speech-language pathologists and the struggles they waged in helping post-stroke patients to regain their capacities to speak. In my nine years at the home, I watched older people whom I had come to know well, and to love, and was witness to the pervasive impact on their personalities of impairments in vision, in hearing, and in speech. I watched the loneliness and anger and frustration of people who suffered these impairments; I saw how their decreased ability to hear and see behavioral cues, to read social situations, to tell us what they needed or wanted and what they were feeling, loosened their ties with the people and the world around them. And I saw and felt how the relationships between the older person and others—staff, family members, other residents, and patients—were corrupted by these impairments in vision, hearing, and speech: how often as we raised our voices in order to be heard, we also became patronizing in both tone and substance, or how often we simply withdrew from the older person who could not

hear us very well, whose eyesight was failing, who could no longer speak clearly.

I witnessed also a pessimism which too often was shared by older person, professional, and family alike. My colleague, Dr. Richard Besdine (1979), writes about the studies of Sir Ferguson Anderson that were done in a working class section of Glasgow, Scotland, in the 1950s. Sir Ferguson found that although free health care was truly available and accessible to older people in Glasgow, there was, nonetheless, "an enormous iceberg of uninvestigated, untreated disease" among the 3,000 people over the age of 55 who participated in the study. And so Sir Ferguson sought for reasons to explain why older people did not seek the medical care they clearly needed, and among the explanations he found was that "Old people pick up society's message that they must accept sickness and disability as part of aging. 'Sickold' has become one word in the language."

That message was delivered to the older people who lived in the home and internalized by them, so that they accepted *sickold* as one word, and took failing eyesight and hearing and arthritic hands and impaired gait, not as health problems about which something could be done, but as the price, the consequence of living into their 8th, 9th, and 10th decades. "So, nobody here sees so good," or "Sure I've got aches and pains, but what's the good of complaining? There's nothing that can be done," or "So, I don't hear so good now; I've heard everything at least once anyway!"

I watched our speech-language pathologists and our audiologists struggle against this pessimism, and I respected the courage and the skill and knowledge which they brought to their work. And then, as part of my work at the Brookdale Center on Aging of Hunter College, and most particularly in the program of the Hunter/Mount Sinai Geriatric Center, I have the opportunity to call Dr. Lynn Clark and Dr. Barbara Weinstein colleagues, and I have come to value enormously their skills and expertise as clinicians and professors in communications and audiology. Indeed, I owe my hearing aid and consequent improved hearing to Barbara, and so I speak not only as

one who has labored in the field of aging for almost three decades, but also as a satisfied consumer of the expert services which a member of this Association has provided to me.

One more prefatory remark before our discussion of research in the field: I speak to you also as one who is deeply concerned about the shortages of well-educated and committed professionals to work with older people now and in the decades ahead. All of the studies of personnel needs point to the present shortages as a crisis which will become a catastrophe in the years ahead if we do not now develop and implement strategies of recruitment and retention of professionals educated for and committed to work with older people. Particularly will the shortage reach catastrophic proportions in the years after 2010, when, to use Dr. Robert N. Butler's felicitous choice of words, the Baby Boom goes to Golden Pond. I commend to the attention of this Association the September, 1987, Report to Congress from the Public Health Service (U.S. Department of Health and Human Services, 1987). This Association was among the professional and provider organizations that responded to the committee's request for information to be used in preparation of the report. I call your attention particularly to pp. 81-82:

Currently audiologists spend about one-third of their time in providing service to elderly persons. In the year 2000, it is projected that a minimum of 8,300 FTE audiology personnel would be required to serve people 65 years of age and older. By 2020, the number of audiologists calculated as needed . . . will be at least 11,800, an increase of more than 40% over the 2000 figure. The estimate could increase by as much as 50%, to 17,700 FTEs in 2020, if the proportion of time spent by audiologists in treating older persons were to increase.

And

Currently, speech-language pathologists devote about 15% of their time to care of elderly persons. By the year 2000, it is projected that at least 10,900 FTE speech-language pathology personnel would be needed to serve older persons. The number is projected to increase to at least 15,800 by 2020. The estimate could increase by as much as 50%, to 23,700 FTEs in 2020, if the proportion of time spent by these personnel in treating older persons were to increase.

I take the participation of this Association in the HHS study and your sponsorship of this research symposium as clear evidence of the recognition of the members of the Association of the dimensions of the personnel shortage and also of your commitment to actions designed to respond to the problem. And for this I salute you, and I also want to add that in my judgment the proportion of time spent by speech-language pathologists and by audiologists in the provision of service to older people does need to increase, and, therefore, the high estimates of personnel requirements in both of these professions should be taken very seriously. And, finally and somewhat parenthetically, I speak to you as a woman who will soon celebrate her 64th birthday, and contrary to what some of you younger members of the Association may think, the year 2000 is just around the corner, and the year 2020 not far behind, and so actions are required now if we

are to have the capability to meet the health needs of older people in 2000 and 2020.

And now, to consideration first of a conceptual framework for research in aging, and then to a look at some of the research of this decade. You know that at least several conceptual frameworks for research in aging—as in most research—are available to us; I speak to you as one who was for most of my professional career a practitioner and administrator, and I go on the assumption that most of you would define yourselves as clinicians and/or academics, engaged in the preparation of new clinicians in the professions which you represent. If I am correct in this assumption, then you are likely to be most interested in conceptual approaches and research findings which help us understand the older people with whom we work; I believe that the "life-course" approach is a most useful theoretical formulation for our purposes. I say this believing that Robert Kastenbaum (1987) is correct when he calls our attention to the difficulties associated with attempts

to translate the life-course approach into appropriate research methodology. Whether or not the promise inherent in the life-course approach finds actualization probably depends upon the ingenuity and persistence that is brought to the research front. The usual challenges to research are faced here as well, often in an intensified form. (p. 388)

The challenges we face are typified by the ambiguities and inconsistencies in the language we use: Often "a developmental approach," "human development over the life-span," and other formulations are used interchangeably, although they may mean differences in both theory and ways to operationalize the theory. There are other problems, yet I would still argue that the life course approach has a particular utility for clinicians and, in addition, that there are researchers of "ingenuity and persistence" working to enrich the theory and to test it in empirical studies. I commend to your attention in particular the work of Glen H. Elder, Jr. (1978), and Tamara K. Hareven and Kathleen J. Adams (1982).

Hareven writes:

The life course approach is interdisciplinary by its very nature: Its heritage combines several psychological, sociological, and demographic traditions. It draws on life history analysis, on life span psychology, on the sociology of age differentiation, and on the concept of cohorts as developed by demographers. . . .

The life course approach is also historical by its very nature. Its essence is the interaction between "individual time," "family time," and "historical time." . . . the life course encompasses "pathways" by which individuals move throughout their lives, fulfilling different roles sequentially or simultaneously. . . .

Three essential features of life course analysis are particularly significant. . . : first, timing, which entails the synchronization of different individual roles over a person's career; second, interaction, which involves the relationship between individual life course transitions and changing historical conditions; and third, integration, which represents the cumulative impact of earlier life course transitions and subsequent ones. (pp. 5, 6)

In Hareven's preface to the book from which I have just quoted, she points out that

The life course approach provides a way of examining individual as well as collective development under changing historical conditions. It shifts the focus of study of human development from stages and ages to transitions and timing of life events. Rather than focusing on stages of the life cycle, a life course approach is concerned with how individuals and families made their transitions into these different stages. Rather than viewing any one stage of life . . . or any age group in isolation, it is concerned with an understanding of that stage in an entire life continuum. (p. xiii)

I think you can hear in Hareven's words the attempt that she and Elder have made to build on, but go beyond the work of Eric Erikson (1959), who analyzes the human life cycle in terms of "the specific dynamics of each of its stages." But Erikson, like Hareven and Elder, was working toward what he called "the complementary interplay of life history and history" (p. 13).¹

I believe that the differences between the Eriksonian approach and that of Elder and Hareven are substantial and consequential. Yet for our discussion today, I do not think we need to attend these differences; rather, the important point of commonality is that all three have recognized the impossibility of talking about older people without attention to the historical context into which they were born, grew up, married or didn't marry, went to work, established (or did not establish) families of their own, entered their middle and then their later years. Where they were born, into what economic and social class, what the religion and ethnicity of their parents were, their gender, their intelligence and schooling, how old they were at the times of transitions in their own families and their own lives, and, equally, how old they were at the time of major historical events during their lifetimes. (Were they too young for World War I and too old for World War II? Were they just starting out in 1929 when the crash came, or were they children whose parents saw their hard-won security lost during the Depression of the 30s? Did their children come into their majority during the cool and conforming 50s, or are they the parents of the children of the 60s?) These are the kinds of questions which the life course approach requires us to ask, and it is in our understanding of the answers to the questions that we accomplish three critical tasks: First, we are able to individualize the older people with whom we work, to understand, to use Elder's word, the "pathways" that have been traveled in becoming the people we see today; and, second, with this understanding comes the respect we must feel, if we are to be honorable and skillful clinicians, for the older person as a person, with his or her unique family and life history. And, third, and here it is to Erikson's writing that I turn, I have said that one of the differences among the researchers has to do with this matter of stages: Hareven and others write of "life course transitions," while the central focus of Erikson is on stages that are defined and

described in terms of the "encounter" between the individual and the environment and the "crisis" generated by that encounter, the psychosocial tasks which confront the individual at each stage.

Granting the differences among the researchers and granting also that Erikson's work is based largely on his clinical experiences and his reflections about those experiences, rather than on rigorously designed and conducted research, I believe that Erikson is above all a wise man, and that we can learn from his writings about ourselves and the people with whom we work. Erikson (1980) says that the polarity in old age is between "integrity" and "despair": Ego integrity in this last stage of the life cycle includes:

the acceptance of one's own and only life cycle and of the people who have become significant to it as something that had to be and that, by necessity, permitted of no substitutions . . . the lack or loss of this accrued ego integration is signified by despair and often unconscious fear of death; the one and only life cycle is not accepted as the ultimate of life. Despair expresses the feeling that the time is too short, too short for the attempt to start another life and to try out alternate roads to integrity. (pp. 104-105)

I commend to you Erikson's latest work, written with his wife, Joan, and their associate, Helen Q. Kivnick (1986): Now with both Eriksons in their ninth decade of life, this work is based on a series of interviews with a group of older people who have been subjects in a longitudinal study of child development. In it, the authors look with more specificity at the crises and tasks of the later years, at the polarity of "generativity and stagnation," at what goes into the capacity for "grand-generativity (which) incorporates care for the present with concern for the future . . ." and at the relationships among the generations.

Erikson and his coauthors deal with many issues which are familiar to you who work with older people—with their deep wish to be remembered after they are gone; with their fear of disability and the sometimes seemingly contradictory wish not to be burdens on their children along with the hope that they will not be abandoned if illness, impairment, and disability become their lot, that they can rely on their children and other family members. *Vital Involvement in Old Age* is, I think, a book worth reading and thinking about.

Now, let me summarize what I have said about our conceptual framework, make one more point about the utility of the life course approach, and then move on to a discussion of some of the important research of the past decade. I have urged consideration of the life course conceptualization, with the recognition that there are research problems still to be faced, because I believe that such a conceptualization most accurately describes older people and the process of aging and because it is a particularly congenial formulation for those who are clinicians or the teachers of clinicians. There is yet another advantage to this formulation—one which takes us for a moment outside the ken of this paper, but one which I believe is important for us to consider. For this point I am

¹See also, Erikson, Erikson, and Kivnick (1975, 1986).

indebted to my colleague, Dr. Harry R. Moody (1988). In his recent book, he writes:

Our image of old age is commonly an image of decline and deficit . . . preoccupation with the problems of the later life can blind us to its triumphs and to its unexplored possibilities. . . .

Public policy repeats this error . . . an attitude that equates old age with a "specter of decline" is itself profoundly destructive of the quality of old age itself. The negative image of old age becomes a self-fulfilling prophecy. A more balanced point of view would include attention to the unexplored positive possibilities of the last stage of life. (p. 4)

Moody points out that the absence of a "human development" approach leads inevitably to "an aging policy that responds only to problems," and then writes that

There are reasons to believe we are now at a historical turning point in our view of later life. A theoretical foundation for a new view of late-life development is now emerging from studies of lifespan development psychology. These studies demonstrate that the human capacity for learning and growth continues well into later life, provided opportunities and incentives are available. Research also shows the devastating effects that poorly designed interventions can have in fostering dependency among the old. (p. 5)

Thus my argument for the utility of the life course formulation rests on my belief that it is a useful approach in our consideration of policy issues and program design, that it saves us from, to use Moody's words, a "problem-focused approach to old age," and helps us think more creatively about policies and programs appropriate for an aging society and supportive to individuals and families in that society.

And, now to some selected areas of research of this decade which seem to me to be most consequential as you think about the connections between the communications sciences and aging. I must begin with a disclaimer, and permit me to illustrate the disclaimer with a story told by Phyllis Freeman, who was the first student to earn her doctorate at the Hunter College School of Social Work. Phyllis and her husband had two young sons, ages 5 and 7, if memory serves me correctly, and at the program celebrating Phyllis's graduation, she told of a conversation that she had overheard between her 7-year-old and one of his friends. Billy had apparently told his friend that his mother was now a doctor, and his friend asked him what kind of doctor she was. Billy wasn't sure; he knew she wasn't a doctor who cut people up, he said, because she couldn't stand the sight of blood. He thought a bit more, according to his eavesdropping mother, and then he said that his mother was the kind of doctor whom people came to see; and she talked and they talked; and then she saw them to the door, and she said something like, "Well, I hope you feel better now that we've talked, and I'll see you next week at this same time." You know that like Phyllis, I am a talking doctor, not a cutting doctor; as a social worker in the field of aging, my own research and my research interests have been in the social sciences and in my profession. Hence the disclaimer: Clearly the biomedical research of this past decade has been of extraordinary importance and produc-

tivity, but I cannot claim sufficient expertise in this area to talk about it with any kind of sophistication and mastery. Let us then recognize that the research aimed at increasing our understanding of the biology of aging² is of enormous importance, as is the biomedical research into etiology and prevention of the physical and mental health problems that are characterized by age-associated increases in prevalence and incidence.³

But it is to the research in the social sciences that I want to turn; three lines of inquiry seem to me to have been among the most productive during this and the past several decades. And, I think that you will see the importance of the life course conceptual framework to these three areas of study.

First is the research which has helped us understand the extraordinary variety that characterizes both the aging processes and older people. One of the earliest studies in this area was *Five Hundred Over Sixty* (Kutner et al., 1980), which was "a form of action research" aimed at understanding older people in their social and physical environments, in order to develop services for them. Willy-nilly, what the authors discovered were the difficulties faced in trying to talk in a useful fashion about older people as a cohort.

For some persons the period of agedness has brought with it unparalleled prestige, fame, and even fortune . . . For others, age has meant unprecedented hardship, chronic degenerative illness, mental disintegration, indigency, and institutionalization. . . . For the majority . . . who have neither fame nor wealth, on the one hand, nor "second childhood" or protracted terminal illness, on the other, old age ushers in a period of unique problems. (p. 13)

Note in these words the problem focus that Moody (1988) writes about; but Kutner and associates were writing more than three decades ago at the dawn of the aging society, and their survey was an influential piece of social science research. Even though it is now of little historical interest, it was one of the earliest works that focused on the heterogeneity of the aging population.

An exhaustive survey of the research in this area is not possible: the work of Bernice Neugarten and James Birren and Robert C. Atchley and George Maddox and Robert N. Butler and Helena Z. Lopata is surely among the most important (in addition to those whose works I have already cited). The most comprehensive and up-to-date bibliography in print, I think, is to be found in *The Encyclopedia of Aging* (Maddox, 1987). I commend this volume and its bibliography to your attention.

By necessity, the research in this area is multidisciplinary, and researchers have studied the aging process and older people from a variety of different vantage points. There has been research devoted to the personality of older people, and to the relationship between earlier experiences and adaptation to the later years (see

²See, for example, Warner, Butler, Sprott, and Schneider (1987).

³See, for example, Blazer (1982); Reisberg (1983); Cassell and Walsh (1984).

the importance of a life framework). Researchers have studied the interplay between person and environment and have worked at teasing out what factors in both seem to account for "successful aging."

One of the consequences of this research has been the recognition of the heterogeneity of the older cohort, and I want to focus on two aspects of the variations in this population. First, as life expectancy has increased and more and more people, in the United States and elsewhere, are living into their 8th, 9th, and 10th decades, there has been recognition that the older population includes at least two generations, and recognition also that it is no more accurate to speak of 65-year-olds and 85-year-olds as a cohort than it is to speak of 15-year-olds and 35-year-olds or 45-year-olds and 65-year-olds in these terms. The 85-year-old and the 65-year-old have, it is true, been together on this earth for 65 years, but in the terms of Hareven (1978) and Elder (1978), they experience their life course transitions at different times, and they experienced the historical events of their lifetimes at different points in their life courses. I need not belabor this point to this audience: You know from your own life and professional experience the necessity to recognize the generational differences among older people.

The second aspect of this heterogeneity has to do with individual differences, and, again, I think the point needs only to be made. There are, I believe, two myths about older people which are among, to use Dr. Butler's (1969) formulation, the "ageist" stereotypes that, unfortunately, continue to be pervasive in our society. According to one myth, old people become increasingly like each other and less like us as they grow older; according to the other, old people are just like they always were, only more so!

Neither myth is sustained by any research, although both permit younger people to distance themselves from their elders and to treat older people in patronizing, infantilizing ways. What the research findings of the past several decades indicate, contrary to the mythology, is that the developmental trend is toward increasing individuation and complexity, so that if we were to study a group of people who today are celebrating their 65th birthdays, we would find more variations in this group than we would if we were to study, for example, a group of 6-year-olds entering first grade today. The 6-year-olds simply haven't lived long enough, experienced enough, traveled the pathways of life enough to have developed among themselves the extraordinary variations that we would see among the 65-year-olds.

These two lines of inquiry—the one aimed at differentiating between the cohorts which constitute the older generations and the second, at differentiating among the members of one cohort—are, I am suggesting to you, among the most productive that have been followed during these decades. They illuminate our understanding of the people with whom we work and of our own aging process; they inform the policy decisions that confront us as a nation; they undergird our efforts to provide an environment in which people can grow old, to use an old-fashioned formulation, gracefully.

A second area of research that has captured the attention of researchers in the middle and later years of this century has to do with the family relationships of older people. Again, I commend to you the *Encyclopedia* bibliography (Maddox, 1987). The works of Ethel Shanas (1979), Eugene Litwak (1985), Elaine Brody (1979), Marjorie Cantor and Virginia Little (1985), Lillian Troll (1979), and Marvin Sussman (1985) are particularly important in this area.

The "social myth" about which Shanas (1979) writes is the myth that older people in our "youth-oriented," "child-centered" society live in lonely isolation, abandoned to their fate by their selfish and uncaring children. It is this myth which the research of the scholars cited above and many others has challenged, and, although the myth endures for a variety of reasons, all of the hundreds of studies of the family relationships of older people that have been done in the last three decades provide evidence that the majority of older people are members of kinship groups; that for the majority who are or have been married and have children, it is to their spouses first and, in the absence of a spouse, to their children that they turn for help if help is needed; and that the majority of never-married and/or childless older people are, if trouble comes, able to rely on siblings, nieces, nephews, cousins, and the children of cousins. Finally, with respect to children who, along with spouses, are the major providers of care to functionally disabled older people, it is clear that regardless of class, of ethnicity, even of the quality of the parent-child relationship, the majority of adult children in the United States live up to the Biblical injunction to honor their fathers and their mothers. Adult children in the United States recognize the bonds of filial responsibility, at the least, and devotion, at the most, which link them to their aged parents: They may have difficulty in articulating in behavior what filial responsibility means in the 1980s, and they may ask sometimes, "How much is enough?" and they may feel stress as members of what Brody (1979) calls the "Sandwich Generation"—the generation confronted by tasks associated with the care of dependent parents and with their roles as spouses, parents, grandparents, friends, workers, citizens—thus, the generation "sandwiched" between the older generation, their own generation, and their descendent generation. But the myth of abandonment is precisely that—a myth—and the rich research about the family relationships of older people has challenged the mythology and, I would argue, has had extraordinary and direct impact on the way policy issues are framed and on the design of public provisions and programs.

Permit me briefly to illustrate the point I am making: Once the evidence was clear that despite all of the changes in family composition, function, and structure to which we have been witness during this century, family relationships remain salient for most older people in the United States, and it is to relatives that older people turn for care, for solace, for meaning in their lives, once it became clear that it is families—not professionals and not social and health agencies and institutions—who are the major providers of care to dependent older people, then

public policy formulation began to take these realities into account. We have a long way to go in this regard: We are a nation that does not have coherent family policies, does not provide the kinds of supports that young families need, and we are a nation that has not fully recognized or responded to the needs of aged parents and, in Brody's (1979) words, "aging families." Nonetheless, we see programs in both the public and the voluntary sectors that are designed to support families as caregivers for sick or cognitively impaired or disabled older members. I would cite to you, for example, the programs aimed at providing respite and other services for family caregivers, particularly for families caring for cognitively impaired older members.

The final area of research that I think is of enormous importance has to do with ethnicity as it affects family structure and function, service organization and utilization, life course transitions, and relationships between professionals and older people *inter alia*. We remain a nation of ethnic heterogeneity, a country that still beckons to people from other nations. Again, the research in this area fits comfortably into our life course conceptualization; it has contributed enormously to our understanding of the heterogeneity of our older population; it has enriched and been enriched by the studies of the family relationships of older people; and, finally, we who are clinicians ignore it at peril to the quality of help we provide our older clients and patients and their families (see Markides & Mindel, 1987).

There are countless other areas of research which are important and which other speakers might have chosen for emphasis: My discussion is clearly more illustrative than exhaustive, and the impossibility of providing coverage to all of the research in gerontology and geriatrics during this and past decades is a sign of the extraordinary work done by hundreds of researchers who bring intelligence, skill, and commitment to their efforts to learn and to teach about older people and aging in our society.

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B. DEFINING THE POPULATION

Chapter 2

CHARACTERISTICS OF THE ELDERLY POPULATION IN THE UNITED STATES

DWIGHT BROCK

National Institute on Aging, Bethesda, MD

The United States has experienced a rapid growth in the number of older people in this century. Although the elderly composed only 4% of the total population at the turn of the century, this percentage rose to 11.3% in 1980 and may be as high as 17% by 2020. Among those 65 and over, the proportion of those in the 75 to 84 and the 85 and over age groups has, and will continue, to increase substantially. While those 85 and older made up only 4% of the population aged 65 and older in 1900 and 9% in 1980, it is projected that by the year 2020, 14% of elderly persons will be age 85 and older, and by 2040 nearly one in five older persons will be in that age group.

Dramatic changes in mortality occurring in this century have led to increased life expectancy at all ages, although the gains for older persons have come mainly in the past 40 years. The gains seen in life expectancy during this century have not been uniform for males and females and for Whites and Blacks. In 1920, the life expectancy of females in the United States was less than 2 years greater than that for males, but by 1984 the difference had increased to over 7 years. This relative improvement in female versus male survival rates has led to an elderly population that comprises many more women than men. The dynamics of this situation can be appreciated by observing that in 1950 there were 89 men aged 65 and over for every 100 women, while by 1984 the number had dropped to 67. The differences are particularly extreme at the oldest ages. In 1984, there were only 41 men for every 100 women aged 85 and older.

Family composition and living arrangements are influenced strongly by the differential mortality experienced by men and women. Overall, the most common living arrangement for an elderly person is to live with one's spouse in a household with no other persons, but this varies greatly by age and sex. For those 75 years of age and older, 65% of men, but only 19% of women have a spouse present in the household. The presence of a spouse is obviously one factor that influences the need for nursing home care.

Diseases of the heart are by far the most frequently occurring cause of death for those aged 65 and over,

leading to 44% of all deaths and causing more than twice as many deaths as the second leading cause of death, malignant neoplasms. Cerebrovascular disease is the third leading cause of death in older persons, followed by pneumonia and influenza. The decline in mortality seen in older persons in the past 40 years has in large part been due to declines in cardiovascular diseases. The decline in mortality from heart disease accounted for half of the decline in overall mortality rates between 1950 and 1979, while the decline in stroke mortality accounted for another one-fourth of the overall decline. Cancer was the only major cause of death to increase during this period, but the rise in cancer mortality was at a modest level, clearly insufficient to offset the drop in mortality due to cardiovascular conditions. This apparently has led to a postponement of death until older ages at which the population is more susceptible to mortality from cardiovascular disease, thus lessening the importance of cancer as a cause of death in older populations.

The high prevalence of chronic disease and the frequent coexistence of multiple conditions result in increasing disability and health care use as people age. Arthritis and hypertension are by far the most common chronic diseases of older persons, followed by ischemic heart disease, cerebrovascular disease, and diabetes. Heart disease is responsible for more doctor visits, hospital days, bed days, and deaths than the other major causes of morbidity in older persons, with arthritis a close second as a cause of bed days. Living longer because of increased survival from the diseases that cause death will lead to a larger population of persons susceptible to those diseases of aging that are not major causes of death but are the major causes of disability.

The use of nursing homes by the elderly varies considerably by age and sex, and statements to the effect that a given percentage of the older population resides in nursing homes are subject to misinterpretation. Most data based on surveys of current residents underestimate the lifetime risk of nursing home placement by a substantial amount. Whereas the statement that 5% of the elderly reside in nursing homes is often heard, the lifetime risk

has been estimated to be at least 25%, and, in at least one study it was estimated to be 35%.

Dementing illness has a tremendous impact on the use of nursing homes by the older population. In the 1985 National Nursing Home Survey, some 63% of the residents were estimated to have disorientation or memory impairment, and 47% had a clinical diagnosis of senile dementia or organic brain syndrome. Cognitive impairment certainly is an important component of research on aging and will increasingly be so as the older population continues to grow.

The need for long-term care is not limited to those persons who reside in nursing homes. Indeed, a study of Americans needing care at home showed that among persons aged 65 and older living in the community, an estimated 2.7 million needed help from another person with one or more activities of daily living. This is more than twice the number of nursing home residents nationwide. Here, too, cognitive impairment is an important factor, as it is in the nursing home, especially as it affects such home management activities (instrumental activities of daily living) as shopping and management of money.

With respect to sensory functioning, diminished vision and hearing are among the most obvious problems and often contribute to a loss of independence. Data from a 1977 National Health Interview Survey (NHIS) Supplement on Impairments showed rates for impaired vision and hearing increasing sharply with age. Among those aged 65 to 74, an estimated 2% could not read ordinary newspaper print, 3% could not recognize a friend across the street, and 6% were unable to hear and understand a normal voice speaking in a quiet room. Among those 85 and older, the rates were 18%, 19%, and 30%, respectively. Data from three community studies known as the NIA Established Populations for Epidemiologic Studies of the Elderly (EPESE) showed similar rates for the baseline survey year of 1982, with some variation among sites. More recent figures from the 1984 NHIS Supplement on Aging reported similar trends with age for the vision questions, but the data on hearing were not comparable with the 1977 data. In the 1977 survey, the hearing question was asked of each person when not using a hearing aid, but in 1984 persons were questioned when wearing their hearing aids. Nevertheless, vision and hearing problems are certainly major disabilities for older persons, especially those 85 and older.

Considering prospects for the future of the older population in the United States requires a look at past and future population projections for those 65 and older. In the past there has been consistent underprojection of this group, most likely because of the unprecedented declines in mortality for this segment of the population. A somewhat less conservative set of assumptions with regard to future mortality decline would provide a hypothetical "upper limit" on the size of the older population in the next century. Regardless of what assumptions are made or which projections are used, there is no question that growth of the older population will be tremendous. Along with that growth, in the absence of any increase in the prevalence of disease or disability in the elderly, the number of disabled persons is bound to increase. The challenge that is clearly before us, then, is not just to prolong life, but to have a major impact on the diseases and conditions that cause disability and loss of independence.

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Chapter 3

THE PREVALENCE OF COMMUNICATIVE DISORDERS IN THE AGING POPULATION

SCOTT CAMPBELL BROWN

Gallaudet University, Washington, DC

A large body of work documents a higher prevalence of communicative disorders for older persons in the United States than for younger people. Although some of the statistics supporting this fact will be reviewed here, it will not be the focus of this paper.

Rather, this paper attempts to demonstrate that a process-oriented analysis of the prevalence of age-associated communicative disorders provides a better understanding of the experiences of older people than a traditional comparative approach. This is true even for the "oldest old," those persons 85 years of age or over.

This paper is concerned with the aging population, not the elderly population. The distinction between the concepts of being elderly and of aging is an important one. An elderly population is a population that includes all people older than some given age. Historically, persons 65 years of age or over have been considered to be elderly. An aging population is a population that is undergoing the process of aging. *Elderly*, a relatively static concept defined by a person's age, is what a person is. *Aging*, a dynamic process, is what a person does.

On some level, the aging population is the entire population. Of course, in practical terms, it is difficult to study whether there is an aging process in children that is the first step to communicative disorders later in life; most aging studies are concerned with phenomena happening to persons in the middle or later years of life.

This paper first reviews the prevalence data for communicative disorders using a traditional approach—comparing prevalence rates between age and sex groups. Then, using hearing impairment as an example, the data are viewed for what they reveal about the age/impairment association (i.e., does age cause a disorder or is it merely correlated with a disorder?). Prevalence data for hearing loss are explored to evaluate the risk for onset, the age at onset, the severity, and the rate of progression or reversal of a given disorder.

SOURCES OF DATA

For this research, tabulations were generated from two sources of data: the 1985 National Health Interview

Survey (National Center for Health Statistics, Moss & Parsons, 1986) and the 1971–75 National Health and Nutrition Examination Survey (Rowland, 1980). These two surveys were conducted by the United States National Center for Health Statistics (NCHS).

The National Health Interview Survey, conducted annually, contains information reported from household interviews on the prevalence of chronic conditions. The conditions examined in this paper are hearing impairments, tinnitus, and speech impairments. The number of people with any one of these conditions is considered to be the population with communicative disorders. As a result, this number is less than the sum of the persons with each of these reported impairments because some people may have more than one condition.

The first National Health and Nutrition Examination Survey, HANES I, contains data for pure-tone air-conduction tests and speech-reception tests for a national probability sample of 6,913 adults, aged 25 to 74 years, tested between 1971 and 1975 (Rowland, 1980). (A few persons age 74 when first interviewed were 75 years at the time of testing. Data for these people are included with those for 74-year-old persons.) The test results can be linked to medical histories and sociodemographic characteristics reported by the respondents. The sampling procedure employed is described in greater detail elsewhere (Engel, Murphy, Maurer, & Collins, 1978; Rowland, 1980; Singer, Tomberlin, Smith, & Schrier, 1982). Each ear was tested in this way using the next list immediately following the last list used for the previous examinee.

Air conduction findings in this study are based on results for the 3,098 men and 3,659 women by age with complete results from all four tests for both ears. For the analysis of the air conduction tests, 156 persons or 2.3% of all of the respondents in the survey are excluded because they had missing data on one or more tests. Although partial data are available for some of these people, their exclusion allows for ease of statistical comparison across tests because the number of respondents (N) is the same for each test.

Speech findings are presented for the 1,169 men and 1,526 women with complete results from the four air conduction tests and the two speech reception measures for both ears. The Revised Central Institute for the Deaf (RCID) lists were used (Elkins, Cauley, & Roberts, 1975). In this paper, the measure for speech reception provides the level of amplification required to miss no more than five words from one of ten 50-word lists of RCID sentences (Rowland, 1980). The speech test results have a lower sample count than the air conduction tests. Therefore, caution is advised in comparing results from the speech tests with those of pure-tone air conduction.

A TRADITIONAL PREVALENCE APPROACH

Attempts to explore the aging process often employ data that provide snapshots of people at one point in time. In traditional prevalence approaches to data, characteristics of persons 65 years of age or over are compared to those for people under 65.

Survey Data Results

In 1985, according to the Health Interview Survey, roughly 23,220,000 people were reported with a communicative disorder. These people accounted for 9.9% of the entire U.S. population. Among persons 65 years of age or over, 30.3% were reported to have a communicative impairment, as opposed to 7.3% of those under 65.

Most of the reported communicative disorders were related to hearing loss. About 21,198,000 people were listed with a hearing impairment, accounting for 9.1% of the entire population. Tinnitus and speech impairment were not as prevalent. Roughly 6,228,000 persons were reported as having tinnitus, and 2,339,000 people were listed with speech disorders. The respective prevalence rates for these impairments were 2.7% and 1.0%.

The reported prevalence of hearing impairments and tinnitus rose with age. Among those 65 years of age or over, 29.4% were reported with a hearing impairment, versus 6.4% of persons under 65. Likewise, of those 65 or over, 9.2% were reported to have tinnitus, while only 1.8% of people under 65 were so reported.

Unlike hearing impairments and tinnitus, the reported prevalence rates for speech impairment did not increase with age in 1985. The respective rates for persons 65 or over and those under 65 years of age were 0.8% and 1.0%.

Differences in prevalence rates by age were also reflected in the age composition of persons reported with communicative disorders. Persons 65 years of age or over accounted for 35.3% of the population listed with communicative impairments. They accounted for 37.6%, 39.8%, and 9.0% of those listed with hearing impairments, tinnitus, and speech problems, respectively.

For all ages combined, men tended to predominate among persons reported with communicative disorders in

the 1985 survey. The sex ratio (the number of men divided by the number of women) among people so reported was 1.364. The highest male predominance was among those with reported speech impairments; the sex ratio was 1.676. The next highest sex ratio was 1.336, for people with reported hearing impairments. Women were predominant among those with tinnitus, where the sex ratio was 0.860.

Probably because men tend to die at earlier ages than women, the sex ratios for persons 65 or over with communicative impairments tended to be lower than those for all ages. The respective ratios for reported communicative, speech, hearing, and tinnitus impairments were 1.027, 1.045, 1.032, and 0.674. These ratios reveal a heavy predominance of women among persons 65 years of age or over with tinnitus and an almost even balance between men and women for the other impairments.

A focus on comparisons between those 65 years of age or over and those under 65, while interesting, masks the increases in prevalence rates that occur within both broad age groupings. There is a gradual rise with age in the reported prevalence of communicative impairments, which can be discerned from Table 1.

A fairly steady rise in the reported prevalence of communicative disorders begins in the age group 20 to 24 years. There is an exception to this rise between the 35 to 39 and the 40 to 44 age groups. Of particular interest is that the reported prevalence rate for persons 85 years of age or over is significantly higher than that for persons 75 to 79.

These data illuminate gradual increases by age for the total population with communicative disorders. However, such data do not reveal the differences in the age patterns for prevalence rates that occur within the different communicative impairments by sex.

For example, the reported prevalence rates for tinnitus tend to rise with age for both men and women but the increases are not consistent. The rates for tinnitus for men 20 years of age or over gradually rise with age, peaking in the 60 to 64 and 70 to 74 age groups. Rates for women, on the other hand, do not show a steady rise until 50 to 54, as shown in Table 2. Their rates peak at 65 to 69 and then fall.

The age patterns for hearing impairment contrast with those for tinnitus. For men 20 or over, prevalence rates for hearing impairment show a steady increase by age groups, with the exception of men 40 to 44. The rates for women 20 years of age or over increase until the 35 to 39 age group, decrease for the 40 to 49 group, and then increase again for groups 50 to 54 and over.

It is clear, therefore, that communicative impairments need to be examined in greater detail in order to understand the underlying patterns of prevalence. However, even detailed data, such as those from the 1985 National Health Interview Survey, can be criticized for a lack of clinical information. For example, the category "hearing impairments" is a broad grouping which may be heterogeneous and underreported. Prevalence data from HANES I, the first National Health and Nutrition Exam-

TABLE 1. Number and percentage of persons with communicative disorders by age group, United States, 1985.

Age group in years	Persons with communicative disorders		
	Number	Percentage	Standard error
Total, all ages	23,219,800	9.9	0.3
0 to 4	259,000	1.4	0.4
5 to 9	857,000	5.1	0.8
10 to 14	570,000	3.3	0.6
15 to 19	523,000	2.9	0.5
20 to 24	618,000	3.1	0.5
25 to 29	921,000	4.4	0.6
30 to 34	1,097,000	5.6	0.7
35 to 39	1,657,000	9.3	1.0
40 to 44	1,096,000	8.1	1.0
45 to 49	1,194,000	10.4	1.3
50 to 54	1,644,000	15.2	1.6
55 to 59	2,060,000	17.8	1.7
60 to 64	2,534,000	24.0	2.1
65 to 69	2,505,000	25.5	2.2
70 to 74	2,031,000	29.6	2.8
75 to 79	1,678,000	30.7	2.7
80 to 84	1,135,000	38.7	3.8
85 and over	840,000	43.1	4.8

Source: 1985 National Health Interview Survey (NCHS et al., 1986).

ination Survey of 1971 to 1975, although dated, provide objective and detailed measures of hearing loss.

Audiometry Data Results

Examination of the HANES I data reveals that age patterns of hearing loss vary by frequency and sex. However, no specific cohorts with unusual patterns are observed. While there are some differences between ears, they are not systematic and easily interpretable. (Some data are thus reported for the right ear only.)

With a few exceptions, the percentage of persons 25 to 74 years of age with an air-conduction hearing threshold level of 51 dB or more in the right ear increases by age at all frequencies. Likewise, with few exceptions, the higher the frequency, the higher the percentage is within age groups, as elaborated in Table 3. The exception here is that the percentages at 500 and 1,000 are very close.

In general, men are more likely to have a loss of 51 dB or more in the right ear than women are. Perhaps the most notable exceptions to this rule occur in the age group 25 to 34 years at 500, 1,000, and 2,000 Hz and in the age group 65 to 74 years at 500 and 1,000 Hz.

Note the consistent patterns at 4,000 Hz. At this frequency, the percentage of men with a hearing threshold level of 51 dB or more is always much higher than that for women. Moreover, 49.1% of the men 65 to 74 years of age had this threshold. Compare this number to the 26.2% reporting hearing loss to the 1985 Health Interview Survey (NCHS, Moss & Parsons, 1986). Moreover, fully 91.5% of men had a threshold 21 dB or more in the right ear (Rowland, 1980).

All measures indicate that the mean hearing threshold level tends to rise with age at 500, 1,000, 2,000, and 4,000 Hz. Data for this measure have been plotted for both ears. Differences occur between measures in the sharpness of the rise. In general, the higher the frequency, the greater the increase.

At 500 Hz, increases in hearing threshold in both ears begin somewhere in the late 30s for men. The exact age is difficult to pinpoint. However, for the right ear, a gradual increase appears to occur sometime after age 34, as shown in Figure 1. As shown for the left ear in Figure 2, increases also occur in the late 30s. After age 51, the mean threshold is always above 10 dB for both ears. In the 60s, it hovers around 15 and by the 70s, around 20.

Patterns for men at 1,000 Hz are similar to those at 500. For both ears at 1,000 Hz, men show some increase in the late 30s, tend to have an average above 10 in their 50s, around 15 in their 60s, and around 20 in their 70s. On the whole, means for 1,000 Hz are slightly higher than for those at 500 Hz.

For 2,000 Hz, the mean decibel level tends to rise above 10 after age 35. Right ear data may imply some small increases during the 40s while left ear data do not. Both ears show increases above 15 in the 50s, above 20 in the early 60s, above 25 in the late 60s, and above 30 (approaching 35) in the early 70s.

Rises in mean hearing threshold level tend to be more consistent by age for men at 4,000 Hz. The rise, which begins sometime in the 30s, is markedly different from the increases for the other three frequencies. The curves at 4,000 Hz do not show a point where increases begin to occur at a faster pace.

In measuring speech reception, increases in the late 30s do not appear for men. The rise for men in mean

TABLE 2. Percentage of persons with hearing impairments and with tinnitus by age, group, and sex, United States, 1985.

Impairment and age group in years	Men		Women	
	Percentage	Standard error	Percentage	Standard error
Hearing impairment				
Total, all ages	10.7	0.4	7.5	0.3
0 to 4	0.5	0.3	0.6	0.4
5 to 9	2.8	0.8	1.6	0.6
10 to 14	2.0	0.6	2.9	0.8
15 to 19	3.3	0.8	1.6	0.6
20 to 24	1.9	0.6	2.9	0.7
25 to 29	4.9	0.9	2.9	0.7
30 to 34	6.2	1.1	3.6	0.8
35 to 39	11.2	1.5	6.4	1.1
40 to 44	9.9	1.7	5.2	1.2
45 to 49	13.5	2.1	6.0	1.4
50 to 54	19.3	2.6	10.0	1.8
55 to 59	22.1	2.8	12.9	1.9
60 to 64	28.9	3.2	17.2	2.4
65 to 69	31.3	3.6	19.6	2.6
70 to 74	34.0	4.7	23.8	3.3
75 and over	44.3	4.6	29.1	2.9
Tinnitus				
Total, all ages	2.6	0.2	2.8	0.2
20 to 24	0.7	0.4	1.4	0.5
25 to 29	1.0	0.4	1.2	0.5
30 to 34	1.1	0.5	2.0	0.6
35 to 39	2.4	0.7	2.9	0.8
40 to 44	2.5	0.8	1.1	0.5
45 to 49	2.7	0.9	0.8	0.5
50 to 54	3.4	1.1	3.8	1.1
55 to 59	7.5	1.6	4.8	1.2
60 to 64	9.2	1.8	8.5	1.7
65 to 69	7.7	1.8	11.7	2.0
70 to 74	11.5	2.7	9.3	2.0
75 and over	8.7	2.0	7.3	1.4

Source: 1985 National Health Interview Survey (NCHS et al., 1986).

decibel levels required to miss no fewer than five words begins after age 40 in both ears, increasing at a relatively steady pace throughout the 50s and 60s. There is a sharper increase after 70 years of age.

Women show more consistent patterns than men. For all of the air-conduction tests, the hearing levels tend to start rising in the early to late 40s and increase thereafter, as shown in Figures 3 and 4. The increases at 4,000 Hz after age 40 tend to be the most consistent for women of all the frequencies. At 500, 1,000, and 2,000 Hz, there is a sharp rise around age 50.

The speech-reception test results for women show a unique pattern. Rises in decibel levels required to miss no fewer than five words do not occur until the 50s, with very steep increases occurring in the late 60s.

From these diverse plots some tendencies emerge. For the air-conduction tests, patterns at 4,000 Hz are somewhat different from those at the lower three frequencies, which appear to be similar to each other. Results at 500,

1,000, and 2,000 Hz imply the beginning of an increase in the late 30s for men and early 40s for women, with sharper increases in the 50s for both sexes. Increases at 4,000 Hz are more consistent, with the starting point perhaps a little later for women than for men. With the exception of results at 4,000 Hz for men, virtually all of the data imply some specified age at onset of hearing loss, with a later acceleration in the rate of loss.

The HANES I data confirm findings from the National Health Interview Survey that most hearing loss is age related and less than severe. Thus, the hearing-impaired population is heterogeneous, including those with mild, age-related hearing losses in one ear, as well as profoundly deaf people who had no hearing at birth.

The Deaf Population

Historically, according to Schein (1987), research interest has focused on prevocally deaf people,

TABLE 3. Percentage of persons 25 to 74 years of age with an air-conduction hearing threshold level of 51 decibels or more for the right ear at 500, 1,000, 2,000, and 4,000 Hz by age group and sex, United States, 1971-75.

Statistic and age group in years	500 Hz		1,000 Hz		2,000 Hz		4,000 Hz	
	Men	Women	Men	Women	Men	Women	Men	Women
Percentage								
Total, 25 to 74	1.9	2.1	2.2	2.0	6.2	2.8	20.7	4.7
25 to 34	0.1	0.9	0.1	0.7	0.4	0.8	4.9	0.9
35 to 44	2.0	1.4	1.4	0.9	2.4	0.3	11.7	1.8
45 to 54	2.0	1.6	2.0	1.2	6.4	1.9	25.4	2.8
55 to 64	3.0	2.1	4.4	2.3	10.8	3.4	32.0	6.8
65 to 74	4.1	6.5	5.6	7.6	19.7	11.5	49.1	17.8
Standard error of percentage								
Total, 25 to 74	0.38	0.44	0.36	0.40	0.63	0.47	1.22	0.50
25 to 34	0.17	0.58	0.17	0.47	0.40	0.50	1.52	0.51
35 to 44	0.81	0.87	0.66	0.54	0.94	0.25	2.43	0.85
45 to 54	0.76	0.89	0.78	0.76	1.47	0.85	2.84	0.97
55 to 64	1.04	0.96	1.21	0.97	2.12	1.10	3.36	1.67
65 to 74	1.37	1.89	1.41	1.99	2.48	2.31	3.35	2.60

Note: Hearing level in decibels re audiometric zero (ANSI, 1969).

Source: Rowland, 1980, Tables 1, 2, 5, 6, 9, 10, 13, and 14, pp. 6-12.

suggesting that there is a "rule" that research occurs in inverse proportion to the size of the population affected: the fewer persons, the more studies. With respect to hearing impairment, the rule further specifies that as age at onset increases, research interest declines: the earlier the onset of deafness, the more studies. (p. 12)

Indeed, older hearing-impaired people are far more numerous than prevocationally deaf persons. Results from the 1971 National Census of the Deaf Population showed that 76.8% of the deaf population lost their hearing after 18 years of age (Schein & Delk, 1974, p. 16). In 1971 and 1977, the National Health Interview Survey estimated that 273,000 and 292,000 people 3 years of age or over were deaf in both ears (Gentile, 1975; Ries, 1982). The respective prevalence rates were 142 and 144 per 100,000 persons age 3 or over. In percentage terms, this is only one-tenth of 1%. Using a different definition of deafness, Schein and Delk (1974, p. 16) estimated a prevocationally deaf population of 410,522 in 1971, a prevalence rate of 203 persons per 100,000. When contrasting that figure with the 7,963,000 people 65 years of age or over with hearing impairments (NCHS, Moss & Parsons, 1986), one can see that the prevocationally deaf population is very small and that the elderly hearing-impaired population is very large.

In discussing the prevocationally deaf population, Schein (1987) argues that the meaning of deafness is culturally determined, that deaf people in one society may be at more or less of a disadvantage than those in some other setting and

that the meaning of deafness can best be apprehended by seeing it as a social condition rather than a disease or even a physical disability. . . . At the same time, we do not deny that deafness can be usefully studied as a physical disability, only that the medical description of deafness does not fully anticipate its social consequences. (p. 3)

The cultures of both the individual and the society play important roles in determining such a disadvantage. To this end, as Schein (1987) notes:

An important demographic aspect of deafness is communication. . . . The cement that binds the Deaf Community is American Sign Language (Ameslan). . . . Ameslan is not "English on the hand," not just another code for the spoken language. It is a language in its own right. Those who use it are usually those who were born deaf or lost their hearing in childhood. Persons deafened in adulthood usually do not become members of the Deaf Community. (pp. 14-16)

Perhaps one reason for this is that older people tend not to learn American Sign Language, if for no other reason than their families may not be willing to do so. Denney (1981, p. 125) cites several sources to state, "Nonverbal abilities such as abstract reasoning, perceptual-motor speed, and spatial abilities appear to decline from early adulthood through old age."

Because people who encounter communicative disorders later in life do not have their own unique language and culture, a cultural approach may not be the most appropriate one to use in studying them. This large group of people is clearly a very different population than the much smaller prevocationally deaf population. At the same time, the increasing prevalence rates by age for tinnitus and hearing impairment suggest that a traditional approach is also not appropriate. Such an approach merely compares characteristics between groups and does not provide much detail about the process that people go through when they encounter communicative disorders. Clearly, a dynamic approach toward data analysis is needed.

A DYNAMIC PREVALENCE APPROACH: HEARING IMPAIRMENT AS AN EXAMPLE

The Process of Aging

For several years, it has been debated whether the

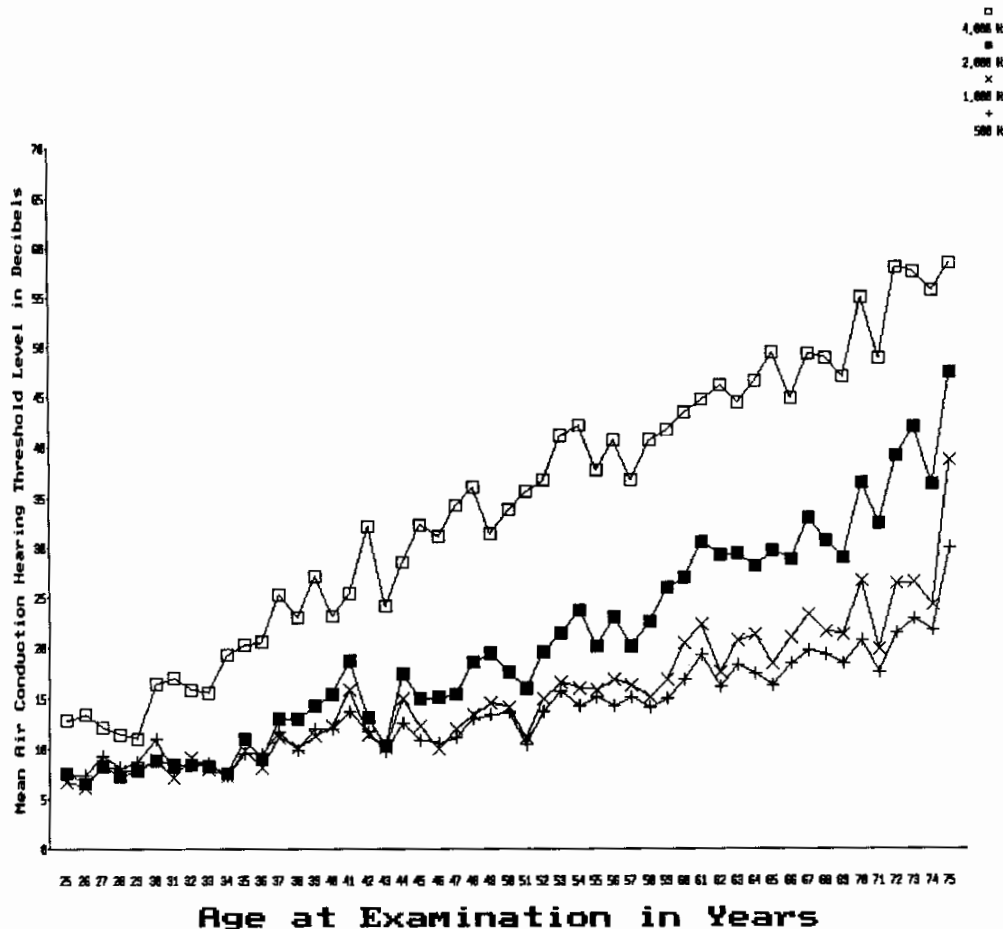


FIGURE 1. Mean air-conduction hearing threshold levels in decibels at 500, 1,000, 2,000, and 4,000 Hz for men, in the right ear, by age, United States, 1971-75. Source: National Center for Health Statistics, First National Health and Nutrition Examination Survey, United States, 1971-75.

onset of functional impairment is being, or can be, delayed as average life expectancy increases (Fries, 1984). Fries (1980, 1984) has hypothesized that chronic illness may be postponed by changes in lifestyle, markers of aging may be modified, and the average age of first infirmity may be raised. Hence, the period of senescence near the end of life may be reduced. Schneider and Brody (1983) have argued the opposite, that morbidity and disability are not declining, and, hence, more people will spend larger percentages of their lives afflicted with chronic conditions. This debate focuses on such factors as risk, onset, severity, and progression of morbidity.

A dynamic prevalence approach looks at a disorder as a process that occurs over time. The impairment has a risk factor related to the chance of a particular person contracting the impairment. The disorder has a beginning, often measured by age at onset. It also has a level of severity, which can increase or decrease as time passes. Such a viewpoint does not insist on the notion that aging causes the disorder. Whether or not aging is an etiology for certain conditions is very controversial at this time.

Besdine (1987, p. 12) describes aging as the inevitable physiologic changes in functions that are separate from the effects of disease that accompany increasing age. The rate of age-related changes varies between individuals but is constant for each individual. Besdine lists 20 examples of linear decline in organ function and 6 parameters that actually increase with age.

Presbycusis

In the case of hearing impairment, the effect of aging on the threshold sensitivity of the auditory system is termed *presbycusis* (Kryter, 1983). A critical question is: To what extent is age per se a significant factor in determining the threshold of hearing sensitivity?

Long ago, Zwaardmaker (1894) hypothesized a Presbycusis Law. He observed that hearing sensitivity for high-pitched tones begins to deteriorate in the fourth decade of life. Kopra (1982) has drawn four conclusions about hearing and aging:

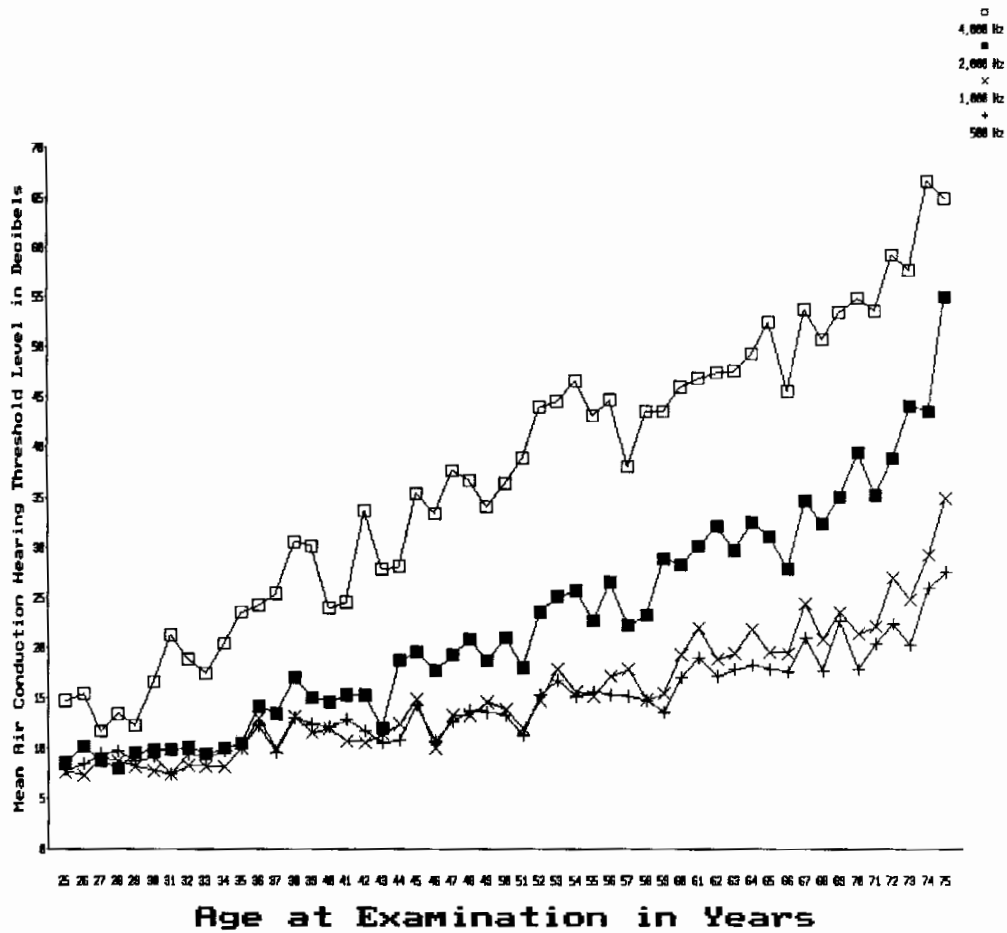


FIGURE 2. Mean air-conduction hearing threshold levels in decibels at 500, 1,000, 2,000, and 4,000 Hz for men, in the left ear, by age, United States, 1971–75. Source: National Center for Health Statistics, First National Health and Nutrition Examination Survey, United States, 1971–75.

1. Measurable changes in auditory sensitivity for high-frequency pure tones (4,000–8,000 Hz) occur by the fourth decade of life for both men and women.
2. The variability in pure-tone thresholds, especially in the higher test frequencies, is greater for the older age groups than for the younger age groups.
3. Men lose auditory sensitivity in the higher frequencies more rapidly as a function of age than women do.
4. The noxious elements of our culture and the unique life-styles that people lead have a significant effect on the degree to which hearing sensitivity changes as a function of age. (p. 249)

In a review of several surveys, Kryter (1983) has concluded that gender, by itself, is not a significant factor in determining the threshold of hearing sensitivity. Rather, he believes that, in the early teens, boys are more exposed to intense noises and sounds than girls are. In other words, although gender is indirectly related to hearing sensitivity, it does not directly cause variations in sensitivity.

Most studies of presbycusis, however, have not been able to truly separate it from other types of hearing loss. Ideally, exploration of the process of hearing disorders

would use a large audiometric data source with information on people's hearing thresholds at several points in time. Such a data source would allow for the examination of changes in the prevalence of hearing impairment at a variety of hearing frequencies as individuals age.

Unfortunately, such a longitudinal data set is not available. The follow-up to HANES I did not include audiological testing. However, an epidemiological approach to exploring data from HANES I can help to discern patterns in the age/hearing-loss association.

Methodology

Of critical importance in the analysis of the HANES I data is discovering the basic association between age and hearing loss. With 51 ages in the cross tabulations of the HANES I data, it is difficult to summarize the age/hearing threshold patterns. Thus, hearing levels at different frequencies have been regressed against age according to a variety of specified models to observe the age/hearing

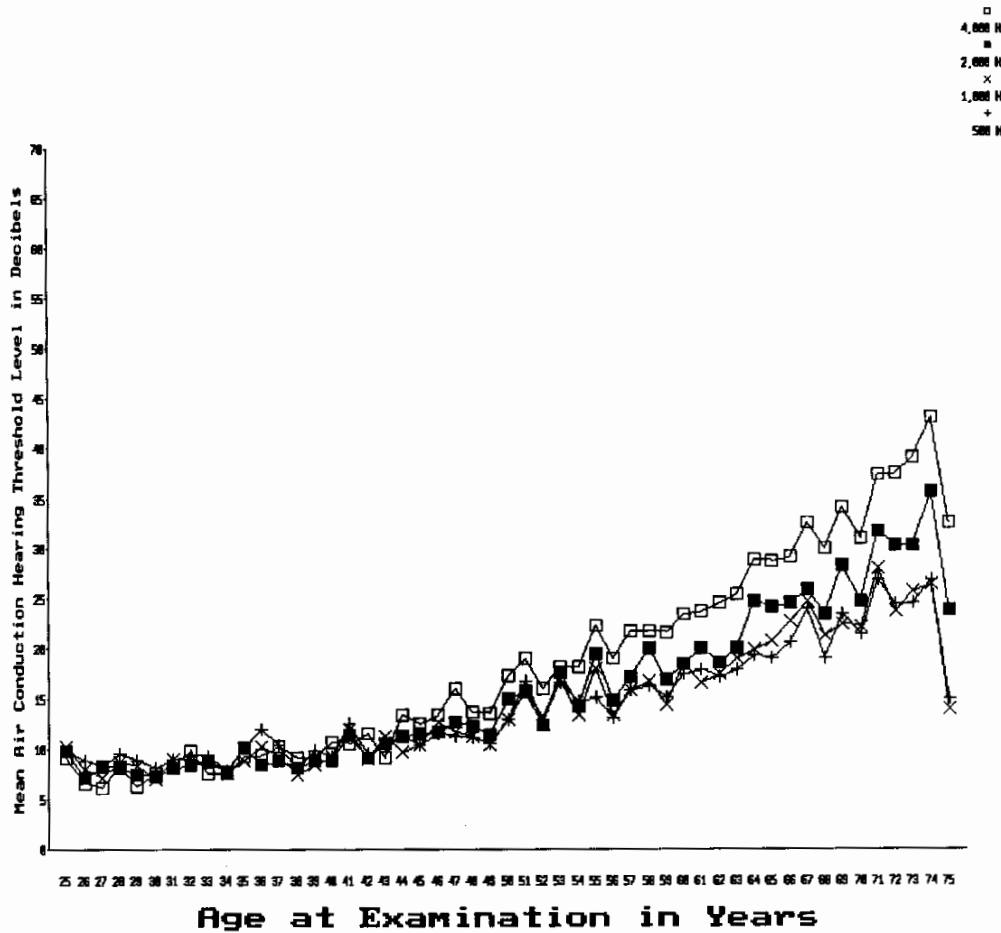


FIGURE 3. Mean air-conduction hearing threshold levels in decibels at 500, 1,000, 2,000, and 4,000 Hz for women, in the right ear, by age, United States, 1971-75. Source: National Center for Health Statistics, First National Health and Nutrition Examination Survey, United States, 1971-75.

loss association. Since several previous studies have documented sex differences in hearing decline (Kopra, 1982), models have been tested separately for men and women.

Results are shown here for six regression models specified under six different assumptions of the underlying association between age and hearing loss: linear, linear with the natural log of age, Gompertz curve, Weibull curve, quadratic, and Gompertz quadratic. These models can be viewed as typology, as follows:

Age in years	Hearing level in decibels	
	As reported	Natural log
As reported	Linear regression	Gompertz
Natural log	Linear log regression	Weibull
Age + age ²	Quadratic	Gompertz quadratic

Important criteria for selecting the optimal set of model assumptions are the R^2 values and the probabilities of F^* , which is the F value derived from goodness-of-fit tests.

R^2 is the proportion of variance in hearing level, or the log thereof, that is explained by the model selected. In general, the higher R^2 , the better the model is. However, certain models may increase R^2 only slightly while also increasing standard error.

In order to discern the most parsimonious model, a measure is needed to identify a model with a high R^2 and a low error. One strategy is to use a statistic that provides an indication of error, the probability value for F^* from goodness-of-fit tests. F^* is a statistic derived to test the proportion of non-prediction that is attributable to lack of model fit against the proportion that is attributable to pure error. A value for the probability statistic of F^* under 0.05 indicates that the model fits the data poorly; the greater the probability value of F^* , the better the model fit is. As R^2 increases with the addition of another term, if the

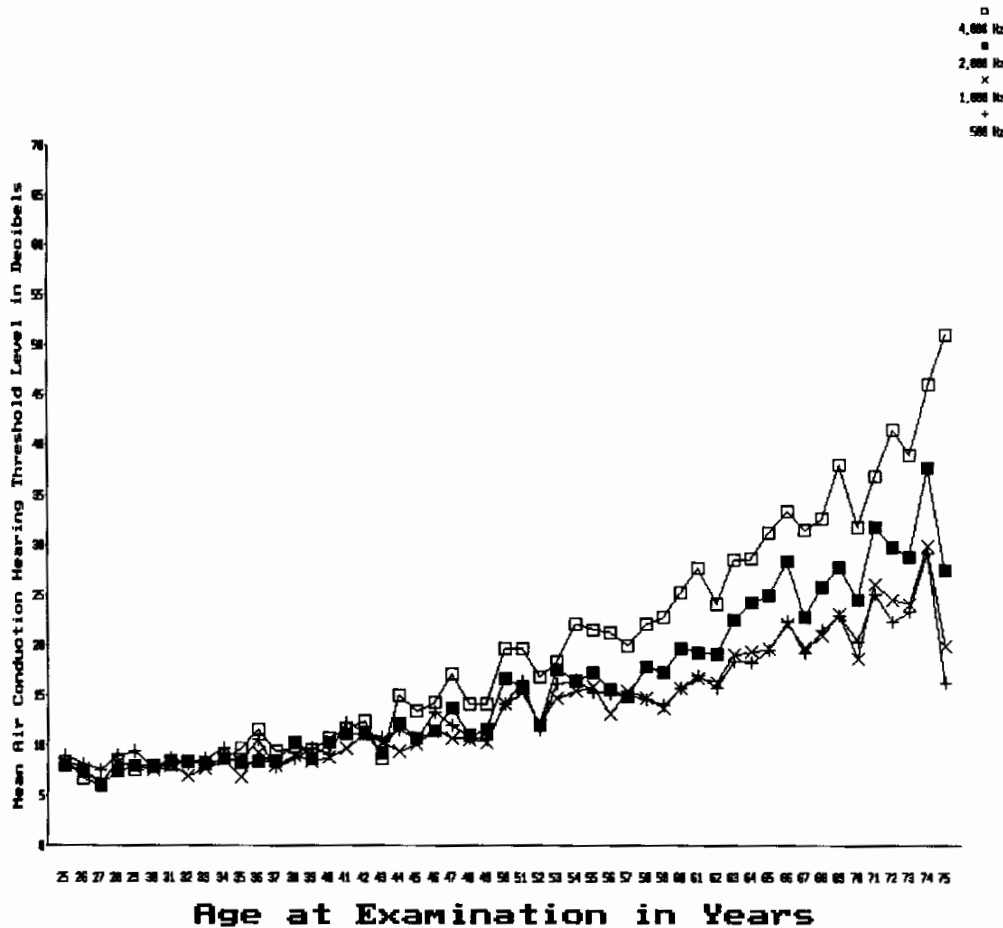


FIGURE 4. Mean air-conduction hearing threshold levels in decibels at 500, 1,000, 2,000, and 4,000 Hz for women, in the left ear, by age, United States, 1971-75. Source: National Center for Health Statistics, First National Health and Nutrition Examination Survey, United States, 1971-75.

probability of F^* declines, the standard error of prediction is increasing.

Assumptions

To interpret these regression results within a dynamic framework, cross-sectional data must be employed to pose hypotheses about a longitudinal process. The analysis, therefore, requires a basic assumption that the age patterns for a population at one point in time are indicative of the aging patterns of individuals as time passes. Under this assumption, several statistical descriptions of the hearing loss function by age can then be obtained by applying the data to a variety of models of age-related hearing decline by sex.

It is recognized that if differences between cohorts in hearing loss actually exist, those differences will have an impact on the validity of the findings. For example, changes in occupational structure over time in the United

States could result in a reduction of occupational noise exposure. Such a reduction could decrease hearing loss among younger as opposed to older workers. Such differences at one point in time could be erroneously identified as aging. Moscicki, Elkins, Baum, & McNamara (1985) warn against interpreting their data in a similar way.

RESULTS

The models yield consistent results. At 500 Hz, women show a higher correlation of age and hearing loss in both ears than do men. One of the clearest patterns from the regressions, as can be discerned in Table 4, is that as the frequency increases from 500 Hz to 4,000 Hz, R^2 also increases. Although the highest R^2 statistics are usually obtained when Age^2 is added to Age under the Gompertz assumption, the R^2 for other models are almost as high.

In general, the patterns in the goodness-of-fit probability values for F^* statistics, as demonstrated by Table 5,

TABLE 4. R-square values from regression models for the measures of and the natural logs of pure-tone air-conduction hearing levels at 500, 1,000, 2,000, and 4,000 Hz, with age, the natural log of age, and age + age² as independent variables, by sex and ear, persons 25 to 74 years of age, United States, 1971-75.

Sex, ear and Hertz	Hearing decibel level			Log of hearing dB level		
	Age	Log _e age	Age + Age ²	Age	Log _e age	Age + Age ²
Men						
Right ear						
500 Hz	0.0868	0.0818	0.0885	0.1055	0.1018	0.1058
1,000 Hz	0.1395	0.1316	0.1422	0.1890	0.1878	0.1894
2,000 Hz	0.2239	0.2100	0.2291	0.2603	0.2578	0.2608
4,000 Hz	0.2761	0.2734	0.2766	0.3061	0.3181	0.3196
Left ear						
500 Hz	0.0857	0.0806	0.0877	0.1064	0.1026	0.1068
1,000 Hz	0.1259	0.1174	0.1299	0.1539	0.1498	0.1541
2,000 Hz	0.2189	0.2053	0.2240	0.2438	0.2402	0.2439
4,000 Hz	0.2936	0.2917	0.2944	0.3068	0.3208	0.3228
Women						
Right ear						
500 Hz	0.1303	0.1159	0.1450	0.1488	0.1374	0.1548
1,000 Hz	0.1519	0.1363	0.1656	0.1742	0.1640	0.1771
2,000 Hz	0.2057	0.1836	0.2278	0.2297	0.2169	0.2330
4,000 Hz	0.2722	0.2463	0.2938	0.3057	0.2942	0.3067
Left ear						
500 Hz	0.1336	0.1214	0.1432	0.1484	0.1392	0.1517
1,000 Hz	0.1509	0.1364	0.1629	0.1742	0.1651	0.1764
2,000 Hz	0.2106	0.1895	0.2299	0.2175	0.2049	0.2216
4,000 Hz	0.3043	0.2766	0.3260	0.3223	0.3120	0.3228

Note: For all equations, Prob > F = 0.0001.

Source: National Center for Health Statistics, First National Health and Nutrition Examination Survey, United States, 1971-75.

indicate that the simple linear and Gompertz quadratics perform well, with Gompertz usually performing better. Note the low probabilities for the simple Gompertz model at 4,000 Hertz for men and for the linear, log and Weibull models for women, indicating a statistically significant lack of fit for these models. The strong performance of quadratic, Gompertz and Gompertz quadratic models implies that a simple assumption of linearity does not adequately describe the age/hearing loss association.

SUMMARY AND CONCLUSIONS

Clearly, few definitive conclusions about the nature of presbycusis should be drawn from these results. It is clear that hearing loss has a strong association with age for all ages above a particular year of life.

This association may not be presbycusis in nature. Many of the differentials shown here may be the result of occupational noise exposure. It is, therefore, necessary to isolate a population where the impact of occupational noise exposure is reduced.

When examining the predictors of hearing loss, occupational noise exposure scores should not merely be added to age as an independent variable in regression equations. Rather, these scores should be employed to predict each individual's deviation from the predicted value of hearing loss for his or her particular age. The ratio of hearing loss to age can also be measured.

The issue thus is framed as, "How does occupational noise alter the age/hearing-loss relation?" rather than "Does age cause hearing loss when the influence of occupational noise is removed?" By discerning which variables predict not just hearing loss but the nature of the age/hearing-loss association under these assumptions, a better understanding of the interaction of demographic factors, aging, and the prevalence of hearing loss will be obtained.

As noted earlier, caution is advised in interpreting results from cross-sectional data to draw conclusions about a longitudinal process, aging. Such results can be employed only to suggest hypotheses to be tested using longitudinal data for aging and hearing loss.

Nevertheless, by employing cross-sectional data to suggest possible patterns for the age/hearing-loss association, a different viewpoint can be brought to the analysis of the prevalence of age-related phenomena. By attempting to view a process rather than only make comparisons, we can begin to understand that the nature of a person's hearing impairment can change over time.

Likewise, a similar process-oriented analysis of the prevalence of other age-associated communicative disorders, such as tinnitus, can suggest what the ongoing experiences of older people with these conditions may be. Such an approach can aid in projecting what the future needs of the aging population with communicative disorders will be. Subsequent analyses of longitudinal and clinical data can then suggest the most appropriate responses.

TABLE 5. Probability of F^* values from goodness-of-fit tests on regression models for the measures of and the natural logs of pure-tone air-conduction hearing levels at 500, 1,000, 2,000, and 4,000 Hz, with age, the natural log of age, and age + age² as independent variables, by sex and ear, persons 25 to 74 years of age, United States, 1971-75.

Sex, ear and Hertz	Hearing decibel level			Log of hearing dB level		
	Age	Log _e age	Age + Age ²	Age	Log _e age	Age + Age ²
Men						
Right ear						
500 Hz	0.6901	0.2492	0.8253	0.8826	0.5421	0.8897
1,000 Hz	0.1350	0.0099	0.2640	0.3759	0.2718	0.3863
2,000 Hz	0.0994	0.0005	0.4524	0.4053	0.1908	0.4324
4,000 Hz	0.7354	0.4085	0.7626	0.0201	0.8952	0.9731
Left ear						
500 Hz	0.5406	0.1626	0.7143	0.7937	0.4232	0.8072
1,000 Hz	0.1973	0.0132	0.4981	0.5283	0.1854	0.5173
2,000 Hz	0.1398	0.0009	0.5524	0.6412	0.2601	0.6292
4,000 Hz	0.1770	0.0873	0.2069	0.0019	0.4834	0.7254
Women						
Right ear						
500 Hz	0.0019	0.0000	0.4410	0.1034	0.0011	0.6141
1,000 Hz	0.0013	0.0000	0.2737	0.2346	0.0040	0.5111
2,000 Hz	0.0000	0.0000	0.4073	0.1727	0.0006	0.4997
4,000 Hz	0.0001	0.0000	0.8881	0.4245	0.0020	0.5511
Left ear						
500 Hz	0.0111	0.0001	0.3492	0.1945	0.0054	0.4922
1,000 Hz	0.0063	0.0000	0.4970	0.5996	0.0251	0.8448
2,000 Hz	0.0001	0.0000	0.2986	0.0631	0.0002	0.2827
4,000 Hz	0.0000	0.0000	0.3964	0.2527	0.0016	0.2791

Source: National Center for Health Statistics, First National Health and Nutrition Examination Survey, United States, 1971-75.

ACKNOWLEDGMENTS

This research was supported in part by a grant from the United States Department of Health and Human Services, National Institute on Aging, grant Number HUD-2 5 R29 AG05609-3. The author wishes to thank Dr. Susan Ahmed, Dr. Judith A. Holt, Dr. Michael A. Karchmer, David Hotchkiss, and Hank Young for their helpful comments and criticisms of this paper.

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**C. METHODOLOGICAL ISSUES IN THE DESIGN AND IMPLEMENTATION
OF RESEARCH IN AGING**

Chapter 4

FUNCTIONAL COMMUNICATION ASSESSMENT OF THE ELDERLY

PAUL RAO

National Rehabilitation Hospital, Washington, DC

A multitude of formal and informal batteries exist that enable the clinician to test for and tease out the various communication processes and modalities that may be impaired in the aged population. This undertaking is termed the *clinical assessment* and is designed to obtain information that establishes a clear and accurate diagnosis. The ideal clinical assessment comes to fruition once the differential diagnostic examination has determined the nature and cause(s) of the disorder. The clinical assessment, especially in the formal test situation, has been designed primarily to isolate the patient and examine his or her ability to process information without benefit of context. Thus, the laboratory environment is often quite estranged from the real world environment in which the patient functions. The Token Test (De Renzi & Vignolo, 1962) is perhaps the best illustration of a language test that requires the respondent to base decisions on sufficient analysis of the linguistic input rather than on contextual cues or conceptual knowledge derived from the situation. If the task were more ecovailid, such as presenting a pen and paper to the patient and asking the patient "to write your name and address," the patient might be able to respond appropriately based on the nonverbal context. Hence the elderly client may appear to perform considerably less well in a test situation which minimizes the extralinguistic influences than in more natural settings. The difference between the clinical and functional assessment of the elderly boils down to assessing what that person can't do in the clinic and what he or she can do in context. The functional assessment of the elderly then, by definition, must focus on communication in context and strive to determine the impact of the deficit on natural communication.

The scope of the functional assessment of the elderly includes all components critical for communication. These processes include oral motor function, hearing, vision, voice, speech, fluency, language, cognition, and communication. Clinicians who work with the elderly are well aware that the communication skills of older adults do indeed differ from those of young or middle-aged adults. According to Dancer (1985), problems such as hearing loss, visual acuity loss, poor memory or cognitive

functioning, slow response time, fatigue, complaints of physical distress, and poor manual dexterity may be present to complicate the communication assessment. The functional assessment of the elderly thus requires a great deal of ingenuity and creativity on the part of the clinician, who must examine the communication components in context while accounting and compensating for the common problems associated with the normal aging processes in each individual, regardless of his or her primary communicative disorder.

