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HEARING
ASSOCIATION

Proceedings of the ASHA Audiology Superconference



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Edited by
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AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION AUDIOLOGY SUPERCONFERENCE

March 7–10, 1991

AGENDA

Thursday, March 7, 1991

- 8:00 a.m. Registration
- 9:00 a.m. Welcome and Introductions
Evelyn Cherow
- GENERAL SESSION: SCIENTIFIC ADVANCES
IN THE STUDY AND TREATMENT OF THE EAR
AND HEARING**
- 9:10 a.m. The road from science to practice
Theodore Glatke
- 9:30 a.m. Research priorities for the National
Institute on Deafness and Other
Communication Disorders
James B. Snow
- 10:00 a.m. Cochlear processes
Josef J. Zwislocki
- 11:00 a.m. Break
- 11:15 a.m. Autoimmune disorders and the
auditory mechanism
Brian F. McCabe
- 12:00 p.m. Discussion
- 12:15 p.m. Lunch on your own
- 2:00 p.m. Meniere's disease
Phillip Wackym
- 2:30 p.m. Perilymph fistula diagnosis and
treatment
Posturography and instability
Hearing conservation measures in
acoustic neuroma treatment
Carol Bowman Jackson
- 3:30 p.m. Break

Thursday, March 7, 1991

**TRACK I: AUDIOLOGY AND ADVANCES IN
CLINICAL PRACTICE**

- 3:45 p.m. Our expanding scope of practice—
the view from the bridge
Donald Morgan
Paul Kileny

**TRACK II: NOISE, HEARING CONSERVATION, AND
MEDICO-LEGAL ISSUES**

- 3:45 p.m. Forensic audiology and medicolegal
issues—An overview
Roy Rowland
- 4:30 p.m. Current trends in litigation and
compensation for occupational
hearing loss
Susan J. Cooper

5:15 p.m. Reception with Exhibitors

Friday, March 8, 1991

**TRACK II: NOISE, HEARING CONSERVATION, AND
MEDICOLEGAL ISSUES (Continued)**

- 8:00 a.m. National hearing health activities and
objectives for the Year 2000
Linda M. Harris
- 8:30 a.m. Sorting out the noise issues
Alice H. Suter

**TRACK VI: MARKETING—INDIVIDUAL
CONSULTATION**

9:00 a.m.–4:00 p.m. Half-hour sessions

GENERAL SESSION

- 9:00 a.m. Coffee with Exhibitors
- 9:45 a.m. **THE AUDIOLOGY FORUM**
(Audioteleconference)
- 12:00 p.m. Join the Exhibitors for Lunch
- TRACK II: NOISE, HEARING CONSERVATION, AND
MEDICOLEGAL ISSUES (Continued)**
- 2:00 p.m. Hearing status of school-age children
and keys to effective hearing
conservation programs
Karen L. Anderson
- 2:50 p.m. Discussion
- 3:00 p.m. What every audiologist needs to know
about industrial audiology
Bradley K. Witt
- 3:50 p.m. Discussion

**TRACK III: AUDIOLOGY SERVICE DELIVERY TO
INFANTS AND TODDLERS**

- 2:00 p.m. Audiologic assessment of infants and
toddlers
Judith Gravel
- 2:45 p.m. Approaches to selection and fitting of
amplification
Kathryn Beauchaine
- 3:15 p.m. Cost-effectiveness and performance
of early identification protocols
Robert Turner
- 3:45 p.m. Discussion

GENERAL SESSION

- 4:00 p.m. Roundtable discussions—meet the
faculty informally for networking
and sharing ideas
or
Visit Exhibits

Saturday, March 9, 1991

TRACK IV: AUTOMATION

8:30–11:00 a.m. Automation—The Possibilities and the Realities: Hardware Considerations; User’s guide to software for teaching, clinical management, diagnostics and rehabilitation; Highlight on software applications
Catherine V. Palmer
Mark Rauterkus

TRACK V: LABS and SMALL GROUP ACTIVITIES

8:00–11:00 a.m. and

12:30–3:30 p.m.

Refer to Lab Activities Handout for details

TRACK VI: MARKETING—INDIVIDUAL CONSULTATION

9:00 a.m.–4:00 p.m. Half-hour sessions

GENERAL SESSION

11:00 a.m.–12:30 p.m. Brunch—An Open Forum with President-Elect Ann L. Carey

TRACK VII: PROGRAM EVALUATION AND QUALITY ASSURANCE

12:30 p.m. The Office of the Forum for Health Care Quality and Effectiveness—Standards of practice
Elaine Corrigan

1:00 p.m. Quality assurance and quality improvement strategies for program management
Fred H. Bess

1:40 p.m. Consumer satisfaction measures—an integral component of service delivery
Barbara Weinstein

2:15 p.m. Infection control and the healthcare worker
Marguerite M. Jackson

2:50 p.m. Discussion

3:00 p.m. Enjoy your afternoon of free time.

Sunday, March 10, 1991

PRACTICE MANAGEMENT AND MARKETING: YOUR PRACTICE IS A BUSINESS: A ROSE BY ANY OTHER NAME

9:00 a.m. Contracting your services, or legal matters matter
Henry D. Schmitz

9:45 a.m. Discussion

10:00 a.m. Buying in and “selling out”
Angela M. Loavenbruck

Discussion

10:45 a.m. Marketing—ya gotta do it!
Tom Smith

Discussion

11:45 a.m.–12:00 p.m. Closing

MARKETING-INDIVIDUAL CONSULTATION

9:00 a.m.–12:00 p.m. Half-hour sessions

TELECONFERENCE AGENDA

The Audiology Forum: Critical Issues

Friday, March 8, 1991

1:00 p.m.–3:00 p.m. (Eastern Time)

1:00–1:05 p.m. Welcome
Evelyn Cherow

1:05–1:25 p.m. Hearing Screening Protocols for Persons over 65 Years of Age
Barbara Weinstein
Angela Loavenbruck

1:25–1:35 p.m. Discussion

1:35–1:55 p.m. Amplification Selection and Fitting for Infants
Kathryn Beauchaine
Judith Gravel

1:55–2:05 p.m. Discussion

2:05–2:25 p.m. The Pragmatics of Upgrading Educational Standards for Audiologists
Paul Kileny
Judith Gravel

2:25–2:35 p.m. Discussion

2:35–2:55 p.m. Autonomy and the Marketplace
Robert Turner
Henry Schmitz

2:55–3:00 p.m. Discussion

PREFACE

“An ASHA ‘Audiology Superconference’—whatever for?” some asked. “For a multiplicity of reasons,” we responded. First and foremost, audiologists recognize that the knowledge and skill bases needed to practice audiology today are expanding rapidly. Second, the scope of the profession continues to change as dramatically as does the technology used in practice. Third, audiologists, when surveyed by ASHA, asked for continuing education in a variety of subject areas. For these reasons, the Superconference multitrack lecture/laboratory/forum/audioteleconference format was structured to address the expanding scope and to provide numerous opportunities for interaction among participating audiologists, the faculty, the manufacturers, ASHA Executive Board members, and National Office staff. An audioteleconference was broadcast from the conference to sites throughout the country to discuss controversial issues affecting audiologists.

The Superconference program was designed to encourage audiologists to expand and fine-tune their practice as well as to consider new areas of specialization and new methods for determining accountability. As public and federal scrutiny of both healthcare and educational delivery systems are shaping the way diagnostic, rehabilitative, and consultative services are delivered, audiologists need to be “ahead of the curve” by staying current about trends that influence our practice and our autonomy. The Superconference program addressed such trends as clinical and administrative applications of automation, total quality management, national health promotion and prevention agendas, consumer satisfaction measures, federal development of clinical protocols for best practice, and other critical and timely topics.

This *ASHA Report* attempts to capture the essence of the Superconference program so that those audiologists unable to travel to the meeting can gain the insights that conference participants and coordinators found to be so valuable.

Evelyn Cherow

ACKNOWLEDGMENTS

The 1991 ASHA Audiology Superconference resulted from the collective planning efforts of Evelyn Cherow, Director of the Audiology Division at ASHA, and Jo Williams, former Director of the Audiology Liaison Branch. A dedicated faculty representing all “walks” of the profession—scientists, practitioners, professors, otolaryngologists, public policymakers—agreed to lecture and, in some instances, offered laboratory sessions. When David Kuehn, Series Editor of *ASHA Reports*, suggested that the comprehensive nature of the program warranted the production of a proceedings, most faculty members succumbed to our late request for chapters, making production of this *Report* a possibility and a reality. Sometimes I sit in awe of the compulsive and dedicated nature of our members that permits mammoth projects of this nature to reach closure. Similarly, I applaud our peer reviewers who gave generously of their time and helped us translate conference offerings into worthy prose.

The constant support of Executive Board members; Patrick J. (Jerry) Carney, 1991 ASHA President; Ann L. Carey, 1992 ASHA President; Executive Director Frederick T. Spahr; and Stan Dublinske, Director of the Professional Practices Department, provided the impetus and commitment to complete this project during a time of national crisis—the Persian Gulf war. Convention and Meetings Division staff, particularly Chase Raiford and Cheryl Russell, provided the necessary finesse to organize the logistics for a very complex program. Joanne Jessen, Mary Montesano, and Maya Porter of the Publications Division lent their expertise for production of this *ASHA Report*. David Kuehn kept prodding to keep this project on the front burner when so many other important emergent issues stole our time and attention.

And to our audiologists, our members, who keep us notified of their lifelong learning needs, we thank you for keeping the lines of communication open. We learn from you and we hope you, in turn, learn from our efforts.

Evelyn Cherow

Chapter 1

THE ROAD FROM SCIENCE TO PRACTICE

THEODORE J. GLATTKE

*University of Arizona
Tucson, Arizona*

When an assignment to speak about issues related to the scientific underpinnings of clinical practice was offered to me, I thought that the preparation would give me the opportunity of reading, and sometimes re-reading, the essays of others. As a consequence, the assignment was accepted with great enthusiasm, for rummaging through such works brings great pleasure to me. The exercise has provided a refreshing view of the people and the ideas and institutions that have contributed to the legacy of audiology.

In many ways, the scientific process and the clinical process employ analogous methods to reach their objectives. Both the clinician and the investigator must have a good knowledge of what is known, lest they repeat past mistakes. Both processes require that observations be made. Both require that questions be crafted with great care. Both require that a hypothesis be formulated and tested. The hypothesis of the scientist translates to a diagnosis in the clinic. The experimental manipulation that leads to hypothesis testing in the laboratory takes the form of treatment in the clinic. If an experiment is well controlled, then the outcome will not be contaminated by extraneous variables. The efficacy of clinical treatment may be held to the same litmus test in many cases.

The profession of audiology stands at the intersection of a host of disciplines (Bess & Humes, 1990; Cherow, 1986). For thoughts about how to sort out the various mileposts on the road from science to practice, I turned to the writings of J. Donald Harris, who was as much a poet as he was the scientific manager of the Behavioral Sciences Division of the Submarine Medical Research Laboratory in Groton, Connecticut. Harris' writing has never failed to bring a smile to my face and to give me a new perspective. This time, an essay (Harris, 1969) steered me back to the 1890s, and reminded me that our clinical foundations contain a substantial amount of brick and mortar provided by Iowa's Carl Seashore. Seashore became director of the University of Iowa's Psychological Laboratory in 1897.

Seashore has been described by Moeller (1976) as both stately and moving ". . . from one project to another, crossing department lines almost at will, bringing to the University an era of innovation unprecedented in its history" (p. 12). In 1921, Iowa University's departments of psychiatry, speech, laryngology, and psychology were called upon to provide the scientific expertise to support

the founding of a new speech clinic. Seashore's relentless pursuit of interdisciplinary cooperation was the taproot for the development of speech-language pathology and audiology at Iowa. It paved the way for Bunch's Iowa Pitch Range Audiometer and the early interest of the Bell Telephone Company in the measurement of hearing (Lierle & Reger, 1966).

Today, we continue to enjoy benefits of Harvey Fletcher's long tenure at Bell Telephone Laboratories. Other roots of the family tree of audiology can be found in S.S. Stevens' program at the Harvard Psychoacoustic Laboratories; the efforts of Davis, Silverman, and Hirsh at the Central Institute for the Deaf; and, of course, in the cooperation of Shambaugh and Carhart, Lierle, and Reger and similar productive partnerships in Chicago, Ann Arbor, Baltimore, and New York.

Sometimes, individuals have crossed disciplines to make substantial contributions to clinical practice. Joseph Hawkins (1988) reminds us that Helmholtz's ". . . life presents a singularly harmonious synthesis of physics and medicine, physiology, psychology and music" (p. 20). The first publication written by von Bekesy to describe his audiometer was highlighted by a number of clinical illustrations, including the identification of sensorineural hearing loss, malingering, and audiometric correlates to tinnitus (von Bekesy, 1947). Hallowell Davis has moved easily between clinical and basic questions, from the Social Adequacy Index to notions about active cochlear processes (cf Davis, 1976). Our distinguished guest, Dr. Jozef Zwislocki, became known to me first through the Luscher and Zwislocki test for differential sensitivity to changes of intensity (Luscher & Zwislocki, 1949). Nearly 38 years ago, he published information that contributed to the successful application of insert earphones for masking and stimulus presentation (Zwislocki, 1953), and, 30 years ago, helped to set the stage for the widespread use of clinical immittance measurements (Zwislocki, 1963). Others, such as Dallos (1988), are constantly providing us with information that is helpful in understanding the nature of both the normal and disordered auditory system.

Finally, many individuals have chosen to focus their scientific energies almost entirely on clinical populations, coaxing order from chaos or allowing chaos to run its course. James Jerger's contributions in this type of work

have touched virtually all of us in some way because of their frequency, scope, and quality. Many others, too numerous to mention, have made substantial contributions to our knowledge base as a result of their investigations of clinical populations.

What features are shared by these and other individuals and institutions who have contributed so much to our profession? I think that there are three:

- The individuals have rigorous educational backgrounds in their respective disciplines.
- Their institutions foster interdisciplinary cooperation in research programs.
- The pathway between the laboratory and clinic was short. Often the two were adjacent to one another; sometimes, they were one and the same. The benefits of the short pathway are found in many forms, and I think that a primary benefit has been the minimization of barriers between investigative and clinical activities.

Research and clinical programs dealing with cochlear implants illustrate these points nicely. As Susan Jerger (1990) noted recently,

Excellent role models for us are the clinicians and researchers working in the area of cochlear implants. These clinicians and researchers have worked together to channel research findings into the solution of clinical problems. The behavioral research findings in cochlear implant subjects have been applied imaginatively and have impacted significantly the structure of clinical practice. Each of us understands only the tiniest fraction of the knowledge in the speech and hearing sciences. Working together, however, we can frame appropriate questions and obtain cogent answers (p. 22).

However, research outcomes are not likely to be integrated into clinical practice if they cannot be shaped into some type of practical or useful protocol. Practicality is likely to be determined by economic factors and the ability of the private sector to support the transition from laboratory to clinic. The private sector includes persons who supply services or goods to the clinicians, the clinicians themselves, and, of course, their clients.

The role of the supplier is well illustrated by recent experiences with computer technology. In 1969, when I was studying with Blair Simmons at Stanford, we spent approximately \$30,000 for a minicomputer, a Digital Equipment Corporation PDP 8/I. The machine was to be used to continue studies of evoked potentials, electrocochleography, and cochlear implants that had begun with the use of borrowed or shared equipment in the early part of the 1960s. For our \$30,000, we received a basic computer with 4,000 words of memory and a hard disk system that handled an additional 32,000 words. We also received several programs coded on punched paper tape. The programs were loaded into the computer through an ancient teletype reader. To that hardware, we added an analog-to-digital converter borrowed from a computer that we had shared with Norman Shumway's heart transplant team, some custom amplifiers, and other accessories. Within 3 years we had added magnetic tapes that enabled us to work with

another 500,000 computer words, and I think our total cost was approximately \$50,000 in early 1970s dollars. We could have purchased a small home in Palo Alto for the cost of that computer. In addition, the machine was decidedly unfriendly, with documentation that assumed a considerable background in computer programming.

Fortunately, computer prices went down while home prices went up and current technology provides us with tremendous power and capacity for a small fraction of the 1970s cost. In addition, software has made the computer into a friendly device. The most friendly instruments have few controls or rely on user communication that is laced with a minimum of jargon. The revolution in digital technology has provided audiologists with the opportunity of adopting evoked potential, vestibular, and immittance techniques and in situ measures of hearing aid performance into routine practice. In addition, digital instruments have nearly replaced standard audiometers and are beginning to be used as alternatives to traditional analog hearing aid circuitry. Finally, they are critical elements in report preparation, correspondence, billing, and other phases of the operation of a clinical practice.

The developments in digital technology and software that are keyed to audiological practice would not have occurred if individuals in the private sector had not kept one eye on research reports and the other on the technical support needs of clinicians who could adopt new methods of assessment and treatment. The manufacturers and software developers, large and small, have helped to maintain the pathway between science and clinical service and I think that their contributions have been critical in this regard. The cochlear implant programs and recent developments in amplification systems all have been heavily dependent on a transition from laboratory to clinic that was supported by the private sector. We should not forget people such as Grason and Madsen and many others when thinking about the contributions of entrepreneurs who have helped the profession step from the laboratory to the clinic.

Another critical milestone along the road between the laboratory and clinical practice marks the publication and integration of information about the research findings. Our journals have been the bedrock in which this milestone is anchored. As Kent (1983) has noted, journals provide an important source of communication for any scientific or professional organization. They provide windows through which information may be passed, and they provide an opportunity to view the health of the profession. Kent (1983) reminded us that a profession must have a substantial research base to control its identity and that a healthy journal program is an essential element in that research base. The archival nature of journals provides us with the opportunity to consider the past while addressing the present. In the current period of diminishing resources and the need for increased efficiency, we are likely to see dramatic changes in the nature of these vehicles. Libraries may soon become information nodes, providing access to, but not storage for, hard copies of the materials that they provide to users. Personal subscriptions already take the form of computer diskettes or on-line reference systems, and it is

likely that the use of such services will increase dramatically in the near future.

Conferences such as this play an important role in bringing information to the consumers of research. Conferences have the advantage of providing the participants with currency, but they suffer from the lack of efficiency. Electronic tools promise to help us maintain currency, an archival system, and the experience of interpersonal exchanges while improving efficiency.

Gorga (1990) recently described a number of technological advancements that have influenced the practice of audiology. They include evoked potential techniques, cochlear implants, real-ear measures of hearing aid performance, computer-based electronystagmography, rotational testing, and posturography. Gorga noted that technological advances have outdistanced information about the perceptual consequences of hearing loss and invited us all to participate in a systematic evaluation of these techniques as we employ them in clinical practice.

In thinking about the pathway from laboratory to clinic, I thought that it was useful to recall how each of the advances mentioned by Gorga came to my attention. Was it in a classroom? Was it at a conference sponsored by an equipment manufacturer, professional association, or academic institution? Was it in a published proceedings of a conference? Was it in a journal?

It is clear that one of the most important services that a professional association can provide may be found in the continuing education opportunities that it offers. More than 50,000 individuals have used the continuing education registration system offered by ASHA, a number that exceeds 80% of the total membership of the organization. This link in the pathway between the laboratory and clinic will continue to grow in importance, and I think that organizations will have to move from traditional vehicles to new forms of conferencing to help their members keep pace with the new information critical to clinical practice. Kent (1990) calls for taking steps to increase scientific consciousness and ability at all levels of the educational process. He challenges us to move away from the thinking that "science" means the study of the normal system. He argues that communication science should embrace the normal and disordered in combined or parallel research programs.

I think that a major problem looms with the supply end of the pathway between science and practice, and that may be found in our failure to attract individuals to careers in science. There are many indicators of this trend. As Green (1989) reported, between 1966 and 1988, the proportion of college freshmen planning to major in the sciences and mathematics fell by half, from about 11.5% to 5.8%. The disciplines leading the way in the decline were mathematics and physical sciences, while interest in biological sciences remains stable at the undergraduate level. The maintenance of interest in undergraduate majors in biological sciences appears to be related to anticipation of careers in medicine, rather than in the sciences themselves.

It is particularly discouraging to note that women's interest in science has been decreasing during a 20-year period in which barriers to careers traditionally favored by men have been reduced or eliminated. Unfortunately, while the

proportion of women studying science or mathematics fell by about 40%, the number of women pursuing studies in business grew by a factor of 6. As a consequence, our culture stands to lose on two fronts, because women will not be contributing to the science labor pool as researchers or to the science teacher pool in our secondary school systems in numbers consistent with their representation in the population at large. Such losses are felt keenly in speech and hearing programs. According to data released by the National Research Council (1990), only 79 persons received a PhD degree in the area of communication sciences and disorders during 1989. This number is far too low to enable us to address the opportunities that we will face in the 1990s and beyond.

Hirsh (1990) notes:

There is still plenty of work to do. We and the hearing-impaired (sic) population will continue to benefit from advances on the technological side in acoustics, electronics and bioelectric recording. We must keep our progress in those areas in touch with comparable developments in technical areas that are not normally in the audiological domain. Perhaps the less predictable progress is on the behavioral side, where we still wrestle with old problems and new hypotheses about the strategies for clinical help (1990, page 28).

By way of a summary, the need for interdisciplinary cooperation in research and rigor in education that has characterized our successes in the past remains substantial. The need for the practitioner to maintain currency with developments extending from business practices to fundamental observations of cochlear dynamics has never been greater. It appears that the pathways between the laboratory and clinic are evolving to take advantage of modern technology and innovations in communications. However, as a profession, we need to contribute what we can to stop the loss of young people to careers in science. If we fail to do this, our professional development will be frozen; if we succeed, we can look forward to a continuation of the dramatic innovations of the past few years.

REFERENCES

- Bess, F.H., & Humes, L.E. (1990). *Audiology: The Fundamentals*. Baltimore: Williams and Wilkins.
- Bekesy, G. von (1947). A new audiometer. *Acta-Otolaryngologica*, 35, 411-422.
- Cherow, E. (1986). The practice of audiology—a national perspective. *Asha*, 28, 31-38.
- Dallos, P. (1988). Cochlear neurobiology: Revolutionary developments. *Asha*, 30, 50-59.
- Davis, H. (1976). Principles of electric response audiometry. *Annals of Otolaryngology, Rhinology & Laryngology*, 85 (Supplement 28), 1-96.
- Gorga, M. (1990). Research developments in acoustical and physiological measures affecting the practice of clinical audiology. In C.M. Shewan (Ed.), *The Future of Science and Services Seminar, ASHA Reports, No 20* (pp. 3-13). Rockville: American Speech-Language-Hearing Association.
- Green, K.C. (1989). A profile of undergraduates in the sciences. *American Scientist*, 77, 475-480.
- Harris, J.D. (1969). Preface. *Forty germinal papers in human hearing* (pp v-vii). Groton, CT: Journal of Auditory Research.
- Hawkins, J.E. (1988). Auditory physiological history: A surface

- view. In A.F. Jahn & J. Santos-Sacci (Eds.), *Physiology of the Ear* (pp 1–28). New York: Raven Press.
- Hirsh, I.J. (1990). State of the art and future research directions: Hearing. Reactions to papers by Michael P. Gorga and Susan W. Jerger. In C.M. Shewan (Ed.), *The Future of Science and Services Seminar, ASHA Reports, No 20* (pp 26–30). Rockville: American Speech-Language-Hearing Association.
- Jerger, S. (1990). The behavioral sciences: Current research findings and implications for clinical audiology. In C. M. Shewan (Ed.), *The Future of Science and Services Seminar, ASHA Reports, No 20* (pp 14–25). Rockville: American Speech-Language-Hearing Association.
- Kent, R.D. (1983). Issue IX: How can we improve the role of research and educate speech-language pathologists and audiologists to be competent users of research? In N. Rees & T.L. Snope (Eds.), *Proceedings of the 1983 National Conference on Undergraduate, Graduate and Continuing Education, ASHA Reports No 13* (pp 76–86). Rockville: American Speech-Language-Hearing Association.
- Kent, R.D. (1990). Sending speech science into another century: Comments on the papers by Jeannette D. Hoit and Diane Kewley-Port. In C.M. Shewan (Ed.), *The Future of Science and Services Seminar, ASHA Reports, No 20* (pp 86–91). Rockville: American Speech-Language-Hearing Association.
- Lierle, D., & Reger, S.N. (1966). The origin and development of audiometric audiology at the University of Iowa. *Transactions of the American Otological Society, 54*, 19–23.
- Luscher, E., & Zwislocki, J. (1949). A simple method for indirect monaural determination of the recruitment phenomenon (Difference limen in intensity in different types of deafness). *Acta Otolaryngologica, Supplement 78*, 156–168.
- Moeller, D. (1976). *Speech pathology & audiology: Iowa origins of a discipline*. Iowa City: The University of Iowa.
- National Research Council. (1990). *Survey of earned doctorates conducted by the National Research Council*. Washington, DC: Author.
- Zwislocki, J. (1953). Acoustic attenuation between the ears. *Journal of the Acoustical Society of America, 25*, 752–759.
- Zwislocki, J. (1963). An acoustic method for clinical examination of the ear. *Journal of Speech and Hearing Research, 6*, 306–307.

Chapter 2

RESEARCH PRIORITIES OF THE NATIONAL INSTITUTE ON DEAFNESS AND OTHER COMMUNICATION DISORDERS

JAMES B. SNOW, JR.

National Institute on Deafness and Other Communication Disorders

Thank you, Evelyn Cherow and Jo Williams, program coordinators, for including the National Institute on Deafness and Other Communication Disorders (NIDCD) in the ASHA Audiology Superconference. Your excellent conference program shows clearly that ASHA and the NIDCD share many similar, current interests and concerns.

The NIDCD is responsible for research and research training related to both normal and disordered hearing, balance, smell, taste, voice, speech, and language and is one of the 13 institutes of the National Institutes of Health in Bethesda, Maryland. To plan ahead amid rapidly emerging science in the Institute's program areas, the NIDCD engages in regular updating of the National Strategic Research Plan (NSRP) that was developed in 1989. This year two expert panels have updated the sections on the vestibular system and language. In 1992 hearing and voice will be updated, and in 1993 speech and the chemical senses will be updated. By repeating this cycle every 3 years, no part of the NSRP will be more than 3 years old.

The NIDCD responds to its mission by fostering critically needed basic research to improve the understanding of human communication while supporting research protocols for prevention, therapeutic intervention, and development of devices that will improve the quality of life for those who have communication disorders.

The NIDCD accomplishes its mandate through research performed in its own laboratories, a program of research grants, career development awards, individual and institutional research training awards, center grants, and contracts to public and private research institutions and organizations. The Institute also conducts and supports research and research training in disease prevention and health promotion. The NIDCD is concerned with the special biomedical and behavioral problems associated with people having communication impairments and disorders.

The Institute is also supporting efforts to create devices that will substitute for lost and impaired communication functions—devices that include cochlear implants, hearing aids, and vibrotactile aids. The NIDCD has made major investments in the development and improvement of multichannel cochlear implants, including a new interleaved-pulse speech processor capable of sampling speech at high

rates. This processor provides impressive gains in understanding speech. The study of digital hearing aids is being pursued with great intensity. Fifteen grants are currently focused on various aspects of hearing aids.

The NIDCD is pleased to have again received an unprecedented commitment of the nation's financial resources to support research and research training in hearing, balance, smell, taste, voice, speech, and language. The Institute's budget for FY 1990 was \$117,283,000 and has increased 15% to \$134,935,000 for FY 1991 (Table 1). The President's budget for the Institute for FY 1992 is \$146,321,000, an 8.44% increase compared to an increase of 6% for all of the NIH. The vast majority of these dollars will go toward supporting investigator-initiated research projects.

In FY 1989, the NIDCD was able to fund 97 new and competing renewal grants, 130 in FY 1990 and an estimated 138 in FY 1991 (Table 2). At the level of the President's budget for 1992, 118 new and competing renewal grants can be funded. The scientific community has responded to the creation of this Institute by providing an increasing number of high-quality applications: 254 in FY 1989, 349 in FY 1990, and 472 in FY 1991. It is estimated that 542 applications will be received in FY 1992. The Institute success rate is declining and will approach the NIH average, which was 24% for FY 1990.

Fifty-nine percent of our current portfolio is research in the program area of hearing and approximately one third of our total portfolio is in neurobiology, including investigations related to neural regeneration, auditory perception, and voice and language disorders. With this substantial interest in the neural bases of disorders such as aphasia, the Institute is pleased to be part of the NIH community of Institutes that are involved in The Decade of the Brain.

One in 1,000 infants is born deaf. Approximately 2 million people in the United States are profoundly deaf. From 40 to 60% of profound neonatal deafness can be attributed to genetic causes. Research in molecular biology and specifically molecular genetics holds great promise for the use of gene therapy in hereditary deafness and other disorders of human communication that are clearly hereditary. The NIDCD has made important progress on two forms of

TABLE 1. National Institute on Deafness and Other Communication Disorders budget (in thousands of dollars).

<i>Areas funded</i>	<i>FY 1990 actual</i>	<i>FY 1991 appropriation</i>	<i>FY 1992 estimate</i>
Research			
Research projects	\$86,419	\$94,178	\$103,577
Research centers	12,001	17,562	18,006
Other research			
Careers	2,295	3,053	3,053
MBRS	240	316	333
Other	905	825	825
Total	101,860	115,934	125,794
Training			
Individual	571	968	987
Institutional	2,548	3,017	3,047
R&D contracts	2,143	2,930	3,027
Intramural	5,159	6,117	6,590
RM&S	5,002	5,969	6,876
Grand total	\$117,283	\$134,935	\$146,321

hereditary deafness, Usher's syndrome and Waardenburg's syndrome. NIDCD investigators have recently narrowed the search for the Usher type II gene to a region on chromosome 1 and plan to fine-map, clone, and characterize the gene. A team of scientists in the NIDCD Intramural Research Program and a network of clinicians are at work studying Waardenburg's syndrome. Geneticists, otolaryngologists, and audiologists throughout the country have been enlisted to provide contacts between intramural scientists and families with hearing loss due to Waardenburg's syndrome who would like to participate in the research. Initially, the focus will be on the mapping of the gene involved in Waardenburg's syndrome. This information can subsequently be used to improve diagnosis and genetic counseling and eventually may lead to gene therapy for syndromes of hereditary deafness.

We are involved in important research in the areas of balance, smell, and taste. Although only 2% of our current portfolio is in balance-related research, this is a growing area within the Institute. NIDCD is supporting balance-related research on the micromechanical properties of the vestibular hair cells that may explain how these cells detect forces acting upon them during movement of the head and changes in gravity and transform this information into neural signals. We are currently in discussion with NASA about a cooperation between NASA and NIDCD-supported scientists.

In other basic science research, investigators studying the sense of smell have found an indication that some forms of Parkinson's disease and Alzheimer's disease may be caused by environmental agents that enter the brain through the olfactory nerve. Studies in the chemical senses represent 15% of our grant support.

The balance of our investigator-initiated research portfolio is in the program areas of voice, speech, and language. Voice research is 7% of the portfolio, speech 8%, and language 9%. Some recent findings from these areas result from work on long-term delay in speaking, research on the

treatment of voice disorders, research on stuttering, and research on language acquisition.

In addition to the ongoing intramural and extramural research studies with which you are familiar, the Institute provides national leadership in the development and recruitment of investigators and a national focus in the search for good research ideas.

The first three National Multipurpose Research and Training Centers have been established. These centers will stimulate important areas of basic and clinical research while providing needed research training opportunities. They will increase the numbers and broaden the capabilities of investigators in the communication sciences. The one at Boys Town in Omaha under the leadership of Patrick Brookhouser addresses hearing loss in children. The one at Johns Hopkins is on basic and applied studies of the auditory and vestibular systems under the direction of Murray Sachs. The one at University of Iowa is on voice and speech disorders under the guidance of Ingo Titze. Continuing education for health professionals will be provided, and these programs will disseminate research results to physicians, other health professionals, and the public. The NIDCD Clearinghouse will be coordinating with these centers to increase dissemination of information.

The Institute's National Strategic Research Plan has identified that there is insufficient incidence and prevalence data on communication disorders. After holding planning meetings with the National Center for Health Statistics (NCHS), the NIDCD is preparing a 10- to 15-year epidemiologic research strategy. This strategy in collaboration with the NCHS will yield incidence and prevalence data in the Institute's seven program areas and will provide reliable and cost-effective data in a systematic and comprehensive manner over the life span. The NIDCD is establishing an epidemiology branch to coordinate these efforts. A current NIDCD initiative is for contracts to be awarded on the epidemiology of specific language impairment in children.

In another effort to supply needed information to the field, the NIDCD held in September of 1990 the first of a series of working group meetings designed to look at the needs of the several constituencies served by the Institute. Each working group has an opportunity to inform the Institute of their special research and research training needs. The first working group provided perspectives of the deaf community and was held September 7, 1990; the second will provide the perspectives of oral, auditory hearing-impaired persons and will be held April 23, 1991; the third will address the research and research training needs of

TABLE 2. National Institute on Deafness and Other Communication Disorders competing research project grants.

	<i>FY 1989 obligations</i>	<i>FY 1990 obligations</i>	<i>FY 1991 estimate</i>
Number of grants	97	130	138
Amount	\$16,973,000	\$22,476,000	\$25,557,000

women and women's health issues on October 3, 1991; the fourth will present the needs of minority persons and minority health issues on April 28, 1992; and the fifth meeting in this series will assess the impact of visual impairment on deaf and hard of hearing persons on September 29, 1992. Each of these groups will be making a report to the Institute that will help the staff in planning for the future.

NIDCD will continue the support of minority-related research and minority scientists. In several of its clinical trials on otitis media, specific attention has been devoted to minority populations such as American Indians and native Alaskans. Although all clinical trials supported by NIDCD include both male and female subjects, recent findings in diseases affecting women differentially have occurred in Meniere's disease, otosclerosis, and voice tremor. The scientific community has become increasingly alert to the unique needs of each of these groups, and the NIDCD is committed to continued attention to the needs of these populations.

The NIDCD employs several different mechanisms to nurture applications in areas of science that are either not receiving enough attention or are particularly promising as links to entire arenas of discovery. Last year (FY 1990) the NIDCD Implementation Plan included requests for applications, requests for proposals, program announcements, workshops and conferences. Research topics for each category included the following:

Requests for Applications

- Recognition and treatment of perilymphatic fistulae
- Development of a vaccine for the prevention of otitis media
- National multipurpose research and training centers
- Multipurpose research and training: Initial development centers

Requests for Proposals

- Reimplantation/explantation of cochlear implants in adult monkeys
- Design and evaluation of pediatric cochlear implants
- National human temporal bone information center
- Epidemiology of specific language impairment
- National information clearinghouse

Program Announcements

- Language learning in children who are deaf
- Treatment efficacy of voice disorders
- Neurobiology of taste pathways
- Genetics: Chemical senses
- Small grants: Communication disorders

Workshops and Conferences

- Clinical assessment of speech and voice disorders
- Balance and vestibular disorders
- Epidemiology/population-based studies
- NIDCD research and training: Perspectives of the deaf community

This year (FY 1991) we are engaged in the development of new initiatives including the following:

Requests for Applications

- Immunologic basis of sensorineural hearing loss
- Neural imaging of CNS processing of speech and language
- Treatment of adult aphasia: Protocols and efficacy
- Nasal chemosensory nerves as portals to the brain
- NIH/NASA vestibular studies

Requests for Proposals

- Protective effects on the deafened auditory nervous system of patterned electrical stimulation
- Development of new diagnostic tests for taste disorders
- Assessment of dense array vibrotactile stimulator
- Establishment of data base on inherited hearing impairment

Program Announcements

- Epidemiology and development of a genetic library of hearing loss
- Development of a model system for early identification of hearing loss
- Mechanisms of voice disorders
- Literacy in deaf persons

Workshops

- Epidemiological studies
- Treatment of adult aphasia
- Hearing impairment and communication disorders in AIDS
- Evaluation of existing therapies for stuttering
- Growth and senescence of sensory receptors in smell and taste

Our implementation plan for next year (FY 92) includes:

Requests for Applications

- Hearing impairment and communication disorders in AIDS
- Predictive efficiency of intra-operative cranial nerve monitoring
- Small grants to facilitate use of new techniques of molecular and cell biology and genetics by resources in deafness and other communication disorders
- Population normative database for vestibulo-ocular tests across the life span
- Treatment efficacy in stuttering: Evaluation of new and existing therapies

Requests for Proposals

- Population studies of deafness and hearing impairment
- Studies on cochlear implant—hearing aid users
- Development of improved percutaneous connectors
- Population database of balance and vestibular disorders

Program Announcements

- Molecular bases of repair/regeneration of the auditory receptor
- Mechanics of the vestibular labyrinth
- Identification of childhood language impairment in multicultural populations
- Use of the x-ray microbeam facility for research in speech production
- Assessment of speech and voice production: Research and clinical applications
- Chemosensory disorders and altered nutrient intake

Workshops and Conferences

- Planning and writing successful grant applications: A workshop for clinicians
- Early identification of hearing disorders in children
- Development of an evoked response test of the vestibular system
- Augmentative communication for the speech impaired: Research needs and directions
- Neural mechanisms of spoken and signed language
- Integration of taste, smell, and touch by the central nervous system
- Speech production in the prelingually deaf child
- Development of tests of the chemical senses

Research grants make up the largest category of support by the NIDCD. These grants may be awarded to universities, medical and other health professional schools, colleges, hospitals, research institutes, for-profit organizations and government institutions that sponsor and conduct biomedical research and development. Research grants may

provide funds for salaries, equipment, supplies, travel, and other allowable direct costs to the sponsoring institution or organization. I shall highlight here a few of the mechanisms that may be of special interest to you:

R03. The Small Grant Program provides support for pilot research or especially innovative/high-risk research to determine the feasibility of a subsequent research project. For example, the pilot research may involve development of tests of new techniques or a small basic, clinical, or epidemiological research project. This program is designed primarily to support investigators changing their areas of research, especially those coming into communication disorders research for the first time from another area, and clinicians with limited research experience. Participation in the program by investigators at minority institutions is encouraged.