A CHARGE

E. Jeffrey Metter (1985), in an open letter in *Asha* regarding the diagnosis and treatment of aphasic adults by speech-language pathologists, opines, "I believe a greater emphasis is needed on approaching each case with the most realistic long-term expectation and being able to specify these clearly and how they will benefit the patient in his day to day life." Hence the charge to speech-language pathologists today is to determine how the patient functions in the real world. Never has the medical mandate been so driven by "outcomes" and daily living skills (DLS) function. The functional assessment must become a staple of the speech-language pathologist's diagnostic armamentarium. The questions the diagnostician must ask bear directly on how well the patient might be able to reintegrate into the community. The three basic questions that must be asked throughout the functional assessment address the larger issue of how to bridge the rehabilitation gap between disability and ability. First, can we change the environment to make it more "user friendly"? Second, can we fit the patient with a prosthetic device that will allow him or her to compensate for the loss? Finally, can we change the patient's behavior? Hence, the functional assessment of an elderly Parkinson's patient might result in a recommendation that he or she attempt to communicate in a quiet environment, using a pacing board and an ALD, and, when there is a breakdown in communication, implement repair strategies such as rephrasing, increased volume, etc.

Thus the functional assessment is designed to determine what the patient's communication liabilities and assets are and what variables might be employed to assist the patient to communicate in his or her environment more effectively. If a disability can be termed a *limitation of choice* (Rao, 1986), then the functional assessment of the disabled older adult can be geared toward determining what increased communication opportunities realistically can be obtained to maximize the patient's communication options.

POTENTIAL COMPONENTS OF A FUNCTIONAL ASSESSMENT

Preinterview Questionnaire

The practice of administering a preinterview questionnaire to patients and significant others is more common in audiology than in speech-language pathology. Its purpose is to obtain a thorough case history. It should be formatted in large type with liberal use of check lists. The questionnaire can be completed through the mail or in the waiting room before formal testing sessions. A form that can be filled out at the patient's leisure is preferred, as it eliminates any time constraints imposed by the appointment itself. The completed form will provide the basis for follow-up questioning in the interview prior to actual testing.

Interview and Case History

Most hearing and speech centers use a simple case history form for all adults. Raiford (1988) makes a strong case for adopting a form specifically oriented to the unique status and needs of older adults. The rationale is that the aged population consists generally of retirees who may have quite unique communication needs based not only on age but also on residential setting. The case history form should probe residential status, social and family contacts, and daily activities and interests.

Speech and language patterns of the elderly patient can be observed during an interview as well as during psychometric testing. During the interview, observations of the patient's interaction with family members or caregivers can provide valuable information on the level of functional communication between the patient and the environment. Behaviors that can be observed during interviews with a suspected dementia patient are word-finding difficulties, circumlocutions and substitutions, irrelevant comments and digressions, and inability to follow conversations appropriately (Obler & Albert, 1984). Groher (1988) presents a summary of medical and social data appropriate for the evaluation of communication disorders in elderly persons that is designed to identify important clues to etiology which will aid in designing the assessment protocol. The section of Groher's summary on medical history focuses on causes

and factors that might result in a communication disorder (e.g., stroke, arthritis, medication, and alcohol abuse). The section on communication status focuses on symptoms, compensatory strategies, and communication settings. The final section on related psychosocial factors focuses on communication needs, emotional status, and pertinent biographical information. According to Groher (1988), the history form only provides some direction concerning areas which are important in assessing the communication status of elderly persons. A case history should also explore the subjective complaint of the communication handicap, the concerns of the spouse or significant other, the motivation level of both patient and partner to work toward remediating the problem, and financial considerations. As Raiford (1988) points out, all of these issues can be pursued in greater detail either through the pretest interview or through the use of scales to assess perception of an attitude toward one's communication impairment.

Attitudinal Scales

Attitudinal scales are perhaps more beneficial to audiologists than to speech-language pathologists because most speech-language clients are simply unable to understand and complete the survey without assistance. Although this fact threatens the reliability of the tool, the information garnered from such an exercise can be extremely valuable in arriving at a rehabilitation needs assessment. Any of several scales that have been developed specifically for use with older adults can easily be employed as one facet of the functional assessment. The Self-Assessment of Communication (SAC) by Schow and Nerbonne (1982), and its correlate version for significant others, consists of 10 questions probing experiences in various communication settings as well as feelings about communication. Felix (1977) has developed the Subjective Communication Report, which is an attempt to obtain a communication history with a yes/no format. The patient can fill out the form, or the examiner can read it aloud. Administration of either of these attitudinal surveys is quick and easy and, with the caveat of response bias, may supply useful information regarding the patient's predispositions to using a prosthetic device, modifying the environment, or changing his or her behavior.

Natural Observation

The home visit is an integral component of occupational and physical therapy practice. The site visit, driven by a series of specific tasks, permits the professional to assess how the patient functions in his or her own milieu. There has been a dramatic increase in the number of speech-language pathologists practicing in the patient's home setting, and those involved in home care are indeed fortunate to be able to observe how a patient actually communicates and goes about his or her daily routines at home. There is no question that this is the ideal way to

learn about the older adult's everyday communicative abilities, about how functionally handicapped he or she is, and about how many real choices the person has. Holland (1982) has described a system for observing aphasic patients in their natural environment. It seems that this framework would be useful with any speech-language pathologist's clientele. The observational categories Holland used for her field visits were as follows:

1. Verbal Output

- a. Form - uses verbal lubricant, uses social conventions, asks questions, makes requests, answers questions and requests, volunteers information
- b. Style - agrees, disagrees, teases, uses humor, sarcasm, or metaphor
- c. Conversational dominance - interrupts or changes topics
- d. Correctional strategies - corrects, clarifies, requests
- e. Metalinguistics - comments on own speaking, responds to phonemic cues

2. Nonverbal Output - adheres to spatial indicators, gestures to maintain conversation, humor and affective states

3. Read/Write/Math - responds to written material, writing, responds to numbers

4. Other - talks on phone, talks to pets, talks to self, responds to household sounds, sings, speaks in a foreign language

Although Holland (1980) had previously reported that 60-minute observations constituted a representative sample, in this field technique, observations were conducted for a period of 2 hours. An observer simply "followed a patient around" and tallied occurrences of the behavior of interest in terms of success or failure. Successes and failures were defined as follows:

Any observed response that communicated the aphasic patient's message was considered to be successful, regardless of the means used to convey it. Conversely, any response that did not succeed in communicating the aphasic person's message, regardless of the means used, was considered a failure.

According to Davis and Wilcox (1985), natural observations, like conversational samples or formal tests, constitute an excellent pragmatic assessment. Of all pragmatic procedures, natural observations yield the most representative information and, therefore, are probably the most useful for planning and conducting treatment. In a field observation, a clinician has the opportunity to determine a patient's important contextual parameters, his/her overall communicativeness, and particular communication strategies that are successful or unsuccessful.

Often, a change in residence is experienced by the aged person, and that may result in placement in age-segregated residences such as nursing homes or retirement communities. Making an assessment in a natural setting in which the patient is comfortable versus in an artificial setting with which the patient may be unfamiliar

and where he/she may feel uncomfortable can certainly skew the results of the functional assessment. Lubinski (1988) provides a decision-making process that is designed to assist clinicians in assessing what approach to implement with a given individual in a nursing home environment, be it a skill, effectiveness, or opportunity approach to intervention. The process includes using three sets of questions that focus on (a) determining the nature, extent, and effect of any specific communication problems; (b) providing a profile of the motivation level of both the elderly patient and primary communication partners to work toward greater communication effectiveness; and (c) determining communication opportunities and barriers to communication within the institutional environment. If you have ever conducted a visit or an observation at a nursing home, you have seen first hand the obvious barriers to communication, from the residents herded in front of a "loud" TV after dinner to lights out at 7:30 p.m. The speech-language pathology "Environmental Communication Consultant" can facilitate communication in a non-speech task such as a crafts group or foster initiation of a book or movie review group. Having examined the opportunities for the residents to exchange information, pleasantries, or questions, the speech-language pathologist must encourage each allied health and nursing staff member to foster these exchanges at every opportunity throughout the resident's day. A tool to foster just such an exchange is a daily log book maintained by each resident and documented by each visitor or interactor throughout the day. This data can be used to jog the resident's memory for any discussion of "what did you do today?"

Communication Questionnaire for Patients

The same benefits and caveats noted regarding the use of attitude scales with communicatively impaired older adults apply to the use of questionnaires. An informal measure of communication efficiency particularly well suited for use with the aged population was developed by Swindell, Pasek, and Holland (1982). Designed primarily as a prognostic tool, it asks the informant to rate the patient's background and communicative and personal style on a 1 to 5 scale. It provides a systematic approach to gathering data from a significant other about an elderly person's communication skills without requiring the patient's participation. Ulatowska, Haynes, Hildebrand, and Richardson (1977) presented questionnaires to aphasic patients, their employers, their family members, and their close friends. Their questionnaire items focused on such areas as the patient's speech habits, his or her communicative needs, and an evaluation of a patient's communicative abilities in his or her employment setting. Obviously, a questionnaire can only fill in a piece of the puzzle of communication in the at-risk elderly population. However, it may be a crucial piece in helping the clinician determine contextual variables that may need to be manipulated in the more complete assessment. For example, Davis (1985) suggests that if an aphasic client does not

handle his or her own money or does not work, there will be no initial need to assess communicative performance in those areas.

Spontaneous Conversational Samples

According to Davis and Wilcox (1985), analyses of face to face interactions provide opportunities to assess the influences of numerous contextual parameters (e.g., facilitation of linguistic context, familiarity of conversational partners, turn-taking abilities). Houghton, Pettit, and Towey (1982) described an approach called the Communicative Competence Evaluation Instrument wherein observations are made in the form of subjective ratings for a number of receptive and expressive behaviors. Prutting and Kirchner (1983) developed a comprehensive checklist of pragmatic behavior that can be used to observe spontaneous behavior. The checklist is organized into three broad categories: utterance acts, propositional acts, and elocutionary acts. The rating of the observed behavior in each of these categories is subsumed under "appropriate," "inappropriate," or "no opportunity to observe." In addition, the authors also generated guidelines for descriptive analyses. Finally, Gurland, Chwat, and Wollner (1982) employed a system to observe spontaneous conversations between aphasic clients and their communicative partners. The system provides categories for coding the occurrence of specific behaviors, both conversational acts and other communicative acts, produced by the communication partners. If the clinician chooses to observe the elderly client in spontaneous conversation, any of the above approaches may provide a satisfactory illustration of how effective the client is in getting a message across.

Elicited Conversational Samples

Davis and Wilcox (1981) and Yorkston, Beukelman, and Flowers (1980) assessed aphasic clients' communicative abilities by asking them to talk about pictures that were hidden from the view of a listener. Davis and Wilcox (1985) admit that although the task is artificial and contrived, it does provide the investigator with an opportunity to observe an aphasic client's ability to convey information to a listener effectively and to rate overall communication effectiveness.

Other analyses of elicited conversation have examined the content of narrative as well as procedural discourse. Ulatowska, North, and Macaluso-Haynes (1981) and Ulatowska, Doyel, Stern, Haynes, and North (1983) analyzed narrative discourse that was obtained with retelling a story, or picture-story tasks. Again, should the clinician choose to perform an analysis of picture description or story-retelling, the tools mentioned above can be used as part of the functional assessment.

Structured Tasks

The functional communication assessment of the older adult requires a rather unique clinical perspective, because the elderly population in general has such unique needs. Lezak (1983) cautions that the clinician should be sensitive to the psychological orientation that elderly persons may bring to a test or structured task. She noted that the most important factor in the assessment may be enlisting the cooperation of the elderly client:

With no school requirements to be met, no jobs to prepare for, and usually little previous experience with psychological tests, a retired person may reasonably not want to go through a lot of fatiguing mental gymnastics that may well make him look stupid to the youngster in the white coat sitting across the table. Particularly if they are not feeling well or are concerned about diminishing mental acuity, elderly persons may view a test as a nuisance or an unwarranted intrusion into their privacy. (p. 118)

It is important to anticipate these feelings and let the patient know, before, during, and after the structured task or test that such misgivings are perfectly natural and understandable. Lezak (1983) suggested testing elderly people with meaningful and nonthreatening materials, such as playing cards. Elderly persons sometimes have little patience for activities that have no apparent relevance to their daily lives, and many structured tasks and tests are filled with such unfamiliar activities.

According to Davis and Wilcox (1985), structured tasks resemble elicited conversation. However, in a structured task the goal is not to obtain a sample of conversational discourse but rather to manipulate a particular variable and observe the effects upon communicative behavior. Prinz (1980) described a task designed to elicit requesting behavior. The task included the creation of situations in which a patient is likely to make a request. For example, the patient may be asked to put a notice on the bulletin board but is not provided with a thumb tack. This situation creates a need to request a tack. The author evaluated the patient's behavior by noting the number and adequacy of requests that were attempted. Apel, Newhoff, and Browning-Hall (1982) devised a task in which they created a need for aphasic patients to request clarification or additional information. The rather ingenious task involved having an unimpaired partner discuss a picture with the aphasic client and interject statements or questions containing nonsense words. They classified the aphasic's response to the clinician's jargon into one of four categories: a nonvocal request for clarification, a vocal request, a verbal request, or a nonrequestive response. Davis and Wilcox (1985) suggest ways in which both Prinz (1980) and Apel et al. (1982) could revise the artificial tasks and make them more realistic. Newhoff, Tonkovich, Schwartz, and Burgess (1982) analyzed aphasic patients' abilities to repair misunderstood messages with a task that is widely found in the child language literature (Davis & Wilcox, 1985). The client is engaged in an hour-long conversation, during which the clinician feigns confusion or lack of comprehension by asking

questions. The aphasic patient's response to these questions is then analyzed to determine what, if any, repair strategies are employed by the patient.

Basili and England (1986) designed a Pragmatic Profile (PP) consisting of nine communicative and nine cognitive items to differentiate global aphasic subjects who interacted well in their environment from global aphasics who did not. The PP is also helpful in differentiating severity levels between subjects who have had a right hemisphere cerebrovascular accident and demented subjects, as well as in differentiating patients affected with a communicative deficit from those with a cognitive deficit. The items have been scripted into a clinical milieu for naturalness so as not to resemble a test situation. Yes/no questions are interspersed with contextual requests; for example, after sniffing, the clinician asks for a tissue.

Finally, Skelly (1979) designed the Skelly Action Test of Auditory Recognition (SATAR), which was planned to resemble a role-played interview wherein the patient is invited into a room, asked to sit down, asked if he or she would like something to drink, etc. Scoring of the 20-item SATAR is +/- and, in the event of poor response (less than 50%), the same test items may be presented in concert with appropriate Amer-Ind Code gestures (Skelly, 1979). Patients consistently responded with a higher degree of accuracy on the SATAR under the auditory/gestural conditions than under the auditory conditions alone. It is anticipated that elderly clients also would benefit from directions given via combined modalities.

Role Playing

Some aphasiologists have attempted to assess their patients' overall communicative effectiveness by engaging them in role-playing activities (Davis & Wilcox, 1981; Holland, 1980; Ulatowska, Macaluso-Haynes, & Mendel-Richardson, 1976). Usually, a simple activity is selected as the theme for the role play (e.g., getting a prescription refilled), and the patient is asked to act as though the activity were really occurring. Holland (1980) employed this role-playing scenario in one portion of the Communicative Abilities of Daily Living (CADL) and evaluated the patient's communicative behavior by scoring the responses as 2 (correct), 1 (adequate), or 0 (wrong). Ulatowska et al. (1976) conducted role-playing assessments in their patients' homes in order to get at the underlying communicative competence of aphasic persons. Scripts and prompts were prepared for such daily living activities as depositing a check in the bank. Communicative effectiveness was determined by specifying the modalities used for communication as well as the delays that accompanied communicative efforts. Finally, Davis and Wilcox (1981) described role-playing techniques that could be performed in the clinical setting. Those realistic "acts" (e.g., asking for help) were used primarily as probes in determining treatment progress. A patient's communicative success was scored in relation to

the number of prompts that had to be provided by a clinician prior to "getting the message across."

Role-playing situations have been found to be difficult for neurologically impaired patients due to the abstractness and artificial nature of the situation. For this reason, Davis and Wilcox (1985) suggest that some degree of caution should be exercised in generalizing the results to clients' natural communicative abilities and that, therefore, role playing is not suitable as a starting point for a functional assessment.

Pragmatic Assessment Procedures

Two diagnostic protocols that have been designed to look at functional communication are Sarno's (1965) Functional Communication Profile (FCP) (1965) and Holland's CADL (1980).

The FCP does not require the patient's cooperation since an informant (significant other) provides information regarding the patients' communicative behaviors. The clinician then rates the patient on 45 examples taken from daily communication situations subsumed under five major headings (movement, speaking, understanding, reading, and other). The CADL was developed to provide a formal aphasia assessment tool that samples such real-life communication situations as making a doctor's appointment and buying a soda. Both the FCP and the CADL are considered ancillary assessment tools to a formal diagnostic battery in aphasia, but they might well complement each other and be used exclusively in a functional assessment of a suspected benign senescence.

Outcome Measures

Accrediting bodies, such as the Joint Commission for the Accreditation of Healthcare Organizations and the Commission on Accreditation of Rehabilitation Facilities, are now requiring rehabilitation specialists to include outcome profiles as part of the patient care assessment tool. A veritable alphabet soup of outcome measures is now commercially available, and neither the accrediting bodies nor the health care industry have settled on the optimal outcome measures for rating communication abilities. Three outcome measures will be described briefly here to provide a sample of available measures.

The Functional Life Scale (FLS) by Sarno, Sarno, and Levita (1973) was designed to provide a quantitative measure of an individual's ability to participate in basic daily activities which are customary for most adults. The scale may be considered a measure of disability or measure of the success or failure of a rehabilitation program. It consists of five broad categories (cognition, activities of daily living, home activities, outside activities, and social interaction) and 44 items, and it is rated on a 5-point scale. The results provide a picture of the patient's functional ability. Although no longer widely in use, the FLS was one of the first outcome measures to attempt to describe

the patient only according to what he or she actually does and not what he or she may have the capacity to do.

Brown, Gordon, and Ditter (1984) developed Rehabilitation Indicators (RIs), which refer to a cluster of functional assessment instruments. The constituents of these instruments can be used separately or in tandem, as dictated by the needs of the users. The component relevant to this discussion is the Skill Indicators (SKIs), which correspond most directly to traditional approaches to functional assessment. The SKIs document the client's behavioral strengths and weaknesses in diverse areas of functioning, (e.g., self care, mobility, and communication). It is the most extensive list of skills in the business, with more than 40 broad categories and over 100 items. Each user can select the subset of skills that is relevant to the setting's program and sense of accountability and employ a rating scale that is suitable for the setting. The SKIs seem particularly well suited to the functional assessment of the elderly. Under the cognition category is a subcategory of "Remembering and Being Oriented." The SKIs for this topic are as follows:

1. Knows own name
2. Knows own address and phone number
3. Knows own age
4. Knows days of week, date, month, and year
5. Remembers names of people frequently encountered
6. Remembers recent events
7. Remembers events of past years
8. Remembers telephone numbers

This list is an example of just how operational the SKIs are and illustrates the functional menu from which the clinician may choose when rating outcomes. When presented with an elderly client who complains of being forgetful, the speech-language pathologist can gather SKI data by observation and/or by reports from the client or the client's family. The result can be a rather extensive rating of skills which permits the professional to get an accurate picture of just what the patient can do (a snapshot of function).

Larkins (1987) presents Functional Communication Measures (FCMs) for 14 different communication headings (e.g., voice, fluency, speech production). The FCMs are scored on a 0-7 scale along a continuum from complete dependence to total independence. The FCMs were designed to be rated by the clinician once the clinical and functional assessment has been completed and then rated regularly thereafter to monitor functional outcomes in the patients. Clearly disordered patients are fairly reliably rated; however, changes in high level cognitive-communicative disordered individuals are difficult to assess due to a ceiling effect. They tend to be rated consistently as 6s as they will seldom reach the norm of 7. Many borderline disordered elderly would indeed fit into this peak/near normal slot of 6 on many of the FCMs.

Whichever outcome measure one selects, it behooves the clinician to make the outcome rating a key component of the functional assessment of the elderly. Ideally, the

speech-language pathologist would first rate the elderly client on the vast array of SKIs pertaining to cognition and communication and then rate the appropriate FCMs. This method would result in a detailed analysis of and the patient's disability really is and how varied are his or her options for compensating.

DECIDING VARIABLES FOR A FUNCTIONAL ASSESSMENT

We have surveyed at least 13 potential components of a functional assessment. Clearly, not all functional assessment approaches are appropriate for all levels and types of communication disorders, nor can they be considered appropriate for all work settings and clinicians. According to Davis and Wilcox (1985) in their recommendations for a pragmatic assessment, it is important to select an assessment approach that will yield representative information concerning a client's communicative strategies. Accordingly, selection and administration of assessment is governed by three variables:

1. the capacity of a given instrument for identifying a person's natural communicative strategies,
2. the severity of the communication impairment, and
3. the work setting and time constraints of the clinician.

Once the speech-language pathologist has considered these three variables, the functional assessment can be tailored to the patient and the setting. The speech-language pathologist can opt for a combination of a standard clinical battery and a functional assessment.

SUMMARY AND CONCLUSIONS

The discussion dealt with the functional assessment of the elderly adult from the moment of the appointment to the completion of the diagnostic work-up. The charge was to provide a menu of informal approaches to pragmatic assessment. The clinician should be able to assess the degree of disability by determining the limitation of choice on the part of the elderly adult. Thereafter, the speech-language pathologist must investigate whether the patient might benefit from a change in environment, a change in behavior, or use of a prosthetic device. The data to support the diagnosis, prognosis, and plan can be garnered from a variety of sources. The foundation of the functional assessment of the elderly is a solid and detailed interview and case history. The clinician will monitor the patient for evidence of disruption to oral motor function, voice, speech, fluency, language, and cognition. Formal examinations may be required to complete the communication profile; however, a host of informal and functional approaches exist to tease out the patient's communicative assets and liabilities. The clinician can choose from natural observation, a home visit, role playing, and skill level ratings. No single prescribed

menu is best for all levels of patients and disorders. One must base decisions about the composition of the functional assessment on the answers to three questions: Is the tool helpful in identifying communication strategies? How severe is the impairment? Considering the work setting and time constraints, what can realistically constitute the functional assessment? Finally, the speech-language pathologist will conduct the assessment and determine whether the elderly adult can be assisted in improving his or her communication skills or in communicating more effectively with existing skills, and whether increased opportunities for communication are feasible. The elderly patient is a challenge to the diagnostician because the patient may bring to the clinic such primary aging problems as presbycusis, fatigue, and slowness, and such secondary aging problems as anomia, dysfluency, and disorientation. The astute clinician does not weigh the results of the standard examination more heavily than the pragmatic assessment, but strives to bring into focus the primary complaint of the person and determine if the complaint can be resolved. The bottom line is, can we expand this individual's choices, thereby minimizing his or her disability? If not, no treatment is recommended. If it is determined that the patient may indeed benefit, the next step is to begin functional communication treatment.

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Chapter 5

RESEARCH METHODOLOGY I. IMPLICATIONS FOR SPEECH-LANGUAGE PATHOLOGY

AUDREY L. HOLLAND

University of Pittsburgh

There are both general and quite discipline-specific methodological issues that apply to research in geriatric speech-language pathology. A core of these issues pertains to the study of aging individuals generally. Superimposed upon it is a set of problems and priorities unique to the study of speech and language disorders of aging adults. This province includes most of the speech and language disorders we have come to associate with neurologic deficits, such as aphasia, dysarthria, apraxia of speech, the various dementias, and so forth, that disproportionately occur in aging adults, as well as disorders of voice associated with the aging process. In this chapter, I will address both general and specific issues, beginning with a brief sampling of the general ones. I will then discuss more specific discipline-engendered issues.

Before beginning, however, I wish to define a few relevant terms and to caution about the usage of a few others. Together with Salthouse (1982), whose ideas permeate this paper, I would like to suggest that one's theoretical assumptions are often embedded in one's definition of *aging*. Therefore, like Salthouse, to avoid a theoretical commitment, let me adopt Birren and Renner's (1977) definition of aging, as follows:

aging refers to the regular changes that occur in mature genetically representative organisms living under representative environmental conditions as they advance in chronological age. (p. 4)

I have already referred to the domain of speech-language pathology as it relates to aging by the less cumbersome term, *geriatric speech-language pathology*. I will continue to use this throughout.

GENERAL METHODOLOGICAL ISSUES

The first general methodological issue, I believe, is simply to convince researchers that there are unique aspects of research in aging and unique problems to be dealt with, as well as controversies among gerontologists

about how a number of them are likely to be most effectively solved. In the not-too-distant past, when concepts of life-span development were beginning to have an impact on contemporary thinking, a few words about aging used to be appended to the end of developmental courses, and a couple of chapters added on to books about children and young adults. Speech-language pathology students seldom dealt with aging issues directly. Rather, those issues were marginal to the study of disorders that had an overrepresentation of the elderly, such as aphasia. Particularly in a profession such as ours, where the research thrust (as well as sources of research funding) has traditionally favored communication problems of children and young adults, research methodologies for aging individuals also were likely to be viewed as simply add-ons. That is, our familiar methods probably were considered appropriate for application to research concerning the communication problems of aging individuals. And, of course, to some extent they are. Scientific research, after all, implies a unique way of thinking about things and applying that thinking systematically through use of scientific method. But, in some ways research on aging is unique.

Variability and Aging

One of the most important ways in which study of the aging differs from study of younger adults and of children is that even within a given culture its aging individuals show the greater diversity. The aging segment of the population is more heterogeneous than are younger adults and children. This fact has general methodological implications, as well as implications that are specific to geriatric speech-language pathology. Most obviously, while in many studies of younger individuals, matching experimental and control samples by age, gender, race, and education might be sufficient, experimental and control samples of aging individuals probably must be matched on a number of other variables as well. These include physical and mental health, socioeconomic sta-

tus, vocation, and a wealth of personal history variables. Variability in aging makes it almost mandatory that studies of older individuals report not only standard deviations but ranges, where appropriate. Because of the heterogeneity of the aging population, it is important to note that generalizability of research findings is probably more limited than when a younger group is studied.

Environment Effects

One of the reasons for the great heterogeneity among the aging is the big-people version of the nature-nurture controversy, called variously "cohort effects" (Schaie, 1965), "cultural change" (Anastasi, 1958), and "environmental change factors" (Salthouse, 1982). The basic methodological problem and research issue is to separate out developmental trends that are truly maturational from those that are the result of living in a specific temporocultural context, that is, from living where and when and under what circumstances. A related problem is to determine the relative contributing weights of natural and sociocultural variables. Researchers like Botwinick (1978) suggest that social variables such as religious beliefs are likely to be more sensitive to social and cultural changes that might have occurred during an individual's lifetime than are such biological variables as reaction speed. However, it should be noted that much research on speech and language is probably squarely between the social-cultural and the biological. Consider, for example, studying the nature of communicative interaction among 75-year-old spouse-pairs. Thus I wish to emphasize the importance of taking environmental change factors into account in planning, conducting, and interpreting communication research.

Cross-Sectional and Longitudinal Research Designs

Regardless of the age of experimental subjects, researchers are invariably confronted with the relative advantages and disadvantages of longitudinal versus cross-sectional research designs. They are required to decide which approach is the more appropriate for the problem to be studied. It is generally agreed that this is a particularly difficult problem for researchers concerned with aging. Cross-sectional research designs compare individuals of varying ages at some particular point in time or study other independent variables in age-matched subjects. An examination, say, of individuals' differing ability to name objects as a function of their age would be cross-sectional if samples of progressively older individuals were compared on an object naming task. In geriatric speech-language pathology, we might use cross-sectional approaches to study problems in the elderly by matching healthy aging individuals with aging language-disordered individuals, as well. The environmental exposure and heterogeneity problems are immediately appar-

ent in such a design. An additional problem is that it is difficult to obtain equally representative samples for all the age groups tested.

The alternative is longitudinal research, in which a selected group of individuals is studied over a long period of time. There are disadvantages to longitudinal research, too, primarily related to the time period required to obtain the necessary observations, the expense involved, and the inflexibility of longitudinal designs. The advantages are that individual aging effects can be studied, and because the same individuals are followed, the comparison group effects are minimized. The recently published *Duke Longitudinal Study of Normal Aging* (Busse & Maddox, 1985) covers the period of 1955-1980 for a carefully selected group of representative aging Americans. It is a gold mine of information, illustrating the power of longitudinal studies. It should be noted that the study had many upbeat conclusions that are relevant to the concerns of the present conference. For example, in healthy individuals, intellectual functioning was maintained until about the 8th decade of life. Of further interest to us is validation of the generally held notion that verbal skills outstrip performance, and that there is a strong relationship between level of intellectual performance and subsequent survival. Finally, the study shows quite clearly that chronological age itself accounts for little variation, reminding us again of the cohort effect and bringing us directly to the health issues as they affect aging research generally.

Before discussing health issues, however, let me suggest that there really is no clear solution to the cross-sectional versus longitudinal research design issue. One possibly fruitful alternative is to attempt to use both in the same study. For example, we (Fromm & Holland, 1989) are studying the dissolution of functional communication skills in Alzheimer patients by comparing a group of patients cross-sectionally at yearly intervals with a sample of Wernicke aphasic patients, and we are following them in a longitudinal comparison with chronically depressed and normally aging controls.

Health Issues

In many ways, health issues for the aging bridge the gap between general research methodology questions and those that specifically relate to the research domain of geriatric speech-language pathology. Most of the disorders that are the focus of our research attention are related to the health (or lack of it) of aging individuals. For the normally aging, the issue is also tricky. Health problems occur disproportionately in aging, and it is not clear to what extent the appearance of health problems is in fact part of the aging process. For the speech-language pathologist, an excellent example is the voice changes that occur in a significant segment of the aging population. It is not clear whether such changes are endemic to the aging process or pathological in nature.

Given the number of problems that aging individuals are likely to have with health, transportation, and so forth,

a continuing concern is that the data base upon which our scrutiny of the aging rests is biased by its overinclusion of the so-called super normal. This is not just a problem that affects aging research, but it is particularly likely to occur with the aging and must be cautioned against. While it is not very likely to be an issue in studies of individuals with disorders of speech and language, it presents additional problems for controlled comparisons with the normally aging.

In designing research, to limit one's control or normative samples to aging individuals whose health is normal, or who have normal hearing or vision, probably limits generalizability of results. Limiting control or normative samples in such a way also is likely to make disordered samples appear to be more impaired than they actually are. There are no obvious solutions to these problems. Again, need exists for being acutely aware of them in design, conduct, and interpretation of research in aging.

As a straightforward example of the value of such awareness, the controversy over whether aphasia is or is not differentially responsive to treatment as a function of age is probably resolved by looking at the matter of general health in aphasic subjects. Our own analysis of the issue suggests that if elderly aphasics are otherwise healthy, they do well in treatment. If they are more representative of their age groups, that is, if they are sicker than their younger aphasic counterparts, they do not fare as well (Holland & Bartlett, 1985).

METHODOLOGICAL ISSUES IN GERIATRIC SPEECH-LANGUAGE PATHOLOGY

The Need for Normative Data

The focus of research in speech-language pathology is rightfully on individuals who have disordered communication. However, even the very definition of *disordered* depends upon understanding of normality and normal variation. The profession has relied heavily upon other disciplines, such as psycholinguistics and sociolinguistics, to help us determine what is meant by normal speech and language, and we will continue to do so.

In addition, distinguished normative work has also come from researchers who consider themselves primarily to be speech-language pathologists. This is particularly true in child language research. Few would argue that our understanding of how children learn to talk is much further advanced than is understanding of how language is maintained or eroded in adulthood. Geriatric speech-language pathology is hindered seriously by the paucity of information regarding language and normal aging, from psycholinguistics and sociolinguistics and other disciplines with vested interest in language issues (such as cognitive psychology) as well as from researchers within the discipline. This situation is changing, and a substantial research effort is underway as efforts to under-

stand the relationship, particularly between cognitive dissolution and language deterioration in dementia, are increasing. Nevertheless, the normative data base that is desperately needed for our work in geriatric speech-language pathology is clearly missing. Ulatowska, Cannito, Hayashi, and Fleming (1985) state the need very clearly:

Another rationale for the study of language in normal elderly people is its immediate relevance to the clinical study of pathological language. First, aging is the single greatest risk factor in stroke. . . . Thus, it is extremely important to know which language changes are attributable merely to aging and which are attributable to stroke. . . . Second, aging is the most common factor associated with language changes in diffuse or multi-infarct brain diseases in dementia. Often in the early stages of dementia there is a delicate boundary between what might be attributed to normal aging versus what may be attributed to the disease process itself. Here again careful documentation of language changes in the elderly is of utmost importance. The present lack of normative data in this area represents a notable hiatus in the clinical assessment of communication disorders. (pp. 126-127)

The methodological implication of all of this is rather stark and clear. Without the normal data base, much of our work with pathological populations is necessarily suspect. The previously mentioned variability in the aging population, as well as the environmental influences, make it likely that what really is needed is a variety of norms, not only related to age, but to setting and communication history. For example, we know that institutionalization affects language use even among individuals who have no apparent language-disorder-related condition. What norms, then, are appropriate for judging language-disordered patients in long-term residential units? (Holland, 1980)

Normal-Disordered Comparisons

It would perhaps be tidy to wait until the normative issues were cleared before the study of disordered speech and language were undertaken. But that is both an irresponsible and an untenable position. It is important to continue the normative work and to be sensitive to the limitations that result from our current deficits, but research describing disorders, delineating mechanisms of breakdown, and effects of treatment is rightfully continuing.

One must be cautious, however, about what can be learned from simple aging-normal, aging-disordered comparisons. For example, it is probably not very informative to discover that individuals with Alzheimer disease perform more poorly on an object naming task than do carefully matched aging normal controls. However, provided that they are followed up carefully, similarities between Alzheimer disease patients and aging normal controls are of much more interest. For example, a study by Nebes, Martin, and Horn (1984) showed that semantic memory structure may remain intact in Alzheimer patients. Nebes et al. (1984) followed that lead and, in a subsequent series of carefully designed studies (Nebes,

Boller, & Holland, 1986; Nebes & Brady, 1988; Nebes, Brady, & Jackson, 1989), have demonstrated that this almost normal ability occurs only in situations that make minimal demands on Alzheimer patients' attentional capacity. Thus, another process, not semantic memory, is critical to explaining the phenomenon. This example is mentioned here to illustrate the methodological wisdom of designing studies that follow up on similarities between patients and controls.

A second way to capitalize upon normal aging subjects as controls for subjects with speech and language disorders is to "handicap" the normal control. In this way, it is sometimes possible to elucidate the variable of interest in normal-aging and disordered-aging comparisons. For example, if one wishes to disentangle the effects of memory and language in such a comparison, one might experimentally inflate the memory demand for the normal subjects to approximate that which is demonstrated by the demented subjects.

Finally, it is often of use to run two sets of control subjects, both younger and age-matched normals. In this way, comparing the two normal groups provides additional insight into differences between the two aging groups.

Disorder-Disorder Comparisons and Questions of Differential Diagnosis

An important area of research concerns describing, defining, and explaining the similarities and differences existing between a number of the disorders that are common in geriatric speech-language pathology. Of concern here are the various aphasias, dementias, and motor speech disorders (including apraxia of speech and the various dysarthrias). That age-at-onset plays a role in determining the type of aphasia a given patient might be manifesting has only been recognized in the past 10 years or so, and is not yet clearly understood. In contrast, the traditional belief that comparatively younger Alzheimer patients are more likely to have aphasia, apraxia, and agnosia, more "hard" neurological signs, and overall faster clinical decline has been challenged recently by both our work (Becker, Huff, Nebes, Holland, & Boller, 1988) and that of others (Sulkava & Amberla, 1982). Again, reasons are not clearly understood. What is clear, however, is that cautious researchers concerned with differential diagnosis of the so-called aging speech and language disorders must be careful about the age of patients, as well as overall health issues and the presence of concomitant disorders, if comparative studies are to be meaningful.

Treatment Studies

Together with assessment studies, research geared to address questions of general efficacy of treatment and comparative effectiveness of various treatments consti-

tutes the bread and butter of clinical research in geriatric speech-language pathology. In fact, concern with efficacy of treatment has distinguished this segment of clinical speech-language pathology for some time. Wertz and his colleagues (Holland & Wertz, 1988; Wertz, Deal, Holland, Kurtzke, & Weiss, 1986) have discussed in detail the plethora of methodological considerations in efficacy research, such as the necessity for random assignment to treatments, rigid specificity in type and amount of treatment administered, and addressing concerns about the reliability of trainers. The matter of treatment of aging subjects simply adds to the list of those concerns. For example, our current good data on efficacy of treatment for aphasia can only be generalized to single-episode left hemisphere strokes in otherwise relatively healthy aphasic patients under the age of 75. We have no direct tests of efficacy of treatment in older patients, or those who have had more than one stroke, or, in fact, for any other of the problems falling under the domain of geriatric speech-language pathology. A particular lack of important data relates to the role of the speech-language pathologist in treatment of Alzheimer disease.

The use of single-subject research designs as a first step in the development of clinical intervention techniques requires special comment. As first order approximations for ultimately more widely applicable approaches, they are extremely helpful.

SUMMARY AND CONCLUSIONS

In this presentation, I have tried to address a few of the methodological concerns that are indigenous to the study of aging individuals, with a particular emphasis on the unique aspects of geriatric speech-language pathology. I have not resolved a single methodological problem along the way, but have tried to give some suggestions about ways to look at some of the problems and ways to work around a few of the others. I have left two major points for these concluding remarks, for I feel them to be of overarching importance to our profession if we wish to overcome our woefully inadequate data base as expeditiously and as rapidly as possible.

1. Most of our current research has focused on changes that occur as individuals age in this society. This is an important focus, but it needs to be tempered in our future work by at least as deep a concern with adaptation to stressful and significant life events. Stability, as well as change, must be taken account of to give a life-span perspective to speech-language pathology. A single example should suffice. Were it possible to demonstrate communicative stability over time as the result of the application of a treatment strategy in patients with Alzheimer disease, a great deal would be accomplished.
2. Finally, the researcher in geriatric speech-language pathology must become acutely aware of the notion that aging, by itself, is not an explanatory variable. That older individuals do x and younger individuals do y gives us no clues about the processes involved, the mechanisms of

change, or even whether the difference is important or not. As with all other areas of aging research, the next step must be taken when age effects are found. Theories and hypotheses must be developed and put to scientific scrutiny.

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II. IMPLICATIONS FOR AUDIOLOGY

BARBARA E. WEINSTEIN

*Department of Speech and Theatre
Lehman College, CUNY
Hunter/Mt. Sinai Geriatric Education Center, New York, NY*

The demographic imperative of the present decade and decades to come points to the growing need for research in human aging in general and the effect of aging on communication and the speech and hearing mechanism in particular. The research agenda for understanding and intervening in age-related communication disorders must be proactive, with a view toward promoting health and functional capacity (Butler, 1988). In the realm of audiology, research is needed to answer a variety of practical and theoretical questions. In planning a research agenda, at all stages one must consider the changes in which aging is manifest. These stages include (a) the formulation of the conceptual and theoretical framework for the study, (b) the development of the design of the study, (c) the processing and analysis of the data, (d) the interpretation of the data, (e) the conduct of a bibliographic search, and (f) the dissemination of findings (Peterson, 1988; Shock et al., 1984). The discussion that follows is an attempt to demonstrate how to integrate the aging literature into audiological research.

DEFINITION OF TERMS

Investigators in the area of hearing and aging must agree on the definition of the terms *gerontology*, *aging*, and *cohort*. The definitions one brings to the research will influence the conceptualization and implementation of a given study and will facilitate efforts to establish research priorities. *Gerontology* is defined as the study of aging in its biological, psychological, and social dimensions (Butler, 1988). This definition implies that gerontology is interdisciplinary in scope. It underlines the importance of a holistic understanding of the human being and the importance of fostering linkages between behavior and biology and between the clinical and basic sciences (Butler, 1988). The term *aging* connotes changes in structure and function with the passage of time (Tobias, 1988). Oftentimes, 65 years is used as the demarcation for the beginning of old age (Shadden, 1988). The term *cohort* refers to groups of individuals who share a common characteristic, such as date of birth.

THE RESEARCH AGENDA FOR AGING RESEARCH

A review of the gerontologic literature reveals five primary goals of aging research (Glass, 1986). They include:

1. *Epidemiologic research*, wherein one attempts to describe patterns of disorders or diseases in population groups and investigates the types of individuals who are most likely to present with or develop a given disease or disorder (Mulvihill, 1988).
2. *Biomedical research*, which attempts to understand the basic processes of aging, to separate normal developmental processes from disease, and to understand the different ways certain diseases behave in the elderly (Butler, 1988; Glass, 1986; Shock et al., 1984; Tobias, 1988).
3. *Behavioral and psychosocial research*, which attempts to understand and analyze the effects on the aged of the interaction of medical disorders, personal factors, social factors, and the environment.
4. *Social science research*, which seeks to find new knowledge that can be applied to enrich the lives of the elderly and the futures of those who will some day be old.
5. *Rehabilitation and technological research*, which develops treatment modalities for intervening in age-related disorders. The interventions are designed to promote health and functional capacity.

A RESEARCH AGENDA FOR AUDIOLOGY

Each of the aforementioned goals of aging research has a correlate in audiological research. In epidemiologic research, valid data on the epidemiology of hearing loss, that is the number of persons affected by hearing loss and the number at risk for its development, remain elusive (Mulvihill, 1988). While available prevalence figures collectively indicate that hearing loss is prevalent among older adults, the data are variable, contradictory, and, in some cases, present a conservative estimate of the proportion of the problem (Nerbonne, 1988). Sampling techniques, differences in the way in which the data are gathered (e.g., audiometric based vs. survey data), differences in how normal hearing and hearing loss are defined, and differences in the populations studied, all serve to confound available prevalence estimates (Nerbonne, 1988). Valid prevalence estimates are important, as the information reflects on the hearing health care needs of the older population and hence in planning for health care services for the elderly. Incidence data are also critical as such information can facilitate attempts at understanding why certain people are more susceptible

to age-related hearing loss than others are (Mulvihill, 1988).

In the domain of biomedical research, the extent to which changes in the ear are due to the aging process *per se*, or to pathological intrinsic processes, extrinsic processes, or societal or environmental factors must be delineated (Tobias, 1988). Preliminary to our understanding of aging versus disease is a delineation of how the structure and function of the peripheral and central auditory pathways vary with age. A clear definition of age-related changes in the ear will help researchers uncover the interaction between physiological factors (e.g., age), pathological factors (e.g., ototoxicity, metabolic disorders), and environmental factors (e.g., noise exposure) in older adults (Glass, 1986; Tobias, 1988).

Although most studies of older hearing-impaired individuals have been behavioral in nature, the research designs have left a number of questions unanswered. For example, in behavioral and biomedical research, the degree to which different etiologies contribute to the overall loss in hearing sensitivity in the elderly remains a challenge to investigators. A clear understanding of the etiology of changes in the structure and function of the ear, and the resultant audiometric patterns, will assist in designing medical and nonmedical interventions. The nature of changes in hearing sensitivity associated with age, the age-related changes in performance on the acoustic immittance test battery, the changes in the perception of degraded and quiet speech, and age-related changes in performance on electrophysiologic measures, including auditory evoked and electronystagmography, have been and continue to be the subject of extensive study in the audiology community (Nerbonne, 1988; Tobias, 1988). The lack of a clear consensus on the effects of aging on performance on any of the above measures mentioned serves as a constant impetus for investigators to continue to explore those areas.

An understanding of the auditory (e.g., audiometric configuration, temporal acuity, frequency selectivity) and nonauditory factors (e.g., cognitive processes) which affect performance on audiometric tests will assist in resolving some of the differences among studies (Tobias, 1988). Further, the ability to control for the audiologic and nonaudiologic variables that affect performance will assist in accumulating normative data. Finally, the audiologic and nonaudiologic correlates of service utilization should be delineated. The information obtained will assist in efforts to increase the numbers of older persons taking advantage of audiologic service.

In the psychosocial realm, the functional impact of abnormal performance on behavioral and electrophysiologic measures has received scant attention. Further, we have yet to demonstrate how an unidentified and unremediated hearing loss can exacerbate the development of confusional states in the elderly (Glass, 1986). The effect of hearing loss on family systems and on relationships in the work place is of increasing importance as individuals live longer and postpone retirement (Glass, 1986). Once we come to better understand the impact of a hearing loss on physical function, mobility, and psychosocial function,

a stronger case for nonmedical intervention in the form of wearable hearing aids and aural rehabilitation can be made.

In the technological domain, despite engineering advances, noise continues to plague most elderly hearing aid users (Tobias, 1988). Further, while the miniaturization of hearing aids satisfies the cosmetic needs of the elderly, manual dexterity problems (e.g., sensory or motor restrictions) continue to interfere with independent use of canal aids and certain in-the-ear units (Tobias, 1988). While considerable research effort has been devoted to establishing criteria against which to judge the adequacy of a given hearing aid, the test procedures continue to have little bearing on the ability of the elderly to function in the real world (Tobias, 1988). Thus, new techniques for measuring and predicting performance of the elderly with a given hearing aid must be explored. Similarly, instruments for quantifying the outcome or the efficacy of service and treatment modalities (e.g., the effect of intervention on health and functional capacity) must be developed. As one function of basic and clinical research is to produce more effective treatments, and to help individuals to function productively and independently, despite their handicaps, we must promote more research linking the ear to behavior (Butler, 1988).

Finally, Tobias (1988) argues for improved hearing conservation among the younger and older populations. One important part of a hearing conservation program is the development of reliable and valid screening techniques. At the present time there is considerable debate about a screening protocol to be employed with older adults. A number of issues surrounding screening must be resolved, including the definition of what to screen for (e.g., speech communication difficulties vs. handicapping hearing loss), procedure (e.g., pure-tone screening vs. self-report) to be employed, role of nonaudiologists in screening programs, desirable intensity levels and frequencies to be employed, referral criteria and priorities, and instrumentation to be used to generate the tonal stimuli. The hearing screening techniques yielding the most favorable test accuracies and predictive values must be identified to promote early identification of handicapping hearing loss in the elderly. It is imperative that the case-finding technique recommended for use with the elderly is cost-effective, portable, nonthreatening, easy to administer, and, above all, reliable and valid.

METHODS

A number of methodological issues must be addressed when studying the elderly. These include criteria for subject selection, selection of materials, and the design of the study.

Subject Selection

In establishing subject selection criteria, the goal is to select a representative sample of elderly individuals.

This will insure that the results are generalizable to a large group of elderly persons (Foldi, 1988). For example, the most rapidly growing segment of the U.S. population consists of individuals over 85 years of age. Those individuals, commonly referred to as the old-old, must be included as subjects, especially when standardizing a test. Further, we must select a heterogeneous sample of elderly individuals with hearing impairments—that is, a clinic as well as a nonclinic sample or a sample from the office of primary-care physicians and senior citizen centers. If the sample is to be representative of the general elderly population, we must keep in mind that approximately 80% of older adults have at least one chronic disease, and multiple chronic conditions are not uncommon (Foldi, 1988). Accordingly, one must insure that individuals with chronic ailments, including arthritis or visual problems, are included in the study. In light of the prevalence of visual problems in the elderly, it is important to test visual acuity in all subjects. If the experimental procedure requires intactness of vision, subjects should be urged to bring their low-vision aids or glasses to the experimental sessions. Further, mental status may fluctuate with certain medical conditions, so, if multiple testing periods are required, a brief test of mental status should be administered at the beginning of each test session.

Procedural Variables

It is imperative that researchers keep in mind that subject mortality will be influenced by a number of factors, as will performance on certain test procedures. Access to transportation and climatic factors will influence the decision to participate in a study. For example, the optimal time for recruiting subjects is fall and spring, when there are no extremes of temperature. Further, arranging transportation will increase the probability that subjects will participate. If lengthy procedures are required, keep in mind that the elderly tire easily and may show decreased attention span or increased error rates over time (Foldi, 1988). Thus, tests should be short or multiple testing sessions employed (Foldi, 1988). An additional procedural concern relates to the selection of test instruments. The instrument should be reliable, valid, and standardized on older adults. Finally, practice items or practice sessions should be built into the design to insure that the subjects understand the tasks required of them (Foldi, 1988.)

As regards the research design, the major issue is the choice of a longitudinal versus a cross-sectional design. The cross-sectional design involves the collection of data at one point in time from a sample of the population (Rayman & Bloom, 1988). Whereas the cross-sectional design reveals the presence of certain age trends, it does not provide a direct measure of age change, nor does it enable one to specify the rate of change on a particular variable (Shock et al., 1984). The longitudinal design permits the collection and analysis of data over time (Rayman & Bloom, 1988). Measurements are made on the

same subject at different intervals, thereby providing information on process or change (Rayman & Bloom, 1988). The longitudinal design enables one to specify the rate of aging for a specified characteristic or variable, such as hearing sensitivity (Shock et al., 1984). According to Foldi (1988, p. 287), each design has its drawbacks and brings with it "certain partiality to the data." In light of the fact that the longitudinal design is more time-consuming, more expensive, is plagued by the problem of attrition, and its data analysis is more complicated, the cross-sectional design is more popular (Rayman & Bloom, 1988). However, given the importance of the information gleaned from a longitudinal design (e.g., change in a dependent variable over time), researchers are encouraged to approximate this design, especially when gathering normative data.

RESULTS

In reaching a decision about the method(s) of data analysis, one must consider the fact that in the elderly population in particular, behavioral factors, biological processes, and social and environmental factors are inextricably intertwined. Multivariate analyses, which enable the researcher to explain the dependent variable on the basis of one or more independent variables, are often the statistic of choice (Rayman & Bloom, 1988). Further, given the large individual differences in performance on criterion variables, it is imperative that at least two measures of dispersion are reported—the range and the standard deviation. By expressing variability in terms of both range and standard deviation, one can better appreciate the spread of scores on the variable of interest.

Data Base Management

A number of data managers or data base management systems are available to facilitate the collection, organization, storage, and processing of data on older adults (Peterson, 1988). Some of the data bases are disease specific, while others were created for a given population. For example, as of this writing, the Dementia Clinic at Burke Rehabilitation Center has data on more than 600 individuals undergoing an evaluation to determine their level of cognitive impairment (Peterson, 1988). According to Peterson (1988), copies of the evaluation forms developed for each patient are available to subscribers.

The Veterans Administration has created a number of data base management systems throughout the country (Peterson, 1988). The Geriatric Research, Education and Clinical Center (GRECC), at the Minneapolis Veterans Administration Center, has available a hospital-based mainframe data base that includes all patient care data relevant for nursing management. For example, the data base includes information on functional, behavioral, and physical status (Peterson, 1988). At the time of this writing it was unclear whether audiometric data are available.

The clinical information system in use at Baylor Veterans Administration Medical Center uses microcomputers. The data base includes information about inpatients and outpatients on the Geriatric Evaluation Unit at that facility (Peterson, 1988). Basic statistical functions are also built into this data management system (Peterson, 1988).

Additional information about data management systems for research on aging can be obtained from the American Association of Medical Systems and Informatics (AAMSI). AAMSI sponsors an annual symposium on computer applications in medical care (Peterson, 1988). It has a professional speciality group program that, perhaps, will include audiology in the future.

DISCUSSION

In the discussion of results deriving from a given study, one must bear in mind the realities of aging as those may influence generalizations, conclusions, or recommendations. Three such realities include:

1. Aging is a highly specific process and a completely individual phenomenon (King, 1988). Variations are especially apparent for the individual senses, including vision, hearing, smell, and taste (King, 1988).
2. The diversity among individuals suggests that no single intervention will be appropriate for all. Rather, a variety of different interventions, tailored to individuals with certain characteristics, is desirable.
3. Aging is associated with decrements in numerous domains (e.g., physiological, psychological, sociological), and, thus, audiologic research demands a correlation among audiologic and nonaudiologic variables.

Information on the health, demographic, and sociological characteristics of the aged may be useful in the discussion of results (Hill, 1988). Statistical data on health status, health needs, diseases, resource utilization, social characteristics, economic factors, expenditures, and demographic trends or factors are available from a number of sources (Hill, 1988). Some of the sources listed by Hill include national and governmental agencies (e.g., National Center for Health Statistics); professional, special interest, and commercial organizations (e.g., American Association of Retired Persons); and the journal literature. An exhaustive list of sources for statistical data relevant to aged persons is contained in Hill's discussion of library research and information retrieval.

Hill also describes in detail automated information retrieval systems available for searching the journal literature on gerontology and geriatrics. The information will be of considerable value in attempts to relate audiologic studies to other studies in gerontology and geriatrics. Selected sources for locating journal literature on aging and the aged include MEDLARS data base and print indices, MEDLINE data base, AGE LINE (a data base produced by the AARP), and *Excerpta Medica-Section 20: Gerontology and Geriatrics* (Hill, 1988). In addition, appearing annually in *The Journal of the American Geriatrics Society* is a selected up-to-date bibliography containing 500-600 references dealing specifically with elderly persons (Hill, 1988). Finally, a retrospective bibliography on aging, dating back to 1948, is available in a landmark work by Shock (1986), *A Classified Bibliography of Gerontology and Geriatrics*. According to Hill (1988, p. 122), "The above bibliographies present excellent overviews of the journal literature of geriatrics and provide ideal sources for identifying articles to be used for citation searching."

CONCLUDING REMARKS

The most important charge to individuals undertaking audiologic studies is the dissemination of results, by means of publications or presentations, to members of the speech and hearing community and to individuals in allied health professions. By communicating with members of related disciplines and professions, we can contribute to research efforts designed at improving function and enhancing the quality of the prolonged lives of all individuals.

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D. A STATE-OF-THE-ART REVIEW

Chapter 6

NEUROLOGICAL AGING¹

JANICE E. KNOEFEL

Veterans Administration Medical Center, Boston, MA

Normal, age-related changes and abnormal, disease related changes may be difficult to discern in the elderly and even more difficult with far advanced age. The separation of normal aging and pathological decline is indistinct, even in research studies.

All functional systems are affected by aging: intellectual, sensorimotor, perceptual, and autonomic.

I review what is known about normal, age-related changes of the nervous system. This discussion will separate neurologic functions into cognitive, sensory-perceptual, and motor systems.

There are a number of documented changes that occur in the aging nervous system. Brain weight decreases. Ventricular size increases. Cell number and cell RNA content decrease. Lipofuscin (a granular, yellowish pigment resulting from degraded intracellular membranes) progressively accumulates in certain types of neurons. Alzheimer type changes occur. Peripheral nerve conduction slows. Latency of central sensory processing is increased. Incidence of visual and auditory loss increases. Neurotransmitters, such as dopamine and acetylcholine, decrease while others are unchanged. Many studies are ongoing and will divulge more data.

But in this discussion, I have chosen not to emphasize anatomical brain aging. Descriptive reviews that examine that aspect in great detail have been published recently (Creasey & Rapaport, 1985; Rinn, 1988). I have chosen not to detail the anatomical, physiological, and neurochemical changes seen in normal aged brains because they don't tell the real story. Those changes alone don't translate into behavior or function.

Studies of human aging are complicated by methodological issues. There is considerable heterogeneity among elderly populations and cultures. There is varying appreciation of what may be called normal and who may be called old.

Selection of experimental design remains a major, unresolved problem in studies of human aging. The relative merits and validity of cross-sectional and longitudinal studies are much debated (Nesselrode & Labouvoire, 1985). As a general rule, cross-sectional studies tend to maximize age-related changes in testing, while longitudinal designs tend to minimize such changes. Differences among age groups, the so-called cohort effects, are seen in areas of nutrition, education, health care, vocation, and avocation. These factors alone may account for a significant portion of the decline with age seen on tests of cognitive and motor skills in cross-sectional studies.

Longitudinal studies, on the other hand, may be biased towards extraordinarily healthy and skilled individuals. Highly motivated and healthy subjects volunteer to be tested in their remarkably preserved functions. Dropout of less motivated subjects and attrition of ill subjects may influence the outcome and prevent generalization to the larger but less extraordinary population.

COGNITION

Included in cognitive functions are attention, memory, language, and intellect. Many authors have discussed problems in the evaluation of cognitive changes in the elderly (Schaie & Hertzog, 1985). I provide here my own analysis of cognitive function in normal aging, and will mention areas of controversy in passing.

Attention

Attention (also known as immediate memory) may be defined as the ability to focus mental energy on a specific stimulus, while effectively screening out distractions from peripheral stimuli. Vigilance is sustained attention. Changing mental set, also called shifting set, is the concept of refocusing attention from one stimulus to another. Divided attention allows attention to be focused on competing stimuli simultaneously.

¹From *Surgical management of the elderly patient* by Mark R. Katic, M. D. (Ed.), 1989, Baltimore-Munich: Urban & Schwarzenberg. Copyright 1989 by Urban and Schwarzenberg. Adapted by permission.

Simple tests of attention are performed equally well by the old and young. Tasks of more sustained vigilance and concentration are not performed as well in old as in young groups of subjects (Wechsler, 1958). Performances on timed tasks of attention show even greater deficits. The symbol digit substitution subtest, a timed test measuring attention, shows an age effect in both cross-sectional (Wechsler, 1958) and longitudinal studies (Granick, 1971). The trail making test, which also requires shifting set, demonstrated significant age related decline in time to performance criteria (Adjutant General's Office, 1944). In addition to impaired performance on tasks of sustained attention, elderly people also show impairment on tests of divided attention.

In summary, the elderly show no decrement on tasks in simple attention. However, tasks of sustained and divided attention reveal significant decreases in performance with age. This effect is compounded by timed performance.

Intact attention and concentration are prerequisites for all aspects of memory functioning and coherent cognitive integration. The elderly person with a decrement in sustained or divided attention may not capture all necessary details in everyday exchanges of information. Similarly, the elderly person is not as facile in shifting from one important idea to another. Attentional slowing and increased need for additional time to register information predispose the elderly to misunderstanding information and instructions.

Memory

Complaints of memory loss are so common in the elderly that it has become the standard belief that memory impairment is the principal cognitive problem of normal aging. This belief may be unwarranted. Memory is mildly impaired with normal aging, but not nearly as much as many people believe. Other cognitive changes may compound memory problems, making the memory impairment of old age seem worse than it really is.

Memory is not a single, unitary cognitive function. Memory involves multiple sequential and parallel processes which are mutually interdependent. To understand memory, one must test not only each of the independent processes, but also the interactions.

Recent memory tasks of orientation are performed equally well in old and young people. Learning and recall of short lists of words and of location of hidden objects are similarly well performed by older groups. The differences seen with age in recent memory are demonstrated with (a) longer, more complex information to be learned and (b) information of little logical associative value. This age difference in recent memory includes groups of both highly educated and poorly educated old people (Rey, 1964). The same effect is seen with supra-span lists of numbers and designs (Davies, 1967).

Material of little logical associative value is more difficult for most older people to learn and recall. The Wechsler Memory Scale subtests of associative learning and

visual reproduction show significant decremental effects with age. The negative age effect upon learning is reduced when logical word association is possible (Hultsch, 1975). Conversely, when nonsense items are presented for learning and recall, the age effect is worsened (Gilbert, 1941). Incidental learning (recall of information not intentionally learned) is diminished in old compared to young groups of subjects (Eysenck, 1974).

Are age-related changes in memory preferential for modality of testing? The effects described (i.e., slight loss with material of logical associative value, greater loss with complex and longer material and with incidental, rather than intentional, learning) are seen with both verbal and visual tests. It does not appear that the deterioration of learning and short-term memory with age is any less for verbal than for visual material.

Remote memory is retained in normal health aging. The information and vocabulary subtests of the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1955) show little change with age. Semantic memory is tested by the vocabulary test; information items test knowledge learned years ago, generally through education. Although older subjects take longer to learn, once the material is learned, it is recalled equally well.

In summary, the elderly show no deterioration in immediate memory, in recent memory for short lists and logically associated material, and in remote memory for information, semantics, and over-learned material. Impairments related to age are seen in learning and recent memory for longer, more complex, and logically unassociated material. Capacity for incidental memory is lessened for both verbal and visual material in older subjects.

The elderly individuals with these typical age related changes in memory and learning may be disrupted in everyday functioning. Difficulty in learning complex material and long lists (e.g., shopping) may affect occupational and daily routine activities. Nonsense words (foreign languages) and logically unassociated facts will be harder to master. Changes in incidental memory ("Where did I put my glasses when I finished the newspaper?") will show up with irritating regularity. This usually leads the elderly to rely more heavily on reminders (written lists for shopping) and on routines (glasses always in the same place). Such difficulties may also be expressed as an unwillingness to attempt new tasks or ways (i.e., the "inflexibility" of the aged). The pace at work may slow, and efficiency in work may drop, as the elderly take longer to master new tasks (e.g., more rehearsals for a sales presentation).

On the other hand, performance of tasks based on remote memory, discussion of information already learned, and attention to the task at hand will be competitive or superior to that of a younger colleague.

Language

Communication—written and spoken, verbal and non-verbal—is a crucial cognitive function useful to everyday life. Language can be defined as the ability to communi-

cate through the use of oral and written symbols (Benson, 1979). Language incorporates the attendant abilities of speech, comprehension of spoken language, repetition of spoken language, naming, reading, writing, discourse, and pragmatics. Each of these aspects of language function can be affected differently in normal aging.

Testing of language probes the major functional areas of language (Strub & Black, 1977). Detailed evaluation of language in normal aging is a relatively new specialty (Sandson, Obler, & Albert, 1987).

It has generally been held that verbal abilities are preserved into old age. The initial 1955 standardization of the WAIS shows a drop of less than one standard deviation in the score for the verbal subtests across ages 25 to 74. This cross-sectional study was felt to reflect major cohort differences in education rather than a true age effect (Wechsler, 1955). Longitudinal studies show that the language functions of vocabulary, information, and comprehension do not change until well past age 70 (Eisdorfer & Wilker, 1973). The apparent preservation of verbal skills has prompted psychologists to label verbal functions as part of "crystallized intelligence," to signal their relative stability (Cattell, 1971), in contrast to "fluid intelligence," indicating functions that deteriorate at a younger age.

However, it is not at all clear that verbal skills are as well preserved into old age as is generally claimed. Differences appear in functional communication for normal controls over 75 years of age (Holland, 1980). Verbal fluency shows a significant decrease with age, although the decrease is not as great for persons with higher educational levels.

Older adults often complain of difficulty finding the intended word or proper name. Sandson and colleagues, using tasks of object naming and action naming, showed a decrease in correct answers from ages 30 to 79. The most common errors for the elderly groups were circumlocutions and unnecessary comments for the object naming tasks, and perceptual errors for the action naming task (Sandson et al., 1987). Their study suggests that the elderly have difficulty retrieving words from an intact lexicon. The findings may explain, in part, the commonly observed loquaciousness in older people. Tasks designed to allow the elderly to define or explain rather than retrieve target words demonstrate that elderly, more often than younger subjects, give superior explanations, but not synonyms (Botwinick & Storandt, 1974).

Comprehension at the one-word level is unchanged in the elderly. Stimuli at the sentence and longer levels show decrements with age (Cohen, 1979). This is true for older adults regardless of educational attainment.

Discourse in the elderly is perceived to be tangential and circumlocutory, often called longwinded. Qualitative studies of discourse (both written and oral) find that older groups use more paraphrasing, full sentences, indefinite terms, comments, and questions (Obler, 1980).

In summary, although verbal subtests of the WAIS show little if any decrement until the mid to late 70s in the absence of disease, major qualitative changes are seen nevertheless in language with normal aging. Decrements

are observed on tests of naming and of comprehension of complex material. The elderly tend to have more elaborate and longer discourse styles. Retrieval of words from an intact lexicon is impaired. Communication remains functional throughout the life span.

Higher Cognitive Functions

Attention, memory, and language are building blocks, the basic processes upon which more complex intellectual functions are founded. For want of a better term, I call these the higher cognitive functions: abstract thinking, concept formation, generalization, mathematical computations, problem solving, and hypothesis testing. These are complex functions, dependent upon the interaction and synthesis of basic neuropsychological processes. A decline or change in any basic process will produce a concomitant change in higher functions (Reese & Rodenheaver, 1985). I have chosen to emphasize conceptualization as that process has been much studied and encompasses significant everyday functioning.

Interpretation of idioms and simple proverbs should be abstract, regardless of age, educational level, and occupation (Cummings, 1985). More complex proverb interpretation will be influenced by educational level, general intelligence, cultural and occupational status, but not by age.

The similarities subtest of the WAIS is considered a "Don't Hold" test in reference to age effects, showing a significant decrease beyond 70 years of age (Wechsler, 1955). This suggests a change in the ability to generate, generalize, compare, and contrast verbal concepts. The same is true for nonverbal concept formation, as measured by the Wisconsin Card Sorting Test (Berg, 1966). The elderly were found to be less efficient, making more errors and needing more trials to criterion. Other tests of problem solving also show age-dependent decrements (Arenberg, 1968; Bigler, Steinman, & Newton, 1981; Rabbit, 1977).

"Mental flexibility" refers to the ability to adapt to new situations, solve novel problems, and change mental set (Lezak, 1983.) A decrement in this cognitive capacity, which also reflects impaired conceptualization, is found as a general trait in the intellectual performance failures of old age (Williams, 1970).

In summary, tests of abstract concept formation should not be affected by age, but will be affected by general intellectual level, educational level, and occupational status. More difficult tests of concept formation and manipulation of acquired knowledge show age-dependent decrements in verbal and nonverbal capacities. Impairments in related measures of mental flexibility, problem solving, and changing mental set are also found in groups of elderly people in a laboratory setting. This set of differences, taken together, has evolved into a general belief that the elderly are deficient, relative to younger people, in higher cognitive processes.

Concept formation and problem solving form the basis for much of the intellectual workload in occupational and

daily living activities. If capacities for concept formation are reduced among the elderly, that may account for the observed peak in creative potential usually described between the ages of 30 to 40 for most individuals (earlier with physical sciences, later for literature and humanities). Rabbitt (1977) has observed that not much original work is accomplished beyond the 5th decade of life.

Unfortunately, laboratory investigations of conceptualization do not seem to relate directly to real-life problems, which elderly people are often able to solve adequately. Elderly people tend to be more cautious than young people in all endeavors (Okun, 1976). This cautiousness, together with reduced speed of information processing and a slight tendency to concreteness of thought, produces poor scores on laboratory tests of problem solving. It is not at all clear, however, that elderly people have less capacity than younger people for conceptualization in real-life situations. Indeed, there is some evidence that older people, with accumulated life experiences to aid them, may actually be better than younger people in solving real-life problems.

SENSORY-PERCEPTUAL FUNCTIONS

Reception, transmission, perception, and interpretation of multimodal sensory information are complex processes requiring the cooperation and interdependence of both the peripheral and central nervous systems. If incoming information is missing or in error, then the individual may commit errors based on insufficient data. Assessment of the state of sensory-perceptual mechanisms in the elderly is essential to the assessment of cognitive functions. The sensory systems considered in this section are visual, auditory, and somatosensory.

Visual Perception

Individuals of any age with impairment of visual function are at significant disadvantage. Age-dependent changes may occur in ocular structures, visual pathways, and cerebral cortical regions responsible for such functions as spatial resolution, perception of depth, color vision, and temporal mediation (Kline & Schieber, 1985). Neuropsychological processes of visuospatial and visuoconstructive tasks are dependent upon these basic visual functions.

Assessment of visual function includes charting of visual acuity, peripheral fields of vision, and color vision as well as the direct viewing of the ocular apparatus, retina, and optic nerve (DeJong, 1979). Visuo-verbal tasks of reading and writing have been considered in the section on language. Visuospatial functioning may be tested through use of visuoconstructive tasks. Constructional tasks include copying two- and three-dimensional line drawings and free-hand line drawings of objects as requested. Observations in real-life situations also pro-

vide information on visuospatial skills; for example, finding the way around the hospital ward, dressing, navigating in the city streets.

Neuropsychological testing of visuo-perceptual functions overlaps inevitably and considerably with evaluation of cognitive and memory tasks (Lezak, 1983). Visuo-perceptual tasks test visual recognition, visuospatial organization, visual conceptualization, and visuomotor performance.

Visual acuity, tested with corrective lenses and ample light (to ensure adequate black-white contrast), should be no less than Jaeger 1 or 2 on the near card. Peripheral visual fields show a consistent constriction starting at about age 40 and accelerating after age 50. Whether a consequence of reduction in pupillary size (i.e., senile miosis) (Weale, 1961) or of retinal ischemia (Wolf & Nadroski, 1971), the constriction is symmetrical bilaterally and affects the temporal field of each eye. Referral for an ophthalmic examination should be made for visual acuity deficits unable to be corrected by eyeglasses, for asymmetrical constriction or loss of peripheral vision, for retinal and optic nerve alterations, and for other undiagnosed ocular abnormalities. Visual evoked potentials in the elderly characteristically show an increase in the latency and amplitude of sensory components; specifically, an increase in the latency of the late components is felt to be reflective of slowed higher order processing (Beck, Swanson, & Dustman, 1980).

Simple visuoconstructive tasks, such as copying words and designs, should still be executed accurately, albeit more slowly, by the older individual. Behavioral observations likewise serve as a good screening battery for serious dysfunction. Impairment in these areas should prompt more detailed, formal testing.

The "classical aging pattern" detected in the WAIS is that of preserved verbal skills in the face of deteriorating performance skills. The WAIS performance subtests are times tasks, requiring motor responses. Block Design, Picture Completion, Picture Arrangement, and Object Assembly tests show a modest decrement with age. The decline in scores on the WAIS performance subtests remains even with the element of speed of response removed (Storandt, 1977).

The highest rate of decline is seen with test procedures that depend upon two or more cognitive processes that are vulnerable to the effects of age. For example, the Digit Symbol subtest of the WAIS taps attention, incidental learning, visuomotor coordination, and speed of response. Scores on this test require the largest age correction of all the WAIS subtests.

In summary, neuropsychological techniques show age related decrements in performance for the majority of visuospatial, visuoconstructive, visual recognition and scanning, visual conceptualization, and visuomotor abilities. Performance in visuospatial assessment tasks containing an element that also tests other age-sensitive cognitive abilities shows an even greater decline with age.

Although much is known about age related decrements in visual and spatial functioning in test situations, the

resulting translation to everyday life is not clear-cut. Elderly people perform more slowly on such visuomotor tasks as driving and walking, but apparently with no less skill under ordinary conditions. The capacity to adapt to different physical surroundings and the ability to use unfamiliar tools and objects are, nevertheless, reduced.

Auditory Perception

As with the visual system, the auditory system shows age related decline in function. Hearing shows decrements in both its sensory and perceptual portions. Obviously, the impact upon verbal and nonverbal communication can be profound.

Tests for auditory acuity should reveal normal results, even though age related changes at every level of the auditory sensory apparatus have been described (Olsho, Harkins, & Lenhardt, 1985). Referral for formal audiologic testing and evaluation for a prosthesis should be made if testing shows a decrement in hearing. Presbycusis is one of the major sensory changes associated with aging. With estimates of up to 75% of the population between the ages of 75 and 79 having hearing problems (Butler & Lewis, 1977), it is difficult to say that hearing loss is not a significant part of aging. Hinchcliffe (1962) describes the findings in presbycusis as follows: impairment of pure-tone thresholds, particularly in higher frequency ranges; impairment of frequency discrimination; impairment of auditory temporal discrimination and sound localization ability; impairment of speech discrimination ability; and decreased ability to understand distorted speech.

Clinically applicable tests include those used to evaluate speech reception threshold, which is progressively impaired after age 50 (Plomp & Mimpen, 1979), and speech discrimination. Most elderly persons with presbycusis require an elevation of speech sound threshold of 5 to 10 decibels for intelligibility (Punch & McConnell, 1969). Speech intelligibility has also been measured under adverse listening conditions (e.g., background noise), and results indicate that such conditions further impair speech intelligibility in the elderly (Bergman, 1971). Those tests simulate real-life situations, and their results correspond to a frequent complaint of hearing-impaired elderly, that of worsening speech perception in noisy surroundings.

Considerable research has looked at auditory perceptual processes in relation to comprehension in the elderly. Much of what we hear in everyday life is ambiguous and must be processed into a meaningful message. Some of the processing mechanisms involve linguistic and contextual devices (semantic, syntactic, phonological, and metalinguistic) (Spencer & Wollman, 1980; Warren, 1970). Some involve attentional and memory mechanisms, and are dependent on processing speed. All of these processing mechanisms seem to be impaired in the elderly to varying degrees. One result is a reduction of auditory comprehension (Olsho, Harkins, & Lenhardt, 1985).

In summary, auditory perceptual function is impaired in the majority of elderly people. The reduced capacity is due to primary sensory loss in hearing, coupled with impaired speech sound discrimination and speech reception thresholds. These difficulties in the peripheral auditory apparatus are compounded by age-sensitive vulnerabilities in central mechanisms linked to auditory processing, including memory for complex material, processing speed, and accessing lexical items in long-term memory stores. Impaired auditory comprehension is exaggerated in settings with increased background noise.

Given what we know about auditory processing in the elderly, we can make specific recommendations for manipulating the environment to improve communication for elders and their families. Appropriate use of amplification, quiet background conditions, clear and well-enunciated speech, and distraction-free environments will foster optimal communication.

Somatosensory Perception

Somatosensation is the sum total of sensation from the skin and viscera; kinesthesia is information of movement coming from the muscles and joints. These senses are important in all tasks of mobility and ambulation, for homeostasis, and for overall well-being. They have been independently studied in the elderly.

Testing of peripheral sensation has, until now, generally been considered to be modality specific; pain, temperature, touch, vibration, and kinesthesia are tested using specific techniques (DeJong, 1979). Each limb, both proximal and distal, is tested, as well as trunk, face, and neck. Cortical contributions are made to the perception of complex sensory signals through integration, interpretation, recognition, and comparison to previous somesthetic memories. The so-called cortical sensory functions (e.g., graphesthesia, stereognosis, two-point discrimination, sensory extinction, and sensory inattention) are also tested individually.

In the elderly, there is loss of receptors in the skin of heavily myelinated sensory nerve fibers and of neurons in the spinal cord and parietal cortex. The largest and longest nerve fibers of the posterior columns, subserving vibration and position in the distal lower extremities, seem the most affected. Peripheral sensory nerve conduction slows with age (Dorfman & Bosley, 1979). There is loss of up to 60% of vibratory sensation in lower extremities and up to 40% in upper extremities (Potvin, Syndalko, Tourtellotte, Lemmon, & Potvin 1980.) Little change in touch sensation is found in the elderly even up to age 75.

In the absence of disease-induced parietal lobe damage, the elderly perform as well as younger groups in tests of finger agnosia. However, they perform consistently less well in tests of two-point discrimination (Bolton, Winkleman, & Dyck, 1966), stereognosis (Axelrod & Cohen, 1961), and graphesthesia (Rey, 1964). The explanation for these sensory decrements is thought to be the combined effect of peripheral sensory blunting and cen-

tral processing impairments (Kenshalo, 1977). Kinesthetic capabilities in normal elderly are found to be impaired in both passive and active movement.

The somatosensory system is yet another neural network that displays deficiencies at several levels in the elderly. Slight, but real, reductions in sensory function interfere with such activities as ambulation and skilled motor movements, as well as with occupational skills that are dependent on these neurosensory functions.