K08. Clinical Investigator Development Award (CIDA). The purpose of this mechanism is to recruit and prepare clinically trained individuals for research and teaching careers in the areas of medical science related to communication sciences and disorders. By supporting individuals with an interest in academic research careers, this award bridges the gap between the initial period of postdoctoral study and a secure academic appointment, or completes the development of research capabilities of someone who may have had minimal research experience.

R29. The FIRST Award. The objective of the FIRST award is to provide, at a domestic institution, a sufficient period of research support for newly independent investigators to initiate their own research and demonstrate the merit of their own research ideas. These grants are intended to underwrite the first independent investigative efforts of an individual; to provide a reasonable opportunity to demonstrate creativity, productivity and further promise; and to help in the transition to traditional types of research project grants.

R01. The Research Project Grant. Investigator-initiated research grants make up the largest single category of support provided by both the NIDCD and the NIH as a whole. This is the most traditional grant activity. These grants are awarded to an organization on behalf of an individual principal investigator (P.I.) to facilitate pursuit of a research objective in the area of the investigator's research interests and competence.

The NIDCD is currently supporting research across the entire biomedical spectrum—from basic research to applied clinical trials and prevention and rehabilitation. I consider each component of the spectrum to be part of a critical chain of progress, each link contributing to our more complete knowledge of the processes of hearing, balance, smell, taste, voice, speech, and language.

Thank you for this opportunity to provide you with an overview of the work of the NIDCD, its mission, its budget, its programs and its initiatives. The NIDCD is answering the need to identify important areas for inquiry, encouraging promising scientists, and fostering research into the normal and disordered processes of human communication so critical to improving the quality of life for individuals who are born with or may acquire communication disorders.

Chapter 3

COCHLEAR PROCESSES: A RESEARCH REPORT

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*Institute for Sensory Research
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The cochlea of the inner ear is an organ of great interest to scientists, audiologists, and otologists. As you well know, the cochlea is the seat of the first step in the auditory sound analysis and of transduction of mechanical vibration into electrochemical processes that lead to the generation of neural action potentials. The cochlea is also a frequent seat of auditory disorders. Accurate diagnosis of these disorders and their eventual treatment or prevention depend on our understanding of cochlear mechanisms.

In the past two decades, a prodigious number of discoveries has revolutionized our concepts of cochlear function. These concepts are only partially included in even the most recent textbooks and handbooks, and in no place is an integrated picture of the cochlear function presented. I will attempt to present it here and to contrast it with the views we held before the revolution took place.

First, let me recall some functional anatomy to which I will be referring. Figure 1 shows in cross section the second turn of the cochlea of a Mongolian gerbil, our main experimental animal. The structures that can be seen are quite similar to corresponding human structures. I am sure you can recognize the basilar membrane with the organ of Corti and the tectorial membrane. The latter is displaced somewhat toward the spiral limbus and away from the organ of Corti due to histological artifact. The normal position of the tectorial membrane is parallel to the reticular lamina of the organ of Corti. It is possible to identify the outer hair cells by their somewhat darker staining and an inner hair cell on the inner side of the tunnel of Corti. It is well established now that the stereocilia of the outer hair cells are firmly coupled to the tectorial membrane and that the coupling of the stereocilia of the inner hair cells is less tight.

More than 40 years ago Békésy (1947) was able to show that sound was propagated in the cochlea in the form of transversal traveling waves on the basilar membrane, whose energy was dissipated before they reached the helicotrema in the cochlear apex so that no wave reflection took place. This discovery is still valid. According to Békésy's observations, the waves produced a local vibration maximum as they ran along the cochlea, and the location of the maximum changed with sound frequency, mov-

ing from cochlear base toward its apex as sound frequency decreased. The dependence of the location on sound frequency resembled the relationship between the subjective pitch and sound frequency, and Békésy assumed that the location constituted the adequate code for pitch, as had been first suggested by Helmholtz in the mid-19th century. The cochlear waves Békésy drew according to his observations are reproduced in Figure 2 for two instants in time. The waves clearly exhibit a vibration maximum, but the maximum is rather flat, and Békésy assumed that it was sharpened up in the nervous system to account for the fine frequency resolution our hearing is capable of. The cochlear frequency resolution, as seen by Békésy (1947) in human postmortem preparation is shown for several cochlear locations in Figure 3. At every location, the vibration amplitude is drawn as a function of frequency. The dashed lines show the results of my mathematical theory (Zwislocki, 1946, 1948, 1950), which provided the physical foundation for Békésy's waves. The agreement of the theoretical results with the experimental ones suggests that the mechanism of Békésy's waves was sufficiently well understood. The theory also accounted well for the empirical location of the vibration maximum along the cochlea.

Since the 19th century, it was believed that vibration of the basilar membrane led to excitation of the hair cells, and at the onset of the 20th century, ter Kuile (1900) provided an explicit model of hair cell stimulation. Because the outer hair cells are located near the middle of the basilar membrane, where the amplitude of vibration must be the greatest, and the inner hair cells are located near its edge, where the amplitude must be small, it was believed that the outer hair cells transmitted the auditory information near the threshold of audibility and the inner hair cells transmitted at higher sound intensities (Stevens & Davis, 1938).

The model of ter Kuile was modified by H. Davis (1958) without changing its principle. It is schematized in Figure 4. According to this model, the hair cell excitation was produced by deflection of the hair cell hairs, or stereocilia, resulting from shear motion between the tectorial membrane and the reticular lamina. The shear motion was due to the geometry of the basilar membrane and the organ of Corti and of the tectorial membrane. It was assumed that,

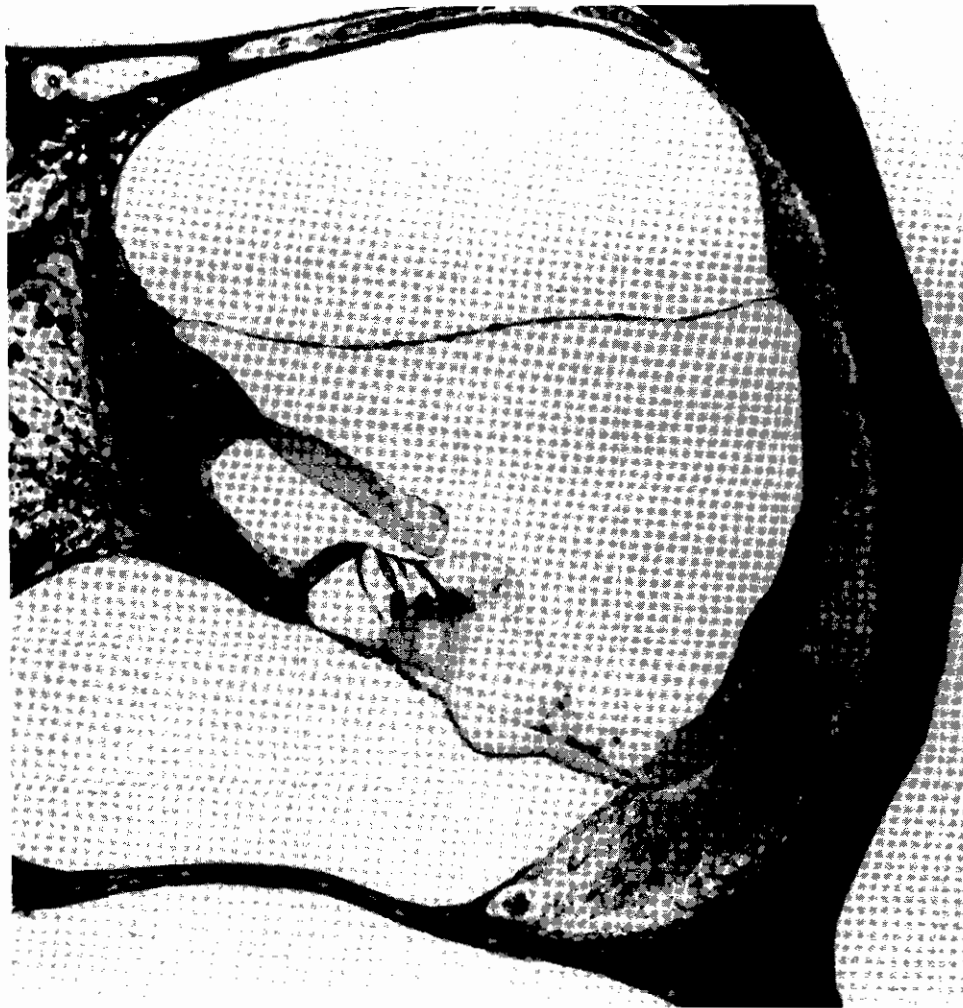


FIGURE 1. Second turn of a Mongolian gerbil cochlea in cross section. The various anatomical parts should be familiar, but note the somewhat more darkly stained outer and inner hair cells and the somewhat displaced tectorial membrane because of histological artifact. Undisturbed, the undersurface of the tectorial membrane is parallel and in close proximity to the reticular lamina.

as seen in the cross section, the basilar membrane and the tectorial membrane motions could be approximated by rotation of two stiff beams around two mutually offset axes. As illustrated in Figure 4, such motions must lead to stereocilia deflection toward the cochlear modiolus during basilar membrane displacement in the direction of scala tympani, and toward the outer wall during basilar membrane displacement in the direction of scala vestibuli. It was found later on that, in the first instance, the cells were hyperpolarized, and in the second, depolarized (Flock, 1971, for review). The latter was associated with the excitation of auditory nerve fibers. The displacement of the basilar membrane toward scala vestibuli, then, was assumed to produce neural excitation.

In the early 1960s, the model of cochlear function sketched above appeared to be well established. Then, one dogma fell after another. Demonstration by Kiang (1965) and his co-workers that the auditory nerve fibers were very sharply tuned eliminated the need for central sharpening of

the auditory frequency analysis. In 1967, Spoendlin discovered that almost all afferent auditory nerve fibers end on the inner hair cells, not the outer hair cells. This made the assumption that the outer hair cells coded sounds at low intensities quite improbable and strongly suggested that the sharp tuning and great sensitivity found by Kiang's group referred to fibers ending on the inner hair cells. It also made the role of the outer hair cells enigmatic. In the same year, Johnstone and Boyle (1967) showed that the local vibration maximum of the basilar membrane is much sharper in live guinea pigs than had been observed by Békésy on postmortem preparations. Rhode (1971, 1973) confirmed these results on live monkeys and demonstrated directly that death was at least a partial cause of the decreased sharpness of tuning in Békésy's experiments. The effect of death on basilar membrane tuning found by Rhode is schematized in Figure 5. A few years later, Russell and Sellick (1977) discovered through pioneering intracellular recordings that the inner hair cells are as sharply tuned as

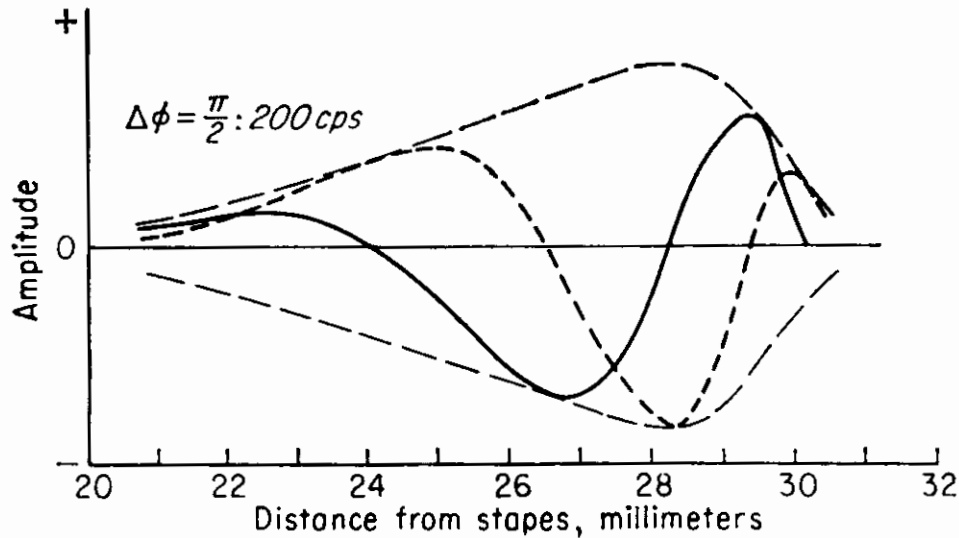


FIGURE 2. Traveling cochlear waves drawn by Békésy for two instants of time according to his microscopic observations. Note that the wave length becomes shorter with the distance from the stapes and the amplitude goes through a local maximum. (Békésy, 1947, as reproduced in Zwislocki, 1980).

the nerve fibers. This means that the sharp tuning found in the nerve fibers is of cochlear origin. The question whether the tuning of the inner hair cells is sharper than that of the basilar membrane has remained controversial. Nevertheless, research at the Massachusetts Institute of Technology (MIT) (Frishkopf et al., 1982; Holton & Weiss, 1983; Peake & Ling, 1980) on lizards has shown that the hair cells can be sharply tuned in the absence of any basilar membrane tuning.

Two additional key discoveries provided an explanation for the increased sharpness of cochlear tuning in a live cochlea. Kemp (1978) discovered that the cochlea was capable of emitting sound, especially when excited by a sound impulse. Five years later, Brownell (1983) found that the outer hair cells vibrate longitudinally when exposed to an alternating electrical field. Since the outer hair cells generate such a field in the cochlea in the form of cochlear microphonics, conditions for a positive electromechanical feed-

back are provided. It is known in the engineering world that positive feedback can lead to spontaneous oscillation, and it is believed that the electromechanical oscillation of the outer hair cells is the cause of the cochlear acoustic emissions. It is also known that a positive feedback counteracts damping and sharpens frequency resolution. Its existence in the cochleas of live animals but not postmortem can explain why cochlear tuning becomes less sharp after death. It also clarifies the role of the outer hair cells which, by providing a positive electromechanical feedback, appear to serve as a kind of cochlear amplifier (Davis, 1983). When the outer hair cells are damaged or missing, the cochlear sensitivity decreases, and a hearing loss results, even when the inner hair cells appear undamaged (e.g., Dallos & Harris, 1978; Liberman & Kiang, 1978; Schmiedt et al., 1980).

For a feedback to be positive, it must be in phase with the input signal to the system. Several attempts have been

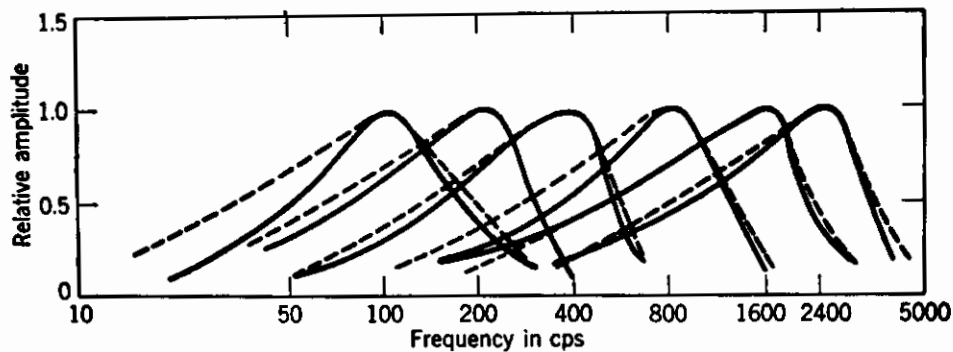


FIGURE 3. Cochlear filter functions determined by Békésy at various locations along the cochlear spiral (solid lines) and calculated according to my original theory (dashed lines). Note that the filter functions, determined postmortem, are not very sharp. (Zwislocki, 1950).

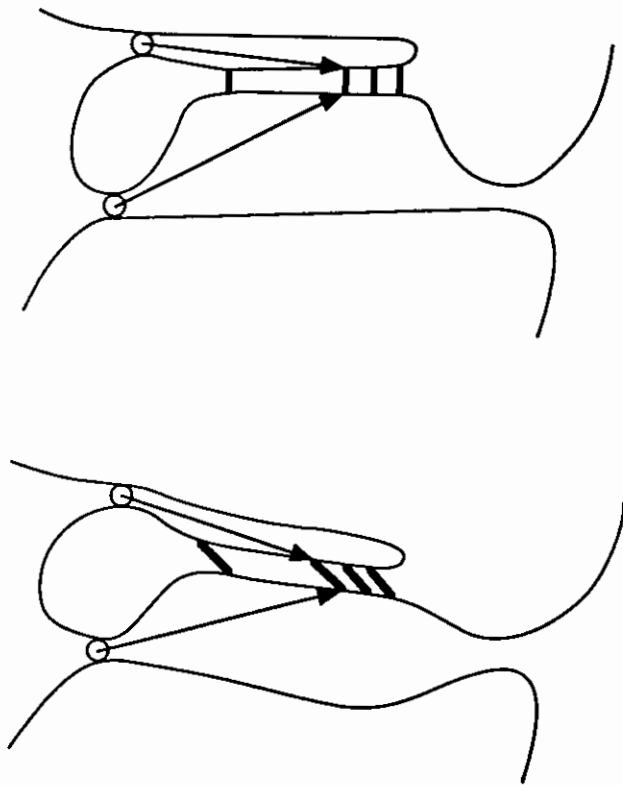


FIGURE 4. Schematic representation of the shear motion between the tectorial membrane and the reticular lamina according to the classical model. In the upper panel the basilar membrane is in its zero position; in the lower panel, it is displaced toward scala tympani. In association with this displacement, the hair cell stereocilia are deflected toward the modiolus, a hyperpolarizing direction.

made at modelling the cochlear feedback (e.g., Neely & Kim, 1983; Mountain et al., 1983; Ashmore, 1986), but the models have not been explicit enough to define unambiguously the feedback phase. As a result, they have not brought to evidence that the classical concept of hair cell stimulation, on which they have been based, leads to a negative rather than positive feedback. This relationship can be derived from Figure 4, given the well-established fact that the outer hair cells become shorter when they are depolarized or excited. As already explained, this is associated with the stereocilia deflection toward the outer wall and, according to the classical model, with the basilar membrane displacement toward scala vestibuli and the tectorial membrane. The shortening of the outer hair cells produces a relative displacement of the reticular lamina away from the tectorial membrane, counteracting the effect of the basilar membrane displacement. As a result, the shear displacement between the tectorial membrane and the reticular lamina is reduced, and with it, the hair cell depolarization. This amounts to a negative feedback. In the lower panel of Figure 4, the basilar membrane is drawn displaced in the opposite direction, toward scala tympani, and the stereocilia deflected toward the modiolus—the hyperpolarizing direction. This is associated with a lengthening of the outer hair cells and a relative displacement of the reticular lamina

toward the tectorial membrane. Again, the effect of the basilar membrane displacement away from the tectorial membrane is counteracted and the shear displacement reduced. To produce a positive feedback, the excitation phase of the outer hair cells would have to be reversed. They would have to be depolarized during basilar membrane displacement toward scala tympani. Under such conditions, the outer hair cells would be shortened, producing a relative displacement of the reticular lamina in the same direction as the displacement of the basilar membrane. This means that the shear displacement between the tectorial membrane and the reticular lamina, and with it the depolarization of the hair cells, would be enhanced—a positive feedback.

Depolarization of the hair cells during basilar membrane displacement toward scala tympani is in direct contradiction of the classical model of hair cell stimulation, and difficult to accept for many scientists. Nevertheless, experimental evidence against the model has been accumulating for almost 20 years. It started with Konishi and Nielsen's (1973) discovery made with the help of very low sound frequencies that most auditory nerve fibers become excited and increase their firing rate during basilar membrane displacement toward scala tympani. Remember that neural excitation is coupled to hair cell depolarization. Because, in their experiments the cochlea had to be opened and the possibility of an artifact was increased, the discovery was not taken seriously at first. However, it was confirmed in my laboratory without tampering with the cochlea (Zwislocki & Sokolich, 1973; Sokolich et al., 1976; Schmiedt & Zwislocki, 1980).

The experiments also showed that elimination of the

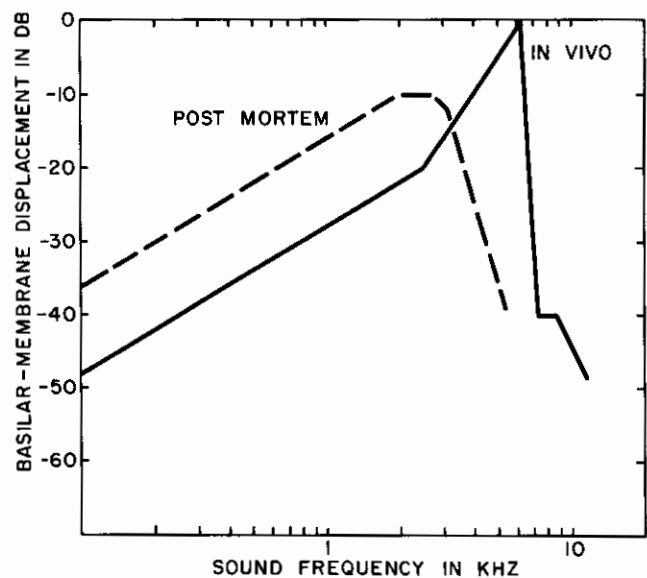


FIGURE 5. Magnitude of basilar membrane vibration as a function of sound frequency for a basal cochlear location schematized according to Rhode's results. The solid line corresponds to in vivo conditions; the intermittent one, to post mortem conditions. Note the difference in the sharpness of tuning and in the best frequency between the two conditions. (Zwislocki, 1980).

outer hair cells reversed the phase of neural excitation, bringing it in line with the classical model. In other words, in portions of the cochlea devoid of outer hair cells, the inner hair cells seemed to be stimulated according to the classical model. This was not true in the portions with a full complement of outer hair cells.

An individual example of the correlation between the neural response phase and the preservation of outer hair cells is shown in Figure 6. The solid line and open circles show the remaining outer hair cells in percent as a function of cochlear location. The intermittent line and closed circles do the same for the inner hair cells. The triangles indicate the inferred cochlear locations of innervation of nerve

fibers. The closed triangles indicate neural excitation during basilar membrane displacement or motion toward scala tympani; the open ones, excitation during basilar membrane displacement or motion toward scala vestibuli, in agreement with the classical model. The correlation between the response phase and the availability of outer hair cells is striking.

Several series of neural recordings performed by others in the presence of normal cochleas essentially confirmed our results (e.g., Sellick et al., 1982; Ruggero & Rich, 1983, 1987, 1988; Ruggero et al., 1986). However, they seemed to be contradicted by direct recordings from the inner hair cells, which were consistent with the classical

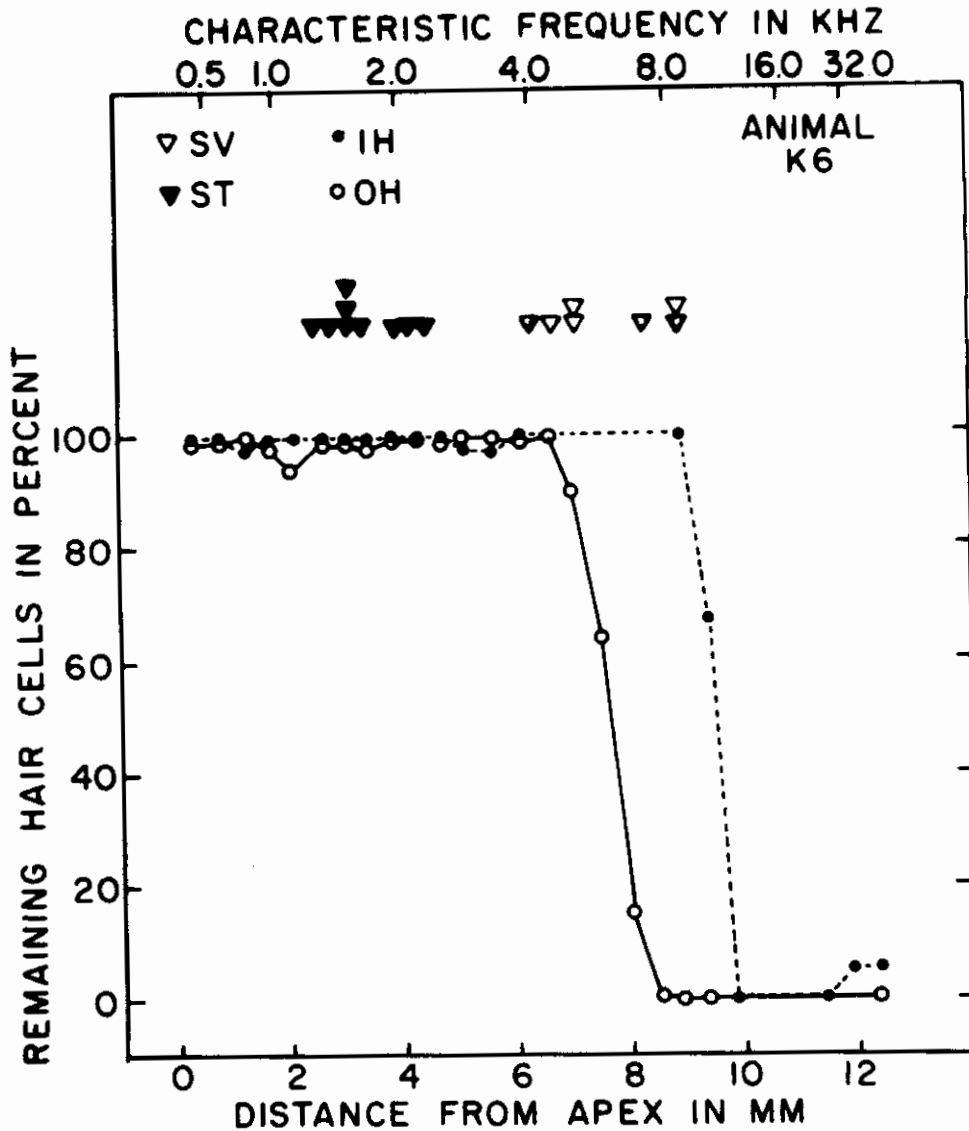


FIGURE 6. Correlation between the percentage of remaining hair cells and the response polarity of the auditory nerve fibers. The solid line shows the percentage of OHCs as a function of the distance from the apex, and the dashed line, that of the IHCs. Note the window of preserved IHCs in the presence of depleted OHCs. In this window, the fibers were excited (increased firing rate) during inferred basilar membrane displacement or motion toward scala vestibuli. In the presence of practically complete sets of both cell types, the excitation occurred during basilar membrane displacement or motion in the opposite direction—toward scala tympani. (Sokolich et al., 1976).

model (Sellick & Russell, 1980; Nuttal et al., 1981). Subsequently, it was shown that the apparent disagreement was likely to have originated, in part, from differences among animal species (Oshima & Strelhoff, 1983), and in part, from an artifact produced by the electrode lodged in the organ of Corti during hair cell recordings (Zwislocki, 1984; Zwislocki & Smith, 1988a).

More recently, it became possible to measure directly the response phases of the outer hair cells. According to the obtained results, the cells are depolarized during basilar membrane displacement toward scala tympani, except at very low sound frequencies and/or very high sound pressure levels. When the sound frequency is varied from very low to high, a phase shift of about 180° can be detected. The same is true when the sound pressure level is increased beyond 80 dB (e.g., Zwislocki & Smith, 1988b; Zwislocki, 1990). These relationships are reproduced in Figure 7 for one outer hair cell. The phase is plotted as a function of log frequency by means of the sinus of the phase to avoid 180° and 360° phase ambiguities. The thinner curve was obtained at 40 dB SPL, the thicker one, at 100 dB SPL. The phase reversal is clearly apparent near the best frequency indicated by the amplitude maximum in the 40-dB curve. The phase shift decreases toward the low frequencies, at the left of the figure. A small positive bump in the thinner curve at the left and a positive slope of the thicker curve at the right are artifactual.

How is it possible for the outer hair cells, and also the inner hair cells, to be depolarized (excited) during basilar membrane displacement toward scala tympani, contrary to the plausible geometrical explanation provided by the classical model? First, it has been found that the stereocilia bundles of the outer hair cells are very stiff (e.g., Flock, 1977; Strelhoff & Flock, 1984) and the tectorial membrane, very compliant (Zwislocki et al. 1988; Zwislocki & Cefa-

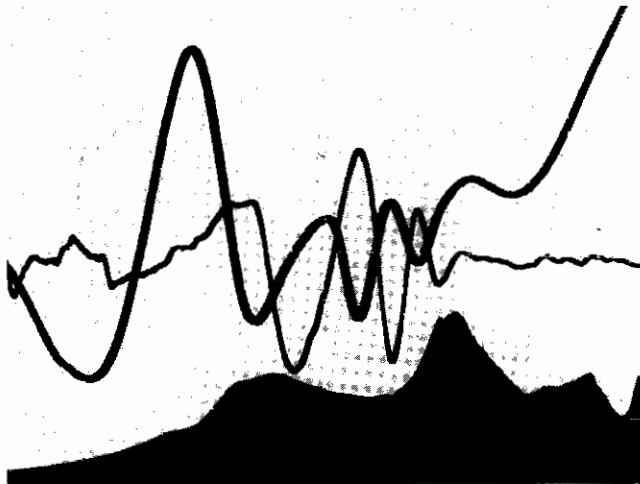


FIGURE 7. Response phases of an OHC plotted as sine functions of sound frequency. The thinner line is for a SPL of 40 dB, the thicker one, for a SPL of 100 dB. Note that in the vicinity of the best frequency (greatest magnitude of the 40 dB curve), the two curves are in phase opposition. The phase difference decreases toward lower sound frequencies (to the left; the small bump in the thinner curve is artifactual). (According to Zwislocki, 1988.)

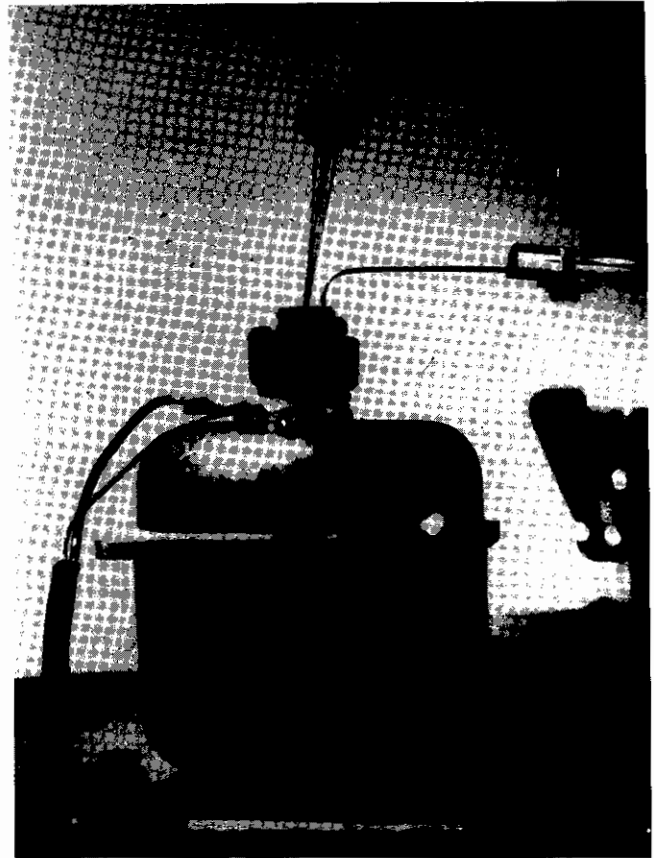


FIGURE 8. An electrodynamic vibrator as a simple qualitative model of a short section of the basilar membrane with the organ of Corti and the tectorial membrane. The bent tube to the right points to the vibrator armature acting as the organ of Corti. The reed over the armature simulates bundles of OHC stereocilia, and a small nut at its tip, the mass of the tectorial membrane. Note that the magnitude of lateral vibration of the reed tip is much greater than the magnitude of vertical vibration of the armature. This is true only near the transversal resonance of the reed. (Zwislocki, 1980).

ratti, 1989), contrary to the assumptions inherent in the classical model. As a consequence, the tectorial membrane cannot act as a stiff anchor for the tips of the stereocilia, but acts rather as a mass load. During basilar membrane oscillation, the mass is driven by the stereocilia, which act as stiff springs. It is well known that a mass driven through a spring is subject to a resonance effect. Near the resonance frequency, its amplitude of oscillation becomes much larger than the amplitude driving the opposite end of the spring. Projected on the cochlear structures, this means that the tectorial membrane vibrates with a larger amplitude than the reticular lamina in the shear motion direction. In the transversal direction, the tectorial membrane must vibrate with the same amplitude as the reticular lamina because of the incompressible fluid between them.

The situation can be modeled by a vibrator with a flexible reed attached nearly vertically to its armature, as shown in Figure 8 (Zwislocki, 1980). The vibrator represents a short segment of the basilar membrane; the reed, corresponding

stereocilia bundles, and a small weight at the top of the reed, represent a corresponding section of the tectorial membrane. The vibrator armature moves vertically at a small amplitude barely perceptible in the photograph taken under stroboscopic illumination. The model tectorial membrane oscillates at a right angle to the oscillation of the armature with a much larger amplitude. The relatively large amplitude is what is needed to reverse the phase of hair cell depolarization, as illustrated in Figure 9. In the upper panel, the basilar membrane with the organ of Corti and the tectorial membrane are schematized in their rest positions. The stereocilia of the three rows of outer hair cells and one row of inner hair cells extend almost vertically from the reticular lamina. In the lower two panels, the basilar membrane is displaced toward scala tympani. The middle panel is drawn for low sound frequencies, well below the resonance frequency of the stereocilia tectorial membrane system. The tectorial membrane is pulled toward the outer wall by the stiff stereocilia of the outer hair cells. Its resulting radial displacement deflects the stereocilia of the inner hair cells slightly toward the outer wall, a depolarizing direction.

The situation corresponds to neural excitation during basilar membrane displacement toward scala tympani. The stereocilia of the outer hair cells are deflected slightly toward the modiolus, a hyperpolarizing direction, because of the elastic reaction force of the tectorial membrane. The lowest panel is for sound frequencies near the tectorial membrane resonance. Here, the radial oscillation amplitude of the tectorial membrane is assumed to be larger than the corresponding oscillation amplitude of the reticular lamina, and the stereocilia of the inner hair cells as well as of the outer hair cells are deflected outward. This situation corresponds to depolarization of both the inner as well as outer hair cells. The response phases illustrated in Figure 9 are in agreement with phase measurements on the hair cells as well as on the nerve fibers. It should be pointed out, however, that the deflection direction of the stereocilia of the inner hair cells in the middle panel can be either outward, as drawn, or toward the modiolus, depending on the balance of the tectorial membrane and reticular lamina displacements at the location of the inner hair cells.

Resonance of hair cell stereocilia has been demonstrated directly in lizards (Frishkopf & De Rosier, 1983). This is not yet possible for mammalian cochleas. However, indirect evidence for the resonance of the mammalian stereocilia loaded with the tectorial membrane is strong. On the basis of stiffness measurements of the stereocilia and the mass of the tectorial membrane, Strelhoff et al. (1985) calculated that the resonance would coincide approximately with the best frequency. The resonance provides the only viable explanation for the complex response phases of the hair cells exemplified in Figure 7. Together with the positive feedback, it accounts for the complicated cochlear response characteristics in the intensity and frequency domains.

Why does the response phase of the hair cells change by 180° in the vicinity of their best frequency when the sound pressure level is increased beyond 80 dB? Very likely because the positive feedback becomes ineffective (e.g.,

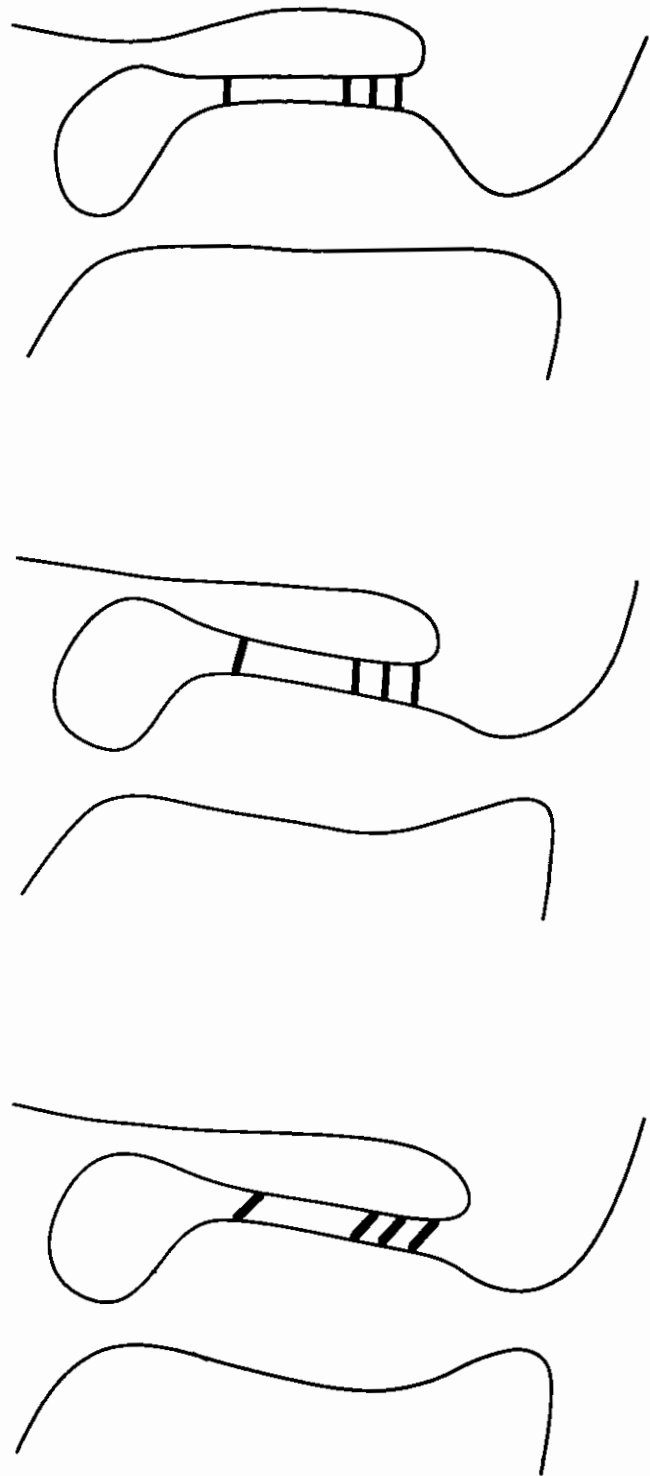


FIGURE 9. Schematic representation of shear motion between the tectorial membrane and the reticular lamina according to the empirically correct new model. In the upper panel, the basilar membrane is in its zero position, in the lower two panels, it is displaced toward scala tympani. The middle panel holds for low sound frequencies, the lowest panel, for the vicinity of the best frequency (resonance of the stereocilia-tectorial membrane system). In the middle panel, the OHC stereocilia are deflected toward the modiolus (inhibition), but the IHC stereocilia, toward the lateral wall (excitation). In the lowest panel, all the stereocilia are deflected toward the lateral wall (excitation).

Kemp, 1978), and the inherent damping of the cochlea prevents the resonance of the stereocilia-tectorial-membrane system. Under such conditions, the relative motion between the tectorial membrane and the reticular lamina follows the classical model.

The increased damping at high sound intensities also affects the response amplitude of the hair cells. This is illustrated in Figure 10, which shows the alternating receptor potential of an outer hair cell as a function of sound frequency plotted logarithmically on the horizontal axis. Every curve has been obtained at a different sound pressure level in 10-dB steps. The lowest curve in the bottom panel corresponds to 20 dB, and the highest, to 50 dB. In the upper panel, the sound pressure level increases from 50 to 80 dB. The amplification was decreased by a factor of 6 for the upper panel. If the system were linear, with constant damping, the response amplitude would increase linearly. This means that the amplitudes of each curve would be about three times greater than the amplitudes of the curve immediately below it, in agreement with the 10-dB steps in sound pressure level. Clearly, the amplitude ratios are much smaller, especially at high sound pressure levels.

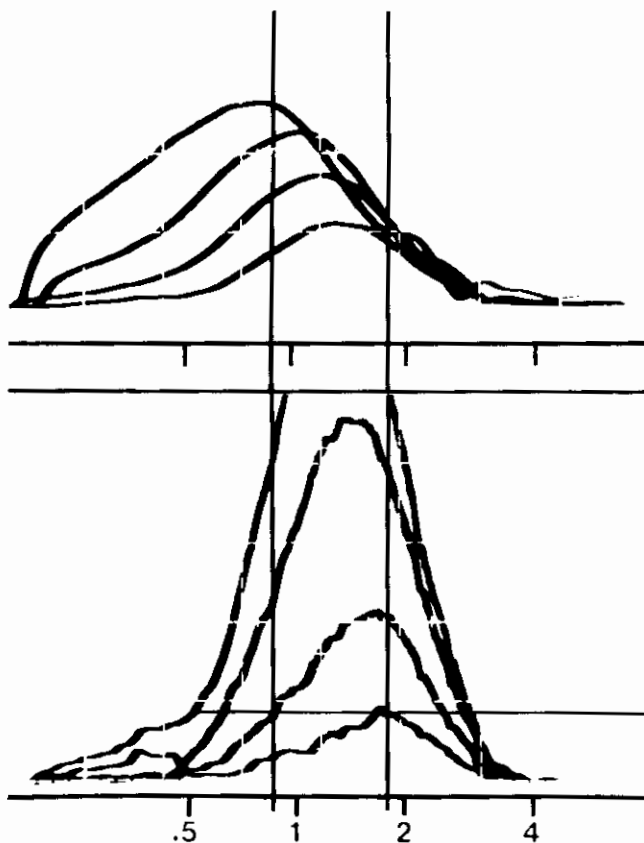


FIGURE 10. Transfer functions (magnitude vs. sound frequency) of an OHC with SPL as a parameter (20–50 dB in the lower panel; 50–80 dB in the upper panel). The amplification in the upper panel is reduced by a factor of 6. The frequency scale is logarithmic, the magnitude scale, linear. Note the compression of the magnitudes at the higher SPLs and the shift of the maximum toward lower frequencies. Note also the bunching of the curves at the high frequency cutoff. (Zwislocki, 1991.)

In addition to the amplitude compression evident in Figure 10, the response maximum is gradually shifted to lower sound frequencies as the sound pressure level is increased. Between 20 and 80 dB, the shift amounts to roughly one octave (Zwislocki, 1991). It has been believed for over a century that the location of the cochlear response maximum determined the subjective pitch. But the relationship between the pitch and sound frequency changes very little with sound intensity (e.g., Stevens & Davis, 1938). How then can the response maximum whose relationship to sound frequency changes by one octave within an intensity span of 60 dB be the adequate code for pitch? According to Figure 10, only the high-frequency cutoff of the response curves remains approximately independent of sound intensity. Could it constitute the cochlear pitch code?

With this latest insight, I will end my list of cochlear concepts that have undergone radical changes since 1965. I think you will agree with me that a revolution in our understanding of the cochlear function has taken place.

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REFERENCES

- Ashmore, J.F. (1986). The cellular physiology of isolated outer hair cells: implications for cochlear frequency selectivity. In B.C.J. Moore and R.D. Patterson (Eds.), *Auditory frequency selectivity*. London: Plenum Press.
- Békésy, G. von (1947). The variation of phase along the basilar membrane with sinusoidal vibrations. *Journal of the Acoustical Society of America*, 19, 452–460.
- Brownell, W.E. (1983). Observations of a motile response in isolated outer hair cells. In W.R. Webster and L.M. Aitkin (Eds.), *Mechanisms of hearing*. Clayton, Victoria: Monash University Press.
- Dallos, P., & Harris, D. (1978). Properties of auditory nerve responses in absence of outer hair cells. *Journal of Neurophysiology*, 41, 365–383.
- Davis, H. (1958). Transmission and transduction in the cochlea. *Laryngoscope*, 68, 359–382.
- Davis, H. (1983). An active process in cochlear mechanics. *Hearing Research*, 9, 1–49.
- Flock, Å. (1971). Sensory transduction in hair cells. In W.R. Loewenstein (Ed.), *Handbook of sensory physiology*, Vol I. Berlin: Springer.
- Flock, Å. (1977). Physiological properties of sensory cells in the ear. In E.F. Evans & J.P. Wilson (Eds.), *Psychophysics and physiology of hearing*. London: Academic Press.
- Frishkopf, L.S., DeRosier, D.J., & Egelman, E.H. (1982). Motion of basilar papilla and hair cell stereocilia in the excised cochlea of the alligator lizard: Relation to frequency analysis. *Neuroscience Abstracts*, 8, 40.
- Frishkopf, L.S., & De Rosier, D.J. (1983). Mechanical tuning of free-standing stereociliary bundles and frequency analysis in the alligator lizard cochlea. *Hearing Research*, 12, 393–404.
- Holton, T., & Weiss, T.F. (1983). Receptor potentials of lizard cochlear hair cells with free-standing stereocilia in response to tones. *Journal of Physiology*, 345, 205–240.
- Johnstone, B.M., & Boyle, A.J.F. (1967). Basilar membrane vibration examined with examined with the Mössbauer Technique. *Science*, 158, 389–390.

- Kiang, N.Y.-S. (1965). Discharge patterns of single fibers in the cat's auditory nerve. *M.I.T. Research Monograph 35*. Cambridge, MA: M.I.T. Press.
- Kemp, D.T. (1975). Stimulated acoustic emissions from within the human auditory system. *Journal of the Acoustical Society of America*, *64*, 1386-1391.
- Konishi, T., & Nielsen, D.W. (1973). The temporal relationship between motion of the basilar membrane and initiation of nerve impulses in the auditory nerve fibers. *Journal of the Acoustical Society of America*, *53*, 325 (A).
- Kuile, E. ter (1900). Die Uebertragung der Energie von der Grundmembrane auf die Haarzellen (The transmission of energy from the basilar membrane to the hair cells). *Pflügers Archiv der Gesellschaft für die Physiologie*, *79*, 146-157.
- Lieberman, M.C., & Kiang, N.Y.-S. (1978). Acoustic trauma in cats. *Acta Otolaryngologica*, Supplement 358.
- Mountain, D.C., Hubbard, A.E., & McMullen, T.A. (1983). Electromechanical processes in the cochlea. In E. de Boer & M.A. Viergever (Eds.), *Mechanics of hearing*. The Hague: Martinus Nijhoff.
- Neely, S.T., & Kim, D.O. (1983). An active cochlear model showing sharp tuning and high sensitivity. *Hearing Research*, *9*, 123-130.
- Nuttall, A.L., Brown, M.C., Masta, R.L., & Lawrence, M. (1981). Inner hair cell responses to the velocity of basilar membrane motion in the guinea pig. *Brain Research*, *211*, 171-174.
- Oshima, W., & Strelhoff, D. (1983). Responses of gerbil and guinea pig auditory nerve fibers to low-frequency sinusoids. *Hearing Research*, *12*, 167-184.
- Peake, W.T., & Ling, A.L. (1980). Basilar-membrane motion in the alligator lizard: Its relation to tonotopic organization and frequency selectivity. *Journal of the Acoustical Society of America*, *67*, 1736-1745.
- Rhode, W.S. (1971). Observations of the vibration of the basilar membrane in squirrel monkeys using the Mössbauer technique. *Journal of the Acoustical Society of America*, *55*, 558-596.
- Rhode, W.S. (1973). An investigation of postmortem cochlear mechanics using the Mössbauer effect. In A.R. Møller (Ed.), *Basic mechanisms in hearing*. New York: Academic Press.
- Ruggero, M.A., & Rich, N.C. (1983). Chinchilla auditory nerve responses to low-frequency tones. *Journal of the Acoustical Society of America*, *73*, 2096-2108.
- Ruggero, M.A., & Rich, N.C. (1987). Timing of spike initiation in cochlear afferents: Dependence on site of innervation. *Journal of Neurophysiology*, *58*, 379-403.
- Ruggero, M.A., Robles, L., & Rich, N.C. (1986). Cochlear microphonics and the initiation of spikes in the auditory nerve: Correlation of single-unit data with neural and receptor potentials recorded from the round window. *Journal of the Acoustical Society of America*, *79*, 1491-1498.
- Ruggero, M.A., & Rich, N.C. (1988). Responses of cochlear afferents to low-frequency tones: Intensity dependence. In J. Syka & J. Poplar (Eds.), *Auditory pathway: Structure and function*. New York: Plenum Press.
- Russell, I.J., & Sellick, P.M. (1977). The tuning properties of cochlear hair cells. In E.T. Evans & J.P. Wilson (Eds.), *Psychophysics and physiology of hearing*. London: Academic Press.
- Schmiedt, R.A., Zwislocki, J.J., & Hamernik, R.P. (1980). Effects of hair cell lesions on responses of cochlear nerve fibers. I. Lesions, tuning curves, two-tone inhibition, and responses to trapezoidal-wave patterns. *Journal of Neurophysiology*, *43*, 1367-1389.
- Sellick, P.M., & Russell, I.J. (1980). The responses of inner hair cells to basilar membrane velocity during low-frequency auditory stimulation in the guinea pig cochlea. *Hearing Research*, *2*, 439-445.
- Sellick, P.M., Patuzzi, R., & Johnstone, B.M. (1982). Modulation of responses of spiral ganglion cells in the guinea pig cochlea by low frequency sound. *Hearing Research*, *7*, 199-221.
- Sokolich, W.G., Hamernik, R.P., Zwislocki, J.J., & Schmiedt, R.A. (1976). Inferred response polarities of cochlear hair cells. *Journal of the Acoustical Society of America*, *59*, 963-974.
- Stevens, S.S., & Davis, H. (1938). *Hearing, its psychology and physiology*. New York: Wiley.
- Spoendlin, H. (1967). Innervation of the organ of Corti. *Journal of Laryngology and Otology*, *81*, 717-738.
- Strelhoff, D., & Flock, A. (1984). Stiffness of sensory-cell hair bundles in the guinea pig cochlea. *Hearing Research*, *15*, 19-28.
- Strelhoff, D., Flock, A., & Minser, K.E. (1985). Role of inner and outer hair cells in mechanical frequency selectivity of the cochlea. *Hearing Research*, *18*, 169-175.
- Zwislocki, J. (1946). Ueber die mechanische Klanganalyse des Ohres (On sound analysis in the ear). *Experientia*, *2*, 415-417.
- Zwislocki, J. (1948). Theorie der Schneckenmechanik: Qualitative und Quantitative Analyse (Theory of the mechanics of the cochlea: Qualitative and quantitative analysis). *Acta Oto-Laryngologica*, Supplement 72, 1-76.
- Zwislocki, J. (1950). Theory of the acoustical action of the cochlea. *Journal of the Acoustical Society of America*, *22*, 778-784.
- Zwislocki, J.J. (1980). Five decades of research on cochlear mechanics. *Journal of the Acoustical Society of America*, *67*, 1679-1685.
- Zwislocki, J.J. (1984). How OHC lesions can lead to neural cochlear hypersensitivity. *Acta Oto-Laryngologica*, *97*, 529-534.
- Zwislocki, J.J. (1990). Active cochlear feedback: Required structure and response phase. In P. Dallos, C.D. Geisler, J.W. Matthews, M.A. Ruggero & C.R. Steele (Eds.), *The mechanics and biophysics of hearing*. Berlin: Springer.
- Zwislocki, J.J., & Sokolich, W.G. (1973). Velocity and displacement responses in auditory nerve fibers. *Science*, *182*, 64-66.
- Zwislocki, J.J., & Smith, R.L. (1988a). Perturbation of cochlear microphonics by an intracellular electrode in the organ of Corti. *Journal of the Acoustical Society of America*, *83*, S 97.
- Zwislocki, J.J., & Smith, R.L. (1988b). Phase reversal in OHC response at high sound intensities. In J.P. Wilson & D.T. Kemp (Eds.), *Cochlear mechanisms: Structure, function and models*. London: Plenum Press.
- Zwislocki, J.J., Chamberlain, S.C., & Slepceky, N.B. (1988). Tectorial membrane I: Static mechanical properties in vivo. *Hearing Research*, *33*, 207-222.
- Zwislocki, J.J., & Cefaratti, L.K. (1989). Tectorial membrane: Stiffness measurements in vivo. *Hearing Research*, *42*, 211-228.
- Zwislocki, J.J., Solessio, E., & Cefaratti, L.K. (1991). Hair-cell transfer functions versus tuning curves, and the place code for pitch. *Association for Research in Otolaryngology Abstracts*, *14*, 129.

Chapter 4

MÉNIÈRE'S DISEASE

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To date there has not been a consensus on the definition of Ménière's disease. However, the classic clinical presentation, as originally described by Prosper Ménière in 1861, includes hearing loss, tinnitus, and episodic vertigo with a normal middle and inner ear and no other associated neurological disorder. This is a very prevalent disease, with approximately 545,000 individuals estimated to be living in the United States with Ménière's disease, according to the 1991 NIH/NIDCD Task Force on Balance and the Vestibular System. This task force estimated that there are 38,250 new cases per year and a rate of occurrence of 15.3/100,000 individuals per year.

Historical Issues

Popular interest in Ménière's disease increased following the publication of a recent article by Arenberg, Countryman, Bernstein, and Schambaugh (1990), who asserted that Vincent van Gogh had Ménière's disease rather than madness and epilepsy, as commonly believed. This same assertion was made by Yasuda in 1979. After reviewing 796 letters written by van Gogh to family and friends between 1884 and 1890, Arenberg et al. (1990) presented the following data to support the clinical diagnosis of Ménière's disease: (a) misdiagnosis was probable since the diagnosis of Ménière's disease was unlikely in late 19th century France, due to the close chronological association of Prosper Ménière's description of the clinical syndrome in 1861 and van Gogh's death in 1890; (b) van Gogh cut off part of his left ear and this led Dr. Peyron, the director of the asylum at St. Remy, France, to speculate that this act was performed during an episode of acute mania with hallucinations of sight and hearing; and (c) in van Gogh's personal letters the authors believed he made specific references to episodic vertigo, tinnitus, and auditory dysfunction.

This article stimulated several authors to write letters to the editor of the *Journal of the American Medical Association* refuting the arguments and conclusions presented by Arenberg et al. (Baker, 1991; Feldmann, 1991; Freedman & Freedman, 1991; Jamison & Wyatt, 1991; Kunin, 1991).

Several of these authors underscored van Gogh's psychopathology by outlining several behavior patterns that were well documented. Baker (1991) pointed out that van Gogh was a difficult, isolated, and lonely child; had repeated, serious bouts of depression; fled all attachments and disappeared for 9 months; had limited and abnormal interpersonal relationships; was unable to maintain long-term employment due to his vile temper; and for extended periods of time lived in unheated huts, slept on straw, and refused to wash or change clothes for weeks at a time. Feldman (1991) called attention to van Gogh's unreasonable acts, which included drinking turpentine and mutilating his left ear. Jamison and Wyatt (1991) outlined the compelling evidence that van Gogh suffered from manic-depressive illness (bipolar affective disorder). An alternative medical etiology of van Gogh's condition was suggested by Kunin (1991), who believes that porphyria (a disorder of metabolism) better explains the tragic symptoms he experienced. Finally, Freedman and Freedman (1991) as well as Jamison and Wyatt (1991) point out that Arenberg et al. (1990) misquoted van Gogh, used passages out of context, and quoted letters that do not exist.

Based on this author's personal study of van Gogh's letters to his brother Theo (Stone, 1937), I believe that Vincent van Gogh suffered from bipolar affective disorder. Van Gogh experienced manic phases during which he worked 12–16 hours per day and then wrote extensive letters to his brother Theo. He experienced psychotic episodes during which he behaved in a bizarre manner, including drinking turpentine, hallucinating, and threatening Gauguin with a razor before he ultimately cut off a portion of his left ear and sent it to a prostitute. He also suffered from repeated episodes of depression that finally resulted in his committing suicide in 1890.

Pathogenesis

The etiology of Ménière's disease remains unclear. Currently, the most common theory is that the disease is caused by an overdistension of the membranous labyrinth

resulting from excessive endolymphatic fluid (endolymphatic hydrops). This accumulation of endolymph may be caused by impaired resorption of endolymph in the endolymphatic duct (ED) and sac (ES) (for review see Wackym, 1990b). These hypotheses are based on (a) histopathologic evidence of endolymphatic hydrops in patients with signs and symptoms of Ménière's disease, (b) histopathologic evidence of a reduced vascularization and fibrosis in the perisaccular tissue reducing the resorptive capacity of the ES, and (c) experimental evidence showing that obliteration of the ED and ES will induce endolymphatic hydrops. These findings seem to support the idea that the ED and ES play important roles in the pathogenesis of Ménière's disease. While endolymphatic hydrops and production of hydrops are almost constant findings, histopathologic changes and abnormalities of the ES have rarely been systematically studied. In 1990, our laboratory published a transmission electron microscopic study comparing the ultrastructure of the intraosseous ESs from patients with Ménière's disease, normal controls, and patients undergoing translabyrinthine resection of acoustic schwannomas (Wackym et al., 1990b). We found that there was wide anatomic variation in the distribution and density of subepithelial connective tissue observed in all three groups. In general, the subepithelial connective tissue density increased from proximal to distal regardless of group. These data suggest that "perisaccular fibrosis" of the intraosseous ES may not be of etiopathologic significance.

In the same ultrastructural study (Wackym et al., 1990b), we found that in ESs from 2 patients with Ménière's disease, there was evidence of abnormal glycoprotein metabolism. This may have important etiopathologic significance since animal studies have demonstrated an association between ES glycoprotein secretion and ES volume (Friberg, Wackym, Bagger-Sjöbäck, & Rask-Anderson, 1986). The accumulation of ES glycoprotein in some patients with Ménière's disease may lead to the dysregulation of inner ear fluid homeostasis and may therefore affect the endolymphatic hydrops.

Viral infections are assumed to play a direct or indirect role in the causation of a number of different inner ear disorders, including auditory dysfunction and vestibular dysfunction (Davis & Johnsson, 1983). While viruses may play an important role in the etiology of inner ear disorders, most evidence has been circumstantial. Palva, Hortling, Ylikoski, and Collan (1978) surgically resected Scarpa's ganglia in 6 patients with Ménière's syndrome and subsequently studied the ultrastructure of these vestibular primary afferent neurons. They found three different types of intranuclear inclusion bodies: yarn-like structures, chromatin aggregates, and light nuclear bodies. Although both serology and viral cultures failed to identify a viral agent, the authors believed that these structures could be viral or virally related. In addition to the structures reported by Palva et al. (1978), several other structures, because of their shape, size, or relation to cell components, have also been mistaken for virus particles (for review see Wackym et al., in press).

When studying the ultrastructure of the intraosseous ES and vestibular epithelia from 4 patients with Ménière's dis-

ease undergoing translabyrinthine (TL) eighth nerve section and 12 patients undergoing TL resection of acoustic schwannomas, we identified many such structures (Wackym, Storper, Fu, House, & Ward, in press). We presented an atlas of normal structures that ultrastructurally resemble viruses. These structures include nuclear bodies, monoparticulate and rosette forms of glycogen, perichromatin granules, filamentous inclusions, altered chromatin, tangentially-cut nuclear pores, secretory granules, micro-pinocytic vesicles, multivesicular bodies, cross-cut microvilli, glycocalyceal bodies, spherical monoparticles, ribosome-lamellar complexes, annulate lamellae, microtubular complexes, and cross-cut, poorly-stained collagen. Objective morphologic methods are required to confirm an association between a specific viral infection and Ménière's disease. The technique of *in situ* hybridization histochemistry allows the histologic localization of specific gene products (e.g., mRNA) (Wackym, Popper, Ward, & Micevych, 1990c). In addition, cellular localization of specific genes, whether normal cellular or viral, can be accomplished with the *in situ* hybridization technique. This method, when combined with immunoelectron microscopy (Wackym, Micevych, & Ward, 1990a; Wackym, Ward, House, Linthicum, & Micevych, 1991), would provide the ability to determine whether there was evidence of a viral etiology of Ménière's disease.

Animal models of inner ear endolymphatic/perilymphatic pressure gradients have provided insight into the fluctuating nature of the cochleo-vestibular dysfunction seen in Ménière's disease (Böhmer, Andrews, & Dillier, 1989). Böhmer et al. (1989) recorded acoustic evoked compound action potential thresholds from guinea pigs in normal control, early hydropic, and late hydropic ears and correlated these thresholds with perilymphatic and endolymphatic pressure measurements. Based on their findings, they presented the following hypothesis: Surgical obliteration of the ED and ES disturbs the balance between endolymph production and endolymph resorption resulting in an enlargement of the endolymphatic space. Decreased endocochlear potential is a sign of this dysfunction. Reissner's membrane becomes distended, but because of its high compliance, no significant pressure gradient between endolymph and perilymph is maintained and cochlear function is not severely affected. When Reissner's membrane has been distended over several weeks, it loses its compliance and further increase of endolymph volume results in increased endolymphatic pressure. Occasionally the increase in endolymphatic pressure may rupture the membranous labyrinth, resulting in acute severe cochleo-vestibular dysfunction due to potassium intoxication.

Diagnosis

Since two of the three classical features of Ménière's disease are audiologic, that is, fluctuating hearing loss and tinnitus, serial audiometric studies are mandatory. In addition to our traditional audiometric testing, electrocochleography (ECoG) is continuing to be of research interest in Ménière's disease. Electrode placement, whether canal or

transtympanic, has been extensively studied, and enhanced amplitude is achieved using a transtympanic needle electrode. The author has personally had both types of electrodes placed and they are of equal discomfort level. Many investigators have used ECoG to study the summation potential/action potential (SP/AP) ratio in a number of inner ear disorders, including Ménière's disease. An increased SP/AP ratio has been reported in Ménière's disease patients, with percentages of patients with abnormal SP/AP ratios ranging from 42 to 68% (for review, see Filipo, Bertoli, & Barbara (1989). In 17.3% of the Ménière's disease patients reported by Filipo, Bertoli, and Barbara (1989), the SP wave form did not have adequate morphology to calculate the SP. The relatively large percentage of patients with Ménière's disease who have normal SP/AP ratios (32–58%) may reflect a period of minimal hydrops during a quiescent phase of the disease, or it may reflect the specificity of the test. It has been demonstrated that the SP/AP ratio improves with glycerol dehydration testing in patients with Ménière's disease, suggesting that the SP/AP ratio reflects the degree of hydrops (Moffat, Gibson, Ramsden, Morrisson, & Booth, 1978). Further research must be completed to assess the efficacy of ECoG for measuring cochlear dysfunction in Ménière's disease.

Recently, intraoperative ECoG has been used by Arenberg, Gibson, and Bohlen (1989) with the goal of assessing inner ear hydrops during endolymphatic sac valved shunt surgery for Ménière's disease. These authors studied 37 patients and found that 12 patients (35%) had an improved SP/AP ratio, 4 patients (12%) had a worsened SP/AP ratio, and 15 patients (44%) had no change in their SP/AP ratio. They used the intraoperative ECoG data to change their surgical management of 3 patients (8%) who, with preoperative consent, then underwent the destructive inner ear procedures, labyrinthectomy or vestibular nerve section. Although no mention was made of whether an institutional human research subjects committee approved this study, such approval would be advised before undertaking this experimental methodology at another institution.

Treatment

The vast majority of patients with Ménière's disease are managed successfully with medical therapy alone. The medical regimen includes a strict low-sodium diet with or without the addition of a diuretic. Those patients who fail medical therapy may be considered surgical candidates. The role of surgical treatment of Ménière's disease has continued to evolve and this will be briefly discussed later in this section.

Of the 5,156 patients with vestibular dysfunction managed in the Victor Goodhill Ear Center, 2,936 have syndromes of unknown or multiple causes, and of these, 259 have Ménière's disease. Of these 259 patients with Ménière's disease, 6 women have been documented to have objective audiologic and vestibular dysfunction associated with the late luteal phase of the menstrual cycle (premenstrual phase) (Andrews, Ator, & Honrubia, in press). The association of menses and Ménière's disease has

long been suspected and was specifically mentioned by Prosper Ménière's in his presentation to the Imperial Academy of Medicine in Paris on January 8, 1861. Andrews et al. (in press) identified two groups of patients in their study; those with reversible and those with irreversible inner ear dysfunction. In all patients, strict control of dietary sodium plus a diuretic was used. Patients with a reversible dysfunction maintained normal inner ear function. Those with an irreversible dysfunction showed control of vestibular symptoms with no further deterioration in hearing. They hypothesized that with aggressive medical management during the early phases of Ménière's disease, reversal of symptoms occurs, although in the later phases the same treatment may only stabilize the disease process.

In the basic science laboratories, our group has been studying the mechanisms by which the endolymphatic duct and sac reabsorb endolymph (Friberg et al., 1986; Wackym et al., 1986, 1987a, 1987b, 1988, 1990d). One of the hypothetical mechanisms of endolymph outflow that we have studied in human inner ear tissue as well as in an experimental model depends on an active, Na^+ , K^+ -ATPase-dependent ion exchange with a passive transepithelial outflow of water (Wackym et al., 1986, 1987b, 1988, 1990d). Using an experimental model of this hypothetical type of endolymph outflow, we studied the effect of a dietary factor that is known to inhibit Na^+ , K^+ -ATPase on the endolymphatic sac epithelium lateral intercellular spaces (Wackym et al., 1990d). This food factor is found in a number of different types of beverages and foods (Table 1), and is felt by Harlan and Mann (1982) to be possibly an important factor in essential hypertension. We found that mice fed a high salt diet plus the food factor for 28 days have statistically significant changes in the size of the lateral intercellular spaces reflecting an impaired ability of the epithelium to reabsorb endolymph. There are no data that suggest that the food factor has clinical significance in the pathogenesis or in the

TABLE 1. Amount of food factor (ATPase inhibitor) in various foods (expressed as units/g dry wt).

Food	Total units
Tea	1860
Cocoa	560
Cucumber	60
Turnip greens	60
Cabbage	36
Pear	21
Carrot	20
Onion	18
Sanka coffee	16
Radish	13
Banana	13
Peach	12
Tomato	12
Coffee	10
Orange	8
Lettuce	7
Beef liver	7
Cantaloupe	7

Note: Adapted with the permission of the American Society for Clinical Nutrition (Harlan & Mann, 1982).

medical management of Ménière's disease; however, this represents another potential area of clinical study.

The surgical management of Ménière's disease has evolved dramatically during the past decade. Before 1981, thousands of patients with Ménière's disease underwent endolymphatic sac operations in hopes of relieving the over-accumulation of endolymph present in their inner ears. This operation is based on three assumptions: (a) the endolymphatic sac is responsible for endolymph resorption; (b) the endolymphatic sac is pathologic in Ménière's disease and inadequate resorption occurs; and (c) surgical drainage will enhance endolymph removal from the inner ear. All three of these assumptions are controversial to varying degrees, and although a few of the issues have been discussed earlier, a complete discussion is beyond the scope of this paper. In 1981, the results of a double-blind placebo controlled study on endolymphatic sac surgery were published (Bretlau, Thomsen, Tos, & Johnsen, 1989). Bretlau et al. (1989) have now published their 9-year follow-up data. They studied 30 patients with Ménière's disease and all patients received surgical procedures. Fifteen received silastic sheet endolymphatic sac shunts (active group), while the other 15 patients underwent simple mastoidectomy (sham surgery group). At 9 years, there are 11 in the active group and 12 in the sham surgery group. There remain no significant differences between the two groups. Although this study generated much controversy and even though there were flaws in the study design, this type of study can never be repeated because of ethical issues.

All of the remaining surgical procedures are directed at eliminating abnormal vestibular function in patients with Ménière's disease that have failed medical therapy and these procedures are not designed to improve auditory dysfunction. Of these, labyrinthectomy destroys any residual auditory function and therefore this class of procedures is reserved for patients with no serviceable hearing and intractable episodic vertigo. The remaining procedures include vestibular nerve section and inner ear streptomycin perfusion. The latter two surgical procedures are designed to ablate peripheral vestibular function while preserving auditory function. However, the technique of inner ear streptomycin perfusion is relatively new (Shea & Norris, 1989) and the effect of this technique on auditory function must be investigated further.

Summary

Ménière's disease is extremely prevalent and continues to present a clinical challenge to the audiologists, otolaryngologists, neuro-otologists, neurologists, general physicians, and other healthcare workers responsible for patients with Ménière's disease under their care. Although our understanding of the pathogenesis, diagnosis, and treatment of Ménière's disease has increased with the substantial international research effort currently underway, more questions than ever remain to be answered.