MOTOR PERFORMANCE

A motor act is required for all behavior to be effected. From the simplest of reflex reactions to the most complex of problem-solving tasks, a motor performance ultimately forms the basis upon which other cognitive and perceptual processes are judged. Thus, a change in motor performance can be expected to have broad implications and wide-ranging effects. Motor performance is significantly affected in normal aging.

Motor testing individually addresses several levels of motor functioning. Muscular strength, tone, tendon stretch reflexes, bulk of musculature, coordination, rapid volitional movements, postural and righting reflexes, skilled motor acts, and gait are all evaluated.

We have sparse data from a handful of cross-sectional studies that look at motor parameters as a function of age (Potvin et al., 1980); there are no comparable longitudinal studies. A moderate decrement, up to 60%, of muscular strength (leg flexion, foot dorsiflexion) and a lesser decrement, up to 40%, in manual dexterity was seen at age 80 compared to age 20.

Speed of skilled motor acts, simple or choice reaction time, and foot or hand tapping have consistently been shown to decrease with age (see Salthouse, 1985, for review). The sum total of all decrements is a slowing of activities. Nonetheless, elderly individuals remain able to improve performance with practice to a degree equivalent to that of the younger comparison group (Salthouse & Somberg, 1982). This principle, the "practice effect" is the theoretical basis for geriatric exercise groups and rehabilitation aimed at improved neuromuscular conditioning.

Normal gait depends on competent motor abilities, but also on somatosensory and kinesthetic sensory systems, which play major roles in balance, mobility, and coordination in the upright position. We have already examined the effects of age related decrements in sensory function. For control of gait, those sensory changes in the elderly are compounded by decrements in motor performance. Gait, even in the healthy elderly person, is thus impaired. As stated by M. Malcolm Crowley (1976) writing at age 80, "Age is not different from earlier life, as long as you are sitting down."

Age related changes cause the gait to assume a characteristic pattern. Posture in the upright position is slightly flexed; forward progress is made more slowly; length of stride shortens; clearance of the foot and heel from the ground decreases; extra steps are taken in turns; side-to-side sway is slightly increased. In its extreme form, this

gait resembles that of Parkinson's disease without the tremor and festination (accelerating gait, starting with slow steps and gaining speed, ending in a run). Although the gait of elderly people is changed to a significant degree, full activities are possible.

Neurophysiological studies show slowing in both peripheral and central components of motor activity. With aging, nerve conduction velocities slow in motor and sensory peripheral nerves, but only to a mild degree (LaFratta & Canestrari, 1966). A greater degree of decrease in speed of the central component of motor processing accounts for the majority of slowing seen in motor acts. That reduction in speed of central processing is demonstrated by comparing reaction times utilizing efferents of varying distance of peripheral nerve conduction. Birren and Botwinick (1955) found no difference in reaction time of jaw, finger, or foot in response to an auditory signal. Central slowing is also demonstrated by the greater magnitude of age related decrements in complex motor tasks. For example, the usual difference between simple reaction time (a motor response to a sensory signal) and choice reaction times (a differential motor response to varying sensory signals) is exaggerated with older age groups (Welford, 1977).

Age-related decrements are seen with standardized tests of manual dexterity and speed. For example, the Purdue Pegboard Test (Vaughan & Costa, 1962) gives a separate set of cut-off scores, up to 30% slower, for those aged 60 and above.

In summary, age-related slowing in all aspects of motor performance has been documented. Relative performance deteriorates more when motor skills are combined with other skills known to be vulnerable to aging. Hence, the complex integrated sensorimotor task of ambulation is affected to a greater degree than simple reaction time. Tasks of greater complexity, which require greater cognitive processing (e.g., choice vs. simple reaction time), show a greater decline in the elderly than simple perceptual or motor tasks. Of note, however, is the fact that the positive practice effect for motor tasks is equal in elderly and young groups.

Although society expects a functional decline in the aged, all motor activities, albeit slower, should be maintained throughout the lifespan, in the absence of disease. The optimal performance of motor acts requires practice and good physical conditioning.

Table 1 summarizes important changes of neurological and neurobehavioral functioning with age. These are generalizations from statistical studies of large groups. To understand how these changes affect an individual, factors such as intelligence, education, occupation, activity, nutrition, avocation, personality, and social support must be taken into account. An individual, free from disease, should be able to maintain an active and independent life through the years.

This optimistic picture of aging is often complicated, however, in individuals of advanced age by significant loss of primary sensory functions. Visual and auditory disturbances are present more often than not, even in otherwise healthy individuals. These losses of primary sensation, coupled with a mild reduction of perceptual and motor speed, seriously compound subtle age related dec-

TABLE 1. Neurological/neurobehavioral functions in aging.

Function	Decline	No change
COGNITIVE		
Attention	Divided attention Sustained attention Changing mental set	Simple attention
Memory	Short-term memory: lengthy information unassociated material Incidental learning: verbal visual	Immediate memory Short-term memory: brief information associated material Remote memory: information Semantics Over-learned material
Language	Comprehension: complex material Active naming	Elaborate narratives Vocabulary Functional communication
Conceptualization	Concept formation: novel information complex concepts Problem solving: novel and complex Changing mental set	Concept formation: idioms and proverbs Problem solving: real life
SENSORY		
Visual	Visual recognition and scanning Visuoconstructive Visuomotor	Visual acuity Visuospatial tasks in real life
Auditory	Primary sensory loss Speech discrimination Auditory processing	Comprehension in quiet
Somesthetic	Peripheral vibratory sensation Cortical sensory abilities	Finger gnosis
MOTOR		
	Choice reaction time Complex sensorimotor tasks	Simple reaction time Practice effect

rements in sensory processing and perceptual functions, which, in turn, exaggerate otherwise mild declines in attention, short-term memory and incidental learning, verbal communication, and complex problem-solving. I conclude that early intervention for optimalization of sensory functions is one of the keys to successful, healthy aging.

Another positive factor we wish to emphasize for healthy aging is the preserved practice effect observed in motor tasks. As individuals age, physiological reserves decrease and the line between healthy functioning and impairment narrows. By maintaining optimal neuromuscular conditioning, in the absence of disease, performance of day-to-day activities may be maintained and, potentially, enhanced.

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Chapter 7

CHRONIC MENTAL ILLNESS AND FUNCTIONAL COMMUNICATION DISORDERS IN THE ELDERLY

JOHN TONER BARRY GURLAND MICHAEL LEUNG

*Center for Geriatrics and Gerontology
Columbia University Faculty of Medicine and New York State Office of Mental Health*

The purpose of this paper is to evaluate the role of communication disorders in the developmental course and functioning in the chronically mentally ill elderly. The results of recent studies, which will be discussed in greater detail, and a review of the literature reveal that certain patterns of poor communication may be characteristic of a subgroup of chronically mentally ill elderly, who become long-term hospitalized patients. The authors hypothesize that these communication problems may have predated or been concurrent with the onset of the disease and may have predicted the long-term hospitalization outcome of the disease. Thus the authors believe that these communication problems or a variation of them in early adulthood in the chronically mentally ill may have been potential indicators of a chronic course for the psychiatric illness.

DEFINITIONS

Chronic Mental Illness

To proceed any further in our discussion of the relation between communication and chronic mental illness, a definition of terms is necessary for *chronic mental illness* and a distinction made between *acute* and *chronic* mental illness. Mental illness is recognized to move from the acute to the chronic mode when certain changes occur in the organization of care and when quality of life issues become merged with quality of care. This shift is highly correlated with the length of illness, but the lapse of time between onset of illness and the shift to chronicity may vary with the type of mental illness, historical and social context, patient characteristics, and treatment approach. Thus, any attempt to define chronicity according to duration of illness solely is likely to be arbitrary and often misleading (Gurland & Toner, in press).

There is a need for research to identify criteria for chronicity of mental illness that will serve better than

duration of illness alone for the purposes of study of the determinants of chronicity, program evaluation, and the planning of appropriate care. According to Gurland and Toner (in press) the examination of candidate criteria should include:

1. Quality of life criteria: (a) impairments of functional status in the performance of the basic and instrumental activities of daily life and in such areas as social relationships, morale and life satisfaction, intellectual processes (e.g., learning, memory), communication skills, work, use of leisure time, initiative, and access to environmental and material resources; (b) severity levels of symptomatic distress or behaviors that are dangerous or disturbing to others because of the mental condition; (c) the extent to which current impairments of the client's functional status are the basis for planning and decisions with respect to the future; (d) the extent to which major options affecting quality of life, such as location of residence and degree of independence, have been predicated on the illness effects; and (e) the extent to which there are areas of functional status that are not touched by the illness, or times (hours, days, or periods) or activities that are free of impairments.

2. Quality (or organization) of care criteria: (a) the weight placed on stabilization, slowing decline or gaining limited improvement of function, rather than attempting a cure in setting the goals of treatment; (b) the breadth of treatment and assistance to the patient in maintaining a community tenure or relocating to sheltered accommodation, or in otherwise adapting to a life restricted by the illness, as contrasted with treatment narrowly directed at relieving symptoms or reversing an illness process; (c) the intensity of consideration of possible long-term side effects of treatment, or of the problems of delivering maintenance treatment; and (d) the limitations imposed on the range of treatment options by health care insurance with a cap on length or frequency of treatment or exclusion of personal assistance and environmental interventions.

It is notable that many of the criteria for defining chronicity are best understood as continua rather than categories; chronicity is a matter of degree. This renders it even more difficult to accept those definitions that depend on a particular duration of illness or a specific number of hospitalizations as validly reflecting the intensity and extensiveness of chronicity.

Functional Communication

The present discussion recognizes that the fields of speech-language pathology, audiology, and neurology, in particular, have contributed immensely to the state of the art of assessment of communication disorders in the elderly. The primary focus of much of this work has been the development of methods of assessment for identifying and characterizing speech, hearing, and language deficits rather than describing communication function. While systematic approaches to the assessment of speech and hearing disorders in the elderly are necessary for our understanding of these disorders, it is often difficult to relate the findings to the mentally ill client's everyday functioning. The critical foci for communication assessment of an elderly person with mental illness would include such questions as: Can the patient be aroused enough to respond to questions? Can the patient give clear and plausible replies to questions? Are there clear-cut inconsistencies and denials in the patient's communication?

Webster's Collegiate Dictionary defines *functional* as "that which affects function but not structure." *Communication* is defined as the interchange of thoughts, opinions, or information by speech, writing, or signs. In the present discussion, a *functional communication disorder* is defined as any impairment in communication regardless of cause, and the focus is on the individual's capacity to exchange thoughts and information clearly and plausibly rather than on speech, hearing, or language deficits.

FUNCTIONAL COMMUNICATION DISORDERS RESULTING FROM CHRONIC MENTAL ILLNESS

There is currently no straight-forward, generally accepted model of communication in those who are elderly and chronically mentally ill that can serve as a means of organizing our approach to this area of study. However, an adaptation of the model suggested by Wallace (1982) and Wallace et al. (1980) for communication problems in younger schizophrenics is relevant. The Wallace model focuses on communication as the product or end point of a process. This process-oriented approach includes "accurately receiving" stimuli, "correctly processing" the stimuli and selecting an appropriate response, and "sending" a response in a manner that guarantees as much as possible that the process will be completed as desired or

as is socially acceptable. It deserves repeating that communication is the end of the process.

A high proportion of chronically mentally ill persons in long-term psychiatric facilities are unable to communicate at even the basic levels (Ricco-Schwartz, Gasquoin, & Toner, 1983). Wing and Brown (1970) attribute communication and other deficits to the effects of long-term institutionalization. Marsden (1976) attributes these and other long-term deficits to treatment approaches. Mathai and Gopinath (1985) challenge those views and indicate that the disease process itself in the chronically mentally ill is responsible for the deficits rather than any differences in the treatment approaches or environments. Mathai and Gopinath examined 80 chronic schizophrenic patients conforming to research diagnostic criteria and between the ages of 20 to 55 and compared them with long-stay manic depressive psychosis patients in the same hospital, long-stay schizophrenics in two other hospitals, and long-stay inpatients and outpatients of equal duration. The authors conclude that the cumulative deterioration of communication and other deficit states are most likely due to the disease process itself. They also suggest that it is possible that the cumulative effects of the disease often mitigate against discharge, which further leads to a concentration of patients with these problems backlogged in the hospital.

FUNCTIONAL COMMUNICATION DISORDERS AS A PRECURSOR TO CHRONIC MENTAL ILLNESS

Although functional communication disorders as a precursor to mental illness have relatively low prevalence, it is important to note the typical circumstances under which this occurs and that those circumstances are most frequently found among elderly long-term institutionalized patients.

Numerous investigators have established the relation between childhood and early adult life chronic hearing impairment and onset of paranoid states. Cooper and colleagues (Cooper & Curry, 1976; Cooper, Garside, & Kay, 1976; Cooper, Kay, Curry, Garside, & Roth, 1974), in their study of 132 long-stay residents and consecutive admissions to psychiatric hospitals in England (65 paranoid patients, 67 affective disorder patients), found that deafness had preceded the psychosis in 21 of the paranoid cases and 8 of the affective cases. Similar findings are reported by Eastwood, Corbin, Reed, Nobbs, and Kedward (1985). Studies conducted on the prevalence of psychopathology in old age (e.g., Gurland & Cross, 1982) report figures for traditional DSM III (American Psychiatric Association, 1987) diagnostic categories common in the elderly, such as dementia or schizophrenia, but make no mention of communication deficits, if any, noted among the study populations.

Bettinghaus and Bettinghaus (1976) examined the variables of psychological change, interpersonal environmental changes, and psychosocial change and conclude

that there is very little research that actually looks at communication patterns and problems with a mentally impaired aging population. Of particular relevance is the attention given to the attitudes of health care providers and the impact they can have on the communication abilities of the institutionalized aged person.

SCREENING FOR FUNCTIONAL COMMUNICATION DISORDERS

Our work in the field of communication screening traces its history to the early U.S./U.K. cross-national diagnostic studies (Cooper et al., 1972; Gurland et al., 1983). During that period, investigators began to look systematically at the criteria used by interviewers to determine whether a person was capable of participating in the cross-national studies. Those criteria ultimately focused on the patient's ability to communicate. In this way, investigators were able to delineate what they observed interviewers doing to get attention from the patient and to describe what it was that gave rise to a decision that the patient had communication problems. This led to the development of a brief communication screening tool, which was first used in the cross-national institutional study (Gurland et al., 1979) and later refined for use in two studies of the prevalence of depression and dementia at state psychiatric hospitals in New York. The refined version of the communication screening tool is called the Patient Functional Communication Screening Instrument (FCS) (Toner, Gurland, & Gasquoine, 1984) and can be found in Appendix A. The FCS consists of five sections. Section 1 includes a greeting command (interviewer extends hand for handshake and greets the patient). If the patient does not respond appropriately to the greeting command, Section 2 (labeled Part 1) is completed by the interviewer. It is designed to arouse the patient and specifically to be administered to those patients who appear to be asleep. If the patient responds appropriately to the greeting command, the interviewer immediately begins Section 3 (Part 2). Section 3 consists of eliciting communication behaviors considered typical for everyday life. Requesting information such as the patient's name, ability to spell name, length of time at that hospital, how the patient has been feeling, health problems, and reason for being at the hospital is designed to evaluate as much of the patient's language function as possible. The questions in this section are phrased in a simple, nonthreatening manner, which is sensitive to avoiding the confusion and ambiguity that often results with the use of medical jargon. The interviewer then completes a rating of the patient's level of insight. This rating determines whether the patient can communicate at the most basic level. If the patient cannot communicate at the level indicated in Section 3, Section 4 (labeled Part 3) is completed by the interviewer with the assistance of an informant. The informant can be any staff person who knows the patient, preferably a nurse or nurse's aide. Part 3 consists of a list of seven major reasons for the patient's

inability to communicate and 21 specific examples of communication problems, such as responsiveness to painful stimuli, shortness of breath, hearing impairment, etc. The interviewer asks the informant to choose only one major reason for the patient's inability to communicate and to choose any number of relevant specific examples of communication problems. Part 3 also requires the informant to make ratings of the patient's expressive and receptive language and comprehension on a 5-point scale, from normal to severe communication problems. The ratings also allow the informant to provide information on the quality of the patient's ability to make use of verbal or nonverbal communication skills. Section 5 (labeled Part 4) requires the interviewer to make ratings on the same type of scale that the informant used in Part 3.

In an interrater reliability study on randomly selected patients, three raters obtained 89% agreement on whether or not the patient had communication deficits severe enough to prevent communication at the most basic levels ($Kappa = 0.85$; $p < .001$). There was 86% agreement between the raters on the reason for the patients' inability to communicate ($Kappa = 0.80$; $p < .01$).

The major purpose of the FCS is to provide a quantifiable measure of the communication abilities of the patient regardless of the severity of the patient's emotional impairment. Another purpose is to provide a method for determining whether the institutionalized patient can communicate sufficiently to express needs and whether staff must be sensitive to the patient's lack of communication skills in planning care. The sequence of decisions to consider in cases where the patient's communication ability is suspect is shown in Figure 1.

BASE-LINE STUDIES OF FUNCTIONAL COMMUNICATION IN ELDERLY PERSONS WITH CHRONIC MENTAL ILLNESS

Research on the prevalence of communication disorders among psychogeriatric patients in state hospitals has been scarce. Numerous investigators have pointed to a paucity of communication among the institutionalized aged (Brodie, 1986; Reed, 1970; Weinstock & Bennett, 1968), but none have studied it systematically. Lubinski (1978-79) explored why there has been so little interest in the verbal communication abilities of the aged, particularly the chronically ill and aged residents of long-term care institutions. While it is pointed out that social gerontologists and speech-language pathologists have investigated areas relating to verbal communication, very little exploration of this topic incorporates a staff or patient perspective. As the ability to communicate verbally is such a vital component of social interaction and contributes so much to a sense of psychological well-being, it provides a fertile area for further investigation and analysis of such issues as isolation, integration, and adjustment of the institutionalized elderly in general, and it

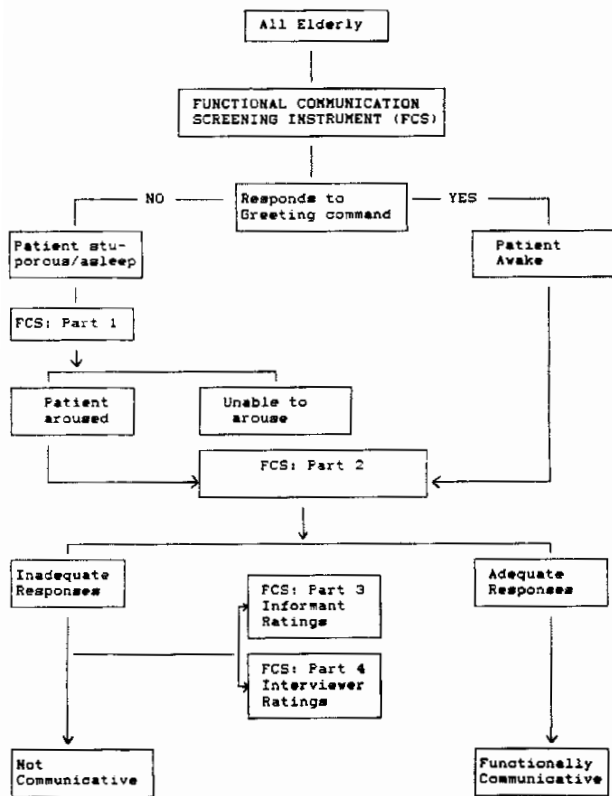


FIGURE 1. Patient functional communication-Decision tree.

holds special significance for long-term elderly psychiatric patients, particularly those in state hospitals. Of the few relevant studies, Bettinghaus and Bettinghaus (1976); Brown, Cornwell, and Krajicek-Weist (1981); and Lipman, Slater, and Harris (1979) are most notable.

Lipman, Slater, and Harris (1979) studied 4,500 verbal exchanges between residents and between staff and residents in British homes for old people. Their study suggests that the interactions between residents are more likely to be supportive and accepting than those between staff and residents, but that even this quality declined as the confusion level of the residents became greater. Interestingly, the quality of staff/resident interactions did not differ depending on whether the resident was confused or not. Despite the cross-cultural variation, the significance of these findings for those clinically involved with long-term confused, psychogeriatric patients indicates a need to examine the patterns of verbal decline from many perspectives.

There are many reasons why communication deficits may be prevalent in psychogeriatric populations; that is particularly the inpatient psychiatric elderly patient. Progressive dementias, long-term institutionalization, years of antipsychotic medication use, increasing sensory deficits, chronic and acute physical ailments, and major depression are all factors conducive to the development of such deficits.

Brown et al. (1981) discuss the depersonalization that often serves to gradually detach elderly institutionalized people from their social systems. The authors describe communication as a variable in the depersonalization process which may ultimately culminate in the nonverbal multitudes that were identified during this study. Toner, Gurland, and Gasquoin (1984) studied the prevalence and treatment of depression in a geriatric inpatient population. A component of their study involved the assessment of the entire geriatric population at the institution ($N = 315$ patients) to determine their ability to participate in a 15-minute semistructured interview. An unusually high number of the patients (73.6%) were found to have a communication deficit severe enough to prevent them from being interviewed. The basis for the communication deficits was assessed using the FCS, which indicated that deficits in language production accounted for more than half of those with communication deficiencies. The implications of such a finding are notable in view of their potential impact on service delivery, staff development, and research.

The results of that study have been replicated in a more recent study of geriatric inpatients in a similar state psychiatric hospital. Toner, Gurland, and Mustille (1988) report that 82.2% of the patients in the replication study had communication deficits severe enough to prevent them from communicating at the most basic levels. Table 1 contrasts Institution #1 and Institution #2 by comparing interviewers' ratings of the major reason for patients' inability to communicate basic needs. In Institution #1, by far the most common reason for the patients' inability to communicate was some type of language deficit, and this accounted for more than half (57.8%) of all those with severe communication problems. The second most common reason was psychotic state, which accounted for more than 20% of all those with communication problems. In Institution #2, however, the most common reason for the patients' inability to communicate was psychotic state (44%), and the second most common reason was some type of language deficit (36%). Those patients who did not have communication problems severe enough to prevent them from communicating at even the most basic levels were then interviewed using the SHORT-CARE Test (Gurland, Golden, Teresi, & Challop, 1984; Gurland & Wilder, 1984).

TABLE 1. Interviewers' rating of major reason for patients' inability to communicate (by institution).

Problem	Institution #1 Total (%)	Institution #2 Total (%)
1. Comatose/stuporous	11 (4%)	22 (8%)
2. Fatigue	2 (1%)	0 (0%)
3. Frailty/illness	3 (1%)	22 (8%)
4. Language deficit	134 (58%)	94 (36%)
5. Inattention	6 (3%)	3 (1%)
6. Psychotic state	49 (21%)	119 (44%)
7. Others	27 (12%)	8 (3%)
Total	232 (100%)	268 (100%)

One percent of the noncommunicative patients in Institution #1 were found to be too frail or ill to communicate. In Institution #2, 8% of the noncommunicative patients fit into the category of physical frailty or medical illness (see Table 1). Many of these patients were bedridden or bound to geri-chairs, and the majority of them were incontinent of both feces and urine. Many of them required gastric tubes for feeding and total nursing care. They were also afflicted by other physical illnesses. A typical example of this type of patient is demonstrated in Appendix B, Case 1.

The population also includes terminal patients who are in stuporous or vegetative states (4% in Institution #1, 8% in Institution #2). They lie in bed with their eyes closed, and they may or may not respond even to painful stimuli. They are totally oblivious to their environment. Total nursing care is required for them. Speech communication is out of the question.

Table 1 also demonstrates an interesting contrast across institutions. In Institution #1, 12% of the patients who were identified as unable to communicate were determined to have "other" reasons for their inability. Those were, in large part, patients who spoke a foreign language. In Institution #2, 3% of the patients were determined to have "other" reasons for inability to communicate. They included patients with severe mental retardation, Huntington's chorea, or patients who simply refused to cooperate. It is interesting to point out that Institution #1 was located in suburban New York, and many patients were

transferred to the institution from New York City, which accounts for higher numbers speaking foreign languages. Institution #2 is located in rural New York State, where the catchment area of the institution consists of a relatively homogeneous English-speaking population.

Since in both institutions nearly all of the patients who were rated as being unable to communicate have multiple problems, sometimes the assignment to a single category is admittedly arbitrary. For example, in Case 2 (see Appendix B), H.P. has language deficits such as inappropriate response to simple commands and muteness or paucity of language, but she also shows psychotic symptoms such as assaultiveness, lack of insight, belligerence, and uncooperativeness. Judging from her long psychiatric history, "psychotic state" was the reason chosen for her inability to communicate.

It is not surprising for a long-term psychiatric hospital to have a majority of patients rated as being unable to communicate because of psychotic state; what is unusual is that language deficits account for more than one-third (36%) of the cases. Among various subcategories within language deficit, muteness is by far the most common. The high concentration of mute patients is demonstrated in Table 2. It is important to note that the subcategories in Table 2 are not mutually exclusive; thus, muteness is indicated as a subcategory for 125 of 268 patients, or about half of this population group. The figures point to

TABLE 2. Subcategories of reasons for patients' inability to communicate (from informant and interviewer).

<i>Reason</i>	<i>Subcategory</i>	<i>Informant total (%)</i>	<i>Interviewer total (%)</i>
Comatose/stuporous	Response to painful stimuli	11 (4%)	17 (6%)
	No response to painful stimuli	1 (0%)	5 (2%)
Fatigue	Patient claims too tired	0 (0%)	0 (0%)
	Patient falls asleep during screening	0 (0%)	0 (0%)
Frailty/illness	Patient cannot get out of bed or sit up in bed	70 (26%)	49 (18%)
	Incontinent (urinary/fecal/both)	66 (25%)	42 (16%)
	Coughing attack, shortness of breath	0 (0%)	0 (0%)
	Pain, such as bedsores	3 (1%)	0 (0%)
Language deficit	Hearing impairments	24 (9%)	19 (7%)
	Inappropriate response to simple commands	8 (3%)	15 (6%)
	Mute	125 (47%)	92 (34%)
	Paucity of language	20 (7%)	33 (12%)
	Verbal/motor problems	2 (1%)	4 (1%)
	Inaudible	4 (1%)	11 (4%)
	Incomprehensible	40 (15%)	39 (15%)
	Foreign language	12 (4%)	9 (3%)
Inattention	Easily distracted	6 (2%)	5 (2%)
Psychotic state	Delusions	14 (5%)	13 (5%)
	Hallucinations	15 (6%)	11 (4%)
	Assaultive	24 (9%)	15 (6%)
	Paranoid	3 (1%)	3 (1%)
	Incoherent (ravings)	90 (34%)	74 (28%)
	Catatonic response (i.e., yes/yes/yes)	6 (2%)	3 (1%)
	Lack of insight	90 (34%)	87 (32%)
Others		84 (31%)	61 (23%)

the need for further study of the role of muteness in the inpatient psychogeriatric population.

Table 3 describes the informant ratings of the noncommunicative patients' expressive language, hearing problems, and comprehension/response to commands. The ratings are relevant only to those patients in Institution #2. Only one patient is rated 1 (client will carry on a conversation with some people), and no patients are rated 0 (client will carry on a conversation with anybody). More than one-quarter of the patients (27%) were rated 2 (can communicate basic needs verbally). The majority of patients were rated either 3 (39%) or 4 (34%). The 3 indicates that the patient can communicate by gestures or facial expressions only. Those with a rating of 4 cannot communicate at all.

With regard to hearing problems among the noncommunicative persons, 20% were rated 1, 2, or 3, indicating mild, moderate, or severe hearing problems. This is a conservative estimate, and prevalence would probably be higher if the patients' hearing were tested by an audiologist.

With regard to the patients' comprehension and receptive language abilities, 42% of the noncommunicative patients can follow simple commands only, and about an equal number respond either inappropriately or not at all. Only 19% (i.e., those with ratings of 0 and 1) have some understanding of language.

The results of these studies reveal that the vast majority of geriatric patients in psychiatric hospitals cannot communicate. This finding has stimulated research into the significance of the large percentage of patients in the state hospitals with poor communication. This was originally attributed to a suspected high prevalence of dementia. Patients with behavior disorders associated with dementia typically are admitted to nursing homes. In recent years, mental hospitals have altered candidacy policy and do not admit demented geriatric patients. Thus the communication problems of those institutionalized patients having the most difficulty must have other origins.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are the result of numerous discussions with various investigators at both Columbia University and Willard Psychiatric Center. Additionally, these conclusions represent discussions with attendees of the Research Symposium on Communication Sciences and Disorders and Aging, sponsored by the American Speech-Language-Hearing Association, Washington, DC, September 8, 1988.

The results of our review of the literature on communication problems of psychogeriatric inpatients have led to the conclusion that this area of research has been greatly overlooked. In addition, the authors have identified in their studies an unusually high number of psychogeriatric inpatients with profound communication problems. These two factors suggest the need for a complete review of therapeutic methodologies used during ward activities for

the geriatric patient. Future in-depth studies of communication disorders in this patient population should be interdisciplinary and involve speech-language pathology and audiology screening, evaluation, and assessment.

Had the numbers of noncommunicative patients identified during the original screening of patients for depression been lower, further inquiry into this area of study might not have occurred. While the utility of the data gathered may vary between facilities, the significance of this visible but unidentified group needs to be addressed both in research and in clinical practice.

More support for this level of inquiry must come from administrators of long-term care facilities and federal funding agencies. Local administrators must also support and encourage health professionals to include the noncommunicating patient in a variety of communication and socialization therapies. The effects of widespread patient communication problems on the morale and effectiveness of staff need to be considered more seriously.

Future research on the topic of communication problems among chronically mentally ill patients should focus on the predictors of which chronically mentally ill geriatric patients end up in institutions and what institutional risk factors should be considered in younger chronically mentally ill patients. The hypothesis that patients' current communication problems were present in some lesser form earlier in their institutionalization and that those communication problems had a significant and negative impact on the patients' ability to work their way through the system, develop supports, etc., deserves scientific inquiry. The following questions should be central to this inquiry:

1. What is it about patient communication problems that keeps patients in the hospital?
2. How do staff deal with noncommunicative patients?
3. If there are predictors, could they be detected when the patients were first admitted to the hospital or within the first few years of hospitalization? and,
4. What components of the process are key factors (i.e., thought disorders, interpersonal skills, language)?

Gray and Stevenson (1980) describe an intervention strategy that uses resocialization groups to increase verbal interaction and thus break the cycle in which the depressed patient ultimately becomes increasingly isolated. Problematic patient characteristics that have been identified by planners of intervention as a focus for special treatment approaches frequently include nonambulation, visual impairment, incontinence, disruptive or bizarre behaviors, and daily living skill deficits. They do not regularly include communication deficits unless a speech-language pathologist or expressive therapy clinician is actively involved. Perhaps, as Rask (1982) notes: "Apathy, withdrawal, and increasing disinterest in surroundings are perceived as normal accompaniments of aging and thus not recognized as increasing psychopathology."

There are many reasons why a lack of communication in inpatients might not be perceived as problematic by the staff, particularly if the staff/patient ratio is low or if

TABLE 3. Informant ratings of noncommunicative patients: expressive language, hearing problems, and comprehension/ability to respond to commands.

Rating	Expressive language (%)	Hearing problems (%)	Comprehens./Resp. to commands (%)
0	0 (0%)	168 (63%)	6 (2%)
1	1 (0%)	9 (3%)	47 (17%)
2	72 (27%)	13 (5%)	112 (42%)
3	104 (39%)	32 (12%)	88 (33%)
4	91 (34%)	46 (17%)	15 (6%)
Total	268 (100%)	268 (100%)	268 (100%)

the patient census or level of physical care is high. The nonverbal patient is not likely to be terribly disruptive to the functioning of a unit. Noncommunication, when compared to other isolated characteristics of the psychogeriatric patient, places fewer demands on staff time. This is especially so if the staff members do not possess a sufficient repertoire of skills to recognize conditions that may be leading to a noncommunication state or to work with the patient who presents a communication problem. Similarly, patients with communication problems may simply be excluded from research studies.

The field of psychiatric research has stopped looking to deinstitutionalization to solve the problems that have existed in institutions for decades and is now committed to identifying predictors of long-term institutionalization. Since older patients have very high rates of communication deficits (mostly due to the long-term side effects of phenothiazines, higher rates of dementia in schizophrenic patients, etc.), and older patients make up the majority of inpatients in state psychiatric facilities, this population is ideal for studies of communication as a predictor of long-term institutionalization. This notion of prediction concerns itself with whether communication problems are the cause of a subsequent course of the psychiatric illness.

In conclusion, among the mentally ill old people in hospitals, there is a predominance of severe communication disorders. However, those communication disorders are poorly defined (speech disorganization, dementia, tardive dyskinesias, neurological problems, effects of long-term institutionalization, effects of phenothiazines, etc.). Old people who are left in the hospital despite all attempts to get them out are the hard core patients. They may well get left in hospitals because of an unattractive, hopeless patient profile. The purpose of future inquiry should be to look at those patients and determine if communication problems are a predictor of institutionalization and, if so, what might be appropriate preventive intervention strategies?

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APPENDIX A
PATIENT FUNCTIONAL COMMUNICATION
SCREENING INSTRUMENT (FCS)

Client:

Interviewer:

Ward:

Date:

Part 1 (Only given if patient appears to be asleep):

Attempt to arouse patient, taking each of the following steps in order:

1. Raise voice, attempt to make eye contact, address patient repeatedly by name.
2. Firmly take patient's hand and continue as above.
3. Firmly tap back of patient's hand and continue as above.

If patient is aroused, go to Part 2; otherwise, go to Part 3.

Part 2:

Hello, my name is _____, may I speak to you?

(Record responses to following questions)

1. What is your name? _____
2. Can you spell that for me? _____
3. How long have you been in this hospital? _____
4. How are you feeling? _____

If the response to the above questions is inadequate, go to Part 3, else continue.

5. I would like you to tell me how you have been over the past month. Has there been anything troubling you over the past month? What kind of problems have you been having?

If Not Mentioned: Have you had any problems with your health?

With your nerves? _____

If Reasons for Admission Not Mentioned:

What happened to make it necessary for you to be here? (Could it be an emotional condition or your nerves?)

Rate as to level of insight:

- 0 Patient gives clear and plausible replies to all questions. Observations and self-report concordant.
 - 1 Patient's account is plausible, but interviewer has to probe a good deal and make inferences to fill gaps.
 - 2 Many doubts about patient's ability to report accurately on problems, and much time must be spent on challenges and probes.
 - 3 Clear-cut inconsistencies and denials. Almost no plausible or verifiable information. Information is regarded as almost meaningless.
- If 0, 1, or 2, read patient the consent form. If 3, go to Part 3.*

Part 3: (To be filled out by interviewer according to information received from informant.)

Obtain the following information from a knowledgeable informant.

Informant is a:

1. Therapy aide
2. RN
3. Other (specify) _____

Is this how the client typically appears? Is this a typical day for the client? Does the patient have any of the following problems?

- | | |
|---|---|
| 1. _____ Comatose/Stuporous | _____ response to painful stimuli |
| | _____ no response to painful stimuli |
| 2. _____ Fatigue | _____ patient claims too tired |
| | _____ patient falls asleep during screening |
| 3. _____ Frailty/Illness | _____ patient cannot get out of bed or sit up in bed |
| | _____ patient is incontinent—urinary or fecal or both |
| | _____ coughing attack, shortness of breath |
| | _____ pain, such as bedsores |
| 4. _____ Language Deficit | _____ hearing impairments |
| | _____ inappropriate response to simple commands |
| | _____ mute |
| | _____ paucity of language |
| | _____ verbal/motor problem |
| | _____ inaudible |
| | _____ incomprehensible |
| | _____ foreign language |
| 5. _____ Inattention (client easily distracted) | _____ delusions |
| 6. _____ Psychotic State | _____ hallucinations |
| | _____ assaultive |
| | _____ paranoid |
| | _____ incoherent (ravings) |
| | _____ catatonic response (i.e., yes/yes/yes) |
| | _____ lack of insight |

7. _____ Other (specify) _____

Comments: _____

Expressive Language:

Can anyone carry on a conversation with this client? Does this client express his/her needs effectively through the use of speech? Does he/she communicate his/her needs by pointing or gestures or writing?

- 0 Client will carry on a conversation with anybody.
- 1 Client will carry on a conversation with *some* people.
- 2 Client can communicate needs verbally.
- 3 Client can communicate needs nonverbally only.
- 4 Client cannot communicate needs.

Receptive Language:

Does this client have a hearing problem?

- 0 None
- 1 Mild (e.g., have to repeat questions frequently)
- 2 Moderate (e.g., have to raise voice and repeat questions frequently)
- 3 Severe (e.g., patient misses most of the questions in spite of raising voice and repeating questions)
- 4 Unknown

Does the client understand what is being said to him/her? Does the client respond to simple commands?

- 0 Client understands all of what is said to him/her.
- 1 Client understands some of what is said to him/her.
- 2 Client will respond to simple commands.
- 3 Client responds inappropriately to verbal stimuli.
- 4 Client shows no response to verbal stimuli.

Part 4: (To be rated by interviewer)

Place one check (✓) in the left-hand column indicating the major reasons for the patient's inability to communicate and then place a check next to any appropriate items in the left-hand column.

- | | |
|---|--|
| 1. _____ Comatose/Stuporous | _____ response to painful stimuli
_____ no response to painful stimuli |
| 2. _____ Fatigue | _____ patient claims too tired
_____ patient falls asleep during screening |
| 3. _____ Frailty/Illness | _____ patient cannot get out of bed or sit up in bed
_____ patient is incontinent—urinary or fecal or both
_____ coughing attack, shortness of breath
_____ pain, such as bedsores |
| 4. _____ Language Deficit | _____ hearing impairments
_____ inappropriate response to simple commands
_____ mute
_____ paucity of language
_____ verbal/motor problem
_____ inaudible
_____ incomprehensible
_____ foreign language |
| 5. _____ Inattention (client easily distracted) | |
| 6. _____ Psychotic State | _____ delusions
_____ hallucinations
_____ assaultive
_____ paranoid
_____ incoherent (ravings)
_____ catatonic response (i.e., yes/yes/yes)
_____ lack of insight |

7. _____ Other (specify) _____

Comments: _____

APPENDIX B
TWO EXAMPLES OF LONG-TERM PSYCHOGERIATRIC PATIENTS

Case 1

D.O.B.: 2/20/1897

DoAd: 9/16/83

E. B. is a 91-year-old man who was brought in voluntarily by his wife on 9/16/83. Prior to this admission, the patient has been hospitalized for about one year at WPC and was released on 8/29/83. One week after this discharge, the patient started leaving his home at night and wandering on the highway. He was unable to comprehend what was said to him by his wife. He had to be told when to eat, when to sleep, and he could not find his way to the bathroom. He was resistive when his wife attempted to bring him back home while he was wandering on the street.

Mental status on admission: The patient was sitting quietly in his chair next to his wife. He had a hearing problem. He was confused and disoriented to 3 spheres. He could not tell the year of his birth but could tell his birthday. He did not know his address. Both his recent and remote memory were impaired. He had a short attention span. His speech was underproductive and slow. His insight and judgment seemed to be poor.

His medical history shows that he was obese on admission. He has adult-onset diabetes mellitus and arteriosclerotic heart disease with compensated heart. He also had surgery for gall bladder, left herniorrhaphy, left orchietomy, prostatectomy, and appendectomy. He has a hearing problem and cataracts in both eyes. He also has arthritis of fingers, knees, and spine. The distal phalange of his left index finger was amputated. He was able to ambulate with a cane on admission but needed assistance.

His diagnosis on admission was multi-infarct dementia, uncomplicated.

The patient has been at WPC since September 1983. His diagnosis remains the same. He is currently confined to his bed, curling up in a fetal position with severe contracture of his hands and arms. He sleeps in his bed most of the time. Eye contact cannot be gained. Even when spoken to in a loud voice or when his shoulder is shaken, he responds with incoherent groans and mumbles. He is totally disoriented to 3 spheres and profoundly oblivious to his environment. The patient's cognitive decline has been profound during the course of the past year. In addition to his dementia, he is nonambulatory and uncooperative with medical intervention. He has multiple serious physical problems, including a seizure disorder with right chronic subdural hematoma, arteriosclerotic heart disease, post multiple abdominal surgeries, mild anemia of chronic disease, history of hyperthyroidism, and guaiac positive stools. The patient is in the terminal stage of dementia and will require continued psychiatric hospitalization for the rest of his life.

Case 2

D.O.B.: 6/20/1917

DoAd: 6/14/83

H. P. is a 71-year-old white female admitted to WPC with a diagnosis of chronic schizophrenia, disorganized type. The patient has a long psychiatric history dating back to her first admission to Rochester State Hospital in 1932. While at Rochester State Hospital, she received several insulin shock treatments in 1936 and metrazol convulsive treatment in 1940. In 1945-47, she received several series of ECT. On 1/29/50, a prefrontal lobotomy was performed on her. In general, the patient's condition never showed any significant improvement. At all times, she showed poverty of ideas, and her replies were monosyllabic. She was also found to be belligerent, easily excited, assaultive, uncooperative, and displaying silly behaviors. Since the early 1950s she started receiving thorazine, but showed only slight improvement.

During all these years, she was found on many occasions to display agitated behaviors, pacing back and forth, having loud outbursts, and occasionally striking others.

Currently, the patient is alert and ambulatory. She keeps marching continuously in front of the nursing station or in the hallway. She doesn't talk to anyone, remaining absorbed in her marching for hours every day. If her routine is interrupted, she was been known to react with physical violence. She is totally uncooperative. Her diagnosis remains unchanged.

E. SPEECH/LANGUAGE SCIENCE TRACK

Chapter 8

SOME IMPLICATIONS OF CURRENT GERONTOLOGICAL THEORY FOR THE STUDY OF VOICE

ROBERT L. RINGEL

Purdue University, West Lafayette, IN

WOJTEK J. CHODZKO-ZAJKO

Kent State University, Kent, OH

Clinical and postmortem studies of the human larynx have revealed significant degenerative changes with advancing age. These changes include muscle atrophy (Hirano, Kurita, & Nakashima, 1983), ligamental deterioration (Kahane, 1983), and cartilaginous calcification (Segre, 1971). In addition, neuronal atrophy (Segre, 1971), neurotransmitter deficiencies (McGeer & McGeer, 1975), and nerve conduction velocity decrements (Wagman & Lesse, 1952) have also been observed, both peripherally at the neuromuscular junction and also in central nuclei critical to the control of the larynx.

Degenerative changes have also been reported in the aging respiratory system. Structural changes in the lower airways and lungs have been shown to reduce the elastic recoil capacity of the lungs. In aging lungs, the pleura have been reported to lack color and luster (McKeown, 1965), and changes in the collagen to elastin ratio result in stiffer, poorly lubricated pleural membranes (Comroe, 1965). The loss of efficiency caused by decreased interthoracic dimensions and reduced distensibility is greatest at near maximal levels of pulmonary performance (Pierce & Ebert, 1965; Turner, Mead, & Wohl, 1968) and is associated with a marked reduction in a large number of measures of respiratory efficiency, including forced vital capacity (Niinimaa & Shephard, 1978; Shock, 1972), forced expiratory volume (Morris, Koski, & Johnson, 1971; Shephard, 1978), and maximal volume of ventilation (Shock, 1972). Senile kyphosis, the exaggerated curvature of the spine, is thought to result from a progressive thinning and degeneration of the vertebral discs and has been shown to be instrumental in the alteration of thoracic shape in the elderly (McKeown, 1965). In addition to this change in thoracic shape, respiratory efficiency has been shown to be compromised in the aged by diminished muscular strength in the thoracic muscles (Dhar, Shastri, & Lenora, 1976) and also by calcification and ossification of the costovertebral and costochondral joints (Grant, 1972). It is likely that impaired pulmonary performance with advancing age results from a combination of factors, including diminished vital capacity, decreased elasticity, and generalized muscular weakness. These

structural changes have the general effect of reducing the mobility of the rib cage which, in turn, decreases the biomechanical efficiency of the respiratory system (Kahane, 1981). It is not at all surprising that structural changes in the laryngeal and respiratory system would be manifest in the operation of these systems (see Table 1).

Age-related changes in the laryngeal cartilages, muscles, and connective tissues may affect the ability of the larynx to function as a sound generator. Decreased compliance of laryngeal cartilages due to calcification (Segre, 1971) or ossification (Kahane, Stadlan, & Bell, 1979) is associated with a disruption of vocal fold vibration (Zenker, 1964). Similarly, mucosal atrophy and drying change the texture and surface architecture of the vocal folds and can lead to asymmetric vibration patterns with a resultant increase of noise within the glottal spectrum (Hirano, 1974). Hodkinson (1982) has suggested that changes in vocal pitch and resonance in old age result from a progressive decrease in elasticity and strength of the laryngeal musculature.

Changes in laryngeal function in elderly persons have been associated with a wide variety of vocal behaviors, ranging from reduced fundamental frequency (Mysak, 1959), decreased vowel prolongation time (Ptacek, Sander, Maloney, & Jackson, 1966), and diminished vocal intensity (Kreul, 1972). However, Kent and Burkhard (1981) have suggested that finer aspects of phonatory behavior, such as pitch perturbation (jitter), amplitude perturbation (shimmer), and spectral harmonics-to-noise (H/N) ratios are likely to be more sensitive to the temporal and mechanical disruptions that characterize the aging vocal folds. Indeed, several recent studies have shown that increases in vocal jitter and shimmer are characteristic of the aging voice (Ramig & Ringel, 1983; Ringel & Chodzko-Zajko, 1987; Wilcox & Horii, 1980).

Changes in the aging respiratory system may limit the speaker's ability to develop an adequate driving force for the production of speech. In particular, weakness in the respiratory muscles can result in a diminished ability to produce the rapid increases in muscular force required for the generation of stress contrasts during speech (Net-

TABLE 1. Some structural changes and functional consequences in aging.

<i>Structural changes with age</i>	
<i>Laryngeal system</i> Muscle atrophy Cartilaginous calcification Ligament deterioration Neuronal atrophy Vocal fold edema Neurotransmitter deficiency Impaired blood supply	<i>Respiratory system</i> Senile kyphosis Pleural drying and thinning Decreased elastic recoil Thoracic muscle atrophy Vertebral degeneration Costovertebral calcification Costovertebral ossification
<i>Functional consequences of aging</i>	
<i>Laryngeal system</i> Reduced fundamental frequency Decreased vowel prolongation time Diminished vocal intensity Increased vocal jitter Increased vocal shimmer Reduced signal-to-noise ratio	<i>Respiratory system</i> Reduced subglottic pressure Reduced vital capacity Reduced forced expiratory volume Inability to generate stress contrasts Diminished endurance Reduced loudness Smaller phrase units

sell, 1978). Hoit and Hixon (1987) report that elderly men, when compared to young men, use larger lung volume excursions per breath group and expend larger lung volumes per syllable. They interpret these findings to indicate that laryngeal valving economy may decrease with age. More recently, Melcon, Hoit, and Hixon (in press) have shown that there are age-related differences in laryngeal airway resistance during vowel production, with lower levels of resistance characterizing the elder group. The failure to use the laryngeal mechanism in an efficient manner may well lead to a need on the part of elderly persons to use greater respiratory force in the production of voice.

Even from this brief review it is apparent that a number of investigations have dealt with the influence of advancing age on the structure and function of the peripheral speech mechanism. Recently, much progress has been made in the technical sophistication with which we are able to evaluate issues of aging and the voice. Although not many years ago researchers were restricted to relatively gross measures of phonatory output, such as fundamental frequency and vocal intensity, today, exquisitely sensitive measures of cycle-to-cycle variation in frequency or amplitude perturbation are available to most investigators. In spite of the impressive technological advances in the study of voice, similar advances in experimental design are yet to be realized.

It is unfortunate that investigators of the voice have remained so traditional in their experimental approaches because recent years have witnessed remarkable change in the approaches which gerontologists have chosen to adopt for the experimental investigation of the aging process. These changes are so pervasive that they influence virtually all aspects of experimental design. In this paper we shall discuss in detail some of the recent advances which have been made in the general area of gerontology in the belief that such information will be of value to those in the communication sciences who conduct research with the elderly.

We have chosen to commence this paper with a discussion of some approaches to the computation of *biological*

age. An understanding of the concept of biological age is of importance because it enables the researcher to take into consideration individual differences among persons of the same chronological age. Next, a case is made for the need to increase awareness of the importance of such factors as *health status* when evaluating age-related changes in performance. The acceptance of the view that health and disease represent the extremes of a single continuum allows us to conceptualize aging as a continuously evolving process rather than as a series of discrete stages of development. Such a perspective, in which the needs of elderly individuals can be seen to differ, depending on their position along a health-disease continuum, has important implications, not only for the conduct of research, but also for clinical practice.

In addition to our discussion of biological aspects of aging, we shall also deal with some methodological issues currently under discussion in the literature on aging. For example, an increased recognition of the influence of *experimental design*, per se, upon the outcome of investigations has drawn much attention to the relative merits of cross-sectional and longitudinal approaches. In our discussion, we note that the shift toward the use of research designs involving large numbers of subjects and many variables has necessitated the development and application of various types of *statistical analyses* which are capable of addressing the complex nature of such designs. The matter of *subject selection* has led us to consider, among other issues, the limitations for the generalizability of results caused by the injudicious removal of all but the most select individuals from the subject pool. Finally, we emphasize the importance of the *selection of variables* that are sufficiently sensitive to detect the subtle changes in performance believed to characterize the aging process and the importance of sampling behavior at several levels of performance intensity. Throughout our paper we will do our best to illustrate the significance of these factors for communication sciences by making reference wherever possible to specific examples from the voice and aging literature.

THE MEASUREMENT OF BIOLOGICAL AGE

It is now well accepted that our understanding of the aging process will require the development of more complex measures of senescence than chronological age alone (Birren & Cunningham, 1985). For example, attempts have been made to replace chronological age with more appropriate measures of senescence, capable of giving a more complete picture of the aging process (Benjamin, 1947; Borkan & Norris, 1980; Comfort, 1969; Ludwig & Smoke, 1980).

The most common approach has been to estimate the "biological" or "functional" age of an individual. In this procedure, the combination of physiological variables which maximizes the prediction of chronological age is used to estimate biological age. From a conceptual viewpoint, those individuals whose biological age exceeds their chronological age are considered "old" for their age, whereas those whose biological age is less than their actual age are considered physiologically "young."

While this approach clearly acknowledges the need to go beyond the mere counting of years lived, it is not without its own shortcomings. The most critical objection centers about the requirement that chronological age be selected as the criterion against which the biological variables are regressed. Because the decision to compute biological age implies a rejection of the adequacy of chronological age, it is unclear how the rejected measure subsequently can be adopted as the criterion in accordance with which biological age is to be defined (Costa & McRae, 1980). This concern is particularly difficult to overcome as there is no immediately apparent alternative criterion to substitute for chronological age in the multiple regression approach.

Other investigators have suggested the use of factor analytic approaches in the attempt to define biological age in the absence of an external criterion (Bell, 1972; Dirken, 1972; Heron & Chown, 1967; Hofecker, Skalicky, Kment, & Niedermulter, 1980; Jalavisto, 1965). The major focus of those efforts has been the identification of a general factor of biological aging in which a number of physiological variables combine with chronological age to form a single independent factor. Although some researchers have claimed that a unitary factor of biological aging can be identified (Heron & Chown, 1967; Jalavisto, 1965), the general consensus is that aging is a multidimensional process and that efforts to reduce physiological variables to a single factor of biological aging are unlikely to meet with success (Borkan, 1978; Costa & McRae, 1980; Ingram, 1983).

Regardless of whether multiple regression or factor analytic procedures are adopted, indices of biological age are seldom efficient predictors of age-related changes in behavior (Ingram, 1983). Indeed, most studies suggest that the single most powerful predictor of functional changes that occur in senescence remains chronological age. In recognition of these concerns, it is probably of only limited value for research to concentrate on the

development of measures of biological age that are intended as substitutes for chronological age. We suggest that it is more useful to develop methods for evaluating physiological status that are intended to be used in conjunction with the measurement of chronological age.

A series of experiments conducted in our laboratories is illustrative of how this type of procedure may be applied in the communication sciences. Throughout these studies a multivariate statistical procedure was adopted for the evaluation of overall physiological health. In this procedure, pulmonary, anthropometric, hemodynamic, and biochemical measures were reduced to a single score, the Index of Physiological Status (IPS). Subsequent analyses examined the extent to which changes in laryngeal performance, which are usually attributed to chronological age effects, could be shown to be sensitive to changing levels of physiological health as measured by the IPS (Chodzko-Zajko & Ringel, 1987; Ringel & Chodzko-Zajko, 1987).

In our initial study (Ramig & Ringel, 1983), the relationship between laryngeal function and underlying body physiology was studied in a sample of 48 men representing three chronological age groupings (25-35, 45-55, and 65-75 years). Voice samples were collected for all subjects during the performance of four phonatory tasks: extended vowel phonation, spontaneous speech, oral reading, and the production of a maximal phonatory range for a vowel. A major finding was that subjects in good physiological health produced maximal duration phonation with significantly less jitter and shimmer and had larger phonatory ranges than did subjects of the same age who were in poorer physiological condition. The phonatory differences between groups were most apparent in the oldest subgroup studied. When the results of the study were analyzed taking only the subjects' chronological ages into account, age-related changes in laryngeal function were quite limited. Shimmer was the only acoustic measure that varied significantly between young and elderly subjects. No significant age-related differences were observed for jitter, fundamental frequency, or phonatory ranges. Thus, if only analyses based on chronological age had been conducted, the relationship between physiological status and acoustic performance would have remained undetected.

A follow-up study was designed to examine these relationships in greater detail (Ringel & Chodzko-Zajko, 1987). Forty-nine male subjects of mean age 61.9 years were selected for the investigation. They were asked to perform a series of phonatory tasks, including maximally prolonged vowels, connected discourse, and maximal phonatory range. Measures of fundamental frequency, maximal phonatory range, jitter, shimmer, and spectral harmonics-to-noise ratios (H/N) were obtained for all subjects.

The subjects were divided into discrete good and poor condition groups according to the IPS fitness criterion. The results indicated that the physiologically healthier individuals exhibited less vocal jitter and shimmer and also had higher H/N ratios, suggesting that increased laryngeal control is associated with better physiological

health. As with the previous studies, mean fundamental frequency was not found to be a sufficiently sensitive measure for the reliable detection of differences between subjects of differing physiological health. These data emphasize the importance of physiological health measures by focusing on speech performance differences between individuals with diverse physiological profiles. The results support the contention that elderly individuals in good health perform vocal tasks in a manner quite different from those in poorer health.

HEALTH STATUS

By tradition, aging has been thought of as either a disease-free (primary) or disease-related (secondary) process. However, recent advances in our understanding of the subclinical levels of pathology render the concept of disease-free aging increasingly less tenable (Shock et al., 1984). Rather than attempting to divide the elderly population into separate and distinct normal and diseased subgroups, we have argued that it may be more helpful to consider the elderly population as being distributed along a health-disease continuum, with exceptionally good physical health at one end and overt pathology at the other (Chodzko-Zajko & Ringel, 1987). Within such a framework, those at the healthy end of the continuum can be expected to experience markedly less functional deterioration than those individuals at the opposite extreme. The importance of such a conceptualization is that it allows us to view functional decline not solely in terms of the aging process but rather as a phenomenon that is dependent upon both age and health status.

Anecdotal and experimental evidence has shown that exceptionally healthy older persons often are capable of functioning at levels of voice production that are the envy of individuals many years their junior. Further, we know that patients with degenerative diseases that strike them at a relatively young chronological age frequently exhibit vocal signs and symptoms characteristic of chronologically much older persons. Also, it has been reported that neurotransmitter concentration levels in the brain of early onset Parkinson disease patients are similar to the level normally found in persons many decades older than the diseased person. It is indeed seductive to suggest that regressive or involutinal diseases are simply a reflection of an accelerated aging process. Although such a conclusion must wait upon more definitive research findings, it does seem clear that future investigations of the processes of aging and of certain neuropathologies are likely to yield insights that are of mutual importance.

Examination of the speech science literature reveals a wealth of evidence to support the contention that "age-related" changes in vocal performance are often less a function of aging and rather more a result of the physiological deterioration that so often, but not always, accompanies the passage of time. Indeed, the relationships between vocal performance and disease are sufficiently well established that dysphonic changes are frequently of assistance in the differential diagnosis of certain diseases

(Aronson, 1985; Darby, 1981; Hodkinson, 1982). For example, pulmonary diseases frequently disrupt airflow in such a way as to reduce the intensity, fundamental frequency, and duration of phonatory output (Weg, 1977). Coronary artery disease has also been shown to be associated with characteristic vocal irregularities, conceivably as a result of both general respiratory inadequacy and impaired pulmonary and laryngeal blood supply (Jacobs & Schuker, 1981). Consistent with this finding, it has been reported that changes in the quality of voice may be an important diagnostic sign in selected cases of hypertension (Taylor, 1981). Diseases, such as the myasthenias, the dystrophies, and malnutrition, which weaken the respiratory, laryngeal, and supralaryngeal musculature, have also been shown to reduce an individual's respiratory source for normal voice production. The acoustic consequences of such disturbances are frequently manifested in inappropriate fluctuations in vocal intensity and fundamental frequency, particularly toward the ends of the respiratory cycle (Walton, 1977). Finally, other diseases of the central nervous system, strokes, neoplasms, and sclerotic growth have all been shown to be associated with increased variability in phonatory output (Aronson, 1985; Darby, 1981).

The literature makes it clear that speech irregularities are an integral part of the total pattern of disease symptomatology, and there is much evidence to support the view that ill health is related to speech performance. What is less clear, however, is the relationship between health status and speech performance at the other end of the continuum, namely, the influence of good health and physical fitness upon the speech performances of the elderly. Studies previously reported suggest that it is reasonable to believe that fitness can influence the rate and extent of speech deterioration in old age (Ramig & Ringel, 1983; Ringel & Chodzko-Zajko, 1987). With but few exceptions most of the research that has addressed the vocal characteristics of advancing age has concentrated exclusively on describing subjects according to chronological age and has entirely ignored the physiological factors upon which may well depend the vocal consequences of senescence. Future studies should make a greater effort to acknowledge the importance of health status in determining the rate and extent of progression of the aging process, first by attempting to include as heterogeneous a sample of elderly individuals as possible and, second, by supplementing traditional measures of chronology with appropriate indices of biological senescence.

EXPERIMENTAL DESIGN

Current trends in gerontological research are characterized by the de-emphasis of cross-sectional designs in favor of more complex longitudinal methodologies. In cross-sectional designs, age changes are not measured directly but are inferred from differences observed between discrete age groups selected at the time of the investigation. The popularity of this approach is due to its ease of application and partially to the fact that results can

be obtained rapidly without the need to follow subjects for extended periods of time. Cross-sectional designs, however, have a number of shortcomings. A major limitation is their inability to differentiate between age and cohort effects. Individuals born within a particular span of years represent the same birth cohort. Since different cohort groups are likely to have been exposed to different educational, cultural, nutritional, medical, and other experiences, apparent differences between age groups may in reality be cohort rather than age effects (Schaie, 1977). A second, perhaps more critical objection to the cross-sectional method is its inability to measure the rate at which behavior changes. Since cross-sectional studies only sample performance at a single point in time, they cannot provide answers to questions concerning the stability of behavior.

In longitudinal studies, repeated measurements are made on the same individual over extended periods of time, permitting the direct measurement of behavioral changes for each participant in a study. From the information thus obtained, it is possible to compute individual and group regression coefficients for a particular variable or set of variables with respect to age. These data enable the investigator not only to determine the stability of a behavior over time for the group as a whole, but also to evaluate the degree of variability that characterizes individual responses within a particular group. Heterogeneity of response with regard to both the rate and the extent of behavioral change is a major characteristic of the aging process and can only be evaluated by experimental designs that permit serial observations over an extended period of time.

In addition to permitting the evaluation of differential rates of aging, another advantage of longitudinal studies is that they enable the researcher to predict the outcome of specific treatments, lifestyles, or risk factors on behavior and subsequently test the accuracy of those predictions. For example, major longitudinal studies, such as the Framingham Heart Disease Study (Kannel, 1978) and the Baltimore Longitudinal Study on Aging (Shock et al., 1984) have contributed significantly to our understanding of relationships between specific risk factors and subsequent morbidity and mortality.

Clearly, longitudinal methodologies could be employed usefully in experimental investigations of the aging voice. To date, much of the information we possess on the vocal characteristics of old age has come from cross-sectional studies in which no effort has been made to monitor the same individuals for extended periods of time. Thus, although we know that advancing age is associated with increases in jitter, shimmer, and spectral noise levels, very little is known about the progression over time of such changes. The application of longitudinal designs would not only allow the researcher to evaluate individual differences between subjects with respect to the rate and extent of vocal deterioration in old age, but would also allow for the testing of effects of treatments, lifestyles, or risk factors on subsequent vocal behavior.

Longitudinal designs require a considerable investment in both time and money; nonetheless, their theoret-

ical advantages are apparent, and it would seem imperative that, wherever possible, longitudinal designs should be given serious consideration. The feasibility of conducting longitudinal studies is greatly enhanced by interdisciplinary collaborations. Such collaborative ventures are, by their nature, better able to acknowledge the multivariate complexity of the aging process. Thus, in addition to the economic attractions associated with the sharing of resources, interdisciplinary projects are likely to enhance our understanding of the complex interactions involved with the aging process to a greater extent than would be possible in a series of smaller, more restricted investigations.

STATISTICAL ANALYSIS

It is a frequent research procedure to treat age as an independent variable which is manipulated by the experimenter to determine its "effects" on some dependent variable of interest. Botwinick (1984) has objected strongly to the treatment of chronological age as an independent variable. He notes that age does not meet the criteria to be classified as an independent variable because it cannot be manipulated experimentally. Furthermore, he suggests that the attribution of a causal dimension to chronological age is inconsistent with our understanding of the biology of aging. A move away from the treatment of chronological age as an independent variable necessitates a philosophical as well as a methodological shift in orientation. The recognition that the "effects" of chronological age cannot be determined in any meaningful causative sense is logically consistent with a move away from reductionistic and explanatory research paradigms in favor of more descriptive and exploratory approaches. Review of the literature on aging suggests that classical confirmatory designs, in which the effects of chronological age are determined for a set of predetermined contrasts of interest, are being replaced gradually by more exploratory designs in which post-hoc analyses are used to search for previously unknown or unconfirmed relationships among large sets of variables.

In addition to the trend toward more exploratory statistical approaches, there has also been a move toward the adoption of more complex multivariate models and a gradual reduction in emphasis on more traditional univariate designs. Maddox and Campbell (1985) have suggested that any attempts at explaining individual differences in behavior that do not take into account the simultaneous influence of multiple factors will be seriously if not fatally flawed. In their opinion, the construction of a meaningful theory of adult development will require the adoption of both multivariate and multidisciplinary approaches. Nesselroade and Labouvie (1985) observe that such a move toward the adoption of multivariate models is consistent with the realization that, in the real world, relationships of interest are not neatly packaged in pairs of variables that meet the assumptions of independence required for traditional univariate analyses.

Examination of the literature dealing with aging and the voice reveals that the vast majority of studies have applied the rather traditional univariate model. Illustrative of such an approach is a study by Ptacek, Sander, Maloney, and Jackson (1966). In that experiment, the performances of younger and older adults were compared for a series of respiratory, phonatory, and articulatory behaviors. Their study, now some 20 years old, is still cited for the insights it provided into the influence of aging on a wide variety of speech-related variables. Ptacek et al., however, made no provision in their design to allow for the evaluation of potential interactions among the dependent variables. Thus, although their experiment established that vital capacity, extended vowel phonation, and maximal diadochokinetic rate all deteriorate with advancing age, it was not possible to determine the relationship among the various respiratory, phonatory, and articulatory parameters. That early study is representative of numerous other investigations which have adopted relatively simple designs in which the effects of such factors as chronological age or sex are determined independently for each of a series of speech-related variables (e.g., McGlone & Hollien, 1963; Mysak, 1959; Shipp & Hollien, 1969; Wilcox & Horii, 1980). In general, those investigations did not seek to examine the complex interactions between variables, and, accordingly, the univariate analyses selected were probably quite appropriate.

In our research we have placed greater emphasis on the need to evaluate interactions between multiple dependent and independent variables. For example, in developing the IPS we used factor analytic procedures to permit us to reduce a large number of biophysiological measures to a single score representative of overall physiological health. Subsequently, we adopted discriminant function analyses in order to determine the extent to which a combination of auditory, speech, somatosensory, visual, and reaction time measures could discriminate between discrete groups of high- and low-fit elderly adults (Chodzko-Zajko & Ringel, 1987). The advantage of procedures such as those employed in that study is that they enable us to examine relationships between speech measures and a variety of other sensory and motor parameters with a degree of sophistication that would be impossible using more traditional univariate approaches.

It would be inappropriate for us to leave the impression that the results of multivariate procedures can be interpreted as unambiguously as, for example, the analysis of variance or covariance. Indeed, part of the beauty of these analyses lies with their interpretive flexibility. There is good reason to believe that these sorts of analyses will be adopted with increasing regularity, particularly as interest continues to shift toward more complex multidimensional investigations of the aging process.

SUBJECT SELECTION

Decisions regarding subject selection criteria are a source of much interest in gerontological research. For

example, in studies evaluating cardiovascular health in elderly subjects, it is a common practice to exclude those subjects who are unable to meet the medical criteria required for participation in an exercise stress test. Similar subject selection strategies have been adopted in the speech science literature on aging. Studies generally have excluded individuals with less than optimal health from the experimental sample. For example, Mysak (1959), in his study of the aging voice, restricted his experimental sample to those individuals who were found to be "free of serious physical, auditory or speech incapacity." Similarly, McGlone and Hollien (1963) limited their investigations to those in a "generally healthy condition," whereas Hollien and Shipp (1972) chose to study only "normal healthy males." Although, in most instances, authors have been vague about the precise criteria they adopt for the definition of normal and healthy individuals, Ptacek et al. (1966) list detailed criteria for the exclusion of subjects with hearing loss, with respiratory and cardiovascular diseases, neurological and psychological disorders, and any structural abnormalities of the larynx.

Having now commented on exclusionary subject selection criteria, we believe it is worth noting how difficult it is to find elderly individuals who have no discernible health problems. Indeed, even if such a sample of subjects could be assembled in sufficient number, there are real doubts as to the extent that such "geriatric supermen" can be considered representative of the elderly population at large. We have suggested that the findings from such studies will, by the very nature of the procedures followed, be restricted to the relatively small portion of the population that was able to participate in the investigation (Chodzko-Zajko & Ringel, 1987). In most cases, the exclusion of large numbers of subjects is not only unduly restrictive, but also unnecessary because post-hoc statistical procedures are available that will allow for the determination of the influence of potential risk factors.

In contrast, the approach we are proposing would make it possible, for example, to test for vocal performance differences between elderly smokers and nonsmokers and thereby contribute to our understanding of the influence of smoking history on age-related changes in the voice. It is certain that the subdivision of an experimental group into several distinct subgroups will require the selection of a relatively large number of subjects. However, advantages of these procedures over the a priori exclusion of large numbers of individuals may well justify the additional experimenter effort.

SELECTION OF VARIABLES

In much the same way that the selection of subjects may have an important effect on the outcome of experimental studies on aging, the procedures adopted for the selection of variables can also exert a considerable influence on an investigation. Age-related deficits are seldom manifest with equal likelihood across all measures of

performance. Elderly individuals seem less likely to exhibit performance decrements on experimental tasks that can be performed comfortably at rest. The same individuals, however, may well demonstrate failures of response when the demand levels of an experimental task are raised (Welford, 1982). These observations are consistent with an approach that encourages investigators to include in their assessment of the integrity of biological systems, among other types of evaluation, the measurement of performance under conditions of maximal or near-maximal effort. It is in furtherance of this concept that stress electrocardiography has gained such an important place alongside more traditional "resting state" measures as an integral part of the diagnostic procedures used in the evaluation of coronary heart disease.

A similar relationship between performance at rest and under stress may also be observed when evaluating vocal performance. For example, performance deficits are less likely to be observed when elderly subjects are asked to phonate at comfortable levels of intensity for brief periods of time. However, when the same subjects are asked to sustain phonation for maximal or near-maximal durations, significant changes in vocal behavior become apparent (Ramig, 1983; Ramig & Ringel, 1983; Ringel & Chodzko-Zajko, 1987). In general, these findings lead us to suggest that even though individuals appear to experience a progressive decline in functional reserve capacity with advancing age, the declines may not manifest themselves in performance breakdowns until subjects are asked to function at, or close to, their performance limits.

In addition to giving careful consideration to the nature of the experimental task, it is also important to consider the sensitivity of the variables selected for the evaluation of age-related changes in behavior. Recent studies in our laboratory have confirmed the initial suggestion of Kent and Burkhart (1981) that some measures of phonatory output, such as mean fundamental frequency, vowel prolongation time, and maximal vocal intensity may not be sensitive enough for the detection of age-related changes in the voice, even when data are obtained from persons who are performing phonation tasks at maximal exertion levels. However, other aspects of phonatory behavior, such as pitch perturbation (jitter), amplitude perturbation (shimmer), and spectral harmonics-to-noise ratios appear to be far more sensitive to the minute temporal and mechanical disruptions that are thought to characterize the vibratory cycle of the aging vocal folds (Ramig & Ringel, 1983; Ringel & Chodzko-Zajko, 1987).

Such observations appear to argue in support of the need for investigators to take special effort, not only to select measures that are taxing enough to tap the diminished functional reserves of elderly subjects, but also to ensure that those measures are sufficiently sensitive to allow for the detection of changes in subject performance. R. D. Kent (personal communication, August 25, 1988) has suggested that an approach similar to that which was used to develop the IPS may also be considered for use in the measurement of senescent changes in vocal performance. For example, a multivariate index could be developed in which the results of a battery of static and

dynamic vocal performance tasks are reduced to a single descriptive score. Such an approach is appealing because the index is likely to be a better descriptor of vocal status than any of its component elements taken in isolation. In a more general sense, the idea of developing measures of speech, voice, and language performance that are based upon multivariate design concepts is rich in potential.

CONCLUSIONS

Recent years have witnessed a marked increase in the number and scope of experimental investigations of the aging process in virtually all areas of pure and applied science. Communication science has played an active role in this resurgence of interest. Indeed, there are good reasons to believe that researchers from the speech and hearing sciences have much to contribute to the increased understanding of the aging process. One area in which the speech scientist may make an important contribution is research on the basic biological mechanisms that underpin senescence. As a result of our own research interests, we have come to realize that the structural changes observed in the aging larynx often parallel more general degenerative processes observed in the body as a whole. For example, atrophy, dystrophy, and edema are characteristic of aging at the cellular level in virtually all physiological systems. These disruptions in the integrity of the cell are frequently precursors of more gross morphological changes, such as decreased elasticity and compliance, demyelination, and neoplastic growth.

Regardless of whether one concentrates on the laryngeal, cardiovascular, pulmonary, or some other physiological system, the functional consequences of aging are often profound. In general, aging organ systems are usually slower and less accurate in function than younger ones. They exhibit not only reduced strength and stability, but also decreased coordination and endurance. Many of the changes observed in the aging laryngeal system are representative of the aging of the body as a whole. Thus, the human voice may be viewed as but one of a number of sensitive windows through which the process of senescent degeneration can be visualized. It is important to note that the output of few physiological systems can be so easily measured as the voice. Vocal output can be recorded in a noninvasive manner with relative ease in virtually all individuals. Accordingly, the laryngeal system may provide an excellent model with which to study the basic biological mechanisms of aging.

Speech science also has an important role to play in increasing our understanding of the dynamics of senescent changes in communicative abilities. Although it is not at all uncommon for individuals to experience declines in vocal performance as they age, relatively little is known about the time course of such changes. Furthermore, at present, it is not well understood why age-related changes in voice are so heterogeneous in nature, with some individuals experiencing almost no functional loss, while others suffer profound and debilitating deterioration. Although increasing our understanding of these

important issues will doubtless require many years of extensive investigation, we are confident that the application of more appropriate research designs, coupled with our ever-increasing technological sophistication, will eventually permit a much broader understanding of the complex dynamics associated with the aging voice.

It would be remiss to conclude a discussion of future research needs without a brief comment on the need for more studies of prevention and rehabilitation. There is now some evidence to suggest that interventional strategies, such as healthful lifestyles, good nutrition, and exercise, may influence the rate and extent of vocal deterioration observed in advancing age. Unfortunately, well-controlled longitudinal investigations have yet to examine these relationships in detail. In addition to the need for further study of prevention, there is also a need for more studies investigating the efficacy of rehabilitative strategies for those individuals whose voices have already begun to show signs of senescent deterioration.

In summary, there are a large number of fertile avenues of research for the speech scientist interested in the study of aging. It is our belief that the communication sciences have much to contribute to our understanding of the aging process. The extent to which we will be able to realize this contribution will depend to a large degree on our ability to respond appropriately to some of the theoretical and methodological issues discussed in this paper.

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Chapter 9

AGE-RELATED CHANGES IN THE PERIPHERAL SPEECH MECHANISM: STRUCTURAL AND PHYSIOLOGICAL CHANGES

JOEL C. KAHANE

Memphis State University, TN

Over the last decade, great interest in aging and its effects on communication has occasioned the publication of several books devoted to the topic (Beasley & Davis, 1980; Jacobs-Condit, 1984; Shadden, 1988; Ulatowska, 1984). In these books, specific chapters have tried to explain the ways in which structural and physiological changes affect performance during speech and voice production. This is a formidable task in that the peripheral speech mechanism is composed of many organs and several organ systems which are highly integrated structurally and functionally. Its tissues, organs, and systems age differently and to different extents (Shock, 1962). Thus, involuntional changes will not be uniform; some organs and systems will be affected more than others.

This paper attempts to summarize the age-related changes through a review of relevant literature and a discussion of the functional implications of these involuntional trends.

RESPIRATORY SYSTEM

Aging of the respiratory system affects the power source of the peripheral speech mechanism. Thus it influences a variety of functions important to voice and speech production, affecting aerodynamic and glottal features as well as prosody and intonation.

STRUCTURAL CHANGES

Thoracic Skeleton

One of the principal changes in the skeletal framework of the respiratory system involves the development of *senile kyphosis* (McKeown, 1965; Reveille-Parise, 1851; Rossman, 1979). This condition causes a narrowing of the anteroposterior dimension of the thorax. It results from an exaggeration of the curvature in the cervical and thoracic regions of the vertebral column caused by thinning of the

anterior aspects of the intervertebral disks. This causes the chest to become concave or "sunken-in chest" with rounding of the back that is sometimes referred to as a dowager's hump.

Changes in the costovertebral joints, exacerbated by senile kyphosis, cause the articular facets of the vertebrae to become flattened, and the angle of inclination of the necks of the ribs to become altered (Macklin & Macklin, 1942). This reduces movements of the ribs. That, in turn, is likely to alter rib cage movements, which may affect the extent to which intrathoracic dimensions may be changed. Pulmonary function is likely to suffer, as the fulcrum in the mechanical system is altered and ossification and calcification of the costal cartilages causes the thorax to become stiffer and less able to respond to respiratory muscle forces.

With increasing age, therefore, the space of the thoracic cage, mobility of the ribs, and compliance and elasticity of the thoracic skeleton all undergo regressive changes. Those changes contribute to the reduction in biomechanical efficiency of the respiratory system, which is principally influenced by changes in the lungs and associated viscera.