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REFERENCES

- Andrews, J.C., Ator, G.A., & Honrubia, V. (in press). The exacerbation of symptoms in Ménière's disease during the premenstrual period. *Archives of Otolaryngology Head and Neck Surgery*.
- Arenberg, I.K., Gibson, W.P.R., & Bohlen, H.K.H. (1989). Improvements in audiometric and electrophysiologic parameters following nondestructive inner ear surgery utilizing a valved shunt for hydrops and Ménière's disease. In J.B. Nadol, Jr. (Ed.), *Ménière's disease: Pathogenesis, pathophysiology, diagnosis and treatment: Proceedings of the Second International Symposium on Ménière's Disease* (pp. 545-561). Berkeley, CA: Kugler & Ghedini Publications.
- Arenberg, I.K., Countryman, L.F., Bernstein, L.H., & Shambaugh, G.E., Jr. (1990). Van Gogh had Meniere's disease and not epilepsy. *Journal of the American Medical Association*, 264, 491-493.
- Baker, H.S. (1991). Van Gogh: Meniere's disease? Epilepsy? Psychosis? *Journal of the American Medical Association*, 265, 722.
- Böhmer, A., Andrews, J.C., & Dillier, N. (1989). Inner ear pressure and cochlear function in experimental endolymphatic hydrops. In J.B. Nadol, Jr. (Ed.), *Ménière's disease: Pathogenesis, pathophysiology, diagnosis and treatment: Proceedings of the Second International Symposium on Ménière's Disease* (pp. 221-223). Berkeley, CA: Kugler & Ghedini Publications.
- Bretlau, P., Thomsen, J., Tos, M., & Johnsen, N.J. (1989). Placebo effect in surgery of Ménière's disease. Nine-year follow-up. In J.B. Nadol, Jr. (Ed.), *Ménière's disease: Pathogenesis, pathophysiology, diagnosis and treatment: Proceedings of the Second International Symposium on Ménière's Disease* (pp. 499-502). Berkeley, CA: Kugler & Ghedini Publications.
- Davis, L.E., & Johnsson, L-G. (1983). Viral infections of the inner ear: Clinical, virologic, and pathologic studies in humans and animals. *American Journal of Otolaryngology*, 347-362.
- Feldmann, H. (1991). Van Gogh: Ménière's disease? Epilepsy? Psychosis? *Journal of the American Medical Association*, 265, 722-723 (letter).
- Filipo, R., Bertoli, G.A., & Barbara, M. (1989). Electrocochleographic findings in Ménière's disease. In J.B. Nadol, Jr. (Ed.), *Ménière's disease: Pathogenesis, pathophysiology, diagnosis and treatment: Proceedings of the Second International Symposium on Ménière's Disease*, (pp. 399-402). Berkeley, CA: Kugler & Ghedini Publications.
- Freedman, A.L., & Freedman, D.P. (1991). Van Gogh: Ménière's disease? Epilepsy? Psychosis? *Journal of the American Medical Association*, 265, 723 (letter).
- Friberg, U., Wackym, P.A., Bagger-Sjöbäck, C., & Rask-Andersen, H. (1986). Effect of labyrinthectomy on the endolymphatic sac. A histologic, ultrastructural and computer-aided morphometric investigation in the mouse. *Acta Otolaryngologica (Stockh)*, 101, 172-182.
- Harlan, D.M., & Mann, G.V. (1982). A factor in food which impairs Na^+ , K^+ -ATPase in vitro. *American Journal of Clinical Nutrition*, 35, 250-257.
- Jamison, K.R., & Wyatt, R.J. (1991). Van Gogh: Ménière's disease? Epilepsy? Psychosis? *Journal of the American Medical Association*, 265, 723-724 (letter).
- Kunin, R.A. (1991). Van Gogh: Ménière's disease? Epilepsy? Psychosis? *Journal of the American Medical Association*, 265, 723 (letter).
- Moffat, D.A., Gibson, W.P.R., Ramsden, R.T., Morrisson, A.W., & Booth, J.B. (1978). Transtympanic electrocochleography during glycerol dehydration. *Acta Otolaryngologica (Stockh)*, 85, 158-166.
- Palva, T., Hortling, L., Ylikoski, J., & Collan, Y. (1978). Viral culture and electron microscopy of ganglion cells in Ménière's disease and Bell's palsy. *Acta Otolaryngologica (Stockh)*, 86, 269-275.
- Shea, J.J., & Norris, C.H. (1989). Streptomycin perfusion of the

- labyrinth. In J.B. Nadol, Jr. (Ed.), *Ménière's disease: Pathogenesis, pathophysiology, diagnosis and treatment: Proceedings of the Second International Symposium on Ménière's Disease* (pp. 463–473). Berkeley, CA: Kugler & Chedini Publications.
- Stone, I. (1937). *Dear Theo. The autobiography of Vincent Van Gogh*. New York: Doubleday.
- Wackym, P.A., Friberg, U., Bagger-Sjögäck, D., & Rask-Andersen, H. (1986). Human endolymphatic duct: Possible mechanisms of endolymph outflow. *Annals of Otolaryngology, Rhinology, and Laryngology*, 95, 409–414.
- Wackym, P.A., Friberg, U., Bagger-Sjögäck, D., Linthicum, F.H., Friedmann, I., & Rask-Andersen, H. (1987a). Human endolymphatic sac: Possible mechanisms of pressure regulation. *Journal of Laryngology and Otolaryngology*, 101, 768–779.
- Wackym, P.A., Friberg, U., Linthicum, F.H., Bagger-Sjögäck, D., Bui, H. T., Hofman, F., & Rask-Andersen, H. (1987b). Human endolymphatic sac: Morphologic evidence of immunologic function. *Annals of Otolaryngology, Rhinology, and Laryngology*, 96, 276–281.
- Wackym, P.A., Glasscock, M.E., Linthicum, F.H., Ball, W.J., Friberg, U., & Rask-Andersen, H. (1988). Immunohistochemical localization of Na⁺, K⁺-ATPase in the human endolymphatic sac. *Archives of Otorhinolaryngology*, 245, 221–223.
- Wackym, P.A., Micevych, P.E., & Ward, P.H. (1990a). Immunoelectron microscopy of the human inner ear. *Laryngoscope*, 100, 447–454.
- Wackym, P.A., Linthicum, F.H., Ward, P.H., House, W.F., Micevych, P.E., & Bagger-Sjögäck, D. (1990b). Re-evaluation of the role of the human endolymphatic sac in Ménière's disease. *Otolaryngology Head and Neck Surgery*, 102, 732–744.
- Wackym, P.A., Popper, P., Ward, P.H., & Micevych, P.E. (1990c). *In situ* hybridization for the study of gene expression in neuro-otologic research. *Otolaryngology Head and Neck Surgery*, 103, 519–526.
- Wackym, P.A., Canalis, R.F., Friberg, U., Rask-Andersen, H., & Linthicum, F.H. (1990d). Size variations in the lateral intercellular spaces of the endolymphatic sac induced by dietary factors. *Laryngoscope*, 100, 217–222.
- Wackym, P.A., Ward, P.H., House, W.F., Linthicum, F.H., & Micevych, P.E. (1991). Technique for transmission and immunoelectron microscopy of the human endolymphatic sac and vestibular epithelia. *Otolaryngology Head and Neck Surgery*, 104, 72–80.
- Wackym, P.A., Storper, I.S., Fu, Y-S, House, W.F., & Ward, P.H. (in press). Differential diagnosis of virus-like particles in the human inner ear. *American Journal of Otolaryngology*.
- Yasuda, K. (1979). Was Van Gogh suffering from Ménière's disease? [In Japanese] *Otologia*, 25, 1427–1439.

Chapter 5

FORENSIC AUDIOLOGY AND MEDICOLEGAL (AUDIOLEGAL?) ISSUES: AN OVERVIEW

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The term *forensic audiology* has been around for some time—for at least 20 years, since this author first presented on the topic to the American Academy of Private Practice in Speech Pathology and Audiology. The concept is much more acceptable now, and even if it was originally borrowed from the idea of forensic medicine, it is useful in discussing the role of the audiologist as a participant in the legal system. *Medicolegal* refers to legal implications of medical problems, and although the term is one we customarily apply to our (audiologists') participation in the legal system, it is suggested that we, as a profession, begin to use the term *audiolegal*.

Definitions:

- *Forensic*—From the Latin *forensis*, public. Belonging to, used in, or suitable to courts of judicature of the public discussion and debate. Argumentative.
- *Forensic medicine*—A science that deals with the relation and application of medical facts to legal problems.
- *Forensic audiology*—A science that deals with the relation and application of audiological facts to legal problems.

Divisions of Law

Table 1 summarizes the major divisions of law, sources of law, and categories in which the audiologist may be a "forensic expert." Federal courts are used in the enforcement of national statutes, constitutional issues, lawsuits involving different states or citizens of different states, federal crimes, etc. State courts are where most personal injury and contract disputes arise. The two systems, federal and state, although similar in hierarchy, are somewhat exclusive in jurisdiction.

Although the foundation of our government and many of the basic rights of individuals are based upon the U.S. Constitution, many more court-related activities are the result of statutes, especially in criminal cases. Most of the princi-

ples that guide the decisions of judges are based on prior cases of common law. (See Table 2.)

The audiologist will frequently function in the category of civil courts in tort (personal injury) cases. It is recommended that the audiologist obtain a copy of the American Medical Association's publication, *Guides to the Evaluation of Permanent Impairment*, third edition. This publication not only provides the charts for measuring hearing disability, but also contains information about report writing.

Audiologists interested in Workers' Compensation should obtain copies of rules used in their respective states. Those rules usually include formulae for determining hearing loss, report writing requirements, and declarations of who may give evidence to the court.

Role of the Audiologist (as it is)

The traditional role of the audiologist in forensics has been as a technician employed by a physician; that is, even though the court often relies upon the data accumulated by the audiologist, it is the physician who often appears before the court as an expert witness.

Occasionally, the audiologist advises the physician or attorney with regard to the client's rehabilitation needs, but generally, the audiologist is viewed as a paramedical person rather than as an independent professional.

Role of the Audiologist (as it ought to be)

The audiologist should be promoted as the authority on hearing function and not be thought of as secondary to or in competition with professionals in medicine. A second area of expertise needed by the court (although the courts are seldom aware of the need) is the role of rehabilitation and its ultimate cost during the lifetime of the client. The audiologist may also be the best expert available to inform the court about the effect hearing loss has in social, vocational, and educational environments.

TABLE 1. The court systems.

<i>Federal</i>	<i>State</i>
U.S. Supreme Court Special courts (claims, patents)	Highest court
Appellate (Circuit) courts (11 circuits)	Appellate courts
Trial (District) courts (92 districts)	Trial courts

MEDICOLEGAL VERSUS AUDIOLEGAL

Conflicts With Medicine

Not only is there a traditional conflict between audiology and medicine with regard to relative roles with patients, but the movement of medicine, especially otolaryngologists, into dispensing of amplification devices has created another problem. Unfortunately, many of our training programs, imbedded within a larger medical setting, allow the persistence of misperception of relative roles.

Conflicts Within the Profession

The history of audiology and the American Speech-Language-Hearing Association (ASHA) is filled with splinter groups attempting to take care of some need or interest that at the time of the organization's creation was not sufficiently addressed by the Association.

Related professional organizations, including the Academy of Rehabilitative Audiology (ARA), the Academy of Dispensing Audiologists (ADA), the American Academy of Audiology (AAA), and the American Academy of Private Practice in Speech Pathology and Audiology (AAPPSPA), are just some of those organizations. Perhaps the movement of ASHA is not as fast as some of us would like, but movement will be slower if we continue to "row" in separate directions.

Training and Titles (Legal vs. Actual)

The court wants to know whether the audiologist, as a witness, qualifies by training and experience as someone it can rely on to explain terms and issues. Usually ASHA certi-

TABLE 2. Law and court divisions.

<i>Criminal Court</i>	<i>Civil Court</i>	<i>Administrative</i>
	Torts Property Contracts	Workers' Compensation

fication and license, if required, is sufficient to qualify an individual as an expert. The title of "Dr." is certainly more impressive than "Mr." or "Ms.," but the real test is in the presentation of the information. Juries and judges will give more weight to the testimony of the witness who gives the better explanation. We have more problems, of course, in states where audiologists are not licensed and are not legally recognized as belonging in the healing arts.

Claimant Versus Defendant Examiner Reputation

Potential forensic audiologists are warned about developing a reputation as "claimant" or "plaintiff" witnesses or examiners versus "defendant" witnesses or examiners. Many attorneys shop for an expert who will present their client's side as being "right." The temptation to become one or the other is hard to resist, and once the reputation is established, the witness not only becomes easier prey for opposing counsel, but also may lose business because it is known that the witness "only works with *those cases*."

Impairment, Disability or Handicap?

One needs to recognize whether the legal issue is about impairment (how much the person's loss deviates from normal), disability (whether the problem significantly interferes with managing everyday duties or responsibilities) or handicap (to what degree this person is affected in this particular environment). The *AMA Guides* and its hearing loss formula are directed toward disability, notwithstanding the fact that the title of the book uses the term *impairment*. The audiologist should be prepared, if asked, to explain in full what the problems are with those terms and to distinguish among their meanings.

Diagnosis, Etiology, Proximate Cause, or Aggravation

Practitioners of medicine insist that only physicians may diagnose or express the etiology in a particular case. Without entering into a semantic argument over the meaning of those terms, it seems that the audiologist is qualified to express in scientific probability terms whether a certain level of noise exposure over a specified time was a primary or aggravating cause of a hearing loss. It also seems that the audiologist is not qualified to discuss the effect of drugs, physical trauma, or disease. The court will be interested in the *proximate cause* (whether it is more or less probable that an event resulted in the injury).

FORMULAS FOR DETERMINING IMPAIRMENT/DISABILITY

The following are examples of formulas used in calculating hearing impairment or disability:

American Medical Association

Monaural Disability

$$\frac{(500 + 1000 + 2000 + 3000\text{Hz})}{4} - 25\text{dB (low fence)} \times 1.5\%$$

(Note: 100% loss is reached at 92dB)

Binaural Disability

$$\frac{(\% \text{ of loss in better ear}) \times 5 + (\% \text{ of loss in poorer ear})}{6}$$

If the client has a total loss in one ear, the binaural percentage will be 16.6. Adoption of the original "speech frequencies" concept appears to be a misperception of the SRT/PTA correlation. Considerable disagreement exists over the use of the 25dB low fence (a disability concept) versus the use of 15dB low fence (an impairment concept). There is no scientific data (or principle) to support the binaural formula. Could it be a misinterpretation of the 6% monaural/binaural improvement in discrimination? The missing 6dB monaural/binaural threshold?

Federal Office of Workers' Compensation Programs

Monaural Disability

$$\frac{(1000 + 2000 + 3000\text{Hz})}{3} - 25\text{dB (low fence)} \times 1.5\%$$

(Note: 100% loss is reached at 92dB)

Binaural Disability—Same as AMA

The difference in this formula compared to the AMA formula is the elimination of 500Hz. Rationale: It is more appropriate for calculating loss from noise exposure.

ASHA Task Force on Hearing Handicap

This formula was recommended by a study group and has not been officially adopted or used by ASHA. Note that there was no change in the binaural formula.

Monaural Disability

$$\frac{(1000 + 2000 + 3000 + 4000\text{Hz})}{4} - 25\text{dB (low fence)} \times 2\%$$

(Note: 100% loss is reached at 75dB)

Binaural Disability—Same as AMA

Perhaps we should consider development of a formula that is more inclusive of audiometric data. For example:

Monaural Impairment

$$\frac{(500 + 1000 + 2000 + 3000 + 4000 + 6000)}{6} - 15\text{dB} \times 1\%$$

(Note: 100% loss reached if no response at indicated frequencies)

Binaural Impairment

$$\frac{(\% \text{ of better ear}) + (\% \text{ of poorer ear})}{2}$$

The author once proposed the development of a weighted audiogram that changed its percentage depending upon frequency band and intensity. Because some frequencies are more critical than others, those bands received a higher percentage of loss per 5dB shift. Similarly, milder losses received a lower proportionate percentage than greater losses per 5dB shift. The instrument was called the Impairment of Communication Percentage Audiogram (ICPA). Suffice it to say, it did not gain the favor of the audiological or medical communities.

PRESBYCUSIS

Does presbycusis exist, and if it does, is it possible to determine its existence in an individual? Does the AMA formula allow presbycusis or hearing loss from aging to be removed from the audiogram before calculating hearing loss percentages? These are important questions that frequently come up in court, and the answers vary depending upon the witness. Perhaps audiologists should devote some time and energy to clarifying these questions.

REPORTS AND THEIR
ACCEPTANCE (EVIDENCE)

The following is a general outline the author recommends for writing a report for an attorney or for the court. After providing the basic identification information, the various headings should be written so the reader can easily find a particular section or item.

1. Complaints (Tell when and where loss is noticed)
2. Case history (Show pertinent work/noise/family history)
3. Examination (Name and describe tests)
4. Results (Explain in simple terms)
5. Degree of impairment/disability (Consider formulas)
6. Effects of loss (Explain in simple terms)
7. Rehabilitation, costs, damage

The *AMA Guides* provides a comprehensive discussion of report writing. The audiologist is also advised to read the rules of the state Workers' Compensation Court to deter-

mine if that court has special requirements for reporting, as each state differs in formula required.

SOLUTIONS (FROM A PRAGMATIC IDEALIST)

Training

Changes in curriculum. If forensic audiology is going to be practiced in a uniform way, then some effort must be made to include its principles in the audiology curriculum. The author presently teaches a course called "Legal Aspects of Speech-Language Pathology" (the program does not offer a degree in audiology), which includes a heavy concentration of topics in ethics, legal structure, federal laws, licensure, contracts, malpractice, expert witnessing, and intellectual property. However, because the course is not related to a "disorder," nor is it a "basic science," graduates must list the course in the section on "related areas."

Changes in practicum. We must also consider the need for opportunities to engage in practicum activities that would add knowledge and understanding to forensics. Experiences of measuring noise levels for industry, screening for industry, and problems of calculating hearing loss and measuring its economic as well as communication effect are all examples of practice areas that should not be left to the school of hard knocks.

Professional degree programs. The author holds a PhD and a "professional" doctorate (JD), and supports the idea of a professional doctorate for audiology. There is not enough time within the present graduate requirements to prepare audiology students for the area of forensics. The title "Dr." is of some value, but the need for additional training is a much more important reason for extending clinical education.

Licensure. Until we have universal state licensure for au-

diology, we will continue to have acceptance problems in some legal systems. Licensure defines the practice of audiology in legal terms. Where we have licensure, we need to work on reducing the exemptions initially included to gain support of other groups. Boards established by law should be strengthened to reflect governance by the professions of speech-language pathology and audiology rather than governance by or in cooperation with the medical profession. Finally, licensure laws need enforcement power. Ability to license is of little value if there is no real power to restrict violators (nonlicense holders as well as licensees).

Health practitioner status. More effort must be given to including audiologists in legislation that identifies them as health practitioners in the same legal category as physicians, dentists, and chiropractors. Without this additional legal identity, audiologists (and speech-language pathologists) will not gain the degree of recognition needed to fully participate in the legal system or to be a full partner within third-party programs.

STRATEGIES

United We Stand

All organizations (ASHA, ARA, ADA, AAA, AAPPSPA, etc.) need to reexamine their commitment to promote the profession(s) and look to the welfare of the public. Now does not seem to be the time to cast stones at the parent organization. Rather it seems to be the time to find mutual goals and make plans to improve our lot and the lot of those we serve.

Rather than trying to solve all problems simultaneously, perhaps we could prioritize some needs and look to individual areas (states) where success seems more likely. For example, we might try to add audiologists (and speech-language pathologists) to the "health practitioner" law in one state before trying to do it in others (and then only one or two states at a time). Or, we might pool efforts to help those colleagues in states that lack licensure.

Chapter 6

NATIONAL HEARING OBJECTIVES FOR THE YEAR 2000

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More than 21 million Americans suffer some hearing impairment. The U.S. Department of Health and Human Services and the American Speech-Language-Hearing Association (ASHA), along with more than 300 other national professional organizations and state health departments, have joined in a cooperative effort to prevent hearing impairment and to provide support and services that will increase the quality of life for people who are hearing impaired by the year 2000. This effort is part of a national health promotion and disease prevention campaign, called *Healthy People 2000*, to improve the health of all Americans in quantifiable ways over the next decade.

According to the consensus document, *Healthy People 2000: National Health Promotion and Disease Prevention Objectives* (1990), the ramifications of auditory disabilities are borne out in developmental, educational, cognitive, emotional, and social aspects of human life. Language delay, poor speech intelligibility, and poor understanding of spoken speech are invisible barriers that can be insurmountable for people with hearing impairments without early diagnosis and without the proper support services.

Inadequate early identification, education, and vocational planning, together with indifference by the public and healthcare providers, limit educational and occupational opportunities for people with hearing impairment (American Medical Association, 1986; Norton & Widen, 1990). People with hearing impairment often have less desirable jobs and housing and lower incomes than those without hearing impairment. (Bess, Lichtenstein, Logan, Burger, & Nolan, 1989; Herbst, 1983).

It is estimated that the annual loss of earnings to people with hearing impairment as a result of their disability totals \$1.25 billion (Lynch & Dublinske, 1985). Older adults with hearing impairment may suffer from reduced interpersonal communication, social isolation, depression, reduced mobility, and exacerbation of coexisting psychiatric conditions (Bess et al., 1983; Herbst, 1983).

Hearing Impairment Prevention

Hearing impairment caused by a number of conditions can be prevented or delayed at onset. Noise-induced hear-

ing loss is often preventable. Some congenital hearing impairments and many of those acquired during infancy are also preventable. In children, hearing loss caused by chronic otitis media and diseases such as meningitis can be reduced through better primary care and the use of new vaccines. Even age-related hearing changes may not be related to structure deterioration as much as they reflect overexposure in industrialized societies to environmental noise and other ototoxic agents.

Early detection and intervention are critical in reducing functional limitation and disability caused by hearing impairment. Early detection in infants is particularly important. Older adults are also likely to benefit from evaluation. Once detected, auditory thresholds in people with hearing impairment can be improved through electro-acoustic amplification with hearing aids and other assistive listening devices. Communication skills can be significantly improved with auditory and speech and language training. Other assistive listening, alerting, or caption decoder devices, such as closed captioned television decoders, are available for improving communicative competence.

Quality of Life

In addition to national objectives for preventing hearing impairment cited above, there are also objectives for maintaining a high quality of life for those Americans who are hearing impaired. These objectives are complementary to the goals of the Americans with Disabilities Act, which call for equitable access to all life enhancement opportunities that contribute to living independently, productively, and in good health.

National Hearing Objectives

Measurable health objectives have been established by the Department of Health and Human Services and the *Healthy People 2000* consortium, made up of over 300 national organizations, including ASHA, and all 50 states. These objectives reflect our collective priorities in improv-

ing the health of all Americans. Specific hearing objectives are targeted toward the prevention of hearing impairment whenever possible and the provision of opportunities for those who are hearing impaired to maintain a high quality of life. It is expected, for example, that through a concerted effort among all levels of government, the private sector, and people with disabilities themselves, significant hearing impairment can be reduced to no more than 82 per 1,000 people by the year 2000. The prevalence is 88.9 per 1,000 as of 1988, according to the National Health Interview Survey (National Center for Health Statistics, 1988).

Early detection is key to the reduction of hearing impairment for Americans. Measurable objectives have been set to increase screening services for all ages. The objective for increasing early detection for children is to reduce the average age at which children with significant hearing impairment are identified, from 24–30 months to no more than 12 months of age by the year 2000. It is expected that when early identification and intervention occurs, children with hearing impairment will make accelerated progress, will be more successful in school, and become more productive members of society.

Providers of primary care for children occupy a pivotal position regarding early identification of developmental problems. If such problems can be identified early, children are more likely to make developmental progress. Since one third of all scheduled pediatric visits are for well-child care, the primary care setting is an ideal place for such screening to occur. A national hearing objective has been established to increase to at least 80% the proportion of providers of primary care for children who routinely refer or screen infants and children for hearing impairments.

In older adults, hearing impairment can lead to isolation, dependence, depression, and sometimes disorientation and confusion (Biering-Sorensen, 1984; International Center for the Disabled, 1985; National Center for Health Statistics, 1989; Sullivan, personal communication, 1990). In many cases, early detection and intervention can help to reduce functional limitation. Routine assessment by primary care providers can help to identify older adults who might benefit from intervention. The Healthy People 2000 objective relevant to older adults with potential hearing impairment is targeted to increase to at least 60% the proportion of providers of primary care for older adults who routinely evaluate people aged 65 and older for various disabilities, including hearing impairment, by the year 2000.

Money is a primary and often-cited barrier to the use of screening services. Consumers and providers alike list cost as a barrier to greater use of these and other preventive services. A Healthy People 2000 objective has been established to improve the financing and delivery of clinical preventive services so that "virtually no American has a financial barrier to receiving, at a minimum, the screening, counseling, and immunization services recommended by the U.S. Preventive Services Task Force." These Task Force recommendations include screening for hearing impairment for children and adults (U.S. Preventive Services Task Force, 1989).

Workplace exposure to excessive noise levels is an important source of hearing impairment. An estimated 8 million workers in manufacturing industries in the United States are exposed to potentially hazardous average daily levels of occupational noise at 80 dBA and above (Personick, 1990). More than 3 million workers in other occupations are exposed to average daily levels above 85 dBA. Healthy People 2000 has targeted the reduction of worker exposure so that no more than 15% of the proportion of workers are exposed to average daily noise levels that exceed 85 dBA by the year 2000.

Even though some forms of employment may be dangerous to workers' hearing health, the opportunity to work is an important factor in one's quality of life. Comparisons between working and nonworking people with disabilities show that those who work are more satisfied with life, much less likely to consider themselves disabled, and much less likely to say that their disability has prevented them from reaching their full abilities as a person. Working people with disabilities also are better educated and have more money than do nonworking people with disabilities. Health insurance coverage and access to workplace health promotion programs are among the other benefits of employment for people with disabilities. The challenge presented by these findings is how to induce the private and public sectors to effect policies and programs that will bring many more people with disabilities, including hearing impairments, into the workforce.

The Healthy People 2000 objective toward this end is to increase to at least 75% the proportion of work sites with 50 or more employees that have a voluntarily established policy or program for the hiring of people with disabilities. The presence of a hiring policy for people with disabilities greatly increases the likelihood that they will be hired. Currently, only 37% of managers say that their company has established a policy or program for the hiring of people with disabilities, and these are mostly managers of large companies.

Another important set of opportunities to which people with hearing disabilities deserve access include self-help information and various forms of education for maintaining good health. Health information and education programs for people with hearing disabilities can help to improve the efficiency and effectiveness of care and reduce subsequent disability. To be effective, education should be provided in a manner that meets individual needs, fosters improved self-management, and facilitates prompt referral, follow-up, and coordination of care.

Self-help groups, in particular, are an important source of information and social support for people with hearing problems and their families. Our national health education objective for people with disabilities is to increase to at least 40% the proportion of people with chronic and disabling conditions who receive formal patient education, including information about community and self-help resources as an integral part of the management of their condition.

Healthy People 2000 also targets mutual help clearinghouses as an important complement to clinical health services. Often referred to as self-help organizations, their

members include people who share or have shared specific physical, mental, or emotional problems. These groups make significant contributions to positive outcomes for persons with disabilities, including their family members and formal and informal caregivers. An estimated 10 million to 15 million people are members of mutual help groups in the United States (Lubin, 1980). By the year 2000, it is expected that mutual help clearinghouses will be available to citizens in at least 25 states.

Summary

From early detection services provided by health professionals to self-help information, there are many ways to help people prevent, delay, or manage hearing impairments. Our national health promotion and disease prevention policy, in the form of these and other objectives, has been developed over the past 3 years. The implementation and ultimate achievement of these objectives will depend upon the collaborative effort of us all during the next decade. This effort should yield fewer hearing problems and a higher quality of life for those with hearing impairments.

REFERENCES

- American Medical Association. (1986). Dementia. Council on Scientific Affairs. *Journal of the American Medical Association*, 256, 2234-2238.
- Bess, F., Lichtenstein, M., Logan, S., Burger, M., & Nelson, E. (1989). Hearing impairment as determinants of function in the elderly. *Journal of the American Geriatric Society*, 37, 123-128.
- Biering-Sorensen, F. (1984). Physical measurements as risk indicators for low-back trouble over a one year period. *Spine*, 9, 106-119.
- Herbst, K. (1983). Psychosocial consequences of disorders of hearing in the elderly. In R. Hinchcliffe (Ed.), *Hearing and balance in the elderly*. Edinburgh, Scotland: Churchill Livingstone.
- International Center for the Disabled. (1985). *ICD survey of disabled Americans: Bringing disabled Americans into the mainstream*, conducted for ICD and the National Council on the Handicapped by Louis Harris and Associates.
- Lubin, J.S. (1980, September). On-the-job stress leads many workers to file—and win—compensation awards. *Wall Street Journal*.
- Lynch, C., & Dublinske, S. (1985, November). *Rehabilitation services and personnel needs for the communicatively impaired*. Unpublished paper for the American Speech-Language and Hearing Association, Rockville, MD.
- National Center for Health Statistics, Centers for Disease Control, Public Health Service. (1988). *National Health Interview Survey*. Hyattsville MD: U.S. Department of Health and Human Services.
- National Center for Health Statistics. (1989). Current Estimates from the National Health Interview Survey. United States, 1988. *Vital and Health Statistics*. Series 10, No. 173, DHHS Pub.No. (PHS) 89-1501. Hyattsville, MD: U.S. Department of Health and Human Services.
- Norton, S., & Widen, J. (1990). Evoked otoacoustic emissions in normal hearing infants and children: Emerging data issues. *Ear and Hearing*, 11(2), 121-127.
- Personick, M. E. (1990, February). Nursing home aides experience increase in serious injuries. *Monthly Labor Review*, 30-37.
- U.S. Preventive Services Task Force. (1989). *Guide to clinical preventive services: An assessment of the effectiveness of 169 interventions*. Baltimore, MD: Williams and Wilkins.
- U.S. Public Health Service. (1990). *Healthy People 2000: National Health Promotion and Disease Prevention Objectives*. DHHS Pub. No.(PHS)91-50212. Washington, DC: U.S. Department of Health and Human Services.

Chapter 7

SORTING OUT THE NOISE ISSUES

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Perhaps it is true of every field, but it certainly seems that the field of noise—its effects, abatement, and regulation—is in constant flux. One consequence of this flux is that a discussion of the issues today can become somewhat outdated tomorrow. With that caveat in mind, it can be helpful to examine and sort out the noise issues, knowing that changes are bound to take place, but with a better understanding of the issues as they are (or were) in 1991.

Two categories of noise issues are discussed in this paper. The first is the important topic of noise exposure criteria, which forms the basis for standards and regulations. The term *criteria* refers to dose/response or stimulus/effect relationships, for example, which levels of noise produce what amount of hearing loss. The second category is that of policy issues for noise, meaning what we should do and how we should do it. The two issues selected for discussion here are the issues of engineering controls and hearing protectors.

CRITERIA

The "Safe" Exposure Level

The question, "What is the safe noise level?" has been debated for decades, and consensus is still lacking. Consensus is much more likely, however, when certain parameters are defined. The definition of the safe level depends upon the amount of hearing loss to be prevented, the audiometric frequencies used in making the determination, the length of exposure, and, of course, individual susceptibility. Traditionally, the medical profession and policymakers in the United States have used an average hearing threshold level or "fence" of 25 dB in the frequencies 500, 1000, and 2000 Hz to make this determination. If less hearing loss is to be allowed or higher frequencies are to be protected, the criterion becomes more stringent and lower noise levels are necessary to meet it.¹

It is necessary to view the criterion level as a time-weighted average (TWA) noise level experienced over a lifetime of exposure. For the workplace, it is usually stated

in terms of an 8-hour, average exposure level over a working lifetime of 40 years.

Back in the late 1960s and early 1970s, many assumed that a TWA of 90 dB(A) was safe, and that everything below that level was harmless. It did not take a great deal of sophistication to realize that the ear did not have such a discrete cutoff, and that 89 dB(A) was not benign. Interestingly, the first version of the Walsh-Healey noise standard, promulgated early in 1969, required an 8-hour TWA of 85 dB(A) (U.S. Department of Labor, 1969a). That standard was in effect for only a short period before it was replaced with a 90 dB(A) permissible exposure limit (U.S. Department of Labor, 1969b). Not long after that, the National Institute for Occupational Safety and Health (NIOSH) recommended a maximum TWA of 85 dB(A) (NIOSH, 1972), and later, that level was used by the Occupational Safety and Health Administration (OSHA) as the "action level" at which to initiate hearing conservation programs (OSHA, 1981, 1983a).

Even at 85 dB(A) there is some risk to the more susceptible members of the exposed population, as can be seen in Table 1. This table contains estimates developed by the International Organization for Standardization (ISO), NIOSH, and the Environmental Protection Agency (EPA), showing the percentage of the exposed population expected to exceed a 25 dB(A) hearing threshold level from noise exposure, after subtracting the percentage of the population that would ordinarily incur this amount of hearing loss from other causes, such as presbycusis. Not until the noise exposure level is lowered to 80 dB(A) does the risk become minimal.

At issue is whether policymakers and employers should view the 90 dB(A) permissible exposure limit or the 85 dB(A) action levels as sufficiently protective. Certainly the 90 dB(A) limit permits too many people to cross the fence, given the ISO, EPA, and NIOSH estimates. But is a 10% to 15% risk level acceptable? Perhaps NIOSH or OSHA will consider an 80 dB(A) action level in future criteria development. The EPA's Office of Noise Abatement identified an

¹ For a more detailed discussion of the development of criteria for noise-induced hearing loss, see Suter, 1988.

TABLE 1. Risk of exceeding a 25-dB fence at 500, 1000, and 2000 Hz after 40 years of exposure to various noise levels. Estimates are from the International Organization for Standardization (ISO), the U.S. Environmental Protection Agency (EPA), and the National Institute for Occupational Safety and Health (NIOSH). (From EPA, 1974a; OSHA, 1981).

Organization	Noise exposure (dB)	% Risk
ISO	90	21
	85	10
	80	0
EPA	90	22
	85	12
	80	5
NIOSH	90	29
	85	15
	80	3

8-hour average workplace level of 75 dB(A) as the "no effect" level, assuming that the average noise level during the remaining 16 hours stayed below that level (EPA, 1974b). The EPA's mandate, however, was very stringent. The Noise Control Act of 1972 directed the agency to identify the noise level at which even the most susceptible members of the exposed population would incur no hearing loss.

The Exchange Rate

In the past, the relationship between sound level and duration used to define an effect or set a standard was called the *doubling rate* or the *time-intensity trade-off*, but in the last decade or so, the term of preference has become the *exchange rate*. For example, OSHA uses a 5-dB exchange rate, meaning that the noise level may be increased by 5 dB with every halving of duration, so that 90 dB(A) is allowed for 8 hours, 95 dB(A) is permissible for 4 hours, 100 dB(A) for 2 hours, and so forth, up to a maximum level for continuous noise of 115 dB(A) for 15 minutes or less. Small exchange rates can be considered conservative and large ones permissive.

Some of the older consensus standards developed in the 1960s used exchange rates that varied according to the temporal characteristics of the noise. For long-duration, fairly steady noise, the exchange rates were only 2-3 dB (for example, see Kryter, Ward, Miller, & Eldredge, 1966). For short-duration, high-level sounds, the exchange rate could be 5-6 dB. Most European countries use a 3-dB exchange rate, also known as the "equal energy rule." Some Canadian provinces and some Australian states use the 3-dB exchange rate, while others use 5 dB. Italy and Japan use the 5-dB exchange rate, as does OSHA in the United States. This rule is less protective than the equal-energy rule, from which it was derived. The less conservative 5-dB rule was justified on the grounds that periodic interruptions during the workday would allow the ear some time to recover from temporary threshold shift (TTS).

Another exchange rate, the 6-dB or "equal pressure

rule," is not used by any government bodies, but is advocated by some. The Air Force and the Department of Defense use a 4-dB rule, which was supposedly designed to protect the critical 1000-Hz audiometric frequency (see Suter, 1983), but it also appears to be a compromise between the more popular 3-dB and 5-dB exchange rates.

The question of the most appropriate exchange rate depends primarily on two important factors. First, the distribution of the noise in time will have some effect on hearing damage. If the sound energy is spread over time, with generous intermittencies, it tends not to be as damaging as if it were all experienced in one continuous exposure. But the intermittencies also need to be long enough and the noise level low enough to permit recovery from TTS.

The majority of hazardous noise exposures are experienced by workers in the manufacturing industries, and the majority of these activities are undoubtedly carried out indoors. In such cases the reverberant conditions, and the activities of other workers and noisy processes, combine to produce a more-or-less steady din. Intermittent periods, although they may sometimes be long enough, would tend to be insufficiently quiet to permit recovery from TTS. It appears that the more appropriate and certainly the more conservative exchange rate would be the 3-dB rule for industrial noise. If the workplace is sufficiently intermittent, and if the activities are conducted outdoors and away from reverberant surfaces, a slightly higher overall exposure level could be tolerated. In such a case, a correction of about 2 dB or so could be made to the permissible exposure limit, rather than a change in the exchange rate.

Impulse Noise

The criteria for exposure to impulse are not nearly as solid as those for exposure to continuous and intermittent noise, but some aspects of the hazard are fairly well known. The damaging properties are dependent mainly on the level, frequency, and duration of the impulse, but also on other parameters, such as rise and decay times and background level between impulses.

At low exposure levels, impulse noise is no more damaging and possibly less so than continuous noise, given equal sound energy. At high sound levels, impulse noise appears to be more damaging, especially above a critical level of about 140-dB sound pressure level. The shape of the curve probably resembles a forward-reclining S, when sound level is plotted on the abscissa and hearing loss on the ordinate. There is also evidence that high-frequency impulses are significantly more damaging than low-frequency ones (Price, 1983 and 1989). Of course, long-duration impulses, such as the reverberant ones found in industry, are more damaging than short-duration impulses, other factors being equal.