Chest Wall

Little information is available about changes in the muscles of the chest wall. Ulfand (1933), McKeown (1965), and Dahr, Shastri, and Lenora (1976) reported that there was weakening in respiratory muscles with increasing age. They noted that weakness became evident by age 30–40. Black and Hyatt (1969) reported that maximum inspiratory and expiratory muscle forces decreased with age. Generalization about these effects must be tempered, as data from Nascher (1914) show that marked atrophy of respiratory muscles occurred only in advanced years (not specified).

Lungs and Viscera

A variety of changes in the lungs and pleural mem-

branes occur with age. The pleural membranes become stiffer because of changes in collagenous and elastic fibers. The lungs become less elastic and more compliant owing to decreases in collagen content and disorganization of collagen and elastic fiber networks (Pierce & Ebert, 1959; Turner, Meade, & Wohl, 1968). Elastin content does not appear to decrease with increasing age. Pierce and Ebert (1965), among others, have found that it remains the same (as in the parenchyma) and may even increase (as in the pleurae, bronchi, and blood vessels) in older pulmonary tissues. The alveolar ducts and sacs enlarge progressively with age. Pump (1971, 1976) has reported that alveoli tend to coalesce in association with disruption of adjacent walls and capillaries. As a result there are fewer alveoli and less total surface area for gas exchange. Age-related changes in the bronchial tree have also been found. With the exception of calcification of the cartilages, little change has been found in the more proximal bronchi, though the diameters of more distal bronchi (less than 2 mm in diameter) decrease with increasing age. Loss of elastic recoil is thought to be the reason for such decreases in diameter and subsequent increases in airway resistance (Gelb & Zamal, 1975; Schmidt, Dickman, Gardner, & Brough, 1973).

FUNCTIONAL CHANGES

A variety of functional changes in respiratory capacity occur with increasing age, though most agree that total lung volume remains unchanged with age (Boren, Kory, & Syner, 1966; Knudson, Clark, Kennedy, & Knudson, 1977). The major changes and typical features of aging include a decrease in vital capacity, increase in residual volume, and decrease in expiratory reserve volume (Boren et al., 1966; Brody et al., 1974; Cohn & Donosco, 1963). Increased pulmonary compliance (Begin, Renzetti, Bigler, & Watanabe, 1975), decrease in chest wall compliance, decreased recoil pressure, and increased functional residual capacity all occur with increasing age (Mittman, Edelman, Norris, & Shock, 1965). When functional residual capacity increases, the change is usually small. Breathing rate has been reported to increase with increasing age (Chebotarev, Korusho, & Ivanov, 1974), while there are decreases in inspiratory muscle pressure and maximum expiratory pressure (Black & Hyatt, 1969).

The most important functional change—the one having the greatest impact on the subdivisions of lung volumes—is reduction in the elastic recoil in the lungs and airways (Pierce & Ebert, 1965). This results in a significant age-related reduction of vital capacity and an increase in residual volume. It has great importance for speech because we speak on exhaled air. Older individuals must function within a narrower range of volumes for speech. Leith and Mead (1967) described the mechanics likely to exert the greatest influence on levels of vital capacity. They reported that different mechanisms operate in young and old adults. In young adults, the magnitude of vital capacity is related to the expiratory force available; in older adults, the leveling factor of vital capacity is

decrease in pulmonary recoil pressures and increase in airway resistance.

The manner in which these biologic changes in the lung influence speech breathing has been studied in a systematic fashion only recently (Hoit & Hixon, 1987; Sperry & Klich, 1988).

Hoit and Hixon suggest that age-related changes in speech breathing result from intrinsic changes in the lungs as well as laryngeal valving deficiencies. They found that their older subjects decreased the size of breath groups used because of the reduced volume of air available to them and adjusted respiratory drive and respiratory mechanics to compensate for laryngeal valving deficits.

Sperry and Klich (1988) studied breathing in older (mean age 65.5 years) and younger (mean age 23.6 years) women (nine in each group) during oral reading. They found that young and old women exhibited similar respiratory functioning for nonspeech tasks and that mean airflow was not affected by age or context or sentence length during reading. Significant differences were found between young and older groups for speech tasks. Older females inhaled more frequently, more deeply (greater volumes), and faster than their younger counterparts did. Older speakers used more of their vital capacities in oral reading and tended to alter their depth of inspiration according to the length of the sentences to be read. Thus, they “preadjusted” their respiratory support based on anticipated need.

Loudness appears to be an important perceptual marker for distinguishing the young from old voice (Ptacek, Sander, Maloney, & Jackson, 1966). Benjamin (1986) has reported that older female voices were perceived as less loud than voices of older males or young adults. This, however, may reflect an encultured voice pattern rather than physiological change.

Objective verification of reduced loudness in older voices has been limited and equivocal. Benjamin (1986) reported that maximal intraoral and vowel intensity (in dB) is reduced significantly in older males and females. These findings are not consistent with those of Ryan and Burk (1974), who found that the vocal intensity of older speakers (over age 70) while reading out loud was significantly greater than that of younger males during reading and impromptu speaking. More research is needed to resolve this issue.

LARYNX

The larynx changes throughout the lifespan. However, relatively little information is available about the details of the structural changes (Kahane, 1983) associated with vocal aging. The following discussion attempts to identify significant physical changes in the larynx that occur with age and the resultant vocal changes that characterize the aging voice.

STRUCTURAL CHANGES

Laryngeal Cartilages

The cartilaginous skeleton of the larynx undergoes changes from birth through adulthood into old age (Kahane, 1983). The principal changes are calcification (Ardran, 1965; Malinowski, 1967; Negus, 1949) and ossification (Chamberlain & Young, 1935; Hately, Evison, & Samuel, 1965; Keen & Wainright, 1958; Roncollo, 1949) of hyaline cartilages in the larynx. The epiglottis, the only elastic cartilage, does not become ossified or calcified. Ossification has been observed in both sexes and occurs earlier in the male than in the female, where it is less extensive. In the male, intrinsic changes in the cartilages have been observed to begin as early as the third decade and continue throughout adulthood.

Significant age-related changes have also been found in the cricoarytenoid joint (CAJ) (Kahane, 1988; Kahane & Hammons, 1987; Kahn & Kahane, 1986). No formal report on the cricothyroid joint has yet been published. Changes in the CAJ include thinning of the articular surfaces, breakdown in and disorganization of the collagen fibers in the cartilage matrix, and surface irregularities. Kahane and Hammons (1987) have also noted age-related changes in the synovial membrane of the cricoarytenoid joint. Taken together, these structural changes in the CAJ may influence the extent of approximation of the vocal folds and the smoothness with which vocal fold adjustments may be made during voicing. Segre (1971) indicated that aging causes loosening of the joint capsule of the cricoarytenoid joint but presented no empirical data to support this contention.

Intrinsic Laryngeal Muscles

Limited information is available on age changes in the intrinsic muscles of the larynx. The consensus among investigators is that the laryngeal muscles undergo atrophy and that some degeneration occurs with advancing age (Bach, Lederer, & Denolt, 1941; Carnevalle-Richi, 1937; Ferreri, 1959; Hommerich, 1972; Kofler, 1932). Several investigators attribute these changes to disturbances in vascular supply to the muscle (Ferreri, 1959; Hommerich, 1972; Leutert, 1964). Bach et al. (1942), however, suggest that undernourishment of laryngeal musculature arises from disturbances in vasomotor fibers of sympathetic nerves supplying those vessels.

Nerve and Blood Supply

Little is known about the effects of aging on the innervation of the larynx. Recent work by Malmgren and Ringwood (1988) on aging of the recurrent laryngeal nerve (RLN) of the rat provides interesting information about mechanisms that may be at work. In old RLN, they

found an increase in the number of completely degenerated fibers, evidence of regeneration of small numbers of neurons, and significant increases in the size of the endoneurial extracellular space. These disturbances suggest that regulatory mechanisms in the nerve, involving ionic and oxidative processes, may be disrupted in the older nerves.

Changes in blood supply to the laryngeal nerves have been reported to occur with increasing age (Ferreri, 1959; Hommerich, 1972; Leutert, 1964). These changes consisted of thickening of capillary walls and reduction in the diameter of the vessels. Leutert noted them as early as the fifth decade.

Glands

Laryngeal glands, mainly from the vestibular folds, lubricate and protect the mucosal surfaces of the vocal folds. Not much is known about the involution of those glands. Hommerich (1972) and Ruckes and Hohmann (1963) reported that mucous glands in the larynx degenerate or atrophy after age 70. Bak-Pedersen and Nielsen (1986) did not find significant changes based on sex or age. Recently, Gracco and Kahane (in press) examined changes in the male vestibular glands and found that they involute with increasing age. Serous and mucous acini were found to atrophy or degenerate and become replaced by adipose and connective tissue. Resultant changes are believed to affect the amount and the quality of the secretions, which, in turn, may cause the epithelial surface of the vocal folds to become dried or less hydrated. This may contribute to a clinical condition seen in geriatrics called *atrophic laryngitis*. Diminished glandular secretions may make epithelial surfaces less well protected against abrasive forces produced during effort closure and vocalization, and from aerodynamic forces developed during vocalization. In addition, epithelial changes may adversely affect the surface topography of the leading edges of the vocal folds, causing them to vibrate irregularly.

Vocal Folds

Since Hirano's description of the layered structure of the human vocal folds (Hirano, 1974), investigators have become increasingly aware of the functional significance of the heterogeneous tissues composing them. They include the epithelium, collagenous and elastic fibers of the lamina propria, and the vocalis muscle. A summary of existing information on age-related changes follows.

Epithelium. There is a disagreement among investigators about age changes in the epithelium of the vocal folds. Some have reported (Eggston & Wolff, 1947; Hommerich, 1972) that laryngeal epithelia increase in thickness with age, while others (Hirano, Kurita, & Nakashima, 1983; Noell, 1962; Ryan, McDonald, & Devine, 1956) report no significant changes. Segre (1971) noted that after middle age the laryngeal mucosa become thin

and yellowish in appearance. Of interest are Noell's observations that with increasing age, laryngeal epithelium becomes less firmly attached to the underlying lamina propria. This could introduce a decrease in structural support to the cover of the vocal fold, which may increase perturbation during phonation (Wilcox & Horii, 1980).

Lamina propria. The three layers of subepithelial connective tissues of the vocal folds—the lamina propria—have been shown to be essential to vocal fold function during voice production (Hirano, 1974). These layers are composed of collagenous and elastic fibers arranged in different arrays and with different mechanical properties. Age-related changes have been noted in the lamina propria (Hirano et al., 1983; Kahane, 1982, 1983; Kahane, Stadlan, & Bell, 1979). Mueller, Sweeney, and Barbeau (1984) studied morphologic characteristics of aged male postmortem larynges specimens. Twenty-five old larynges (mean age, 81 years) and 10 young specimens (mean age, 44.7 years) were studied. The researchers reported several involuntional changes, including bowing, atrophy, and cordal sulcus of the vocal folds. They reported that 75% of the older group exhibited an arrowhead configuration of the rima glottidis that was not found in the younger group. Lederer and Hollender (1951) refer to variations in cadaveric forms of the rima glottidis attributed to Fein (no citation given). Two arrowhead configurations were among the 10 configurations presented. Thus, the arrowhead configuration of the rima glottidis described by Mueller et al. (1984) as reflecting involuntional change may simply represent one form of postmortem fixation of the vocal folds. There may, however, be some predilection to that configuration, and further research may provide an explanation for it.

In general, changes in the lamina propria are greater in the male than in the female. The connective tissues in the different layers of the lamina propria involute differently. These are summarized as follows:

1. Connective tissues in the superficial layer of the lamina propria thicken and become edematous (Hirano et al., 1983). They represent the greatest changes in the cover of the vocal folds.
2. The intermediate layer of the lamina propria becomes thinner after age 40 (Hirano et al., 1983). This is occasioned by a decrease in the density of fibers and deterioration in their contour. Kahane, Stadlan, and Bell (1979) and Kahane (1983) reported that after age 50 elastic and collagenous fiber bundles began to lose their well-defined weave. Collagenous fibers showed a greater tendency toward separation and waviness, while elastic fibers frequently showed fragmentation and breakdown.
3. Significant changes have been found in the deep layer of the lamina propria in the male while little change appears to take place in the female (Hirano et al., 1983; Kahane, 1982, 1983). In the male, appreciable changes occur after age 50 in collagenous fibers, which are the principal fiber component in this layer (Hirano et al., 1983; Kahane, 1983).

Those changes consist of breakdown in fiber organization (fibrotic, according to Hirano et al., 1983) and increased density of collagenous fibers. The latter may result from clumping together or spreading apart of usually tightly bound fibers.

Changes in the lamina propria likely contribute to bowing of the vocal folds and irregularities in the medial (vibratory) surfaces of the vocal folds. These structural alterations provide opportunity for producing aperiodicity, irregularities in vocal fold vibration, and incomplete proximation of the vocal folds.

Vocalis muscle. Vocalis fibers of the thyroarytenoid muscle have been shown to be the most functionally significant component of the muscle during voice production. Because of their mechanical and functional properties, the vocalis fibers of the thyroarytenoid muscle are referred to as the *body* of the vocal folds (Hirano, 1974). Specific age-related changes have been reported in the thyroarytenoid muscle (Ferrerri, 1959; Hommerich, 1972; Kersing, 1986; Leutert, 1964; Sato & Tauchi, 1982; Segre, 1971). They include atrophy, degeneration, decrease in fiber diameter, breakdown in internal diameter (Ferrerri, 1959; Hommerich, 1972; Leutert, 1964; Sato & Tauchi, 1982), and breakdown in fibrous support of the muscle (Hommerich, 1972; Kahane, 1982; Leutert, 1964; Segre, 1971). Histochemical studies of aging vocal fold musculature (Kersing, 1986; Sato & Tauchi, 1982) have shown that type 1 and type 2 fibers decrease significantly in the vocal fold in association with other intrinsic and metabolic changes in the thyroarytenoid muscle. Sato and Tauchi (1982) reported that those changes were greatest after age 80. Another factor contributing to involution of laryngeal muscles may be alterations in the blood supply to them (Ferrerri, 1959; Hommerich, 1972; Leutert, 1964).

FUNCTIONAL CHANGES

The myriad changes in connective tissues, muscles, and articular surfaces of joints in the larynx appear to contribute to several alterations in vocal performance (Kahane, 1987). Weismer and Fromm (1983) have shown how the effects of aging of the larynx manifest themselves in segmental and nonsegmental characteristics of speech. The following discussion summarizes data on changes in level and stability of fundamental frequency, vocal range, and glottal efficiency.

PERCEPTION OF PITCH AND MEASUREMENT OF FUNDAMENTAL FREQUENCY

Of all vocal parameters, pitch has been studied most extensively. Ptacek et al. (1966) found that trained listeners perceived that older male speakers had lower pitch than younger counterparts. Seven of 10 judges deemed pitch level an important vocal characteristic for differen-

tiating the age of the speaker. That finding was not supported by data from Hollien and Shipp (1972), who provide convincing evidence that after the fifth decade of life, fundamental frequency increases in males.

Age-related changes in fundamental frequency in the female are not as well defined as in the male. Some investigators have reported little noticeable change (McGlone & Hollien, 1963) while others (Endres, Bambach, & Flosser, 1971; Honjo & Isshiki, 1980; Saxman & Burke, 1966) have shown that there is a slight lowering of fundamental frequency with increasing age. More recent work has shown that elderly speakers exhibit a decrease in fundamental frequency stability (Linville & Fisher, 1985a, b; Stoicheff, 1981; Wilcox & Horii, 1980) compared to younger counterparts.

More discrete analyses have interpreted cycle-to-cycle variation in fundamental frequency (jitter) as an expression of control or mechanical stability of vocal folds. Increased pitch variability in males has been observed to accompany increased age (Mysak, 1959; Mysak & Hanley, 1958). While a slight decrease in pitch variability has been reported in older female voices (McGlone & Hollien, 1963), Wilcox and Horri (1980), using computer extraction techniques, reported increases in both sexes of mean perturbation values.

Ramig and Ringle (1983) point out that chronologic age may not be the key determinant of cycle-to-cycle variation in fundamental frequency. They found that physical condition of the older speaker (biologic age or condition) was most important and was most closely associated with increased jitter values. Amplitude variation (shimmer), however, was not increased significantly in persons with poor physical conditions, which suggests that other mechanisms may be operating.

Pitch control and pitch range have been shown to depreciate with increasing age. Endres, Bambach, and Flosser (1971) conducted a 20-year longitudinal study on several female subjects and found that those speakers lost their ability to vary fundamental frequency. Linville and Fisher (1985a, b) and Linville (1988) reported corroborating data. In addition, older speakers also exhibited more restricted pitch range than did younger counterparts (Endres et al., 1971; Linville, 1988; Ptacek et al., 1966).

Measures of laryngeal control, such as voice onset time (VOT), have shown that there is no significant difference in voice onset times for single word tasks between young and old male and female adults (Sweeting & Baken, 1982). No significant differences in VOT were found between younger and older female subjects (Morris & Brown, 1987; Neiman, Klich, & Shuey, 1983).

There have been a few reports about voice quality changes which accompany aging. Hoarseness has been perceived as an identifying characteristic of older male voices (Hartman & Danhauer, 1976; Ptacek et al., 1966). Honjo and Issiki (1980) have shown that hoarseness characterized the voices of 20 Japanese women (mean age, 75 or older) but was not perceived in comparably aged older male voices. It appears that hoarseness may be associated with geriatric voice quality but may not be a characteristic feature of it.

Deficiencies in laryngeal valving reported by Melcon, Hoit, and Hixon (1988) in older males may also contribute to voice difficulties and reduced glottal efficiency. Melcon et al. found that in older men, reduced glottal resistance and increased respiratory effort were associated with adjustment in the length of the breath group used during speech. This reduction in laryngeal valving may affect phonation time and loudness and may be a partial factor in the observations of several investigators who have characterized vocal performance in older males as "hypofunctional" (Benjamin, 1986), tenseness (Ryan & Burk, 1974), and reduced phonation time. Krueel (1972) reported that the reduction in phonation time amounted to as much as 26% for sustained valve productions.

PHARYNX AND VELOPHARYNGEAL MECHANISM

The pharynx and velopharyngeal mechanism are important not only in speech and voice production but also in swallowing and respiration. Although swallowing appears to be most affected by aging, speech may also become affected adversely because of altered resonatory properties.

STRUCTURAL CHANGES

Pharyngeal Epithelium

Aging does not cause gross changes in the epithelial lining of the pharynx. Ferreri (1959) reported that pharyngeal epithelium thins with increasing age, and there is a reduction of sensory innervation to the pharyngeal wall.

Muscular Changes

Little empirical data are available on the aging of pharyngeal or velar muscles. Kiuchi, Sasaki, Arai, and Suzuki (1969) and Zaino and Benvenuto (1977) reported that the pharyngeal muscles become weakened and the pharynx becomes dilated. Weakness in the pharyngeal walls is further suggested by the predisposition of the elderly to the development of pharyngeal diverticulae (Leese & Hopward, 1986). Sheth and Diner (1988) point out that the pharyngeal muscles lose their tonicity and eventually atrophy. This may account for the higher incidence of motor incoordination observed in the pharynx of older people during swallowing. Several investigators have noted that while there is normally only slight change in speech with aging, appreciable swallowing changes occur in the elderly (Elliot, 1988; Sheth & Diner, 1988; Sonies, Stone, & Shawker, 1984).

Little information is available about aging of soft palate musculature. Atrophy of the uvula (Bucciante & Luria, 1934) and tensor and levator veli palatini (Tomoda, Morii, Yamashita, & Kumazawa, 1984). Tomoda et al. (1984)

reported that the greatest changes occurred in the tensor veli palatini. This would appear to have greatest implications for eustachian tube function in the elderly and probably minimal effect on speech given the limited role of the tensor veli palatini muscle during speech (Fritzell, 1969).

FUNCTIONAL CHANGES

Pharynx

Many authors have reported decreases in pharyngeal motility with increasing age, noting that it is less coordinated and more effortful than in younger individuals (Kiuchi et al., 1969; Sheth & Diner, 1988; Sonies, Baum, & Shawker, 1984; Zaino & Benventano, 1977).

Effects on Speech

Not much is known about vocal tract resonance changes in the aged and their effects on speech. Changes in the elasticity of the pharyngeal walls along with weakness of the soft palate suggest that speech or voice may be adversely affected to some degree. Though scant evidence is available, two studies supply support for this notion. Endres et al. (1971) found progressive decrease in the frequency of the first formant and attributed this to increase in the length of the vocal tract. Linville and Fisher (1985) did a cross-sectional study of 75 women from young, middle, and old age groups. They found significant decreases in frequencies of the first and second formants with age, though the decrease was more substantial for the first formant. The authors reasoned that this could result from enlargement in width or changes in shape of the pharynx because of atrophy or weakness in the pharyngeal musculature and supporting structures in the trachea and lungs.

Little work has been directed toward describing speech changes resulting from aging in the soft palate or velopharyngeal mechanism. A perceptual study by Hutchinson, Robinson, and Nerbonne (1978) has provided the only empirical evidence of involitional change in the velopharyngeal mechanism during speech. They reported increased nasalance (an algorithm derived from the ratio of nasal to oral sound pressure levels) in persons after age 50, compared to younger counterparts. The most common form of velopharyngeal deficiency was a mild level of hypernasality, which the authors ascribed to weakness of the velar muscles.

ORAL CAVITY

The oral cavity is the center of activity for chewing, swallowing, and speech. Most age-related changes in this area do not appear to have adverse or direct effects on speech.

STRUCTURAL CHANGES

Epithelium

Structural, mechanical, and topographic changes have been associated with aging of oral mucosa. Those changes consist of thinning, loss of elasticity, and less firm attachment of the epithelium to connective tissue and bone (Klingsberg & Butcher, 1960; Squire, Johnson, & Hoops, 1976). They result from intrinsic changes as well as dryness from decreased salivary production. Changes in oral epithelium are most apparent after age 70. Thinning of the epithelium and reduction in structural support make the epithelium more susceptible to trauma. Surface changes in mucosa result in drying and a decrease in protective (keratinized) layers of oral mucosa after age 50. Squire et al. (1976) reported development of roughened areas in the mucosa, which are not typically keratinized. These changes are thought to be the result of changes in chewing pattern and manipulation of the bolus during the oral preparatory and oral phases of swallowing.

Salivary Glands

It has long been held that salivary function decreases with increasing age (Chauncey, Borkan, Wayler, Feller, & Kapur, 1981; Leeming & Dymock, 1978; Mason & Chisholm, 1975). The deficits consist of diminished amounts of saliva as well as changes in its chemical composition. Saliva from older individuals tends to be thicker, lacking some of the serous components as well as providing less of the cleansing action it normally provides. Reduced amounts of saliva have been shown to cause dryness in the oral mucosa, making bolus formation more difficult as well as contributing to an increase in the incidence of dental caries and periodontal disease.

It is believed (Klein, 1980) that changes in salivary flow are caused by destruction of gland acini: obstruction, adhesions, and hyalinization of salivary ducts; and infection or disease in the stroma of the glands.

Such changes may not occur uniformly. Baum (1981) has shown that salivary flow from the parotid glands does not show broad, negative changes with increases in age. He did report, however, that in postmenopausal women there is a 25% decrease in salivary flow. The data suggest that changes in salivary function may be influenced greatly by endocrinologic factors more than, or in addition to, structural changes in the glands.

Oral Sensation

Surprisingly little information is available on changes in oral sensibility with increasing age. Truex (1940) reported that there is a decrease in sensory innervation to the oral cavity resulting from loss of cells in the trigeminal ganglion. There have been no reports on changes in

receptors in oral epithelium. Canetta (1977) reported decreases in several sensory functions after age 70, including reductions in sensory, oral form, pressure, and touch discrimination.

Dentition

There are many reports on dental changes in aging (Borman, 1974; Heath, 1982; Smith & Sheiham, 1979). The greatest consequences of tooth loss are temporomandibular joint problems and masticatory inefficiency. These in turn may influence swallowing efficiency and the extent and rate of resorption of bone in the mandible and maxilla, which causes loss in height of the alveolar ridge. This affects facial appearance as well as being deleterious to dental and occlusal conditions. Klein (1980) reports that 3 years after tooth extraction, 50% of the alveolar ridge is lost. Bone loss is well associated with development of periodontal disease.

FUNCTIONAL CHANGES

Changes in the aging oral cavity include thinning of the epithelium, dryness of the oral mucosa, reduction in salivary gland function, loss of teeth, and some resorption of alveolar bone in the mandible and the maxilla. These changes influence function in several ways.

Effects on Prosthetic Appliances

Dentures may be difficult to wear because of soreness in the mouth resulting from irritation of the mucosa. This occurs because of fragility of the oral tissues caused by structural weakness and dryness. A poor fit of dentures may be due to areas of resorbed bone in the alveolar processes.

Predilection to Disease

The oral mucosa of older individuals is more prone to pathology because of decreased cleansing action resulting from diminished salivary secretions. Also, the mucosa tends to heal more slowly and is more readily subject to infection. Mucosa is also more subject to trauma in older individuals resulting from biting of cheek mucosa during chewing.

Effects on Speech

Dryness of the oral cavity may affect the speed and ease of tongue movement across oral surfaces to articulatory targets. Diminished salivary secretion is likely to affect bolus formation and transport as well. It is also possible that changes in the composition of the walls and in the

size of the resonator may cause resonance changes, but this is as yet unexplored.

TONGUE

The tongue is a versatile organ, important for taste, swallowing, and speech. Age-related changes appear largely to affect visceral functions although alterations in articulatory precision and rate also appear to be age related.

STRUCTURAL CHANGES

Epithelium

Epithelium of the tongue becomes thin with age, particularly in the center. The most common change in the aging tongue is loss of sensory papillae (taste buds). Papillae decrease in number and size. According to Kaplan (1971), they may decrease in number by as much as 60%. Filiform and fungiform papillae are most affected. Loss in taste buds begins to occur earlier in females (40–45 years) than in males (50–60 years): however, no significant loss of sensitivity appears to occur until the fifth decade. A marked decline appears to take place from the sixth to the eighth decades (Cooper, Bilash, & Zubak, 1959). Loss of papillae results in areas of smoothness on the dorsal surface of the tongue. Klein (1980) noted that in over 50% of persons over age 65, fissuring of the tongue surface increases with age, and veins on the undersurface of the tongue increase in prominence.

Muscles of the Tongue

Few reports exist that document changes in tongue musculature. Bucciante and Luria (1934) reported that lingual muscles undergo atrophy with increasing age. Loss of muscle mass and tonus have also been reported (Kaplan, 1971). Others have noted that there is a nonuniform increase in fatty tissue in the tongue. Yamaguchi, Michiyo, Yukiyo, Hiroyuki, and Shusaku (1982) reported an increase of amyloid deposits in the aged tongue. The significance of these findings to speech and swallowing has not been established. Sonies, Baum, and Shawker (1984) reported that ultrasound measurement of maximum thickness and midpoint measurement of the tongue were greater in the young adult than in elderly counterparts. The investigators were not able to ascertain if the diminished dimensions in the elderly were the result of muscle atrophy, changes in muscle tonus, or lessened muscular support. In any event, the differences were not found to compromise speech in substantial ways.

Nerve Supply

No loss of motor innervation has been documented, although reductions in range of motion and speed of movement have been reported and will be discussed in a subsequent section. Loss of taste has been the sensory loss most described.

FUNCTIONAL CHANGES

Taste

Loss of taste has been associated with aging after age 50 (Cohen & Gitman, 1959; Cooper, Bilash, & Zubek, 1959) and has been attributed to the decrease in the number of taste buds and changes in sensory nerves. The effects of those changes on appetite and nutrition (Schiffman & Covey, 1984) need to be considered, but so far they have not been examined in a systematic fashion. The paucity of research no doubt is related to the difficult problems of designing adequate psychophysical studies to answer questions (Weiffenbach, 1984).

Sensation

Little work has been done on age-related sensory changes of the tongue, though limited data exist on vibrotactile thresholds (Fucci, Petrosini, & Robey, 1982). Fucci et al. studied lingual vibrotactile detection thresholds in children, young adults, and elderly persons and found decreases in lingual sensation in the elderly that they attributed to sensory-end organ deterioration. Petrosini, Fucci, and Robey (1982) found that when the duration of the lingual stimulus was increased there were corresponding increases in the ability of the elderly to detect tactile stimuli on the tongue. The importance of vibrotactile sensitivity to speech has not been clearly established (Crary, Fucci, & Bond, 1981; Sandyk, 1981).

Mobility

Results from a few studies (Ammerman & Parnell, 1982; Ptacek et al., 1966) suggest that tongue movements become slowed in elderly persons. This has been determined from diadochokinesis (Ptacek et al., 1966), alternate motion rates (Ammerman & Parnell, 1982), and assessment of range of motion during vowel and consonant production (Sonies, Baum, & Shawker, 1984). Diadochokinetic rates were found to decline after age 60.

Effects on Speech

There appears to be little if any detectable negative effect on speech resulting from age-related muscular or

sensory changes in the tongue. However, results from a study by Baum and Bodner (1983) suggest that in males, with increasing age, there is a decrease in tongue stability, tonus, and muscle mass. These changes provide conditions that may contribute to some deterioration of speech or articulatory precision.

Benjamin (1986) provides some support for this position. She found that with increasing age there was a tendency for greater dispersal of vowel formant ratios. In addition, reduced or altered motor control appeared to be expressed in the longer silent intervals in plosives of older speakers compared with younger counterparts. Further evidence for decreased articulatory control in older speakers appears supported by reports of reduced rates of articulation (Ryan & Burk, 1974) and speech (Hartman & Danhauer, 1976).

TEMPOROMANDIBULAR JOINT AND CRANIOMANDIBULAR MUSCLES

The temporomandibular joint (TMJ) and its associated muscles are concerned principally with effecting actions that tear and grind food during mastication. The contribution of the TMJ to speech resides in its roles in coarticulation and oral resonance. Aging changes largely affect factors related to mastication; little is known about the effects on speech.

STRUCTURAL CHANGES

Temporomandibular Joint

The TMJ frequently undergoes regressive changes with aging. Those changes largely involve alterations in the mandibular condyle; the articular (glenoid) fossa is the next most common site. The articular disc is affected least frequently.

Changes in the TMJ are highly influenced by the status of dentition and supporting structures for the teeth. Those structures normally help to cushion or buttress forces to the TMJ by distributing them throughout the bones in the facial skeleton. Several investigators (Blackwood, 1966; Johnson, McCabe, & Askew, 1964; Vaughn, 1943) have shown that anatomical changes to the TMJ in edentulous and aged persons consist of reduction in the size of the mandibular condyle, flattening of the articular surface, and thinning of the articular fossa.

Craniomandibular Muscles

Age-related changes in the muscles of mastication have not been studied extensively, and the information that does exist is incomplete. Investigators (Baum & Bodner, 1983; Greenfield, Shy, Alvord, & Berg, 1957; MacMillan,

1936) have indicated that weakness exists because of muscle atrophy. In addition, poorer function results from decreased biomechanical efficiency due to alterations in the points of muscle attachment to the mandible because of resorption or remodeling of bone. Baum and Bodner (1983) reported significant alteration in the masseter and temporalis muscles. They noted that the mass of the muscles and the ability of the muscles to raise the mandible decreased with increasing age. They determined that muscle changes were not influenced by the total number of retained teeth so long as 20 or more teeth were present.

FUNCTIONAL CHANGES

Aging of the temporomandibular joint and masticatory muscles appears to decrease biting force and functional movements of the mandible during chewing but seems to have little effect on speech.

Kaplan (1971) reported that biting force decreases from 300 lb/sq inch in young people to 50 lb/sq inch in older persons. Heath (1982) found that masticatory efficiency in denture wearers was only one-sixth that of dentate adults. He also found that chewing time of older adults was appreciably different, being twice as long and more variable compared to that of young adults.

Functional movements of the masticatory apparatus also appear to decrease with age. Carlsson (1984) reported that masticatory efficiency is most influenced by the status of dentition, while age per se has little influence on functional performance. Feldman, Kapur, Alman, and Chauncey (1980) note that masticatory function is the primary consideration in the nutrition of the elderly. They state that tooth loss significantly decreases masticatory performance by limiting the ability of persons to reduce the size of food particles to manageable sizes. This in turn affects the number of chewing strokes made (number of times food has to be chewed to be made into a manageable size) before the bolus can be swallowed. In addition, the effort required to chew food adequately and prepare it for swallowing has been found to influence greatly the dietary preferences and nutrition of older persons (Baum & Bodner, 1983).

The effects of changes in the masticatory apparatus, particularly the temporomandibular joint, on speech have not been reported. Such data would provide insight into coarticulatory behavior and oral resonance in aged speakers.

FACIAL MUSCLES

The facial muscles that contribute to the structure and function of the circumoral region are important in visceral and speech functions. Circumoral muscle function is important in providing for adequate lip seal during swallowing, preparation of the bolus, and articulation of consonants and vowels. The following discussion summa-

rizes the limited information available on age-related changes in the facial muscles.

STRUCTURAL CHANGES

Loss of muscle tonus, muscle atrophy, loss of elasticity, breakdown of collagenous fibers in the dermis, and decreased vascularization characterize reported changes in the facial muscles (Gonzales-Ulloa & Flores, 1965; Pitanguy, 1978). Levesque, Corcuff, de Rigal, and Agache (1984) have shown that advancing age results in lessened ability of the skin of the face to recover from deformational stresses. This change, in association with shrinkage of the connective tissues attaching the muscle fibers to the facial skin and reduced muscle tonus, smooths out the natural folds in the face and makes it appear less expressive.

FUNCTIONAL CHANGES

Few significant functional changes appear to result from aging of the facial muscles. Baum and Bodner (1983) note that alteration of lip posture and tonus may be the reason for labial spill of saliva, which they report is not uncommon in older patients. No information is available on any articulatory changes associated with bilabial or labiodental production. Changes in the connective tissues, facial muscles, and epithelium of the face appear to have their greatest effects on facial appearance.

CONCLUDING REMARKS

This paper has attempted to summarize the array of age-related changes in the peripheral speech mechanism reported in the literature and to identify sites and expressions of dysfunction that may exist. Some general trends have emerged from this review. They include:

1. The data base from which information has been drawn is far from complete. Many gaps exist. Most data are based on Caucasian males although there recently has been greater attention devoted to involutional changes in the female. Virtually no information is available on age-related changes in black speakers.
2. Changes occur earlier in the male and are more extensive than in the female.
3. Different tissues within an organ, as well as organs within systems, age differently, at different times, and usually to different extents. This is called *differential aging* and is an important concept in understanding the biology of involutional change.
4. Changes in connective tissues play critically important roles in the involution of the speech mechanism, particularly in the respiratory system and larynx.

5. In most cases, structural and functional changes appear to manifest themselves after the fifth decade.
6. Biologic age rather than chronological age is the most important determinant of involutional change and the best predictor of change.

Over the last two decades, much has been learned about the aging of the speech mechanism. This work has provided information about basic characteristics of speech or vocal change and has stimulated further inquiry about the characteristics and processes of involution of speech and voice production.

Though significant gains have been made, much still needs to be uncovered and explained. For example, little is known about racial differences and aging of the speech mechanism. The ways in which systemic changes impact on or are reflected in speech and voice production are not well understood. Such information will contribute enormously to our understanding of the biology of aging of the peripheral speech mechanism.

Information is needed about every component of the peripheral speech mechanism. Efforts must be directed not only at defining structural changes; companion studies need to be designed to examine the mechanical properties of tissues. In this way it will become possible to state how structural change translates into alterations in mechanical and physiologic efficiency.

Descriptions of aeromechanical processes during speech and voicing are essential. Aside from acquiring needed information about pressure and flow dynamics during speech and voicing, aerodynamic studies provide the opportunity for studying the interrelationships among organ systems, such as the respiratory system and the larynx. This is well illustrated in a recent study by Melcon et al. (1988), who illustrated how laryngeal changes (transglottal valving efficiency) influence respiratory behavior in older males.

Our knowledge of vocal tract dynamics and velopharyngeal mechanics in the aged is virtually nonexistent, as are studies on coarticulatory function. Contemporary speech science technology easily permits efficient and noninvasive examination of these physiological behaviors. The information gained will be invaluable in providing insight about the involution of the vocal tract and articulatory processes.

The study of aging of the speech and vocal mechanism offers innumerable challenges to the scientist and clinician. Taking maximal advantage of available technology, information, and resources from such disciplines as engineering, medicine, and the basic sciences can make it likely that many of today's enigmas will be unravelled. The challenge lies in asking good questions and having the courage to search for the answers.

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Chapter 10

EFFECTS OF AGE ON APHASIA

ROBERT T. WERTZ

NINA F. DRONKERS

Veterans Administration Medical Center, Martinez, CA

Stein (1974) observed there is considerable evidence for recovery of function after lesions in young adults, but much less is known about behavioral sparing after brain damage in senescent subjects. The reasons for this, he concluded, are that the "aged . . . are quite susceptible to disease, do not respond well to anesthesia, tend to be vicious, and do not perform well after even moderate food or water deprivation" (p. 413). Stein, of course, was discussing older rats. Similar observations have been made about research on older humans.

The purpose of this paper is to discuss the influence of age on aphasia, specifically, age's influence on the severity of aphasia, type of aphasia, spontaneous recovery from aphasia, and improvement in aphasia. To do this, it is necessary to consider the influence of aging research methodology on what we think we know about the influence of age on aphasia.

METHODOLOGICAL INFLUENCES ON AGING RESEARCH

We are told that we live and learn. Less often observed, but certainly as true, is that we live and lean. How that tilt is quantified in aging research may have an influence on the results obtained. For example, some employ a classification system—*young, middle age, old, oldest*. These are somewhat arbitrary, and, because they are, they will differ among investigations. Others look for relationships between age and behavior by computing correlations. While this is legitimate, we sometimes forget there is a difference between a significant relationship and a significant difference. Performance may or may not be significantly related to age, but whether it is or is not tells us nothing about the presence or absence of a significant difference between or among different ages. Further, there is a tendency to "block" on age groups, for example, 41 to 50, 51 to 60, 61 to 70, etc. The problem here, of course, is that there may be greater variability within a block, 41 to 50, than there is between the trim point for one block and the beginning of the next, 50 and 51. Finally, most aging research is cross-sectional and not

longitudinal. Cross-sectional aging research can be, as Holland demonstrated earlier in this conference (see Chapter 5), extremely misleading.

Another methodological influence on results of aging studies, specifically those on age and aphasia, is the care taken to select a sample from the appropriate population. All behavior cannot be explained by the presence or absence of brain damage, and brain damage does not, necessarily, place one in the same population. For example, language deficits in dementia are similar but not the same as those in aphasia. Finally, age is not the only variable in aphasic patients that may influence initial severity, type of aphasia, and improvement. Thus, research on the influence of age on aphasia must differentiate among conditions that may masquerade as aphasia, for example, the language of the normal aged, environmental influence on language of the normal aged, and language deficits in dementia. And, the influence of age must be compared with the influence of coexisting, perhaps equally potent, variables.

Normal Aging

Boone and his colleagues (Boone, Bayles, & Koopmann, 1982) observed that the typical person over 65 communicates very well. Age, per se, is not a deterrent to good communication. However, increasing age does bring physiologic changes to the hearing, language, and speech mechanisms which may alter the way a person communicates. Therefore, if one is interested in the effects of age on aphasia, one must consider the effects of age on language in the aged nonaphasic person.

Botwinick (1967) reviewed over five hundred studies on aging. Less than a handful touched on language. It has been popular, for example, to investigate age-related changes in performance on a visual-closure task (Read, 1988). Older individuals, 70 to 79, make more errors than younger individuals, 50 to 59. Investigations of phonology, semantics, and syntax in the aged are less popular, and investigations on the influence of poor performance in one domain (for example, visual-closure) on perfor-

mance in another domain (e.g., language) are almost nonexistent.

Nevertheless, several reviews of aging's effects on normal language (Bayles & Kaszniak, 1987; Davis, 1984; Obler & Albert, 1981; Wertz, 1984) exist, and Emery's (1985) recent research on language in the normal aged should place the word *language* in the index of books on aging and behavior. Her results indicate that there is a direct relationship between age and performance on language, memory, and problem solving measures. "The greater the deficits, the higher the age" (Emery, 1985, p. 51).

Bayles and Kaszniak (1987) have summarized observations of language in normal aging. First, semantic memory is preserved in normal aging. Vocabulary appears to increase throughout adulthood. Second, use of semantic memory—ideation, inference, association—however, declines with age. These changes are subtle and have little effect on communication.

Third, studies of descriptive discourse and naming indicate that older adults have more difficulty in generating ideas than younger adults. Fourth, grammar is spared across the life span. Fifth, perceptual deficits—in hearing and vision—are the most common age-related changes that affect communication. Sixth, latency of response increases with age, but when the constraints of time are waived, older persons' performance approximates that of young adults. And, seventh, depression, being more common in the elderly, may influence test performance.

Table 1 shows performance for normal adults collected by Wertz and Lemme (1974) in seven decades on three measures—the Token Test, a measure of auditory comprehension (De Renzi & Vignolo, 1962); the Word Fluency Measure, a timed task requiring verbal production of words beginning with a specified letter (Borkowski, Benton, & Spreen, 1967); and the Coloured Progressive Matrices, a measure of nonverbal visual thinking (Raven, 1962). Generally, there is a decline in performance on all measures after age 49, however the decline is not orderly across decades, variance is high within decades, and performance is influenced by years of education.

Thus, examination of the effects of aging on aphasia must consider the preservation or disruption of performance that results from normal aging, the disruption of performance that results from being aphasic, and the interaction between the two—age and aphasia.

Environmental Influence on Language

Where one resides may influence his or her communication. Lubinski (1981) has documented the disastrous effects an abnormal environment can have on a normal older person's communicative ability. She uses the phrase "a communication-impaired environment" to describe institutionalized settings where there is reduced opportunity for successful, meaningful communication. This typifies some, not all, of the acute and chronic care facilities, where at least one in five of our nation's elderly will spend time prior to demise. Obler and Albert (1981) indicate that the normal elderly use various strategies to cope with age's influence on auditory comprehension and naming abilities. For example, they employ syntax to assist naming ability and context to improve comprehension. Placed in an unfavorable environment where few listen or speak, the older person finds these strategies no longer result in solutions, and they are abandoned.

Holland's (1980) standardization of the Communication Abilities in Daily Living (CADL) provides data to document the effects of environment on communication. Younger, age 56 to 65, and older, over age 65, normal adults in institutional environments displayed significantly lower CADL scores than their cohorts who resided in noninstitutional environments. Moreover, her aphasic sample yielded the same results; poorer CADL performance by institutionalized aphasic persons than by non-institutionalized aphasic persons.

So, attempts to determine the effects of age on aphasia must add social milieu to the equation. Where one resides may confound cortex as well as the disruption that may result from aging and does result from being aphasic.

Dementia

All brain damage does not result in aphasia. Language may decline in the elderly. It does decline in the elderly who become demented. Those who suffer Alzheimer's, Pick's, Huntington's, or Creutzfeld-Jakob disease or who have sustained multiple infarcts or display idiopathic Parkinson's disease will experience gradual and progressive deterioration in language and other mental functions.

TABLE 1. Performance by normals in different age groups on the Token Test, Word Fluency Measure, and Coloured Progressive Matrices ($N = 30$ in each group). (Adapted from Wertz and Lemme, 1974.)

Age group (in years)	Token test			Word fluency			Coloured matrices		
	\bar{x}	Range	SD	\bar{x}	Range	SD	\bar{x}	Range	SD
20-29	57.97	48-61	3.49	69.50	39-112	19.66	30.90	19-36	4.25
30-39	59.07	46-61	3.20	72.03	43-96	14.79	32.67	19-36	5.20
40-49	58.33	49-61	2.76	69.93	47-96	14.02	31.27	20-36	5.26
50-59	54.20	16-61	10.53	69.63	44-97	14.88	24.97	10-35	6.85
60-69	57.53	49-61	3.13	66.53	46-101	14.80	31.83	16-36	5.46
70-79	53.40	25-61	7.79	61.30	39-94	15.98	27.20	10-36	8.09
80-89	53.53	41-61	4.97	61.57	30-99	18.45	26.43	14-35	6.50

Some (Bayles & Kaszniak, 1987) differentiate between language impairment in dementia and language impairment in aphasia. Others (Appell, Kertesz, & Fisman, 1982) do not. The latter suggest that demented patients are aphasic, mainly because they can be classified into an aphasic taxonomy on a test for aphasia. We are among the former. Poor performance on a test for aphasia does not make one aphasic. Subsequent to a left hemisphere stroke, examination of aphasic performance on the Western Aphasia Battery (WAB) (Kertesz, 1982) reveals a different distribution across aphasic types than the distribution for probable Alzheimer's disease. In dementia, an inordinate number of patients are classified as global and Wernicke's aphasia, and essentially no patients are classified as Broca's or transcortical motor aphasia. In aphasic patients who have suffered a stroke, one finds fewer global and Wernicke's aphasic patients, many Broca's, and some transcortical motor. Moreover, the careful work of Bayles and Kaszniak (1987), using measures designed to explore dementia, provides obvious differences between aphasia and dementia in phonology, semantics, syntax, and cognition. Finally, the onset, rapid in aphasia and slow in dementia; prognosis, expected improvement in aphasia and decline in dementia; and management, abundant in aphasia and sparse in dementia, do not make calling one the other very useful.

More important, examination of the effects of age on aphasia will be influenced by the presence or absence of demented patients in the aphasic sample. Some investigators (Wertz et al., 1981, 1986) have employed age cut-offs to reduce the possibility of dementia coexisting with aphasia subsequent to a left hemisphere thromboembolic infarct.

Coexisting Variables

Age, as a variable in aphasia, does not simply exist; it coexists with a number of other variables that may influence initial severity, type of aphasia, and improvement. These variables have been summarized (Darley, 1972; Rosenbek, LaPointe, & Wertz, 1989; Wertz, 1985) in several reports. They include gender, education, health, cause of aphasia, site and size of the lesion, time postonset, initial severity, type of aphasia, social milieu, dura-

tion and intensity of treatment, and a variety of nonlanguage behaviors. Thus, age does not simply act to affect aphasia; it interacts with other variables that may or may not affect aphasia.

Duffy and Keith (1980) provide evidence on the relationship of three variables—age, education, gender—with performance on the Porch Index of Communicative Ability (PICA) (Porch, 1967) by normal and aphasic adults. Table 2 shows that age and education correlate significantly with PICA overall, gestural, and graphic performance by normal adults. In addition, age correlates significantly with PICA test time for normal adults. In their aphasic sample, age correlated significantly with overall, gestural, and graphic PICA performance. Age correlated significantly with education in both normal adults and aphasic patients. Education was significantly related with all PICA scores in normal controls but only with the graphic score in aphasic patients. Gender was significantly related to overall and graphic scores in the normal controls but was not significantly related to PICA performance in aphasic patients.

Thus, any investigation of age's influence on aphasia must consider how results are influenced by other variables. This can be done by establishing rigid selection criteria that exercise some control over the influence of variables (Wertz et al., 1981, 1986), using analyses of covariance that employ one or more variables as covariates (Wertz et al., 1981, 1986), and determining the predictive power of variables in multiple regression analyses (Duffy & Keith, 1980; Porch, Collins, Wertz, & Friden, 1980; Holland, Greenhouse, Fromm, & Swindell, 1989).

INFLUENCE OF AGE ON APHASIA

Holland and Bartlett (1985) observed, "The relationships among aging and the condition of aphasia are rich, complex, and theoretically challenging" (p. 141). There is a literature, but it is small and incomplete. The most frequently asked questions about the influence of age on aphasia involve: What is the influence of age on severity, type of aphasia, spontaneous recovery, and improvement? These are questions that will be addressed here. We will review agreement and disagreement in previous

TABLE 2. Correlations between and among age, education, sex, and PICA performance for normal (N) adults and aphasic (A) patients. (Adapted from Duffy and Keith, 1980.)

Variables	Age		Education		Sex	
	N	A	N	A	N	A
PICA Overall	-.34**	-.18*	.51**	.12	-.24**	-.11
Gestural	-.29**	-.18*	.20*	.11	-.01	-.08
Verbal	-.34**	.14	.25**	-.13	-.08	-.11
Graphic	-.21**	-.17	.53**	.32**	-.30**	-.11
Test time	.34**	-.03	.00	.03	-.06	.11
Sex	-.11	.03	-.08	.01		
Education	-.23**	-.23**				

* Significant at $p < .05$.

** Significant at $p < .01$.

reports and compare both with our results obtained in the second Veterans Administration Cooperative Study on Aphasia (Wertz et al., 1986).

VA Cooperative Study

The VA Cooperative Study was designed to compare the influence of clinic treatment by speech-language pathologists with home treatment by trained volunteers and deferred treatment. All patients received 12 weeks of treatment, 8 to 10 hours each week, during a 6-month treatment trial. All met the same selection criteria at entry and were assigned randomly to one of the three treatment groups. At the end of the trial, there were no significant differences in improvement among groups. Therefore, the three groups may be combined, and pretreatment and final performance may be used to examine the effects of age on aphasia.

Rigid selection criteria, shown in Table 3, were used to select study patients. These included: age, 75 years or younger; gender, male; time postonset, 2 to 24 weeks at entry; cause of aphasia, first, single thromboembolic infarct; localization, lesion confined to the left hemisphere; history, no previous neurologic involvement or coexisting major medical or psychological disorder; sensory-motor status, at least a 40 dB speech reception threshold, unaided, in the better ear, at least 20/100 visual acuity, corrected, in the better eye, and adequate motor ability in at least one upper extremity to gesture and write; literacy, premorbid ability to read and write English; prior treatment, no more than 2 weeks of language treatment prior to entry; initial severity, from the 10th through 80th overall percentile on the PICA at entry; and social milieu, living in a noninstitutionalized environment.

All patients received a complete neurological evaluation at entry and at 6, 12, 18, and 24 weeks after entry. A battery of speech and language measures was administered at the same points in time. The battery included: the PICA; the CADL; the Reading Comprehension Bat-

tery for Aphasia (RCBA) (LaPointe & Horner, 1979); the Spreen and Benton (1969) revision of the Token Test; and the Coloured Progressive Matrices (CPM) (Raven, 1962).

Ninety-four patients completed the 6-month clinical trial. Descriptive data for those patients at entry are shown in Table 4. Mean age was 59 years, mean years of education was 11 years, mean weeks postonset was 7 weeks, and mean severity of aphasia was at the 49th overall percentile on the PICA. The distribution of age in the sample of 94 patients permitted selecting subsamples in "young," 45 to 55, and "old," 65-75, age groups. Descriptive data on the 25 young and 16 old patients at entry are shown in Table 5. There were no significant differences ($p < .05$) between groups for years of education, weeks postonset, or initial severity on the PICA. Our data permit determining relationships between age and performance for the group of 94 patients and determining the presence or absence of significant differences in performance between the young and old patients.

Age and Severity

The influence of age on severity of aphasia has been examined in two ways. First, one can ask, is the aphasia more severe in older persons than in younger ones? Second, one can ask, is improvement of aphasia less in older persons than it is in younger ones? Obviously, the questions are not the same, but, unfortunately, some of the literature implies they are. We separate them here.

Age's relationship to severity of aphasia receives little agreement in the literature. Smith (1971) reports that severity of aphasia increases with increasing age. Culton (1971) observed severity of aphasia is not greater in older patients. Miceli et al. (1981) found the severity of aphasia increased with age in patients with neoplasms but not in patients who had suffered cerebrovascular accidents. Duffy and Keith (1980), Holland (1980), and Porch (1967) all found significant negative correlations between age and severity of aphasia, implying that older patients have

TABLE 3. Selection criteria for aphasic patients in the VA Cooperative Study. (Adapted from Wertz et al., 1986.)

Variable	Criterion
Age	75 years or younger
Sex	Male
Time postonset	2-24 weeks
Etiology	Single thromboembolic infarct
Localization	Confined to left hemisphere
History	No previous neurologic involvement or coexisting major medical or psychological disorder
Sensory-motor	Auditory: at least 40 dB SRT unaided in better ear Visual: at least 20/100, corrected, in better eye Motor: ability in at least one upper extremity to gesture and write
Literacy	Premorbid ability to read and write English
Treatment	No more than 2 weeks of language treatment prior to entry
Severity	10th-80th PICA Overall
Social milieu	Living in a noninstitutional environment

TABLE 4. Descriptive data at entry on 94 aphasia patients who completed the 6-month VA Cooperative Study clinical trial.

Variable	\bar{x}	Range	SD
Age in years	59.04	43-75	6.43
Education in years	11.26	3-18	2.63
Weeks postonset	7.16	2-24	5.91
PICA Overall percentile	49.57	10-80	20.07

TABLE 5. Descriptive data at entry on 25 young, aged 45-55, and 16 old, aged 65-75, aphasic patients who completed the 6-month VA Cooperative Study clinical trial.

Variable	\bar{x}	Young Range	SD	\bar{x}	Old range	SD
Age in years	52.04	46-55	2.83	68.38	65-75	3.32
Education in years	11.68	6-16	2.32	9.94	3-18	3.59
Weeks postonset	8.44	2-22	6.44	7.06	2-22	5.62
PICA Overall percentile	41.20	14-78	16.82	47.75	15-79	22.16

more severe. And, Holland and Bartlett's (1985) older sample, age 77 to 93, was more impaired than their younger sample, age 19 to 49. Is aphasia more severe in older patients? Davis and Holland (1981) conclude, "In spite of a paucity of clear evidence, it is commonly believed that as age increases the severity of aphasic impairment increases" (p. 213).

Our results on age and severity of aphasia are shown in Tables 6 and 7. Correlations between age and severity at entry into the VA Cooperative Study, Table 6, indicate no significant relationships between age and severity of aphasia on the PICA, CADL, RCBA, or Token Test. There was a significant relationship ($r = -.22, p < .05$) between age and performance on the CPM, a test of nonverbal, visual thinking. Thus, in our sample of 94 patients, we found no significant relationships between age and severity of aphasia.

A comparison of our young and old groups, Table 7, revealed one significant difference ($F = 4.394, df = 1, 39, p < .04$) between groups. This was for PICA verbal performance, and it indicated that the old group performed significantly better than the young group did. Is aphasia more severe in older patients? Our results indicate it is not.

TABLE 6. Correlations between age and severity at entry in the VA Cooperative Study on five measures.

Measure	r
PICA Overall percentile	-.02
Gestural	-.06
Verbal	.13
Graphic	-.09
CADL	-.05
RCBA	.00
Token Test	.09
Coloured Progressive Matrices	-.22*

*Significant at $p < .05$.

Age and Type of Aphasia

Considerable interest has been given to the relationships between age and type of aphasia. The report by Obler and colleagues (Obler, Albert, Goodglass, & Benson, 1978) that Broca's aphasia is more common in young patients and Wernicke's aphasia is more common in older patients has been confirmed by several investigations (Brown & Grober, 1983; Eslinger & Damasio, 1981; Holland, 1980; Miceli et al., 1981; Steinvil, Ring, Luz, Schechter, & Solzi, 1985). There is additional evidence that globally aphasic patients tend to be older (Eslinger & Damasio, 1981; Holland, 1980; Obler & Albert, 1981; Steinvil et al., 1985). Eslinger and Damasio (1981) add that conduction aphasic patients tend to be younger, and Steinvil et al. (1985) report that anomie aphasic patients are younger than global and Wernicke's aphasic patients. Kertesz and Sheppard (1981) caution that their Broca's patients appear younger than their global and Wernicke's aphasic patients, but they were not significantly younger.

Schechter, Schejter, Abarbanel, Groswasser, and Solzi (1985) report that the relationships between age and aphasic type may vary with time postonset. Within 1 month postonset, they found no relationship between age and aphasic type. At 4 to 6 months postonset, their Broca's aphasic patients were significantly younger than their Wernicke's aphasic patients. Holland and Bartlett (1985) also found an influence of time postonset on type of aphasia. Early postonset, they observed global aphasia in both their young, 19-49, and old, 77-93, groups. Broca's aphasia appeared only in the young group, and Wernicke's aphasia appeared only in the old group. At 3 months postonset, global and Wernicke's aphasia were found only in the old group, and Broca's aphasia was found only in the young group.

Those in our sample of 94 patients were classified at entry, mean of 7 weeks postonset, with the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972).

TABLE 7. Comparisons between young (45–55) and old (65–75) aphasic patients at entry in the VA Cooperative Study on five measures.

Measure	Group \bar{x}		\bar{x} Difference
	Young (N = 26)	Old (N = 16)	
PICA Overall percentile	41.20	47.75	-6.55
Gestural	41.72	44.13	-2.41
Verbal	34.72	45.69	-10.97*
Graphic	51.72	55.38	-3.66
CADL	79.04	84.13	-5.09
RCBA	57.80	63.31	-5.15
Token Test	82.92	100.69	-17.77
Coloured Progressive Matrices	21.20	18.19	3.01

Significant at $p < .04$.

The results are shown in Table 8. Twenty-four percent of the sample were unclassifiable; followed by Wernicke's, 19%; Broca's, 16%; anomic, 15%; and all other types, less than 10%. The youngest group was Broca's aphasia, and the oldest was transcortical sensory aphasia, represented by one patient. Globally aphasic patients were the second youngest group, and Wernicke's, conduction, anomic, mixed, and unclassifiable groups showed mean ages of 60 to 61. There was no apparent relationship between age and aphasic type beyond an indication that nonfluent patients, including those who were global, were younger.

Examination of our young and old groups, shown in Table 9, begins to reveal a few differences in type of aphasia as a function of age. More global and all Broca's aphasic patients were in the young group. Wernicke's aphasic patients were found in both groups, however, the percentage of Wernicke's patients was greater in the old group. Paired comparisons for age between types of aphasia indicated Broca's aphasic patients were significantly younger than Wernicke's aphasic patients [$F = 2.225$, $df = 6, 83$, $p < .05$]. No significant difference appeared in any other paired comparison.

We found, as have others (Holland & Bartlett, 1985; Kertesz & McCabe, 1977; Schechter et al., 1985), that change in type of aphasia is rampant. Forty-eight percent of our 94 patients changed in their type of aphasia between entry and 6 months. In the young group, 40% changed aphasic type, and in the old group, 56% changed aphasic type. Table 10 shows that in the young group, the number of Wernicke's, mixed, and unclassifiable patients was reduced over time. There was an increase in the

number of Broca's and anomic patients by 6 months, but there was no marked reduction in global patients. Change in aphasic type in the old group was more frequent, Table 11, but trends were not obvious. There was a reduction in Wernicke's aphasia over time and a migration toward anomic aphasia. The one global patient at entry remained global 24 weeks later, and one Broca's patient appeared at 24 weeks, emerging out of mixed aphasia at entry. Finally, Table 12 shows a comparison of the young and old groups at entry and 24 weeks postentry. The early difference in Broca's aphasia, more younger patients, has increased by 24 weeks. The early difference in Wernicke's aphasia, more older patients, has decreased by 24 weeks. The lack of difference in conduction aphasia at entry has changed to show more young and no old conduction patients at 24 weeks. The small difference between groups in anomic patients at entry has increased by 24 weeks to show even more old patients. And, there is a tendency for more younger patients to be classified at 24 weeks and more older patients to remain unclassified.

Our results support two observations in the previous literature. First, Broca's patients are significantly younger than Wernicke's patients. Second, the time postonset when age and aphasic type are compared may influence the results obtained.

Age and Spontaneous Recovery

Spontaneous recovery, improvement in aphasia believed to result from physiological restitution during the

TABLE 8. Mean age in each type of aphasia on the Boston Diagnostic Aphasia Examination for 94 patients at entry in the VA Cooperative Study.

Aphasic type	N	\bar{x}	Age range	SD	% of sample
Global	6	56.83	53–66	4.71	6
Broca's	15	54.07	44–63	6.14	16
Transcortical motor	3	57.67	56–59	1.53	3
Wernicke's	18	60.94	50–75	7.55	19
Transcortical sensory	1	63.00	—	—	1
Conduction	7	61.00	53–68	4.62	8
Anomic	14	60.00	43–74	6.84	15
Mixed	7	60.00	54–66	4.55	8
Unclassifiable	23	59.91	46–71	6.12	24

TABLE 9. Type of aphasia in young (45-55) and old (65-75) patients at entry in the VA Cooperative Study.

Aphasic type	Young (N = 25)		Old (N = 16)	
	n	%	n	%
Global	3	12	1	6
Broca's	7	28	0	0
Transcortical motor	0	0	0	0
Wernicke's	5	20	5	31
Transcortical sensory	0	0	0	0
Conduction	1	4	1	6
Anomic	1	4	2	13
Mixed	3	12	2	13
Unclassifiable	5	20	5	31

TABLE 10. Change in aphasic type between entry and 24 weeks postentry in the young (45-55) group.

Type and # at entry	Type at 24 weeks	#	# of type at 24 weeks
Global	Global	2	2
	Broca's	1	
Broca's	Broca's	6	10
	Unclassifiable	1	
	Transcortical motor	0	
Wernicke's	Wernicke's	3	3
	Broca's	1	
Transcortical sensory	Unclassifiable	1	0
	Transcortical sensory	0	
Conduction	Conduction	1	3
	Anomic	1	
Anomic	Anomic	1	3
	Mixed	1	
Mixed	Mixed	1	1
	Broca's	2	
Unclassifiable	Unclassifiable	1	3
	Conduction	2	
	Anomic	2	

TABLE 11. Change in aphasic type between entry and 24 weeks postentry in the old (65-75) group.

Type and # at entry	Type at 24 weeks	#	# of type at 24 weeks
Global	Global	1	1
	Broca's	0	
Broca's	Broca's	0	1
	Transcortical motor	0	
Transcortical motor	Transcortical motor	0	1
	Wernicke's	3	
Wernicke's	Wernicke's	3	3
	Anomic	2	
Transcortical sensory	Transcortical sensory	0	0
	Conduction	0	
Conduction	Conduction	0	0
	Unclassifiable	1	
Anomic	Anomic	1	5
	Unclassifiable	1	
Mixed	Mixed	0	0
	Broca's	1	
Unclassifiable	Unclassifiable	1	5
	Unclassifiable	2	
	Transcortical motor	1	
	Anomic	2	

first few months postonset, may be influenced by age. The duration of spontaneous recovery has not been precisely defined. Culton (1969) and Vignolo (1964) limit its duration to 2 months postonset. Eisenson (1964) extends the period to 3 months. And others (Butfield & Zangwill, 1946; Godfrey & Douglas, 1959; Luria, 1963; Marks, Taylor, & Rusk, 1957) set the limit at 6 months. Any examination of age's influence on spontaneous recovery must permit the recovery to be spontaneous. Patients

cannot be treated during this period, because treatment may interact with spontaneous recovery and influence results. Only a few investigators have followed untreated patients during the early period postonset.

Culton (1969) found no influence of age on spontaneous recovery. Kertesz and McCabe (1977) followed a mixed group—5 patients were treated and 31 were not—and observed no relationship between age and improvement at 3 months postonset. Holland and Bartlett (1985) mea-

TABLE 12. Percentages of aphasic types in young and old groups at entry and 24 weeks postentry.

Aphasic type	Young	Entry Old	Difference	Young	24 Weeks Old	Difference
Global	12	6	6	8	6	2
Broca's	28	0	28	40	6	34
Transcortical motor	0	0	0	0	6	6
Wernicke's	20	31	11	12	19	7
Transcortical sensory	0	0	0	0	0	0
Conduction	4	6	2	12	0	12
Anomic	4	13	9	12	31	19
Mixed	12	13	1	4	0	4
Unclassifiable	20	31	11	12	31	19

sured change in untreated patients between 48 hours postonset and 10 to 12 weeks postonset. They report (p. 147) their older patients, age 77 to 93, "ended the spontaneous recovery period in much poorer shape than did the youngest patients," age 19 to 49. Does age influence spontaneous recovery? The data are sparse, and those that exist conflict.

We were able to examine the relationship between age and spontaneous recovery in 22 patients in our deferred treatment group. Those 22 patients were entered in the VA Cooperative Study and followed for 12 weeks before they were treated. Their weeks postonset at entry ranged from 2 to 12 weeks. We calculated the amount of improvement on five measures between entry and 12 weeks after entry and computed correlations to determine the relationships between spontaneous recovery and age. The results are shown in Table 13. None of the correlations was significant ($\alpha = .05$), indicating no strong relationships between age and spontaneous recovery.

Age and Improvement

Results on the relationship between age and improvement in aphasia are cyclical. Early reports (Eisenson, 1949; Sands, Sarno, & Shankweiler, 1969; Vignolo, 1964; Wepman, 1951) indicated that older patients made less ultimate improvement than younger patients. Those reports were followed by investigations (Basso, Capitani, & Vignolo, 1979; Kertesz & McCabe, 1977; Sarno & Levita, 1971) that showed no significant relationship between age and improvement in aphasia. Recently, however,

TABLE 13. Correlations between age and spontaneous recovery for 22 patients who were not treated during a period of 2 to 12 weeks postonset to 14 to 24 weeks postonset.

Measure	r
PICA Overall percentile	.26
Gestural	.20
Verbal	.17
Graphic	.31
CADL	.22
RCBA	.09
Token Test	.01
Coloured Progressive Matrices	-.02

evidence (Holland et al., 1989; Marshall & Phillips, 1983; Schechter et al., 1985; Steinvil et al., 1985) indicates that older patients do not improve as much as younger patients. But occasional disagreement continues. For example, Porch et al. (1980) found age did not increase predictive precision in their multiple regression analysis designed to provide a prognosis for aphasia.

Sarno's (1980) observation is sage. She suggested that older patients do as well in treatment, if all else is equal, as younger patients. The discrepant results may be explained by all else not being equal in the investigations that have examined the influence of age on improvement. Cause of aphasia differs among studies, and so does the amount, intensity, and duration of treatment within and among investigations. Moreover, some reports compared mean age among groups. Others used correlations to determine a relationship between age and improvement. And, some separated age groups by a decade or more. Finally, little control has been exercised over other variables that may influence improvement. Kertesz (1988) observes that age has less influence on improvement than do the size and location of the lesion that causes the aphasia. Does age have an influence on improvement? The answers are inconsistent.

Our evidence results from patients who met the same selection criteria and who received the same amount of treatment, 8 to 10 hours a week for 12 weeks, during a 6-month period. While the type of treatment—speech-language pathologist, trained volunteer—and the time treatment was initiated—immediately or deferred for 12 weeks—differed, there were no significant differences in improvement among treatment groups at the end of the 6-month clinical trial. Thus things were essentially equal between the younger and older aphasic patients studied.

Table 14 shows the relationships between age and improvement on five outcome measures after 12 weeks of treatment during the 6-month trial. All correlations are low, and none is significant ($\alpha = .05$). Table 15 shows mean improvement in the young, 45 to 55, and old, 65 to 75, groups at the end of the 6-month clinical trial. While all differences indicate that the younger group made more improvement, none of the differences is significant ($\alpha = .05$). Thus, age appeared to have no effect on the amount of improvement made by our patients.

TABLE 14. Correlations between age and amount of improvement on five measures after 12 weeks of treatment during the 6-month, VA Cooperative Study clinical trial. ($N = 94$).

Measure	r
PICA Overall percentile	.10
Gestural	-.01
Verbal	-.01
Graphic	.13
CADL	.04
RCBA	.01
Token Test	-.09
Coloured Progressive Matrices	.03

CONCLUSIONS AND DISCUSSION

Our results indicate no consistent significant relationships between age and severity of aphasia. Older patients did not display more severe aphasia than younger patients. We did observe that our Broca's aphasic patients were significantly younger than our Wernicke's aphasic patients. No other significant effect of age on type of aphasia emerged. Further, we found no significant relationship between age and amount of spontaneous recovery. Untreated older patients improved essentially as much as untreated younger patients during the first few months postonset. Finally, age had no influence on the total amount of improvement obtained following 12 weeks of treatment during the 6-month clinical trial. Older patients improved essentially as much as younger patients.

These results are characterized by the lack of significant effects of age on aphasia. Only two analyses reached significance. One can be explained, and the other we accept as real. First, we observed the older patients, 65 to 75, performed significantly better on the PICA verbal subtests than younger patients, 45 to 55. While there was no significant difference between groups on any other measure, including the PICA overall percentile, there were more global and Broca's aphasic patients in the younger group than in the older group. The kind of verbal impairment in those younger patients may have reduced scores on the PICA 16-point multidimensional system more than the kind of verbal impairment in the more fluent older group. Second, we observed that our Broca's aphasic patients were significantly younger than our Wernicke's aphasic patients. This is a consistent result in all investigations that have examined age's effects on type of aphasia. It emerged in our results when all other things were, as controlled by our selection criteria, essentially equal. Thus, we accept its existence as real. More debatable is an explanation for its existence.

Why do our results differ from those of others? We expect the difference lies in our sample. It was exceptionally clean. All patients had suffered a single, first thromboembolic infarct. The lesion was confined to the left hemisphere. All were in good health postonset, and none had a history of previous central nervous system involvement. All had adequate sensory and motor abilities to

perform on our measures. All were between 2 and 24 weeks postonset at entry, and there was no significant difference in time postonset between younger and older patients. Initial severity varied among patients, but there was no significant difference in initial severity between younger and older patients. All resided in a noninstitutionalized environment. Five clinical neurological examinations during a 24-week period guarded against undetected previous episodes, another episode during the course of the study, or coexisting dementia. And, all patients received the same amount of treatment during a fixed time period. We agree with Sarno (1980). When everything else is equal, age has no significant effect on severity, spontaneous recovery, or improvement in aphasia.

CAUTIONS IN THE STUDY OF AGE'S INFLUENCE ON APHASIA

We conclude by offering some cautions to those who investigate the effects of age on aphasia. They emerge from the mistakes we have made in our clinical research and in our clinical practice and from those we suspect reside in the literature.

First, all behavior cannot be explained by brain damage. Brains differ, and so does experience. There is a range of normal behavior in both the young and the old, and those who journey into aphasia carry their premorbid luggage with them. The efforts of Duffy and Keith (1980) to determine normal aging's influence on measures used to appraise and diagnose aphasia should be applauded and expanded.

Second, every hole in the head does not result in aphasia. If we are interested in age's influence on aphasia, we must insure that older patients are aphasic, not demented or suffering coexisting aphasia and dementia. Bayles and Kazniak's (1987) efforts to differentiate dementia from aphasia and Holland and Bartlett's (1985) exploration of dementia in older aphasic patients are admirable and should be emulated.

Third, new ways of looking permit seeing new things. Neurology has gone from safety pin and rubber mallet to extremely sophisticated neuroradiological and electrophysiological methods in less than two decades. PETT and SPECT scans demonstrate that the organic location of a lesion must be related to its functional influence. The precision of MRI makes us wonder whether we will ever again find a case of unilateral left hemisphere infarct without evidence of hypertensive episodes in the right hemisphere. Silent episodes—strokes patients do not know they have had—are common, now that we have means to see them. What is now visible in the brain may be more abundant in the aging brain because of its longer opportunity to occur.

Fourth, age, as a variable, does not simply exist; it coexists with other variables that may have equally potent effects on aphasia. Age's effects on aphasia will only emerge when we neutralize coexisting variables through

TABLE 15. Mean improvement in the young and old groups at the end of the 6-month, VA Cooperative Study clinical trial.

Measure	Group \bar{x} Improvement		\bar{x} Difference
	Young (N = 26)	Old (N = 16)	
PICA Overall percentile	18.21	17.56	.65
Gestural	21.36	18.06	3.30
Verbal	13.04	10.75	2.29
Graphic	17.80	17.56	.24
CADL	22.12	19.13	2.99
RCBA	14.20	13.25	.95
Token Test	26.36	16.81	9.55
Coloured Progressive Matrices	3.52	2.94	.58

rigid selection criteria and appropriate statistical methods. These may reduce the application of results, but results should apply to someone. Failure to control coexisting variables will permit application of results on aging to no one.

Whether age has an influence on severity, type, spontaneous recovery, or ultimate improvement of aphasia will be determined when we increase the rigor in our methodology. How one obtains results influences the results obtained. We found no significant influence of age on aphasia, although others have.

ACKNOWLEDGMENTS

This research was supported, in part, by the Veterans Administration Cooperative Studies Program and Health Services Research and Development. We acknowledge the contributions of colleagues who participated in the Veterans Administration Cooperative Study: David G. Weiss, Ph.D.; James L. Aten, Ph.D.; Robert H. Brookshire, Ph.D.; Luis Garcia-Bunuel, M.D.; Audrey L. Holland, Ph.D.; John F. Kurtzke, M.D.; Leonard L. LaPointe, Ph.D.; Franklin J. Milianti, Ph.D.; Richard Branngan, M.D.; Howard Greenbaum, M.D.; Robert C. Marshall, Ph.D.; Deanie Vogel, Ph.D.; John Carter, M.D.; Roberto Silva, M.D.; Norman S. Barnes, Ph.D.; Roy Goodman, M.D.; Frederic L. Darley, Ph.D.; Thomas Friden, Ph.D.; Allen Rubens, M.D.; and C. James Klett, Ph.D. Most of all, we thank Luci Varian for her precision in putting our words into print.

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Chapter 11

DEGENERATIVE NEUROLOGICAL DISORDERS

BARBARA B. SHADDEN

University of Arkansas, Fayetteville

The topic of degenerative disorders potentially encompasses virtually every progressive neuropathy known to man. Since in Chapter 14 Sonies gives prominence to neuromotor aspects of aging and degenerative disorders, it seems fitting to restrict this paper to a discussion of dementia. Dementia-producing conditions have profound consequences for the language and communication systems of older individuals—consequences that are just beginning to be understood with any clarity.

This chapter will review major areas of current research focus, particularly as they relate to communicative behavior, assessment, and intervention. Available research methodologies will be summarized and critiqued, and a series of research needs will be identified. Of necessity, however, some background information concerning definitions, prevalence/incidence, classification, and terminological dilemmas must be provided.

PUTTING DEMENTIA IN PERSPECTIVE

Definitions

According to Coover and Wilson (1987), a disorder termed *dementia senile* was first recognized as a medical entity as early as 1838 by Esquirol. By the 1890s, Kraepelin identified the fact that psychiatric syndromes in the aged could be accompanied by gross cortical changes. However, the critical discovery of the presence of senile plaques and neurofibrillary tangles in demented individuals under the age of 65 was first documented by Alois Alzheimer in 1906 (Gottfries, 1986). Until the 1960s, senile dementia was differentiated from this Alzheimer's syndrome because of its supposed association with arteriosclerotic disease. However, recent research advances have dispelled the mythology of morphologic differences between the presenile and senile forms of dementia (Brody, 1984). We have also moved away from such generic terms as *organic brain syndrome*, *senile psychosis*, and *chronic brain syndrome*.

Dementia is considered to be a syndrome, defined medically as a constellation of signs and symptoms associated with a morbid process (Bayles & Kaszniak, 1987). In everyday terms, dementia refers to a condition of chronic, progressive deterioration in mental functioning leading to total dependence. No specification of cause or underlying disease process is required (Cummings, 1985). According to the DSM-III-R (American Psychiatric Association, 1987), the requirements for diagnosis of dementia include (a) impairment in short- and long-term memory; (b) disturbance in abstract thinking, judgment, other higher cortical functions, or personality; (c) interference with activities of daily living and interpersonal relationships; and (d) evidence of specific causally-related organicity or lack of evidence for any nonorganic mental disorder. The latter criterion is significant because, of the more than 50 potential causes of dementia (Haase, 1977), the most common disorder is Alzheimer's disease, in which clinical diagnosis can only be confirmed through autopsy findings (Khachaturian, 1985).

Prevalence and Incidence Data

Golper (1988) notes that dementia-related conditions cost this society an estimated 20 billion dollars annually. Alzheimer's disease is also listed as the fourth most common cause of death in the elderly. This tremendous financial and social drain imposes massive demands upon both the health planning industry and researchers. Reasonable estimates of incidence and prevalence of dementing disorders are essential to adequate planning and research. Unfortunately, the accuracy of such figures is challenged by problems in specifying clearly the variety of dementia groups and including all levels of severity. Data are most complete for Alzheimer's disease, which accounts for more than half of all reported cases of dementia; another 15 to 25% are attributed to multi-infarct dementia (Tomlinson & Henderson, 1976).

It is estimated that between 1.2 and 4 million Americans suffer from dementia caused by Alzheimer's disease (U.S. Office of Technology Assessment, 1985). Between 3

and 15% of the over-65 population are afflicted by Alzheimer's disease. If statistics on the prevalence of severe dementia are combined with those on mild or moderate dementia, percentages may rise to as high as 21 or 22% (c.f., Bollerup, 1975; Kay, Beamish, & Roth, 1964; Nielsen, 1962); particularly in individuals over 80 years of age. Data concerning the incidence of dementia each year are also confounded by issues of etiology, severity, and patient age, with estimates ranging from 4 per 1000 to 15 per 1000 for moderate and severe dementia in individuals over age 60 (Lauter, 1985).

Current Classification and Terminological Dilemmas

The clinical and research literature in dementia is a terminological nightmare. While there is a fairly strong agreement on the most common forms of dementia, the exact classification systems used vary widely. In addition, clinical questions related to the reversibility of dementing disorders and the masquerading of some disorders (pseudodementias) as true dementias continue to plague our endeavors.

One of the more common ways of describing the dementias is to utilize the DSM-III-R classification system (APA, 1987). The DSM-III-R divides the dementias into primary degenerative dementia (PDD), which encompasses both dementia of the Alzheimer's type (AD) and Pick's disease; multi-infarct dementia (MID); and other dementias grouped loosely together. Some researchers include unique categories, as seen in Golper's (1988) identification of a cluster of disorders involving dementia with dysarthria (e.g., PD, HD, amyotrophic lateral sclerosis and multiple sclerosis).

Implicit in the latter approach is recognition of the cortical/subcortical dichotomy proposed by Cummings and Benson (1983). According to this classification scheme, the site of most prominent neurological change would dictate clinical classification. For example, AD would be considered cortical, whereas HD and PD would be subcortical dementias. Motor speech is presumed to be relatively better spared in cortical dementias, with language comprehension and usage less impaired in subcortical dementias. Cummings and Benson (1984) suggest this dichotomy is less an anatomical concept than a clinical one. However universal acceptance for the concept has not been obtained because of a perceived lack of exclusivity of defining characteristics and lack of independence of neurological regions (Whitehouse, 1986).

Common Disorder Types

Alzheimer's disease. According to the DSM-III-R (APA, 1987), the diagnostic criteria for AD include all dementia characteristics as well as evidence of an insidious onset with steady, progressive deterioration over time and

exclusion of all other specific causes of dementia. Guidelines for clinical diagnosis have been identified (Foster, 1987), although definite diagnosis is only obtainable through autopsy or biopsy. The neuropathy of AD includes (a) neurofibrillary tangles, (b) neuritic plaques at axonal terminals, (c) areas of granulovacuolar degeneration, and (d) loss of cortical and white matter volume. Other neurochemical changes associated with AD include cholinergic deficits, noradrenergic system changes, and other chemical reductions, most notably involving the neuropeptides, somatostatin, and substance P (Bayles & Kaszniak, 1987).

Typically, if there is no clear etiology, and behavioral symptoms are consistent with diagnostic criteria, a diagnosis of AD is applied. AD is associated with onset after the 50th year of life and a slow progression to death in about 8 to 12 years. Characteristic EEG and CT changes are noted at various stages, as well as PET changes in metabolism in frontal and temporoparietal association cortices (Cummings, 1985).

Vascular or multi-infarct dementia (MID). According to the DSM-III-R (APA, 1987), MID is distinguished from other dementias by the stepwise deteriorating course of the disorder, associated with early, "patchy" distribution of deficits, focal neurological signs, and evidence of related and significant cerebrovascular disease. No one single stroke nor the simple presence of chronic cerebrovascular disease is judged to be sufficient to this diagnosis; instead, an accumulation of several strokes is generally viewed as the culprit. A postmortem loss of 50 or more grams of brain tissue is required for autopsy diagnosis (Tomlinson, Blessed, & Roth, 1970). Cummings (1985) states that hypertension is the most common etiological factor. Unlike AD, MID strikes more men than women and is associated with younger patients. Symptoms and deficits tend to be highly variable. Rogers, Meyer, Martel, Mahurin, and Judd (1986) have distinguished three subgroups clinically: those with large cerebral infarction or chronic ischemia caused by large vessel thrombotic strokes or multifocal embolic strokes; those with numerous small, subcortical lacunar infarctions (often involving the middle cerebral artery); and those with Binswanger's disease, a subcortical atherosclerotic encephalopathy of the penetrating cerebral arteries.

Parkinson's disease. Bayles and Kaszniak (1987) state that there are four subtypes of the parkinsonism syndrome (idiopathic, drug-induced, postencephalitic, and arteriosclerotic), with the idiopathic most common. Age at onset ranges between 50 and 69 years, and reduced longevity is reported. Prevalence is about 1 per 1000 in the general population, increasing to 1 per 100 in the population over 50 years of age. Extrapyramidal symptoms dominate, associated with depigmentation of the substantia nigra of the basal ganglia and loss of dopamine. Motor signs include tremor, rigidity, and bradykinesia. It is estimated that approximately 30% of all Parkinson's patients develop dementia (c.f., Boller, Mizutani, Roessman, & Gambetti, 1980).

Pick's disease. Like AD, Pick's disease is idiopathic, appearing in late mid-life and associated with prominent

aphasia. Morphologic changes involve neuronal loss, inflated cells, and intraneuronal Pick bodies, particularly in the inferior frontal and anterior temporal cortex. Unlike with AD, memory, visuospatial skills, and mathematical abilities are spared early on; however, marked personality changes, prominent disinhibition, and elements of Klüver-Bucy syndrome emerge close to onset (Comings, 1985).

Huntington's disease. Huntington's chorea or disease (HD) symptoms begin earlier in adult life (middle thirties to early forties). HD is an autosomal dominant genetic disorder with changes occurring first in either personality, motor function, or cognition. The disease course is 10 to 20 years (Coover & Wilson, 1987). Neuropathy includes both marked brain atrophy and specific deficits in neurotransmitter substances and their synthesizing enzymes. Since the caudate nucleus and putamen of the basal ganglia are affected, motor deficits (typically choreic movements) dominate. Dysarthria and dysphagia are common.

Other causes. Other common causes include Creutzfeldt-Jakob disease and Korsakoff's disease. Descriptions and lists of multiple causes of dementia can be found in Bayles and Kaszniak (1987), Foster (1987), Tonkovich (1988), and Wertz (1978). One of the major diagnostic dilemmas presented in reviewing these data is the problem of distinguishing reversible from irreversible dementia syndromes.

Reversible Versus Irreversible Dementias

Of the many potential causes of dementia, it has been estimated that 10 to 33% of adults diagnosed as having dementia may have a reversible or "secondary" (remediable) medical or psychiatric condition. The dementia is considered reversible if the observed cognitive deterioration cannot be determined to have a structural CNS basis and resolves with treatment. In one recent study, almost half of 107 patients with dementia had other treatable illnesses, with 15 demonstrating potentially reversible dementia (Larson, Reifler, Featherstone, & English, 1984).

Tonkovich (1988) lists categories of reversible causes of dementia, including drug toxicity, depression, visual and hearing disorders, metabolic and endocrine disorders, normal pressure hydrocephalus, intracranial masses, infection (CNS or systemic), and arteriosclerotic complications. It is particularly important to distinguish dementia from delirium (or acute confusional state). The discriminating diagnostic indicators for delirium include clouding of consciousness and a relatively abrupt onset and fluctuating course (DSM-III-R, APA, 1987).

Dementia Versus Pseudodementia

Depression is sometimes considered separately under the heading of *pseudodementia*. Kiloh (1961) first introduced the term *pseudodementia* to describe instances of

marked cognitive deficit in the absence of neurological or medical causes. Bayles and Kaszniak (1987) describe *pseudodementia* as cognitive impairment associated with some psychiatric disorders. In contrast, Foster (1987) expands the definition to include poor education, mental retardation, aspects of normal aging, sensory deprivation, and depression as causal agents. It is commonly agreed that depression is a major cause of *pseudodementia* (50% of all cases, according to Tyler & Tyler, 1984). Some studies have suggested that from 30 to 50% of patients diagnosed as having a degenerative dementia were subsequently found to be suffering from unrecognized affective disorders (Nott & Fleminger, 1975; Ron, Toone, Garralda, & Lishman, 1979).

Tonkovich (1988) has outlined the major clinical signs that may differentiate dementia and depression. In contrast to AD, onset is rapid in depression and causally linked, symptom progression is rapid and marked by pronounced preoccupation with deficits, vegetative symptoms are common, and speech comprehension and production are generally intact or do not show progressive decline. Unfortunately, depression is common in some dementia-producing disorders (e.g., HD), creating diagnostic problems.

Subtypes Within Dementia Classifications

Researchers are just beginning to identify potential subtypes within several of the more prevalent forms of dementia, including AD, MID, and PD. Several approaches have been developed to differentiate the AD population. It has been recommended that classification be based upon age of onset (before/after 65 years), familial occurrence and presence of trisomy 21, and coexistence of other relevant conditions (McKhann et al., 1984). One of these other conditions may be the presence and relative prominence of communication disorders, (cf. Chui, Teng, Henderson, & Moy, 1985). Cerebral glucose metabolic profiles (from PET studies) and neurobehavioral profiles also appear to identify two prominent AD subgroups—those with predominant visuospatial deficits of a focal right hemisphere nature and those with disproportionate language (left hemisphere) problems (Chase et al., 1984a,b; Friedland, Brun, & Budinger, 1985; Haxby, Duara, Grady, Cutler, & Rapoport, 1985). A third subgroup has been described as being those with prominent memory problems at onset (Albert & Moss, 1984).

Several subgroups of MID patients were described earlier. Those with large cerebral infarctions may be further subdivided, based upon hemisphere and arterial distribution affected. For example, impairment of blood flow to the angular gyrus results in the angular gyrus syndrome: fluent aphasia, alexia with agraphia, Gerstmann syndrome, and constructional deficits. Criteria for differential diagnosis of angular gyrus syndrome from AD have been identified by Cummings, Benson, and Tsai (1982).

It has been suggested that at least 30% of PD patients develop dementia associated with both cortical and sub-

cortical pathology. At present, there exist few clear diagnostic criteria to allow discrimination between these groups or to identify clear clusters of behaviors and deficits associated with each (c.f., Boller et al., 1980). Also, little is known about the complicating effects of pharmacological management of Parkinson's disease.

Neurobiological Substrates

Considerable national research effort in the last 10 years has been devoted to identifying the neurological substrates of dementing disorders and associated risk factors. To date, those risk factors identified in AD appear to be a first order relative with AD, age of mother at subject's birth, and history of head injury (Bayles & Kaszniak, 1987). Principle theories of causation currently fall into two camps: those looking for genetic factors and those examining environmental and infectious factors.

Genetic research has been stimulated by evidence that members of some families seem to have a greater risk of developing AD, in an autosomal dominant fashion. It has been suggested that a language-disordered subtype of AD is associated with a dominant genetic marker (Breitner & Folstein, 1984). Genetic comparisons are being drawn to Down's syndrome individuals, many of whom develop AD in later years.

Explorations into environmental and infectious factors have considered the significance of reports of elevated levels of aluminum found postmortem in brains of AD patients. Since some dementing disorders, like Creutzfeldt-Jakob disease, are known to be associated with infectious agents, a search for a similar infectious process in AD also continues, with prions receiving particular attention (see Glenner & Wurtman's, 1987, symposium text for research directions.)

Relatively less attention is being paid to forms of dementia other than AD. In general, there is a gap in the research literature on studies attempting to correlate behavioral and neurological data in various populations of demented individuals.

OVERVIEW OF RESEARCH AVENUES OF INVESTIGATION

The hallmark of dementia is the breadth of its behavioral symptomatology, neurological substrates, and consequences. This vast scope demands that research and management considerations cross many professional boundaries. Thus, it is not surprising that speech-language science research related to dementia has a much stronger interdisciplinary flavor than found in many other communicative domains.

Outside of speech-language pathology, research interests include (a) epidemiology, (b) neurobiological substrates of dementia types and stages of dissolution, (c) etiology, (d) appropriate medical and neuropsychological procedures for accurate differential diagnosis, (e) medical

treatment modalities, (f) caregiver effects, (g) documentation of progression through use of severity indices, and (h) clinical/behavioral management of the dementia patient and caregivers.

Research domains in speech-language are understandably more restricted. As a framework for examining current research endeavors and future research needs, the following discussion will focus on *research initiatives*, defined as areas of common concern in existing communication-based clinical practice and research activity.

RESEARCH INITIATIVE 1: SPECIFYING THE NATURE OF THE LINGUISTIC DEFICIT IN DEMENTIA

At first glance, it appears impossible to determine the nature of the linguistic deficit in dementia, given the diverse causes and subtypes of various dementing disorders. The problem is simplified by the fact that most investigations concerned with linguistic deficit per se focus exclusively on Alzheimer's disease. There are two categories of questions being raised. The first pertains to the description of linguistic behaviors and deficits in AD, with growing attention to the cognitive and neurological substrates that influence communicative behavior. The second set of questions addresses the differentiation of normal language behavior in the elderly from the language characteristics of the mildly demented patient. In practice, the two overlap considerably, since most studies contain at least one control group of nondemented subjects.

Common Linguistic and Communicative Deficits in AD

Regardless of cause, it is commonly agreed that demented individuals have trouble with tasks requiring thinking, reasoning, and understanding of logical relationships. Generally, the degree of communication impairment is proportional to the overall cognitive impairment, with linguistic and communicative deficits assumed to be related to breakdown in ideation and in translation of ideas into linguistic symbols (Bayles & Kaszniak, 1987). Thus, it might be predicted that phonology, morphology, and syntax would be relatively better preserved in dementia than semantics and pragmatics.

Early research with AD subjects repeatedly has confirmed this prediction. As a result, more recent investigations concerning the linguistic deficit in dementia have tended to focus on two concerns: (a) the precise nature of semantic and discourse behaviors and deficits in AD, and (b) the extent to which research data can confirm or disconfirm the expectations generated by linguistic and neurolinguistic models of communication behavior.

Bayles and Kaszniak (1987) argue strongly that deficits in dementia are ultimately more communicative than

structural. As such, they can only be understood by taking into consideration such nonlinguistic skills as memory, perception, attention, intelligence, and information processing. These authors contend that linguistic comprehension deteriorates in dementia because of a decrease in the individual's sensitivity to context and in the ability to form expectations, make inferences, and distinguish given and new information.

From a language pragmatics perspective, therefore, discourse tasks would appear to offer the greatest potential for defining communicative characteristics. In such tasks, AD patients have been shown to produce fewer relevant information units, more perseverative responses, more empty phrases, more pronouns without antecedents, and more exophoric references. They also demonstrate diminished ability to produce ideas or to explain the moral of a story, different patterns of discourse cohesion, reduced coherence, increased turn taking, and increased numbers of words (Bayles, 1985; Bayles, Boone, Tomoeda, & Slauson, 1986; Hier, Hagenlocker, & Shindler, 1985; Nicholas, Obler, Albert, & Helm-Estabrooks, 1985; Ripich & Terrell, 1988; Shekim & Lapointe, 1984; Ulatowska et al., 1987). With increasing severity of dementia, perlocutionary and illocutionary acts, frequency and diversity diminish; the only remaining tool may be the production of utterance acts (Bayles, 1985).

Although Bayles and Kaszniak (1987) caution against inferring too much from performance on single tasks, it is clear that certain semantic skills are impaired in even the mildly demented patient. Confrontation and generative naming, vocabulary, and paradigmatic associations all show decrements. The significance of those deficits, however, lies in the information they can provide as to which underlying components of the neurolinguistic system are intact and which are impaired.

Of particular concern are the processes and contents of episodic and semantic memory. Nebes (1985) defines episodic memory as an autobiographical record of unique events in experience that are encoded and maintained in relationship to a particular temporal-spatial context. He considers semantic memory relatively context free, a thesaurus of organized knowledge of words, concepts, and their associations, as well as rules for manipulating these symbols. In contrast, while Bayles and Kaszniak (1987) define semantic memory as the repository of conceptual, propositional, and schematic knowledge (with both conscious and unconscious processes), they argue that the actual lexical representations for this conceptual knowledge are stored elsewhere.

Memory research involving tasks such as semantic priming provides valuable data about the nature of communicative decrement. Based on a review of this literature, Bayles and Kaszniak (1987) conclude that both the processes and, probably, the contents of semantic memory are impaired in AD. In contrast, Nebes's (1985) research with the priming aspects of semantic information has led him to conclude that the problem is not one of content disruption in semantic memory, but instead one of conscious access to processes and contents.

The benefits of research based on a reasonable conceptual model of the underlying components and processes of linguistic and cognitive systems are considerable. For example, in 1983, Fodor proposed that mental functioning is contingent upon at least six modular perceptual systems (input) and a nonmodular central system. Modular components are presumed to have a fixed neural architecture and can be selectively and characteristically impaired. The degree to which selective impairment is or is not observed in certain disorders can be seen as a test of such a model.

Kempler, Curtiss, and Jackson (1987) recently attempted to investigate the independence of the syntactic and lexical systems of linguistic processing in 20 AD patients. Results are discussed in terms of an apparent pattern of preservation of automatic functions. Syntax is viewed as relatively more automatic than semantics because the range of alternatives is constrained, and each instance of grammatic structure occurs frequently in normal language usage. In contrast, lexical selection is a relatively open-ended control process that requires attention and use of short-term memory capacity in the appropriate lexical searches. In support of modularity, Kempler and colleagues (1987) conclude that some degree of autonomy can be granted to more automatic functions of the syntactic system. In contrast, Bayles and Kaszniak (1987) propose that semantic memory is the central system, and its characteristic pattern of breakdown belies Fodor's (1983) proposed absence of fixed wiring for this component. In both instances, while data are being gathered about the aspects of the linguistic/cognitive system that are impaired in dementia, the predictions of various models of neural organization can be investigated.

Neurological Substrates

Kempler et al. (1987) also propose that our linguistic and communicative investigations in dementia should be sensitive to various models of the underlying neurology of behavior—the neuronal organization of the CNS. Another component of this research initiative should be the correlation of various morphological and biochemical changes with changes in language behavior. Peach (1987) notes that many changes observed at autopsy in AD patients are also observed to lesser degrees in reputedly healthy older individuals. He speculates that neurofibrillary tangles, for example “might contribute to a functional decline in such language processes as auditory-verbal association and motor-speech programming” in the absence of documented clinical decline in these skills” (p. 246). If dissolution of language is a threshold phenomenon (Katzman & Terry, 1983), it may be possible ultimately to correlate morphological and biochemical changes not only with language breakdown in dementia, but also with variations in skills found within the normal spectrum of the heterogeneous older population.

Distinguishing Communication in Dementia From Aspects of Normal Aging

In order to define the linguistic and communicative characteristics of dementia, similar behaviors in normal aging populations must be clearly specified. (See reviews in Bayles & Kaszniak, 1987; Benjamin, 1988; Obler and Albert, 1981; Peach, 1987; Shadden, 1988b.) This specification is essential both to an understanding of the nature of the communicative deficit in dementia (Is it an extension of the aging process or a radical deviation?) and to the process of differential diagnosis between normal age-related communicative changes and mild forms of dementia.

To illustrate this research concern, the behavior sometimes termed *verbosity* can be considered. In a recent study, Gold, Andres, Arbuckle, and Schwartzman (1988) examined correlates of high verbosity and off-target speech in healthy older adults. Since verbosity in some form is associated with other neurologically impaired populations (see, for example, Mackisack, Myers, & Duffy, 1987), and off-target behavior is characteristic of dementia, questions about the differentiation of those with mild dementia from at least some healthy older adults or other clinical populations must be raised.

As noted earlier, many studies of dementia include some control group of nondemented older adults used for baseline purposes. In an investigation by Sasanuma et al. (1985), for example, control subjects differed from demented subjects on all measures. However, in very few instances has the expressed purpose of the investigation been to determine discriminating tasks or behaviors that distinguish (classify) the two groups with any reliability.

Several investigations have attempted specifically to discriminate between healthy elderly persons and individuals in the early stages of dementia. Storandt, Botwinick, Danziger, Berg, and Hughes (1983) compared mild AD and normal older subjects on a variety of tasks. Discriminant analysis allowed them to differentiate the two groups 98% of the time based on the Wechsler Memory Scale (Wechsler, 1945), Mental Control and Logical Memory, the Trailmaking Test—Form A (Reitan, 1969), and a word fluency measure. Bayles and Boone (1982) reported that five language measures differentiated AD and normal older subjects: story-retelling, sentence correction, sentence disambiguation, verbal expression, and naming. In an extension of this work described by Bayles and Kaszniak (1987), AD and normal subjects were best discriminated by verbal description, followed by story retelling and a pragmatics tasks. For PD and HD patients, the FAS Verbal Fluency Measure (Borkowski, Benton, & Spreen, 1967) was most discriminant.

RESEARCH INITIATIVE 2: DEFINING THE PROGRESSION OF DEMENTIA

The identification of various stages in the progression of dementing disorders is commonly agreed to be a

priority. However, except for a few isolated case studies and clinical reports, longitudinal research has been restricted primarily to the Alzheimer's disease population (c.f., Ferraro & Jervis, 1936; Holland, McBurney, Moossy, & Reinmuth, 1985; Wechsler, Verity, Rosenschein, Fried, & Scheibel, 1982). Extensive data concerning the progression of AD have been derived from two major longitudinal studies summarized in Bayles and Kaszniak (1987) and reflecting the separate work of these two authors. Their data, along with other smaller scale studies, support the existence of three fairly clearly defined stages in the deterioration of communication skills associated with cognitive breakdown in AD individuals. Although excellent summaries of these stages can be found in a variety of sources (e.g., Golper, 1988; Ostuni & Santo Pietro, 1986; Overman & Geoffrey, 1987), the most comprehensive description is provided in Bayles and Kaszniak (1987).

As noted earlier, semantic and pragmatic knowledge appear to be affected before phonologic and syntactic knowledge, and episodic memory deficits exceed semantic memory deficits (in the mild stage). Propositional language use is consistently affected before automatic language use, as reflected in early preservation of all language forms despite disruption of language content. Given the nature of these changes, it is not surprising that the communication deficits of AD patients in the early stage may be ignored. Even in the moderate stage, AD patients retain fluent, generally grammatical, speech which may be used in a conventional social fashion in some contexts. More research is needed concerning discourse changes in the person with AD over time.

Research concerning the progression of dementia is complicated by the methodologic difficulties of identifying severity of the disorder and equating severity across studies. Clinical judgments of severity have been shown to display questionable reliability and validity, at least with aphasic individuals (DeYoung, 1987). In dementia research, the most common quantitative measures of severity are scales of mental status, although duration of illness has been advocated by some clinicians. Among the more frequently used measures are: the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975), the Blessed Orientation and Memory Examination (Blessed, Tomlinson, & Roth, 1968), the Mattis Dementia Rating Scale (Mattis, 1976), and the Global Deterioration Scale (Reisberg, Ferris, & Crook, 1982). No one measure is commonly accepted, and there is a need for expanded normative and psychometric data on most instruments. The quantification of severity becomes particularly important when interetiologic comparisons are attempted.

RESEARCH INITIATIVE 3: DIFFERENTIAL DIAGNOSIS

Much of the recent research in communication disorders has been concerned with differential diagnostic considerations within and across dementia types, as well

as between dementia and other neurogenic speech-language disorders. Each of these topics will be addressed briefly.

Distinguishing Dementia Types by Communication Characteristics

Although differentiation of dementia syndromes by communication characteristics can be extrapolated by comparing data from studies of each disorder type, there are few interetiologic investigations. Many have appeared within the last five years (c.f., Bayles & Kaszniak, 1987; Bayles & Tomoeda, 1983; Boller et al., 1980; Butters et al., 1983; Fuld, Katzman, Davies, & Terry, 1982; Hier et al., 1985; Mayeux, Stern, Rosen, & Benson, 1983; Mildworf, 1978; Morris, Cole, Banker, & Wright, 1984; Moss, Albert, Butters, & Payne, 1986; Overman, 1979). Thus it is not surprising to find that data are incomplete.

Only a few noteworthy research findings will be mentioned. Bayles and Kaszniak (1987) report that comparisons of AD, PD, and HD patients revealed remarkable similarities at the mild level of severity. On a battery of tests, only the mild HD and AD patients could be distinguished, based on poorer HD performance on a sentence disambiguation task. For moderately demented subjects, the AD and HD groups were again the only ones who could be differentiated, this time on verbal description and confrontation naming tasks. These findings are intriguing, since other researchers have implied that verbal skills may be less impaired in HD than in other dementing disorders (Mildworf, 1978).

Large-scale comparisons of AD and MID do not exist. In one study, the nature and extent of naming deficits distinguished mild and more severely impaired AD and MID subjects from normal controls, but these same deficits did not differentiate the two dementia groups (Overman, 1979). Hier et al. (1985) noted that, although disintegration of language functions was noted in both AD and MID groups, AD patients became more verbose but less precise and informational, whereas MID patients tended towards increased telegraphism.

Several investigations have compared Korsakoff's syndrome (KS) with other dementing disorders. HD subjects were distinguished from those with AD and KS by their ability to use verbal mediators to facilitate contextual memory (Butters et al., 1983). In a second study, both HD and KS patients exceeded AD patients in the ability to recall verbal stimuli after a 2-minute delay (Moss et al., 1986). Morris et al., (1984), described a hereditary dysphasic dementia that lies on a continuum between Pick's Disease and AD.

It should be clear from the preceding discussion that interetiologic comparisons of communication characteristics in dementia are sparse. Carefully controlled investigations of communication behaviors in the various dementias are needed. Methodological issues that must be considered include (a) assignment of severity level and

severity matching, (b) matching according to subtype or vascular pathology and locus of lesion (in MID), (c) the type of measure used, and (d) the presence and interference of accompanying deficits.

Differentiating Subtypes Within the Dementias

A similar paucity of research is found when intraetiologic comparisons are attempted. It was suggested earlier that distinct subgroups may exist within the AD, MID, and PD populations. In each instance, language deficits appear to play a prominent role in the observed variation, but limited data are available to confirm that impression. For the AD group, Bayles and Kaszniak (1987) identified a number of variables that can be viewed as affecting the nature and extent of language impairment, including: distribution of morphologic changes, age at onset, familial history, and rate of disease progression. Although approximately one-third of all Parkinson's patients develop dementia, little is known about their language characteristics or predictive morphological and history factors. Similarly, MID patients have seldom been grouped according to locus and extent of vascular pathology for correlation with communicative and neurologic attributes.

Dementia Versus Aphasia

The final differential diagnostic dilemma to be considered here was best summarized by Rosenbek (1982), in his controversial question, "When is aphasia not aphasia?" In other words, is it appropriate to designate observed language impairment in dementia as some form of aphasia? The degree of concern raised by this question can be inferred from the variety of alternate terms cited in different sources: *Alzheimer's aphasia* (Bayles & Kaszniak, 1987), *dyslogia* (Critchley, 1964), *language of generalized intellectual impairment* (Halpern, Darley, & Brown, 1973), *regressive aphasia* (Emery, 1985), or *the aphasia of dementia* (Golper, 1988). At least two schools of thought exist concerning this issue.

As Golper (1988) points out, many clinicians and researchers view aphasia as a disruption in primary language processes; intent and communicative concept are preserved, but the use of appropriate linguistic rules and forms is impaired. For these professionals, the term *aphasia* should be reserved for instances of language impairment secondary to abrupt onset and focal neurological lesions, typically of the left hemisphere. After reviewing the literature on this topic, Wertz (1982) concludes that communication in dementia can and should be differentiated from aphasia on the basis of language performance and neurological data. His final justification is that the label *aphasia* not only serves as a diagnosis but also carries implications for prognosis and management.

Other speech-language pathologists are less comfortable with abandoning the aphasia label. As Rosenbek (1982, p. 365) points out, "Altered brains have a limited

repertoire of speech and language mistakes they can make . . .," regardless of etiology. Kitzelman (1981) differentiates aphasia from dementia by the degree to which language impairment is isolated in the two disorders. The existence of aphasia in dementia is asserted by a number of prominent researchers (e.g., Cummings, Benson, Hill, & Read, 1985; Kertesz, 1985).

Some professionals fear that outright denial of aphasic impairment in dementia may effectively limit research comparisons of the similarities and differences among these disorders. For example, the prominence of aphasia-like symptomatology has been noted in the early stages of AD (c.f., Appell, Kertesz, & Fisman, 1982; Cummings et al., 1985; Kirshner, Webb, Kelly, & Wells, 1984; Mayeux, Stern, & Spanton, 1985; Wechsler, 1977). As Horner and Riski (1988) indicate, aphasia may be (a) an important diagnostic feature in dementing disorders, (b) the single or most prominent feature of early dementia, and (c) a diagnostic indicator in younger patients and a prognostic warning of rapid decline.

While the philosophical issues cannot be resolved here, the actual research being conducted has at least three major research foci: (a) comparison of the language of AD with various aphasic syndromes (c.f., Appell et al., 1982; Gewirth, Shindler, & Hier, 1984; Hier et al., 1985; Nicholas et al., 1985; Obler, Albert, & Helm-Estabrooks, 1982); (b) attempts to differentiate aphasic and demented subjects on various language measures (e.g., Horner, 1985; Horner, Dawson, Heyman, & Fish, 1988; Horner, Lathrop, Fish, & Dawson, 1987; Nicholas et al., 1985; Wertz, 1982); and (c) efforts to illuminate the aphasia/dementia paradox by exploring the nature and course of language deficits in anomalous disorders, such as slowly progressive aphasia (e.g., Duffy, 1987; Folstein & Breitner, 1981; Horner & Riski, 1988; Morris et al., 1984).

Research data remain inconclusive in some areas. Persons with AD most often resemble those with anomic aphasia in the early stages and Wernicke's aphasia (or transcortical sensory) in the more severe stages. The characteristics of some MID patients, in contrast, more closely approximate those of patients with Broca's aphasia. Bayles and Kaszniak (1987) provide an extensive table of dimensions useful in differentiating various aphasic types and characteristics from AD, PD, and HD.

Clear differentiation of left hemisphere aphasia, AD, and, occasionally, right hemisphere impairments has proved elusive with use of standardized aphasia test batteries. The problems of using aphasia protocols to discriminate among populations that are probably not aphasic are further compounded by reliance on summary scores for statistical measurement and by poor control of subject type or disorder severity. When qualitative performance differences are examined more closely, differential patterns of response have been reported. For example, in the Nicholas et al. (1985) study, AD subjects produced more empty phrases than Wernicke's aphasics did; however, Wernicke's aphasics produced greater numbers of neologisms and verbal or literal paraphasias. Many authors agree that differential diagnosis of aphasic and demented communication impairment is best accom-

plished through recourse to nonlinguistic tasks and behaviors.

The final avenue of research concerns such unusual syndromes as slowly progressive aphasia or hereditary aphasic dementia. Horner (1985) reported that the Western Aphasia Battery showed no significant differences among groups of subjects with progressive language disorders, AD, and left hemisphere aphasia. These findings were used to support the value of continuing to talk in terms of aphasia and to use standard assessment batteries until more is known about distinctive language characteristics. Similarly, both Duffy (1987) and Horner and Riski (1988) found the presence of aphasia (and/or apraxia, dysarthria, and agnosia) useful in highlighting the existence of discrete disorders that do not fall readily into the traditional aphasia or dementia classification schema.

RESEARCH INITIATIVE 4: THE NATURE AND APPROPRIATENESS OF DIAGNOSTIC PROTOCOLS

Research initiatives 1, 2, and 3 are predicated upon the adequacy of the assessment batteries used to diagnose and describe dementia syndromes. Medical protocols deemed sufficient to these tasks are described in other sources (cf. Golper, 1988, and Foster, 1987). Our concern lies with defining a set of procedures sufficiently sensitive to (a) identify the presence of dementia, (b) differentiate communication deficits in dementia from other speech and language disorders, (c) differentiate communication behaviors in various types and subtypes of dementia, and (d) chart the progression of behaviors over time. According to Bayles and Kaszniak's (1987) guidelines, tasks should be able to assess the integrity of the contents and processes of semantic memory; they should also analyze communicative skills beyond the sentence level (with emphasis upon abilities measured in discourse and conversation). In general, it is suggested that an ecologically valid test paradigm be used that focuses upon generative, nonautomatic, active, and creative abilities (Bayles, 1985).

It is clear that recommended procedures provide considerable potential overlap with the neuropsychological evaluative process. There also is no one commonly accepted manner in which goals can be met. Overman and Geoffrey (1987), for example, state that the typical evaluation should include a history; behavioral observations of speech-language and communicative interactions; administration of a comprehensive aphasia language test; administration of one or more specific language tests, as needed; and possible inclusion of psychometric measures designed to evaluate cognitive deficits. In contrast, while Golper (1988) notes the efficacy of various standard speech and language tests, she lists areas typically assessed in a dementia evaluation, including orientation, naming (confrontation, responsive, and generative), written and oral discourse, conversational style, verbal mem-

ory and sentence comprehension, verbal repetition, interpretation of idioms and proverbs, sentence construction, reading, numerical functions, drawing, pantomime expression, and spatial recognition memory. Many of these areas are included in the Arizona Battery for Communications Disorders in Dementia (ABC) (Bayles & Kaszniak, 1987).

Several problems should be apparent from this discussion. First, the inclusion of standard aphasia batteries raises a variety of diagnostic dilemmas. By themselves, such tests are insufficient to the task of differential diagnosis of dementia because of the importance of nonverbal signs. Even as supplements to evaluation, they may fail to differentiate aphasia from dementia, since most aphasia tests are designed to assign language deficit patterns to an appropriate aphasic classification.

A second problem is that we are almost forced into a dichotomy between standardized and nonstandardized tests—a dichotomy that frequently reflects the difference between clinical and research methodologies and goals.

Finally, aspects of normal aging must always be considered in any diagnostic protocol. Factors to monitor include sensory functioning, slowing, fatigue, test-taking attitudes and response biases, and the need for age-appropriate reliability and validity data.

RESEARCH INITIATIVE 5: THE EFFECTS OF DEMENTIA UPON CAREGIVERS

One of the more devastating aspects of dementia is its effects upon caregivers. An understanding of these effects requires both recognition of the impact of the gradual cognitive deterioration and knowledge about the nature of families roles and patterns, social support networks, and stages in reaction to communicative disorders or any form of loss (Shadden, 1988a). Caregiver burden is constant; its unrelenting nature led Mace and Rabins (1981) to describe the coping process as living with a "36-hour day." The unusual nature of the chronic grief experienced by caregivers and the intense demands of the caregiving task have prompted a number of researchers to investigate the nature of caregiver burden and the factors that influence perception of burden (c.f., Ory et al., 1985; Zarit, Reever, Bach-Peterson, 1980).

The literature reports inconsistent findings with respect to the factors influencing perceived burden or stress, but Bayles and Kaszniak (1987) suggest examination of the patient's behavior, the caregiver's own limitations as related to the dependent patient, and environmental and social conditions. Of particular interest has been the issue of formal and informal support networks, for the elderly in general and for family members of a demented patient (c.f., Chappell, 1983; Goudy & Goudreau, 1982; Lipman & Longino, 1982; Rundall & Evashwick, 1982). There is some evidence that social support (particularly from family) allows caregivers to cope more effectively.

What is consistently lacking in the literature is any attempt to examine the effects of different dementing disorders upon caregivers. In addition, although communication breakdown is mentioned in several studies of factors increasing caregiver stress, there are no systematic investigations of the effects of specific communication behaviors (nature and severity of disorder) upon caregiver adjustment.

RESEARCH INITIATIVE 6: MANAGEMENT STRATEGIES

Most speech-language pathologists would agree that the major components of an intervention program with a dementia patient would include diagnosis, monitoring, patient rehabilitation, and family counseling and management. The degenerative nature of dementia has been responsible for a "hands-off" intervention approach in the past, but our increasing role in assessment and enhanced awareness of family concerns have heightened sensitivity to communication needs. There is surprising consensus as to the nature of necessary patient and family interventions, although, remarkably, there is little experimental support for the management techniques being recommended.

Patient Interventions

The majority of patient intervention techniques are indirect; that is, they are less concerned with manipulating or training the client and more concerned with the surrounding environment and linguistic attributes of communications directed to the client. Direct treatment tends to occur in two instances. First, Golper (1988) suggests we may occasionally provide speech-language treatment in spite of the dementia. In other words, we may choose to address static deficits (as in some MID cases) or progressive neuromotor problems (as in PD) when the cognitive decline is not expected to interfere excessively with treatment. Second, in a related fashion, Golper and Rau (1983) discuss diagnostic-prognostic therapy for mildly demented individuals to determine the efficacy of patient-directed services.

In most instances, however, indirect management strategies are employed; a number of authors have addressed the nature of such strategies (Bayles & Kaszniak, 1987; Bollinger, Waugh & Zatz, 1977; Glickstein, 1985; Golper, 1988; Golper & Rau, 1983; Overman & Geoffrey, 1987). All of the described environmental or linguistic manipulations focus upon providing communicative opportunities and maximizing communicative performance. Efficacy studies are limited. The best known is an investigation of comprehension-enhancing strategies, in which Obler, Obermann, Samuels, and Albert (1985) were able to establish that combining written and auditory cues served to aid comprehension. The lack of management research is particularly alarming in view of

increased opportunities for speech-language pathology involvement in special programming for demented patients (e.g., adult day care or nursing home special units such as that described by Cleary, Clamon, Price, & Shullaw, 1988).

A number of group intervention programs have been devised for the elderly in general and AD patients in particular. Barr (1988) provides an extensive review of relevant group programming options, including support groups, resocialization groups, memory training, maintenance of cognitive functioning, reality orientation, and family interventions. Unfortunately, speech-language pathology participation in such activities is limited at this time. Little is known about the effects of such interventions on communication.

Caregiver Interventions

The goals of family intervention should be to help family members regain stability in all aspects of functioning. Four basic caregiver needs can be identified: information, management techniques, counseling, and support. A family's particular constellation of needs, however, can only be identified through needs assessment. This assessment process should be a routine part of any dementia evaluation. However, because of a lack of questionnaires designed specifically for use with caregivers of demented patients, assessment is either highly informal or dependent upon scales designed for other populations (e.g., aphasic individuals or the elderly in general). We have little systematic data concerning specific caregiver needs as related to patient communicative deficits.

At least five approaches to caregiver management can be identified: support groups, counseling, training for participation in patient management activities, provision of information, and assistance in obtaining other household and patient care support services. Each of these approaches is described briefly by Shadden (1988a). Speech-language pathologists have participated in the development of some excellent resource materials for families (c.f., Bollinger et al., 1977; Ostuni & Santo Pietro, 1986). However, as with patient treatment, few (if any) management efficacy studies have been completed, at least from the perspective of communication deficits and their effects on caregivers.

DIRECTIONS FOR FUTURE RESEARCH

Research Tools and Methodological Problems

There currently is available a wide variety of sophisticated and sensitive research tools that can be incorporated into investigations of the nature, progression, and

differential diagnosis of dementia, as well as its management. Each of these tools will be identified briefly:

1. Linguistic analyses—formal aphasia tests, other standardized tests of linguistic competence and performance, discourse and other pragmatic analyses, research-oriented linguistic tasks;
2. Nonlinguistic analyses—the entire neuropsychological battery of tasks (excluding language) as well as various behavioral rating scales;
3. Medical work-up—the comprehensive series of examination and laboratory procedures currently considered to be standard in dementia diagnosis;
4. Neurobiological measures—noninvasive, invasive, and post-mortem procedures used primarily for research purposes in order to chart morphological or biochemical markers of various dementing conditions;
5. Caregiver measures—in addition to modification of existing protocols in speech-language pathology (c.f., Chapey, 1986; Chwat & Gurland, 1981; Florance & Conway, 1986), there is a variety of scales related to caregiver burden (Zarit et al., 1980), depression (Radloff, 1977), and life satisfaction (Berkman, 1971). Suggestions for probing support networks are provided by Biegel, Shore, and Gordon (1984), and scales such as the CARE (Gurland et al., 1977-78), OARS (Pfeiffer, 1976), and Philadelphia Geriatric Center Multilevel Assessment Instrument (Lawton, Moss, Fulcomer, & Kleban, 1982) may provide additional caregiver profiles;
6. Measures of treatment efficacy—recent advances in the use of statistical alternatives, such as single-subject designs, markedly increase the researcher's options in measuring the effects of management strategies (Connell & Thompson, 1986; Kearns, 1986; McReynolds & Thompson, 1986).

Despite this encouraging array of research tools, a number of methodological problems can be identified. Bayles and Kaszniak (1987) review cross-sectional versus longitudinal designs, problems, and issues in internal and external validity. Although cross-sectional designs involving dementia subjects are less likely to show the confounding of cohort effects seen in other aging research (because of the relatively brief duration of the dementing illness), there remain problems with the greater variability found in demented subject groups as compared with control groups.

Potential threats to internal and external validity stem from a variety of sources: the inability to manipulate presence or absence of dementia experimentally, the reliability of the clinical diagnosis of dementia, the representativeness of the subject sample (e.g., range of deficits represented), selective subject attrition, the representativeness of tests designed to sample a hypothetical construct, and the construct validity of the measures used (Bayles & Kaszniak, 1987). In addition to these methodological issues, the following factors might be noted: problems in recruiting subjects (Williams, Vitiello, Ries,

Bokan, & Prinz, 1988), the lack of a consistent methodology for assessing severity, problems in matching subjects across disorder types, the influence on test behavior of variables related to normal aging, and the lack of systematic models of linguistic behavior and neurological substrates for normal and disordered language functioning.

Specific Needs

Based upon this review of current research initiatives in dementia, research tools, and methodological concerns, it is appropriate to close this paper with a plan of action. The following "wish list" of research needs reflects input from colleagues Bayles, Golper, Groher, and Horner. However, needs are organized into the discrete research initiative headings described earlier in this paper for purposes of consistency and clarity. No attempt has been made to give an order of priority to avenues of investigation, although a hierarchy of needs may be implicit in some instances.

Nature and extent of communicative deficits in dementia. Specification of the nature and extent of communicative deficits in dementia requires at least three interlacing avenues of investigation. First, additional information is needed concerning speech, language, and communication changes in normal older adults, with particular emphasis upon behaviors reflected in discourse and conversational tasks. An attempt must be made to work systematically within given linguistic models to discover the cognitive requirements for communicative behaviors. The neurochemical and morphological substrates for language behavior and change in aging must also be identified.

Second, the nature of communicative deficits in dementia must be investigated further. Only the most recent research in Alzheimer's disease has attempted to manipulate task variables systematically in order to specify the underlying components of linguistic and cognitive systems that are impaired in dementia. Proposed models of linguistic dysfunction warrant further investigation, in conjunction with simultaneous measures of the neuropathy and neurochemistry of AD. There is limited research concerning communication attributes in other dementing disorders, or correlations of those attributes with the nature and extent of the underlying neurological degeneration. For example, we lack data on the correlation between linguistic performance and number, size, and site of infarctions in MID. We know little about linguistic and communicative changes observed in some PD patients and almost nothing about the relationship of those changes to other behavioral measures or to pharmacological interventions. Systematic discourse analysis should provide insight into both the nature of the communicative deficit and the appropriateness of our models of neuro-linguistic organization.

Third, data are needed concerning the differences between the communicative performance of mildly demented individuals and that of normal older adults. Clearly, such data may evolve out of the lines of investi-

gation suggested above, but specific research is needed to identify with precision the boundaries of thresholds between normal and pathological behavior.

Stages in the progression of dementia. Most studies of disease progression have been performed with AD patients. Longitudinal measures of speech, language, and communicative behaviors in other forms of dementia, particularly MID, PD, HD, and Pick's disease, are required. Appropriate stage descriptions must be developed. Documentation and correlation of all behaviors (and of brain function and structural integrity) are required if predictive patterns of dissolution of skills are to be identified. In addition, researchers must attempt to explore and reach consensus concerning measures of severity of disorder within and across dementia types.

Differential diagnosis. Differential diagnosis in dementia involves discriminating among dementia types (and subgroups within types) and distinguishing dementia-based language disorders from aphasia. In attempting to distinguish among dementia types, it is probable that the data gathered through the first two research initiatives will provide a strong base for determining specific research needs. Nevertheless, it is clear that more longitudinal and cross-sectional studies are needed. The primary issues must be (a) control of subject characteristics (type and subtype of dementia), (b) stage of progression (severity), and (c) extensiveness of testing. The third variable is of particular concern, since it is probable that nonlinguistic measures may provide the key to differential diagnosis with some disorders. The cortical-subcortical controversy could be resolved through such large-scale studies, but particular attention should be paid to language deficits in subcortical dementias and motor speech deficits in cortical dementias. Similar tightly controlled studies could permit clarification of the existence and nature of subgroups within AD, MID, and PD by systematically considering such variables as language characteristics, neurological data, age of onset, history, dominant presenting behaviors, and nature and rate of disease progression.

We lack extensive data concerning the communication profiles and disorder progression in patients with reversible dementias or pseudo-dementias, despite the prominence of speech and language in clinical descriptions of differences among some of these disorders. It is unclear whether communication testing alone could provide sufficient evidence for differential diagnosis.

With respect to the differentiation of aphasia from dementia, there is no immediate solution to the controversy concerning the use of the term *aphasia* to describe behaviors in demented individuals. AD communication characteristics and those of certain aphasia types will continue to bear striking similarities clinically, and practicing speech-language pathologists will continue to rely heavily on standard aphasia batteries for differential diagnosis. There are also some unusual forms of dementia or aphasia that appear to be neither "fish nor fowl" (e.g., the hereditary dysphasic syndrome or slowly progressive aphasia). Finally, the degree to which clinicians and researchers are uncomfortable with the term *aphasia* as applied to dementing disorders will remain irrevocably

tied to their definition of aphasia and their prognostic and therapeutic interpretation of the label. Thus, this avenue of research cannot be ignored. Further specification of the nature and progression of deficits in dementia and the similarities and differences between diffuse and focal lesion disorders may allow us to resolve the controversy. For the present, there are some advantages to adopting a term such as *aphasia of dementia* to clarify the construct being evaluated.

Horner (personal communication, 1988) suggests that the differential diagnosis of stroke syndromes from dementia will require focus upon (a) identifying the most distinguishing features of aphasia in focal disease versus aphasia in diffuse, dementing illness; (b) determining the localizing value of dysarthria or apraxia co-occurring with dementia; and (c) exploring the prognostic significance of aphasia as a prominent manifestation of a dementing illness. With these research goals in mind, several caveats must be offered. First, a full-scale dementia battery of tests should be added to any standard aphasia battery in group comparison studies. Second, subject controls must be tightened to allow more precise specification of aphasia or dementia type (or subtype), stage of progression of dementia or stage in recovery in aphasia, and severity level. This is particularly problematic in aphasia, where the terms *mild*, *moderate*, and *severe* may have very different clinical meanings. With these caveats in mind, the possibilities for comparative and longitudinal research are virtually limitless.

Defining the nature and appropriateness of diagnostic protocols. The eventual goal of all clinicians is the identification of appropriate assessment batteries for particular client populations. At present, no diagnostic protocol for dementia is commonly accepted, although the Arizona Battery (Bayles & Kaszniak, 1987) is most widely recognized. In the future, it would be advisable if all research investigations could use, as a baseline, a core battery of tasks to which particular measures could be added in order to address unique experimental questions. This core battery should include both linguistic and nonlinguistic measures, creating a common data pool. Of particular concern is the analysis of discourse behavior. Given the recent proliferation of discourse-based research and the variety of measures used in different investigations, it is imperative that researchers begin to standardize the types of measures and tasks used in discourse analysis. It is further recommended that measures of client/caregiver interaction be included in the core battery.

Caregiver effects. Although an extensive body of literature concerning caregiver burden in dementia has developed, speech-language pathology has slighted our potential contribution in this arena. Information is needed concerning the nature of caregiver burden as it relates to the stages of dissolution of various dementing illnesses and the communication characteristics associated with these stages. Research should consider such factors as family context, client behavioral problems, and social supports (Niederehe & Scott, 1987). The unique focus here, however, should be upon whether the nature and degree of communicative deficit contribute predict-

ably to caregiver burden and caregiver needs. Since this information may be influential in matching caregiver interventions to caregiver needs, data on patterns of interaction between caregiver and patient will allow identification of the relative facilitating or interfering nature of specific interactional behaviors.

Management issues. Given the presumed importance of management issues in dementia and the relative consensus among clinicians concerning appropriate interventions, there is a surprising lack of experimental validation of recommended management strategies. Which family support strategy works best at what stages in the disorder or under what circumstances? In other words, predictors for success in caregiver intervention must be identified. There is also a need for systematic studies of the effects of programs designed to train interactional skills.

Virtually no experimental support has been provided to document the efficacy of recommended client management strategies. Generally, such strategies take the form of environmental adjustments or modifications of verbal and nonverbal cuing. Linguistic and nonlinguistic communicative variables need to be varied systematically, and the effects upon comprehension, performance, and frequency of interaction in different patient subgroups must be measured. The influence of environmental modifications should be determined by comprehensive pre- and post-analyses of a wide range of communicative behaviors. Speech-language pathologists must become more active in the design and experimental validation of the increasing number of special care units for dementia patients found in nursing homes.

CONCLUSIONS

Dementia exacts a heavy social, psychological, physical, and economic toll upon patient, family, and society at large. One of the dominant characteristics of all forms of dementia is a progressive breakdown in speech, language, or communication skills. The nature of this breakdown plays a critical role in differential diagnosis of various syndromes, in determination of severity level, and in predicting the daily problems that will be experienced by caregivers and patients alike. The research needs identified in this paper must be pursued actively.

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Chapter 12

THE AGING PROCESS AND ITS POTENTIAL IMPACT ON MEASURES OF ORAL SENSORIMOTOR FUNCTION

BARBARA C. SONIES

The W.G. Magnuson Clinical Center, Bethesda, MD

ANTHONY J. CARUSO

Kent State University, Kent, OH

Studies from several laboratories employing diverse methods have suggested that in the course of normal (nonpathologic) aging, both anatomic and physiologic changes can be detected in the oral mechanism (e.g., Amerman & Parnell, 1981; Baum, 1981; Baum & Bodner, 1983; Bosma, 1976; Feldman, Kapur, Alman, & Chauncey, 1980; Ferguson, 1987; Sonies, Stone, & Shawker, 1984). Studies such as these have yielded critical perspectives on the normal aging process and its effect on oral motor performance associated with speech and swallowing. Moreover, as the elderly population in the United States continues to grow, and, presumably, the number of elderly persons with communicative and swallowing disorders involved in remediation increases, the importance of these still developing normative data bases on oral motor performance cannot be underestimated.

Of particular interest to us have been several reports indicating differences in old versus young adults in factors associated with speech production (Amerman & Parnell, 1981; Baum & Bodner, 1983; Benjamin, 1981; Kent & Burkhard, 1981; Wilcox & Horii, 1980). There are few data to suggest, however, that the normal, nonpathologic aging process affects speech production in any appreciable manner. Although studies have shown that oral, palatal, and laryngeal tissues change, teeth are lost (Ferguson, 1987; Kahane, 1981), speech articulatory output is such a well-established, overlearned, redundant process that only a serious insult to the system is likely to result in compromised or perceptibly altered speech (Sonies, Baum, & Shawker, 1984). In other words, non-pathological age-related changes are not likely to reduce the robust capability for on-line articulatory adjustments needed to produce normal-sounding speech. Interestingly, the above cited studies of normal aging have revealed several imperceptible changes associated with speech, (e.g., slowing of reaction time, slightly reduced oral neuromotor function, slight muscular atrophy, some weakness of the tongue, and changes in tissue composition of the oropharynx). It should be noted, however, that data regarding dynamic aspects of speech movements in the elderly have often relied exclusively on acoustic

parameters as an indirect measure of articulatory (e.g., tongue, lip, or vocal fold) kinematics (Amerman & Parnell, 1981; Benjamin, 1981; Kent & Burkhard, 1981; Ptacek, Saunder, Maloney, & Jackson, 1966; Sweeting & Baken, 1982; Weismer & Fromm, 1983; Wilcox & Horii, 1980). Although studies of the acoustic signal have provided numerous insights into the processes involved in speech production, acoustic analysis may not be the measure of choice for articulatory movements since (a) some acoustic measures may not accurately and precisely reflect underlying speech movement events (Caruso & Burton, 1987) and (b) different patterns of speech movement can produce the same acoustic end product (Atal, Chang, Mathews, & Tukey, 1978; Gracco & Abbs, 1986; Hughes & Abbs, 1976; Stevens & House, 1955).

Historically, most direct investigations of physiologic events associated with oral function have focused on young adults, in part, due to the constraints of previously available instrumentation. Technological advances resulting in ultralightweight, noninvasive, minimally intrusive instrumentation now permit direct monitoring of orofacial and oropharyngeal performance throughout a large portion of the human life span, from young children (Caruso, Conture, & Colton, 1988) to the elderly (Sonies, Baum, & Shawker, 1984; Sonies, Stone, & Shawker, 1984). While the purpose of this paper is to present selected instrumentation that can provide direct measures of oropharyngeal movement events for speech and swallowing, we will discuss each of these in separate sections.

INSTRUMENTATION AND PROCEDURES FOR MEASUREMENT OF ORAL PERFORMANCE

This section will identify different types of equipment and procedures that may be used in studying oral sensorimotor function in the older person. The specifications and

characteristics of equipment will not be presented here, because they have been adequately described elsewhere (see Abbs & Watkin, 1976; Baken, 1987; Schneider, Diamond, & Markham, 1986; Weiffenbach, Cowart, & Baum, 1986). This section will briefly describe *what* these different apparatus and procedures actually measure and *how* they may be utilized to study oral function in the elderly.

Orofacial Sensory Function

Interest in characterizing the impact of the normal aging process on orofacial sensory function has grown steadily during the last 10 years (see Baum, 1981; Ferguson, 1987). Various techniques and procedures have been established to investigate oral, lingual, and facial sensory mechanisms in animals and humans (Abbs & Welt, 1986; Bosma, 1976; Franks, Crompton, & German, 1984; Schneider et al., 1986; Schneider & Lidsky, 1981; Weiffenbach et al., 1986). Investigations such as these have resulted in (a) testable hypotheses regarding neural loci for normal orofacial sensory function and (b) a still developing data base regarding changes in orofacial sensory mechanisms as a result of age.

As part of the National Institute of Aging's Baltimore Longitudinal Study of Aging, the National Institute of Dental Research has been involved in investigating the normal aging process and oral sensory status (Baum, 1981; Weiffenbach et al., 1986). In general, their studies have indicated that as people age, their perception of selected stimuli in the oral area declines (J. Weiffenbach & C. Tylenda, personal communication, August 1988). Figure 1 displays intensity judgments of perceived viscosity (i.e., density or "thickness" of tasteless liquids) and of local pressure on the tongue as a function of stimulus strength for different age groups. These data suggest that the increase in perceived intensity with increased stimulus strength is "steepest" for the youngest adults (ages 25–39 years) and declines with age. Alternative analyses of these data suggest that sensory transmission also becomes less reliable with age. It is important to emphasize that direct links between either of these types of lingual sensory measures and tongue movements for speech cannot be made from the available literature. It may be speculated, however, that these documented age-related sensory changes suggest that, to achieve normal-sounding speech, elderly speakers may be required to make compensatory tongue movements that are unnecessary for their younger counterparts.

Speech Motor Function

One of the fastest developing areas of research in speech production is related to technological advances designed for collection of large samples of multiarticulate orofacial movements. The development of photo-optic (see Walker, Talbot, Doran-Quine, & Ludlow, 1986), photoelectric (see Ohala, Hiki, Hubler, & Harshman,

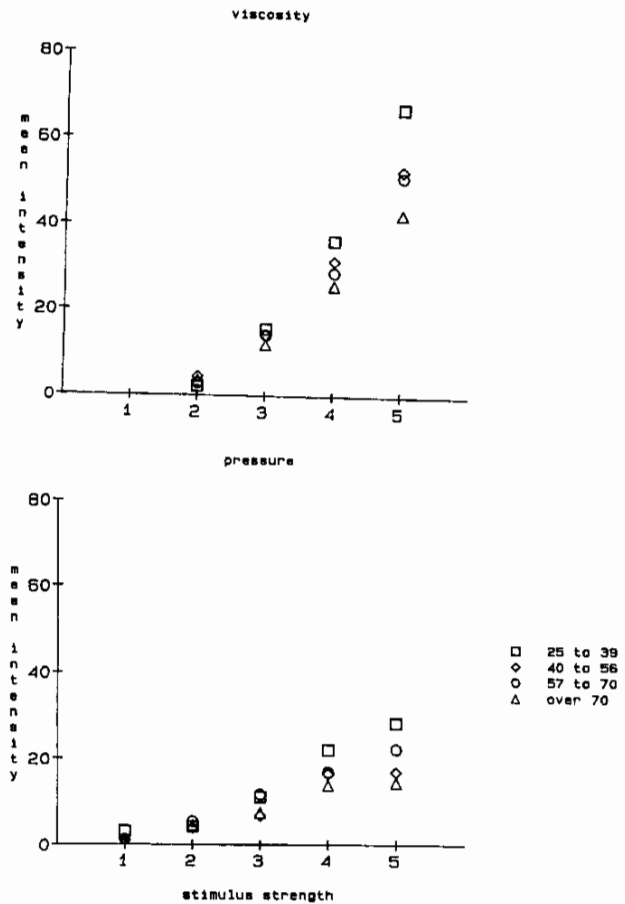


FIGURE 1. Intensity judgments of viscosity and local pressure on the tongue as a function of stimulus strength for various normal age groups (used with permission from J. Weiffenbach).

1968), and strain gage transduction systems (e.g., Abbs & Gilbert, 1973; Barlow, Cole, & Abbs, 1983; Muller & Abbs, 1979) permits kinematic analyses of upper lip (UL), lower lip (LL), and jaw (J) movements; moreover, use of such instrumentation has been critical to the development of hypotheses regarding motor control processes for normal speech (cf., Folkins & Cauty, 1986; Gracco & Abbs, 1986, 1987; Kelso, Bateson, Saltzman, & Kay, 1985), stuttering (Caruso, Abbs, & Gracco, 1988; Caruso, Gracco, & Abbs, 1987), and motor speech disorders (Connor, Forest, Cole, Gracco, & Abbs, 1987; Hunker & Abbs, 1984). The noninvasive instruments (photo-optic, photoelectric, and strain gage transduction systems) generally work by attaching the sensing device to the UL, LL, or J. In fact, most of the experiments mentioned have attached the transducers midsagittally at the vermillion border of the UL and LL using an adhesive that minimally interferes with normal speech movements. Jaw transducers are usually placed under the chin in a location that yields negligible artifact from skin movement. The signals that result from the lip and jaw movement transduction systems have often been used to make the following mea-

tures: (a) *movement onsets*: the time at which the movement of interest occurred; (b) *movement peak velocities*: the maximum velocities in the movement gestures; (c) *movement peak displacements*: maximum amount of movement associated with a particular gesture (e.g., lip closure); and (d) *relative timing*: the time of movement onset or the time of movement peak velocity of one structure (e.g., UL) relative to another structure (e.g., LL).

An interesting application of this technology in the study of orofacial movement has been documented by Malcolm McNeil and his colleagues (McNeil, Caligiuri, & Rosenbeck, in press). Figure 2 displays velocity traces transduced from the LL transducer using a head-mounted strain gage transduction system. The LL transducer in this case is documenting a combined LL plus J velocity (LL + J). The waveforms shown in Figure 2 display velocity data capturing onset of the closing gesture for the *op* in *stop* through the opening gesture for *fa* in *fast* in the stimuli *stop fast*. This figure shows three consecutive LL + J velocity traces for a normal elderly subject (N5) and three consecutive LL + J velocity traces for an apraxic subject (A3). In contrast to the normal traces, there were striking differences in the timing of the peaks and the smoothness of the trajectory for the apraxic subject. Hypotheses based on similar data from the same subjects regarding speech motor control in normal elderly and pathological elderly subjects are being developed (see McNeil et al., in press).

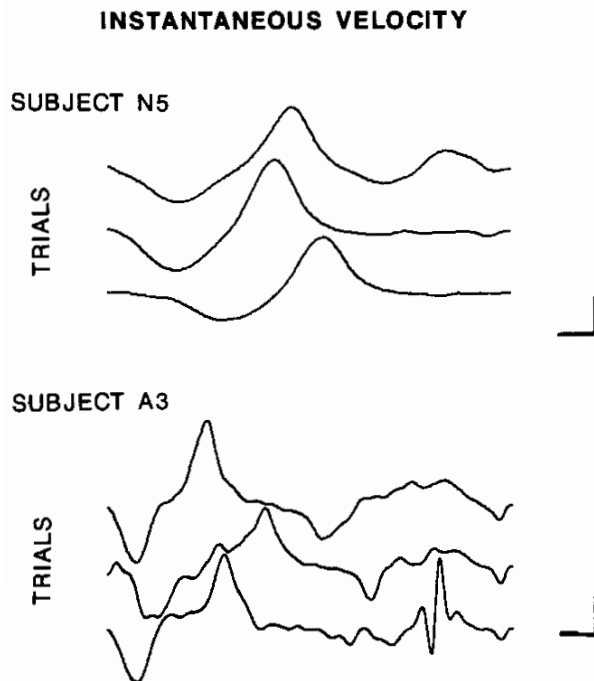


FIGURE 2. Three lower lip plus jaw (LL + J) velocity traces for one normal subject (N5) and one apraxic subject (A3). Horizontal and vertical calibrations represent 75 ms and 18.15 mm/s for N5, and 95 ms and 12.66 mm/s for A3, respectively (with permission from M. McNeil).

One major restriction of the transduction systems is that they generally are limited to either (a) one or two dimensional movement patterns, (b) transducing only two structures, or (c) cumbersome adaptations for three-dimensional analyses. These limitations are unfortunate since they may be in part responsible for the fact that the majority of studies during lip and jaw movement have been restricted to one-dimensional (usually superior-inferior) analyses. Thus, the hypotheses regarding motor control processes for normal and disordered speech largely have ignored, or at least trivialized, the importance of anterior-posterior as well as lateral-medial dimensions associated with speech movements (e.g., *p*) thought to be produced largely by superior-inferior UL, LL, and J movements.

Three dimensional analysis of lip and jaw movements. The advent of orofacial movement transduction techniques that permit the acquisition of large samples of speech movement data in all three dimensions holds immense promise for further understanding of the sensorimotor mechanisms involved in multiple movement coordination for normal and disordered speech. We currently are involved in developing a video-based motion analysis system for three dimensional analysis of lip and jaw movements (Caruso, McGuire, Stanhope, & Sonies, 1988). One area of particular interest is the application of this technology to further our understanding of the neuromotor processes underlying speech movements in elderly. Figure 3 displays upper lip (UL), lower lip (LL), and jaw (J) displacement data in the anterior-posterior, medial-lateral, and superior-inferior dimensions associated with a normal 75-year-old woman's production of *sapapple*. Preliminary analysis of this one utterance indicated that the present superior-inferior movement data associated with the first closing movement (the first *p* in *sapapple*) closely approximate published strain gage results with normal young adults using the same speech stimulus (see Caruso et al., 1988; Gracco & Abbs, 1986). In addition, the present data demonstrate a striking amount of anterior-posterior movement during closure for *p*—thought to be largely accomplished via movement in the superior-inferior direction. For example, prior to LL movement in the superior direction, the LL moves more than 3 mm anteriorly, and, as the LL reaches its peak superiorly, a 6-mm movement, it also moves from its peak anterior position to a peak posterior position (a 4-mm movement). In other words, movement in the anterior-posterior dimension may be considerable or even equivalent to movement in the superior-inferior dimension for a sound produced by bilabial closure. Finally, as expected in normal speakers, medial-lateral movement during bilabial closure for *p* is minimal. However, deviations in medial-lateral movement patterns may typify important changes in abnormal lip and jaw movement associated with various structural (A. J. Caruso, personal communication, August 1988) or neurological impairments.

Ultrasound system for tongue movement. The application of real-time ultrasound to investigations of tongue motion during speech was first described by Sonies and

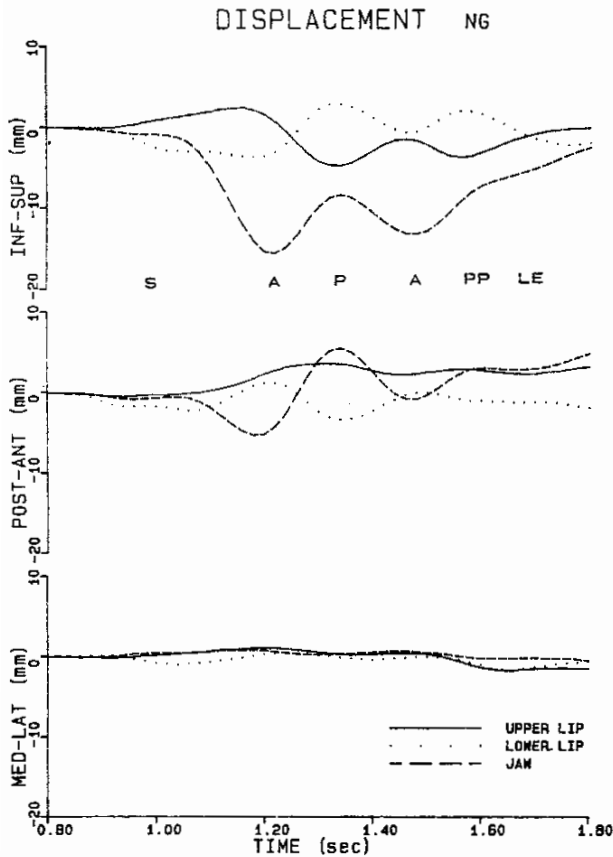


FIGURE 3. Upper lip, lower lip, and jaw displacements associated with one normal geriatric (NG) subject's single production of *sapapple*. The top graph displays movement in the superior (+) - inferior (-) direction; the middle graph displays movement in the anterior (+) - posterior (-) direction; and the bottom graph displays movement in the medial-lateral direction with positive values indicating movement to the subject's right and negative values indicating movement to the subject's left.

her colleagues (Sonies, Shawker, Hall, Gerber, & Leighton, 1981). Since that time, ultrasound imaging has been used to (a) visualize in detail the intrinsic soft tissues of the tongue and floor of the mouth (Gritzmann & Fruhwald, 1988; Keller, 1987; Shawker & Sonies, 1984; Shawker, Sonies & Stone, 1984a, b; Watkin & Washington, 1987); (b) characterize tongue shape during vowel production (Morrish, Stone, Shawker, & Sonies, 1985; Morrish, Stone, Sonies, Kurtz, & Shawker, 1984; Shawker, Stone, & Sonies, 1985; Stone, Morrish, Sonies, & Shawker, 1987; Stone, Shawker, Talbot, & Rich, 1988); and (c) obtain three-dimensional models of the vocal tract (Watkin & Rubin, in press). Perhaps the most important feature of ultrasound is that it has no known negative bioeffects and is harmless to human tissue. Because limits need not be set on the length of a study, large data samples can be acquired to investigate the effects of phonetic context or alterations of soft tissues on speech production. Furthermore, methods of quantifying a wide set of parameters relevant to speech can be collected

using digitization of x - y coordinates (Figures 4 & 5). (See Morrish et al., 1984, 1985; Stone et al., 1987, 1988.)

Ultrasound has been used to study tongue motion in elderly adults during speech (Sonies, Baum, & Shawker, 1984). Even though there were no perceptible acoustic changes between the speech of young and old subjects, considerable alterations were found in both tongue thickness and tongue position during production of selected phonemes. Although the implications of these data to normal aging are uncertain, we anticipate that future normative studies of aging will uncover whether or not these reported positional differences are related to older speakers' attempts to produce or maintain normal sounding speech.

INTRODUCTION: SWALLOWING IN AGING

Various instrumentation has been employed to amass a large body of work which indicates that, unlike speech, swallowing activity does indeed deviate markedly during the normal course of aging (Elliott, 1988; Shawker, Sonies, Stone, & Baum, 1983; Sheth & Diner, 1988; Sonies, Parent, Morrish, & Baum, 1988; Sonies, Stone, & Shawker, 1984). It is speculated that the normal aging process has a more pervasive effect on swallowing than on speech because the swallowing mechanism appears to have limited capability to compensate successfully for age-related changes in muscular tissue, sensory function, salivary flow, and other age-associated physiological alterations. Correspondingly, pathological conditions that affect the already diminished (aged) oropharyngeal mechanism may serve to all but eliminate the largely reflexive activity involved in swallowing. In fact, the incidence of swallowing disorders appears to increase with age, espe-

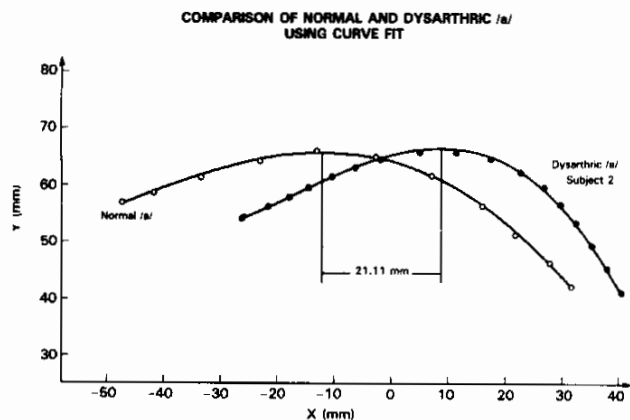


FIGURE 4. Ultrasound comparisons of tongue surface curvature in normal and dysarthric production of /a/ using curve fitting. Distance in mm is displayed on both the x (anterior/posterior) and y (inferior/superior) axis. Minus (-) numbers indicate anterior direction, (i. e., toward alveolum). The dysarthric subject produces /a/ with a more posterior retracted tongue posture and moves less than the normal subject, whose tongue has a more flattened posture with more extensive motion).

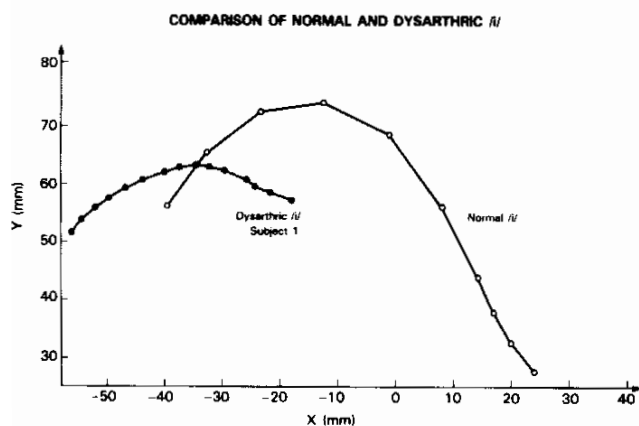


FIGURE 5. Ultrasound comparison of normal and dysarthric production of /i/. Distance in mm is displayed on both the x (anterior/posterior) and y (interior/superior) axis. Minus (-) numbers indicate anterior direction, (i.e., toward alveolum). Notice that the dysarthric subject barely retracts the tongue, keeping it bunched in a forward position whereas the normal production is highly sloped and posterior in the oral cavity).

cially for institutionalized elderly, and may reach 30% to 40% in nursing homes (Siebens, Trupe, & Siebens et al., 1986). More specifically, as one ages, the incidence of neurologic disorders increases, and it is well known that dysphagia is a concomitant of many of the common neurologic conditions, such as Parkinson's disease and stroke (Bucholz, 1987; Lieberman et al., 1980; Robbins, 1987; Robbins & Levine, in press; Robbins, Logemann & Kirschmer, 1986). With advanced age there are remarkable changes in the structure and biochemistry of neural and muscle tissues, and those changes negatively affect the force and rate of the coordinated activity needed to swallow and transport food (Aniansson, Hedberg, Henning, & Grimby, 1986; Brown, 1987; Gutmann, 1977; Oertel, 1986; Pradhan, 1980; Rosenheimer & Smith, 1985; Silberman, Finklebrand, Weiss, Gershon, & Renick, 1983). The elderly are predisposed to pharyngeal and esophageal pouches, diverticulae (Leese & Hopwood, 1986), higher incidences of dysmotility, and aspiration, in part, because the muscles of the circumoral area, pharynx, and esophagus lose their tonicity and ultimately atrophy (Baum & Bodner, 1983; Pelemans & Van Trappen, 1985; Sheth & Diner, 1988; Thompson & Keelan, 1986).

Ligamentous laxity especially affects the larynx by causing it to shift anteriorly and downward, thereby changing the tonicity of the upper esophageal sphincter and the shape of the esophagus itself (Sheth & Diner, 1988). Esophageal motility disorders and gastric reflux are probably the most common symptoms of dysphagia in the elderly (Pelemans & Van Trappen, 1985; Sheth & Diner, 1988; Steinheber, 1985; Thompson & Keelan, 1986). Age-related changes in muscle activity are exacerbated by systematic changes that occur with advanced age. For example, reductions in salivary flow, commonly associated with xerostomia or Sicca syndrome, appear to be more common with advanced age and serve to impede seriously the oral initiation of swallowing (Fox, van der

Ven, Sonies, & Weiffenbach, 1985; Hughes et al., 1987). In addition, the effects of medication commonly taken by the elderly can substantially reduce salivary flow (Darley, Aronson, & Brown, 1975; Helm et al., 1982; Helm, Dodds, & Hogan, 1987; Kapila, Dodds, Helm, & Hogan, 1984; Sreebny & Schwartz, 1986). Poor dentition and missing teeth are yet other factors common in aging that may cause changes in food preferences, negatively affecting nutrition as well as the ability to prepare food to a swallow-ready consistency (Feldman et al., 1980; Heath, 1982). To compensate partially for inadequate dentition, Price and Darvell (1981) suggest that elderly edentulous persons use the tongue during oral preparation of the bolus. Numerous other conditions could be mentioned that might affect swallowing in the elderly (Gray, 1988; Klinger & Strang, 1987; Moleman et al., 1986; Sonies, 1987), but our purpose here is to be selective, rather than exhaustive.

The effects of aging on the selected temporal characteristics of oropharyngeal swallowing in normal adults were reported recently by Sonies and colleagues (1988) at the NIH Warren G. Magnuson Clinical Center. Ultrasound imaging was used in their study. A group of healthy, unmedicated subjects ranging in age from 18 to 74 years were asked to perform sequential dry (without a bolus) and wet (with a water bolus) swallows. The previously mentioned advantages of ultrasound imaging provided a technique to quantify otherwise obscure observations of hyoid excursion during swallowing. Specifically, objective temporal measures that included onset of hyoid motion and duration of hyoid movement from rest to maximum anterior displacement were able to be obtained during dry and wet swallows. From those data, three interesting findings emerged: (a) both male and female older subjects' swallows were longer in duration than those of younger subjects for both dry and wet swallows; (b) older women (55+ years) presented with significantly longer swallows than any other subgroup of subjects under investigation; and (c) a unique pattern of multiple hyoid gestures, never seen to date in younger normals, typified 64% to 80% of subjects above age 55. It is speculated that those extra hyoid gestures may be reflective of the subtle neuromuscular changes previously mentioned or that the hyoid and base of the tongue are less firmly supported by the floor muscles of the mouth, which are known to lose tonus with age.