Unfortunately, OSHA's permissible exposure limit for impulse noise is a recommended (rather than mandatory) sound pressure level of 140 dB, with no other explanation in that part of the standard.² The hearing conservation

² The current OSHA noise standard can be found in the yearly update of the Code of Federal Regulations at 29 CFR 1910.95.

amendment, however, was explicit about the measurement of impulse noise for purposes of the hearing conservation program. All types and levels of noise are to be included in the assessment of workers' noise doses, including continuous, intermittent, and impulse noise. The best (and the only convenient) way to make this assessment is by using a dosimeter or an integrating sound level meter. Any attempt to separate impulse noise from other types of noise is considered erroneous.

OSHA's enforcement policy has extended this nonseparation practice for purposes of enforcing the entire standard, including the engineering requirements, although this policy has not been without controversy. Measuring the peak sound pressure level may also be a useful activity (to see whether the 140-dB level has been exceeded), so long as in the assessment of total worker noise exposure, one integrates impulses with other types of noise energy.

The controversy surrounding the separation or integration of impulse noise arose when some companies and their consultants maintained that their workers were not overexposed because neither the sound energy of impulses without the background noise, nor the steady noise without the impulses, exceeded the 90-dB(A) TWA. Thus, workers were allowed to be exposed to two separate "doses" of noise. These parties complained that the use of dosimeters overestimated workers' exposures due to the contribution of impulse noise. The work of acoustical experts such as Earshen (1986) has done much to resolve this issue, and OSHA uses dosimeters almost exclusively to enforce its noise standard.

Combined Effects

Increasing attention is being paid to the combined effects of noise and other agents, especially in the workplace. These effects can range from no effect, or even a subtractive effect, to an additive effect, which is thought to characterize the effects of noise plus presbycusis, to synergistic effects, where noise and the other agent produce a hearing loss that is greater than the additive effect. As one would expect, the higher the levels of noise and the greater the dose of the other agent, the greater will be the resulting hearing loss. The ototoxic properties of certain drugs, notably the aminoglycoside antibiotics (the "mycin" drugs), are heightened by noise exposure. Numerous studies of kanamycin plus noise exposure have revealed additive and some synergistic results (Humes, 1984). High doses of salicylates (aspirin) accompanied by noise exposure can produce TTS (McFadden & Plattsmier, 1983), but permanent losses do not seem to occur. Cisplatin, used in cancer chemotherapy, is known to be toxic to the auditory system, and has been shown to interact significantly with noise exposure (Boettcher, Henderson, Gratton, Byrne, & Bancroft, 1989).

A variety of industrial agents, which can be potent neurotoxins, have been shown to be capable of producing hearing loss (Fechter, 1989). These agents include heavy metals, such as lead and mercury; organic solvents, such as

toluene, xylene, and carbon disulfide; and an asphyxiant, carbon monoxide.

These interactive effects may help to explain the large individual differences in susceptibility to noise-induced hearing loss. Unfortunately, these are very complex relationships and criteria for exposure to these effects will be difficult to develop. At least, they should spur policymakers and employers to exercise extra caution in implementing and enforcing hearing conservation measures when agents such as heavy metals, organic solvents, carbon monoxide, and ototoxic drugs are involved.

POLICY ISSUES

Engineering Controls

Contrary to the opinions of some "instant experts" in the noise and hearing conservation field, the HCA did nothing to change the previously existing requirements for engineering controls. The HCA merely amended the existing standard, which called for the use of engineering or administrative³ controls whenever the permissible exposure limit of 90 dB(A) was exceeded.

The problem is, however, that for more than a decade OSHA has not enforced the requirements for engineering controls with nearly the vigor that it did in the 1970s. In fact, the reluctance to enforce these requirements began prior to the Reagan Administration, although enforcement policies took a definite downturn after 1980. As a result of several legal decisions, the courts began to require OSHA to prove that noise control measures were economically as well as technically feasible. This was often very difficult for compliance officers to document. More and more companies contested these citations, and OSHA had to take them to court to require them to use engineering controls to solve their noise problems. Department of Labor attorneys were reluctant to take these cases, and OSHA personnel were encouraged to settle them rather than litigate.

In 1983, OSHA issued Instruction CPL 2-2.35, giving guidance for enforcing the noise standard's requirements for engineering and administrative controls (OSHA, 1983b). This instruction tells OSHA compliance personnel to issue citations for lack of engineering controls only when these controls are both technically and economically feasible, and in any case, not until a worker's exposure levels are so high that hearing protectors may not reduce noise levels to within the 90 dB(A) TWA. OSHA considers this higher TWA to be around 100 dB(A).

The instruction states further that engineering controls are not "reasonably necessary when an employer has an

³ Administrative controls refer to the practice of rotating workers in and out of the noise to control the duration of their exposures. The success of this practice depends upon the availability of areas that are relatively quiet and of personnel that can be switched from job to job. Administrative controls are actually seldom used because these criteria are difficult to meet, and union contracts often preclude rotating employees to jobs for which they are not trained or where they might receive different wages.

ongoing hearing conservation program and the results of audiometric testing indicate that any existing controls and hearing protectors are adequately protecting employees . . ." (OSHA, 1983b). But neither in this instruction nor in any other policy statements does OSHA define what is meant by "adequately protecting employees." The instruction directs the local OSHA official to use "professional judgment" to supplement the guidelines.

The result of this policy is to discourage companies from using the most effective means of reducing workers' noise exposures, namely engineering controls. It also gives the local OSHA personnel a great deal of latitude, which has the effect of decentralizing the authority and producing a hodgepodge of enforcement policies among the different OSHA regions and areas. In addition, it gives employers and their consultants (often audiologists) the responsibility of deciding what is meant by "adequately protecting employees" with hearing protectors and other hearing conservation measures, and of second-guessing the enforcement policies of the OSHA officials in their area. To make matters more complicated, nearly half of the states have their own OSHA programs instead of relying on the federal program, and some of them have not adopted this instruction.

Legally, the HCA has not supplanted the requirement for engineering controls, but in practice it has. The fact that this policy has not been legally challenged is an interesting issue in itself.

Problems With Hearing Protection

Too often the criterion for choosing a hearing protector is "bigger is better," and this is reflected in the manufacturers' attempts to get the largest possible Noise Reduction Ratings⁴ (NRRs) for their protectors. We now know that the attenuation of hearing protectors, as they are worn in the occupational setting, is often very different from the attenuation achieved in the laboratory. Even the NRR, which is supposed to reflect the attenuation achieved by 95% of the wearers, is far removed from the real-world situation because the mean attenuation values in the laboratory are quite high and the variability is small by comparison to the results found in field attenuation tests.

In a summary of 10 studies, Berger (1983) showed that most hearing protectors in the field provide only one third to one half the attenuation that they do in the laboratory. NIOSH has produced two field studies of hearing protector attenuation that reveal similar results (NIOSH, 1978; Lempert and Edwards, 1983). In the implementation of the OSHA instruction described above, compliance officers are to derate the NRR by 50% in determining whether to issue citations for lack of feasible engineering controls (OSHA, 1983b). Although the instruction has its negative aspects, derating the NRR by 50% is probably a step in the right direction.

⁴ The Noise Reduction Rating (NRR) is a statistic representing the mean attenuation minus two standard deviations in a population of trained listeners. This rating is currently required by the EPA to be published on the hearing protector's label (EPA, 1979).

Hearing conservation professionals usually maintain that hearing protectors have little or no adverse effects on speech communication, and actually improve communication in some circumstances. This can occur because hearing protectors attenuate the noise and the desired signal by equal amounts within a given frequency range, reducing both to a level where there is less distortion and providing better listening conditions. These improvements can be experienced when the noise level is above 80-90 dB(A), the listener has normal hearing, and the talker is not wearing protectors.

However, hearing protectors usually have an adverse effect on speech recognition and the detection of warning signals when the listener has a hearing impairment (Lindeman, 1976; Rink, 1979; Chung & Gannon, 1979). This appears to be true of listeners with average hearing threshold levels greater than 30 dB at 2000, 3000, and 4000 Hz (Lindeman, 1976). The mechanism for this occurrence is the reduction of certain signals below the level of audibility, eliminating important speech and warning cues, particularly those in the high frequencies. This is exacerbated by the fact that nearly all hearing protectors provide substantially greater attenuation in the high frequencies than in the lows.

In addition to hearing loss, other conditions interact with hearing protectors to degrade speech and signal recognition. When the talker as well as the listener wears hearing protectors, the talker's voice level will usually be reduced due to the "occlusion effect," thereby reducing the intelligibility of speech provided to the listener (Howell & Martin, 1975; Hoermann, Lazarus-Mainka, Schubius, & Lazarus, 1984). Also, both ear plugs and ear muffs adversely affect the ability to localize acoustic signals. This is especially true of ear muffs, which, in addition to degrading left-right localization, drastically interfere with localization in the vertical plane (Russell & Noble, 1971; Noble, 1981). These findings have potentially serious implications for safety in noisy workplaces.

The issues surrounding hearing protectors offer some real dilemmas for policymakers in this area. First, the NRR fails to reflect protectors' real-world attenuation, causing serious underprotection in some cases, with a resultant loss of hearing. It would behoove the EPA, which requires manufacturers to label hearing protectors with the NRR, to revise its regulations. The fact that many of the industrial users are already hearing impaired should discourage the selection of protectors with too much attenuation. The advent of hearing protectors that provide uniform attenuation across frequencies should mitigate this disadvantage somewhat (Allen & Berger, 1990; Killion, de Vilbiss, & Stewart, 1988). But we should be aware that when workers complain about hearing protectors interfering with the perception of speech and warning signals, there is often ample justification for doing so.

The criteria and policy matters discussed above are just a few of the noise and hearing conservation issues that could benefit from "sorting out." Others involving particulars of the hearing conservation amendment and a whole host of environmental noise issues also merit consideration but will not be addressed here because of time and space con-

straints. The reader can be assured, however, that for every group of complex noise issues that gets sorted out, another is ready to take its place.

REFERENCES

- Allen, C.H., & Berger, E.H. (1990). Development of a unique passive hearing protector with level-dependent and flat attenuation characteristics. *Noise Control Engineering Journal*, 34, 97-105.
- Berger, E.H. (1983). Using the NRR to estimate the real world performance of hearing protectors. *Sound and Vibration*, 17 (1), 12-18.
- Boettcher, F.A., Henderson, D., Gratton, M.A., Byrne, C., & Bancroft, B. (1989). Recent advances in the understanding of noise interactions. *Archives of Complex Environmental Studies*, 1, 15-21.
- Chung, D.Y., & Gannon, R.P. (1979). The effect of ear protectors on word discrimination in subjects with normal hearing and subjects with noise-induced hearing loss. *Journal of the American Auditory Society*, 5, 11-16.
- Earshen, J.J. (1986). Sound measurement: Instrumentation and noise descriptors. In E.H. Berger, W.D. Ward, J.C. Morrill, and L.H. Royster, (Eds.) *Noise and hearing conservation manual*. Akron, OH: American Industrial Hygiene Association.
- Environmental Protection Agency. (1979). Noise labeling requirements for hearing protectors. *Federal Register*, 44, 56130-56147.
- Fechter, L.D. (1989). A mechanistic basis for interactions between noise and chemical exposure. *Archives of Complex Environmental Studies*, 1, 23-28.
- Hoermann, H., Lazarus-Mainka, G., Schubeius, M., & Lazarus, H. (1984). The effect of noise and the wearing of ear protectors on verbal communication. *Noise Control Engineering Journal*, 23, 69-77.
- Howell, K., & Martin, A.M. (1975). An investigation of the effects of hearing protectors on vocal communication in noise. *Journal of Sound and Vibration*, 41, 181-196.
- Humes, L.E. (1984). Noise-induced hearing loss as influenced by other agents and by some physical characteristics of the individual. *Journal of the Acoustical Society of America*, 76, 1318-1329.
- Killion, M., de Vilbiss, E., & Stewart, J. (1988). An earplug with uniform 15 dB attenuation. *Hearing Journal*, 41, 14-17.
- Kryter, K.D., Ward, W.D., Miller, J.D., & Eldredge, D.H. (1966). Hazardous exposure to intermittent and steady-state noise. *Journal of the Acoustical Society of America*, 39, 451-464.
- Lempert, B.L., & Edwards, R.G. (1983). Field investigations of noise reduction afforded by insert-type hearing protectors. *American Industrial Hygiene Association Journal*, 44 (12) 894-902.
- Lindeman, H.E. (1976). Speech intelligibility and the use of hearing protectors. *Audiology*, 15, 348-356.
- McFadden, D., & Plattsmier, H.S. (1983). Aspirin can potentiate the temporary hearing loss induced by intense sounds. *Hearing Research*, 9, 295-316.
- National Institute for Occupational Safety and Health (NIOSH). (1972). *Criteria for a recommended standard: Occupational exposure to noise*. U.S. Dept. Health, Education, and Welfare, Centers for Disease Control, Public Health Service, National Institute for Occupational Safety and Health. Pub. No. HSM 73-11001.
- National Institute for Occupational Safety and Health (NIOSH). (1978). *A field investigation of noise reduction afforded by insert-type hearing protectors*. U.S. Dept. Health, Education, and Welfare, Centers for Disease Control, Public Health Service, National Institute for Occupational Safety and Health. DHEW (NIOSH) Pub. No. 79-115.
- Noble, W.G. (1981). Earmuffs, exploratory head movement, and horizontal and vertical sound localization. *Journal of Auditory Research*, 21, 1-12.
- Occupational Safety and Health Administration (OSHA). (1981). Occupational noise exposure: Hearing conservation amendment. *Federal Register*, 46, 4078-4179.
- Occupational Safety and Health Administration (OSHA). (1983a). Occupational Safety and Health Administration, Occupational noise exposure: Hearing conservation amendment; final rule. *Federal Register*, 48, 9738-9784.
- Occupational Safety and Health Administration (OSHA). (1983b). *Instruction CPL 2-2.35*, Office of Health Compliance Assistance, Nov. 9, 1983.
- Price, G.R. (1983). Relative hazard of weapons impulses. *Journal of the Acoustical Society of America*, 73, 556-566.
- Price, G.R. (1989). Hazard from an intense midrange impulse. *Journal of the Acoustical Society of America*, 86, 2185-2191.
- Rink, T.L. (1979). Hearing protection and speech discrimination in hearing-impaired persons. *Sound and Vibration*, 13 (1) 22-25.
- Russell, G., & Noble, W.G. (1976). Localization response certainty in normal and in disrupted listening conditions: Toward a new theory of localization. *Journal of Auditory Research*, 16, 143-150.
- Suter, A.H. (1983). *The relationship of the exchange rate to noise-induced hearing loss*. Report prepared under contract to JRB Associates and submitted to the Occupational Safety and Health Admin., U.S. Dept. Labor, Washington, DC (Docket OSH 011 no. 511).
- Suter, A.H. (1988). The development of federal noise standards and damage risk criteria. In D.M. Lipscomb (Ed.), *Hearing Conservation in Industry, Schools, and the Military*. Boston: College-Hill.
- U.S. Department of Labor. (1969a). Section 50-204.10. Occupational noise exposure. *Federal Register*, 34, 790-791.
- U.S. Department of Labor. (1969b). Section 50-204.10. Occupational noise exposure. *Federal Register*, 34, 7948-7949.
- U.S. Environmental Protection Agency. (1974a). Occupational noise exposure regulation: Request for review and report. *Federal Register*, 39, 43802-43809.
- U.S. Environmental Protection Agency. (1974b). *Information on levels of environmental noise requisite to protect the public health and welfare with an adequate margin of safety*. (EPA 550/9-74-004) Washington, DC: U.S. Environmental Protection Agency.

Chapter 8

KEYS TO EFFECTIVE HEARING CONSERVATION PROGRAMS: HEARING STATUS OF SCHOOL-AGE CHILDREN

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The incidence of school-age children with hearing loss varies depending upon the research studied. It has been reported that 24.4% of children aged 5 to 10 years present some type of middle ear disease (Eagles, 1972). It is important for teachers and school administrators to realize that approximately 5 children per elementary class will have some degree of hearing loss in one or both ears at any time. The incidence is greater in preschool and kindergarten classes than in upper elementary grades.

HEARING LOSS CATEGORIES

Unilateral Hearing Loss

Approximately 2% of school-age children have hearing loss in only one ear (Bess, 1985). We have just begun to realize the impact unilateral listening has on speech perception, learning, self-image, social skills, behavior, etc. Research has indicated that almost half of all children with unilateral hearing loss require educational support services and/or grade retention, and many have significant behavioral or social difficulties.

Fluctuating Hearing Loss

Approximately 85% of children "outgrow" ear problems by the age of 10 (Kessner, Snow & Singer, 1974). Of the general population, 12% have histories of chronic otitis media and fluctuating hearing, and twice as many students who are considered learning disabled (LD) have had chronic ear problems than non-learning-disabled students. Incidence of chronic otitis media in the LD population has been identified as 20–25% (Reichman & Healey, 1983), although some studies have found a much higher incidence (Sarff & Ray, 1981). When the students considered to have attention deficit disorders are considered, almost three fourths have had chronic ear problems (Hagerman & Falkenstein, 1987). A study of identification of gifted students

indicated that 75% of the students who had gifted characteristics but who did not score in the superior range on intelligence tests had had chronic ear problems (Silverman, Chitwood, & Waters, 1986). In summary, fluctuating hearing and degraded listening ability affect a child's optimal cognitive development and his or her ability to function in school in terms of attention, distractibility, organization, and so forth.

Minimal Sensorineural Hearing Loss

The professional literature has repeatedly emphasized that a child with hearing ability in excess of 15 dB is at risk for developing educational difficulties. However, most medical practitioners and many audiologists continue to classify children with hearing ability up to 25 dB as "normal hearing" (Bavosi & Rupp, 1984). This controversial hearing loss category (16–25 dB) affects children most in a classroom situation, where they are expected to perceive and understand information in noisy and reverberant listening environments. In studies that have considered the incidence of students who were unable to pass a 15-dB hearing screen, approximately 30% of students in the regular classroom and 75% of students receiving special education services were identified as having minimal or greater (15–40dB) hearing losses (Sarff & Ray, 1981). Whether the hearing loss is conductive and fluctuating or sensorineural, a minimal hearing loss does indeed place a student at risk for educational difficulties.

Mild to Profound Hearing Loss

Four trends in the last decade affect the state of the school-age child with hearing loss: (a) fewer deaf children are being born, (b) more children with milder degrees of hearing loss are receiving amplification, (c) more children with hearing loss also have additional disabilities, and (d) more children are being identified at earlier ages and receiving intervention prior to school age (Upfold, 1988).

The impact of early intervention has allowed many children who are deaf to function with minimal support in the regular education setting. The lack of intervention for many children with minimal or mild hearing impairments has created language, learning, and school function problems for multitudes of students. The audiogram alone is no longer the primary determinant of the degree of success a child will be able to experience in the regular education setting. The earliness of identification and rigorosity of intervention are primary factors in the success of a child's educational future. Therefore, it is paramount that effective identification programs be in place so that intervention can occur as early as possible (Downs, 1991).

COMPONENTS OF A HEARING CONSERVATION PROGRAM

The purpose of identification audiometry is to identify all children with hearing loss as defined by the screening criteria used. The challenge of the educational audiologist is to determine which of these identified children are at critical risk for developing educational difficulties because of hearing loss. The criteria and model used in an identification program can assist or confound the identification of both the educationally significant sensorineural and fluctuating conductive populations with hearing loss. When we complete the hearing screening process, we are just beginning the process of identifying children's needs. The school hearing screening program is at the beginning of a chain of events that can ultimately be considered an effective school hearing conservation program. The components, depicted in a flowchart in Appendix A, are listed below.

1. Obtain history of chronic ear problems or known hearing loss for each child upon enrollment.
2. Inform classroom teachers of students at highest risk of educational difficulties because of hearing loss history in preschool years.
3. Identify school-age children with stable and fluctuating hearing loss via screening.
4. Recommend amplification for these students whenever appropriate.
5. Refer children with apparent otitis media for medical management.
6. Perform regular educational/hearing monitoring of children with significant histories of otitis media.
7. Determine those children who currently may have educational difficulties.
8. Obtain educational support services for children with apparent learning/school function difficulties.
9. Conduct regular audiological monitoring of all students with permanent hearing loss.
10. Provide education for students with high-frequency loss and their peers regarding the affects of noise on hearing ability.
11. Provide inservice education for teachers regarding the affects of hearing loss on listening and learning.
12. Create dialogue between the local medical commu-

nity and the schools regarding children's hearing needs.

Identifying Hearing Loss: A Suggested Program

Hearing screening programs have been conducted in the schools for decades with varying degrees of effectiveness. For over two decades, it has been recognized that pure-tone screening is an ineffective method of identifying children with recurrent otitis media (Melnick, Eagles, & Levine, 1964; Brooks, 1971). Because of the episodic nature of chronic otitis media, all of the children who do not have otitis media on the day hearing screening is conducted will "pass" with both pure-tone and tympanometry screening methods, despite the chronicity of their history. As the educational impact of fluctuating minimal and mild hearing loss is accepted by educators, it is paramount that audiologists do a better job in determining effective methods for identifying this population.

Get the History Up Front

Research supports the finding that children who have had recurrent middle ear problems prior to the age of 2 years and continuing throughout the preschool years are at greatest risk for auditory, language, and cognitive development delays (Howie, 1979; Sak & Ruben, 1982). The frequency of ear problems, how long the episodes last and how much hearing loss is present are the factors that determine the impact on the development of language, listening skills, and cognition. To effectively identify the children who may experience educational difficulties from fluctuating conductive hearing loss, we need to take their history of ear and hearing problems into account as part of the screening process. The majority of children who are identified during the hearing screening process will have hearing loss due to otitis media. Therefore, with history information available, we are able to identify the majority of children who are at greatest risk for learning problems due to fluctuating hearing loss as they enter school. A questionnaire entitled History of Ear and Hearing Problems (Appendix B) is an example of a form that can be included in a school district's standard enrollment process.

"Red Flag" Children and Let the Teachers Know!

With the hearing history known prior to the start of screening, it is possible to "red flag" the children with chronic otitis media histories. At the start of each school year, primary teachers can be notified of the students in their class who have had a history of ear and hearing problems. Teachers can then be encouraged to seat the children favorably in the classroom and to be alert for behaviors that may be due to an ear and hearing problem. Via inservice education, teachers need to be made aware of the impact of mild and fluctuating hearing loss upon paying attention, following directions, developing phonics skills and lan-

guage, and so forth. Children with otitis-prone histories who appear to be struggling may obtain support services earlier if the teachers are already aware of their potential risk for educational difficulties.

With a system of red flagging in place, the high-risk students are easily identifiable so that their tympanometry and hearing results can be considered more closely than other students following mass screening. For example, the audiologist may wish to rescreen a red-flagged child who has a tympanogram with extreme negative pressure or a borderline gradient measure, whereas these values would be considered "passing" for students without significant histories. The red-flagged student would then be given the benefit of the doubt and rescreened in case these borderline values suggested otitis media may be developing.

Screen, Screen, Screen (and make sure it's QUIET)

Screening should be performed as early in the school year as possible so that students with previously unidentified permanent hearing loss and children experiencing current ear problems may obtain the appropriate attention in order to curtail as much educational delay as possible.

Pure-tone screening. Screening is performed at 1000 Hz, 2000 Hz and 4000 Hz at 20 dB and any student who fails to respond at this level at any frequency in either ear is rescreened in 4 to 6 weeks. If tympanometry is not a part of the identification program, screening at 500 Hz should also be performed (ASHA, 1985).

The use of hearing screening equipment with a single hand-held earphone or an otoscope-type device has achieved some popularity. It is critical to realize that the acoustic environment requirements are much more stringent for this equipment when compared to the use of two earphones (Bienvenue, Michael, & Chaffinch, 1984). Because of the typically noisy conditions found during school hearing screening, equipment that utilizes single-ear sound presentation is probably not appropriate for use in school environments.

Tympanometry screening. ASHA has recently published guidelines for the use of acoustic immittance measures in addition to pure-tone screening methods. New components included in the protocol are the use of otoscopy and obtaining a brief history. Tympanometric width, or gradient, is suggested instead of negative pressure measures to detect children with active otitis media. Refer to these 1990 Guidelines (ASHA, 1991) for a complete review of the recommended screening criteria.

Stick to schedule. To be effective, a rescreen must be performed within 4 to 6 weeks for children failing initial hearing screening. Prompt referral for medical and/or audiological following rescreen is critical. Waiting periods longer or shorter than 4 to 6 weeks compromise the effectiveness of identifying children with ear/hearing problems that are educationally significant.

Determination of Needs: A Necessary Next Step

The vast majority of school programs have defined identification procedures but fall short in providing adequate

follow-up services. Without deliberate involvement of teachers with regard to the school performance and auditory needs of children with hearing loss, there is little hope of improving the educational plight of the child with a hearing problem.

Determination of Amplification Candidacy

The majority of children will fail hearing screening because of otitis media and will be able to seek medical solutions to their hearing problems; however, a small percentage of children with minimal, unilateral, or mild to moderate hearing losses can appropriately undergo at least a trial period with amplification.

Despite being a time-honored recommendation, preferential seating is not the answer for the child with an educationally significant hearing loss. This common misconception must be clarified and emphasized to teachers, administrators, and parents so that we may avoid the common belief that favorable seating equals the redemption of good hearing. Sitting close to the teacher assists students' speechreading efforts and can enhance their alertness, but favorable seating does little to clarify the speech signal from interfering background noise (Leavitt & Flexer, 1991).

Success in the educational setting depends upon the perception and subsequent comprehension of information, primarily information provided verbally by the teacher or during group discussions in an environment that is typically noisy and reverberant. Even with special support services, the students with minimal, mild, unilateral, or fluctuating hearing loss will usually receive the majority of their education in the mainstream classroom. Consequently, it is critical that the school provide whatever amplification equipment is necessary for the child to benefit from the educational setting. Hearing technology is available in a variety of forms today. No one amplification device is the answer for all degrees of hearing loss or all individual needs. The audiologist must be open to trying not only hearing aids and personal FM systems, but also soundfield amplification systems or assistive listening devices to best meet classroom listening needs.

Determination of Educational Significance

All degrees of hearing loss affect listening ability to some degree; however, not all of the children identified with hearing loss have demonstrable difficulties learning or functioning in the educational setting. Some students function extremely well in school despite their hearing loss and other students, sometimes with lesser degrees of hearing loss, may struggle as they try to achieve in the classroom setting. For this reason, school administrators should not assume that all students with hearing loss are experiencing educational difficulties or that all of these students will perform well. Therefore, each student identified during the hearing screening process with permanent hearing loss or a significant history of fluctuating hearing loss should be screened for educational difficulties. A discussion of sev-

eral procedures for screening for educational difficulties in this student population follows.

Asking the Teacher

This is probably the most common method that is used to obtain information about how a student is functioning in the classroom. Children who are having difficulties in many areas or those with behavior problems can be easily identified in this manner. However, the effects of mild and fluctuating hearing loss are often subtle and masked by the appearance of inattention or lack of effort. Therefore, the teacher may not recognize that the student is performing at less than his or her ability because of hearing problems.

Using Informal Checklists

Many audiologists working in the schools have used some sort of checklist about student behavior and performance. Unfortunately, informal lists of questions can only be subjectively interpreted and are not usually definitive in identifying specific problem areas children may be experiencing in the classroom. Often, informal checklists fail to compare students to class peers, especially in the areas of attention and distractibility.

Screening by A Speech-Language Pathologist

It has been estimated that perhaps one third of children receiving speech and language remediation may present histories of recurrent otitis media (Shriberg & Kwiatkowski, 1982). Unfortunately, the subtle effects of minimal, unilateral, mild, and fluctuating hearing loss on language development do not always appear when using many test instruments. In addition, areas of social skills, classroom participation, and behavior, which are often affected in some way for a child with hearing loss, are not typically reflected on speech and language test measures.

Using a Formally Designed Checklist

To date, only one instrument is available that has been specifically designed to screen the classroom performance of the child with hearing loss. The Screening Instrument For Targeting Educational Risk, or S.I.F.T.E.R. (Anderson, 1989), is composed of three questions in each of five areas: Academics, Attention, Communication, Class Participation, and School Behavior. Teachers respond on a scale of 1–5 for each question. The responses are entered onto a scoring grid that indicates whether a student passes, fails, or has marginal performance in each of the areas. The S.I.F.T.E.R. can be used to screen children's classroom performance for any of the following purposes: children identified following hearing screening, students with histories of ear and hearing problems who are at risk for educational problems, children with significant hearing loss (amplified or unamplified) who have performed well in the classroom

in the past, and children who were previously in restrictive special education settings who subsequently have been placed into a mainstreamed setting with lesser special support.

Children who are identified as having failing or marginal scores in any or all of the five areas could then be considered for full assessment by the school Child Study Team. The S.I.F.T.E.R. is a screening instrument and should not be used to determine a child's functioning level or need for support services.

Categorizing Children Identified During Screening

Even fairly small school districts may have more than 100 students identified with hearing problems during hearing screening. In terms of educational, medical, and audiological management needs, it may be efficient to categorize these students and deal with them individually within their categories. Once the educational information is obtained, the children who failed hearing screening can be sorted into the following categories: Educationally Significant, Medically Significant, Educationally and Medically Significant, and Neither Educationally nor Medically Significant. Following the steps of obtaining an ear problem history, screening, referral/evaluation of screen failures and gathering educational information, the children with the greatest need for educational assessment, special services, or close monitoring by the educational audiologist will be apparent. The application of these categories has been illustrated in Appendix C. It is important to note that children who experience changes in hearing and/or educational performance will be likely to change categories.

Possible Service Options as Determined by Student Needs

School systems are required to offer an array of services to special education students so that their individual educational needs can be met by an appropriate program. The needs of students with hearing loss can vary greatly depending upon many behavioral, academic, social, emotional, motoric, cognitive, and language development factors.

Educational Support

Educational support services for students with educationally significant hearing loss can be considered on a continuum. The amount of special support required by each student can vary considerably; however, children with different degrees of hearing loss typically can experience similarities in speech, language, listening, amplification, psychosocial, and educational needs. Appendix D provides examples of general educational and audiology service needs of students with different degrees of hearing loss.

Audiological Support

Support by the educational audiologist is dictated largely by the job description within a school district (or contracted district). Typical support activities may include annual re-evaluation of students with hearing loss; regular hearing aid monitoring; assisting families in the procurement of hearing aids; helping students adjust to new amplification; monitoring a child's hearing and middle ear status; and conducting auditory training, speechreading instruction, and language habilitation. Most audiologists providing services in schools perform some or all of these support activities in addition to active participation and supervision of the identification program.

HEARING LOSS EDUCATION

The majority of school personnel and students are uninformed about the impact of hearing loss on listening and learning. The educational audiologist is in a unique position to provide information about hearing loss to teachers, school administrators, parents, and students.

Noise-Induced Hearing Loss

One critical area of need for hearing conservation education is informing students of the hazards of excessive noise on their hearing ability. Because of the rising numbers of children acquiring noise-induced hearing loss at ever-decreasing ages, education about the impact of excessive noise on hearing would be a worthwhile addition to the health curriculum of every school district. The audiologist is a logical instigator of this curriculum and should play a crucial role in the development of curriculum materials. Some areas that could be covered in the hearing loss curriculum include how the ear works, how noise can damage hearing, what is a hearing loss and how it can affect life quality, what kind of noises or noisy activities are most dangerous to hearing, warning signs of overexposure to noise and of hearing loss, and responsibly protecting one's ears and hearing. Information on hearing health can be presented to children as young as preschool and should be considered to be of equal importance as dental health, care of eyes and vision, and personal hygiene issues.

Fluctuating Hearing Loss

Even with an excellent hearing screening program, some children with hearing loss will remain unidentified. No valid teacher referral of students with suspected hearing loss can occur without teachers having a basic working knowledge of how hearing loss can affect a student's behavior and school performance. A brief inservice for school staff members can increase the knowledge of teachers regarding the educational impact of even minimal hearing loss, provide a more valid referral of student hearing prob-

lems by teachers, and increase the visibility and effectiveness of the audiologist in the schools.

CONCLUSION

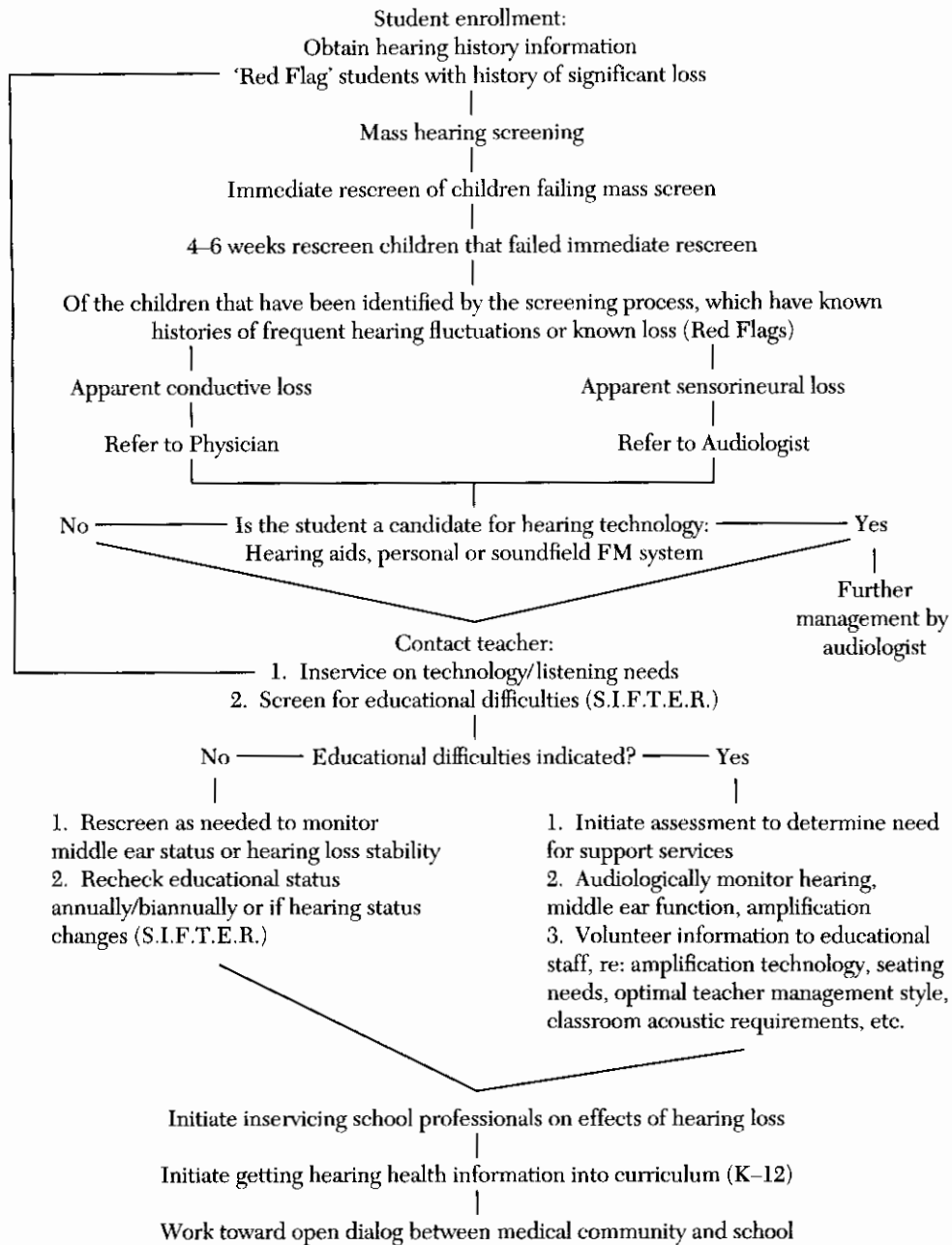
In summary, a school hearing conservation program begins with improving the awareness of administrators and teachers of the educational impact of hearing loss. A hearing screening program should focus on identifying all children who are at risk for educationally damaging hearing loss, and on sharing information with the classroom teacher. Once children with hearing loss are identified, they must be evaluated relative to the hearing technology available to maximize children's auditory learning environment. To validate the hearing screening process within the public school context, children with identified hearing problems must also be screened for educational difficulties, including assessment for special support services when appropriate. Finally, the educational audiologist has a role in providing services to students with hearing loss and in infusing the education of students about healthy hearing habits and prevention of hearing loss into the school curriculum.

REFERENCES

- Anderson, K. (1989). *Screening instrument for targeting educational risk (S.I.F.T.E.R.)*. PRO-ED, Austin, TX.
- ASHA Committee on Audiometric Evaluation. (1985, May). Guidelines for identification audiometry. *Asha*, 27, 49-52.
- ASHA Working Group on Acoustic Immittance Measurements and the Committee on Audiologic Evaluation (1990). Guidelines for screening for hearing impairment and middle-ear disorders. *Asha*, Supplement to April, 32, 17-24.
- Bavosi, R., & Rupp, R. (1984). When "normal" hearing is not normal. *Hearing Instruments*, 35, 9.
- Bess, F. (1985). The minimally hearing-impaired child. *Ear and Hearing*, 6, 43-47.
- Bienvenue, G., Michael, P., & Chaffinch, J. (1984). Reference threshold sound pressure level for the Welch Allen Audioscope. *Journal of the Acoustical Society of America*, 75, 1887-1892.
- Brooks, D. (1971). A new approach to identification audiometry. *Audiology*, 10, 334-339.
- Downs, M. (1991). Twentieth century pediatric audiology: Prologue to the 21st. *Seminars in Hearing*, 11, 408-411.
- Eagles, E. (1972). Selected findings from the Pittsburgh Study. *Translations of the American Academy of Ophthalmology and Otolaryngology*, 76, 343-348.
- Hagerman, R., & Falkenstein, A. (1987). Ear infections and hyperactivity? *Clinical Pediatrics*, 26, May 1987; as reported in *Parent's Pediatric Report*, November 1987, 70.
- Howie, V. (1979). Developmental sequelae of chronic otitis media: The effect of early onset of otitis media on educational achievement. *International Journal of Pediatric Otorhinolaryngology*, 1, 151-168.
- Kessner, D., Snow, C., & Singer, J. (1974). Assessment of medical care in children. *Contrasts in health status*. Washington, D.C.: Institute of Medicine, National Academy of Sciences, 3.
- Leavitt, R., & Flexer, C. (1991). Speech degradation as measured by the Rapid Speech Transmission Index (RASTI). *Ear and Hearing*, 12, 115-118.
- Melnick, W., Eagles, E., & Levine, H. (1964). Evaluation of a recommended program of identification audiometry with school-age children. *Journal of Speech and Hearing Disorders*, 29, 3-13.

- Reichman, J., & Healey, W. (1983). Learning disabilities and conductive hearing loss involving otitis media. *Journal of Learning Disabilities, 16*, 272-278.
- Sak, R., & Ruben, R. (1982). Effects of recurrent middle ear effusion in preschool years on language and learning. *Journal of Developmental and Behavioral Pediatrics, 3*, 7-12.
- Sarff, L., & Ray, H. (October, 1981). Why not amplification in every classroom? *Hearing Aid Journal, 43*-52.
- Shriberg, L., & Kwiatkowski, J. (1982). Phonological disorders I: A diagnostic classification system. *Journal of Speech and Hearing Disorders, 47*, 24-39.
- Silverman, L., Chitwood, D., & Waters, J. (1986). Young gifted children: Can parents identify giftedness? *Topics in Early Childhood Special Education, 6*, 23-37.
- Upfold, L. (1988). Children with hearing aids in the 1980's: Etiologies and severity of impairment. *Ear & Hearing, 9*, 2.

APPENDIX A
 OUTCOMES OF A HEARING CONSERVATION PROGRAM



APPENDIX B
HISTORY OF EAR AND HEARING PROBLEMS

Children who have had many ear infections and periods of hearing loss are more likely to have language, vocabulary, and listening difficulties when they start school. We would like to identify these students so that we are more aware of their possible hearing problems and can be alert for present or developing learning problems.

Parent or guardian, please answer the following questions:

Child's Name _____ Birthdate _____



	<u>NO</u>	<u>YES</u>
1. Did your child have <i>any</i> ear problems before the age of 1?	_____	_____
2. Has your child ever had a draining ear?	_____	_____
3. Approximately how many ear problems has your child had in his/her life? 0-2 _____ 3-5 _____ 6-10 _____ 10 or more _____		
4. Does your child tend to have four or more ear problems each year?	_____	_____
5. Has your child had an ear problem in the last 6 months?	_____	_____
6. Has your child ever had an ear problem that lasted 3 months or longer? (with or without medication)	_____	_____
7. Has anyone related to the child had many ear problems? (parents, brothers or sisters, cousins)	_____	_____
8. Has your child ever been seen by an ear doctor (Otologist)? If yes, what doctor _____ No/Yr of last visit? _____	_____	_____
9. Has your child ever had tubes placed in his/her eardrums? If yes, how many times? _____ At what age(s)? _____	_____	_____
10. Does your child have any permanent hearing loss that you know about? (For example: deaf in one ear, can't hear high pitch sounds) Please describe:		

EAR PROBLEM = ear infection, ear aches, draining ears, medicine taken for ears, doctor noticed fluid behind eardrum, hole in eardrum, etc.

APPENDIX C
CATEGORIZING CHILDREN THAT ARE IDENTIFIED DURING THE ANNUAL SCHOOL HEARING LOSS IDENTIFICATION PROGRAM

Category	Description	Example	Management
Medically Significant	A child who is currently experiencing otitis media but has no apparent significant history of recurrent ear problems	Otitis media associated with upper respiratory infection; occurs once or twice/yr	Medical treatment; preferential seating, retest hearing following completion of treatment to ensure hearing problem has resolved
Educationally Significant	Sensorineural hearing loss or stable conductive hearing loss that has adversely affected a child's school achievement	30dB sensorineural loss; Moderate loss 750-2000 Hz; or sharply sloping high frequency loss including 2000 Hz	Personal hearing aids as needed, personal or sound field FM system, annual hearing evaluation, favorable seating, support services as appropriate
Educationally and Medically Significant	A child with significant history of recurrent ear infections and fluctuating hearing loss that affects educational progress and continues to cause hearing loss frequently	Otitis media continuously since infancy; unoperated eardrum perforation, chronic draining ears	Medical treatment; personal or soundfield FM, special support services as appropriate; seat preferentially; monitor hearing (3/4 times/yr)
Neither Educationally Nor Medically Significant	A child with a known stable hearing loss that has good school performance despite the hearing loss	Mild high frequency loss, mild unilateral hearing loss, loss at 1500 Hz in one ear only	Monitor hearing annually for hearing loss changes, seat favorably to allow easy visualization and encourage attention in classroom

APPENDIX D RELATIONSHIP OF DEGREE OF LONG-TERM HEARING LOSS TO PSYCHOSOCIAL IMPACT AND EDUCATIONAL NEEDS

Degree of Hearing Loss Based on modified pure tone average (500-4000 HZ)	Possible Effect of Hearing Loss on the Understanding of Language & Speech	Possible Psychosocial Impact of Hearing Loss	Potential Educational Needs and Programs
<p>NORMAL HEARING -10 to +15 dB HL</p>	<p>Children have better hearing sensitivity than the accepted normal range for adults. A child with hearing sensitivity in the -10 to +15 dB range will detect the complete speech signal even at soft conversation levels. However, good hearing does not guarantee good ability to discriminate speech in the presence of background noise.</p>	<p style="text-align: center;"></p>	<p style="text-align: center;"></p>
<p>MINIMAL (BORDERLINE) 16-25 dB HL</p>	<p>May have difficulty hearing faint or distant speech. At 15 dB student can miss up to 10% of speech signal when teacher is at a distance greater than 3 feet and when the classroom is noisy, especially in the elementary grades when verbal instruction predominates.</p>	<p>May be unaware of subtle conversational cues, which could cause child to be viewed as inappropriate or awkward. May miss portions of fast-paced peer interactions, which could begin to have an impact on socialization and self concept. May have immature behavior. Child may be more fatigued than classmates due to listening effort needed.</p>	<p>May benefit from mild gain/low, MPO hearing aid or personal FM system dependent on loss configuration. Would benefit from soundfield amplification if classroom is noisy and/or reverberant. Favorable seating. May need attention to vocabulary or speech, especially with recurrent otitis media history. Appropriate medical management necessary for conductive losses. Teacher requires inservice on impact of hearing loss on language development and learning.</p>
<p>MILD 26-40 dB HL</p>	<p>At 30 dB can miss 25-40% of speech signal. The degree of difficulty experienced in school will depend upon the noise level in classroom, distance from teacher and the configuration of the hearing loss. Without amplification the child with 35-40 dB loss may miss at least 50% of the class discussions, especially when voices are faint or speaker is not in line of vision. Will miss consonants, especially when a high frequency hearing loss is present.</p>	<p>Barriers beginning to build with negative impact on self esteem as child is accused of "hearing when he or she wants to," "day-dreaming," or "not paying attention." Child begins to lose ability for selective hearing, and has increasing difficulty suppressing background noise which makes the learning environment stressful. Child is more fatigued than classmates due to listening effort needed.</p>	<p>Will benefit from a hearing aid and use of a personal FM or soundfield FM system in the classroom. Needs favorable seating and lighting. Refer to special education for language evaluation and educational follow-up. Needs auditory skill building. May need attention to vocabulary and language development, articulation or speechreading and/or special support in reading. May need help with self esteem. Teacher inservice required.</p>
<p>MODERATE 41-55 dB HL</p>	<p>Understands conversational speech at a distance of 3-5 feet (face-to-face) only if structure and vocabulary controlled. Without amplification the amount of speech signal missed can be 50% to 75% with 40 dB loss and 80% to 100% with 50 dB loss. Is likely to have delayed or defective syntax, limited vocabulary, imperfect speech production and an atonal voice quality.</p>	<p>Often with this degree of hearing loss, communication is significantly affected, and socialization with peers with normal hearing becomes increasingly difficult. With full-time use of hearing aids/FM systems child may be judged as a less competent learner. There is an increasing impact on self-esteem.</p>	<p>Refer to special education for language evaluation and for educational follow-up. Amplification is essential (hearing aids and FM system). Special education support may be needed, especially for primary children. Attention to oral language development, reading and written language. Auditory skill development and speech therapy usually needed. Teacher inservice required.</p>
<p>MODERATE TO SEVERE 56-70 dB HL</p>	<p>Without amplification, conversation must be very loud to be understood. A 55 dB loss can cause child to miss up to 100% of speech information. Will have marked difficulty in school situations requiring verbal communication in both one-to-one and group situations. Delayed language, syntax, reduced speech intelligibility and atonal voice quality likely.</p>	<p>Full-time use of hearing aids/FM systems may result in child being judged by both peers and adults as a less competent learner, resulting in poorer self concept, social maturity and contributing to a sense of rejection. Inservice to address these attitudes may be helpful.</p>	<p>Full-time use of amplification is essential. Will need resource teacher or special class depending on magnitude of language delay. May require special help in all language skills, language-based academic subjects, vocabulary, grammar, pragmatics as well as reading and writing. Probably needs assistance to expand experiential language base. Inservice of mainstream teachers required.</p>
<p>SEVERE 71-90 dB HL</p>	<p>Without amplification may hear loud voices about one foot from ear. When amplified optimally, children with hearing ability of 90 dB or better should be able to identify environmental sounds and detect all the sounds of speech. If loss is of prelingual onset, oral language and speech may not develop spontaneously or will be severely delayed. If hearing loss is of recent onset speech is likely to deteriorate with quality becoming atonal.</p>	<p>Child may prefer other children with hearing impairments as friends and playmates. This may further isolate the child from the mainstream; however, these peer relationships may foster improved self-concept and a sense of cultural identity.</p>	<p>May need full-time special aural/oral program with emphasis on all auditory language skills, speechreading, concept development and speech. As loss approaches 80-90 dB, may benefit from a Total Communication approach, especially in the early language-learning years. Individual hearing aid/personal FM system essential. Need to monitor effectiveness of communication modality. Participation in regular classes as much as beneficial to student. Inservice of mainstream teachers essential.</p>

(continued next page)

Degree of Hearing Loss	Possible Effect of Hearing Loss on the Understanding of Language & Speech	Possible Psychosocial Impact of Hearing Loss	Potential Educational Needs and Programs
PROFOUND 91 dB HL or more	Aware of vibrations more than tonal pattern. Many rely on vision rather than hearing as primary avenue for communication and learning. Detection of speech sounds dependent upon loss configuration and use of amplification. Speech and language will not develop spontaneously and is likely to deteriorate rapidly if hearing loss is of recent onset.	Depending on auditory/oral competence, peer use of sign language, parental attitude, etc., child may or may not increasingly prefer association with the deaf culture.	May need special program for deaf children with emphasis on all language skills and academic areas. Program needs specialized supervision and comprehensive support services. Early use of amplification likely to help if part of an intensive training program. May be cochlear implant or vibrotactile aid candidate. Requires continual appraisal of needs in regard to communication and learning mode. Part-time in regular classes as much as beneficial to student.
UNILATERAL One normal hearing ear and one ear with at least a permanent mild hearing loss	May have difficulty hearing faint or distant speech. Usually has difficulty localizing sounds and voices. Unilateral listener will have greater difficulty understanding speech when environment is noisy and/or reverberant. Difficulty detecting or understanding soft speech from side of bad ear, especially in a group discussion.	Child may be accused of selective hearing due to discrepancies in speech understanding in quiet versus noise. Child will be more fatigued in classroom setting due to greater effort needed to listen. May appear inattentive or frustrated. Behavior problems sometimes evident.	May benefit from personal FM or soundfield FM system in classroom. CROS hearing aid may be of benefit in quiet settings. Needs favorable seating and lighting. Student is at risk for educational difficulties. Educational monitoring warranted with support services provided as soon as difficulties appear. Teacher inservice is beneficial.

NOTE: All children with hearing loss require periodic audiologic evaluation, rigorous monitoring of amplification and regular monitoring of communication skills. All children with hearing loss (especially conductive) need appropriate medical attention in conjunction with educational programming.

REFERENCES

Olsen, W. O., Hawkins, D. B., & Van Tassel, D. J. (1987). Representatives of the Longterm Spectrum of Speech. *Ear & Hearing*, Supplement 8, pp. 100-108.
 Mueller, H. G. & Killion, M. C. (1990). An easy method for calculating the articulation index. *The Hearing Journal*, 43, 9, pp. 14-22.
 Hasenstab, M. S. (1987). *Language Learning and Otitis Media*, College Hill Press, Boston, MA.

Developed by
 Karen L. Anderson, Ed S & Noel D. Matkin, Ph.D (1991)

Adapted from: Bernero, R. J., & Bothwell, H. (1966). *Relationship of Hearing Impairment to Educational Needs*. Illinois Department of Public Health & Office of Superintendent of Public Instruction.
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Chapter 9

WHAT EVERY AUDIOLOGIST NEEDS TO KNOW ABOUT INDUSTRIAL AUDIOLOGY

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Like most audiologists, as a wide-eyed college freshman, I did not know what an audiologist was. After all, no one—but no one—ever goes through childhood telling Mom and Dad that they want to be an audiologist when they grow up. But by my junior year, I discovered that audiology melded many of the other subjects I enjoyed—physics, linguistics, acoustics, and psychology. I also wanted to be part of a helping profession. I wanted to “save the hearing of humanity.”

In the midst of my graduate training, I was exposed via a research project and a guest lecturer to the then-emerging field of hearing conservation. Though the prospect of working in industry amused me, I was still bent on becoming a clinical audiologist (after all, what other type of audiologist was there, I mused) to “save the hearing of humanity.” But by the time I completed my first job out of graduate school, working as an industrial audiologist for the Santa Fe Railroad, I came to realize that the profession of audiology was not as confining as I had once thought and that indeed, the term *audiologist* could be preceded by qualifiers other than *clinical*.

Since the day I left graduate school, I have never tested 250 Hz, fit a hearing aid, or tested a pediatric patient. I have never administered an acoustic immittance exam, an ENG, or BSER. I hesitate to admit that in my professional life, I have never administered a word discrimination test or any kind of speech test or bone conduction. I have never applied masking.

What right, one might ask, do I have to call myself an audiologist? If ever there was a “stepchild” in audiology practice, industrial audiology is it. But I enjoy the satisfaction that comes from preventing more hearing loss in one day than most audiologists prevent in a year. Indeed, I have discovered the path toward “saving the hearing of humanity.” That path has taken me through factories, mills, foundries, and other familiar haunts of the industrial audiologist.

The Audiologist in Industrial Settings

Today, there are several hundred full-time industrial audiologists in private practice. Furthermore, there are ap-

proximately 50 corporate audiologists around the United States working in larger utilities and manufacturing and aerospace concerns. For example, 3M, Kodak, General Dynamics, and Boeing employ full-time audiologists to administer their Hearing Conservation Programs. The U.S. armed forces employ nearly 130 active-duty audiologists. But certainly the majority of audiologists providing services to industry do so part-time. The 1988 ASHA Omnibus Survey reported that 48% of responding audiologists provide hearing conservation services to industry in one degree or another.

An audiologist providing services to industry could be involved in any of the following roles:

- *Audiometric testing.* The core of a Hearing Conservation Program is annual audiometric testing. Contrary to popular belief, there is still a very large market for audiologists to administer audiometric exams in industry; this task has not been overtaken by technicians.
- *Expert review of audiograms.* Audiologists are often called upon to review audiograms generated within industry, to identify problem cases or those needing follow-up. Some states (California, for example) require that *all* audiograms administered in industry be reviewed by an audiologist or physician, not just those targeted as “suspect.”
- *Noise monitoring.* Spurred by regulations from the Occupational Safety & Health Administration (OSHA) or the employer’s insurance carrier, many companies seek professional help in documenting noise levels in their facilities. There is no mandate stipulating the credentials of those providing noise monitoring, and the audiologist is often the most qualified professional to provide this service.
- *Training instructor.* Annual employee training is one component of OSHA regulations for hearing conservation. Although many companies use any of the excellent training materials available on the market, the audiologist may be called upon to supplant or supplement these other resources.
- *Hearing conservation program manager.* Industries

with noise control problems will often contract with the audiologist to manage their Hearing Conservation Program to comply with OSHA requirements.

- *Expert witness.* The audiologist may be asked to provide expert testimony in litigation resulting from workers' compensation claims or civil suits for noise compliance, particularly with regard to hearing handicap and disability assessment (see Appendix).

While the audiologist is the most qualified professional to provide these services to industry, in many cases, the audiologist may lack formal graduate training in noise control, noise measurement, or hearing conservation in industry. Continuing education and on-the-job training often substitute for the graduate course in industrial audiology.

Components of a Hearing Conservation Program

In 1983, following several years of public comment and administrative stays, OSHA's Hearing Conservation Amendment (OSHA, 1983) became federal regulation. Principal portions of the Hearing Conservation Amendment were authored by Alice Suter, an audiologist working at the time in OSHA's Office of Physical Agents Standards. The Amendment was a significant benchmark for audiologists, as it was the first time audiologists had been mentioned in federal noise control rule making, according to Dr. Suter.

The Hearing Conservation Amendment outlined five elements of an occupational Hearing Conservation Program. The 26 states with state-approved OSHA plans are required to meet or exceed these federal rules. (Check with your state office of Occupational Safety and Health to verify the regulations that apply to your jurisdiction.) These five elements are as follows:

1. Noise monitoring
2. Annual audiometric testing
3. Employee training
4. Hearing protectors
5. Record keeping

A brief discussion of each of these components follows. The topic of audiometric testing is dealt with in greater detail, because it is the point where most audiologists make their initial jump into industrial audiology.

Noise Monitoring

Time-weighted noise monitoring is required in industry to determine noise levels ≥ 90 dBA (the "permissible exposure limit," at which hearing protection is required and engineering controls are considered), and noise levels ≥ 85 dBA (the "action level" at which employees must be included in a continuing Hearing Conservation Program). The 85-dBA action level was set 5 dB below the permissible exposure limit as a precautionary measure, to protect an additional 10–14% of the workforce from suffering ma-

terial impairment due to noise exposure at those levels (OSHA, 1981).

OSHA regulations allow the audiologist to measure noise either by means of a sound-level meter (for area monitoring, where noise sources are relatively constant) or by means of a noise dosimeter (for personal monitoring, where noise sources are intermittent or variable). The resulting noise levels can be displayed graphically on a plot of the location or in tables to aid in identifying affected workers.

Noise levels need be measured only once (not annually) for a given work environment. Noise levels can be generalized to similar work environments; that is, it is not necessary to measure every noise source for every worker at every location in the plant. OSHA standards allow an employer to generalize noise exposure measurements from one employee to another, provided there is evidence indicating the exposures would be similar.

Audiometric Testing

The protocols for industrial testing differ from clinical testing. For example, a clinical audiometric evaluation complete with air conduction, bone conduction, speech tests, acoustic immittance, and reflexes would be disallowed in an OSHA-standard Hearing Conservation Program if it did not include air conduction thresholds at 3000 Hz and 6000 Hz in both ears—test frequencies required by OSHA regulation.

The basic component of an OSHA-standard audiometric testing program is air conduction testing at 500, 1000, 2000, 3000, 4000 and 6000 Hz. But the simplicity of industrial audiometric testing does not warrant any easing of quality controls. On the contrary, the following points address a few of the more common misconceptions about industrial audiometric testing:

- *Speed versus accuracy.* Because it is volume-intensive, clinical audiologists may view industrial testing akin to a cattle drive—"move 'em in and move 'em out." In reality, clinical audiologists testing in industry can have the tendency to test too quickly. When tone-off times are too brief, the worker who is tested only once a year will often respond with falsely elevated thresholds.
- *Screening only.* OSHA-standard audiometric testing requires the same protocols for threshold determination as clinical testing. Indeed, accurate threshold determination is even more critical in industry. In the clinic, a 10-dB difference between current and past tests may warrant no action. In industrial audiology, a 10-dB difference between current and baseline exams sets into motion a significant chain of events affecting the employee, the employer, OSHA compliance, and follow-up protocols. Since the case history and air-conduction exam are the only tools available in industrial audiology, quality control becomes paramount.
- *Burnout in industrial testing.* The prospect of burnout in industrial audiology is a serious point to consider, as the sheer volume of audiograms can be overwhelming

at times. From my personal experience in private practice, I find solace from the monotony of administering hundreds of air conduction tests by the fact that I am at a new location every day. The variety of the work in industrial audiology becomes tremendous. In a given week, one can test firefighters, lettuce cutters, coin counters, fabric weavers, or metal grinders.

- *Guerrilla audiology.* Because hearing conservation must compete with production time in industry, there is an intense emphasis on getting the job done in a timely manner. Veteran industrial audiologists are prepared for any conceivable breakdown: spare audiometers, spare patch cords and response lights, and a soldering iron and electrical tape need to be within reach. Many mobile testing services route their power cord through an Uninterruptible Power Supply, or "UPS box," to ensure continued power in the event of a power outage or accidental unplugging of the power cord.
- *Limitations of industrial testing.* Throughout the audiometric testing program, the industrial audiologist cannot escape the fact that only the simplest type of testing is being employed—pure-tone air conduction testing. It is unwarranted for the industrial audiologist to make recommendations regarding etiology of hearing loss or potential hearing aid use based solely on the air conduction audiogram.

Industrial audiograms, whether administered on-site or off-site, must go through an expert review to determine the need for audiologic or otologic follow-up and the presence of a standard threshold shift (STS)—a significant decline in an employee's hearing compared to his/her baseline exam. OSHA is specific in defining what constitutes a standard threshold shift in hearing (10-dB average shift at 2000, 3000, and 4000 Hz in either ear, with the optional use of published aging corrections). But OSHA is not so specific in its definition of audiograms needing audiologic or otologic follow-up. Except where some state jurisdictions have set criteria for follow-up (Oregon, for example, sets criteria for medical referrals based on threshold levels), the audiologist is free to use any acceptable criteria for referring problem audiograms.

Because the success of a Hearing Conservation Program hinges on the attitudes of employees toward hearing protection, it is important to inform the employee as much as is practicable about the audiometric results. After being pulled from a production line and sitting in a quiet booth for several minutes, it would be a disservice to tell the employee that he will be informed of the results "only if there is a problem." The typical employee has three pressing questions following the audiometric exam:

1. "What is my hearing like right now?"
2. "Has my hearing gotten any worse since the original test?"
3. "What should I do about it?"

Case studies in Hearing Conservation Programs demonstrate that when the worker receives immediate feedback

answering these three questions following the audiometric test, there is a decline in the rate of standard threshold shifts (STS) and the use of hearing protectors improves dramatically without compulsion from supervisors (Zohar, Cohen, & Azar, 1980; Witt, 1989).

Audiologists reviewing industrial audiograms need to be aware of the distinction between an OSHA STS and Workers Compensation formulas—the two are "apples" and "oranges" (see Appendix A). The OSHA STS is intended to answer the question, "Has this worker lost any critical hearing since the baseline test?" An employee can suffer an STS regardless of whether he/she has normal hearing or a severe hearing loss (see Case Studies in Tables 1 and 2 below). Workers' Compensation formulas for hearing loss, on the other hand, are intended to answer the question, "Does this worker currently have a material hearing impairment?" Workers' Compensation formulas do not consider whether the loss is getting worse or remaining stable.

OSHA compliance and Workers' Compensation liability are independent of one another. Workers may file a claim for hearing loss regardless of whether an effective OSHA-standard Hearing Conservation Program is in place. Compliance with OSHA's Hearing Conservation Amendment by no means absolves an employer from future claims for hearing loss by employees. The disparity between OSHA and Workers' Compensation is best illustrated by the dollar figures of each. In 1986, the average fine paid for an infraction of OSHA's Hearing Conservation Amendment was \$14. In the same year, the average award for a Workers' Compensation claim for hearing loss was \$8,606. In practice, however, an employer's best defense against hearing loss claims will be a continuing, effective OSHA-standard Hearing Conservation Program.

In reviewing audiograms, OSHA regulations make no reference to many critical decisions that are left to the reviewing professional. With the exceptions noted above, there are no criteria for determining which audiograms warrant audiologic or otologic follow-up. There is no reference in OSHA regulations to otoscopic findings. It is also left to the reviewing professional to revise the baseline exam when, in the reviewer's opinion, a threshold decline or threshold improvement is persistent.

It becomes the industrial audiologists's challenge, then, to work with the employer to reduce the amount of noise-induced hearing loss to its most minimal progression. Analysis of the audiometric test results is the best tool to address that challenge.

Hearing Protection

In an OSHA-standard Hearing Conservation Program, a choice of hearing protection must be made freely available to all employees exposed to ≥ 85 dBA. Use of hearing protectors is mandatory for employees working in TWA noise levels > 90 dBA, and likewise required of any employee who has suffered a standard threshold shift, as determined by annual audiometric testing.

In defining the requirement that a "variety" of "suit-

TABLE 1. Case Study 1. Workers' Compensation versus OSHA STS.

	LEFT						RIGHT					
	.5k	1k	2k	3k	4k	6k	.5k	1k	2k	3k	4k	6k
2/5/90	10	5	0	0	0	5	5	10	5	5	0	10
3/9/91	10	5	10	15	10	5	10	10	0	10	5	10

Note. The audiometric data presented here show how OSHA standard threshold shift is independent of Workers' Compensation formulas for hearing impairment. The above employee demonstrates an OSHA STS, even though thresholds are within normal limits clinically.

able" hearing protectors be made available, OSHA inspectors are looking for the following specifics:

- *Variety* means at least one type of earplug and one type of muff protector.
- *Suitable* means a hearing protector that reduces noise exposures below permissible levels, according to the Noise Reduction Rating (NRR) of the protector. Although instructions to inspectors vary by region, most OSHA inspectors will cut the published NRR in half to obtain a real-world estimate of a hearing protector's noise-reducing capabilities.

Fortunately for the industrial audiologist, there is a wealth of information regarding the choice and use of hearing protectors in industrial settings, including advantages and disadvantages of each type and their real-world versus published attenuation data. Much excellent information is available directly from hearing protector manufacturers and suppliers. Other organizations provide objective comparison data on hearing protectors.

As with all personal protective equipment, a host of common myths are associated with hearing protector use. The industrial audiologist must work to dispel these myths, even if they emanate from the lips of corporate safety directors. Some of the most common misconceptions to evolve take form in the following questions:

- Q. Do earmuffs cut out more noise than earplugs?
- A. No. All hearing protectors are required by the EPA to carry a noise reduction rating (NRR). Foam earplugs currently have the highest NRR on the market—about 30 dB of noise reduction when used properly. Most earmuffs carry an NRR of 20–25 dB when used properly.
- Q. How can I hear fellow workers or warning signals if I wear hearing protectors?

A. Generally, hearing protectors improve the signal-to-noise ratio in the workplace, making speech communication much easier when hearing protectors are properly worn.

Q. Can earplugs cause ear infection?

A. "... The likelihood of earplugs causing outer ear infections (otitis externa) is minimal. Although it would seem that placing a dirty or gritty foreign object in the ear canal could easily lead to irritation or infection, the data from existing Hearing Conservation Programs seem to indicate that the external ear is fairly resistant to such abuse. Nevertheless, cleanliness should be stressed and certain individuals such as diabetics or others who are prone to infection should be more carefully monitored.

"When an ear infection is reported, earplugs should not necessarily be assigned the blame. Other causative agents may be excessive cleaning of the ear, recreational water sports, habitual scratching and digging at the ears with fingernails or other objects, environmental contaminants, and systemic conditions such as anemia, vitamin deficiencies, endocrine disorders, and various forms of dermatitis" (Berger, 1983).

Q. Will I double my protection if I wear earmuffs over my earplugs?

A. No. The amount of noise reduction reaches a ceiling point beyond which additional protection is not helpful, because bone conduction of sound cannot be easily attenuated. The combination of earmuffs and earplugs certainly increases the protection from noise, particularly in areas of extreme high noise levels. But the amount of protection is not a doubling of the noise reduction ratings.

Q. If an earplug is inserted too deeply, can it damage the eardrum?

TABLE 2. Case Study 2. Workers' Compensation versus OSHA STS.

	LEFT						RIGHT					
	.5k	1k	2k	3k	4k	6k	.5k	1k	2k	3k	4k	6k
2/5/90	10	15	35	75	80	95	15	20	35	65	70	80
3/9/91	10	15	40	75	90	95	10	20	40	70	75	90

Note. The audiometric data presented here show how compensability for hearing impairment is independent from OSHA STS. The above employee demonstrates a significant loss, compensable according to AAO formula for hearing impairment. There is, however, no OSHA standard threshold shift in hearing.

- A. The question almost becomes moot when we consider that nearly all earplugs are designed to prevent an insertion that would approach the eardrum, and the sensitivity of the ear canal increases as foreign objects approach the eardrum. Workers who insert earplugs deeply into the canal would have a natural reaction of pain or discomfort long before the earplug did any damage to the eardrum itself.

Employee Training

An OSHA-standard Hearing Conservation Program must provide annual training to employees covering the effects of noise on hearing, the use and care of hearing protectors, and the purpose of annual audiometric testing. The training is to be provided to all employees exposed to noise levels ≥ 85 dBA.

Although OSHA's Hearing Conservation Amendment is very flexible in its training requirement (an employer may choose any appropriate medium to train the employee—brochures or booklets, training videos, safety lectures, etc.), an effective program will measure what employees learn. With prevention of hearing loss as the end goal, what is taught in the annual training becomes secondary to what is learned and internalized.

Prevention of noise-induced hearing loss is a loop that starts with the identification of noise at its source and flows through the Hearing Conservation Program, audiometric testing, and program evaluation. But the loop is not closed until the noise-exposed worker is trained in the effects of noise and the precautionary measures to avoid noise exposure.

Record Keeping

When OSHA defined the components of a Hearing Conservation Program in 1983, it proposed an innovative change from most of its safety standards. Instead of applying a published baseline value universally to all employees (as it does for blood lead levels, or toluene exposure levels, for example), it established a baseline for each individual employee. This was a brilliant departure from OSHA's normal pattern of standardized baselines, but for employers and program managers, it was a data management nightmare come true. A foundry with 100 employees has 100 different baselines to reference.

Fortunately, the arrival of computers on the work desk in the 1980s was concomitant with the arrival of the Hearing Conservation Amendment of OSHA. The powerful data management software now available even to computer tenderfoots lightens the burden of managing the records generated from a Hearing Conservation Program.

Although OSHA regulations simply require the maintenance of noise exposure records for 2 years and audiometric records for the duration of employment, our current litigious climate in industry demands that employers maintain noise measurement and hearing conservation records as long as they are in business.

The Business of Industrial Audiology

The question that is posed in most discussions of industrial audiology is inevitable: Is industrial audiology any more lucrative than clinical audiology? Obviously, the answer bears most directly on the fact that most industrial audiologists operate in private practice. But industrial audiologists have no better access to markets than their successful clinical counterparts in private practice. Indeed, access to a successful market is independent of whether the audiologist is clinical or industrial.

As evidenced by ASHA survey statistics indicating that 48% of audiologists are providing hearing conservation services, it is possible to offer services to industry without the significant capital investment of a mobile van or trailer outfitted with all the trappings of on-site testing. Industrial audiology services are often an adjunct to a clinical operation; in many cases, audiologists operate industrial services out of offices within their homes. The following services lend themselves well to the latter type of involvement:

- Noise monitoring and mapping
- Reviewing audiograms
- In-house audiometric testing (for employers/clients who have test booths on location)
- Training
- Hearing Conservation Program management

Summary

It is not difficult to comply with noise regulations or hearing conservation standards in industry, but it is not easy to prevent hearing loss. It requires ongoing effort to implement an industrial Hearing Conservation Program, evaluate its effectiveness, and make additions or adjustments as needed. The result, however, will be a continuing, effective program that does precisely what it is intended to do—conserve hearing.

RESOURCES

ASHA Special Interest Division 8: Hearing Conservation and Occupational Audiology

10801 Rockville Pike
Rockville, MD 20852
(301) 897-5700

- ASHA brochure, *Noise in Your Workplace*
- Variety of brochures and monographs dealing with hearing loss, effects of noise, and hearing conservation.

OSHA

Office of Information & Consumer Affairs
U.S. Department of Labor
200 Constitution Ave., N.W.
Washington, D.C. 20210
(202) 523-8151

- Federal OSHA's Hearing Conservation Amendment (*Federal Register*, March 8, 1983).
- OSHA Publication 3074

National Hearing Conservation Association
900 Des Moines Street, Suite 200
Des Moines, IA 50309
(515) 266-2189

- Public information and referral service for hearing conservation service providers.
- Training guidelines.

Council for Accreditation in Occupational Hearing Conservation

611 East Wells Street
Milwaukee, WI 53202

- Guidelines for training and certification of course directors and occupational conservationist technicians.

National Institute of Occupational Safety & Health
Division of Standards Development

4676 Columbia Parkway
Cincinnati, OH 45226-1998
(800) 35-NIOSH

- Booklet, *A Practical Guide to Effective Hearing Conservation Programs in the Workplace*

Cabot Safety Corporation
7911 Zionsville Road
Indianapolis, IN 46268
(317) 872-1111

- *EAR-Log* technical monographs
- Product samples, posters, brochures
- Annotated list of employee training films available

REFERENCES

- Berger, E. (1983). Responses to questions and complaints regarding hearing and hearing protection, Part I. *EARLog*, 8, Cabot Corporation.
- Occupational Safety & Health Administration (OSHA). (1981). Occupational Noise Exposure; Hearing Conservation Amendment: (29 CFR 1910). *Federal Register*, 46, 4084.
- Occupational Safety & Health Administration (OSHA). (1983). Occupational Noise Exposure; Hearing Conservation Amendment: Final Rule (29 CFR 1910). *Federal Register*, 48, 9738-9784.
- Witt, B. (1989). Immediate feedback in audiometric testing. *Proceedings of the 1989 Industrial Hearing Conservation Conference*. 75-78.
- Zohar, D., & Cohen, A., & Azar, N. (1980). Promoting increased use of hearing protectors in noise through information feedback. *Human Factors*, 22(1), 69-79.