Instrumentation and Procedures for Measurement of Swallowing

Instrumental procedures used to investigate swallowing can be separated into two general categories: invasive and noninvasive. *Invasive* procedures require insertion of a catheter or tube transnasally or transorally, insertion of electrodes or needles, or, perhaps unique to our view, exposure of the subject to some degree of radiation. These procedures generally provide information on the oropharynx and may include the esophagus. Some invasive procedures may be used to delineate anatomy, while others may

be employed to describe physiologic events. *Noninvasive* procedures are those that do not require insertion into tissues or the body cavities, or expose the subject to radiation, and minimally interfere with function. The noninvasive research procedures we will present are unique in that they will allow large samples of kinematic data to be collected in one or more of the three dimensions while focusing on the interactions among several structures.

Although instrumentation has undergone a continual process of refinement and enhancement for clinical use, the analogous development of objective, quantifiable measures used to analyze data collected from those techniques is just emerging for research (Humphreys et al., 1987; R. Nelson, personal communication, August 1988). We will discuss the latest advancements in both technological and procedural approaches which we believe can best characterize swallowing behavior.

Invasive Procedures for Swallowing

Cineradiography and videofluoroscopy. Cineradiography was the standard procedure used to study swallowing for both clinical and research purposes until very recently when concern over radiation effects coupled with improved technology made videofluoroscopy the procedure of choice for studies of the dynamic aspects of swallowing. Radiographic techniques necessitate the ingestion of radiopaque substances so that swallowing activity throughout the entire gastrointestinal system can be visualized. The oropharynx was largely ignored in the study of swallowing until recently when the standard videofluoroscopic procedure was modified by Logemann (1983) to study the oral and pharyngeal phases of swallowing with small amounts of barium of different consistencies. One advantage of videofluoroscopy is that it permits observations of swallowing to be recorded and stored on videocassette, thus enhancing its application as a clinical tool. Unfortunately, this one advantage is alone insufficient to thoroughly study the complex nature of swallowing dynamics. In recognition of this limitation, many investigators are interfacing several instrumental techniques (e.g., manofluorography, electromyography, scintigraphy, and videofluoroscopy) in an effort to observe and understand more fully the intricacies of swallowing. It is these simultaneous data acquisition techniques that appear to have greatest potential for studying the process of swallowing across the life span because they allow visualization of the rapid temporospatial events in the oropharynx that are directly responsible for bolus transport and transformation.

Videofluoroscopic research has provided us with descriptive patterns of dysphagia associated with a variety of conditions (Blonsky, Logemann, Bosches, & Fisher, 1975; Leopold & Kagel, 1983; Logemann, 1988; Robbins, Logemann, & Kirschner, 1986). The majority of this work has focused on the temporal order of the various events during the course of oropharyngeal activity (Curtis, Cruess, Dachman, & Maso, 1984; Logemann, 1987; Sivit, Curtis, Crain, Cruess, & Winters, 1988). Lof & Robbins

(1988) have recently drawn on this body of information to discern more salient temporal parameters of the swallow (e.g., response and delay times from initiation of bolus movement to initiation of maximal hyoid elevation). Interestingly, even these recent measures are being extended to include timing of laryngeal closure (e.g., ventricular and vocal-fold adduction) and laryngeal elevation during swallowing (J. Logemann, personal communication, August 20, 1988).

One major concern of videofluoroscopic studies is the lack of uniformity in both technological (bolus size, field of exposure) and measurement (head vs. tail of bolus) procedures, which makes direct comparisons of subjects across studies, or even within the same study, difficult if not impossible. Computerized digitization of the image could reduce some of this methodologic error (Humphreys et al., 1987); however, in our view, the critical issue is the development of widely accepted, standardized procedures that would permit similar comparisons to be made among different laboratories. Development of such standardized procedures is beginning to occur, as evidenced by studies determining the relationship of bolus characteristics (size and consistency) and swallowing in normal aging persons (Dodds et al., 1988; Kahrilas, Dodds, Dent, Logemann, & Shaker, 1988; Robbins & Levine 1988). Some investigators have reported statistical relationships between bolus size and extent of hyoid excursion, while others have noted trends for the same events in both normal and pathological populations (Dodds et al., 1988; Hamlet, Jones, Mathog, Bolton, & Patterson, in press; Rasley & Logemann, 1987; Tracey & Logemann, 1987; Tracey, Logemann, & Kahrilas, 1987). Although these investigators have used a variety of techniques to measure the effects of bolus size on the swallow, there appears to be general agreement with the finding that the ability to handle a relatively large-sized bolus (i.e., 20 cc) is negatively affected by age. We would like to emphasize the importance in future research of using either a standard bolus size or a series of graded increments in bolus size to investigate the effects of aging on swallowing.

Manofluorography. The simultaneous acquisition of manometric and videofluoroscopic data has been called manofluorography. This procedure, first reported in 1986 by McConnel, Mendelsohn, and Logemann, provides an excellent research tool that allows for the comparison of patterns of fluid pressure changes (i.e., bolus) in the oropharynx to be made while simultaneously visualizing dynamic aspects of bolus transport. In spite of several constraints noted with this procedure (e.g., transnasal or transoral placement of a catheter and potential measurement error related to variation in catheter position), this technique holds particular promise in the future study of swallowing (Dodds et al., 1975). Manofluorography uniquely provides for calculation of tongue driving pressure, which, to our knowledge, has been implicated for the first time as a critical factor in swallowing. Tongue driving force, "a measure of pressure produced by the tongue applied directly onto the bolus tail in the oropharynx" (see McConnel, 1988, p. 72), may be more important

than pharyngeal peristalsis in moving the bolus through the pharynx in normal subjects. If substantiated, this hypothesis should add an important new direction to future swallowing research. Results of additional studies with disordered patients have implicated the importance of collecting tongue driving force measurements simultaneously with observations of laryngeal elevation and closure in attempting to understand pathological swallowing patterns (Hamlet et al., in press; McConnel, Mendelsohn, & Logemann, 1987; McConnel, 1988; McConnel, Cerenko, Hersh, & Weil, 1988; McConnel, Cerenko, Jackson, & Hersh, 1988; Mendelsohn & McConnel, 1987; Robbins, Stancher, Hamilton, & Levine, 1987).

Scintigraphy. Scintigraphy, a relatively new radionuclide procedure, has been paired with videofluoroscopy and also offers promise as a method for measuring the movement of the bolus. The absorption rate of an orally ingested bolus mixed with 200–500 mCi of Technetium 99 (T-99) is measured over time. As the bolus is ingested, scintigraphy is used to locate its position grossly in the pharynx and larynx, and, if aspirated, in the trachea and lungs. Simultaneous use of videofluoroscopy allows for more precise observation of anatomical location and physiologic activity during transport of the bolus. This procedure reportedly emits less radiation than videofluoroscopy alone (Humphreys et al., 1987). Recent work by Hamlet and her colleagues indicated a substantial correlation ($r = 0.66$) between scintigraphy and videofluoroscopy when measuring pharyngeal transit time during swallows in the same subjects, thus establishing the validity of the technique (Hamlet, Patterson, Muz, & Jones, 1988). Although scintigraphy has been used to study the transit of the bolus through the esophagus (Kazem, 1972), the application of the technique to the study of bolus transit in the oropharynx is recent (Espinoza, 1986; Humphreys et al., 1987; Muz, Mathog, Miller, Rosen, & Borrero, 1987). One important advantage of scintigraphy is that it can be used to detect aspiration at any time after a bolus is ingested (Espinoza, 1986; Muz et al., 1987). It is one of the few procedures that can locate material that has passed into the tracheobronchial tree and quantify the residual amount of bolus. Particularly challenging is the application of this technology to monitor bolus flow with sufficient precision to establish accurate indices and critical lung tolerance levels of aspiration in the elderly. It is now possible to measure the amount of aspiration in the stoma of tracheostomized patients (R. Mathog, personal communication, August 22, 1988). As future research emerges and techniques are documented in the literature, application of scintigraphy can be made to the study of swallowing in aging.

Noninvasive Procedures: Swallowing

Ultrasound imaging. The application of ultrasound to the study of swallowing was a natural outgrowth of the previously mentioned studies of speech (see section on "Ultrasound System for Tongue Movement"). Because unique properties of ultrasound allow for visualization of

the coordinated movements of the tongue within the oral cavity without radiopaque enhancement or added stimulants, the technique is well-suited for application to elderly and, perhaps, infirm patients. The oropharyngeal swallow, bolus containment and transport, as well as tongue/hyoid interactions, can be studied naturally, dynamically, and repeatedly (Shawker, Sonies, & Stone, 1984a). Ultrasonic recordings appear to be the best method, in our view, for obtaining durational measures of the oropharyngeal swallow because that is the only technique that can noninvasively compare patterns of tongue/hyoid interaction with or without a bolus (Sonies et al., 1988; Stone & Shawker, 1986). Normal adults throughout the age span show a consistent pattern in which unstimulated (indigenous) swallows are longer in duration than stimulated (bolus) swallows using various size boluses. This difference in the timing of stimulated and unstimulated swallows is unaffected by normal aging (Sonies et al., 1988). Interestingly, this same comparison between stimulated and unstimulated swallows has been found to be aberrant in patients with Sjörger's disease (SD), a condition associated with reduced salivary flow (Caruso, Sonies, Fox, & Baum, 1988). Preliminary analysis of a subgroup of the SD population reveals that both stimulated and unstimulated swallows are abnormally long. Even more strikingly, in this same SD subgroup, duration of bolus (10 cc) swallows was longer than for nonbolus swallows—a pattern, rarely, if ever seen in normals.

As previously mentioned, the ability to investigate tongue movement synchronously with hyoid movement is an advantage of the ultrasound technique (Sonies et al., 1988; Stone & Shawker, 1986). By affixing pellets to the tongue's surface, specific point measurements of direction, rate, and extent of tongue/hyoid activity were determined (Shawker, Stone, & Sonies, 1985; Stone & Shawker, 1986). The onset of tongue activity was found to co-occur with transport of the bolus and the ascent of the hyoid. Furthermore, in studies of neurologically impaired patients, ultrasound studies revealed abnormal patterns of tongue activity and bolus transport (Shawker, Sonies, & Stone, 1984a). Of equal importance is the finding that impairments of tongue motion during swallowing are highly predictive of aspiration, and, thus, with further investigation, ultrasound studies could become a standard tool to identify, a priori, those patients who are at risk for pulmonary compromise (Sonies & Macrae, 1987). Our present interpretation of these findings appears to be in agreement with studies suggesting that tongue activity or force is critical to the initiation and completion of the entire oropharyngeal swallow (McConnel, 1988; Robbins, Stancher, Hamilton, & Levine, 1987; Sonies et al., 1988).

CONCLUSIONS AND IMPLICATIONS FOR RESEARCH IN SPEECH AND SWALLOWING DURING THE COURSE OF AGING

The majority of speech-related studies with the normal elderly population have investigated either sensory or

motor function, and relatively little attention has been focused on documenting how age-related sensory changes may affect motor responses in the speech articulators. Moreover, studies of speech in the aging population have compared oral movements of normal elderly to those of pathological elderly subjects. Unfortunately, in our view, there are relatively few studies with a sufficiently large number of subjects to establish a normative data base on the impact of aging over the life span on articulatory movements. Such studies would provide numerous insights into the effect of age on the sensorimotor control processes for coordinated orofacial movements.

In young adults, sensorimotor mechanisms underlying speech movement patterns have been investigated using unanticipated perturbations techniques (Folkins & Abbes, 1975, 1976; Gracco & Abbs, 1982; Kelso, Tuller, Bateson, & Fowler, 1984). Perturbation analyses involve testing sensorimotor contributions to control of particular motor acts by introducing an unanticipated error and examining the corrections that occur in response to that error. Specifically, to investigate sensorimotor control of speech gestures, some investigators have used a DC brushless torque motor to introduce unanticipated loads on the lower lip (Caruso et al., 1988; Gracco & Abbs, 1982, 1985). Those data have been used to (a) characterize both muscle activity and resultant articulator movement changes in response to the loads and (b) develop testable hypotheses regarding sensorimotor mechanisms underlying speech movement coordination. We would encourage applying the same techniques to the study of lip and jaw movements in the elderly in order to identify and quantify changes in the response characteristics of those sensorimotor actions as a function of aging.

Additionally, numerous developments in instrumentation for the acquisition of speech movement signals, as well as parallel advancements in signal digitization and processing, make the challenge of simultaneously obtaining and analyzing lip, jaw, and tongue movements more enticing than ever. The challenge, as we see it, is to interface already existing technology that would permit sufficiently high resolution to monitor articulatory movements without any exposure to X-rays. We are concerned with the cumulative effects of radiation exposure over the life span—even minimum exposure for research in either speech or swallowing (e.g., as documented with use in the X-ray microbeam system) may have harmful, unrealized long-term effects in the elderly. Simultaneous, non-radiated recordings of lip, tongue, and jaw activity would more completely unify our concept of how the major articulators in the supraglottal component of the speech production mechanism interdependently interact during complex coordinated speech movements. Moreover, application of this technology to the study of aging may indicate how subtle changes or decreases in function for one structure can be negated or minimized by compensatory activity in other structures. This approach for studies of the elderly is compelling in light of (a) findings in normal young adults that compensations are evidenced in an unperturbed articulator when another articulator is loaded (see Gracco & Abbs, 1985; Kelso et al., 1984;

Shaiman, Abbs, & Gracco, 1985), and (b) speculations that some pathologies differentially impair orofacial function (see Abbs, Hunker, & Barlow, 1983). In essence, we believe the focus of speech research is shifting from one that characterizes function of a single independent structure to that of identifying the sensorimotor mechanisms and modeling the events involved in programming and executing movements of many structures.

Similarly, never before has the study of swallowing contained such promise for the elderly. Many centers in both the United States and Europe are integrating multidisciplinary talents and interests for the purpose of scrutinizing as yet unsolved questions regarding the oropharyngeal swallow. The study of swallowing is coming of age with the continual development of objective, quantifiable measures in parallel with interfacing techniques to study the same structures during both speech and swallowing. In any rapidly progressing field, it is difficult for scientific and technological advances to develop in pace. At present it appears that technological advances outweigh our ability to interpret the complex patterns derived from the instrumentation. We are struck with the similarity of this observation to a statement made during a period when speech technology was rapidly evolving: "to this point (in time), the ability to transduce and record physiological indices of speech production has far outdistanced any comparable ability to measure, analyze and summarize these data." (Abbs & Watkin, 1976, p. 72)

We believe that future investigative efforts should focus on the development of established, quantified, and standardized indices of swallowing rather than developing new instruments for data acquisition. The imminent charge to this field is the edification of normative data bases of swallow behavior throughout the human life span. It is these data bases that will overwhelmingly add power to the interpretation and synthesis of normal and pathological manifestations involved throughout the continuous process of swallowing. The accumulation of such knowledge will greatly facilitate pioneering efforts in detailing the complex neural mechanisms underlying swallow behavior.

ACKNOWLEDGMENTS

We wish to acknowledge the contributions of the following individuals: J. W. Dodds, Sandra Hamlet, Thomas Kepple, Jerri Logemann, Robert Mathog, Fred McConnel, Douglas McGuire, Malcolm McNeil, Richard Nelson, Joanne Robbins, Steven Stanhope, Carolyn Tylenda, Ken Watkin, James Weiffenbach. The authors also would like to express appreciation to Helen Khan for assistance in preparation of the manuscript.

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F. HEARING SCIENCE TRACK

Chapter 13

AGING: STRUCTURAL AND PHYSIOLOGICAL CHANGES OF THE AUDITORY AND VESTIBULAR MECHANISMS

AINA JULIANNA GULYA

Georgetown University, Washington, DC

Aging appears to be an inescapable fate of all biological systems, including those of man. The sensorineural elements of the auditory and vestibular systems, as well as the neurons of their central pathways, are classified as fixed, postmitotic cells (Nadol, 1980). As such, they are incapable of further division, and their lifespans are determined by the rate of progression of senescence to cell death (Kenney, 1982a).

The cellular mechanisms underlying aging have been variably hypothesized as: (a) a genetically programmed phenomenon with "death" genes sequentially terminating certain cellular processes cumulatively manifesting as aging; (b) cumulative errors in the repair or translation of DNA and RNA, eventually proving catastrophic to cell survival; (c) the elaboration of a pituitary "killer" hormone; or (d) the formation of free radicals (elements with an unpaired electron) which, among other effects, can disrupt membrane and enzyme function, interfere with intracellular information transfer, or result in the formation of the membrane-bound "aging pigment" (Kenney, 1982a).

The physiologic consequence of aging in the auditory system is manifested as presbycusis, while, in the vestibular system, "disequilibrium of aging" develops. In the human temporal bone, it is infinitely difficult to distinguish those changes that can be attributed solely to aging from those related to genetic factors, toxins, climate, diet, noise exposure, or disease. Compounding the difficulty are the variable patterns of "degeneration" and their variable degree of presentation in the individual. Nonetheless, it is only by observation of the aged human temporal bone that testable theories regarding the manifestations of aging can be developed.

The remainder of this discussion will review the histopathologic and ultrastructural alterations associated with aging, in both auditory and vestibular systems, and will attempt to correlate, to the extent permitted by available evidence, the physiologic (functional) consequences of those alterations.

The changes of aging in the ossicular chain, although visible (Gussen, 1971), do not appear to contribute any

significant conductive component (Etholm & Belal, 1974) and are not a significant consideration in the study of presbycusis. Thus, it has been within the cochlear and retrocochlear structures that the histopathological correlates of presbycusis have been sought.

Within the cochlea, morphologic alterations in organ of Corti, especially its sensory cells, the spiral ganglion cells and their dendritic processes, the stria vascularis, and the basilar membrane, have been particularly scrutinized for their roles in presbycusis and attempts to correlate specific audiometric configurations with specific histopathologic patterns (Schuknecht, 1955, 1964, 1974) have been relatively successful.

SENSORY PRESBYCUSIS

A gradually progressive degeneration of the organ of Corti, particularly the outer hair cells (OHCs), has been associated with the process of aging (Figure 1). Beginning as early as infancy (Johnsson & Hawkins, 1972a), but more noticeably by middle age (Schuknecht, 1964), the organ of Corti degenerates; however, the process advances so slowly that even in the very elderly only a few millimeters of the basal cochlea are affected (Schuknecht, 1974). Upon light microscopic examination, in initial stages, the organ of Corti is distorted and flattened (Schuknecht, 1974). With microdissection and surface preparation techniques applied to the osmium tetroxide treated labyrinth (Bredberg, 1968; Johnsson & Hawkins, 1972a, 1977), a loss of the OHCs is documented as most severe in the third row (outer most) and least severe in the first row. Breaks in the reticular lamina are filled by the phalangeal scars of Deiters' cells. With progression, the inner hair cells (IHCs) and supporting cells are lost, and eventually the entire organ of Corti disappears, to be replaced by a mound of epithelial cells (Schuknecht, 1974). A secondary neuronal degeneration occurs, variably attributed to a loss of the supporting cells, damage to distal neural processes, or the loss of the IHCs. Spiral fibers persist, although radial fibers degenerate, if the

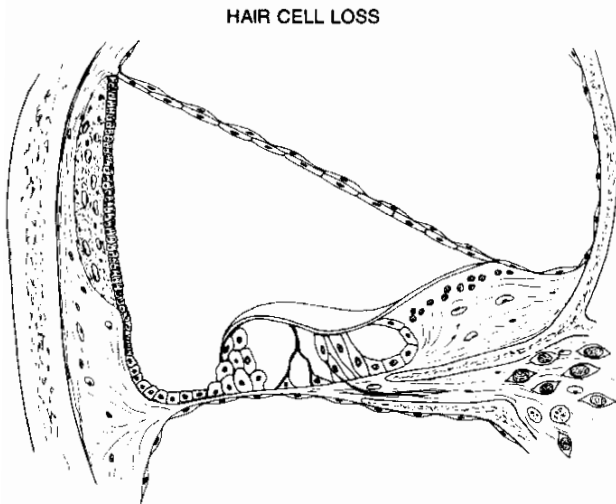


FIGURE 1. Line drawing of the outer hair cell loss associated with sensory presbycusis (compare to Figure 7).

organ of Corti degeneration is confined to the lower third of the basal turn (Johnsson & Hawkins, 1972a).

OHC loss may occur at the apex as well (Bredberg, 1968; Johnsson & Hawkins, 1972a, 1977), but appears to be accompanied by little, if any, neural degeneration. In contrast, animal studies (Bhattacharyya & Dayal, 1985; Dayal & Bhattacharyya, 1986a,b), although also showing hair cell loss with aging in a variety of species, suggest that the process extends from a beginning point in the cochlear apex.

Ultrastructural changes putatively preceding complete cellular destruction include lipofuscin accumulation and giant cilia formation (Soucek, Michaels, & Frohlich, 1987).

Lipofuscin is a strongly autofluorescent, golden-brown granular pigment that seems to accumulate progressively in a variety of aging cells, including neurons (Ishii, Murakami, Kimura, & Balogh, 1967; Sun et al., 1988) and hair cells (Schuknecht, 1974) among others. It is thought to represent insoluble end products of metabolism that gradually accumulate in the lysosomal fraction (Ishii et al., 1967). No lipofuscin is demonstrable in the inner ears of humans less than 6 years of age (Ishii et al., 1967), but with age it progressively accumulates, particularly in the subcuticular portions of the cochlear hair cells; the apical zones of Hensen's, Claudius', and pillar cells; and the cells of the spiral ganglion, as well as in the apices of the vestibular supporting and sensory cells and the neurons of Scarpa's ganglion (Ishii et al., 1967; Raafat, Linthicum, & Terr, 1987). Increasing amounts of lipofuscin have also been correlated with a greater tendency for autolysis (Gleeson & Felix, 1987) and with the degree of hearing loss (Raafat et al., 1987). It thus seems that such pigment-laden cells are poorly functional, if at all, and may be physiologically "feeble."

Schuknecht (1955, 1964, 1974) has coined the term *sensory presbycusis* to describe that form of presbycusis

characterized by the loss of hair cells in the basal cochlea. Typically, the onset of the hearing loss is in middle age, and it manifests (Figure 2) as a bilaterally symmetric, abruptly dropping threshold curve with the maintenance of good discrimination scores.

NEURAL PRESBYCUSIS

Loss of neurons and nerve fibers out of proportion to organ of Corti depletion has also been correlated with presbycusis (Jorgensen, 1961; Schuknecht, 1955, 1964; Suga & Lindsay, 1976). Although the basal turn displays the most marked losses, the neuronal population often is depleted throughout the cochlea (Figure 3) (Schuknecht, 1974). The surface preparation technique enables excellent visualization of the degree of loss of afferent nerve fibers, although neuronal bodies themselves cannot be counted (Bredberg, 1968; Johnsson & Hawkins, 1972a, 1977). The neural changes have been ascribed to compressive effects exerted by "hyperostotic" formations at the cribose area of the base of the modiolus (Stern-Padovan & Vukiceric, 1980), but this theory has not gained wide acceptance. Rather, it is thought (Hansen & Reske-Neilsen, 1965; Jorgensen, 1961; Schuknecht, 1974; Suga & Lindsay, 1976) that the spiral ganglion depletion is a manifestation of the same process of neuronal senescence and death that is seen in the central auditory pathways.

The mechanism of cell loss is unclear, although lipofuscin accumulation has been documented (Raafat et al., 1987). In aging mice, four stages of spiral ganglion cell degeneration have been noted: incipient demyelination, contact and fusion, clumping, and resorption resulting in fluid-filled spaces (Cohen & Grasso, 1987). Pauler, Schuknecht, and Thornton (1986), in a light microscopic study, directly correlated the innervation density of the 15- to 22-mm region of the cochlea with capacity for speech discrimination; however, the variability of the

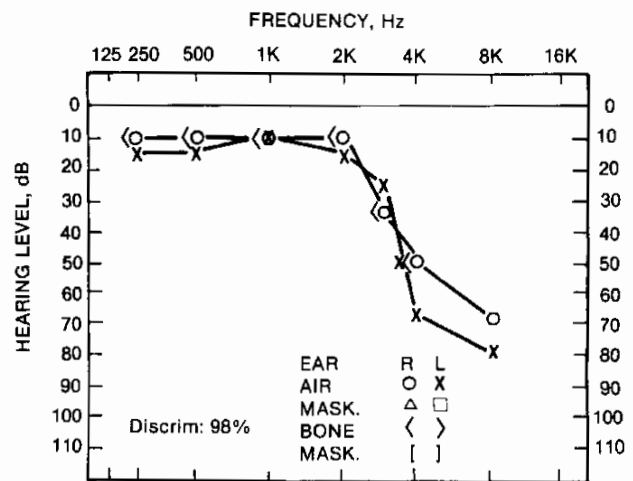


FIGURE 2. Audiogram typical of sensory presbycusis.

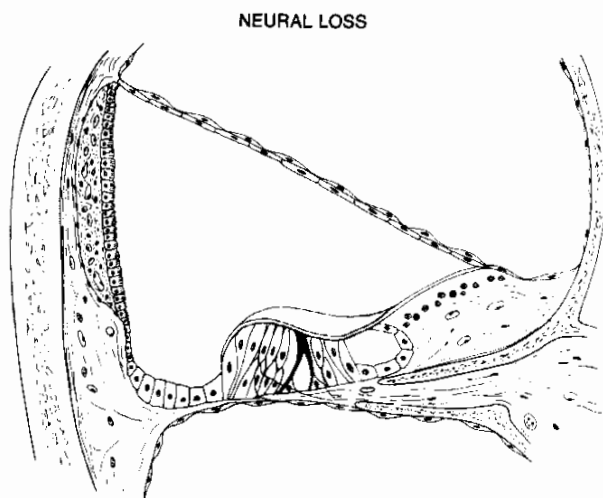


FIGURE 3. Loss of cochlear neurons and their fibers is believed to underlie neural presbycusis (compare to Figure 7).

effect of neuronal loss on speech discrimination scores forced consideration of other possibly influential factors, including ultrastructural changes (Nadol, 1979).

Nadol (1979) conducted an electron microscope (EM) study of two temporal bones with typical neural presbycusis. Although hair cells were normal, the neural fibers, particularly those in the basal turn, showed degenerative changes, including a decreased number of synapses at the bases of the hair cells, "accumulation of cellular debris in the spiral bundles, abnormalities of the dendritic fibers and their sheaths in the osseous spiral lamina, and degenerative changes in the spiral ganglion cells and axons" (Nadol, 1979). The supporting cells enveloping dendritic twigs contained vacuoles filled with pleomorphic vesicles and granules. "Myelin figures" were found both in unmyelinated afferent dendritic fibers and in spiral ganglion cells and their surrounding cells. Myelin sheath disorganization, especially at the paranodal areas and the regions near the clefts of Schmidt-Lanterman, was noted in both dendritic and axonal fibers. Such alterations in the myelin sheath would be expected to interfere with saltatory conduction and result in delay and loss of energy as conduction instead passes through the cell body ("Discussion," 1987).

The term *neural presbycusis* (Schuknecht, 1974) has this neural degeneration as its histopathologic correlate and is manifested audiometrically (Figure 4) by a loss of speech discrimination out of proportion to the loss of pure-tone thresholds. Its onset is determined by predominantly genetic factors (Schuknecht, 1974), and it becomes manifest only when the remaining neural elements no longer can transmit and encode acoustic stimuli effectively, usually in late life.

METABOLIC PRESBYCUSIS

Patchy atrophy of the stria vascularis, especially in the middle and apical turns (Johnsson & Hawkins, 1977) is

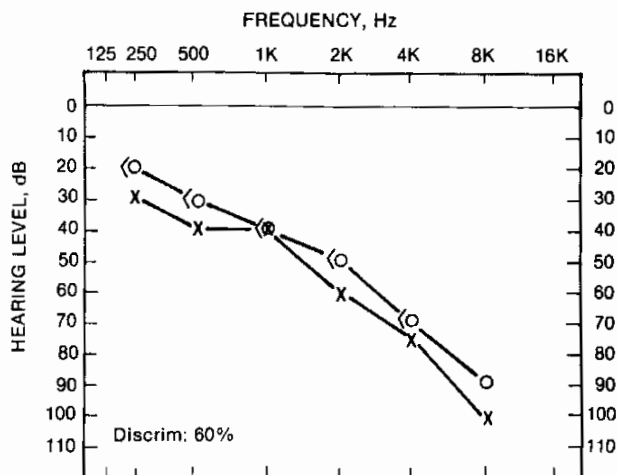


FIGURE 4. A downward sloping audiogram with speech discrimination scores somewhat worse than expected is suggestive of neural presbycusis.

regarded as a phenomenon of aging with relevance to presbycusis (Figure 5). Functionally, the stria is regarded as (Schuknecht, 1974): (a) the source of the positive 80-mV endocochlear potential; (b) a site of endolymph formation; (c) the site of oxidative metabolism, which generates the energy essential for cochlear function; and (d) the regulator of the ionic gradients of the inner ear fluids (Pauler, Schuknecht, & White, 1988). Disruption of any of these physiologic processes logically would be expected to result in hearing loss.

The precise precipitant of the degenerative changes in the stria remains undetermined, although Jorgensen (1961) related the capillary wall thickening noted in the stria to its atrophy. More recently, Johnsson and Hawkins (1977) have closely related "devascularization" of the lateral wall of the cochlea, as noted in phase-contrast

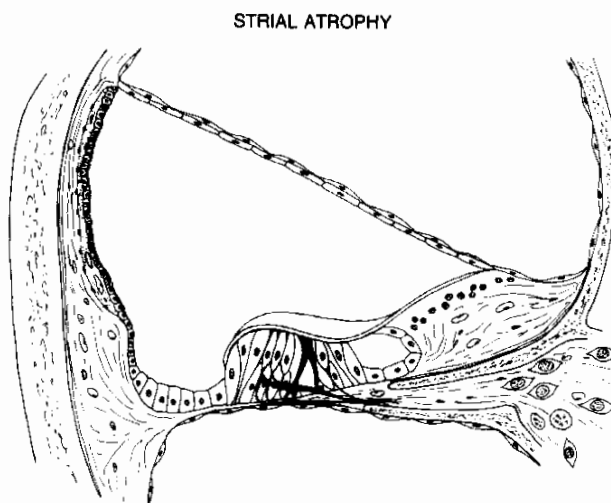


FIGURE 5. Atrophy of the stria vascularis appears to be related to metabolic presbycusis (compare to Figure 7).

microscopic examination of the aging ear, with atrophy of the stria vascularis and spiral ligament. Alternatively, Pauler et al. (1988) suggest that there is a genetically determined predisposition for early cellular decay.

Upon EM examination (Schuknecht, 1974), the marginal cells show the most marked alterations, although all three layers can be involved. The stria may be reduced to a mere strip of basal cells along the endolymphatic space (Kimura & Schuknecht, 1970). Secondary hair cell loss is a disputed consequence of stria atrophy (Johnsson & Hawkins, 1977; Pauler et al., 1988). Computer-aided morphometric techniques have been used to demonstrate a statistically significant relationship between stria atrophy and hearing loss (Pauler et al., 1988).

The term *metabolic presbycusis* (Hashimoto & Schuknecht, 1987; Schuknecht, 1964, 1974; Schuknecht & Ishii, 1966) is used to describe the flat audiometric configuration (Figure 6) that reflects stria atrophy; it begins its slowly progressive course in the third to sixth decades of life, and it is characterized by excellent speech discrimination, often remaining normal until the loss is greater than 50 dB.

MECHANICAL PRESBYCUSIS

Disruption of the motion mechanics of the cochlear duct has been hypothesized to explain the finding of presbycusis unaccompanied by any cochlear sensorineural defect upon histopathologic exam (Schuknecht, 1964) (See Figure 7). Structural alterations of the basilar membrane in particular (as well as deterioration of the spiral ligament) have been documented and may account for some hearing loss. Mayer (1919-1920) reported calcification of the basilar membrane while Crowe, Guild, and Polvogt (1934) demonstrated hyalinization in addition to calcification. Nomura (1970) described a "lipidosis" of the basilar membrane (deposition of neutral fat and cholesterol in the pars pectinata). Nadol (1979) documented a marked thickening of the basilar

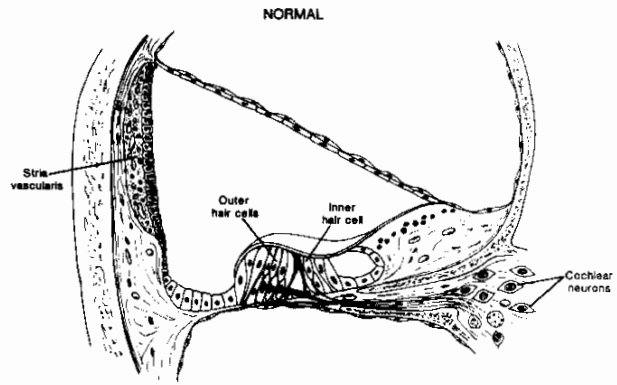


FIGURE 7. The cochlea of a patient with cochlear conductive presbycusis presents no abnormal findings by light microscopic examination.

membrane in the basal 10 mm of the cochlea, resulting from an increased number of fibrillar layers.

Alternatively, atrophy of the spiral ligament, progressive from onset in childhood, leads to an altered configuration of the cochlear duct or even, in extreme cases, to disruption of the lateral wall of the cochlear duct (Schuknecht, 1974). Such changes could conceivably alter cochlear motion mechanics (Schuknecht, 1974).

The hearing loss hypothesized to stem from these changes in the basilar membrane and spiral ligament is variably termed *mechanical* (Schuknecht, 1964) or *cochlear conductive presbycusis* (Schuknecht, 1974). It is characterized (Figure 8) by a downward-sloping threshold curve; discrimination scores vary inversely with the steepness of the slope.

Although pure forms of the various patterns of cochlear degeneration occur, they may also appear in a variety of combinations, resulting in variable audiometric configurations.

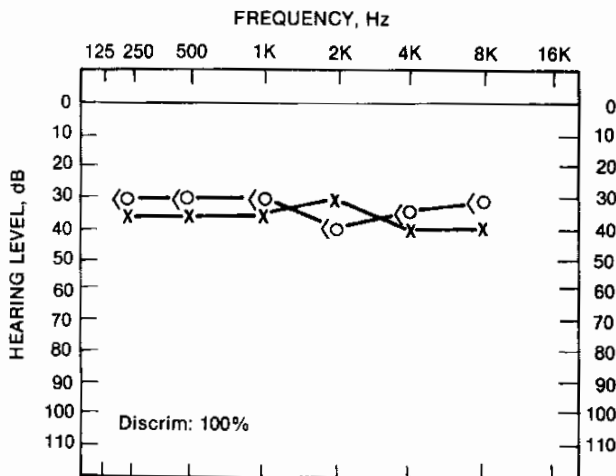


FIGURE 6. Metabolic presbycusis typically manifests a "flat" pure-tone curve with excellent speech discrimination.

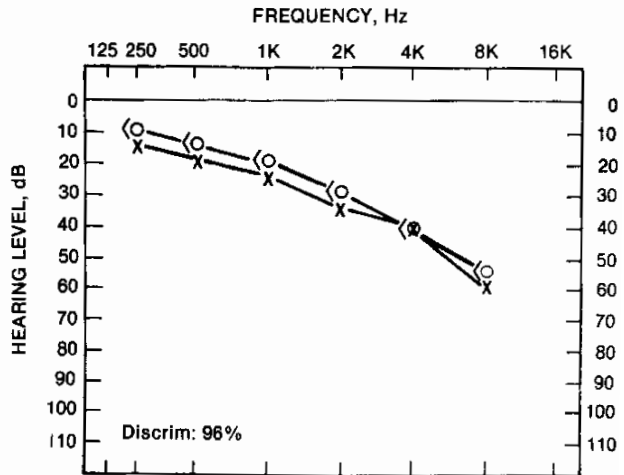


FIGURE 8. A gently sloping downward curve is associated with a good speech discrimination score in this audiogram representative of cochlear conductive presbycusis.

CHANGES IN BRAIN CELLS

It has been assumed that pathologic alterations of aging could affect the central auditory pathways. Schuknecht (1955, 1964, 1974) related the spiral ganglion cell loss of neural presbycusis to similar changes in the central nervous system (CNS), but corroborative evidence has been slow in coming.

Brody (1955) showed that with aging from birth to 95 years, there is a progressive depletion of cellular population, but it was not uniform throughout the cerebral cortex. Of all areas studied, the superior temporal gyrus manifested the greatest decline in cell number, dwindling from an average population of nearly 4,000 cells in the newborn to only 1,100 cells in the 70- to 95-year-old population.

Data regarding loss of brainstem elements are contradictory. It has been reported (Brody, 1985; Kenney, 1982b) that there is no apparent loss of cells except in the locus ceruleus, a region noted for high neuronal norepinephrine concentration and extensive arborization to the cerebral cortex, cerebellum, brainstem, and spinal cord (Brody, 1985). Reported changes in the central auditory structures related to aging have included (a) atrophy and degeneration of ganglion cells in the ventral cochlear nucleus (Arnesen, 1982; Dublin, 1986; Kirikae, Sato, & Shitara, 1964) and medial geniculate body, with a variable admixture of degenerative cells among the relatively normal cells of the superior olivary nucleus and the inferior colliculus (Kirikae et al., 1964); (b) dorsal cochlear nucleus degeneration (Arnesen, 1982; Hansen & Reske-Neilsen, 1965), with accumulation of corpora amygdala in the inferior colliculus (Hansen & Reske-Neilsen, 1965); (c) degeneration, edema, and fragmentation of myelin throughout the auditory system (Dublin, 1986; Hansen & Reske-Neilsen, 1965); and (d) lipofuscin accumulation (Hansen & Reske-Neilsen, 1965; Kirikae et al., 1964; Konigsmark & Murphy, 1972).

In contrast, Konigsmark and Murphy (1972) provide evidence suggesting that there is no neuronal loss in the ventral cochlear nucleus with age, but that there is an initial increase in its volume in the early decades, with a decrease beyond the fifth decade; the secondary volume loss was not related to neuronal loss but to other parenchymal changes (e.g., loss of axis cylinders, of myelin, of glial cells, of blood vessels, or of extracellular space). Studies in the aging rat fail to reveal any evidence of cell loss in the cochlear nucleus, although degenerative changes are noted occasionally by EM (Feldman & Vaughan, 1977), and cell loss, associated with loss of calyces terminals, has been detected in the medial nucleus of the trapezoid body (Casey, 1986).

RELATION OF HEARING DEFICITS TO SPECIFIC CENTRAL AUDITORY CHANGES

It has been difficult to assign specific functional deficits to specific changes in the central auditory pathways,

except when gross lesions are present; peripheral hearing loss is an important confounding factor in assessing central auditory function. Thus, while poor performance in the elderly population has been documented for the competing sentence test (Welsh, Welsh, & Healy, 1985), the low-pass filtered speech test (Kirikae et al., 1964; Welsh et al., 1985), the binaural fusion test (Welsh et al., 1985), the rapidly alternating speech perception test (Welsh et al., 1985), and the compressed speech test (Welsh et al., 1985), strict neuroanatomical correlates are lacking.

VESTIBULAR SYSTEM CHANGES

The study of the aging of the vestibular system is an enormously complex task, compounded by the system's myriad of functional interconnections in the CNS. Degenerative alterations are not uniformly distributed among the five components, but appear to be particularly prominent in the cristae ampullares and the macula of the saccule, with relatively fewer changes seen in the macula of the utricle. The structures that alter with age, in a fashion similar to that seen in the cochlea, are the sensory cells, the supporting cells, the first order neurons, and the afferent nerve fibers; in addition, in the vestibular system, the otoconia undergo morphologic alterations with aging, and those changes have functional import.

With modification, the surface specimen technique has been used to evaluate changes in the hair cell populations of the cristae and maculae (Rosenhall, 1972a,b, 1973; Rosenhall & Rubin, 1975). Up to the age of 40 years, there is no demonstrable change in the hair cell population; after that age (Rosenhall, 1972a), however, there is a significant decline, culminating in an average of 40% decline in total hair cell population of the cristae, which generally is distributed evenly among the cristae in the age 70 and older population. There is great individual variation in the loss, with some showing as much as a 60% loss. The central area of the summit of the cristae is particularly affected in comparison to the periphery (Rosenhall, 1973). Discrimination between Type I and Type II hair cells is not reliable with the surface preparation technique (Rosenhall, 1973).

By EM study (Engström, Bergström, & Rosenhall, 1974; Ishii et al., 1967; Rosenhall & Rubin, 1975), changes reminiscent of those in the cochlear system have been identified. Thus, accumulation of lipofuscin is detected in the sensory and supporting cells of the aged vestibular labyrinth, particularly in the Type I hair cell. Cilial disarrangement, fusion, and the formation of giant cilia or blebs have also been reported (Engström, Ades, Engström, Gilchrist, & Bourne, 1977; Rosenhall & Rubin, 1975). Loss of sensory hairs in aged individuals has been attributed variably to preparation artifact reflecting an increased fragility of the attachment of the stereocilia to the cuticular plate or to chemical changes in the aging cupula that cause the cilia to become tethered in the canals of the cupula (Rosenhall & Rubin, 1975). Laminated structures (Engström et al., 1977) in sensory and

supporting cells, which have a direct relationship to the cuticle and reticular membrane, increase in number with increasing age. Vesicular structures appear in increasing numbers with age, especially in the supporting, but also in the sensory, cells (Engström et al., 1977). Long-spaced collagen ("luse-bodies") is found in the loose tissue beneath the sensory epithelium (Engström et al., 1977; Gleeson & Felix, 1987; Spoedlin, 1970).

Such documented hair cell changes in the cristae may underlie the symptoms of ampullary disequilibrium of aging (Schuknecht, 1974). Affected individuals note a persistent sensation of rotation with quick, angular movements of the head; although the hallucination is usually momentary, subsequent unsteadiness may persist for hours (Schuknecht, 1974). Supporting the hypothesis that this dysfunction derives from visualized degenerative changes in the ampullary mechanism are studies suggesting that there is a decreased response to caloric and rotational stimuli in the healthy aged population (Bruner & Norris, 1971; Karlsen, Hassanein, & Goetzinger, 1981; Peterka, Black, Newell, & Schoenhoff, 1987; Wall, Black, & Hunt, 1984).

Changes in the sensory cell population of the maculae have also been observed with the modified surface preparation technique (Rosenhall, 1972b, 1973; Rosenhall & Rubin, 1975). In individuals over 40 years of age, a decrease in the hair cell population becomes evident, averaging a 20-30% reduction in both the saccule and the utricle in those over age 70 (Rosenhall, 1973; Rosenhall & Rubin, 1975). The degeneration appears to be distributed equally over the entire macula, without any predilection for the striola (Rosenhall, 1973).

By EM study (Rosenhall & Rubin, 1975), apical osmiophilic inclusions, particularly in the Type I hair cell, are noted in the maculae. The macular striola appears as a dark stripe in old individuals because of such inclusions (Rosenhall & Rubin, 1975). The ciliary loss affects the hair cells of the maculae to a lesser extent than those of the cristae (Rosenhall & Rubin, 1975).

Otoconial degeneration is progressive with aging. A decreased number of otoconia are noted in middle and advanced age (Ross et al., 1976); the decrease is more pronounced in the saccule than in the utricle. A specific pattern of degeneration has been demonstrated in the saccule (Ross et al., 1976). Beginning posteriorly and proceeding anteriorly along the macula, degeneration of the otoconia progresses from pitting to the assumption of a fibrous appearance; the midportion disappears, eventually resulting in an otoconium fragmented into two parts (Ross et al., 1976).

Macular disequilibrium of aging has been related to degenerative changes in the otolithic organs (Schuknecht, 1974). Individuals note vertigo upon changes of head position with respect to gravity (Schuknecht, 1974) and, when arising from bed, find that they must rest on the edge of the bed before continuing to move up and about. Saccular degeneration has been noted in association with cochlear changes of aging (Schuknecht, Igarashi, & Gacek, 1965).

Deposits, presumably of a specific gravity greater than endolymph, have been documented on the cupula of the posterior semicircular canal. These deposits are thought to represent insoluble products resulting from degenerative alterations of aging in the utricle or the semicircular canals. Affected individuals note transient episodes of severe vertigo upon the assumption of certain head positions. Although usually the syndrome is self-limiting, it may persist for the remainder of the individual's life (Schuknecht, 1974).

Loss of the vestibular ganglion cells and nerve fibers appears to be a consequence of aging as well. Richter (1980) documented a significant decrease in the average number of ganglion cells after the age of 60 years. By the microdissection technique, Johnsson (1971) found an obvious degeneration of the saccular nerve network, while the utricular network was affected only mildly. Loss of vestibular nerve fibers, beginning around age 40, results in an average loss of 37% in the elderly (Bergström, 1973a). In addition, there is a trend for the remaining vestibular fibers to have a thinner diameter (Bergström, 1973b), which is especially evident in ampullary nerve branches. Such changes would result, presumably, in a slowed nerve conduction.

Vestibular ataxia of aging may be related, in part, to some of the changes noted in the vestibular nerves and neural networks (Schuknecht, 1974). Support of such a hypothesis stems from studies showing decreased vestibulospinal function with increasing age (Peterka et al., 1987). Individuals, especially those in their seventh and eighth decades, as a manifestation of loss of vestibular control over the lower limbs, maintain sitting and standing postures without difficulty, but experience constant disequilibrium when moving; their caloric responses are normal for their age (Schuknecht, 1974). Central structures may also play a role, as suggested by a demonstrated deterioration in adaptive capabilities (an active, central process) for the vestibulospinal reflex with age (Norré, Forrez, & Beckers, 1987). Apparently, there have been no studies that have examined the histopathology of the human central vestibular system.

THE ROLE OF VASCULAR CHANGES

Vascular insufficiency may play a role in the described degenerative changes of the cochlea and vestibular labyrinth, but to separate its role from any primary degenerative process is difficult (Babin & Harker, 1982).

Jorgensen (1961) found an increased frequency of PAS-positive thickening of the capillary walls in the stria vascularis with aging, but no remarkable changes in the capillary network of the spiral ligament elsewhere. He related these findings especially to the severity of the arteriosclerosis in the blood vessels at the base of the skull, but found no correlation between the changes in the stria vessels and the extent of atrophy of the organ of Corti.

By microdissection and surface preparation techniques, Johnsson (1973) and Johnsson and Hawkins (1972b, 1977) have demonstrated atrophy and devascularization of the spiral ligament accompanying strial atrophy in the osmium tetroxide treated labyrinth. The capillary network manifested the alterations associated with aging to the greatest extent, with scala vestibuli capillaries being more severely affected than those of the scala tympani (Johnson, 1973). To a lesser extent, the radiating arterioles of the spiral ligament of the scala vestibuli also show narrowing, thickening of the wall, and atrophy; the arterioles of the scala tympani are much less affected (Johnsson, 1973).

A form of vascular pathology frequently seen in elderly patients consists of changes in the outer and inner spiral vessels of the basal cochlea (Johnsson, 1973). The vessel walls thicken, the widened perivascular space fills with a hyaline substance, and the lumen is occluded, leaving only an avascular channel basally (Johnsson, 1973).

The vessels of the vestibular labyrinth apparently are much less affected by aging (Johnsson, 1973; Johnsson & Hawkins, 1972b; Jorgensen, 1961). The perilymphatic spaces of the canals show the most obvious changes, with atrophy of the capillaries crossing those spaces (Johnsson, 1973).

The arterial vessels of the internal auditory canal show a progressive degeneration with age, most pronounced in the tunica adventitia; an increase in the thickness and compactness of the adventitial tissue, with progressive loss of fibroblasts, evolves into hyalinization (Fisch, Dobozi, & Grieg, 1972). The smallest vessels studied (vasa nervorum) show the alterations the earliest and to the greatest extent; those alterations eventually culminate in a narrowed lumen. In contrast, the larger cochlear, vestibular, and labyrinthine arteries show no stenosis up to the 9th decade of life (Fisch et al., 1972).

CONCLUSIONS

In conclusion, many alterations observed in the sensorineural and vascular structures of the inner ear have been related to the process of aging. It is difficult to determine the exact physiologic and functional consequences of those alterations. Confounding factors, such as disease, toxins, etc., complicate analysis. Some strides have been made despite these difficulties, but much remains to be done, particularly if we are to cope successfully with our aging population.

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Chapter 14

SPEECH UNDERSTANDING AND AGING*

J. V. TOBIAS¹ R. C. BILGER² H. BRODY³ G. A. GATES⁴ G. B. HASKEILL⁵ D. V. HOWARD⁶
L. A. MARSHALL⁷ M. A. NERBONNE⁸ J. A. PICKETT⁹

¹ Industrial Audiology, Ledyard, CT, ² University of Illinois, Champaign, ³ State University of New York, Buffalo, ⁴ Washington University Medical Center, St. Louis, MO, ⁵ Veterans Administration Center, Seattle, WA, ⁶ Georgetown University, Washington, DC, ⁷ Naval Submarine Medical Research Laboratory, Groton, CT, ⁸ Central Michigan University, Mount Pleasant, ⁹ Windy Hill Lab, Surry, ME

A person whose hearing loss has decreased his or her ability to understand speech may feel isolated—separated from social activities, from family, and from friends by a decreased capacity to communicate. This unwanted solitude may be the most debilitating aspect of hearing loss (Tobias, 1977).

Folk wisdom, scientific investigation, and clinical experience all suggest that, as the median age of the population increases, we will face a rising proportion of people with hearing problems. The fact that we have a term like *presbycusis*, which means the hearing loss that accompanies old age, indicates long-standing recognition that the elderly often show signs of deafness.

In 1977, a working group of the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA), chaired by J. M. Pickett, published a report describing factors that act on the hearing of the elderly (National Research Council, 1977). The current report updates that earlier one, touching on ways in which general physiological aging can be seen, ways in which measurements of hearing can be affected by older listeners' abilities to learn and to remember and by shifts in their willingness to say they have heard some signal, ways in which noisy or deteriorated or low-redundancy speech signals influence hearing, and ways in which sensory aids can help hearing problems.

For the sake of clarity, we try to avoid the classical audiological vocabulary that has referred to measures of a listener's ability to understand speech sometimes with

the word *articulation*, sometimes with the word *discrimination*, sometimes with the word *intelligibility*, sometimes with other, even less accurate nouns. Instead, we try to limit ourselves to the term *speech understanding*.

BIOLOGICAL ASPECTS

PHYSIOLOGICAL CRITERIA FOR AGING

The term *aging* connotes changes in structures and function occurring with the passage of time and includes at least three separate processes: intrinsic time-related degeneration, the cumulative effect of extrinsic insult (due to disease and trauma) and intrinsic insult (due to wear and tear), and age-related susceptibility to disease. Presumably the latter two processes are avoidable or remediable; the first is not. Research into aging must attempt to distinguish among these three separate but parallel processes.

Organ systems do not age uniformly. Neither do the components of a single organ system. We cannot even predict the status of one system from measurements made on another. Biological markers of the aging process (i.e., intrinsic degeneration) ought to be established, but none currently exists. Certainly we can describe age-related changes in an organ system, but they reflect the physiological status of the individual only insofar as impairment of that system affects overall function.

Delaying physiological aging by appropriate intervention is still an important goal of gerontology. Measures of physiological aging would help to determine the effectiveness of such interventions.

Presbycusis

Presbycusis is the sum of hearing losses that result from several varieties of physiological degeneration. Some

* The National Academy of Sciences/National Research Council Committee on Hearing, Bioacoustics, and Biomechanics recently commissioned a Working Group on Speech Understanding and Aging whose members wrote a tutorial paper, "Speech Understanding and Aging," that was published in the *Journal of the Acoustical Society of America*, 83, 859-895, 1988. With the permission of the Acoustical Society and its parent organization, the American Institute of Physics, these excerpts are reprinted here.

degeneration results from insults due to noise exposure (both usual and unusual), some from insults due to known or unknown exposure to ototoxic materials, some from systemic medical disorders (such as arteriosclerosis, hypertension, renal disease, diabetes mellitus), and some from treatment of those disorders. Most, and maybe all, of these effects can probably be modified by genetically determined susceptibility.

Histologic Observation

Loss of high-frequency sensitivity begins in adolescence. Even infants lose hair cells in the basal end of the cochlea (Johnsson & Hawkins, 1972a, b). That these changes occur before significant exposure to noise or development of vascular disease suggests that biological aging begins very early.

Schuknecht (1964) postulated four distinct types of presbycusis on the basis of audiograms and postmortem histopathological findings: sensory (loss of hair cells and secondary degeneration of associated neurons), neural (primary degeneration of ganglion cells and central auditory pathways), metabolic (atrophy of the stria vascularis), and mechanical or cochlear-conductive (stiffening of the basilar membrane).

Currently available epidemiological information does not indicate the relative frequency of Schuknecht's types of presbycusis. Most cases seem to fall into his sensory category; pure neural types are infrequent. The metabolic type appears to be genetically determined and may be misclassified as a form of presbycusis (Lowell & Paparella, 1977). The mechanical (cochlear-conductive) type is hypothetical and has yet to be verified.

CENTRAL AUDITORY PATHWAY

The aspect of aging that is easiest to discuss is the way in which the auditory nervous system deteriorates as subjects get older—easy because very few studies exist. Most of the information we have comes from descriptive reports rather than from scientifically controlled research; most reports lack audiological histories, quantitative techniques, and adequate numbers of specimens of various ages. So although we can guess that damage to neural structures may increase with age and that some of that damage ought to influence auditory function, actual age-based correlations between function and structure are not available.

Associating age-related changes in hearing with relevant age-related changes in anatomy requires experiments that use (a) adequate numbers of subjects (both human and animal) whose audiological histories are known, (b) a broad sample of ages and pathologies, and (c) excellent technique not only in tissue preparation but in experimental design. To date, very few studies meet even one or two of these criteria. None meets all three.

FUNCTIONAL ASPECTS

EFFECTS OF AGING ON AUDITORY THRESHOLDS

Bunch et al. (1929) and Bunch (1931) were among the first to explore the reduction in hearing sensitivity that accompanies aging, and later research (Corso, 1959, 1963a, b; Glorig & Nixon, 1960, 1962; Glorig, Wheeler, Quiggle, Grings, & Summerfield, 1957; Goetzinger, Proud, Dirks, & Embrey, 1961; Hinchcliffe, 1959; Sataloff & Menduke, 1957) confirmed and refined their findings.

When the National Institute for Occupational Safety and Health (NIOSH) (1972) compared data from subjects who were screened for noise exposure with subjects from the 1965 Public Health Service's Health Examination Survey (Public Health Service, 1965) who were not, mean threshold values at 2,000 Hz and above were consistently worse for the unscreened population for all age groups. Routine exposure to noise clearly contributes to the age-related declines in hearing sensitivity, so accurate assessment of the relation between the aging process and auditory sensitivity depends on accurate knowledge of subjects' noise-exposure histories. Demonstrated ototoxic effect of certain drugs and animal studies that relate serum cholesterol levels to auditory sensitivity suggest that similarly precise knowledge of medication and dietary histories may also be required.

METHODOLOGICAL PROBLEMS

Studies of elderly listeners are difficult to compare because different test methods produce different results. Data collected in one experiment will be comparable to those in another only if the subject groups are matched for age, degree of hearing loss, physical and mental health, cognitive talents and abilities, and general verbal skill. Because randomly chosen elderly subjects typically include people with vastly different auditory histories and pathologies, experimenters whose data analyses parcel out subgroups of subjects contribute particularly useful information.

Subject Selection

Heterogeneity of the group. Elderly listeners are often assumed to be a homogeneous group when, in fact, they conglomerate into subgroups with diverse pathologic conditions and cognitive abilities (Marshall, 1981). Their only commonality may be age. Although seldom emphasized, such auditory differences in pathologic conditions and cognitive abilities found within elderly groups of subjects may exceed differences found between young and elderly groups (Krauss, 1980).

Valid measures of sensory ability. Cognitive factors such as response bias and learning affect measures of sensory ability, but an experiment's purpose defines what

the experimenter should do about them. If, on one hand, the purpose is to measure a sensory system's best possible performance, then these factors must be experimentally controlled or measured. If, on the other hand, the purpose is to determine how an elderly individual will perform in a novel listening situation, controlling these factors could give a false impression.

Subjects can show large practice effects when they are tested on nonspeech signals (Moore, 1976; Turner & Nelson, 1982), particularly complex signals (Watson, 1980). Therefore, unless we test subjects until their performance approaches asymptote, we might reach erroneous conclusions about the ability of the auditory system. Well-practiced tasks, such as listening to everyday speech in common acoustic environments, show negligible learning effects. However, for the Speech Perception in Noise (SPIN) test, Matthies, Bilger, & Rzeczkowski (1983) reported an age effect in the first day's results; it disappeared by the third day. Thus, learning can even influence tests that are intended to represent real-life listening situations. Speech-understanding tests that use *novel* stimuli such as interrupted speech certainly could evidence sizable learning effects, but the tests are usually given in such brief forms that they underestimate actual auditory ability.

In the SPIN test (Kalikow, Stevens, & Elliott, 1977), subjects repeat the last word of each of 50 sentences. In half of the sentences, the last word (always a monosyllabic noun) is closely related to the context; in the other half, the last word is not so closely related. A 10-talker babble is the noise. Bilger, Nuetzel, Rabinowitz, & Rzeczkowski (1984) prepared a Revised SPIN Test that includes eight psychometrically equivalent forms.

Because the SPIN test includes two kinds of material that are of quite different difficulty, it presents unique advantages as a test of speech understanding. Bilger, Steigel, & Stenson (1976) found that, for 128 hearing-impaired listeners, the difference in difficulty between high- and low-predictability items was independent of the degree of hearing loss.

Subjects whose performance is influenced by cognitive factors (such as motivation, attention, or criterion for responding) produce aberrant SPIN test results. For example, some listeners are hesitant to respond when they are not absolutely sure that a response will be correct or when they think the speech stimulus is less than perfect. These listeners score high on the high-predictability items of the SPIN test but score very, very low on the low-predictability items. Inattentive or uncooperative listeners tend to miss both high-predictability and low-predictability items.

Other procedures that test more than one level of difficulty give results similar to those found with the SPIN test (Bilger, Nuetzel, Trahiotis, & Rabinowitz, 1980). Therefore, any such test should provide results that will tell us whether we have obtained valid scores.

Procedures. A subject's score on any hearing-for-speech test is not a very good predictor of that person's real-life ability to understand speech. Several aspects of the testing procedure present potential problems: the task itself,

the pacing of the task, the acoustic conditions under which the testing is conducted, and how the test materials are delivered to the subject.

An ideal testing procedure would use the subject's response to the previous test item to trigger the presentation of the next one. Unfortunately, the recorded test materials that are available to the audiological community present the test items at fixed intervals—usually one every 10 seconds. For some subjects, this rate is too slow; for others, it is too fast. If a subject has not completed a response before the next test item is presented, he or she may become confused or discouraged. The audiologist gains two advantages by stopping the recorded test at the end of each test item and waiting for the response. If the test halts until the subject responds, the subject learns to respond to every test item. If the subject needs additional time to organize and make a response, then, by providing the extra time, the tester can maintain the subject's cooperation and motivation. The only real advantage of live-voice signal presentation in testing hearing for speech is that the test is always paced appropriately, which no doubt reinforces those audiologists who still do live-voice testing. However, the large variability between talkers and even between one talker's own repetitions of a single word means that live-voice-test results will always be nonstandard (you cannot safely compare results on one such test with results on another); the unreliability of live-voice tests means that they cannot provide a valid basis for generalizing from test results to speech understanding.

People seldom listen to real-life speech in the relatively noise-free environments that are provided by the typical sound-treated audiometric room (and recordings of test materials are normally made in quiet rooms). Although noise can be added to this test environment, one must choose the types of noise from all those available. White (Gaussian) noise is probably not appropriate for testing hearing for speech because its spectrum is too uniform and its time variations too regular; it does not imitate real-life noise. Although a babble of many voices has some claim to real-life validity, few people spend their lives listening to speech in the cocktail-party environment usually associated with such babble. No single kind of noise—not even traffic noise or restaurant noise—will be totally satisfactory as a distractor/competitor.

Reverberation is a special kind of noise that is common in everyday listening. But sound-treated rooms are generally designed to be low-reverberation spaces, and speech-test recordings are commonly made in such rooms. Speech recorded in reverberant rooms is almost never used by audiologists, and no commercial recordings are available.

COGNITIVE CONSIDERATIONS

What a person perceives depends not only on the signal that reaches the ear (a process that starts at the bottom of the analysis system and works its way up) but on what the

person expects to hear (a process that starts at the top and works down).

For both methodological and substantive reasons, anyone who studies relations between speech understanding and aging must recognize the significance of cognitive (top-down) processing. Methodologically, one must know which aspects of cognition decline with age in order to interpret age-related differences in performance. For example, many tests of speech understanding contain a memory component, so age differences in accuracy of understanding might be due all or in part to a decline in memory. If memory were the primary factor, then signal amplification might not improve speech understanding at all.

The cognitive deficits of the elderly often can be overcome by appropriate training, and many elderly people appear to compensate for their cognitive decrements by calling on their accumulated knowledge. Elderly individuals have been taught to use mnemonic techniques with resulting improvement in their long-term memory (Schmitt, Murphy, & Sanders, 1981; Zarit, Cole, & Guider, 1981). They have also been taught to improve problem-solving skills (Denney, 1981). Just as important, people who become expert in a particular field when they are young often maintain their performance into advanced age. Analyses of skilled bridge players (Charness, 1983), chess players (Charness, 1981), and typists (Salthouse, 1983) offer important insights into exactly how this compensation occurs. For example, Salthouse found that elderly typists who type as rapidly as young typists (despite significantly slower simple reaction time) do so by looking further ahead in the text being typed. These demonstrations indicate that once we have a better understanding of how changes in cognition contribute to difficulties in speech understanding, we should be able to develop methods for helping elderly people overcome and compensate for such deficits. We may also learn a great deal from skilled elderly listeners themselves who, like Salthouse's typists, have consciously or unconsciously developed means of compensating for the changes in hearing and cognition that accompany aging.

SPEECH UNDERSTANDING

NOISY AND DEGRADED SPEECH

Difficult Listening Tasks: Central Versus Peripheral Degradation

Elderly adults often do worse on difficult speech-understanding tasks than young adults with similar audiograms. Audiologists developed these difficult tasks primarily to detect central auditory nervous system (CANS) lesions such as tumors. Young adults with CANS lesions typically have normal pure-tone sensitivity and speech-understanding ability for easy listening conditions but show a decrement in performance on dichotic speech tasks; on speech signals that are degraded by

filtering, periodic interruption, time compression, time expansion, or the presence of a competing signal; or on release from masking (Noffsinger & Kurdziel, 1979).

When an older adult shows decreased performance on these tests, we tend to attribute the problem to a CANS lesion just as we do for younger patients. However, peripheral and cognitive factors could also contribute.

Difficult Listening Tasks: Everyday Listening Conditions

Everyday listening includes competing noise, reverberant rooms, fast or unclear talkers (and is beginning to include computer-synthesized speech), and telephone-limited bandwidths, all of which can reduce speech understanding. Unfortunately, current audiological evaluations are not designed to evaluate individuals in everyday listening conditions. And most of the research data on competing noise, reverberant rooms, fast or unclear talkers, synthetic speech, and telephone-limited bandwidths were obtained monaurally under earphones, a situation that has the advantage of matching a test result to a specific audiogram but the disadvantage of ignoring binaural cues. We do not know how much an individual's speech-understanding difficulties are due to sensory distortions or how much they are due to the person's cognitive ability to interpret a distorted signal. This distinction is important because, in rehabilitation, some form of signal processing might help with the peripheral distortions (Villchur, 1977), and compensatory strategies might help with the cognitive difficulties.

Speech Understanding in Noise for Aging Listeners

Perhaps our major problem in interpreting the literature on how aging listeners understand masked speech is that we do not know how to separate the influence of the masker from the influence of a hearing loss that produces an unmasked speech-understanding test score significantly lower than 100%. A person with such a loss could show any of four different results.

One result could be that the function describing the dependence of test score on signal-to-noise ratio (S/N) for the aging or hearing-impaired listener would be parallel to that for normal-hearing listeners, as reported by Smith and Prather (1971) for aging listeners and by Cooper and Cutts (1971) for hearing-impaired listeners. A second result could be that the function for an aging or hearing-impaired listener could reflect a constant percentage decrement in speech scores as S/N is made poorer; that is, the function would have a slope of less than 1.0, as inferred by Ross, Huntington, Newby, & Dixon (1965). A third result could be that the function could have a slope that is steeper than 1.0, as Suter's (1978) data may be interpreted to indicate. The fourth outcome could be that an aging or hearing-impaired subject could perform at an

essentially constant level until the S/N is adverse enough to cause normal-hearing subjects to score as poorly as that listener does; for more adverse S/Ns, both normal-hearing and hearing-impaired subjects would perform comparably, as the Bilger et al. (1976) findings seem to show (however, their conclusion is based on only two data points, one for no noise and one for a S/N of +5 dB).

Explanation of Differences Between Young and Elderly Listeners

Studies that compare young and elderly listeners are limited in the range of hearing levels and the types and levels of maskers used. However, mean data for young and elderly listeners usually show small but consistent differences even when the groups are equated for peripheral hearing sensitivity. These differences might be attributable to peripheral, CANS, or cognitive factors.

Reverberation

Increasing reverberation decreases speech understanding. Increasing age makes the problem worse, even prior to appreciable hearing loss (Bergman, 1971; Nabelek & Robinson, 1982). In Nabelek and Robinson's study, reverberation times of 0.4, 0.8, and 1.2 seconds were chosen to represent listening conditions in small rooms, medium-size conference rooms or auditoriums, and larger areas such as assembly halls, churches, and theaters. Even for the shorter reverberation times, listeners in their forties whose mean hearing levels are within normal limits do worse on the Modified Rhyme Test than young adults. Listeners over the age of 60 who have pure-tone losses but 90% or better word-recognition scores for nonreverberant speech perform considerably worse than middle-aged subjects. For increasing reverberation times, the decrement grows with increasing age.

The effects of reverberation on some aspects of speech understandability are similar to those of noise (Gelfand, 1982; Nabelek, 1982), but Nabelek and Dagenais (1986) reported different patterns of vowel errors for reverberant and for noisy speech. The underlying mechanisms are probably different.

LANGUAGE COMPREHENSION

We have talked mostly about identifying sequences of sounds as one does in sentence or monosyllabic-word tests, but such identification is only part of what is necessary for understanding; listeners also need to comprehend the meaning of such sequences of sounds. Comprehension studies usually require people to answer questions about a sentence or a story or to retell it in their own words; verbatim report of the exact words presented is not necessary, and it may not even be sufficient.

Comprehension of a sentence or story or conversation requires the listener to go beyond the words—he or she must also make inferences because talkers do not explicitly state information that they believe listeners can easily infer using everyday knowledge (Clark & Haviland, 1977; Harris & Monaco, 1978; Schank & Abelson, 1977). Therefore, either the identification of the sequence of sounds in a story or the comprehension of its meaning could be deficient while the other remains intact. An elderly person might have auditory deficits that prevent precise identification of individual sounds but still be able to comprehend the meaning of the message by calling on nonlinguistic context and permanent knowledge to infer what must have been said. Conversely, an individual may be able to identify all the sounds individually but, due to cognitive deficiencies, be unable to comprehend the meaning of the message. Therefore, we have to study how both identification and comprehension vary with age and with peripheral hearing loss. The potential discrepancy between identification and comprehension may be partly responsible for the modest size of the correlations between self-assessment of hearing handicap and audiometric test scores (Weinstein & Ventry, 1983).

Some aspects of language comprehension decline with aging. Such declines are particularly notable under fast rates of presentation (e.g., Cohen, 1979, experiment 1; Pezdek & Miceli, 1982), and, although the possibility has not been investigated, such declines are likely to be aggravated when coupled with a peripheral auditory deficit. The literature contains some obvious inconsistencies, particularly in the case of the studies concerning sensitivity to levels of text structure. This disarray is not surprising given the complexity of the processes involved and the fact that studies of language comprehension and aging were almost nonexistent until the late 1970s. It is encouraging that recent studies are more analytic than earlier ones and that they take advantage of more detailed models of prose comprehension to test specific hypotheses about the sources of age differences. In a review of the literature on discourse processing and aging, Hartley, Harker, & Walsh (1980) suggested a variety of ways in which contemporary theories of discourse processing might be applied to analyses of aging.

Devices that might aid perceptual processes such as language comprehension are probably far in the future. But devices that aid sensory processes are common today.

SENSORY AIDS

Wearable hearing aids continue to be the most popular sensory aids for the hearing impaired, but for many applications, special-purpose devices, such as group listening systems, are better. In the past, only the profoundly hearing impaired used nontraditional devices. Novel applications have not yet been well explored, particularly with the geriatric population.

Wearable Hearing Aids

Some hearing aids now include a connector for an accessory lapel microphone. Although this inclusion of a hard-wired remote microphone may look like a step backward in the era of miniaturization, it does bridge the gap between hearing aids (which are small enough to wear unobtrusively) and assistive listening devices (which are usually bulky enough to be noticed) and also provides a direct solution to the signal-to-noise problem by allowing the microphone to be moved nearer to the signal source.

People who are 65 and older show significantly improved speech understanding with binaural amplification (Antonelli, 1978; Bentzen, Frost, & Skaftason, 1969). However, user acceptance of binaural hearing aids is reported to be low among presbycusics (Corso, 1977; Frederiksen, Blegvad, & Rojskjaer, 1974; Jensen & Funch, 1968). The type and amount of post-fitting training may provide a key to this seeming incongruity. Ward (1980) reviewed the effects of follow-up training, predominantly among people over 60, and concluded that hearing-aid usage increases by 50% after as little as 1 hour of training.

The criterion test for hearing-aid performance in the engineering shop, in the laboratory, and in the clinic has been (and remains) improvement in the understanding of speech in noise. Yet no test of speech in noise accurately predicts speech understanding in everyday listening situations, a fact that has resulted in a considerable body of research and has led to a plethora of new speech tests (Olsen & Matkin, 1979). The ability of these newer speech tests to discriminate meaningfully among similar hearing aids has not yet been established convincingly, especially for geriatric listeners.

Other Auditory Aids

The number and variety of contained-area sound systems have been expanding rapidly. Once restricted to deaf-education and auditory-training classrooms, group systems are now installed in public buildings, auditoriums, and churches. For many uses, such systems are better than personal hearing aids because they move the microphone pick-up point to the signal source, thereby overcoming signal-to-noise ratio problems. Systems may use FM broadcast techniques, modulated infrared light, induction loops, AM broadcast techniques, or hardwiring (Nabelek, Donahue, & Letowski, 1986; Ross, 1982; Vaughn, 1983; Williams, 1984). Although each approach has its own advantages, the first three are receiving the most attention.

Other Sensory Communication Aids

The auditory system can be stimulated not only acoustically but electrically (Levitt, Pickett, & Houde, 1980),

and the characteristics of sensations that are provided by implanted electrode systems are under vigorous investigation (Parkins & Anderson, 1983). The object of the stimulation is the auditory nerve; the recipients of implants call the sensation hearing. Some implants use electrodes in the cochlea; others use electrodes on or near the round window in the middle ear to direct electrical signals into the cochlea.

The hearing provided by implants is only rudimentary, so these devices are intended solely for the totally deaf. The small part of the elderly hearing-impaired population that has acquired total deafness might possibly benefit from the kinds of implants that are currently available. However, most profoundly deaf people are not totally deaf and probably have more residual capacity for understanding speech than can be provided by the current implant systems.

Some patients who totally lose hair-cell function through accident or because of pharmacological or disease factors may be suitable candidates for implants. But because the hearing sensations experienced by implantees are not like the ones they experienced when they could still hear more or less normally, the limited benefits of implants might be limited even more for those patients who have cognitive problems.

SUMMARY

The large number of people affected suggests that hearing loss may be one of our biggest health problems. Because the amount of hearing loss increases with age, the expanding size of the aging population should cause our concern to expand too.

This report has considered what is currently known about the influences on speech understanding of hearing loss, of memory and other cognitive processes, of the underlying anatomy and physiology, of hearing conservation practices, and of prosthetic and rehabilitative techniques. We suggested that major short-term payoffs should result from intense work on hearing-aid development, on hearing rehabilitation, and on the reduction of the number of affected older individuals by improved hearing conservation among the younger population. We suggested that major long-term (and probably even greater) payoffs should result from studies of the anatomical and physiological factors in presbycusis, of the interaction of central and peripheral mechanisms required for speech understanding, and of how those various factors individually and in combination vary with age.

Despite the many first-rate studies of the problems that an aging population has in understanding speech and despite the gradual broadening of our knowledge base, we obviously need to learn a great deal more. The evidence that relates hearing loss to aging is unclear: we are not certain that age itself causes deterioration in the auditory system. Correlating hearing decrements with age is difficult because we lack clinically applicable procedures for measuring physiological age. Interpreting the results of psychoacoustic studies is difficult because

we do not yet know how to explain the differing results from seemingly similar experiments. Identifying the causes of measured changes in speech understanding is difficult because we usually cannot differentiate among the contributions of peripheral, central, and cognitive processes.

Despite the gaps in our knowledge, we are certain that lifelong good hearing-conversation practices would significantly reduce the negative effects. And we know that hearing aids can help a lot of people—certainly many more than are currently being helped. But masses of research will be needed before we can build a practical and general set of true statements about the physiological, sensory, perceptual, and cognitive processes that determine the ways in which both younger and older listeners analyze and interpret speech signals.

RESEARCH RECOMMENDATIONS

We have commented on a number of areas in which additional research would be valuable. This section lists unanswered or inadequately answered questions—issues that we need to study, to clarify, and to understand. The order of presentation mirrors the order of topics in the report and is not an order of priorities.

ANATOMY AND PHYSIOLOGY

Correlating age-related changes in hearing to age-related changes in anatomy requires experiments that use adequate numbers of subjects (both human and animal) whose audiological and neurological histories are known, that use a broad sample of ages and pathologies, and that use excellent technique in tissue preparation and in experimental design. Estimates of physiological aging require studies that will improve our ability to analyze such processes as time-related degeneration, wear and tear, disease, trauma, and susceptibility to further damage, and our ability to distinguish among them. Assessing the physiological age of an auditory system will require accurate assessment of medical, genetic, social, and audiological factors; audiological data cannot be limited to measurements of the reception of pure tones and isolated words. Well-supported brain and temporal-bone laboratories and colonies of appropriately selected animals would provide specimens to help to determine the effects of aging on auditory physiology and anatomy. The National Institute on Aging's Longitudinal Aging Program could provide valuable information by routinely incorporating auditory testing into the examinations; additional information would result from subjects permitting brain and temporal-bone studies to be made after their deaths. Here are some specific questions to be answered:

1. How can we measure the physiological age of an auditory system?

2. How does the physiological age of the auditory system correlate with the physiological age of other organ systems?
3. Does neural damage increase with age?
4. How does audiological function correlate with neural structure?