APPENDIX

Formula for OSHA standard threshold shift:

STS is an average shift in either ear of 10 dB or more at 2000, 3000, and 4000 Hz.

Formula for American Academy of Otolaryngology (AAO-HNS) hearing impairment:

1. Obtain average for pure-tone thresholds at 500, 1000, 2000, and 3000 Hz for each ear.
2. Subtract 25 dB (the low fence) from each average. (The 92-dB high fence is the maximum hearing loss to be figured into the computation).
3. Multiply the remainder for each ear by 1.5% to obtain the "Monaural Hearing Impairment" for each ear.
4. To obtain the "Percentage Binaural Impairment," multiply the monaural impairment for the better ear by 5, and add the monaural impairment for the poorer ear; then divide by 6 (i.e., the better ear is given five times the weight of the poorer ear in determining binaural loss).

Chapter 10

AUDIOLOGIC ASSESSMENT OF INFANTS AND TODDLERS

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The assessment of hearing in infants and young children remains one of the most clinically challenging tasks of audiologic practice. Current auditory electrophysiologic procedures, as well as otoacoustic emissions, acoustic immittance measurements, computer-assisted behavioral test procedures, and electroacoustic (real-ear) assessment techniques have gained rapid popularity for use in the evaluation and follow-up of infants, toddlers, and difficult-to-test children. While these newer procedures have facilitated the technical assessment process per se, the role of the pediatric audiologist has not diminished in importance; rather, it has become more critical.

The demands on today's clinician are multiple. The pediatric audiologist must (a) acquire and compile meaningful background information, (b) select the test procedures most appropriate for an individual child, (c) administer (or at least supervise) all assessment procedures, (d) examine the concordance among test outcomes, (e) determine the reliability of the results, (f) assess the validity of the clinical findings, and finally, (g) interpret and convey the outcome to parents and professionals involved in the child's present and future care.

Guidelines for Audiologic Assessment

Unfortunately, while our professional preparation provides academic and practical training in adult audiologic assessment, in general, audiologists receive little specific coursework and a paucity of practicum experience in pediatric audiology (Oyler & Matkin, 1987). Moreover, unless employed by a facility specifically servicing young children, many audiologists assess hearing in infants and toddlers only occasionally rather than in daily practice. With infrequent contacts, there is little chance to gain clinical expertise with the population.

The need for a comprehensive document designed to provide direction and support for clinicians involved in the audiologic assessment of infants and toddlers has been recognized. Recently, the ASHA Committee on Infant Hearing developed the "Guidelines for the Audiologic Assess-

ment of Children from Birth Through 36 Months of Age" (ASHA, 1991) to serve as the basis for a pediatric assessment strategy. The document provides the rationale, the background, the justification, and the ethical, practical, and legislative mandates for such guidelines.

The Guidelines strongly support the use of the test battery approach (Jerger & Hayes, 1976) in the assessment of infants and young children, specifying the auditory brainstem response (ABR), acoustic immittance measurements, and behavioral test procedures as the essential components of the pediatric test armamentarium. In addition, the Guidelines stress (a) the need for timely, accurate, and comprehensive hearing evaluations of infants and young children, (b) the selection of tests and interpretation of data appropriate for the child's developmental age, (c) the need for frequency-specific and ear-specific assessments of auditory function, and, (d) the importance of evaluating speech recognition ability.

Although three assessment procedures compose the assessment battery, only two are recommended for routine use: a behavioral hearing assessment and acoustic immittance measurements. The Guidelines suggest that while the ABR is an extremely useful technique, it is not always necessary in the assessment of every young child when a reliable, frequency-specific behavioral audiologic evaluation can be completed. Moreover, the Guidelines point out that the conventional click-ABR does not meet the requirement of a "frequency-specific" measure and recommend the addition of a 500-Hz tone to assess low-frequency sensitivity.

There are cases for which the ABR would be considered the test of choice for estimating threshold, for example, in infants 4 months of age and younger and in children with severe developmental deficits. Regardless of the ABR outcome, or the age/developmental level of the young child, however, the Guidelines stress that a behavioral assessment of auditory function should be completed routinely.

Whenever possible (usually beginning at about 5 to 6 months of age), operant conditioning procedures are recommended (visual reinforcement audiometry (VRA), or conditioned play audiometry) for frequency-specific

threshold evaluation. When conditioning procedures are inappropriate or unreliable, the Guidelines recommend that the clinician observe the child's auditory behaviors directly and solicit the parents report of their child's hearing ability. The use of traditional behavioral observation audiometry (BOA) (Northern & Downs, 1984) as the sole method of determining threshold sensitivity in very young infants or highly-compromised children is discouraged.

In addition to tests of sensitivity, acoustic immittance procedures (tympanometry and acoustic reflex assessment) are viewed as an integral component of the pediatric test battery. The Guidelines state that while optimum test parameters for acoustic immittance assessment in infants (e.g., probe frequency for tympanometry) remain controversial (Margolis & Shanks, 1990), the routine use of acoustic immittance procedures is recommended during each audiologic visit, irrespective of the age of the child and prior to interpreting behavioral and electrophysiologic estimates of hearing sensitivity. The need to obtain bone conduction thresholds (with behavioral and electrophysiologic procedures) is also suggested, in order that the type of hearing loss can be delineated and the cochlear reserve estimated.

Finally, the Guidelines stress that an assessment is not complete until caregivers and other professionals involved in the case have been informed of the results and habilitation and/or medical plans have been formalized.

At our clinical research facility at the Rose F. Kennedy Center, Albert Einstein College of Medicine, we have developed a test protocol for use in our routine assessment of hearing in infants and young children. Several factors related to the choice and incorporation of test procedures were considered, including (a) the suitability of the procedure to our site, (b) the time/cost versus benefit of the measures, and, (c) the demonstrated reliability and validity of the procedures.

Table 1 presents our standard protocol for infants and

toddlers (based on Gravel & Stapells, 1990). Our facility serves a neuro-developmentally at-risk pediatric population; therefore, the protocol is divided according to chronologic/developmental ages, similar to the categories adopted in the recent ASHA Guidelines. Frequently, a child's developmental level has been determined by formal methods prior to audiologic assessment (Wallace, 1989). Lacking such information, in the case of infants born prematurely, we routinely employ the "corrected age" of the baby when selecting and interpreting test outcomes.

The discussion that follows describes the measures listed in Table 1. These procedures meet our previously mentioned inclusion criteria and are in good agreement with those recommended in the ASHA Guidelines. Although other measures, such as cortical auditory evoked potentials (Kurtzberg, 1989) or otoacoustic emissions (Abdo, Feghali, & Stapells, submitted) may also be used for auditory system evaluation, the "core" of our audiologic assessment is composed of the procedures discussed below.

ABR Evaluation

The specific protocols for the electrophysiologic, frequency-specific assessment of air- and bone-conduction thresholds in infants and toddlers are presented in their entirety in Stapells (1989). Briefly, Stapells suggests that the high-intensity click-ABR be used for the assessment of the integrity of the auditory pathways to the level of the brainstem (i.e., a neurologic assessment). Moreover, he recommends that auditory sensitivity not be estimated from conventional click-ABR thresholds, but determined using frequency-specific (tonal) stimuli. Specifically, a "tones in notched noise" technique is recommended (Stapells, Picton, Perez-Abalo, Read, & Smith, 1985) minimally including 500 Hz and 2000 Hz, and additionally, when possible,

TABLE 1. Preferred pediatric protocol for assessing auditory sensitivity.

For neonates and infants (birth to 3 months chronologic/developmental age):
1. Immittance: Tympanogram and ipsilateral acoustic reflexes (660 Hz)
2. Frequency-specific ABR (ABR ^{FS}): minimally, air-conducted 2000-Hz tones in each ear (normal: 20-30 dB nHL)
3. Neurologic ABR: High-intensity clicks (I & V)
4. If ABR ^{FS} is abnormal, knowledge of middle ear and neurologic status essential
a. Bone-conducted ABR ^{FS}
b. Observe behavioral responses to sound (air and bone-conducted)
For older infants (4 or 5 months-12 months):
1. Visual Reinforcement Audiometry: Frequency-specific stimuli, preferably ear-specific. (Secondarily, responses to speech stimuli): Air-conducted.
2. Immittance: Tympanogram and acoustic reflexes (660/220 Hz).
3. If above abnormal: Bone-conducted behavioral testing.
4. ABR ^{FS} if unable to obtain reliable behavioral responding to frequency-specific stimuli using an operant conditioning procedure after maximum of 2 visits: ABR protocol same as for younger ages.
For toddlers (13 months-30 months):
1. Visual Reinforcement Audiometry (or variant): Frequency-specific stimuli, preferably ear-specific: Air-conducted. (Secondarily, assess speech detection and speech recognition; informally or formally.)
2. Immittance: Tympanogram and acoustic reflexes (220 Hz).
3. If abnormal: Bone-conducted behavioral testing.
4. ABR ^{FS} if unable to demonstrate reliable behavioral responding to frequency-specific stimuli using an operant conditioning procedure after 2 visits: ABR protocol same as younger ages.

Note: Based on Gravel and Stapells (1990).

4000 Hz (Stapells, 1989). This tone-ABR procedure is highly correlated with the pure-tone audiogram in persons with normal hearing and listeners with hearing impairment (Stapells, Picton, Durieux-Smith, Edwards, & Moran, 1990). Other frequency-specific techniques have also been demonstrated to provide reliable audiometric information (e.g., Gorga, Kaminski, Beauchaine, & Jesteadt, 1988).

Although the air-conducted frequency-specific ABR is very useful, it is not sufficient, particularly in pediatric practice. The bone-conducted ABR has now become a routine part of our audiologic assessment armamentarium (Stapells, 1989; Stapells & Ruben, 1989). It has proven to be extremely useful clinically, providing information on both the type of hearing loss, the degree of sensorineural involvement, and in the case of bilateral conductive deficits, a cochlea-specific response (Gravel, Kurtzberg, Stapells, Vaughan, & Wallace, 1989; Stapells, 1989; Stapells & Ruben, 1990; Yang, Rupert, & Moushegian, 1987).

When administered and interpreted appropriately, the frequency-specific and the air- and bone-conducted ABR provide an accurate estimate of auditory sensitivity in the vast majority of our pediatric clinical cases. However, we have found that in some cases of infants with otitis media, the air-conducted ABR significantly overestimates the actual degree of hearing loss caused by the transient middle ear pathology (Gravel et al., 1989; Stapells, 1989; Stapells & Gravel, 1990). While infrequent in occurrence, this finding is clinically relevant, particularly when infants are assessed using ABR alone and without benefit of acoustic immittance assessment and/or pneumo-otoscopic inspection. The ABR threshold elevation seen in some cases of otitis media is greater than that normally considered consistent with conductive disorder alone. Thus, without information to the contrary (such as behavioral thresholds or bone-conducted responses), the clinician could conclude that the hearing loss found on ABR assessment was mixed or sensorineural in type (Gravel et al., 1989; Stapells, 1989; Stapells & Gravel, 1990).

At our facility, an ABR is never completed without some behavioral assessment of auditory function, although the reverse is not always true. The utility of the ABR as a measure of auditory sensitivity is directly related to an infant's or young child's ability to provide reliable behavioral responses to tonal stimuli. Moreover, it is unwise to view the ABR (particularly the conventional click-ABR) as a test of "hearing" in its most global sense. Clinicians frequently may disregard this fact in their haste to accept as valid only "objective" electrophysiologic findings. However, once a clinician has inappropriately diagnosed a case based on a traditional click-ABR alone, the experience is usually sufficiently sobering for the practitioner to arrive at the same conclusion regarding hearing and the ABR (see Gravel et al., 1989; Stapells, 1989).

Acoustic Immittance Measures

Our acoustic immittance procedures presently incorporate the reports of Marchant, McMillan, Shurin, Johnson, Turcyk, Feinstein, and Panek (1986), as well as those of

Holte, Margolis, and Cavanaugh (1991). Specifically, at our facility, admittance tympanograms are obtained from infants under 6 months of age using a 660-Hz probe frequency (Marchant et al., 1986), in addition to the conventional 220-Hz probe stimulus (Holte et al., 1991). A flat (noncompliant or Jerger Type B) tympanogram (in the presence of an unoccluded ear canal) is considered evidence of conductive pathology (otitis media). In our very young babies, should the 220-Hz and 660-Hz tympanograms differ, we presently give greater weight to that obtained using the 660-Hz probe frequency in determining the presence or absence of middle ear dysfunction (Marchant et al., 1986). When the baby's state makes it apparent that only one tympanogram will be obtained, the 660-Hz probe is the frequency of choice. Within this same young infant age group, the presence of ipsilateral acoustic reflexes is examined using a 660-Hz probe frequency only (Marchant et al., 1986).

When an infant or young child is being assessed with both ABR and behavioral audiometry, frequently a "quick" screening tympanogram (220-Hz probe) is obtained prior to the behavioral assessment. We then reserve the more complete acoustic immittance assessment (two-frequency tympanograms and ipsilateral acoustic reflex assessment) until the child is asleep and quiet for ABR assessment.

Behavioral Audiologic Assessment

As previously suggested, there is a tendency among audiologists today to minimize the importance of behavioral assessment in pediatric audiologic practice, or when electrophysiologic procedures are available, to abandon behavioral testing entirely. These circumstances have arisen for several likely reasons. First, the clinician may lack confidence in his or her ability to reliably assess hearing in infants by "subjective" methods. Secondly, the audiologist's past training and experiences may have suggested that infants are incapable of providing "threshold" responses.

Indeed, when appropriate psychometric procedures are used, both observational (Olsho, Koch, Halpin, & Carter, 1987) and conditioning (Wilson & Thompson, 1984) procedures become powerful tools that can be incorporated into routine clinical use. Behavioral methods presently available allow us to reliably delineate normal hearing function, and to assess and monitor the type, degree and configuration of any existing peripheral hearing loss (Bernstein & Gravel, 1990; Diefendorf, 1988; Gravel, 1989). Moreover, suprathreshold procedures allow the evaluation of speech discrimination ability (Eilers, Wilson, & Moore, 1977), frequency (Olsho, 1984) and intensity (Sinnott & Aslin, 1985) discrimination, and higher-order binaural auditory abilities such as speech-in-noise discrimination (Nozza, Rossman, Bond, & Miller, 1990) and release from masking (Nozza, Wagner, & Crandell, 1988).

Of critical importance is the fact that behavioral audiometric test procedures are efficient, safe, and cost-effective. As clinicians, we must consider the reasons we are willing to spend time, effort, and considerable financial investment in electrophysiologic, acoustic immittance, and real-ear measurement equipment, and yet hesitate to de-

vote similar clinical resources toward the improvement of our behavioral procedures, facilities, and equipment.

Visual Reinforcement Audiometry

The behavioral assessment techniques used for infants and young children at our facility are versions of the operant head-turn procedure. Clinically, the audiometric test procedure is known as visual reinforcement audiometry (VRA). It is important to realize that VRA is not a generic term that can be used to refer to any test technique that employs visual reinforcement. The term VRA should be used to designate a specific audiometric test procedure such as described by Wilson and Thompson (1984).

VRA is not a localization procedure. When the infant is rewarded for making a "correct" localization (in the direction of one loudspeaker versus another), the correct term is conditioned orienting response (COR) audiometry. The confusion in terminology appears to arise from the motor response itself, that is, the head turn. Because the same movement is also made when an infant searches for the source of a sound, clinicians tend to equate the two events.

The head turn, however, is merely a motor response appropriate for infants. The act itself is similar to a block-drop during play audiometry, or a hand-raise or button-push during conventional audiometric assessment. The head turn is only the method by which the infant indicates that a sound has been detected.

In the VRA procedure the head turn is brought under stimulus control (operantly conditioned). During the shaping or training phase, the VRA procedure may capitalize on the infant's natural tendency to search for the source of a novel sound. The infant usually turns spontaneously, looking in the direction of the loudspeaker upon the initial presentation of a suprathreshold stimulus (Thompson & Folsom, 1984). Usually the loudspeaker is located directly (approximately 90°) to one side of the baby. Placing the visual reinforcement display close to the loudspeaker allows the clinician to easily "reward" that initial localization response.

However, the spontaneous localization is not necessary to the success of the VRA procedure. Although in normal-hearing infants an initial response usually occurs at low levels (30 dB HL; Thompson & Folsom, 1984), in some cases (as with infants with profound or unilateral hearing loss), a directional response may not occur. If the spontaneous response does not occur after increasing the intensity of the signal, then the clinician must teach the infant the correct response. In addition, the clinician may choose to change the stimulus presentation mode to facilitate shaping such as changing from a soundfield stimulus presentation to a low-frequency bone-conducted signal, or presenting a high-level signal through an earphone (or insert) receiver.

Repeated pairings of an audible (or vibrotactile) stimulus with the activation and illumination of the reinforcement teaches the infant to associate the presence of the stimulus with the availability of visual reinforcement. Shaping is complete when the infant detects the stimulus and turns in anticipation of the reinforcement. Concomitantly, the in-

fant must be taught not to respond when no stimulus is present. For a reliable VRA assessment, both conditions are equally important (Bernstein & Gravel, 1990).

Once the association is learned, regardless of the mode of stimulus presentation (soundfield speaker, earphone, bone oscillator), the response contingencies remain the same (stimulus, response, reward; no stimulus, response, no reward) as does the response itself (a uni-directional head turn towards the reinforcement display). When a change is made to a different transducer (i.e., earphone, bone oscillator), usually all that is required is that the infant is reacquainted with the "correct" response.

Clinicians frequently ask if this means that our facility has only one visual reinforcement display. A single display unit (housing three separate toys) located in one corner of the test suite is utilized exclusively for both our clinical and computer-controlled VRA procedures. However, a second visual reinforcement unit (located in an adjacent corner) is available for use in a forced-choice discrimination paradigm (Bernstein, 1989). During VRA procedures, the second display unit is hidden from the infant's view. Such an arrangement (two displays, one out of view) could allow the clinician interested in maintaining the availability of two reinforcement units for COR audiometry to do so. It is recommended, however, that thresholds be obtained with VRA prior to exploring localization abilities. (See Gravel, 1989, for a complete description of the facilities, test suite arrangement, and the modifications incorporated.)

Optimizing the Clinical VRA Procedure

Whether the clinician is using a manual test technique or a VRA procedure assisted by a logic system or computer, the following factors should be considered when attempting to optimize audiometric information: (a) reducing bias, (b) increasing attention and motivation, and, (c) decreasing the false-alarm rate. (See Eilers, Miskiel, Ozdamar, Urbano, & Widen, 1991, for an excellent discussion of other factors that increase the efficiency and accuracy of the VRA procedure.)

Reducing bias. The most important way to reduce observer bias is with the inclusion of catch trials (non-signal, control trials) into the VRA procedure. Regardless of whether the assessment is accomplished manually or is assisted by a logic system or computer, catch trials are critical. When the VRA procedure is computer-assisted, catch trials can be programmed to occur randomly during the threshold search with whatever frequency the clinician feels appropriate (Bernstein & Gravel, 1990; Eilers et al., 1991).

When using either a single-examiner or two-examiner manual VRA procedure, a recording form that provides for both signal and catch trials is appropriate. The use of a simple recording form serves to maintain a response record and provides a schedule for the examiner to deliver control trials randomly throughout the threshold search. An example of such a form is presented as an Appendix.

Examination of the infant's responses during catch trials helps to determine the degree of confidence that can be

placed in the behavioral result. A high false-alarm rate (usually greater than 25%) indicates that the infant was not under stimulus control; that is, the infant had not learned the response contingencies and was essentially randomly turning towards the reinforcers during the threshold search. In this case, the audiologist can have little confidence that the obtained threshold reflects true hearing sensitivity (Bernstein & Gravel, 1990; Eilers et al., 1991).

When computer-assisted, VRA can be bias-free even when a single examiner is used, as in the ISP (Interweaving Staircase Procedure, Bernstein & Gravel, 1990) and IVRA (Intelligent VRA, Intelligent Hearing Systems, Inc.) procedures. The computer controls the trial type and delivers a signal that marks the onset and duration of a trial and masks the examiner as to trial type. Through a foot-switched interface with the computer, the examiner indicates when a head-turn response occurs during a trial. The computer delivers reinforcement only when a response is made during a signal trial.

The use of catch trials to reduce bias is also critical during manual VRA. Using two audiologists to assess infants can be justified only when the examiner responsible for distracting the infant (located inside the test suite) is unaware of whether a signal or control trial is being presented. This can be easily accomplished by having the test-examiner mark the onset and duration of every trial (both signal and catch) with white noise (presented through headphones). This trial marker should be sufficiently loud to mask test signals presented to the infant. The delivery of reinforcement is made only when the infant responds appropriately during a signal trial, determined from the vote of the unbiased examiner. Unless the examiner in the booth with the infant is "deafened" as to trial type, two-person testing has the same degree of bias as a single-examiner manual VRA procedure.

The possible bias introduced by the parent holding the infant during testing must also be considered. Ideally, the parent wears earphones through which masking (taped music) is delivered. Thus the parent cannot provide any cue to the infant. Some clinicians, however, are reluctant to mask the parent during audiologic assessment, feeling that the parent should have knowledge of both the level and frequency of the sounds to which the infant is, or is not, responding. This awareness, they feel, facilitates the counseling process.

Increasing attention and motivation. Sufficient audiologic data can be obtained with VRA only when the infant continues to respond over repeated trials. Ideally, if air-conducted thresholds can be obtained at 500, 2000, and 4000 Hz in each ear and unmasked bone-conduction thresholds assessed at the same frequencies, the audiologist would have ample information on which to base follow-up strategies. Thus, it is critical that the infant's attention and motivation are high throughout the test session.

Several methods have been suggested to optimize and monitor attention and motivation during VRA assessment. First, increasing the novelty of the reinforcement serves to maintain the attention of the infant (Trehub & Schneider, 1984; Wilson & Thompson, 1984). This can be accomplished by using several animated and illuminated toy rein-

forcers that are out of view (behind dark smoked Plexiglas) except during periods of reinforcement (see Gravel, 1989, for an example of such a visual display unit).

Other ways to increase attention include shortening the reinforcement period (Culpepper, 1990a), changing the response task (during play audiometry, Thompson, Thompson, & Vethivelu, 1989), or changing the stimulus (as from warble tone to narrow band noise, Culpepper, 1990b). Primus (1988) suggests that signaling the approach of a trial (as in telling the child to listen) increases attention to the task. Finally, a break in the session, during which the toy reinforcers are changed, has frequently proven to be beneficial at our facility.

Bernstein and Gravel (1990) have suggested monitoring the infant's attention and motivation during a computerized VRA procedure by the inclusion of high-level probe trials during the threshold search. Examining the infant's rate of response to the probe trials during the test session allows the audiologist to determine whether the child was equally attentive at the beginning, middle, and end of the threshold search.

Decreasing the false alarm rate. As discussed previously, a high false alarm rate is a problem during VRA assessment. When we obtain a high rate of false alarms during a threshold search, we first attempt to retrain the infant on the response contingencies. Increasing the number of unrewarded catch trials during the reshaping phase, as well as increasing the novelty of the toy used to keep the infant's attention at the midline position, may be beneficial.

Indeed, it could be the case that the false alarm rate is high because the stimulus used to condition the child was not audible. That is, the infant never learned the response contingency because he or she was never aware of the stimulus. This possibility, of course, is always of concern to the pediatric audiologist who frequently examines young children with hearing loss. As suggested previously, determining whether the infant provides reliable responses when a low-frequency bone-conducted (vibrotactile) signal or a higher-intensity air-conducted signal is presented can provide valuable information as to the reason behind a high false alarm rate.

Obtaining Ear-Specific Thresholds

Ear-specific responses can be accomplished using behavioral test procedures. It appears that clinicians have a misconception regarding their ability to obtain ear-specific thresholds from young infants. In a recent review of our clinical and research records (Gravel & Traquina, in press), over 80% of infants between 6 months and 24 months of age provided ear-specific thresholds using conventional earphone presentation (TDH-49 earphones, MX-41/AR cushions with padded infant headband). Generally, preparing the parent, readying the reinforcers, and persistence are rewarded. It is important to note that the age group with which we were least successful in obtaining ear-specific responses was the 20- to 24-month-olds. Not surprisingly, it is less of a problem to obtain ear-specific responses from infants than from toddlers.

TABLE 2. Test results required before fitting amplification (under 4 months).

For NICU infant:	
1.	Outcome of ABR air and bone conduction: Reliable results at least two test visits, one after the age of 3 months CA in the absence of middle ear involvement
2.	Consistent findings by behavioral assessment (for air and bone conduction)
3.	Consistent immittance (typanometry and acoustic reflex)/otoscopy findings
4.	In process of clearance by ENT (includes CT, bloods, ENG with fistula tests, ophthalmologic exam)
5.	Provisions for habilitation/follow-up program/plan
For infant with bilateral atresia (cranio-facial):	
1.	Outcome of ABR ^{FS} air and bone conduction at earliest exam
2.	Provisions for habilitation/follow-up program
For healthy, full-term neonate with familial history of hearing loss:	
1.	Outcome of ABR ^{FS} air and bone conduction: Reliable results at two test visits in the absence of middle ear involvement
2.	Consistent findings by behavioral assessment (air and bone conduction)
3.	Consistent immittance (typanometry and acoustic reflex)/otoscopy findings
4.	In process of clearance by ENT (includes CT, bloods, ENG with fistula tests, ophthalmologic exam)
5.	Provisions for habilitation/follow-up program/plan.

Note: Based on Gravel and Stapells (1990).

More recently, we have had similar if not somewhat better results using insert receivers (EAR-3A) with pediatric eartips. However, in our experience infants and toddlers who vehemently refuse earphones generally treat insert receivers with the same degree of respect.

Recommendations for Amplification

Frequently, we are asked when it is appropriate to fit amplification to infants, that is, how soon we feel comfortable fitting hearing aids and what criteria are used to make that decision. Table 2 presents the information required before fitting amplification to infants under 4 months of age (based on Gravel & Stapells, 1990). These recommendations are based on our experience with a high-risk population, the majority of whom had highly compromised courses in the neonatal intensive care unit (NICU) resulting from very low birthweight (<1500 grams), severe perinatal asphyxia, and/or who required prolonged mechanical ventilation. Note that our criteria differ for NICU infants than for infants born with a specific craniofacial malformation (bilateral atresia), or for healthy fullterm babies suspected of having familial, congenital hearing loss.

We feel this somewhat conservative approach to amplification recommendation is justified with a high-risk population. While the early identification of hearing loss is critical, it is equally true that a thorough and accurate assessment of hearing (as we have previously defined it) is imperative before parents are counseled and habilitation is initiated. We find this entire process to be more of a problem in an NICU population, as well as in infants who experience a high incidence of middle ear involvement. Often our initial findings are modified in the early months of life (postterm and following discharge from the NICU). For example, the stability of the ABR is best at about 3 months to 4 months corrected age (Stapells, 1989; Durieux-Smith,

Picton, Edwards, MacMurray, & Goodman, 1987). Thus, we do not advocate the diagnosis of hearing loss or fitting of amplification during the NICU period. The goal of completing a thorough audiologic assessment, amplification selection, evaluation, and the initiation of an early intervention program (Joint Committee on Infant Hearing, 1991) can still be accomplished in a timely manner.

In summary, the audiologic assessment of infants and toddlers has been facilitated for the pediatric audiologist by recent technologic advances in auditory electrophysiology, acoustic immittance measure procedures, and behavioral audiometric techniques. Although progress has been significant, it is still the careful, thoughtful, highly trained, and knowledgeable clinician who must incorporate the procedures into a comprehensive audiologic assessment.

REFERENCES

- Abdo, M.H., Feghali, J.G., & Stapells, D.R. (1991). *Transient evoked otoacoustic emissions: Clinical applications and technical considerations*. Manuscript submitted for publication.
- American Speech-Language-Hearing Association. (1991). Guidelines for the audiologic assessment of children from birth through thirty-six months of age. *Asha*, 33 (Suppl. 5), 37-43.
- Bernstein, R. (1989, February). *Choice discrimination learning in infants*. Paper presented at the Association for Research in Otolaryngology, St. Petersburg, FL.
- Bernstein, R.S., & Gravel, J.S. (1990). A method for determining hearing sensitivity in infants: The interweaving staircase procedure (ISP). *Journal of the American Academy of Audiology*, 1, 138-145.
- Culpepper, B. (1990a, November). *Effects of reinforcer duration on habituation rates of preterm 2-year-olds*. Presented at the Convention of the American Speech Language Hearing Association, Seattle.
- Culpepper, B. (1990b, November). *Post-habilitation response recovery of preterm 2-year-olds in VRA*. Presented at the Convention of the American Speech Language Hearing Association, Seattle.
- Diefendorf, A.O. (1988). Behavioral evaluation of hearing-im-

- paired children. In F.H. Bess (Ed.), *Hearing Impairment in Children*. Parkton, MD: York Press, 133-151.
- Durieux-Smith, A., Picton, T.W., Edwards, C.G., MacMurray, B., & Goodman, J.T. (1987). Brainstem electric-response audiometry in infants of a neonatal intensive care unit. *Audiology*, 26, 284-297.
- Eilers, R.E., Miskiel, E., Ozdamar, O., Urbano, R., & Widen, J.E. (1991). Optimization of automated hearing test algorithms: Simulations using an infant response model. *Ear and Hearing*, 12, 191-198.
- Eilers, R.E., Wilson, W.R., & Moore, J.M. (1977). Developmental changes in speech discrimination in infants. *Journal of Speech and Hearing Research*, 20, 766-780.
- Gorga, M., Kaminski, J.R., Beauchaine, K.A., & Jesteadt, W. (1988). Auditory brainstem responses to tone bursts in normally hearing subjects. *Journal of Speech and Hearing Research*, 31, 87-97.
- Gravel, J.S. (1989). Behavioral assessment of auditory function. *Seminars in Hearing*, 10, 216-228.
- Gravel, J.S., Kurtzberg, D., Stapells, D.R., Vaughan, H.G., & Wallace, I. (1989). Case studies. *Seminars in Hearing*, 10, 272-290.
- Gravel, J.S., & Trequina, D. (in press). Experience with the audiologic assessment of infants and toddlers. *International Journal of Pediatric Otorhinolaryngology*.
- Gravel, J.S., & Stapells, D.R. (1990). *Preferred pediatric protocol for assessing auditory sensitivity*. Presented at the American Academy of Audiology Convention, New Orleans.
- Holte, L., Margolis, R.H., & Cavanaugh, R.M. (1991). Developmental changes in multifrequency tympanograms. *Audiology*, 30, 1-24.
- Jerger, J., & Hayes, D. (1976). The cross-check principle in pediatric audiometry. *Archives of Otolaryngology*, 102, 614-620.
- Joint Committee on Infant Hearing. (1991). 1990 position statement. *Asha*, 33 (Suppl. 5), 3-6.
- Kurtzberg, D. (1989). Cortical event-related potential assessment of auditory system function. *Seminars in Hearing*, 10, 252-261.
- Marchant, D., McMillan, P., Shurin, P., Johnson, C., Turcgyk, V., Feinstein, J., & Panek, D. (1986). Objective diagnosis of otitis media in early infancy by tympanometry and ipsilateral acoustic reflex thresholds. *Journal of Pediatrics*, 102, 590-595.
- Margolis, R., & Shanks, J. (1990). Tympanometry: Basic principals and clinical applications. In W. Rintelmann (Ed.), *Hearing assessment* (2nd ed) (pp. 179-245). TX: ProEd.
- Northern, J.L., & Downs, M.P. (1984). *Hearing in children* (3rd ed). Baltimore: Williams & Wilkins.
- Nozza, R.J., Rossman, R. Bond, L., & Miller, S. (1990). Infant speech-sound discrimination in noise. *Journal of the Acoustical Society of America*, 87, 339-350.
- Nozza, R.J., Wagner, E.F., & Crandell, M.A. (1988). Binaural release from masking for a speech sound in infants, preschoolers, and adults. *Journal of Speech and Hearing Research*, 31, 212-218.
- Olsho, L.W. (1984). Infant frequency discrimination. *Infant Behavior and Development*, 7, 27-35.
- Olsho, L.W., Koch, E.G., Halpin, C.F., Carter, E. (1987). An observer-based psychoacoustic procedure for use with young infants. *Developmental Psychology*, 23, 627-640.
- Oyler, R., & Matkin, N. (1987). National survey of educational preparation in pediatric audiology. *Asha*, 29, 27-33.
- Primus, M. (1988). Infant thresholds with enhanced attention to the signal in visual reinforcement audiometry. *Journal of Speech and Hearing Research*, 31, 480-484.
- Sinnott, J.M., & Aslin, R.N. (1985). Frequency and intensity discrimination in human infants and adults. *Journal of the Acoustical Society of America*, 78, 1986-1992.
- Stapells, D. (1989). Auditory brainstem response assessment of infants. *Seminars in Hearing*, 10, 252-261.
- Stapells, D.R., & Gravel, J.S. (1990, February). *Tone-ABR and behavioral thresholds from infants with normal middle ear status or conductive involvement*. Paper presented at the Association for Research in Otolaryngology, St. Petersburg, FL.
- Stapells, D.R., Picton, T.W., Durieux-Smith, A., Edwards, C., & Moran, L. (1990). Thresholds for short-latency auditory evoked potentials to tones in notched noise in normal-hearing and hearing-impaired subjects. *Audiology*, 29, 262-274.
- Stapells, D.R., Picton, T.W., Perez-Abalo, M., Read, D., & Smith, A.D. (1985). Frequency specificity in evoked potential audiometry. In Jacobson, J. (Ed), *The auditory brainstem response* (pp. 147-177). San Diego: College Hill Press.
- Stapells, D.R., & Ruben, R.J. (1989). Auditory brainstem responses to bone-conducted tones in infants. *Annals of Otolaryngology, Rhinology, and Laryngology*, 98, 941-949.
- Thompson, G., & Folsom, R.C. (1984). A comparison of two conditioning procedures in the use of visual reinforcement audiometry (VRA). *Journal of Speech and Hearing Disorders*, 49, 241-245.
- Thompson, M., Thompson, G., & Vethivelu, S. (1989). A comparison of audiometric test methods for 2-year-old children. *Journal of Speech and Hearing Disorders*, 54, 174-179.
- Trehub, S.E., & Schneider, B.A. (1984). A normative picture of infant auditory development. *Seminars in Hearing*, 5, 1-7.
- Wallace, I.F. (1989). Role of developmental evaluations in assessing auditory system function. *Seminars in Hearing*, 10, 262-271.
- Wilson, W.R., & Thompson, G. (1984). Behavioral audiometry. In J. Jerger (Ed.), *Pediatric audiology*, (1-44). San Diego, CA: College-Hill Press.
- Yang, E.Y., Rubert, A.L., & Moushegian, G. (1987). A developmental study of the bone conduction auditory brain stem response in infants. *Ear & Hearing*, 8, 244-251.

APPENDIX

Sample test form for use during VRA assessment:

Name: _____

Date: _____

Age: _____

Examiner: _____

Test Frequency: _____ Hz

Threshold: _____ dB HL

Start Level: _____ dB HL

Step Size: _____ dB

FA#/C# = _____ %

<i>Level</i>	<i>Response</i>	<i>Level</i>	<i>Response</i>	<i>Level</i>	<i>Response</i>	<i>Level</i>	<i>Response</i>
___	1. S ___	___	11. C ___	___	21. C ___	___	31. S ___
___	2. S ___	___	12. C ___	___	22. S ___	___	32. C ___
___	3. S ___	___	13. S ___	___	23. S ___	___	33. S ___
___	4. C ___	___	14. S ___	___	24. C ___	___	34. S ___
___	5. S ___	___	15. S ___	___	25. S ___	___	35. S ___
___	6. C ___	___	16. S ___	___	26. S ___	___	36. S ___
___	7. S ___	___	17. C ___	___	27. C ___	___	37. S ___
___	8. S ___	___	18. S ___	___	28. S ___	___	38. C ___
___	9. S ___	___	19. S ___	___	29. S ___	___	39. S ___
___	10. S ___	___	20. S ___	___	30. S ___	___	40. S ___

Key: + = Hit - = Miss FA = False Alarm CR = Correct Rejection

Comments:

(75% signal trials; 25% catch trials w/o signal.)