AUDIOLOGICAL MEASUREMENT

All the specialists who work with older people's hearing express concerns about methodology. A particularly useful early step toward improvement would be for researchers to parcel out pertinent subgroups of subjects—people whose hearing losses are comparable or whose etiologies are similar, for example—instead of lumping together the data from heterogeneous groups for statistical analysis. Accurate tests of central-auditory abilities require enough information about peripheral abilities so that their contributions can be separated out. Therefore, we need large-scale studies of the influence of such factors as audiometric configuration, critical bandwidth, degree of hearing loss, and etiology of the loss. Audiometric tests of pure-tone sensitivity and word recognition are clearly inadequate to measure hearing handicap; an effective test battery needs to be devised. Here are some specific questions to be answered:

1. How do subjects with related pathologies differ audiotically from other subjects?
2. What conductive hearing problems (e.g., canal collapse) affect the elderly and to what degree?
3. How do medication and diet contribute to the decrement in auditory sensitivity seen in older patients?
4. Does the disparity between predicted and obtained speech-understanding scores for the aging listener result simply from the statistical problem of predicting percentages of words understood from decibels of hearing loss, or does it really represent a complex speech-understanding problem?
5. How do identification and comprehension of speech signals vary with age and peripheral hearing loss?

NOISY AND DEGRADED SPEECH

Hearing-impaired subjects' auditory performance is below normal without noise and presumably must be worse when the signal is partially masked. Speech-understanding decrements that vary with age without respect to hearing loss may be influenced by peripheral frequency and temporal analysis abilities, CANS dysfunction, and the subject's acceptance criterion; we need to try to assess the contributions of each of these factors, and, more generally, we need to determine how those contributions differ between young and elderly listeners with similar amounts of hearing loss. Although young and old subjects show no measurable criterion differences, younger listeners are nevertheless more accurate in judging whether

their responses to noisy speech are correct; some aspects of auditory processing, cognition, and attitude must account for such age-related changes, but so far the causes are obscure. We also need new data on interactions among noise level, noise spectrum, and configuration of hearing loss in order to determine differential effects of noise on listeners with sensorineural losses. Both reverberation and noise are common causes of poor speech understanding, but most of the research has been on noisy, not reverberating speech. We need to learn the relations among temporal resolution, reverberant speech, and speech understanding. Technology is producing new degradations to speech signals: synthetic speech is becoming common, television programs are artificially speeded up to meet time constraints, and more and more frequently, we find speech that is degraded in several ways concurrently. Here are some specific questions to be answered:

1. How does age affect the understanding of words heard in noise?
2. What proportion of the performance decrement that occurs when older listeners listen to noisy speech is attributable to masking and what proportion is attributable to other factors?
3. Are listeners with sensorineural losses affected by noise differently than are normal-hearing listeners?
4. How does reverberation affect speech understanding?
5. How do high-frequency hearing loss and aging affect speeded-speech understanding?
6. What perceptual and cognitive problems do elderly individuals experience in trying to understand synthetic speech?
7. When several kinds of speech degradation arise at once, are the performance decrements additive?

LANGUAGE AND COGNITION

Persistent failure to understand what is being said can result in frustration and discouragement, which in turn can lead to less aggressive listening and to a sense of resignation that can be truly handicapping. A concerted effort must be made to determine how age-changes in cognition influence speech understanding; slower mental activity, from whatever cause, can affect responses to speech under difficult listening conditions. Comprehension studies need to be related to studies of identification of isolated sounds and words in order to permit us to determine how various levels of sensory loss influence semantic integration and the drawing of inferences, but we must study the comprehension of language directly rather than via later memory tests. We need analytic studies of language understanding that build on models of discourse comprehension. Here are some specific questions to be answered:

1. How does reduced working-memory capacity or mental slowing affect speech understanding as one grows older?
2. How do the relative contributions of top-down and bottom-up processes vary with age, hearing loss, and listening conditions?
3. Why does the ability to draw inferences that require the integration of new facts decline in old age, when generic knowledge from semantic memory does not?
4. Does a listener's attitude regarding his or her hearing impairment affect communication success?

SENSORY AIDS

Here are some specific questions to be answered:

1. In what ways are implants better than vibrators, and in what ways are vibrators better than implants?
2. Are there ways in which compression amplification can be used effectively in hearing aids?
3. What kinds of computer networks would be most helpful and advantageous for the elderly population?

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Chapter 15

FUNCTIONAL IMPACT OF HEARING LOSS ON THE ELDERLY

FRED H. BESS SUSAN A. LOGAN

Vanderbilt University School of Medicine, Nashville, TN

MICHAEL J. LICHTENSTEIN

*Geriatrics Research, Education, and Clinical Center
Audie L. Murphy VA Hospital, San Antonio, TX*

Sensorineural hearing loss is one of the most common chronic conditions in the elderly, affecting about 30% of those over 65 years of age (Bergman, 1971; Davis, 1983; Feller, 1981; Herbst, 1983; Moss & Parsons, 1986). In the eighth and ninth decades of life, the prevalence of hearing loss in older persons increases to 85–95% (Glass, 1986). Although hearing loss affects a substantial number of elderly, there is limited and conflicting information on the impact of hearing impairment on functional status and psychosocial well-being. Measures of functional health status provide us with insight into the prognosis of a condition, the impact of intervention on general health, and the ramifications of a disease on an individual's quality of life.

Most reports on the functional status of the hearing impaired are from case-series observations or based on interview surveys that did not measure hearing loss directly. Such studies have associated hearing loss in the elderly with psychosocial withdrawal (Alpiner, 1978; Hull, 1978; Maurer & Rupp, 1979; Rousseau, 1987; Weinstein, 1985), poor self-concept (Glass, 1986; McCarthy, 1987), negativism (Alpiner, 1978), senility (Maurer & Rupp, 1979), embarrassment (Weinstein, 1985), frustration (Davis, 1983; Weinstein, 1985), depression (Herbst, 1983; Weinstein, 1985), isolation (McCarthy, 1987; Weinstein, 1985), and loneliness (Hull, 1980; Maurer & Rupp, 1979). The U.S. Health Interview Survey reported that hearing impairment compromises physical mobility and independent activity of the elderly (Havlek, 1986).

Several investigators have used communication-specific interview scales to assess the functional impact of hearing loss on older individuals. Predictably, those studies revealed that hearing-impaired elderly experience a variety of listening and emotional complications (Schow & Nerbonne, 1982; Weinstein, 1984, 1985).

Two controlled studies have contrasted elderly subjects who have impaired hearing with subjects having normal hearing, across several different dimensions of function. Herbst (1983), for example, noted that hearing loss was associated with poor health, reduced mobility, reduced activities, reduced interpersonal relations, re-

duced enjoyment of life, and increased depressive symptoms. In contrast, however, Salomon and coworkers (Salomon, 1986; Salomon, Vesterager, & Jagd, 1988; Vesterager, Salomon, & Jagd, 1988) reported that life satisfaction, self-perception, and general activity level were not directly influenced by hearing level. The studies, however, did not control for patient variables that could influence the outcome measure of functional status.

To gain a better understanding of the problems associated with aging, the relationship between hearing loss and adverse functional and psychosocial consequences in the elderly must be clarified. Reported here are further details of the results of a study (Bess, Lichtenstein, Logan, Berger, & Nelson, 1989) designed to examine the relationship between hearing loss in older individuals with scores on a standardized validated measure of functional status.

METHODS

Internists working in six practices agreed to participate. Each practice referred a consecutive sample of 50 patients over 65 years old to the Bill Wilkerson Hearing and Speech Center for an audiologic assessment. Three hundred and four patients were referred by the six practices. Of those, 178 kept their appointments for testing. There were no significant differences between those who kept their appointments and those who did not with regard to age, sex, number of illnesses per subject, and number of medications. Of the 178 persons tested at the Bill Wilkerson Center, 152, or 86% completed a measure of functional health status. More specific details on methodology, as well as the characteristics of the population studied have been reported elsewhere (Bess et al., 1989; Lichtenstein, Bess, & Logan, 1988).

The test used to assess functional health status was the Sickness Impact Profile, commonly referred to as the SIP. It is a 136-item self-administered questionnaire that assesses psychosocial function in a behavioral context. The individual items are weighted and grouped into 12 sub-

TABLE 1. Main scales and subscales of the sickness impact profile (SIP).

Main scales	Subscales
Physical	Ambulation Mobility Body care and movement
Psychosocial	Social interaction Communication Alertness behavior Emotional behavior
	(Additional independent measures)
	Sleep and rest Eating Work Home management Recreation and pastimes
Overall	Combines all of the subscales

scales as shown in Table 1. The subscales include ambulation, mobility, body care/movement, social interaction, communication, alertness, emotional behavior, sleep/rest, eating, work, home management, and recreation/pastimes. In addition, there are three main scales: physical (combining ambulation, mobility, and body care/movement), psychosocial (combining social interaction, communication, alertness, and emotional), and overall (combining all 12 subscales). The higher the SIP score, the greater the functional impairment. The SIP has been shown to be a valid, reliable measure that has been used in many studies to measure sickness-related dysfunction (Bergner, Bobbitt, Carter, & Gilson, 1981; Bergner, Bobbitt, Pollard, Martin, & Gilson, 1976; Carter, Bobbitt, Bergner, & Gilson, 1976; Pollard, Bobbitt, Bergner, Martin, & Gilson, 1976). Sample questions taken from different scales of the SIP are shown in Table 2.

RESULTS

The mean results for the persons with hearing impairment and those not hearing-impaired are shown in Figure 1. Hearing impairment is defined as (a) a 40-dB HL loss at

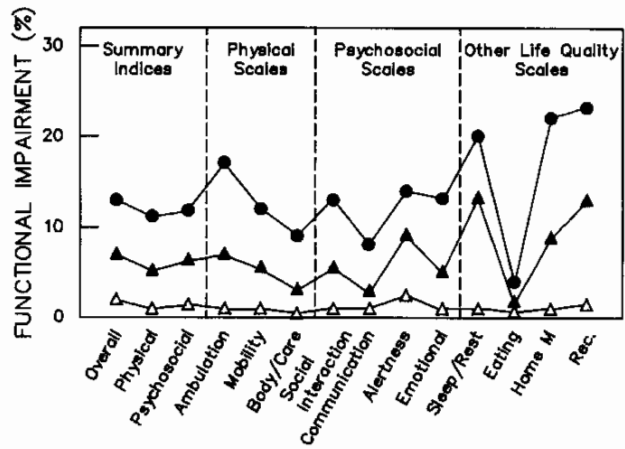


FIGURE 1. Mean scores obtained on various scales of the Sickness Impact Profile (SIP) for unimpaired young adults (open triangles), nonhearing-impaired elderly (filled triangles), and hearing-impaired elderly (filled circles).

1,000 or 2,000 Hz in both ears, or (b) a 40-dB loss at 1,000 and 2,000 Hz in one ear (Ventry & Weinstein, 1983). The

TABLE 2. Samples questions from the sickness impact profile (SIP).

Main Scale	Item	Subscale
Physical	I do not maintain balance	Body care/movement
	I stay within my room	Mobility
	I walk more slowly	Ambulation
Psychosocial	I laugh or cry suddenly	Emotional behavior
	I do not speak clearly when I am under stress	Communication
	I make more mistakes than usual	Alertness behavior
	I show less affection	Social interaction
	(Additional Independent Measures)	
	I am not doing <i>any</i> of the housecleaning that I would usually do	Home management
	I am doing fewer community activities	Recreation/pastime

figure is divided into four panels, illustrating first the data for the summary indices (total scores) on the SIP scale, followed by the physical and psychosocial subscales and then several other independent life quality measures. The open triangles represent normative data for young adults. Their average scores are seen to range between two and three for all subscales. The second set of data, represented by filled triangles, depicts the average scores obtained by elderly individuals in our study with no hearing impairment (i.e., passed Ventry and Weinstein criteria). The perceived functional impairment for this subgroup is somewhat greater than that obtained for the normative data. Finally, the filled circles denote the scores obtained by the hearing-impaired elderly in our study. The average SIP scores for most subscales are seen to be higher than the SIP scores of the elderly patients with normal hearing.

We also examined the impact of varying degrees of hearing loss on functional health status. The unadjusted associations between degree of hearing impairment and the SIP scores (main scales and subscales) are shown in Table 3. For the physical scale, the mean SIP score increases from 3.3 in those with no hearing impairment to 18.9 among those with a loss of 41 dB HL or greater in the better ear. Similar results are seen for the psychosocial dimension, the overall dimension, and most of the subscales.

It is recognized that factors other than hearing loss can affect functional health status. Hence, a step-wise multiple linear regression was used to adjust for baseline differences in age, race, sex, education level, number of illnesses, presence of diabetes and ischemic heart disease, number of medications, near-visual acuity, and mental status between the two groups (Armitage, 1971). In this multivariate analysis, the score of each SIP scale served as the dependent variable. The regression coefficient is reported as a change in SIP score per change in

hearing level, and these data are shown in Table 4. This table, adapted from Bess and coworkers (1989), illustrates the change in SIP scores for the three main scales and their associated subscales, with an accompanying change in hearing level after controlling for case-mix differences and other confounding variables. The data in Table 4 depict the SIP score change with every 10-dB change in hearing level. That is, for the physical dimension, a SIP score change of 2.8 will occur with each 10-dB increase in hearing loss. For the psychosocial and overall scales, the SIP score changes are 2.0 and 1.3, respectively.

The use of functional measures in the clinical setting can best be demonstrated by presenting several case illustrations.

Case Illustration 1

Our first case illustration (L. S.) is a 67-year-old female who was referred to the hearing and speech center by a primary care physician because she had failed an audiologic screening using the pass/fail criteria developed by Ventry and Weinstein (1983). The patient reported difficulty understanding speech both in group situations and in the presence of background noise. She also reported that her hearing loss had become progressively worse over the past several years. The audiogram of this patient is shown in Figure 2. Note that the patient exhibits a very mild bilateral sensorineural hearing loss. It is also seen that the patient exhibited an HHIE-S score of 26—a score that suggests a significant self-perceived communicative impairment. The SIP score data, however, are relatively normal and suggest that independent living or life quality has not yet been compromised by the hearing impairment. The subject purchased one hearing aid and, during the trial period, decided to acquire a second amplification system. The patient is judged to be a successful hearing

TABLE 3. Mean sickness impact profile (SIP) scores by level of average decibel loss in the better ear.*

SIP Scale	N	0-16 dB		N	17-25 dB		N	26-40 dB		41 dB or greater		
		Mean	(SD)		Mean	(SD)		Mean	(SD)	N	Mean	(SD)
Ambulation***	46	4.8	(10.5)	53	5.4	(8.6)	38	15.9	(15.0)	16	25.4	(21.1)
Mobility***	46	3.3	(8.2)	53	4.2	(9.1)	38	7.5	(11.5)	16	22.6	(21.1)
Body care/Movement***	46	2.6	(5.2)	53	3.3	(7.2)	38	6.9	(9.1)	16	14.8	(14.1)
PHYSICAL DIMENSION***	46	3.3	(6.6)	53	4.0	(6.5)	38	9.1	(9.8)	16	18.9	(15.7)
Social Interaction***	46	4.6	(9.0)	53	6.6	(10.2)	38	8.8	(12.1)	16	20.2	(16.6)
Communication+	46	3.4	(7.5)	53	3.4	(7.0)	37	6.4	(10.6)	16	10.0	(13.9)
Alertness+	46	4.3	(8.7)	53	9.2	(18.5)	38	14.0	(21.0)	16	15.3	(20.6)
Emotional**	46	3.1	(6.4)	53	5.2	(12.5)	38	9.9	(15.9)	16	18.5	(26.3)
PSYCHOSOCIAL DIMENSION***	46	4.0	(6.9)	53	6.2	(10.2)	37	9.6	(12.1)	16	16.8	(16.1)
Sleep/Rest	46	12.0	(21.1)	53	14.2	(17.8)	38	18.8	(19.8)	16	27.2	(29.8)
Eating**	46	1.6	(3.3)	53	2.4	(4.2)	36	2.7	(4.3)	16	6.9	(9.9)
Work	11	15.4	(24.4)	14	14.2	(27.2)	8	16.5	(23.4)	2	52.7	(24.6)
Home Management***	46	6.1	(12.0)	53	9.5	(15.8)	38	20.0	(21.6)	16	31.3	(35.2)
Recreation/Pastimes**	46	11.7	(16.7)	53	12.4	(16.7)	36	22.1	(25.5)	16	29.7	(30.0)
OVERALL**	46	5.3	(7.6)	53	6.6	(8.8)	38	11.3	(12.1)	16	17.1	(14.8)

* Decibel loss averaged over 500, 1,000, and 2,000 Hz in the better ear.

+ $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

TABLE 4. Change in sickness impact profile (SIP) scores per 10-dB change in average decibel loss in the better ear.*

SIP Scale	Change per 10-dB loss		Percent variance**
	SIP change (Std err)	p value	
Ambulation	4.2 (0.7)	<0.001	27
Mobility	3.3 (0.7)	<0.001	21
Body Care/Movement	1.9 (0.4)	<0.001	10
PHYSICAL DIMENSION	2.8 (0.5)	<0.001	24
Social Interaction	2.7 (0.6)	<0.001	16
Communication		0.053	
Alertness		0.269	
Emotional	2.9 (0.8)	<0.001	7
PSYCHOSOCIAL DIMENSION	2.0 (0.6)	<0.001	8
Sleep/Rest	3.1 (1.1)	<0.01	4
Eating	1.0 (0.3)	<0.01	9
Work		0.11	
Home Management	4.9 (1.1)	<0.001	19
Recreation/Pastimes	2.7 (1.2)	<0.05	3
OVERALL	1.3 (0.6)	<0.02	5

* Changes associated with hearing levels adjusted for age, race, sex, education, number of medications, number of illnesses/conditions, near vision, and mental status.

** Percent variance is the amount of variance in the SIP scale attributed to hearing at the step when hearing entered the model.

aid user. The SIP scores prior to and following the use of amplification are shown below the audiogram. It is seen that all SIP scores improved following one year of hearing aid use. In fact, the overall SIP score has been reduced from 3.3 to a score of zero.

Case Illustration 2

Our next case illustration (O. F.) is a 75-year-old female who also failed an audioscope screening and was referred to the hearing and speech center for an audiologic evaluation. The patient reported that she had had a mild loss in her left ear since childhood, thought to be caused by an episode of measles. She also reported difficulty in group situations and in the presence of background noise. The audiogram of this patient is seen in Figure 3, which shows that the patient exhibited a mild, sloping sensorineural hearing loss in the right ear and a moderate-to-severe hearing loss in the left ear. The subject exhibited an HHIE-S score of 28, a level associated with a significant communicative handicap. Note also that the SIP scores obtained prior to amplification were slightly elevated. The patient obtained a hearing aid in the left ear and reports excellent benefit from amplification. She also noted that the amplification system allowed her to handle difficult listening situations in a more effective manner. Following approximately one year of amplification, the post-SIP scores have improved for all three main scales. That is, the overall score was reduced from 5.2 to 2.3, the physical score was reduced from 2.0 to .90, and the psychosocial scale was reduced from 5.0 to 1.2.

Case Illustration 3

Our third example (W-0) is a 65-year-old retired male who was referred to the center by a primary care physician for an

audiologic evaluation. As had the other elderly subjects, he reported difficulty understanding speech in group situations and in the presence of background noise. His audiometric data is shown in Figure 4. The subject exhibited a bilateral, mild-to-moderate sensorineural hearing loss with a precipitous drop in the high-frequency region. The subject's perceived ability to communicate, as exhibited by the HHIE-S, was indicative of a communicative impairment. His SIP scores prior to use of amplification were very high for the three main scales. That data provided valuable information relative to the management of this particular patient. For example, given the high values of perceived dysfunction, it was apparent that he would require greater efforts in the orientation and counseling process. Accordingly, counseling sessions were devoted to physical management of the hearing aid, the limitations of amplification, and special listening situations.

Finally, it is of interest to examine the SIP scores following use of amplification for one year. There is significant improvement for all three main scales. The overall SIP score was reduced from 49.0 to 15.0, the physical score from 21.3 to 10.2, and the psychosocial score from 53.0 to 17.0. Such data suggest that the patient is exhibiting excellent benefit from amplification and subsequently improved life quality.

In each case, we are unaware of any other co-intervention to aural rehabilitation that may account for the observed changes in SIP scores.

DISCUSSION

This study demonstrates that poor hearing in the aged is associated with poor physical and psychosocial function. Even milder forms (17 to 26 dB HL) of hearing impairment were seen to impose negative effects on function. After adjustment for confounding variables, the higher SIP scores observed on all three main scales with

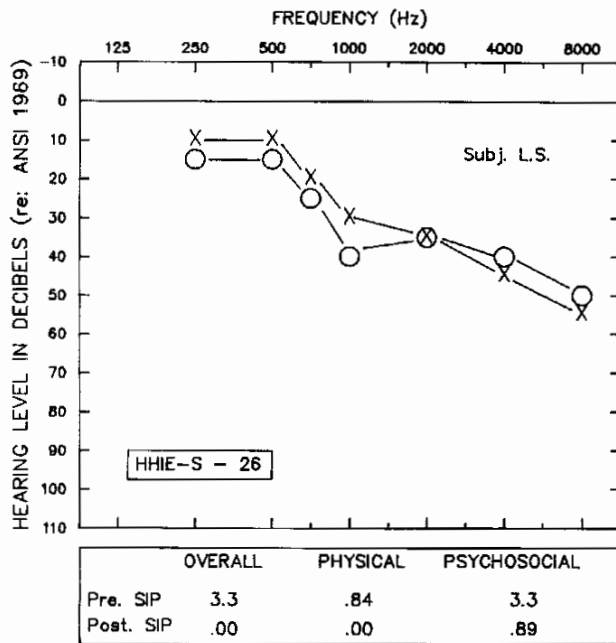


FIGURE 2. Case illustration (1) of a hearing-impaired elderly patient.

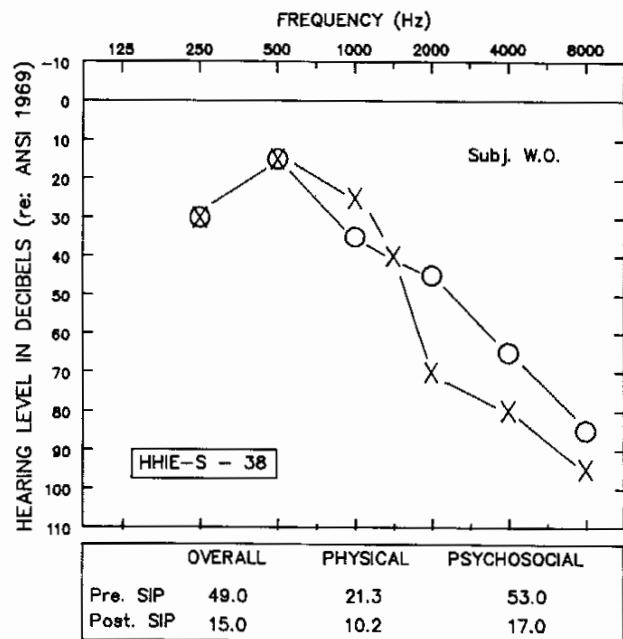


FIGURE 4. Case illustration (3) of a hearing-impaired elderly patient.

every 10-dB increase in hearing loss provide strong evidence for a relationship between degree of hearing impairment and functional capacity.

To appreciate the impact of hearing loss on function, it is of interest to examine the SIP scores obtained on subjects with other chronic conditions. The total mean SIP scores for an

unimpaired adult population typically fall between two and three, whereas scores for heart transplant recipients after one year average 9-10, and terminally ill and stroke patients score in the 30-40 range (Hart & Evans, 1987; McSweeney, Grant, Heaton, Adams, & Tims, 1982). In this study, the hearing-impaired elderly averaged overall SIP scores of 13.4, and those with losses of 41 dB HL or greater had an average score of 17.1. Hence, it is seen that hearing loss imposes a significant effect on functional health status, and the impact is comparable to that of other chronic conditions.

It also has been demonstrated that global scales of functional health status appear to have clinical application with the hearing-impaired elderly population. Our experience suggests that global measures of functional status can assist us in the audiologic management of the hearing-impaired elderly. Of special interest is the potential use for the SIP as an outcome measure in evaluating hearing aid success as well as different rehabilitation strategies. Toward this end, randomized, controlled trials on amplification and hearing aid orientation programs using the SIP scale as a primary means for measuring hearing aid success are needed.

In summary, we examined the functional health status and psychosocial well-being of hearing-impaired elderly as measured by the SIP. After adjusting for case-mix differences and other confounding variables in this population, we found hearing loss to be strongly associated with increased behavioral dysfunction in the elderly. These results suggest that, contrary to consensus and public policy, hearing loss is a major determinant of function in older persons. Efforts should be made to improve hearing health care services to this population.

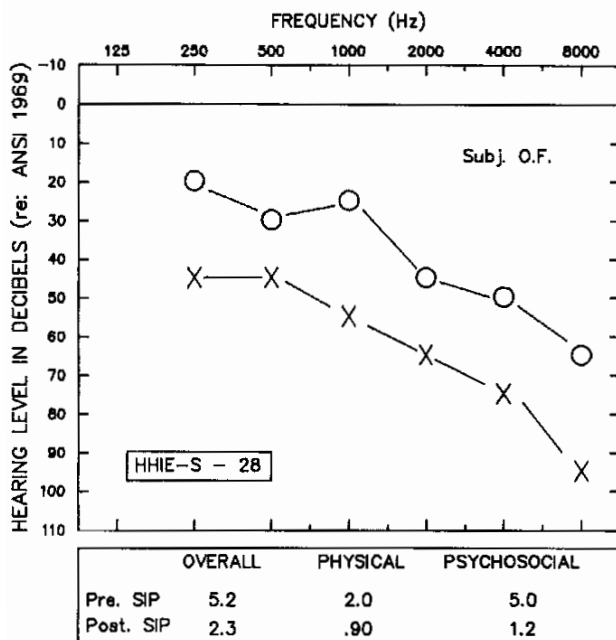


FIGURE 3. Case illustration (2) of a hearing-impaired elderly patient.

ACKNOWLEDGMENTS

We thank Drs. Anderson Spickard, Taylor Hays, Craig Heim, Mark Houston, Frank Gluck, John Griscom, F. Tremaine Billings, and Ms. Susan Amberg for taking time to participate in this study; Mary Sue Fino and Joann Sacks for help with data collection and entry. Dottie Adams provided expert manuscript preparation.

Some of the data reported herein were adapted from an article which appeared in the *Journal of the American Geriatric Society* (Bess et al., 1989).

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Chapter 16

CENTRAL AUDITORY PROCESSING DISORDERS AND AMPLIFICATION APPLICATIONS

BRAD A. STACH

The Methodist Hospital and Baylor College of Medicine, Houston, TX

Central presbycusis, or central auditory processing disorder (CAPD) that results from the aging process, is a growing concern among those who work with the elderly population. Evidence is mounting that the prevalence may be higher than commonly thought. In addition, there are increasing indications that CAPD may have a negative impact on benefit from conventional hearing aid amplification. It is possible that such problems can be overcome only by additional assistance in the form of a remote microphone amplification device, such as a personal FM system.

In this chapter we summarize what is known about the aging central auditory nervous system and its impact on speech understanding. In addition, we explore the effects of central presbycusis on benefit from conventional hearing aid amplification. Finally, we address the possible benefits of remote microphone technology for ameliorating the communication handicap that results from central presbycusis.

THE NATURE OF CENTRAL PRESBYCUSIS

Central presbycusis is the term used to describe the central auditory processing disorder that results from the aging process. From a clinical viewpoint, it is most commonly identified on the basis of speech audiometric test results. Its most typical manifestations are an inability to understand speech in the presence of background competition, an inability to understand speech that is presented rapidly by time-compression, and an inability to perform well on dichotic speech measures. While results on these behavioral speech measures are widely known, it is the changes in the peripheral system that are most often measured and most often attributed to hearing loss that results from the aging process. Although peripheral aging effects are important to understand, it may well be that the central aging effects have a more adverse influence on the communication abilities of elderly pa-

tients. It is important, therefore, to understand the underlying nature of central presbycusis.

Evidence of Central Auditory Nervous System Aging

Structural changes occur throughout the auditory system as a result of the aging process. Studies have shown changes in the outer ear (Hinchcliffe, 1962; Matsunaga, 1962), the middle ear (Etholm & Belal, 1974), and, of course, the cochlea (Igarashi, 1972; Johnson & Hawkins, 1972; Jorgensen, 1961; Nadol, 1979). More important, when considering central presbycusis, changes or reductions in neural elements have also been found in the eighth nerve (Krmptotic-Nemanic, 1971; Schuknecht, 1964) and auditory brainstem and cortex (Brody, 1955; Corso, 1976; Hansen & Reske-Nielsen, 1965; Hinchcliffe, 1962; Kirikae, Sato, & Shitara, 1964). Thus, there is anatomic evidence that the central auditory nervous system may change as a result of the aging process. Changes in function would be a logical manifestation of the structural changes.

Functional degradation of the central auditory system has been inferred from changes in electroacoustic and electrophysiologic characteristics related to the aging process. Studies have suggested age-related alterations in the stapedius muscle reflex (Wilson, 1981) and the auditory brainstem response (Otto & McCandless, 1982; Rowe, 1978). In addition, degradation in function has been noted at higher levels in the system, as manifested by changes in the middle latency response (Clayworth & Woods, 1984), late vertex response (Ford & Pfefferbaum, 1979; Goodin, Squires, Henderson, & Starr, 1978; Squires, Goodin, & Starr, 1979), and P-300 task-related potential (Smith, Thompson, & Michalewski, 1980; Squires et al., 1979).

Functional degradation has been demonstrated most convincingly by the use of "sensitized" speech audiometric measures to quantify decrements in speech processing (Antonelli, 1970; Bergman, 1971; Berman et al., 1976;

Bosatra & Russolo, 1982; Hinchcliffe, 1962). Age-related changes have been found on degraded speech tests that use both frequency alteration (Bocca, 1958) and temporal alteration (Konkle, Beasley, & Bess, 1977; Lutterman, Welsh, & Melrose, 1966; McCroskey & Kasten, 1982; Sticht & Gray, 1969). Tests have also found dichotic performance to be adversely affected by aging (Arnst, 1982; Fifer, Jerger, Berlin, Tobey, & Campbell, 1983). Finally, aging listeners do not perform as well as younger listeners on tasks that involve understanding speech in the presence of background noise (Goetzinger, Proud, Dirks, & Embrey, 1961; Jerger, 1973; Jerger & Hayes, 1977; Konig, 1969; Orchik & Burgess, 1977; Pestalozza & Shore, 1955; Shirinian & Arnst, 1982).

Prevalence

Estimates of the prevalence of central presbycusis have not been available for at least two reasons. First, measures of central auditory processing ability are not often carried out routinely in most settings. Second, it is no simple matter to separate, on speech-based measures, changes that result from peripheral hearing loss from those changes that result from CAPD.

In a recent study, we attempted to estimate the prevalence of CAPD in a clinical population (Stach, Spretnjak, & Jerger, 1990). Seven hundred patient files, for 100 patients from each of seven half-decades, were evaluated from the clinical service of The Methodist Hospital Audiology Service at the Neurosensory Center of Houston, Texas. Files were drawn consecutively, except that those with a history of middle ear disorder, psychiatric disorder, and neurologic disorder, including dementia, were eliminated from the study. Central auditory disorder was defined on the basis of test results from the Synthetic Sentence Identification (SSI) test (Jerger, Speaks, & Trammel, 1968) and patterns of test results from the comparison of SSI to PB-words (Jerger & Hayes, 1977). A patient was considered to have CAPD if (a) "rollover" of the performance-intensity function exceeded 20%, (b) the discrepancy between the PB-word and SSI scores exceeded 20%, or (c) the absolute SSI score was depressed to a level that could not be explained on the basis of the degree of peripheral sensitivity loss. The latter comparison was made against empirically established norms for hearing loss and SSI performance and helped to insure against potential bias due to the inevitable increase in peripheral hearing loss that occurs with age.

Results are shown in Figure 1. Speech audiometric abnormalities increased systematically with increasing age, to a prevalence in excess of 90% in the oldest age group. These prevalence estimates suggest that central presbycusis is a common manifestation of the aging process in those patients who seek medical or audiologic services for hearing loss. While the prevalence in the population at large is probably substantially lower, in a clinical population the likelihood of encountering a patient with some degree of central auditory disorder is quite high.

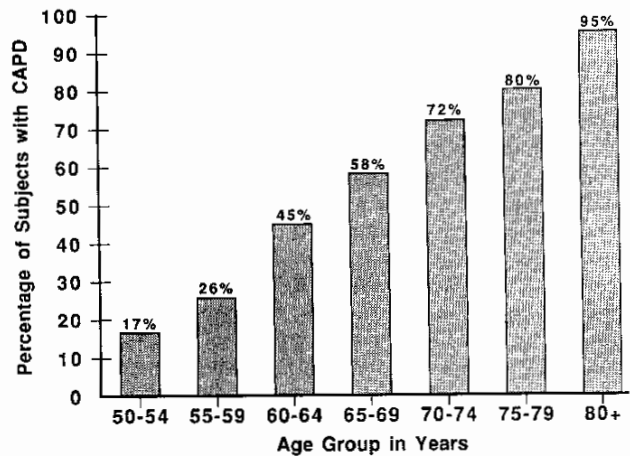


FIGURE 1. Prevalence of CAPD in 700 presbycusis patients as a function of age group (from Stach et al., 1990).

Potential Confounding Variables

Since behavioral measures are often used to describe central presbycusis, critics of the concept have suggested that performance on the speech-based tasks can be explained by peripheral hearing loss or concomitant cognitive deficits (CHABA Working Group on Speech Understanding and Aging, 1988). It is certainly the case that peripheral sensitivity loss can affect performance on speech audiometric measures. It is equally likely that a patient with dementia may be unable to perform the behavioral tasks required to measure central processing ability. Nevertheless, we have found that the efforts to explain the concept of central presbycusis as a mere manifestation of one or both of those effects is simplistic, at best.

By way of example, the prevalence data described previously were analyzed to assess the possibility that increased loss of peripheral sensitivity was, in fact, the cause of increased speech audiometric abnormalities. Subgroups of 20 patients each were matched for hearing loss, on the basis of pure-tone average (average of thresholds at 500, 1,000, and 2,000 Hz), across the age range. Results of the matching process are shown in Figure 2A.

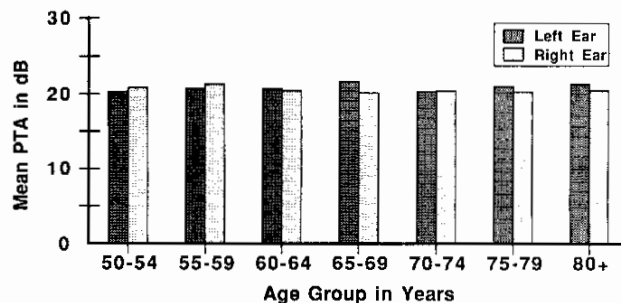


FIGURE 2A. Mean pure-tone average of the right and left ears of subgroups of 140 presbycusis subjects as a function of age group.

Despite nearly identical peripheral hearing loss, the prevalence of CAPD increased systematically with age, as shown in Figure 2B. While this was expected because the criteria for CAPD had built-in controls for degree of hearing loss, nevertheless, the results serve to point out that central presbycusis cannot be explained simply as an artifact of peripheral hearing loss.

With regard to cognitive influences on speech audiometric measures, we recently reported data showing that results on speech audiometric tests of central function were not necessarily related to cognitive disability (Jerger, Stach, Pruitt, Harper, & Kirby, 1989). Results from 23 patients with a neuropsychological diagnosis of dementia, who had been seen for audiologic evaluation, were evaluated. Among the cognitive deficits found were those of memory, tolerance of distraction, mental tracking and sequencing, and cognitive flexibility. Yet, despite such deficits, 12 of the 23 subjects (52%) yielded speech audiometric results consistent with normal central auditory function. That the CAPD found in the remaining 11 subjects could be related to cognitive deficits could not be ruled out. Neither could the possibility that results on the neuropsychological evaluation were confounded by the effects of CAPD. In any event, the fact that demented patients could perform well on behavioral speech audiometric tests argues against the simplistic explanation that central presbycusis can be explained as easily by cognitive decline as by a specifically auditory central deficit.

THE EFFECT OF CENTRAL PRESBYCUSIS ON HEARING AID USE

Of course, central presbycusis would not be considered much of a problem if it had no obvious consequence on communication ability or on amelioration techniques. However, evidence is mounting that CAPD can affect hearing aid use adversely. Three lines of evidence sug-

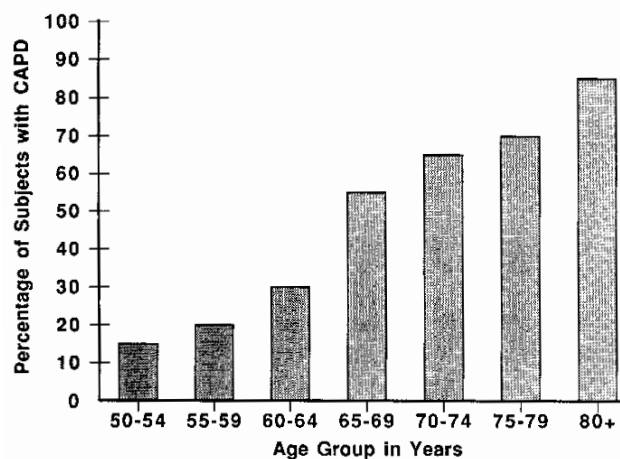


FIGURE 2B. Prevalence of CAPD in 140 presbycusis patients, matched for hearing loss, as a function of age group.

gest this relationship: (a) patients with CAPD do not perform as well with hearing aids as patients with only peripheral deficits, (b) patients with CAPD do not appear to be as satisfied with hearing aid use, and (c) some patients with CAPD do not benefit as much from hearing aid use as those with a strictly peripheral hearing loss.

Aided Performance

Hearing aid performance has been found to be affected adversely by central processing disorder. Hayes and Jerger (1979) evaluated aided performance in a sound field by a group of patients with a speech audiometric pattern consistent with peripheral auditory deficit and a group with a pattern consistent with central auditory deficit. They found that those with CAPD did not perform as well with hearing aids as those without CAPD. They also found that performance declined with increasing degree of the central auditory deficit. Even with age and degree of hearing loss controlled, the CAPD group performed more poorly.

Hearing Aid Satisfaction

Hearing aid satisfaction also has been found to be affected adversely by CAPD. Jerger and Hayes (1976) found that those who rated hearing aid use as unsatisfactory performed more poorly with hearing aids in a difficult listening situation than those who were satisfied with hearing aid use. McCandless and Parkin (1979) found that a surprising 89% of those who were classified as having a central site-of-lesion had rejected hearing aid use. Finally, Hayes, Jerger, Taff, and Barber (1983) found that aided speech audiometric results in a difficult listening situation were substantially poorer in a group that found hearing aid use to be unsatisfactory. It appears that hearing aid wearers who have mixed peripheral and central disorder are generally less satisfied with hearing aids than those with only peripheral hearing loss.

Hearing Aid Benefit

Attempts also have been made to evaluate hearing aid benefit, rather than satisfaction, based on the idea that a patient may benefit from hearing aid use but be dissatisfied because of such nonauditory factors as earmold fit or hearing aid appearance. One recent attempt to evaluate the relationship between hearing aid benefit and CAPD suggested that CAPD does not appear to have an adverse effect on benefit (Kricos, Lesner, Sandridge, & Yanke, 1987). Classification of central function was based on PB-SSI patterns, and perceived benefit was based on a questionnaire, the Hearing Aid Performance Inventory (HAPI). Results showed that those with peripheral speech audiometric patterns obtained scores on the HAPI similar to scores of those with central speech audiometric patterns. Interestingly, results also showed no relation-

ship between age and scores on the HAPI or degree of hearing loss and scores on the HAPI, two factors that a sensitive measure would be likely to differentiate.

We also attempted to study this relationship between CAPD and hearing aid benefit (Stach, 1990). Audiologic results from a large group of hearing aid wearers were reviewed to form two groups of 12 subjects matched for age and degree of hearing loss. One group had a speech audiometric pattern consistent with mixed peripheral and central auditory disorder, and the other had a pattern consistent with only peripheral disorder. Benefit was judged on a 5-point scale following telephone interviews by an audiologist who was "blind" to the design of the study. Results are shown in Figure 3. While the benefit ratings assigned to the peripheral group were mostly positive, those assigned to the central group were distinctly dichotomized. While some subjects benefited from hearing aids, others reported no benefit. Overall, the prognosis for successful hearing aid use was found to be reduced if CAPD were present.

Cause/Effect Relationship?

If CAPD occurs as a result of the aging process, then it is likely to progress over the years. Also, if CAPD can result in limited benefit from hearing aid use, then it is likely that benefit can become diminished as CAPD progresses. Therefore, it is theoretically possible that a successful hearing aid wearer can become unsuccessful as central presbycusis progresses. We reported previously on what appeared to us to be just such a case (Stach, Jerger, & Fleming, 1985).

Subject CT was first seen for an audiological evaluation at the age of 70 years. At that time he had a mildly sloping, symmetrical hearing loss and evidence of very mild CAPD on the right side. Although he was having communication problems, he did not feel that a hearing aid was warranted. He was evaluated several times over the next 9 years. At the age of 75, he was fitted with a hearing aid

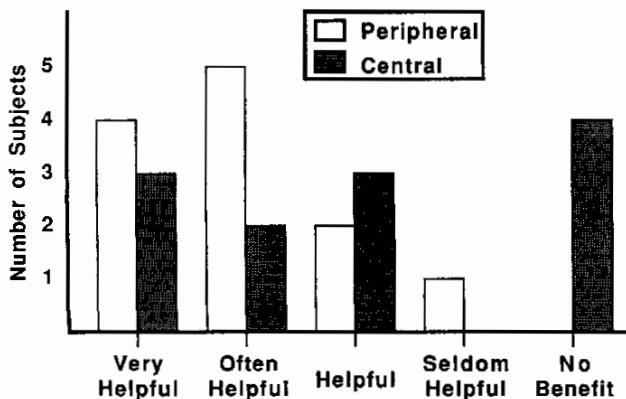


FIGURE 3. Distribution of hearing aid benefit ratings by subjects with a peripheral pattern of auditory disorder and by subjects with a mixed peripheral and central pattern (from Stach, 1990).

on the right ear and wore it with a fair, but decreasing, amount of success over the next several years. At age 79, he became convinced that his hearing aid was no longer functioning. He reported that it was amplifying sound, but not clearly. Since an electroacoustic analysis revealed a properly functioning hearing aid, audiological testing was repeated. Results showed that his peripheral sensitivity had changed only minimally, but that his central function had declined substantially. Figure 4 shows the results of serial evaluations over the 9-year period.

We found this case to be a persuasive argument that a decline in central auditory function, independent of peripheral changes, could result in a parallel decline in benefit from hearing aid use. This patient was considered an excellent candidate for amplification because of the degree of peripheral hearing loss, the mild slope, and good speech understanding in quiet. That he became an unsuccessful user strengthens the argument that CAPD can impact negatively on success with conventional amplification.

ALTERNATE AMPLIFICATION STRATEGIES

The most important manifestation of central presbycusis is a reduction in the ability to understand speech in the presence of background competition. While the adverse effects of noise on speech understanding is greater in listeners with peripheral hearing loss than in those with normal hearing, it is likely that those effects will be confounded by the additional deficit resulting from

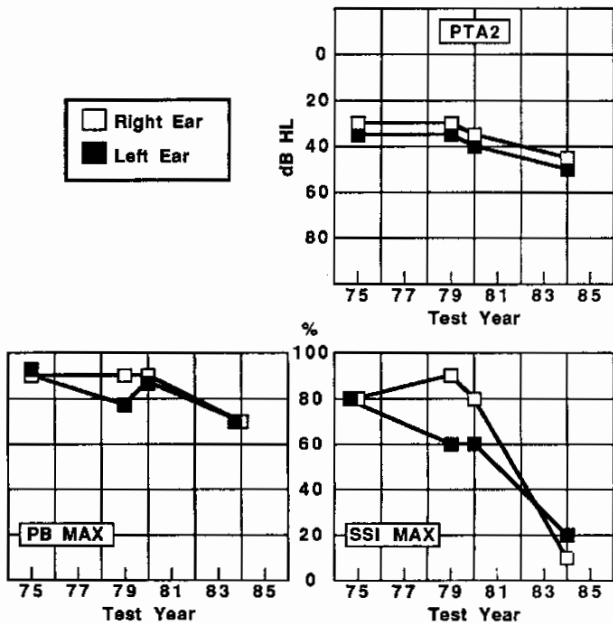


FIGURE 4. Changes in pure-tone average (PTA2—average of 1000, 2000, & 4000 Hz) and speech audiometric scores over a 9-year period. Subject CT was age 70 years at the initial evaluation in 1975 (from Stach et al., 1985).

CAPD. Although modern conventional hearing aids offer minor frequency response alterations aimed at reducing background noise, there is no evidence to suggest that such acoustic alterations can overcome a problem as substantial as CAPD. Indeed, to provide the listening conditions in which the patient with CAPD can function successfully, the use of remote microphone technology may be the only solution.

Remote Microphone Amplification

The use of remote microphone technology, specifically personal FM systems, by adults has been growing over the past several years. Once restricted almost exclusively to classrooms for the hearing impaired, FM systems are now becoming the amplification system of choice for many adults, especially the elderly. Since decrease in hearing aid benefit can result from central auditory disorder, and since central auditory disorder is often characterized by inability to function well when the signal-to-noise ratio is unfavorable, we have begun to recommend the use of personal FM systems to the elderly with central auditory disorder.

We recently summarized our clinical experience with FM system use (Stach, Loisel, Jerger, Mintz, & Taylor, 1987). Over a 2-year period, we identified 170 patients as potential FM system users. Of these, 73 (42.9%) used FM systems successfully. Of all patients identified, 108 were adults, 35 of whom were eventually successful FM system users. Of the 35 adult users, 18 (51%) were over the age of 65 at the time of dispensing. Five of those patients had a primarily peripheral auditory disorder pattern, and 13 had a mixed peripheral and central pattern. A more recent analysis of our clinical experience showed that 45 elderly patients had tried an FM system in our clinic. Nine of them elected to purchase a device without any trial period. The remaining 36 patients used a device from our loaner stock for at least 2 weeks. Following that trial period, devices were dispensed to 15 (42%) of the patients. Of the 24 patients to whom a device was dispensed, 7 had a primarily peripheral auditory disorder pattern, and 17 had a mixed peripheral and central pattern.

We recently have completed a small pilot study of the impact of FM devices on the lifestyles of seven elderly patients. In addition to a complete battery of audiometric measures, a battery of quality-of-life tests, including measures of personality, socioeconomic status, physical health status, emotional symptomatology, social interaction, participation in daily living, and life satisfaction, was administered. Results of the pilot data support the hypothesis that use of FM systems can help hearing-impaired older people maintain active involvement in social situations and daily activities involving communication with family and long-time acquaintances. In addition, we have learned that there is considerable variability in the frequency of FM system use and in situations in which patients use these systems to aid their hearing. Also, some FM system users appeared to be more hampered than

others by the technological features and physical demands of using the device or were reluctant to enlist the cooperation of others to use the FM system in social situations. Our overall impression was that the use of FM systems adds a new and decidedly positive dimension to our ability to assist those with central presbycusis in meeting their amplification needs.

An Illustrative Case

The following case serves as an illustrative example of the patients we have served. The patient was evaluated and managed by the clinical staff of The Methodist Hospital Audiology Service. Her case is representative of the success that we have experienced with the application of FM assistive devices to those with central auditory disorder. While she is typical of our patients in her audiologic results and the benefit that she receives from an FM system, she is atypical in that she currently is using only an FM system instead of combining use of an FM system with conventional hearing aids.

Subject MC, a 76-year-old female, was evaluated at our facility as the result of a hearing complaint. She reported having a hearing loss in both ears, probably greater on the left. She also reported difficulty in all listening environments and was interested in obtaining a hearing aid. She reported no dizziness or tinnitus, and her medical history was rather unremarkable.

Audiologic testing was routine, except that the patient became somewhat upset during the SSI test, due to her apparent frustration over the difficulty of the task. Results of the audiologic evaluation are shown in Figure 5A. She had a moderate, flat, symmetric, sensorineural hearing loss. Middle ear function was normal bilaterally. Results of speech audiometric testing were consistent with significant central auditory processing disorder, as characterized by a depressed SSI maximum score and PB-SSI discrepancy in excess of 20%. Neither abnormality could be explained by the degree or configuration of the peripheral hearing loss.

Because of the nature and degree of her hearing loss, an FM system was used during the routine patient counseling session. Her reluctance to use the system initially was not atypical, but, by the end of the session, she was reluctant to part with the device.

Since we judged her prognosis for success with conventional hearing aids to be questionable, and since her major communication needs were in noisy environments, we made the decision to carry out a clinical evaluation of the device. At the time of the FM system evaluation, we also made ear impressions for conventional hearing aids, since it was our conventional wisdom that this was necessary. Following the FM system evaluation, the patient decided against a trial period with a loaner device and, instead, elected to purchase the device. She returned 3 weeks later, filled with anecdotes about her success with the new amplification system. At that time, hearing aids and the FM system were evaluated for comparison purposes.

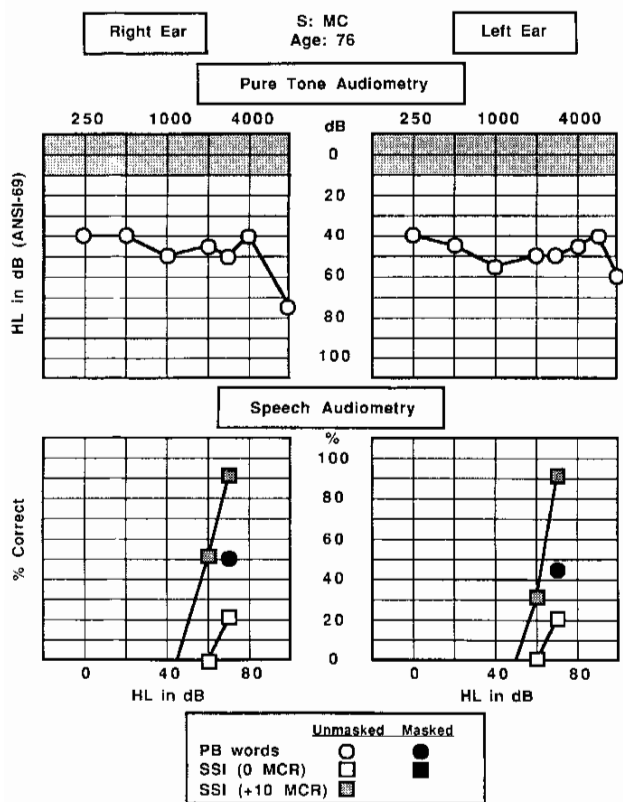


FIGURE 5A. Pure-tone and speech audiometric results in Subject MC, a 76-year-old patient with mixed peripheral and central presbycusis.

Figure 5B shows the results of the hearing aid evaluation. The procedure used was described previously (Herger & Hayes, 1976). Briefly, a message (sentences from the SSI) was presented at a fixed sound-pressure

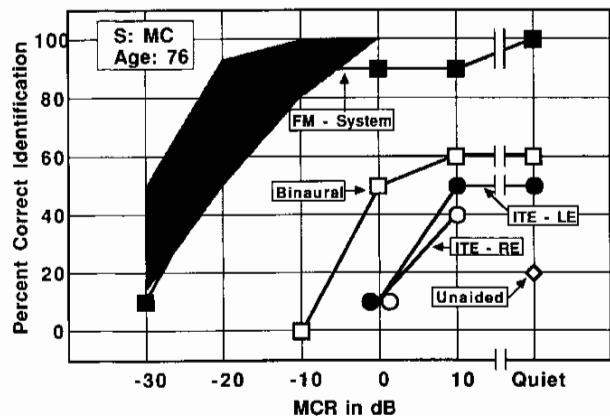


FIGURE 5B. SSI hearing aid evaluation results in Subject MC, a 76 year-old patient with mixed peripheral and central presbycusis, with an in-the-ear (ITE) hearing aid on the right ear (RE), left ear (LE), and both ears (binaural) and with an FM system coupled to the right ear. Shaded area represents range of performance for normal listeners.

level from a speaker directly in front of the patient. Competition (single talker monologue) was presented from a speaker directly behind the patient. The competition was varied in intensity, and percent-correct identification scores were computed at the resulting message-to-competition ratios (MCR). Results show that use of hearing aids resulted in some improvement over the unaided condition, especially in the binaural configuration. However, regardless of the ear or ears aided, performance was substantially below normal performance. With an FM transmitter placed at the front speaker, thereby enhancing the signal-to-noise ratio, and with a broadband insert earphone on her right ear, performance was enhanced substantially. It is of interest to note that performance with the FM system and the hearing aids was not parallel, as might be expected from simply moving the microphone closer to the source. Instead, it appears that because of the superior fidelity of the FM device, speech understanding was enhanced beyond that which could be explained by simply enhancing the signal-to-noise ratio.

Subject MC uses her FM device with success in numerous listening situations, including in church, in the car, at the dinner table, and while watching television. She reports that use of the device has enhanced her quality of life by allowing her to resume participation in functions she had long since given up.

SUMMARY

Central presbycusis is quite prevalent in the elderly population. While CAPD is certain to adversely affect the communication abilities of elderly patients, its impact on benefit from conventional hearing aid amplification may be even more detrimental. It appears that some individuals with combined CAPD and peripheral hearing loss do not benefit as expected from hearing aids and may require additional assistance in the form of a remote microphone amplification device, such as a personal FM system. Implementation of FM technology in this population has had a substantial and positive impact on the communication skills and quality of life of many such patients.

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**G. INFLUENCES OF TECHNOLOGY ON RESEARCH ON COMMUNICATION
SCIENCES AND DISORDERS**

Chapter 17

THE ROLE OF TOPOGRAPHIC AND QUANTITATIVE ELECTROPHYSIOLOGY IN COGNITIVE ISSUES IN AGING

TERESE FINITZO JAMES BARTLETT KENNETH D. POOL

The University of Texas at Dallas and the Neuroscience Research Center

The elderly brain is less efficient in complex cognitive processing, in elaborative encoding, and extensive activation, in response to stimulus information (Craik & Simon, 1980; Salthouse, 1985). While such normal aging of cognition is not pathological, it does have obvious relevance to the diagnosis of cognitive impairments, such as those in aphasia and dementia (Morris & Kopelman, 1986). Unfortunately, our theoretical understanding of the neurophysiologic processes that underlie behavioral alterations with age has lagged far behind the accumulation of facts. Part of the problem is the complexity of those facts. However, another part of the problem is, clearly, our ignorance of the roles played by such neurophysiologic "hardware" factors as neuronal structure or number, processing "software" factors like task-specific strategies, and such contextual factors as perceived meaningfulness of tasks (Poon, 1985). Disentangling these factors will demand increased knowledge of the relations between cognitive and neurophysiologic processes across the adult life span. Although we know something about the aging of cognitive processes and something about the aging brain, we know frustratingly little about how—or in many cases even whether—one affects the other. For example, do progressive neuronal changes in the temporal lobe relate to changes in auditory perception, and is the change (behavioral as well as electrophysiologic) continuous or step-wise?

MEASUREMENT TECHNOLOGY

Recent technological innovations in clinical medicine can assist in disentangling the role of "hardware" factors as they affect the aging brain and cognitive decline. We can examine both structure and function of the nervous system using magnetic resonance imaging (MRI), positron emission tomography (PET), single photon emission computed tomography (SPECT), and quantitative and topographic electrophysiology. Each has its role to play. However, while "static" measures, like MRI, can provide exquisite images of the aging brain's structure

with resolutions under 3 mm, there is no direct link between anatomy and behavior. Relating structural images to behavior requires speculation about the intervening neurophysiologic substrate.

Functional brain imaging offers a dynamic rather than static approach and allows us to study brain *in vivo*, to identify functional changes in and beyond sites of structural damage. It furnishes the needed interface between behavior and anatomy.

One advantage of functional metabolic imaging techniques, like SPECT and, especially, PET, is spatial resolution on the order of 6 to 20 mm. Conversely, a limitation of metabolic measures is their inability to examine temporal characteristics to determine whether the altered behavior is a consequence of altered metabolism or vice versa. Temporal resolution varies from several seconds to as much as several minutes, depending on the specific technologies used. Theoretically, a behavioral impairment resulting from timing or sequencing errors in brain activity might coexist with normal metabolism.

Electrophysiology's strength has been in assessing the electrical activity that is synchronized and thus related to the processing of a stimulus. Its major limitation has been in identifying the site or area of the brain engaged in an abnormal or, indeed, a normal physiologic process. The limited contribution to date of EEG and evoked potential studies to understanding the subtle processes of normal aging may be due, at least in part, to the traditional approach to data collections and analysis which localizes effectively in time but less effectively in space.

One reason is that few evoked potential (EP) studies have described or analyzed data at more than three or four electrodes, typically at Fz, Cz, and Pz or O1 and O2. Figure 1 is a single-channel, long-latency cortical auditory evoked potential recorded at Cz and displayed for 500 ms of poststimulus activity. There is simply too little information in this traditional single-channel EP to lateralize even a major hemispheric brain lesion such as stroke, let alone to differentiate the subtle distinctions one might expect in normal aging. The problem with

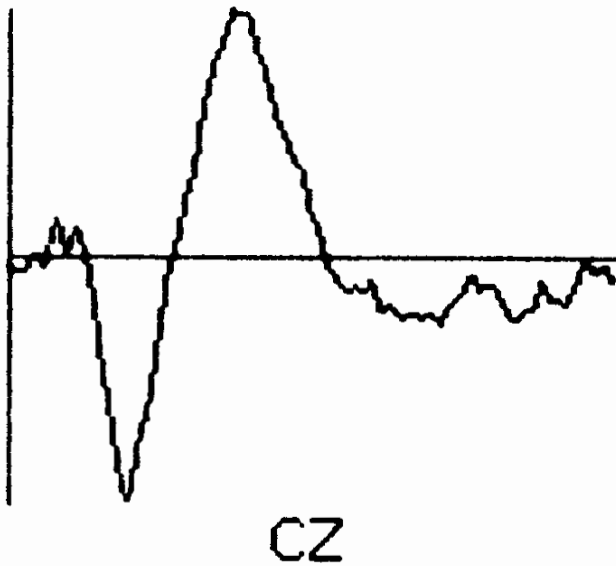


FIGURE 1. Single-channel cortical auditory evoked potential (AEP) recorded from Cz, averaged and displayed for 508 ms.

electroencephalograms (EEG) is a related one. Figure 2 is a display of a single page from a 25-channel EEG collected in our laboratory. Typically, a single study may contain several hundred such pages. In this case, there may be too much information in the millions of bits of data in the raw EEG to allow researchers to discriminate by visual inspection alone electrical profiles that accompany cognitive alterations.

These methodologic and technical limitations do not eliminate electrophysiology as a player in this arena. The introduction of quantitative, statistical, and topographic analysis to electrophysiology provides an expanded view of brain electrical activity. At its core, electrophysiology is EEG and evoked potentials, but now the ability to collect and easily quantify multiple-channel electrophysiologic data profoundly alters interpretation.

While classical EEG is collected spatially from multiple electrodes and examined visually for frequency content and site of lesion with quantitative analysis, we can evaluate the absolute amount of delta (0.5–3.5 Hz), theta (4–7.5 Hz), alpha (8–11.5 Hz), and beta (12.0 Hz and above) frequencies in the EEG activity for a subject, patient, or group. The absolute EEG activity can be compared to that of a normal group, and differences quantified by region. In Figure 3, quantitative EEG spectral waveforms, obtained from 20 scalp electrodes according to the 10–20 International System of electrode placement, are displayed. Basically, these are Fourier transforms of multiple 2-s segments taken from the raw EEG. The Fourier analysis reveals the absolute amplitude of each frequency band in the EEG. Such an approach can also be applied to other aspects of EEG frequency, such as power, symmetry, coherence, and relative or normalized amplitudes.

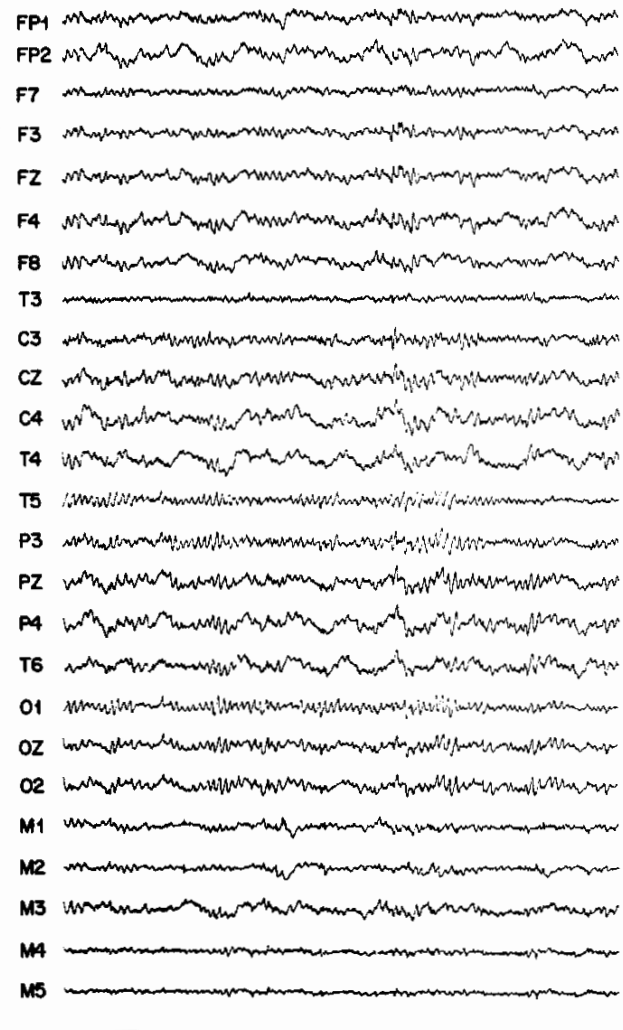


FIGURE 2. Twenty-five channel raw EEG referenced to linked ears. F refers to frontal, T to temporal, C to central, P to parietal, and O to occipital. M refers to extra-cerebral electrodes to monitor artifacts. Odd numbers are on the left; even numbers are on the right. Z refers to midline electrodes.

Yet the power of this technology is not the quantification alone, but rather the introduction of topology that adds the needed spatial component to the electrical activity. The topology enables us to understand “where” as well as “when.” The impact of topology is readily seen in EPs. EP waveforms traditionally are examined temporally, with little attention to spatial distribution. That is, we inspect the latency and amplitude of individual response components (recall the single-channel EP displayed in Figure 1). In Figure 4, we display a 500-ms post-stimulus average of the same long-latency cortical auditory evoked potential, obtained simultaneously from multiple (20) scalp electrodes rather than one. Careful examination does reveal that the morphology of the auditory evoked response varies with scalp location of the electrodes. Generally, the potential is maximal over the

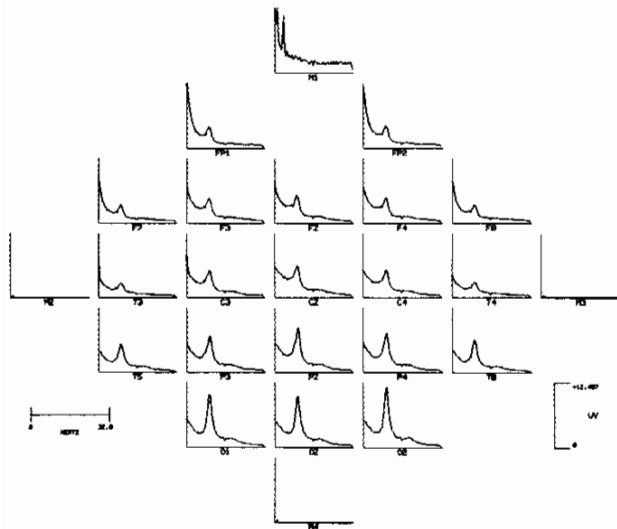


FIGURE 3. Fast Fourier transforms (FFT) of raw EEG provide quantitative information on the absolute amplitude of frequencies present in the EEG.

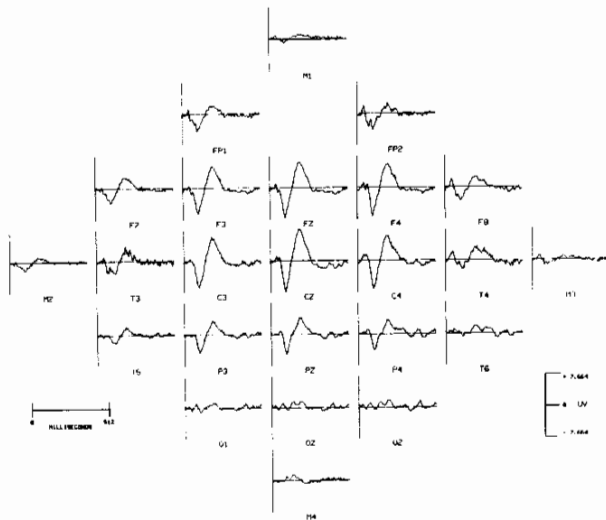


FIGURE 4. AEPs recorded simultaneously and displayed at 20 scalp locations.

frontal central electrodes and minimal or nearly isoelectric over the temporal electrodes, but the effect, viewed as waveforms alone, is not a compelling one.

In Figure 5, the auditory evoked potential amplitude at 100 ms is displayed topographically and in color. Initially, we proposed that mapping the waveforms simply facilitated visual inspection of the data (Finitzo & Pool, 1987). Indeed, it is easier to recognize that amplitude is symmetric broadly over the entire head at 100 ms in this figure than by looking at the 20 waveforms displayed in Figure 4. While Figure 5 is only a single frame of data from the 500-ms waveform displayed temporally above, the amplitude is now displayed spatially. In Figure 6, we readily can observe a different spatial distribution for a

small group of patients with left middle cerebral artery infarction (Pool, Finitzo, Hong, Rogers, & Pickett, in press). Note that the normally symmetric potential appears to be pushed over into the right hemisphere and out of the damaged left hemisphere (Pool et al., in press).

The topology contributes to understanding the slope and gradient of the potential, which is information difficult to discern from the temporal display of the waveforms. Moreover, the topology can be viewed for each 4-ms latency increment, thus maintaining the temporal resolution, or as a movie over the entire 500 ms. Such alternatives may afford the clinician new, albeit complicated, information about the location of the underlying electrical generators. Quantitative and topographic analysis is a different way of thinking about electrophysiology (Kraus & McGee, 1988).

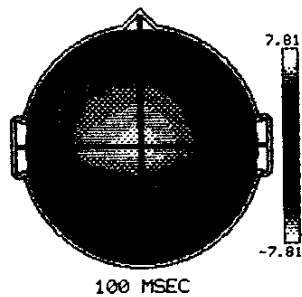
Such analysis may allow detection of clusters of individuals with similar profiles, which relate to similar cognitive/behavioral performance in aging populations. In the past, we have discovered behavioral clusters and attempted to use them to understand normal and pathologic patterns of aging. However, success in relating such behavioral clusters to other aspects of brain function has been limited. Interindividual and longitudinal studies have been complicated by subject variability as well as the slow temporal course of performance alterations with age. We advocate augmenting the behavioral profiles with the electrophysiologic profiles. Perhaps the interindividual differences will be more clear-cut and the rate of detectable change more rapid.

However, before we are to declare that brain electrical activity measures can be employed in documenting cognitive decline in the elderly, links must be established between specific quantitative electrophysiologic features and specific cognitive abilities (Thompson, Patterson, & Michaleski, 1987). Tackling such complex cognitive questions, however, necessitates that we focus first on basic issues. In the next section, we summarize briefly earlier electrophysiologic aging research and introduce representative quantitative data to demonstrate the approach we advocate.

APPLICATION OF QUANTITATIVE AND TOPOGRAPHIC ELECTROPHYSIOLOGY IN AGING

Electrophysiologic changes associated with aging have been studied for nearly half a century (Fenton, 1986). However, not surprisingly, elderly subjects are not a homogeneous population. In electrophysiologic studies to date, not all adults even show the effects of aging (Krauhin, Gordon, Stanfield, Meares, & Howson, 1986). In some cases, the difficulty in replicating findings is due to methodologic and technical inadequacies. First, adequate numbers of subjects over a broad age are seldom available. More commonly, one reads that 59 subjects spread over 7 decades were tested (Barrett, Neshige, & Shibasaki, 1987; Gordon, Krauhin, Stanfield, Meares, &

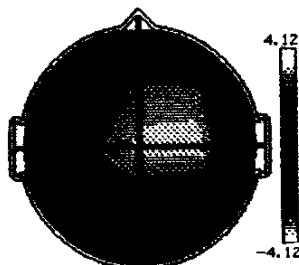
NORMAL GROUP



100 MSEC

FIGURE 5. Topographic display of AEP amplitude at 100 ms for a normal control group.

LMCA GROUP



104 MSEC

FIGURE 6. Topographic display of AEP amplitude at 104 ms for a group of patients with left middle cerebral artery infarction. Note the reduced amplitude especially over the left hemisphere. Asymmetry to the topology is seen in comparison to the symmetric response over both hemispheres in Figure 5.

Howson, 1986). It is not that 59 subjects are inherently too few. In some research, however, given the large number of electrophysiologic variables, such an N size is inadequate for appropriate statistical power or to develop normal models for electrophysiologic aging. Second, physical and mental status of the subjects is often overlooked. Third, audiologic histories are virtually unreported, a distressing discovery since many of the experiments include auditory paradigms. Finally, violation of assumption of statistical models is common. If our aim is to develop a model that is clinically useful, then adherence to those assumptions is in order (Thompson et al., 1987). Specifically, numerous investigators have attempted, using a linear regression, to evaluate the extent to which latency and amplitude of P300 changed with age (Goodin, Squires, Henderson, & Starr, 1978; Pfefferbaum, Ford, Wengrat, Roth, & Kopell, 1984a). Thompson et al. (1987) take issue with those predictive regression attempts for failing to assure that variances are equal at all measurement points. Indeed, the relationship in question

may not even be a linear one (Brown, Marsh, & LaRue, 1983).

Age-Related Differences in EEG and EEG Spectra

EEG studies in aged populations have identified a diffuse increase in delta and theta activity and a slowing of the posterior dominant alpha rhythm, but even these simple global descriptions generate controversy and are not universal (Soininen, Partanen, Helkala, & Riekkinen, 1982). Moreover, correlations between the EEG and clinical judgments of cognitive deterioration, while initially encouraging, have been difficult to replicate when dementias of mixed etiology are introduced (McAdam & Robinson, 1956; Merskey et al., 1980).

Two explanations for the discrepancy in age-related EEG changes have been reported (Duffy, Albert, McAnulty, & Garvey, 1984). The first is basic to visual inspection of an EEG, which has been an important diagnostic tool in the identification of focal paroxysmal findings, but which has been less successful in identifying abnormalities of EEG background. Unaided visual inspection is vitally dependent on the expertise of the electroencephalographer. The second may be due to the inclusion of unrecognized disease, such as hypertension, diabetes, or arteriosclerosis, that may alter an EEG in study populations. Duffy et al. (1984) studied 63 healthy males between 30 and 80 years of age using quantitative EEG spectra in 10 different resting and activated conditions. In contrast to many others, they reported that alpha frequency in the eyes-closed state did not decrease with age and that only a minimal alpha amplitude to age correlation was observed ($R = -.276, p < 0.05$). There was a strong correlation between alpha reactivity ($R = -.457, p < 0.001$) and age. Alpha reactivity is defined as the ratio of eyes-closed alpha amplitude to eyes-open amplitude. Alpha activity is "blocked" in eyes-open states. The behavioral correlate to the electrophysiologic effect may be declining vigilance and environmental sensitivity. Surwillo (in Salthouse, 1985) postulated that the alpha rhythm is a central timing mechanism for most neural operations. If cycle time is slower in one system than another, duration of all resulting processes will be affected (Salthouse, 1985).

EEG was also measured in different behavioral states, such as listening to speech or music, reading, or doing various neuropsychological tests like the Kimura Figure or Paired Associates Test (see Salthouse, 1985). Most age-associated EEG changes were maximal in the temporal lobes bilaterally. Right hemispheric age changes were observed to be correlated with visuospatial performances. Temporal lobe-defined EEG features were correlated with scores on both verbal and nonverbal memory. In general, Duffy et al. (1984) identified more right hemispheric electrophysiologic features to be related to aging. While this work suffers from some of the same technical limitations described earlier, such as a relatively small sample size and a large number of electrophysiologic measures, it is nonetheless intriguing as it supports clas-

sic brain behavioral concepts for preferentially greater aging in the right hemisphere (Albert & Kaplan, 1980).

In the next figures, we use normative data resident in the BEAM® system (Nicolet Instrument Corporation) to demonstrate EEG spectral differences for different age subjects. Because these data are part of the normal data base, all subjects have undergone extensive neurologic examination and some psychological testing, including a Hooper, WAIS, and handedness scale (F. Duffy, personal communication, 1984). Audiograms were not obtained. The most we can say is that subjects who admitted to hearing difficulties on a preliminary questionnaire were excluded. The elderly were studied more extensively because they were a part of the Boston VA study on aging (Duffy, 1984). Figure 7 is a comparison of EEG delta amplitude for 70- to 79-year-old subjects on the left and 20- to 29-year-old subjects in the middle. Both images are scaled in microvolts to the higher maximum of the two groups corrected for small sample sizes and set to t score of 2.65 to achieve $p < 0.01$. Note that there is no increase in the absolute delta activity in the normal older subjects, which would be seen as a yellow/white color change in the t map. Similarly, there is no alteration in theta or alpha amplitudes in this group of elderly. Figure 8 displays the alpha group comparison. In contrast, as shown in Figure 9, there is an increase in fast (beta) activity. Unfortunately, while the physiology of delta and theta and even alpha has been studied, little is known about the meaning of increased beta. Inferences also linking beta to attention processes have been suggested.

We have not studied activated EEG in aging populations, although we have compared EEG at rest with EEG during the Wisconsin Card Sort Test (Heaton, 1981) in schizophrenic patients. The critical issue in assessing EEG in different cognitive states is to select tasks of importance in aging populations.

Consider, for example, divided attention tasks, which frequently have shown deficits on the part of the elderly as compared to young adults (Craik, 1977). Such age differences have been found with the dichotic listening procedure, in which spoken verbal items are presented via headphones as two simultaneous, auditory channels. The elderly are impaired in recalling the items, presumably due to an age-related deficit in division of attention

(c.g., Inglis & Caird, 1963). Salthouse and his colleagues (Salthouse, Rogan, & Prill, 1984) have extended this finding to the visual modality, adding controls for age differences in (a) performance under single-channel (non-divided-attention) conditions, (b) strategies for "trading off" one channel against another, and (c) output interference arising from subjects making multiple responses in recalling the stimuli.

What sorts of neural differences might underlie these behavioral differences in divided-attention and other types of cognitively complex tasks? Two speculations that have been offered recently are that the behavioral differences reflect (a) changes in frontal-lobe functioning (Albert & Kaplan, 1980) and (b) diffuse cortical thinning, which might reduce inhibition of spread of excitation between neighboring regions of cortex, increasing interference between processing in these regions (Kinsbourne, 1980). The first hypothesis, at least, has a clear implication of EEG spectral differences between young and older subjects who are performing different versions of cognitive tasks: When divided-attention requirements are added to a task, or when a single task is changed to be more cognitively complex, spectral differences in the frontal brain region might become more marked. Kinsbourne's cortical thinning principle has less clear implications for EEG differences, though it may be consistent with some EP data that we discuss below.

Age-Related Differences in Evoked Potentials and Event-Related Potentials

There is ample evidence supporting age-related latency increases for the cognitive dependent P300 (Goodin et al., 1978; Pfefferbaum et al., 1984a,b; Brown, Marsh, & LaRue, 1983). Additional information may be provided by topographic analysis, as we do not know if P300 at the midline electrodes is correlated to different processes (either neural physiologic or behavioral) over temporal regions. On the other hand, the evidence relating P300 to declining cognitive vigilance and its clinical value in diagnosing dementia generate sharp disagreements.

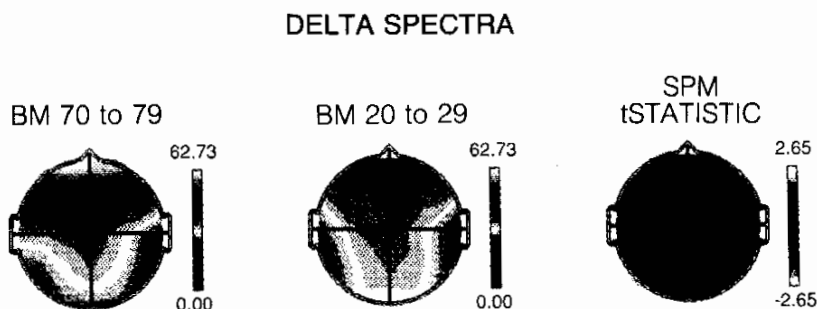


FIGURE 7. EEG delta spectral amplitude displayed for 70- to 79-year-old subjects on the left, and 20- to 29-year-old subjects in the center. The image on the right is a t -test corrected for small sample size. There is no significant increase in slow (i.e., delta) activity seen in the aged group.

ALPHA SPECTRA

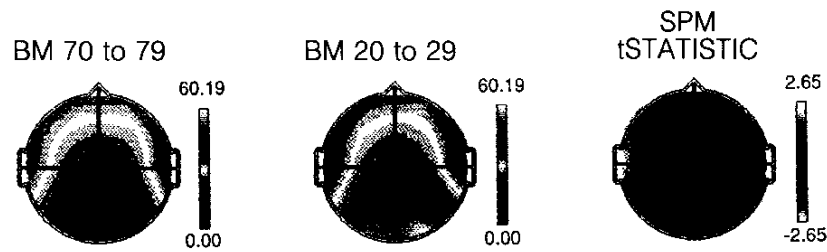


FIGURE 8. A display similar to that in Figure 7, but for the alpha spectra.

BETA SPECTRA

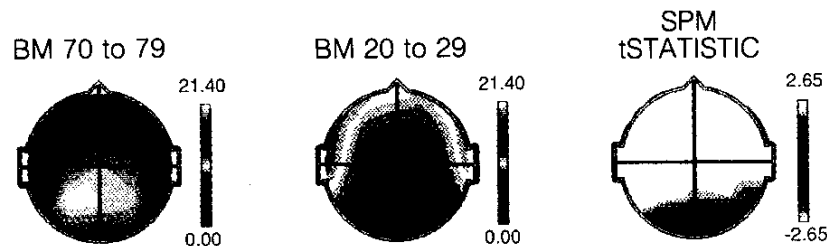


FIGURE 9. A display similar to that in Figure 7, but for beta (flash) activity. Note that there is a significant increase in fast activity in the aged population.

There are several explanations for discrepancies in event-related potential (ERP) research in aging populations, some of which we have described previously as generic to electrophysiological studies. However, the most elementary question that must be asked is whether the primary sensory system, from the periphery to the sensory related cortical EPs, is intact. Alterations in primary sensory components of the EPs, although not classically pathologic in nature, could subtly limit the accuracy of subsequent cortical processing. Such changes in electrocortical function might contribute to the higher level cognitive performance differences seen with aging. If high level processes are "misinformed," they will be unable to make accurate assessments of incoming information. We must rule out, or define, the contribution of inaccurate neurophysiologic input at lower levels as the cause for subtle sensory, perceptual, and cognitive changes in aging.

How might one examine primary electrocortical effects in aging populations using mapping? We would like to demonstrate some of the more robust findings in EP aging research using quantitative and topographic analyses. We present data for PA or PI of the middle latency response, N1 or N100, and P2 or P200 of the long latency potentials.

PA is a central (C3-Cz-C4) positive potential which averages 1.5 uv in amplitude and 32–40 ms in latency in young, healthy normal subjects (Pool et al., in press). Evidence from our work and that of others (Dieber, Ibanez, Fischer, Perrin, & Mauguier, 1988; Kileny, Paccioretti, & Wilson, 1987; Kraus, Ozdamar, Hier, &

Stein, 1982) suggests that, while the potential has a maximal amplitude at Cz, it probably is generated in the temporal lobe at the level of the superior temporal gyrus, because of the orientation of this electrical dipole.

Figure 10 topologically displays PA amplitude for 70- to 79-year-old normal adults on the far left, and for 20- to 29-year-old normal adults in the center image. These data are also the normative data resident in the BEAM® system. As in images presented above, the amplitude for the two figures is scaled in microvolts to the maximum of the two groups to facilitate visual comparison of the images. Indeed, the amplitude of the PA is enlarged in the older adults as compared to the younger subjects. The third image is again the statistical map quantifying the amplitude differences. Note the statistically significant and symmetric enhancement in PA amplitude with age, a finding also reported by Woods and Clayworth (1986). Of interest is the fact that latency did not differ significantly in either this or Woods and Clayworth's (1986) group comparisons. Furthermore, they ruled out audiometric differences between their groups as the cause for this finding. Figure 11 is a similar display of data for N100. To review briefly, N100 is a vertex-negative potential with an approximate 6-uv amplitude in young normal adults, with a latency that can vary in normals from 76–116 ms (Goff, Matsumiya, Allison, & Goff, 1977; Pool et al., in press; Wood & Wolpaw, 1982). Note that the amplitude of this potential is also enhanced for the older subjects. This finding is in contrast to that of Goodin et al. in 1978. The third map is again the *t*-test map, which shows that the

CORTICAL AUDITORY EVOKED POTENTIAL (Pa)

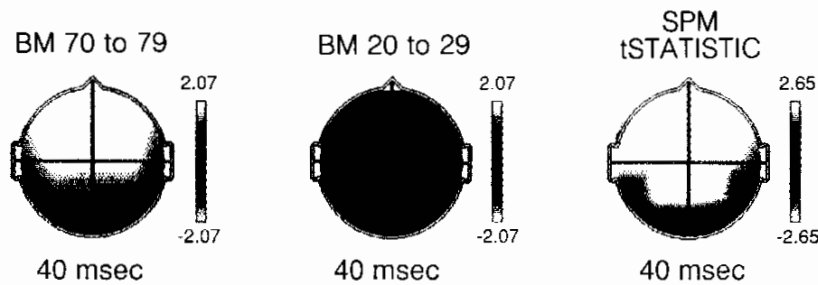


FIGURE 10. A display of PA amplitude at peak latency for two age groups, with the elderly on the left, and the younger subjects in the middle. The *t*-test map shows significantly increased PA amplitude for the elderly subjects.

CORTICAL AUDITORY EVOKED POTENTIAL (N100)

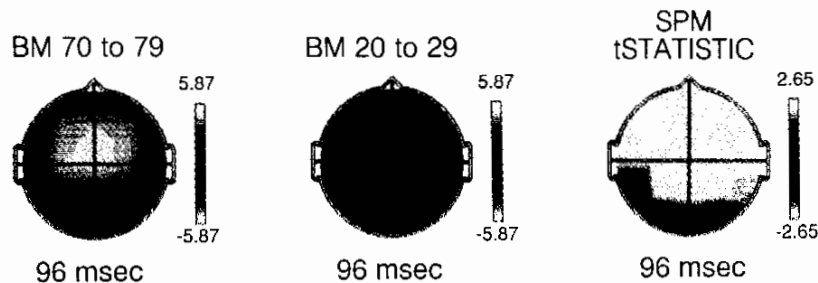


FIGURE 11. A display of N100 amplitude at peak latency for both groups. The *t*-test map again shows increased amplitude in the elderly.

amplitude increase occurs at multiple electrodes over the surface of the scalp. In this comparison, as in Pfefferaum, Ford, Roth, and Kopell (1980), latency was not substantially altered.

Woods and Clayworth (1986) postulate that age-related increases in PA may reflect a gradual reduction in thalamic reticular nucleus inhibitory inputs to the medial geniculate body and, subsequently, to the cortical PA generator. In a similar vein, Dustman and Shearer (1987) hypothesize that a relative reduction in cortical inhibition accompanies normal aging. It is this reduced inhibition that produces increased excitation that may be reflected as larger cortical EPs for PA and also N100. Kinsbourne's (1980) cortical thinning hypothesis, mentioned previously, is obviously a similar notion. On the assumption that increased excitation is the cause of the large early EPs in the elderly, both ideas fit the data.

One can similarly examine P200. Goodin et al. (1978) reported an increase in the latency of P200 with age and a decrease in amplitude. Figure 12 is the same color-graphic display for the P200 response (older subjects on the left, younger subjects in the middle, and *t*-test map on the far right). Note that elderly subjects' amplitude is reduced relative to that of the younger subjects, but the statistics here are deceiving. Amplitude is lower for the elderly subjects at 164 ms, but that seems to be due to the

fact that P200 peak latency in this group is increased to 208 ms. When amplitude at that latency is compared to that for the younger subjects, many of the differences are eliminated.

The "least-disputed" conclusion from behavioral research is that information processing is slowed in old age (Salthouse, 1985). The electrophysiologic latency increase in P200 and P300 would be broadly consistent with such behavioral findings. However, latency increases with age are not universal with all potentials; specifically, PA and N100 show amplitude effects only. Thus, while Salthouse's central effect theory might indicate a relationship between electrophysiology and behavior, a more selective effect appears to be present. Hypothesis-driven research is needed to understand mechanisms altering latency and amplitude.

FUTURE DIRECTIONS

With the impact of resting state EEG and primary sensory evoked potentials known, or at least controlled, activated EEG and event-related potentials can be examined as they relate to cognitive questions involving speed of processing, attention, and memory. The purpose will be to tap specific aspects of brain function in the elderly

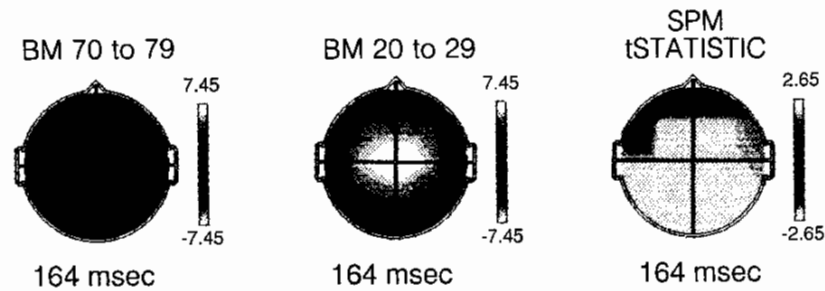
CORTICAL AUDITORY
 EVOKED POTENTIAL (P200)


FIGURE 12. A display of P200 amplitude at the peak latency for the younger subjects. The reduced amplitude of the elderly is due to a latency alteration. When the elderly subjects are compared to the younger subjects at peak P200 for both groups, there is no amplitude difference.

to address whether there are common neurophysiological substrates producing such seemingly disparate behavioral effects as slowing in choice reaction time, reductions in episodic memory, and inefficiencies in divided attention and prose comprehension. Alternately, there might be interindividual differences in neurophysiologic substrates that have similar behavioral manifestations.

Longitudinal studies will be useful to address the question of whether aging is continuous or step-wise. It is this general approach that has potential for marrying electrophysiology with cognitive behavioral questions in aging and for carrying our knowledge forward. In this way, future research in aging and cognition can integrate multiple technologies to explore anatomy, metabolism, and electrical function. The field is a relatively uncharted one for continued explorations (Thompson et al., 1987).

ACKNOWLEDGMENTS

The authors wish to acknowledge the work of Frank H. Duffy, M.D., Associate Professor, Harvard University. Dr. Duffy and his colleagues conducted the research on and collected the normative data base resident in BEAM^{II}. Beth Wallace, M.C.D., assisted us in manuscript preparation. This work was supported by NINCDS grant NS 18276 and NIA grant AGO 7798.

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Chapter 18

MICROCOMPUTER APPLICATIONS IN RESEARCH ON TREATMENT OF APHASIA

RICHARD C. KATZ

Department of Veterans Affairs Outpatient Clinic, Los Angeles, CA

Aphasia is an acquired disturbance of communication resulting from damage to language dominant areas of the brain. For most patients, aphasia is manifested by language problems in all modalities: talking, listening, reading, writing, and gesturing. Other motor and sensory problems affecting communication, such as dysarthria and apraxia of speech, frequently coexist with aphasia. As the cause of aphasia is damage to the brain, behavioral, emotional, and intellectual characteristics associated with brain impairment also may be observed in these patients, including perseveration, lability, and impairments in attention (Eisenson, 1973), memory (Loverso, 1986), and abstract attitude (Goldstein, 1948). These problems can affect motivation and independence, ultimately influencing the potential for recovery, the success of treatment, and the quality of life for aphasic patients.

APHASIA TREATMENT

Treatment facilitates recovery. Aphasia treatment is the systematic application and modification of conditions designed to help patients maximize their ability to use language and, if necessary, help patients compensate for language impairment by using alternate strategies to communicate.

The benefits of treatment for aphasic adults have been documented repeatedly through carefully controlled studies of individual patients (e.g., Prescott & McNeil, 1973; Sparks, Helm, & Albert, 1974) and of groups of patients (Hagen, 1973; Wertz et al., 1981). Results must be applied with caution, however. Patients vary according to different factors. Some of those factors are familiar, such as the type, severity, and chronicity of aphasia, and physical and psychological conditions. Others factors are less obvious, including the existence of relevant problems prior to aphasia and the patient's style of learning. Wepman (1970, p. 128) wrote, "Too many patients get better and too many fail to do so without our knowing why. If we knew why or even if we knew only the stages through which they recovered when they do perhaps we

could begin to understand why others do not get better." Darley (1972) wrote that the question clinicians and researchers should be asking is not "Does therapy work?" but for whom does it work, what does the treatment consist of, when should treatment begin and end, and how frequently should treatment be provided. Answering these questions is an essential part of any treatment program.

Methods are described in the literature (e.g., McReynolds & Kearns, 1983) to help clinicians measure the effectiveness of specific treatment activities for each aphasic patient. Assessing performance is an essential part of aphasia therapy (Holland, 1970; LaPointe, 1977). Some guidelines for the content of treatment are generally accepted by most clinicians. Schuell (1974) expected aphasia treatment to be consistent with accepted theories of language and brain function, and thus recommended frequent and repeated sensory stimulation for the organization, storage, and retrieval of behaviors necessary for language activity. Porch (1981) wrote that aphasic patients should interact within a reasonably stimulating language environment in order to reach their language potential.

In addition to addressing the language needs of aphasic people, other treatment factors, (e.g., motivation, dependency, and quality of life), are concerns that may become increasingly important as recovery slows and the degree of disability and its subsequent effect on life become more apparent to the patient and family. Under conditions of perceived helplessness and hopelessness, people frequently become depressed (Seligman, 1975) and have greater difficulty coping with and adapting to changes and problems (Coelho, Hamburg, & Adams, 1974). Bengston (1973), Langer and Rodin (1976), Schulz (1976), and others have shown that giving some options and responsibilities to persons in otherwise dependent situations (e.g., the institutionalized elderly) can have strong positive effect on their satisfaction and physical well-being. Wertz (1981) wrote that we should allow patients to maintain as much independence as possible and that a long-term goal of treatment is to have patients become

their own therapists. Decision-making and expression of personal preferences by each patient should be a basic part of patient management and treatment whenever possible.

MICROCOMPUTERS AND TREATMENT

By incorporating the principles of stimulation, accountability, and independence into the development of treatment software, the microcomputer can become a powerful clinical tool. The computer can administer treatment activities designed by a clinician or programmer, measure patient performance on the task, and store responses for later analysis by the clinician, thus increasing the amount of time patients are involved in supervised, productive, treatment activities. Sophisticated computer programs can modify the treatment task and select appropriate contingencies in response to the patient's performance.

Many computer enthusiasts imply that just about anything is possible with computers. Ten years ago less than 5% of audiologists and speech-language pathologists used computers. Five years ago that figure rose to about 27%. Currently more than 50% report using computers, with more than half of them using computers directly with patients during treatment (R. Burkholz, personal communication, 1987). Other people feel that what we do in therapy with our patients can never be quantified and coded to the degree necessary to write computer treatment programs that are truly efficacious. Loverso (1987) and others have pointed out that most computer advocates focus on "appealing" features of computers, such as cost effectiveness and operational efficiency, while the real issue that demands the attention of clinicians is treatment effectiveness; treatment activities must be effective before they can be efficient.

For proper development of treatment software, both views are valuable: the imagination and willingness of the enthusiasts and the scrutiny and demands of the skeptics. Clinicians are responsible for the treatment effectiveness, not the microcomputer, software, programmer, designer, or publisher. Clinicians make decisions based on theoretical knowledge and clinical experience.

Until we can describe to other clinicians precisely how to treat specific problems in individual patients, it is unreasonable, unethical, and a misrepresentation of aphasia therapy to assume that at this time a machine can perform the functions of a clinician.

RESEARCH

A computer is only as good as its software. Treatment programs are limited less by the hardware on which they run than by the abilities and imagination of clinicians and researchers. One way clinicians can ensure that software is efficacious is to develop their own treatment programs. Mills (1988) suggested that clinicians who program with

only limited programming skills tend to produce limited programs. To that we may add that programmers who program with only limited understanding of treatment principles tend to produce limited treatment software.

The following studies investigated the efficacy of various computerized treatment programs written by clinicians and researchers for aphasic adults. The studies go back less than 10 years. It will be interesting to look back in another 10 years and see the impact microcomputer technology will have on aphasia rehabilitation and on our field.

Auditory Comprehension

Impaired ability to understand speech is frequently the focus of aphasia treatment. Computers, however, are limited in the ability to manipulate and produce natural sounding speech. Computer-generated speech is usually characterized by distorted sounds and disrupted prosody.

There are three different types of computer-controlled artificial speech. *Analog speech* is simply tape recorded speech controlled by the computer through a special device. Analog speech has high intelligibility, but vocabulary is limited to the prerecorded words and in the sequence the words were recorded. Many tasks can be built around computer-controlled analog speech, but the lack of ability to access the speech output in any order as needed (e.g., for repetitions and randomization) makes analog speech inadequate for most treatment functions.

Digitized speech uses an auditory digitizing device to measure the pitch and loudness of a sample of natural speech many thousand times each second. The frequency and intensity values of the sample are then stored as numbers in a file on a disk. Every time the sample of speech is played back, the digitizer, controlled by special software, reads the stored pitch and loudness values from the disk and reproduces the speech sample with good clarity, prosody, and rate. Faster sampling rates (4 kilobytes and above) result in higher speech fidelity, but require greater amounts of computer memory. Also, computer response time is inherently slow as values are read from disk to computer memory. Like analog speech, vocabulary is limited to the words and phrases already stored on disk, but output can be accessed by the program as many times and in any order required.

Synthesized speech uses an auditory synthesizing device to generate the most common form of computer speech. There are basically two types of synthesized speech. *Phoneme-based speech* produces recognizable speech from a large set of phonemes and other sound combinations stored not on a disk, but on a special memory chip in the synthesizer. Practically any utterance can be generated quickly by sequencing sounds. Speech, however, is only moderately intelligible as many sounds are distorted. For example, the sounds for the phonemes /t/ and /s/ usually differ only in duration. Also, as speech is pieced together from phonemes, prosody and rate are severely disrupted, further adding to the artificial nature of the output. This makes synthesized speech adequate for people with normal language ability (e.g., in education,

recreation, and industry), but inappropriate for aphasic patients, most of whom have difficulty understanding normally produced speech. In *phrase-based speech*, digitized representations of entire words and phrases, rather than phonemes and sounds, are first read from a disk and loaded into special memory chips on the synthesizer. Every time the speech sample is needed, the values are read quickly from the memory chip by the synthesizer, thus reducing latency by avoiding the slow process of reading information from the disk drive. The prosody of the words and phrases is preserved somewhat, and the quality of speech is better than with phoneme-based speech.

Mills and Thomas (1983) compared the intelligibility of various forms of artificial speech for six aphasic subjects, specifically, phoneme-based synthesized speech, speech digitized at a 4-kilobytes sampling rate, and analog speech recorded on a tape recorder. The subjects performed a sentence comprehension task best with analog speech and worst with synthesized speech. Later, Treadwell, Warren, and Wilson (1985) compared two different forms of computer-controlled, synthesized speech to live speech. Nine aphasic subjects performed a semantic-categorization task that required listening to the name of a category while viewing three words printed on the computer screen. The subjects then pointed to the appropriate word that was an example from the named category (e.g., CAKE, CAR, TREE were printed on the screen as the subjects heard, "Which one is a vehicle?"). Subjects responded best to live speech (94%) and demonstrated only a slight reduction in accuracy in response to phrase-based synthesized speech (91%). Phoneme-based speech produced the poorest performance (61%).

Mills and Thomas (1981) and Mills (1982) used a microcomputer to provide auditory comprehension practice for an aphasic adult 2 months post-CVA, himself a former computer programmer. Four line drawings of common objects were presented on the screen as auditory commands naming one, two, and three of the drawings were presented by the computer and a speech digitizer at a 4-kilobytes sampling rate. The subject responded by pressing the key or keys associated with the target picture or pictures and then pressing the return key. Pressing the return key alone provided a repetition of the auditory stimulus. Different auditory feedback statements were also provided by the digitizer depending on the accuracy of the response. An error on the first attempt resulted in an auditory prompt to try again. If an error was made on the second attempt, auditory feedback was provided as a box was drawn around the correct target. A correct response resulted in auditory feedback followed by the next stimulus. Over 5 months, improvement for the subject was observed in increased accuracy and decreased response time and need for repetitions both on the computer task and on the Porch Index of Communicative Ability (PICA) (Porch, 1981).

Verbal Output

Although microcomputer and microprocessor-driven

devices are developed to help physically impaired patients compensate for speech output problems, a considerable degree of linguistic ability is required to operate the devices, which, unfortunately, makes them less appropriate for aphasic patients than many realize. Microcomputer technology currently is being used to evaluate and help treat the phonologic and phonation problems of patients with some types of neuromotor speech difficulties, as in dysarthria and dysphonia. At this time, however, the state of the art in computer technology is not developed to the degree required to use microcomputers to treat semantic and grammatic problems in the verbal output of aphasic patients.

Colby (1968), a psychiatrist, made extensive use of computers and speech synthesizers to increase verbalization in autistic and other nonspeaking children (e.g., Colby & Kraemer, 1975; Colby & Smith, 1973). Later, Colby and his colleagues (Colby, Christinaz, Parkison, Graham, & Karpf, 1981) designed and built a small, portable microcomputer to facilitate verbal production in dysnommic aphasic subjects, people for whom word-finding was the major communication problem. The specially built computer contained a small liquid crystal display (LCD) for displaying text and a small keyboard so that subjects could respond to the text. The intervention program was stored on microchips (called EPROMs) in the computer so that a disk drive was not required, further reducing the size and weight of the microcomputer. The computer was carried by subjects on a sling/shoulder strap combination, making the device available during actual conversations in function settings. When experiencing word-finding problems, the aphasic subject pushed a key on the small keyboard to activate the program. The microcomputer displayed on the small screen a series of questions designed to help identify the forgotten word, for example, "Do you remember the first letter of the word . . . the last letter . . . any other words that go with the forgotten word?" The subject answered with a single key press and provided other information as requested by the program. Responses were analyzed, and a list of the most probable words (selected from a lexicon of 80,000 words) was displayed across the screen, beginning with those most likely. This type of cue is appropriate for dysnommic patients, in that most can recognize and say the forgotten word after a visual or auditory model. When the subject recognized the word displayed on the monitor, he or she pressed a key to hear the word produced by a built-in speech synthesizer. Subjects were able to use the microcomputer successfully in functional communicative settings.

A serendipitous and clinically significant finding was the generalization of the cuing algorithm to noncomputer settings (Christinaz, personal communication). After enthusiastically using the microcomputers for several weeks, some subjects reported that they no longer required the device. They reported that when they forgot a word and did not have the microcomputer immediately available, they began to ask themselves the same series of questions displayed for them on the computer monitor over the previous several weeks. The subjects, it ap-

peared, had *internalized the cuing algorithm without needing to be prompted* by the microcomputer. The microcomputer used in this study provided two functions: actively assisting in word finding while modeling an independent, self-cuing compensatory strategy. Furthermore, these activities occurred repeatedly and daily, during actual conversations, and, in all likelihood, made a significant impression on the subjects and others involved in the communicative interactions. Thus the microcomputer served compensatory, therapeutic, and motivational roles for those aphasic subjects.

Reading

Because time and resources for treatment sessions are limited, aphasia therapy usually focuses on auditory comprehension and verbal expression, skills that are the most functional and social for patients. Difficulty in reading and writing, however, can also affect the quality of life and degree of independence for aphasic patients. Clinicians attempt to treat reading and writing problems without significantly reducing the time assigned to auditory and verbal activities. Although limited, microcomputers may present an immediate and potentially powerful solution for providing patients with supplementary reading and writing treatment activities. Microcomputers are primarily visual devices and so are easily used to display reading material to patients. Indeed, a majority of the software available for education and rehabilitation focuses on visual and reading skills. The keyboard is designed to accept typing, a skill closely related to writing. In addition, reading and writing are communicative activities usually done alone; therefore, these activities when provided by a computer are readily accepted by many patients as familiar and socially appropriate.

A computerized reading test and hierarchy of treatment tasks were developed to evaluate the feasibility and effectiveness of using microcomputers to test and treat reading problems of aphasic patients with minimal assistance from a clinician (Katz & Nagy, 1982). Five reading activities and one math task were incorporated into a consistent computer format that could be operated by aphasic subjects through the keyboard with minimal assistance from a clinician. Subjects selected treatment tasks through an on-screen menu and were prompted to enter their name, the number of items they wished to attempt, and other options. Also included on the disk were programs that allowed the clinician to review subject performance stored on disk. The 5 mildly and moderately impaired aphasic subjects (PICA overall percentile averaged 74 points) improved on the computer tasks during the 8- to 12-week treatment period and on the multilevel computer reading test that required them to point instead of type responses. No change, though, was shown on standard and nonstandard language tests administered through traditional procedures before and following the treatment period.

This study demonstrated that aphasic subjects could operate microcomputers independently, using treatment

programs that were organized in logical, predictable sequences, were menu-driven, and anticipated common errors. The program provided subjects with language stimulation activities that were structured and accountable. The content of the tasks, however, did not appear to be focused on each patient's needs as evidenced by the lack of change in the pre- and posttreatment measurements. However, by permitting subjects to select tasks and other options, the program allowed them to accept more active roles in their treatment by encouraging independent behavior, judgment, and decision-making.

Katz and Nagy (1983) attempted to improve word recognition skills for aphasic subjects through tachistoscopic presentation of sight vocabulary words. Sight vocabulary words were exposed individually for approximately 0.01 second on the screen. The 5 mildly and moderately impaired aphasic subjects (PICA overall percentile averaged 75 points) were first required to match (recognition) and later to type from memory (recall) the 65 target words in sets of 13. Duration of exposure time of the stimulus word was increased by 0.2 second on repetition following error responses, thus giving the subject increasingly more time to examine the word. Each word was presented at least four times in each session, depending on the accuracy of the responses. By the end of the treatment phase, each subject had responded to hundreds of stimulus presentations. As in the previous study, subjects improved on the task, but performance did not generalize to noncomputer reading and writing tests presented before and following the treatment phase. This study demonstrated that the computer can present and modify treatment stimuli with a high degree of speed and precision. Intervention that requires little or no linguistic processing, however, such as duration of stimulus exposure time, appears to be of limited practical benefit to aphasic adults; increasing the time did not affect the accuracy of response. Microcomputers could become more effective treatment tools if programs provided patients with cues that were communicatively and linguistically relevant in response to the patient's performance.

Katz and Nagy (1985) later took a different approach to improve reading comprehension of functional words in aphasic patients. Five severely impaired aphasic adults (PICA overall percentile averaged 35 points) were shown computer line drawings of a dozen semantically related common household objects (e.g., knife, spoon, fork, dish, cup, etc.) and required to match the correct name to the picture. The program began as a simple word discrimination task and became more difficult as the number and type of multiple choice names gradually were increased from two to six. If session criterion (11 out of 12 correct) was achieved, an additional multiple-choice foil was added to the field for the next session; initially, visually similar foils were added. Those were followed by semantically related foils. If session performance dropped below 9 out of 12 correct, the next session began with one less multiple-choice foil. The number of multiple-choice items displayed for a stimulus word was also reduced by one during a session if an error response was made. In

this way, subjects could maintain a high degree of accuracy while continuing to be challenged by the new foils.

In addition to adjusting the number of visually similar and semantically related foils, the program generated and printed out at the end of each session four different writing activities for the subject. The activities were based in part upon the subject's performance during the session. This "homework" was completed by patients on their own, outside of the clinical setting.

Three subjects averaged 39% improvement on reading tests administered before and following the treatment phase. They maintained a high degree of accuracy for most sessions and demonstrated steady increase in the number of multiple-choice items from session to session. The 2 most severely impaired subjects did not show improvement. One could not perform well even at the lowest level (two multiple-choice items), and the other consistently failed when the first semantically related foil was introduced. The intervention provided by the program clearly was not effective for them. The results of the study emphasized that computer programs designed for severely impaired patients should prepare contingencies for patients who may have difficulty with the initial level of activity and thus require additional cuing. Also, the program for such patients should offer alternative cues if a single approach fails to improve performance after a given number of attempts at the task.

Writing

Many reading comprehension activities are easily transferred to the computer. Writing activities, however, are less easily adapted. The most obvious problem is the inability of the common microcomputer to evaluate handwriting and printing. The computerized writing treatment programs described in the literature substitute typing for writing during the intervention. In a comparison of writing and typing abilities of aphasic subjects, Selinger, Prescott, and Katz (1987) examined 7 subjects with left hemisphere damage to assess differences between PICA graphic scores on subtests A through E using standardized PICA graphics responses and PICA responses typed on a microcomputer. No differences were found between scores on the PICA subtests generated with pencil and paper and on a microcomputer. Those results suggest that the graphic language abilities of brain-damaged adults are represented equally by the two output systems.

At the simplest level, computer programs that treat writing assess accuracy by comparing the typed response with a model of the target (Figure 1). The response is coded by the program as correct or incorrect. One of two contingencies is presented. More sophisticated programs frequently use a series of binary conditional branching steps to evaluate a typed response and present appropriate contingencies (Figure 2). Each branch presents the patient with new information, selected to enhance and stabilize performance and to help learning generalize from typing to writing.

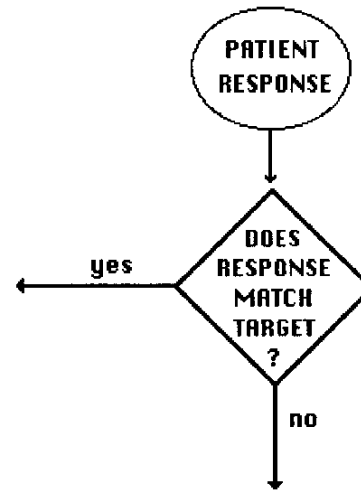


FIGURE 1. Simplest level of evaluation.

Several investigators have incorporated complex branching techniques in computerized writing programs to provide multilevel intervention. Seron, Deloche, Moulard, and Rouselle (1980) described a rudimentary program on a minicomputer that helped aphasic patients learn to type words to dictation. Intervention consisted of three levels of feedback: (a) the number of letters in the target word; (b) whether the letter typed was in the word; and (c) when a correct letter was typed, whether that letter was in the correct position. After an average of 15 sessions completed within about 2 months, the group of 5 subjects wrote words more accurately on a pre- and posttreatment set of words.

Katz and Nagy (1984) used complex branching steps to evaluate responses and provide patients with specific feedback in a computerized spelling task. Single and multiple cues from a hierarchy of six were selected by the program in response to the number of errors made for each of 10 stimuli. Additional feedback included repetition of the successful and most recently failed cues and pencil-and-paper copying assignments automatically generated by the computer printer. Pre- and posttests of writing revealed improved spelling of the target words for 7 of the 8 aphasic subjects.

Glisky, Schlacter, and Tulving (1986) reported the ability of 4 memory-impaired, nonaphasic subjects to type words in response to definitions displayed on the computer screen. Cues included displaying the number of letters in the word and displaying the first and subsequent letters in the word, one at a time, as needed. Cues continued until either the subject typed the word correctly or the program displayed the entire word. All subjects improved in the ability to type the target words without cues. Subjects maintained their gains after a 6-week period of no treatment and demonstrated generalization to another typing task, although generalization to writing was not measured.

Katz, Wertz, Davidoff, Shubitowski, and Devitt (1989) developed and tested a computer program designed to

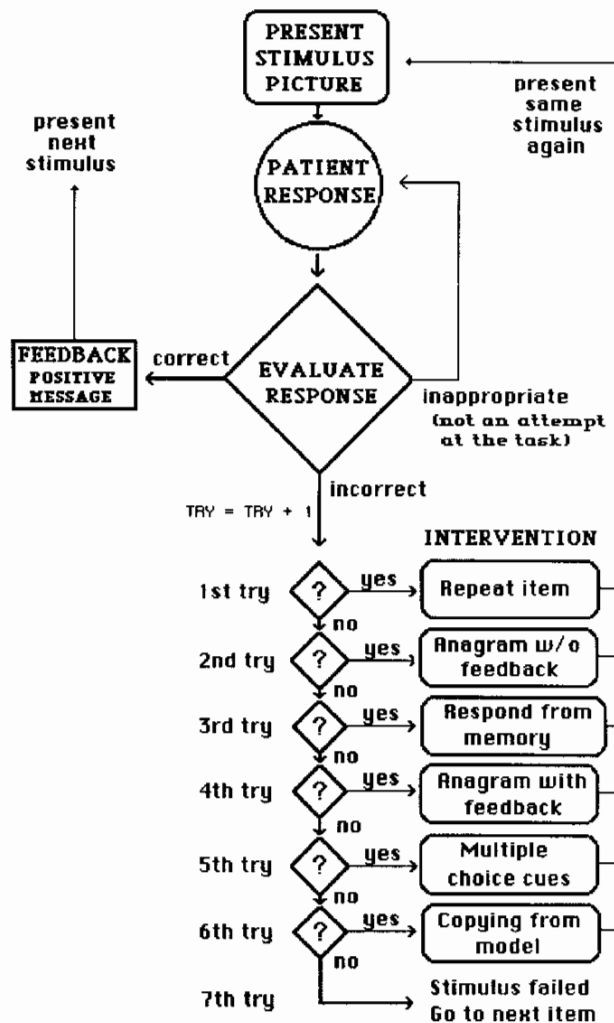


FIGURE 2. Series of binary conditional branching steps to evaluate a response.

improve written confrontation naming for 9 aphasic subjects with minimal assistance from a clinician. The treatment program (Figure 3) required subjects to type the names of 10 animals in response to pictures displayed on the computer monitor. If the name was typed correctly, feedback was provided, and another picture was displayed. If an error was made, hierarchically arranged cues were presented, and response requirements were modified. Five of the 9 subjects reached criterion within six treatment sessions, and the performance of all 9 subjects improved on the computer task. In addition, improvement was measured on noncomputerized written naming tasks, such as written confrontation naming of the treatment stimuli and written word fluency for animal names. Improvement was also noted on the PICA writing modality score. Improvement, however, did not extend to PICA overall and reading scores or to written word fluency for an unrelated category. The lack of change in the latter language activities emphasized the general stability of

the chronic aphasic subjects who participated in this study and helped to stress the improvement observed in the treatment-related measures.

Comparison of Traditional and Computer Treatment Mediums

As treatment programs become more complex and surpass the current level of drill and practice software, microcomputers will better reflect more of what we actually do with our patients in therapy. Comparing the effect of similar activities provided by two different mediums should give researchers insight into the way our patients learn, the influence of the medium, and the effectiveness of the treatment.

Some researchers feel that, because of their speed, reliability, and relative autonomy, microcomputers are ideally suited to administer tests to aphasic patients who can then work at their own pace without fear of embarrassment (Enderby, 1987). Odell, Collins, Dirks, & Kelso (1985) developed two computerized versions of the Raven Coloured Progressive Matrices (RCPM) (Raven, 1975) on an IBM PC system that used high-resolution graphics and a touch screen input device to administer and analyze test performance quickly and accurately with minimal supervision from a clinician. They compared the two computerized versions of the RCPM with a traditional, clinician-controlled, paper booklet administration of the test. The performances of 16 aphasic subjects were essentially equivalent under all three conditions, leading the authors to conclude that the computer conditions did not present greater visual or cognitive demands on the subjects.

Wolfe, Davidoff, and Katz (1987) compared the performances of adults without brain damage and aphasic adults on another nonverbal problem-solving task, "The Towers of Hanoi" (Prescott, Loverso, & Selinger, 1984). The performances of 19 aphasic and 19 patients without brain damage were compared using two different methods of presentation: (a) two-dimensional color computer simulation of the puzzle and (b) the actual wooden model to be manipulated. Subjects without brain damage performed equally well under both conditions. As in the Odell, Collins, Dirks, and Kelso (1985) study, aphasic subjects demonstrated similar performance on the task under both conditions. Aphasic subjects, however, required more time to complete the puzzle in the computer condition than when manipulating the actual wooden model. Also, under the computer condition, aphasic subjects made more illegal moves; that is, they attempted to move the pieces in a sequence not in accordance with the rules of the puzzle. The results suggest that while the computer medium did not affect the accuracy of performance for the aphasic subjects, task completion took longer and was less efficient.

Loverso, Selinger, and Prescott (1979) developed and tested a treatment protocol for aphasic patients in which verbs were presented as pivots (i.e., starting points) and

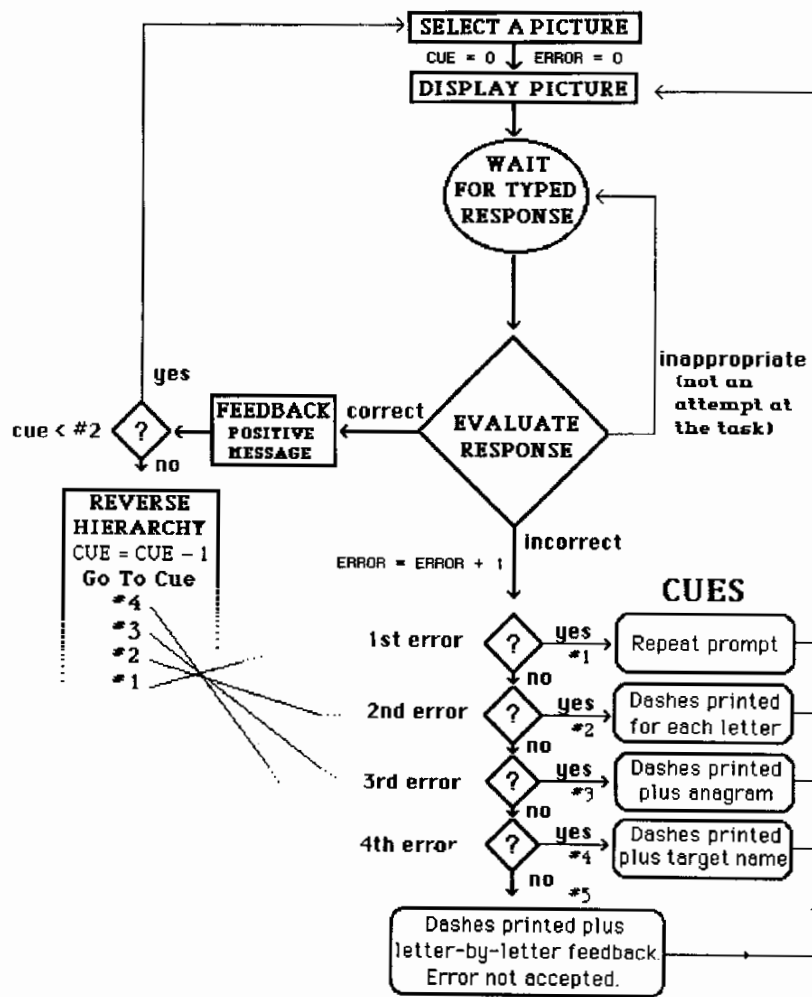


FIGURE 3. Flowchart illustrating sequence of steps in confrontation naming treatment program.

paired with different *wh*-question words to provide strategic cues to elicit sentences. They demonstrated statistically significant improvement on the PICA following 3½ months of treatment for two aphasic patients. In a later study, Loverso, Prescott, Selinger, Wheeler, and Smith (1985) compared the effects of the same treatment approach when provided by a clinician and by a microcomputer and speech synthesizer assisted by a clinician. The aphasic subject responded in the clinician-only condition by speaking and writing and in the computer and clinician-assisted condition by speaking and typing. Feedback included response accuracy and models of the target response. The subject improved under both conditions, but took longer to reach criteria under the computer and clinician-assisted condition. Based on the subject's improvement, both on the treatment tasks and on subsequent administrations of the PICA, the authors concluded that the listening, reading, and typing activities under the computer and clinician-assisted condition had a positive effect on language performance and that the microcom-

puter was an effective mode for providing supplemental language treatment.

STUDIES IN PROGRESS

Several interesting studies not completed at this time deserve mention here. Steele, Weinrich, Kleczewska, and Carlson (1987) are developing and testing a graphically oriented, computer-based alternate communication system for chronic, global aphasic adults, called Computer-Aided Visual Communication system (C-VIC). C-VIC is something like an intelligent pointing board. The program runs on a Macintosh computer and uses a picture-card design (metaphor) that is well-suited for the high-quality graphic capacity of the Macintosh and appropriate for pictorially oriented nonverbal aphasic patients. Subjects use the mouse device to select one of several pictures (called *icons*), each of which represents a general category. The selected icon then "opens up" to reveal

pictures of the items in the selected category. After the patient selects the desired item, the picture is added to a sequence of other selected pictures; this "string" of pictures represents the message. The researchers currently are involved in developing icons that are recognized most easily by aphasic patients and others in the environment, in incorporating animation to represent actions, and in using artificial intelligence techniques to improve the speed, scope, and functionality of the program.

In another report, Steele (1987) described projects underway in Holland and Sweden that involve the development of computer-based aphasia treatment programs. One project, "Computer-Assisted Language Training in Aphasia" (A. C. Sheats, personal communication, 1986), involves the development of an IBM-compatible microcomputer-based language training system for aphasic patients that is intended to supplement traditional speech treatment in auditory comprehension (through digitized speech), reading, and writing (i.e., typing). Several microcomputers will be interconnected and share treatment tasks, the order and content of which are controlled by the clinician.

Some patients, because of physical limitations or logistics, are unable to travel to a hospital or clinic to receive speech and language treatment. Several studies are developing protocols for providing treatment through telephone lines. Vaughn et al. (1987) compared the efficacy of remote treatment of aphasia by TEL-Communicology (TEL-C) with traditional face-to-face treatment for four groups of aphasic subjects. TEL-C uses microprocessor driven devices over the telephone lines and requires some level of clinician assistance. All groups improved following treatment; the data showed no difference between TEL-C and face-to-face treatment groups. In addition, the cost of traditional treatment was almost twice the cost of TEL-C. In another study, Wertz, Dronkers, Knight, Shenaut, and Deal (1987) compared the effectiveness of closed circuit television, computer-controlled video laser disk, and traditional face-to-face interaction for providing appraisal and treatment to aphasic patients in remote settings. Results suggested no significant differences among the three conditions in the diagnoses assigned to the subjects. In addition, subjects in all three treatment conditions have demonstrated clinically significant change (between 12 and 17 percentile points on the PICA). At this point, no significant differences in improvement among the groups have been observed, suggesting that aphasic patients can benefit from treatment provided in any of the three conditions.

Katz and Wertz (1988) and Katz, Wertz, Lewis, Esparza, and Goldjarb (in press) described a series of hierarchically arranged reading and writing treatment programs for the Apple II microcomputer. Depending on the subject's performance, the main program selects the next task automatically, either moving up or down the hierarchy, or repeating the current task. The authors are testing the effectiveness of the programs by comparing improvement in patients who receive computerized language treatment with that of patients who receive computer stimulation

("nonlanguage" activities) or no treatment. Pilot testing on some writing programs indicated that aphasic subjects learned the tasks, and improved performance transferred to related, cursive writing tasks. In addition, at this point, aphasic subjects working on the reading programs improved more on post-treatment test scores than subjects in the computer stimulation and in the no treatment group, suggesting that treatment software can benefit the patient.

SUMMARY

New technologies have started revolutions that need not frighten us. Many new tools are yet to be utilized fully, including video laser disks, photographic quality graphics, natural sounding speech, and a new generation of computer programs, such as Hypercard, which allow clinicians to expand the usefulness of computers. The microcomputer is becoming a basic treatment tool for clinicians, just as paper and pencil have been tools in education. The growing body of research data indicates that microcomputers can be used by speech-language clinicians for treating patients with aphasia, but we have a long way to go. We still have not answered Darley's questions. It is not apparent how effective computer programs used by speech-language clinicians are in providing all aspects of treatment and how well the programs respond to patients suffering from different types and severities of aphasia.

Patients interact within a world of people, not computers. The technological advances described here are a new means to achieve an old goal, to help clinicians improve the communicative abilities of people with aphasia. Theoretically, if all intervening variables are known, the value of a treatment could be the same regardless of the medium through which it is delivered. Expert systems aside, computers will never have all the abilities clinicians demonstrate every day in therapy. However, to more closely approximate what clinicians do in treatment, more powerful treatment programs are needed that allow the clinician to have control of task parameters and content. As the effectiveness of such programs is evaluated, a data base can be developed that will organize what we have learned about aphasia, communication, behavior, learning, and therapy. The information will influence all aspects of patient management and, ultimately, help improve the quality of life for our patients.

ACKNOWLEDGMENT

This project was supported in part by the Veterans Administration Rehabilitation Research and Development, Department of Medicine and Surgery.

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Chapter 19

A FUTURIST'S PERSPECTIVE: TECHNOLOGY AND THE AGING POPULACE

MARGARET A. WYLDE

Institute for Technology Development, Oxford, MS

By now you probably are able to recite the basic statistics about our aging population as easily as you are able to spout forth the Pledge of Allegiance. It is difficult to pick up any current reading material that doesn't include the phrase, "The population over the age of 65. . . ." Lip service about this age group has hit an all-time high, but as one surveys the advances in applications of technology to solve problems encountered as we become older one wonders if the rhetoric is anything more than opportunism or Chicken Little crying that the sky is falling.

The population over the age of 65 is not a homogenous group of individuals but includes as much diversity and complexity, as many needs and desires, as are present in any other segment of the population that spans more than 30 years. On first glance, when dissecting this age group, one sees that in a few short years half of the 34.9 million who are over the age of 65 actually will be over the age of 75 (see Figure 1). A second look (see Figure 2) shows that

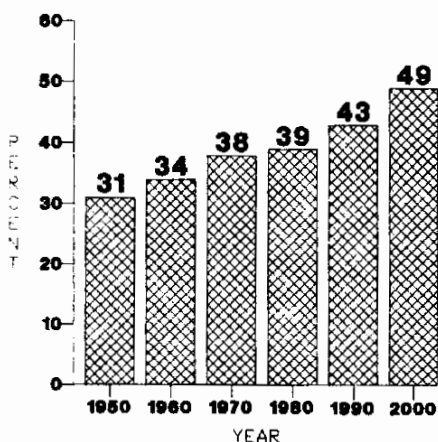


FIGURE 1. Percentage of elderly persons who are age 75 and over: 1950 to 2000. Source: U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 952, May 1984, and Decennial Censuses of the Population, 1950-1980. Reprinted from *Aging America: Trends and Projections* (1985-86 Edition). Washington, DC: U.S. Senate Special Committee on Aging.

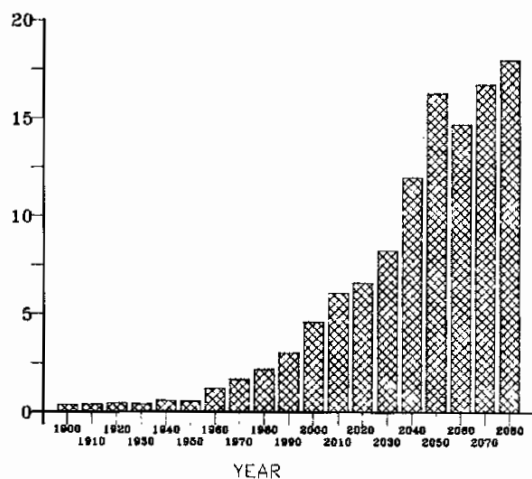


FIGURE 2. Actual and projected increase in population 85 years and older: 1900-2080. Sources: "America in Transition: An Aging Society" (Current Population Reports Series P-23, No. 128) by M. Taueber (1983, Sept.). Washington, DC: U.S. Bureau of the Census, and "Projections of the Population of the United States, by Age, Sex, and Race: 1983 to 2080" (Current Population Reports Series P-25, No. 952) by G. Spencer (1984, May), Washington, DC: U.S. Bureau of the Census. Reprinted from *Aging America: Trends and Projections* (1987-88 Edition). Washington, DC: U.S. Senate Special Committee on Aging.

we are at the base of a mountain of 85-year-olds, and the slope is rapid and steep. Finally, few people realize the number of individuals in the United States, and other countries for that matter, who are over the age of 100 years (see Figure 3). You remember this group, Willard Scott used to say happy birthday to someone reaching the century club almost every day of the week. Now, he usually provides birthday greetings to more than one every day of the week.

Today there are almost 50,000 people 100 years old or older, by the year 2,000 this number will double, then it will double again the decade after that. In 2050, there will be more than 1,029,000 of us enjoying Mr. Scott's greetings. Although the population is not distributed evenly

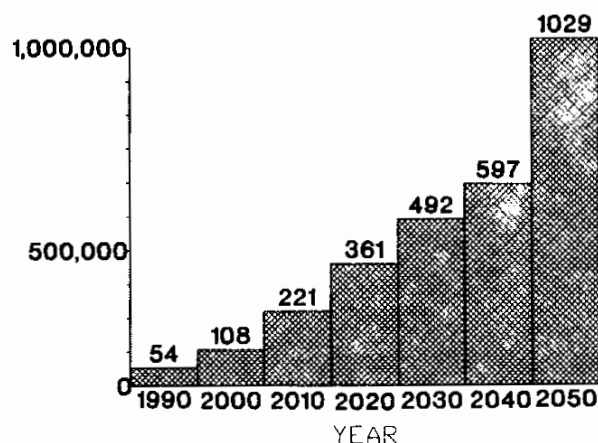


FIGURE 3. Projections of the population aged 100 and over: 1990-2050. Source: *Projections of the Population of the United States, by Age, Race and Sex: 1983 to 2080*. (U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 952) (1984). Washington, DC: U.S. Government Printing Office.

across the land, if the projected number of 100-year-olds were parceled equally among the 50 states you would find 20,580 centenarians in every state.

The increasing numbers and proportions of older people are the result of death being postponed and declining birthrates.

Mortality and Morbidity

Declining mortality is a direct result of advanced medical technology. We have learned how to heal people who are sick and mend people who have been injured. Declining mortality rates do not necessarily connote declining morbidity rates. A recent article in the *Wall Street Journal* describing the impact of treatments for the HIV virus brought the contrasts between mortality and mor-

bidity to light. The article suggested that with prospective new treatments the rate of death among those with Acquired Immune Deficiency Syndrome (AIDS) would decline, but, because a cure has yet to be identified, those with AIDS could expect to survive with a chronic illness, much as do individuals with diabetes. The mortality rate among individuals inflicted with the HIV virus is expected to decline, but the rate of morbidity will increase as more individuals survive but are not cured.

We are living longer because we are surviving illnesses and accidents that before the era of high-tech medicine would have been fatal. The longer we persist, the greater are our chances that we will succumb to limitations in our abilities caused by illness or injury.

Table 1 summarizes the numbers of individuals with limitations in activities of daily living as a function of increasing age. The limitations of survival are particularly evident in those over the age of 85 years. Half of those in this age group, who live in the community as opposed to an institutional setting, need help bathing and getting around inside. Almost 80% need help with heavy work and shopping for groceries, while one-third need assistance with medications.

These figures and the projections (see Figure 4) indicating that the millions of individuals with limitations in activities will increase proportionately with the increase in numbers of older adults, suggest that, despite our frantic fitness efforts, we have a distinct possibility of succumbing to the effects of our technological society. We can conclude that the numbers of individuals who will have problems taking care of themselves will grow as rapidly as the aging of the population. The challenge we face is to find appropriate solutions to meet the changing needs of our populace.

THE APPROACH TO RESOLVING PROBLEMS

Two approaches have been prevalent in the efforts to

TABLE 1. Percentage distribution of functionally disabled elderly, living in the community, reporting ADL limitations, by type of activity and by age, race, and sex, 1982.

Respondents	Bathing	Dressing	Percentage reporting limitation			Continence	Eating
			Getting to the toilet	Getting in and out of bed	Getting around inside		
Total	42.1	19.5	20.9	26.0	40.1	24.2	6.0
Age 65-69	33.6	19.2	15.8	23.8	32.4	23.5	5.9
70-74	37.6	17.7	18.4	23.8	35.5	23.8	4.3
75-79	41.5	20.1	19.7	25.5	39.0	24.4	5.3
80-84	47.6	19.2	22.6	26.4	44.0	23.8	6.1
85 & over	53.2	21.9	29.8	31.5	52.5	25.9	8.9
Sex							
Male	37.9	22.0	14.6	24.7	38.6	20.7	7.0
Female	44.4	18.1	22.7	26.7	40.9	26.2	5.5
Race							
White	43.0	19.0	20.9	26.2	39.5	23.6	5.8
Black & other	35.8	22.8	20.5	27.8	44.1	28.7	7.4

Note: From *Long Term Care for the Elderly: A Factbook* (p. 74) by D. L. Rabin and P. Stockton, 1987, New York: Oxford University Press. Copyright 1987 by Oxford University Press. Reprinted by permission.

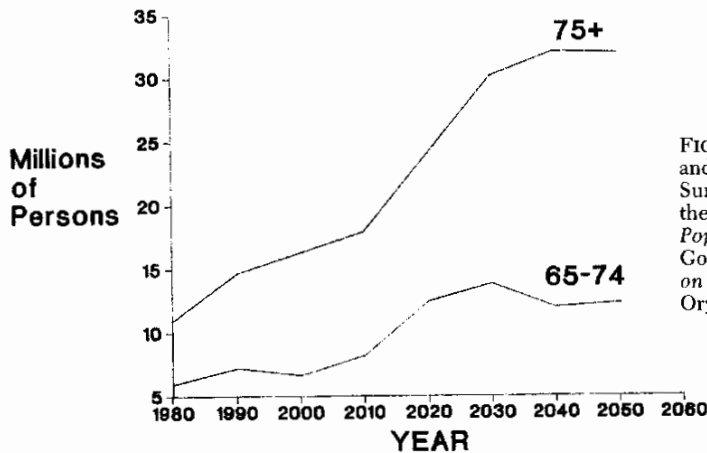


FIGURE 4. Limitation in activity due to chronic condition actual and projected, 1980–2060. Based on 1980 Health Interview Surveys, National Center for Health Statistics and U.S. Bureau of the Census (1982), "Projections of the U.S.: 1982–2050," *Current Population Reports* (Series P-25, No. 922), Washington, DC: U.S. Government Printing Office. Note: From *Statistical Handbook on Aging Americans* by F. L. Schick (Ed.) (1986), Phoenix, AZ: Oryz. Copyright 1986 by Oryz Press. Reprinted by permission.

meet the needs of older individuals who have difficulty completing activities of daily living. The first is called the *Prosthetic Solution*, and the second is the *Service Solution*.

The Prosthetic Solution

A prosthetic solution assumes that the problem an individual encounters in everyday life is a result of an inadequacy or error in the individual rather than an inappropriately designed environment. Thus, rather than questioning and redesigning the difficult-to-negotiate environment, the human is considered the problem and special devices are manufactured that interface the imperfect human with the presumed perfect environment.

The grab bar is an example of a prosthetic solution, a band-aid. The grab bar was designed originally to aid individuals in wheelchairs while transferring from the chair into the bathtub. The grab bar was developed for a specific population and under the assumption that the design of the bathtub needed no improvement and that the individual having difficulty negotiating its depths was the problem. The solution applied frequently when an individual has difficulty bathing, regardless of that person's functional limitation, is to install a grab bar. Perhaps, particularly with the increasing numbers of individuals who are unable to bathe independently, the basic design of the bathtub should be revisited.

Thus there are several problems with prosthetic solutions:

1. A prosthetic solution assumes that the problem is caused by something wrong with the individual rather than recognizing that the environment (or product) may have limitations.

2. A prosthetic solution is often focused on solving a single problem or compensating for a specific functional limitation. This results in a single function product that

may suffer from an unnecessarily restricted market—the market being only those people who need the prosthesis.

3. Aesthetic composition of a prosthetic solution is often subordinate to its functional requirements and, due to the prospective small market, may be ignored or eliminated.

4. The prosthetic solution is based on the assumption that current design standards, those using the average, young adult male as the model are appropriate. This standard defies logic. We ask the least able to conform to the standards of the most able. It would be unusual to see a prosthetic device for a young adult male living in an environment created for individuals with functional limitations.

The Service Solution

A second solution frequently employed to assist individuals unable to perform a task independently is to employ the assistance of another. Service solutions may have been more effective in the days when the young vastly outnumbered the old and when women concentrated their work efforts on home and family.

Declining birthrates and the continual aging of the population have led to a dramatic change in the proportion of young people to old people (see Figure 5). Having fewer in the younger generation impends a diminishing supply of persons able and available to provide aid to a growing body of people for whom the environment is incompatible.

In addition to the shrinking proportion of people to provide assistance, there are fewer traditional caregivers, women, providing help on a full-time basis, either formally or informally. Today, rather than a strong majority of women providing homemaker services, almost three-fourths of working-age women are employed outside the home. That those employees also are challenging typical roles for women is evidenced by the declining numbers

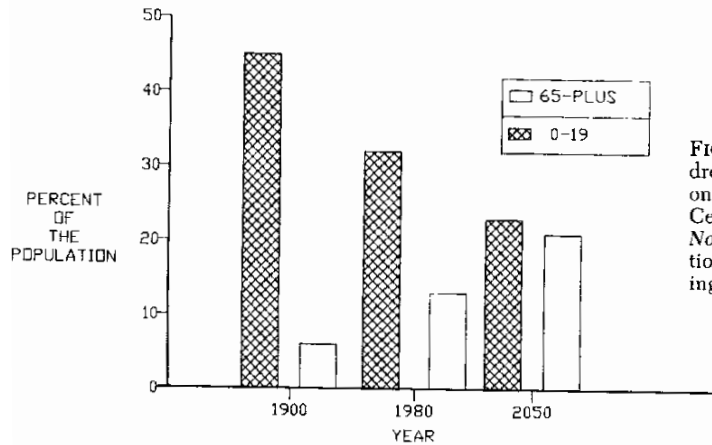


FIGURE 5. Actual and projected change in distribution of children and 65-plus persons in the population: 1900-2050. Based on *Current Population Reports* (Series P-25, No. 952) and *Census of the Population, 1900*, by U.S. Bureau of the Census. Note: From *Aging America: Trends and Projects* (1985-86 Edition). Washington, DC: U.S. Senate Special Committee on Aging.

of women entering nursing and the growing numbers becoming physicians.

The persistent plan to satisfy the needs of older adults by providing services fails to factor in the declining supply of personnel. This, plus, perhaps, an increase in numbers of the acutely ill which may result from the success of AIDS treatments, portends a plan that cannot meet the demand. In fact, we are not helping all who need help today.

Finally, a human service solution frequently is viewed as inhumane. The American populace was conceived on independence. A service solution programs dependence and is in conflict with our basic tenets of self-sufficiency, self reliance, privacy, dignity, and self-worth.

SOLUTIONS THROUGH TECHNOLOGY

The Need for Technological Solutions

Prosthetic and service solutions to meet the needs of older adults potentially are ineffective and infeasible given the realities of today and the projections for tomorrow. Technology, particularly advanced medical technologies, has created the problems we are facing. Technologies have created opportunities for life, now it is time to focus on creating and adapting technologies to improve the quality of life.

Perspectives from 1965. If we roam through some of the expectations for technology articulated in the mid 1960s we can see that many expectations were exceeded and other achievements detained. Someone predicted that by 1986 we could sit in the confines of a completely enclosed, interior room and view the surf breaking over the rocks and foaming up the beach while we are talking with the full-color, full-scale holographic image of a friend. We could walk completely around our friend and view the back of his or her head. Despite having the technology, we aren't there yet.

Someone postulated that satellite transmission to a business or home would never be feasible, yet drive down some country roads or look at the rooftops of many office buildings and count the satellite dishes.

Magnavox Company, some time in 1966 or 1967, introduced a low-priced facsimile device that transmits printed material over ordinary telephones. The Magnafax was a desk-top unit used with regular telephone systems. The office worker dials the number of another office, then transmits letters, signatures, blueprints, or other printed material. It took 20 years for this technology to become adopted, but the later half of the 80s will be known as the era of the fax machine.

Technoblocks. In many instances, it isn't innovation, but application, that slows the march. In the examples cited, the technologies existed long before their use became commonplace. This is true particularly when considering the application of technologies to solve problems of older adults.

Several events may have impeded the adoption of such technologies. First, there are those who may have fought progress because of fear. In those instances, it could have been the fear of "Big Brother," the invasion of privacy. Second, others may have fought exploitation of technologies because it would have affected their business adversely. Third, the reason may have been the perpetual lack of communication between R & D and the market. Those inventing the technologies have little idea of the real needs of the marketplace and thus have difficulty translating their inventions into products with a perceived need. Finally, the application of a technology frequently is slowed while the product waits for a serendipitous discovery to help drive down its cost to the end-consumer.

Technology and the field of human communication sciences. Technological innovation in the communication sciences, as with most fields bordering that of medicine, has been dominated by activity in the realm of diagnosis, with little advancement in technological solutions to the problems of everyday living encountered by the communicatively limited person. Perhaps this neglect on our

part to get out of the laboratory and onto the turf of our clientele is evidenced by the fact that "Communication" does not appear on the accepted lists of "Activities of Daily Living" or "Incidental Activities of Daily Living." It is untenable that we have represented our clientele so poorly that the ability to communicate has been forgotten when thinking of the activities of daily living important to survival.

This oversight goes hand in hand with the progress made in the adaptation and adoption of technologies for the communicatively impaired end-user. The strides made in diagnostic technology have far out-paced the efforts in technology to improve everyday existence. Where are the technological innovations that permit the communicatively impaired ease of communication in everyday life? Where are the conveniences for those who do not match the "norm"?

The discipline of human communication sciences rightly can be accused of adopting the traditional stance when looking for solutions for the communicatively impaired. We have accepted the prosthetic and the service solutions. We have accepted what exists of the traditional communication vehicles and have not questioned the basic product. We have stayed in the laboratory and have not ventured into the field.

The telephone is a good example. Basically, we have accepted the telephone, a primary communication device, as it is and have glibly watched as our clients struggled with first one prosthetic solution then another. Our response has been, if you cannot hear over the telephone, you need (a) a hearing aid, (b) a hearing aid headset, (c) an amplifying headset, (d) an electromagnetic induction amplifier for those phones with weak signals, (e) all of the above.

We have accepted the telephone for the individual with normal hearing and have not asked why the features couldn't be expanded to accommodate a broader segment of the marketplace. Many of the features would not only assist those considered the communicatively impaired, but would also aid the temporarily inconvenienced person, suffering from a cold or the competition of background noise. With the increasing numbers of individuals who are over the age of 65 years, there comes an increasing number of consumers who have difficulty using the

telephone. Again, is it appropriate to define the basic product as the one that is convenient for the able-eared (able-bodied)?

Evidence of our lack of focus on improving the quality of everyday life is apparent with the advent of groups such as the Organization for Use of the Telephone (OUT) and Self-Help for the Hard-of-Hearing (Shhh). These consumer groups have organized to rally against being ignored as new telephones are introduced to the marketplace and because, beyond the hearing evaluation and application of the traditional hearing aid, there is little technology available to improve communication.

Finally, if we just look at the hearing aid, and particularly some of the trends with hearing aid design, we recognize that the primary focus of research has been to achieve a single function—to improve the amplified sound in the individual's ear. This focus, however, may miss the possibilities of developing technology that might alleviate the problems of those aging individuals who have a multiplicity of functional limitations, including reduced vision, tactile sensitivity, manual dexterity, and upper limb range of motion.

THE ROLE OF TECHNOLOGY AND THE CHANGING POPULACE

Technology will be required to fill the gap between the need for assistance created by a larger population of older adults and the numbers of individuals who will be available and capable of delivering that assistance. The application of technology, however, needs to go beyond diagnosis and the confines of the laboratory. The basic function and design of products need to be reevaluated, now that the physical construct of our populace is changing. Technological applications need to expand beyond prosthetic solutions and must be used to create products that fit a broader spectrum of abilities, broader segments of the marketplace.

Innovation appears at the boundary of disciplines. We need to look for solutions beyond the traditional scope of our discipline, both within and outside of the scientific community.

CLOSING REMARKS AND SUMMARY

Over the past 2 days, we have learned that the elderly have far less memory loss than conventional wisdom suggests; therefore, everyone who was here for the opening segments of this meeting will remember the question I posed. . . “Why is the sky dark at night?” I hope you also remember that my Dad’s answer, that “the sun went down and we are on the dark side of the earth in a shadow,” satisfied me when I was 10, but not as I matured, or shall I say aged? I am pleased to review the answer now, and to use it as a springboard to foster more critical thinking about experiments that might be considered to tell us more about aging.

The question was, as you recall, why was the *sky* dark at night. The answer that my father gave was in part an explanation of why the *earth* was dark at night. We are, on earth, of course deprived of the sun’s direct light at night time because, as the earth rotates around its axis, roughly one half of its sphere faces the sun while the other half does not. This accounts in part for the dark side of the earth looking different from the light side. However, the light from the sun streams around us, moving away from our line of sight at night. It is that moving away that imparts on the light a Doppler shift. That is to say, the light of the sun is there, *but it is in a frequency range we can’t see with the naked eye*. The sky in fact is lit up brightly at night with infra-red light.

Our meeting was rich in discussion of new technology. Barbara Sonies, in a very comprehensive technology presentation, reported on an infrared light application for measuring speech movements noninvasively. Richard Katz, on the other hand, showed how application of some very clever Apple-based programs could be quite successful treatment with some elderly persons with aphasia. And Brad Stach showed how successful some patients with “central problems” can be when they use an FM system instead of traditional hearing aids.

We see many things in the night sky that are reflections (moving toward us) of sunlight, such as airplanes in the twilight sky which flash light at us, or ships on the horizon which look brightly lit while the rest of the earth looks dark, or even satellites or space junk which have reflected sunlight toward our eyes. The principle that there is light that our eyes can’t see, or sounds that our ears cannot hear is an important reminder as we draw hypotheses about the communication disorders in aging. It should remind us that studying the body at the biological and (invisible) molecular level will yield many but not all of the secrets of how and why tissues age.

The salient and unifying principle in this conference is that age itself is not a *cause* of any of the sensory and motor deficits that affected the aged. Rose Dobrof opened the meeting by highlighting that principle and asking us to look at ourselves as we age, through the life course approach. Dwight Brock and Scott Brown gave us clear pictures of the demographics of aging, the gender difference and the importance of separating 80+ year olds from the general population of 65 years and over. The incidence of motor, sensory and cognitive deficits, plus problems with activities of daily living accelerate in the 80+ age group. We were reminded later in the meeting of the danger of over-interpreting statistical trends as being representative of any individuals by Audrey Holland’s suggestion (credited to Dr. L. LaPointe) that if any of us as individuals were in fact described by the population demographics in Miami, we would perforce be Hispanic as youths, become Anglos at middle age, and be Jewish when past 65.

Paul Rao’s down-to-earth review of assessment procedures for the elderly have to be viewed vis a vis Dr. Wylde’s lament that in the generic category of Activities of Daily Living, “communication” is rarely if ever mentioned. Yet, Fred Bess clearly indicated from his work with the Sickness Impact Profile (SIP) that people with communication problems in hearing seem to be impacted more by their other

infirmities than are people without hearing loss. While Bess clearly was not saying that hearing loss per se was *causing* the Impact Profile to score the patients as more disabled than the normal-hearing, he was suggesting that whatever the factors were that led to hearing loss, they were also highly correlated with elements that immobilized and incapacitated the patients. Incapacity secondary to vascular disease, diabetes, inflammatory or stress diseases such as, arthritis, might co-exist and be correlated with the presence of hearing loss simply by virtue of the common underlying causes of the respective problems.

Janice Knoefel reviewed the neurology of the aging brain and reminded us that there are broad systemic changes including enlargement of the ventricles and reduction in cell body size. She also highlighted the ubiquitous depositing of lipofuscin throughout the body as a systemic marker for the aging process. Aina Gulya, in the hearing sciences discussions, gave a lucid and scholarly review of the temporal bone and auditory system of the elderly, and noted in her report the common finding of lipofuscin deposits throughout the aging temporal bone. On the last day, when Terese Finitzo discussed the paradoxical observation that late evoked potentials are often larger in the elderly than in the young, it would have been interesting to consider the notion that larger ventricles enhance conductivity to the surface of the skull, and loss of stores or metabolism of ACH and related efferent transmitters might lead to an apparent increase in evoked potential amplitude. Furthermore, it is conceivable that lipofuscin deposits (see later for brief definition) follow differential paths with respect to activity in the efferent vs. afferent systems. As a general rule, if we are seeing auditory-specific deficits, testing of analogous visual or somato-sensory performance might sometimes tell us if we are dealing with a central or a peripheral phenomenon.

Brad Stach presented what was to me an intriguing notion. He showed how central vs. peripheral losses may be spotlighted by comparing a patient's PB scores in quiet to his SSI with ipsilateral competing messages. It seems as if a "central problem" can be operationally defined when the SSI score drops sharply with increased competing message intensity compared to the monosyllables in quiet. Since the phenomenon is a monaural rather than a binaural or dichotic observation, it will require special experimentation to clarify whether the finding reflects an age-related change in cochlear mechanical resolution or in fact some more esoteric central change. Stach offers some good support for the notion by pointing out that, in patients with known and circumscribed central auditory nervous system lesions, the same discrepancy between monosyllabic performance and competing SSI with single talker competition can often be seen.

Robert Ringel and Wojtek Chodzko-Zajko undertook what was to me a most satisfying intellectual exercise, and that was to try to formulate a general theory of aging and to predict and/or categorize the behavioral consequences of the basic anatomic and physiologic changes. They included in their formulation the consideration of synaptic and dendritic changes as well as changes in the elasticity of integument and other tissues. In my impromptu summary, I used their slides as a starting point for my discussion of the need to design studies from a sound theoretical framework on aging.

Surprising by its absence, incidentally, in all the presentations was any discussion of the underlying mechanics of what makes a person look old. We know, for example, that loss of body-fat, the concomitant loss of skin elasticity, wrinkling, crow's feet, accumulations of melanocytes in sun-exposed skin (so-called liver spots), Dowager's hump and related skeletal changes, loss of height, drooping of the nose tip, chin, brow and eyelids, and graying of hair might all be related to a number of systemic mechanisms. These include the loss of lipid (fat) cells throughout the body, loss of collagen elasticity, aberrations of calcium metabolism, reduction in the production of progesterone and/or testosterone as well as changes in the deposits of lipofuscin (a fatty pigment formed by the solution of pigment in fat), and/or changes in oxidative metabolism related to any and all melanocyte stimulating hormones. Are the mechanisms of these obvious manifestations of aging also related to the same mechanisms which underlie slowing of neural reaction times, weakening of muscle contractions, adsorption of calcium in the bones, etc.

A broadly based theory of aging should try to encompass as many of the obvious

facts and principles and predict corollaries. For example, as we said earlier, the sky appears to be dark at night because the available light is in a frequency range which is not visible to humans. That should lead to a prediction that the sky is in fact brightly lit with infra-red light which should be visible with the proper translating lenses. Having a unifying principle whose manifestations should be measurable can lead to many important findings. Thus, to extrapolate to the question of aging, we should note that deposits of lipofuscin are said to be critical markers of aging tissue. Are the underlying mechanisms of lipofuscin deposit part of the same mechanisms that adsorb body fat, destroy or change pigment stimulating hormones and/or weaken collagen elasticity? Can the mechanisms be detailed enough to be reversed, predicted, or slowed? Are the mechanisms present in Progeria (pathologically accelerated aging)?

Regardless of the underlying physiologic mechanisms, Drs. Toner, Rao, Holland, Wertz, Bess, and Shadden all remind us of the importance of remaining sensitive to the vast diversity that we see in people of all ages and mental statuses. Their presentations, viewed from a broad perspective, highlight how such people, after they suffer either aphasia or related mental or degenerative diseases, produce a multitude of coping mechanisms that reflect their original diversity.

Jerry Tobias' summary of the benchmark CHABA report of Speech Understanding and Aging, was most thought-provoking. After Tobias' talk, and stimulated by the Symposium reports on federal funding and research priorities presented by Leonard Jakubczak, Alfred Duncker, and Ralph Naunton, Tobias and I decided to see if we could interest some of the country's most distinguished older psychophysicists to participate in an experiment in which they were to be the subjects as well as designers. We reasoned that they would not only have spent years collecting data on themselves, but that they would enjoy designing a series of new experiments on themselves designed to see which of their auditory faculties had indeed changed, and how. Discussions with Drs. Ringel and Chodzko-Zajko produced a homologous notion that speech and voice studies might be productive on scientists whose voices had been recorded years ago and could be reanalyzed with modern techniques. One could use the same utterances today as were recorded years ago to permit microstructural digital analysis of any changes that might have taken place over the years. Such data would shed enormous light on the longitudinal changes that take place in the hearing, speech and voice systems. Learning from Rose Dobrof, Margaret Wylde, Audrey Holland and David Cunningham of AARP, we could also ask these people what they see as the major changes that have taken place in their lives and how they have coped and adapted. They could certainly guide us in a more precise search for the elements of communication that change with aging and which need our direct scientific and clinical attention.

We parted from this conference with appreciation for the organizers, especially Evelyn Cherow, Cynthia Shewan, and Barbara Weinstein who, with the support of ASHA's Scientific and Professional Programs and Executive Boards, conceived of this program. The support of Fred Spahr, James Lingwall, and other members of the National Office staff, Jo Williams, Michelle Ferketic, Camille Catlett, and Chase Raiford, were especially appreciated.

Clearly, we gathered at this symposium to summarize and direct our thinking about the aging process and communication disorders. Let us hope that history will view our efforts as being those of well-intentioned inquiring minds, working within supportable scientific frameworks, and producing important new insights.

Charles I. Berlin