Chapter 11

APPROACHES TO SELECTION AND FITTING OF AMPLIFICATION FOR INFANTS AND TODDLERS

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Implicit in the goal of early identification of hearing loss is the early initiation of habilitation and amplification. The focus of this paper is to address three areas related to amplification of hearing-impaired infants and toddlers (birth to 18 months): identification issues as they relate to early amplification, selection of amplification, and assessment of aided function.

IDENTIFICATION ISSUES

The Goal of Early Identification of Hearing Loss

The Joint Committee on Infant Hearing (JCIH) supports the early identification of hearing loss and initiation of early intervention services (ASHA, 1991). The current recommendation is to screen the hearing of at-risk neonates (birth to 28 days) by 3 months of age and to have diagnostic ABR testing completed no more than 6 months later. Infants (29 days to 2 years) who are found to have a risk factor should be tested as soon as possible after the identification of the risk factor, or at least within 3 months after the factor has been identified.

The justification for early identification of hearing loss is two-fold. First, the notion of critical periods for language acquisition is well accepted. Second, animal studies support the notion that lack of input to the auditory system may result in physiological and/or pathological changes in the auditory nervous system (for a review, see Ross & Seewald, 1988).

The statistics on early identification of hearing loss show variable results, and, in general, suggest that we have not fulfilled our goal. Reports over the past 5 years suggest that the average age of identification varies from 7.6 months to 19.0 months of age (Elssmann, Matkin, & Sabo, 1987; Mace, Wallace, Whan, & Stelmachowicz, in press; Mahoney & Eichwald, 1986; Stein, Jabaley, Spitz, Stoakley, & McGee, 1990). Mace et al. (in press) reported a wide age range for identification of hearing loss depending on the degree of loss. In general, children with moderate losses or

greater were identified before 2 years of age. Thus, most of the infants and toddlers currently fit with amplification will have at least a moderate hearing loss.

The definition of educationally significant hearing loss has expanded in the past 10 years to include those with mild and unilateral hearing loss (Bess, 1985; Bess & Tharpe, 1986; Blair, Peterson, & Viehweg, 1985; Oyler, Oyler, & Matkin, 1987). Recent data suggest that these children typically are not identified until they are older than 4 years of age (Mace et al., in press), well beyond the infant and toddler years.

Impact of Technology

Technological advances have affected early fitting of amplification on two levels: testing options and amplification devices. The effect on testing options will be discussed first.

Current technology has affected both our ability to identify hearing loss and to measure aided status. For example, the use of auditory brainstem response (ABR) testing in the intensive care nursery has enhanced our ability to provide early diagnosis of hearing loss. Also, there is some promise in the use of evoked otoacoustic emissions (OAE) for use in the identification of hearing loss (Bray & Kemp, 1987). Aided testing with probe-tube microphone systems has furthered our ability to provide reliable measures of insertion and in situ gain and real-ear estimates of SSPL90.

Inroads also have been made in amplification systems. One of the most visible effects has been a reduction in the size of ear-level instruments, which are the devices most commonly fit on young children (Martin & Gravel, 1989). In small children, this can enhance retention of the device. In some cases, it also may enhance the parent's acceptance of the device. Improvements have been made in the increased flexibility of amplification devices, including hearing aids and auditory trainers. This flexibility is further increased with the availability of the special purpose Etymotic (e.g., low-pass, notch-filtered) and other filtered tone hooks. There also are other options available to improve

retention of ear-level devices (e.g., Huggie aids and smaller tone hooks). With the advent of the tamper-proof battery compartment, safety issues have begun to be addressed. Computerized preselection systems have had an effect on adult hearing aid fittings, and by the end of 1991, a computerized preselection system for young children may be commercially available (Seewald, personal communication). Advanced circuitry (e.g., automatic signal processing, other noise-reduction circuits and the Etymotic K-amp) has been employed in some devices with adult patients, but their efficacy for use with infants and toddlers has not been established.

SELECTION AND FITTING OF AMPLIFICATION SYSTEMS

Key Considerations in Pediatric Amplification

When selecting amplification for infants and toddlers, there are both acoustical and practical issues to consider. Because modifications may need to be done as more information about the residual hearing becomes available or if the child experiences fluctuating hearing loss, it is important to choose a device that has flexible electroacoustic characteristics. The device should also be compatible with a variety of tone hooks to further enhance its flexibility.

The additive advantages of directional microphones and binaural fitting have been demonstrated (Hawkins & Yacullo, 1984) and should be considered essential for pediatric fittings. The availability of direct audio input is important given the likelihood that the child will use an auditory training device in the habilitation program. For this same reason, the telecoil strength should be a consideration in the event that the child will use an auditory trainer with a neck loop.

On a practical level, tamper-resistant battery compartments can improve the safety of the fitting in this age group. Regardless of whether this safety device is used, the parents should be provided with hearing aid battery precautions and the National Battery Ingestion Hotline number. Volume control covers can be used to ensure that the recommended setting is maintained. Loss and damage warranties should be considered, and the parents should be encouraged to insure the devices after the manufacturer's warranty expires.

Formula Approaches for Fitting Gain and Output

For young children, the use of formula or prescriptive approaches for fitting gain and output is essential. In most cases, the goal is to ensure that speech is audible within the patient's dynamic range (Skinner, 1988; Skinner, Pascoe, Miller, & Popelka, 1982). A critical consideration in using any formula approach is to keep the fitting goal in mind. The long-term speech spectrum used to define average conversational speech affects the extent to which a fitting is viewed as successful. Variations in the speech spectrum are

accounted for by gender, age, distance, how the measurement is made, and what stimulus is used to generate the speech signal (Cox & Moore, 1989; Olsen, Hawkins, & Van Tasell, 1987). Cornelisse, Gagne, & Seewald (1991) evaluated the speech spectrum of various talkers at a reference position (30 cm and 0° from the mouth) and at the tragus of the talker. They observed that at the tragus, more low frequencies and fewer high frequencies were measured than at the reference position. They suggested that we must remember that the speech spectrum delivered to the ear is different if the patient is a listener versus a talker and that we need to think of the patient as a communicator as well as a listener. The talker's ability to monitor his or her own speech also must be considered as critical.

Various speech spectra have been characterized on dB SPL and dB HL audiograms (Olsen et al., 1987; Skinner, 1988). Recently, Mueller & Killion (1990) proposed using a simplified method to calculate an Articulation Index (AI), shown in Figure 1, that can be used for decision-making and for patient counseling. The AI has been used to predict the intelligibility of speech (e.g., Dirks, Bell, Rossman, & Kincaid, 1986; Pavlovic, 1988, 1989).

Humes & Hackett (1990) and Sullivan, Levitt, Hwang, and Hennessey (1988) have shown that comparisons between adult prescriptive approaches suggest no major differences in aided speech scores. Thus, to date, no adult formula approach clearly has been shown to be superior.

There is some question that these adult formulas cannot simply be applied to infants and toddlers because of the many differences between these two groups. Perhaps the primary difference is that infants and toddlers are learning speech and language and may require a better signal-to-noise ratio or greater input than an adventitiously hearing-impaired adult. Further, the substantially smaller ear-canal

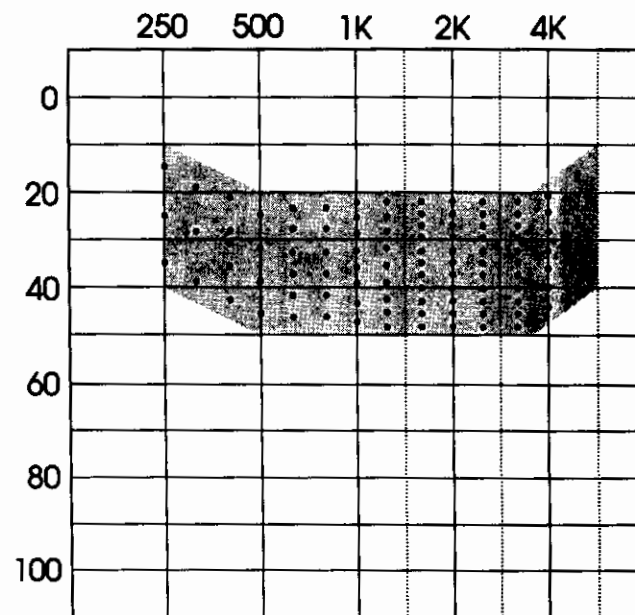


FIGURE 1. The count-the-dot audiogram for calculation of an Articulation Index (AI) (Mueller & Killion, 1990).

size has several ramifications. First, it may affect the SPL delivered to the ear (Feigin, Kopun, Stelmachowicz, & Gorga, 1989). Secondly, it has been shown that the resonance frequency of the ear canal in children below 2 years of age is higher than in an adult (Kruger, 1987). Further, the size of the infant/toddler ear also can affect the earmold fitting such that on the smallest ears, even a tube fitting may actually occlude the entire canal. Thus, most modifications in this population must be made electroacoustically rather than with earmold modifications. In this age group, we often have less threshold information and little, if any, speech recognition information. It is not possible to measure most comfortable loudness (MCL) or loudness discomfort levels (LDL). Thus, fittings must be based on threshold data alone. Infants and toddlers have limited abilities for communicating their reactions to amplification. Consequently, we must be able to troubleshoot systematically their reactions to amplification. We must step through possible problems, from fit and comfort of the earmolds to the fit or function of the hearing aids.

Two threshold-based approaches for fitting amplification that are specific to children will be discussed next. The first is the optimal aided audiogram that has been popularized by Matkin (1987). The target aided thresholds are shown in Table 1. The rationale for these targets is to provide aided thresholds within the average conversational speech spectrum, with 5 dB of reserve gain. It should be noted that these targets are not intended for profound losses, where the goal may be altered to the detection of speech.

The second pediatric approach is the desired sensation level (DSL) approach, proposed by Seewald, Ross and colleagues (Ross & Seewald, 1988; Seewald, 1988; Seewald, Ross, & Spiro, 1985; Seewald, Ross, & Stelmachowicz, 1987; Stelmachowicz & Seewald, 1991). The goal of this fitting procedure is to deliver an amplified speech signal to the child that maximizes residual hearing across frequency (Ross & Seewald, 1988). The recommendations for the amplified desired sensation level of speech are shown in Figure 2. Note that the desired sensation level varies as a function of degree of hearing loss on a frequency-by-frequency basis. This approach provides targets to accommodate any given hearing loss.

Both of these pediatric approaches have recommendations for SSPL90 that vary with the degree of hearing loss and are based on average expectations. Previous research has shown that LDLs vary with frequency and cannot be predicted from threshold (Hawkins, Walden, Montgomery, & Prosek, 1987; Kawell, Kopun, & Stelmachowicz, 1988). Work with children has provided reliable methods to estimate LDLs in children as young as 5 years mental age (Macpherson, Elfenbein, Schum, & Bentler, in press). There are

no proven solutions, however, for obtaining LDLs in children younger than 5 years of age. If we are unable to make real-ear measures, we must depend on average values for real-ear to coupler differences, and to use these values to estimate and select real-ear SPL (Feigin et al., 1989). Careful observation of the child's behavior for loudness intolerance is critical, and thresholds must be monitored for possible changes.

For infants and toddlers, decisions about electroacoustic characteristics often must be made with minimal information. Limited behavioral test data must be supplemented with the behavioral observations of parents and teachers and with evoked potential test findings. ABR testing with clicks alone is not a solution to the problem of limited threshold information because the click-evoked ABR estimates only a limited frequency region. For this reason, click-evoked ABRs should be supplemented with tone-evoked ABRs (Gorga, Kaminski, Beauchaine, & Jesteadt, 1988; Stapells, Picton, Perez-Abalo, Read, & Smith, 1985). These tone-evoked ABR thresholds can be used to estimate behavioral thresholds.

Facilitating Adjustment to Amplification

One aspect of facilitating adjustment to amplification is addressed through communication with the parents, caregivers, and therapists. They should be trained to troubleshoot and care for the devices. To do so effectively, they should be provided with the necessary information and tools (e.g., a listening tube or stethoscope, a battery tester, an earmold blower, extra batteries, and a moisture-reduction device). Close contact with the parents, caregivers, and therapists during the initial phases of fitting assists in monitoring progress, and encouragement can be provided. With this close communication, fitting expectations can be compared with the child's performance, questions and issues addressed, and intervention strategies that enhance auditory skill development can be developed.

Audiologic follow-up visits are planned at frequent intervals to monitor thresholds, to ensure adequate adjustment to amplification, and to change settings on the hearing aid as new information is acquired. Some investigators have suggested that infants and toddlers be seen at least every 3 months for audiological assessment (Matkin, 1987; Stelmachowicz, Larson, Johnson, & Moeller, 1985).

Recent Expansions

Two recent expansions in fitting amplification have been in the areas of fitting children with unilateral hearing loss and the home use of auditory trainers. Because the focus of this discussion is on infants and toddlers, we will not discuss unilateral hearing losses because, as noted above, these are not often identified prior to 4 years of age (Mace et al., in press).

Infants and toddlers may be candidates for the home use of auditory trainers. Some centers have used auditory trainers in this application as the primary and initial device

TABLE 1. Optimal aided thresholds (Matkin, 1987).

	Frequency (Hz)				
	250	500	1000	2000	4000
db HL	30	30	25	20	20

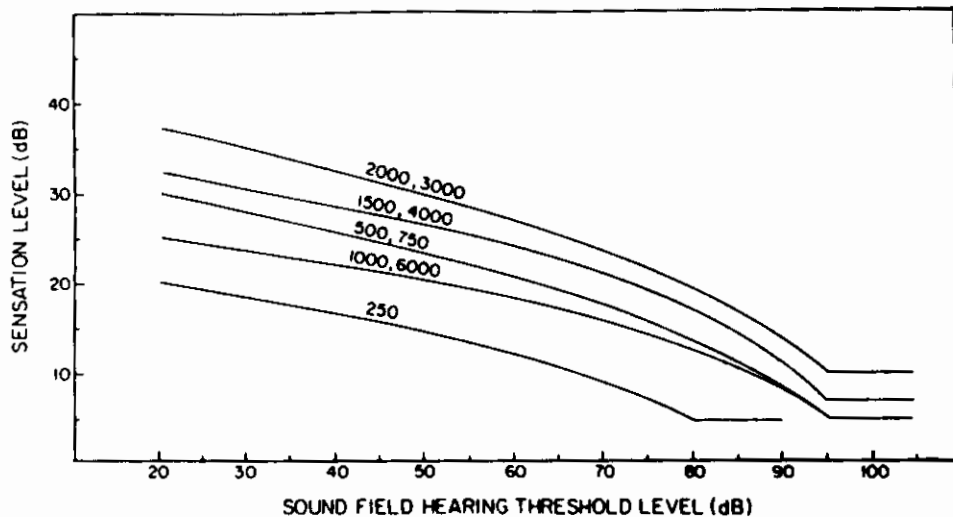


FIGURE 2. The desired sensation levels (DSL) for the amplified long-term speech spectrum. Levels are plotted as a function of sound field thresholds and frequency (Seewald & Ross, 1988).

for children with severe to profound losses. Benoit (1989) reported on a group of 1- to 4-year-olds with severe, profound hearing loss who were fit with auditory trainers for home use. The parents in that study reported that use of the device increased the amount that they talked to their child. They also reported that the microphone-transmitter acted as a reminder to talk to their child. However, there was no actual testing done on the children in this study to evaluate changes in their speech, language, or auditory skills. More research in this area is necessary to delineate further the efficacy of home use of these devices.

ASSESSMENT OF AIDED PERFORMANCE

Behavioral Methods

Behavioral and objective methods for assessment of aided performance will be discussed next. In the area of behavioral methods, functional gain has been used to estimate insertion gain. The reliability of aided sound field thresholds and functional gain has been addressed in adults (Hawkins, Montgomery, Prosek, & Walden, 1987; Humes & Kirn, 1990) and children as young as age 5 years (Stuart, Durieux-Smith, & Stenstrom, 1990); however, the reliability of aided sound field thresholds for infants and toddlers has not been studied. Functional gain or aided sound field thresholds can be used in cases when probe-tube microphone measures are not possible, for example, when there is limited cooperation for probe-tube microphone measures, when there is wax or slight drainage in the ear canal, in cases of atresia or stenosis, in the assessment of a bone-conduction device, and if there is limited access to probe-tube microphone equipment. The limitations of functional gain as compared to probe-tube microphone measures include the fact that measures are not valid if there are re-

gions of normal sensitivity (Rines, Stelmachowicz, & Gorga, 1984). Behavioral methods are more time-consuming and provide only threshold information, with no estimate of aided performance for speech-level inputs or hearing aid maximum output.

Objective Methods

Two objective methods will be discussed: probe-tube microphone measures and ABR measures. Probe-tube microphone measures provide objective real-ear estimates of in situ and insertion gain and SSPL90. One advantage the measures have over functional gain is that they can reflect aided performance for average speech inputs. Other advantages are (a) they account for the impedance, resonance, earmold, and insertion loss on an individual; (b) they are fast, so many comparisons can be obtained in a short time; (c) they provide good frequency resolution; (d) estimates of gain can be obtained in regions of normal hearing; and (e) real-ear SSPL90 can be documented.

The limitations of using probe-tube measures with the pediatric population are that some ear canals may prove to be too small for placement of the probe and earmold without feedback, especially in cases of severe to profound hearing loss, and some children simply may not tolerate the procedure.

Real-ear measures, however, are especially useful because of the demonstrated range of variability of real-ear to coupler differences between subjects. Feigin et al. (1989) evaluated and compared these differences in children from 4 weeks to 5 years of age and in a group of adults. For the children, mean real-ear to coupler differences were greater than that observed for adults at all frequencies. The children showed a larger difference than adults, but with the same pattern, that is, greater real-ear to coupler differences with increasingly higher frequencies. For children, 10% of the time this difference exceeded 14 dB, whereas,

in adults, 10% of the time this difference exceeded only 8 dB. The authors concluded that there was a greater risk of overamplification with children if 2cm³ coupler values were used to estimate SSPL90. Unfortunately, ear canal volume alone was not a useful predictor of this difference.

Consideration should be given also to situations in which insertion gain and functional gain do not agree. Some of these instances have been described by Stelmachowicz and Lewis (1988) and will be reviewed briefly here. As previously stated, when there are regions of normal hearing, functional gain is not an accurate estimate of the SPL developed in the ear because internal hearing aid noise can mask aided thresholds. Thus, functional gain would underestimate insertion gain in those cases. Also, if a hearing aid is set with high gain and low output, functional gain overestimates actual gain for average speech inputs. Also, in some patients with profound hearing loss, "thresholds" may be vibrotactile rather than auditory responses and insertion gain may overestimate functional gain.

Another objective approach to amplification is through the use of evoked potentials. The ABR has been proposed for use in hearing aid selection and assessment (for a review, see Beauchaine & Gorga, 1988; and Mahoney, 1985). Parameters that have been evaluated include comparisons of aided and unaided responses for (a) latency shifts (Cox & Metz, 1980; McPherson & Clark, 1983), (b) thresholds shifts (Beauchaine, Gorga, Reiland, & Larson, 1986; Kileny, 1982), and (c) changes in the slope of latency-intensity function (Hecox, 1983). Others have proposed using amplitude to estimate loudness (Davidson, Wall, & Goodman, 1990) and to prescribe maximum output and/or the need for compression (Keissling, 1982; 1983). To date, conflicting results have been reported about the relationship between ABR amplitude and loudness (Darling & Prince, 1990; Davidson et al., 1990). Thornton, Yardley, and Farrell (1987) and Thornton, Farrell, and McSporrin (1989) have postulated using the slope of the latency-intensity function to estimate LDL.

Although promising, many problems have been identified in using the ABR for hearing aid evaluation and assessment. Each hearing aid introduces changes in the stimulus because it acts as a filter. Kileny (1982) demonstrated that the hearing aid can ring after a transient is introduced, affecting the response. Temporal delays introduced by the hearing aid are not predictable (Beauchaine et al., 1986). Unless measured and accounted for individually, the temporal delays may affect the supposed success of a fitting suggested by latency shifts. Compression circuits cannot be assessed with the ABR because the stimuli necessary to elicit the ABR are shorter than the compression times in the aids and the attack time of the hearing aid cannot follow the transient stimuli; yet even this relationship is not predictable (Gorga, Beauchaine, & Reiland, 1987). Most of the ABR-hearing aid work has been done with clicks, and this stimulus typically estimates high-frequency sensitivity (Coats & Martin, 1977; Jerger & Mauldin, 1978; Gorga, Worthington, Reiland, Beauchaine, & Goldgar, 1985). For profound losses, predictions of gain cannot be made from ABR data because there is no baseline for comparison. Fi-

nally, the relationship between loudness and amplitude and slope is not clearly established.

Given these precautions and problems with using the ABR to fit and evaluate hearing aids, a recommended protocol for patients on whom we cannot obtain behavioral thresholds might be to obtain frequency-specific ABR thresholds for a range of frequencies to estimate behavioral thresholds. Next, preselect a hearing aid or device using a method with a goal to make speech audible. Gain and output should be assessed in a coupler for estimates of these parameters, with average real-ear to coupler differences applied, and individual probe-tube microphone assessments should be used when possible. The child should be monitored with continued attempts at behavioral thresholds in the unaided condition, and adjustments made in the amplification as new information is obtained.

SUMMARY

In summary, early intervention is feasible on almost any patient given current technology. Technological advances have influenced early identification and amplification. Advantages in speech intelligibility have been demonstrated for improving signal-to-noise ratios. Research has delineated similarities and differences between children and adults. Although much progress has been made, many questions remain when fitting infants and toddlers, especially in the area of validation of the device of choice. A focus of the fitting scheme should include the parents or caregivers as key figures in the success of amplification selection and fitting. Without their support, acceptance, cooperation, and enthusiasm, the child will not succeed with use of amplification no matter what selection and assessment procedures are used.

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REFERENCES

- American Speech-Language Hearing Association, (ASHA). Joint Committee on Infant Hearing. (1991). 1990 Position Statement. *Asha* (Suppl. 5), 33, 3-6.
- Beauchaine, K.A., & Gorga, M.P. (1988). Applications of the auditory brainstem response to pediatric hearing aid selection. *Seminars in Hearing*, 61, 74.
- Beauchaine, K.A., Gorga, M.P., Reiland, J.K., & Larson, L.L. (1986). Application of ABRs to the hearing-aid selection process: Preliminary data. *Journal of Speech and Hearing Research*, 29, 120-128.
- Benoit, R. (1989). Home use of FM amplification systems during the early childhood years. *Hearing Instruments*, 40, 8-12.
- Bess, F.H. (1985). The minimally hearing-impaired child. *Ear and Hearing*, 6, 43-47.
- Bess, F.H., & Tharpe, A.M. (1986). Case history data on unilaterally hearing-impaired children. *Ear and Hearing*, 7, 14-19.

- Blair, J.C., Peterson, M.E., & Viehweg, S.H. (1985). The effects of mild hearing loss on academic performance of young school-age children. *The Volta Review*, 87, 87-93.
- Bray, P., & Kemp, D. (1987). An advanced cochlear technique suitable for infant screening. *British Journal of Audiology*, 21, 191-204.
- Coats, A.C., & Martin, J.L. (1977). Human auditory nerve action potentials and brainstem evoked responses. Effects of audiogram shape and lesion location. *Archives of Otolaryngology*, 103, 605-622.
- Cornelisse, L.E., Gagne, J.P., & Seewald, R.C. (1991). Ear level recordings of the long-term average spectrum of speech. *Ear and Hearing*, 12, 47-54.
- Cox, L., & Metz, D.A. (1980). ABER in the prescription of hearing aids. *Hearing Instruments*, 31, 12-15.
- Cox, R.M., & Moore, J.N. (1989). Composite speech spectrum for hearing aid gain prescriptions. *Journal of Speech and Hearing Research*, 31, 102-107.
- Darling, R.M., & Price, L.L. (1990). Loudness and auditory brainstem evoked response. *Ear and Hearing*, 4, 289-295.
- Davidson, S.A., Wall, L.G., & Goodman, C.M. (1990). Preliminary studies on the use of an ABR amplitude projection procedure for hearing aid selection. *Ear and Hearing*, 11, 332-339.
- Dirks, D.D., Bell, T.S., Rossman, R.N., & Kincaid, G.E. (1986). Articulation index predictions of contextually dependent works. *Journal of the Acoustical Society of America*, 80, 82-92.
- Elssmann, S.F., Matkin, N.D., & Sabo, M. (1987). Early identification of congenital sensorineural hearing impairment. *The Hearing Journal*, 40, 13-17.
- Feigin J.A., Kopun, J.G., Stelmachowicz, P.G., & Gorga, M.P. (1989). Probe-microphone measures of ear-canal sound pressure levels in infants and children. *Ear and Hearing*, 10, 254-258.
- Gorga, M.P., Beauchaine, K.A., & Reiland, J.K. (1987). Comparison of onset and steady-state responses of hearing aids: Implications for use of the auditory brainstem response in the selection of hearing aids. *Journal of Speech and Hearing Research*, 30, 130-136.
- Gorga, M.P., Kaminski, J.R., Beauchaine, K.A., & Jesteadt, W. (1988). Auditory brainstem responses to tone bursts in normally hearing subjects. *Journal of Speech and Hearing Research*, 31, 87-97.
- Gorga, M.P., Worthington, D.W., Reiland, J.K., Beauchaine, K.A., & Goldgar, D.E. (1985). Some comparisons between auditory brain stem response thresholds, latencies, and the pure-tone audiogram. *Ear and Hearing*, 6, 105-112.
- Hawkins, D.B., & Yacullo, W.S. (1984). Signal-to-noise advantage of binaural hearing aids and directional microphones under different levels of reverberation. *Journal of Speech and Hearing Disorders*, 49, 278-286.
- Hawkins, D.B., Montgomery, A.A., Prosek, R.A., & Walden, B.E. (1987). Examination of two issues concerning functional gain measurements. *Journal of Speech and Hearing Disorders*, 52, 56-63.
- Hawkins, D.B., Walden, B.E., Montgomery, A., & Prosek, R.A. (1987). Description and validation of an LDL procedure designed to select SSPL90. *Ear and Hearing*, 8, 162-169.
- Hecox, K.E. (1983). Role of auditory brainstem responses in the selection of hearing aids. *Ear and Hearing*, 4, 51-55.
- Humes, L.E., & Hackett, T. (1990). Comparison of frequency response and aided speech-recognition performance for hearing aids selected by three different prescriptive methods. *Journal of the American Academy of Audiology*, 1, 101-108.
- Humes, L.E., & Kirn, E.U. (1990). The reliability of functional gain. *Journal of Speech and Hearing Disorders*, 55, 193-197.
- Jerger, J., & Mauldin, L. (1978). Prediction of sensorineural hearing level from the brainstem evoked response. *Archives of Otolaryngology*, 104, 456-461.
- Kawell, M.E., Kopun, J.G., & Stelmachowicz, P.G. (1988). Loudness discomfort levels in children. *Ear and Hearing*, 9, 133-137.
- Keissling, J. (1982). Hearing-aid selection by brainstem audiometry. *Scandinavian Audiology*, 11, 269-273.
- Keissling, J. (1983). Clinical experience in hearing-aid adjustment by means of BER amplitudes. *Archives of Otolaryngology*, 238, 233-240.
- Kileny, P. (1982). Auditory brainstem responses as indicators of hearing aid performance. *Annals of Otolaryngology, Rhinology and Laryngology*, 238, 233-240.
- Kruger, B. (1987). An update on the external ear resonance in infants and young children. *Ear and Hearing*, 8, 333-336.
- Mace, A.L., Wallace, K.L., Whan, M.Q., & Stelmachowicz, P.G. (in press). Relevant factors in the identification of hearing loss. *Ear and Hearing*.
- Macpherson, B.J., Elfenbein, J.L., Schum, R.L., & Bentler, R.A. (in press). Thresholds of discomfort in children. *Ear and Hearing*.
- Mahoney, T.M. (1985). Auditory brainstem response hearing aid applications. In J. T. Jacobson (Ed.), *The auditory brainstem response* (pp. 349-380). San Diego: College-Hill Press.
- Mahoney, T.M., & Eichward, J.C. (1986). Model program V: A high-risk register by computerized search of birth certificates. In E.T. Swigart (Ed.), *Neonatal hearing screening*. San Diego: College-Hill Press.
- Martin, F.N., & Gravel, K.L. (1989). Pediatric audiologic practices in the United States. *The Hearing Journal*, 42, 33-48.
- Matkin, N.D. (1987). Hearing instruments for children: Premises for selecting and fitting. *Hearing Instruments*, 38, 14-16.
- McPherson, D.L., & Clark, N.E. (1983). ABR in hearing aid utilization: Simulated deafness. *Hearing Instruments*, 34, 12-15.
- Mueller, H.G., & Killion, M.C. (1990). An easy method for calculating the articulation index. *The Hearing Journal*, 43, 14-17.
- Olsen, W.O., Hawkins, D.B., & Van Tasell, D.J. (1987). Representations of the long-term spectra of speech. *Ear and Hearing*, 1005-1088.
- Oyler, R.F., Oyler, A.L., & Matkin, N.D. (1987). Warning: A unilateral hearing loss may be detrimental to a child's academic career. *The Hearing Journal*, 18, 20-22.
- Pavlovic, C.V. (1988). Articulation index predictions of speech intelligibility in hearing aid selection. *Asha*, 32, 63-65.
- Pavlovic, C.V. (1989). Speech spectrum considerations and speech intelligibility predictions in hearing aid evaluations. *Journal of Speech and Hearing Disorders*, 54, 3-8.
- Rines, D., Stelmachowicz, P.G., & Gorga, M.P. (1984). An alternate method for determining functional gain of hearing aids. *Journal of Speech and Hearing Research*, 27, 627-633.
- Ross, M., & Seewald, R.C. (1988). Hearing aid selection and evaluation with young children. In F.H. Bess (Ed.), *Hearing impairment in children* (pp 190-213). Parkton, Maryland: York Press.
- Seewald, R.C., Ross, M., & Stelmachowicz, P.G. (1987). Selecting and verifying hearing aid performance characteristics for young children. *Journal of the Academy of Rehabilitative Audiology*, 20, 25-37.
- Seewald, R.C. (1988). The desired sensation level approach for children: Selection and verification. *Hearing Instruments*, 39, 18-22.
- Seewald, R.C., Ross, M., & Spiro, M.K. (1985). Selecting amplification characteristics for young hearing-impaired children. *Ear and Hearing*, 6, 48-53.
- Skinner, M.W. (1988). *Hearing aid evaluation*. Englewood Cliffs, NJ: Prentice Hall.
- Skinner, M.W., Pascoe, D.P., Miller, J.D., & Popelka, G.R. (1982). Measurements to determine the optimal placement of speech energy within the listener's auditory area: A basis for selecting amplification characteristics. In G. A. Studebaker & F.H. Bess (Eds.), *The Vanderbilt hearing-aid report: State of the art-research needs* (pp. 161-169). Upper Darby, PA: Monographs in Contemporary Audiology.
- Stapells, D.R., Picton, T.W., Perez-Abalo, M., Read, D., & Smith, A. (1985). Frequency specificity in evoked potential audiometry. In J. T. Jacobson (Ed.), *The auditory brainstem response* (pp. 147-177). San Diego, California: College-Hill Press, Inc.
- Stein, L.K., Jabaley, T., Spitz, R., Stoakley, D., & McGee, T. (1990). The hearing-impaired infant: Patterns of identification and habilitation revisited. *Ear and Hearing*, 11, 201-205.
- Stelmachowicz, P.G., Larson, L.L., Johnson, D.E., & Moeller, M.P. (1985). Clinical model for the audiological management of hearing-impaired children. *Seminars in Hearing*, 6, 223-237.

- Stelmachowicz, P.G., & Lewis, D.E. (1988). Some theoretical considerations concerning the relation between functional gain and insertion gain. *Journal of Speech and Hearing Research*, 31, 491-496.
- Stelmachowicz, P.G., & Seewald, R. (1991). Probe-tube microphone measures in young children. *Seminars in Hearing*, 12, 62-72.
- Stuart, A., Durieux-Smith, A., & Stenstrom, R. (1990). Critical differences in aided sound field thresholds in children. *Journal of Speech and Hearing Research*, 33, 612-615.
- Sullivan, J.A., Levitt, H., Hwang, J., & Hennessey, A. (1988). An experimental comparison of four hearing aid prescription methods. *Ear and Hearing*, 9, 22-32.
- Thornton, A.R.D., Farrell, G., & McSparran, E.L. (1989). Clinical methods for the objective estimation of loudness discomfort level (LDL) using auditory brainstem responses in patients. *Scandinavian Audiology*, 16, 225-230.
- Thornton, A.R.D., Yardley, L., & Farrell, G. (1987). The objective estimation of loudness discomfort level using auditory brainstem evoked responses. *Scandinavian Audiology*, 16, 219-225.

Chapter 12

AUTOMATION: THE POSSIBILITIES AND THE REALITIES

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With the advent of small, affordable, flexible, friendly desktop computers, the audiologist has access to a valuable clinical and teaching tool. Now the audiologist needs access to information about selecting a computer system and about available audiology-related applications.

The purpose of this paper is to review computer applications for the clinician, the teacher/student, and the administrator. The paper offers suggestions on how to keep up with the never-ending stream of technology information and how to make the best decisions as a consumer of computer applications. Information is provided regarding consultants, compatibility, and communication systems. Finally, a list of available software for the audiologist is presented in Appendix B. Although we cannot claim that this list is complete, we have done our best to go through all of the available resources to compile the most complete information possible. Contact information for any application mentioned in the text can be found in this product listing. Most importantly, this paper is meant as a resource for the current or potential computer user. Readers are given sources for more information in each section.

The authors bring an audiologist's and technologist's viewpoint to the material. Catherine Palmer, an Assistant Professor at the University of Pittsburgh, recently completed a 2-year grant sponsored by the American Speech-Language-Hearing Foundation and Apple Computer. She authored software for the selection of assistive listening devices. Students in her lab at the University of Pittsburgh have access to a variety of interactive computer teaching tools that cover topics such as anatomy, hearing aid selection, and middle ear assessment, as well as an automated clinic. Catherine is a contributing editor to the *Audiology Today* journal for the column entitled "Computer Applications in Clinical Audiology" and is a member of the American Speech-Language-Hearing Association (ASHA) 1991 convention Technology Track subcommittee. Mark Rauterkus is the president and founder of Support Syndicate, Inc., a book and software publishing company. The company is committed to using technology with an emphasis on practicality and productivity. Services include computer system design, consulting, development, and distribution of a variety of intelligence products.

The Computer's Relationship to the Audiologist

The computer is a tool. A tool is defined as "1. a thing for working on something; 2. anything used in an occupation or pursuit" (Webster's New World Dictionary, 1970). A new tool must be useful in order to incorporate it into the clinical or educational setting. We will define *useful* as doing a task in a more efficient manner, more accurately, or taking over multiple tasks. *Useful* also includes making new tasks possible. As you read this paper, evaluate each computer application in terms of your own clinical or educational arrangement. Remember, the consideration of new tools in any workplace requires some long-term vision in order to identify improved work load and patient care. Any new tool requires an expense of money and time.

Available Resources, or How to Keep Up

The audiologist using technology in any setting is faced with the dilemma of finding time to keep up with the general advancements of technology and the specific advancements in clinical/educational audiology. The computer you use to run your software is most likely a general purpose computer, which is improved independently of anything happening in audiology. This is a bonus, because you are guaranteed a state-of-the-art system, but only if you keep up with the developments. While the audiologist can't be expected to keep up with all of the computer journals as well as all of the audiology journals, it is worth identifying some sources of information that provide a summary of important developments to the clinician. In Appendix A, we offer suggestions of resources that can help keep you knowledgeable.

New Computer Developments

Use a computer consultant. You should expect your consultant to provide a newsletter with updated information. The consultant should also provide any upgrade informa-

tion for products that you purchased. If you bought your computer hardware locally, encourage your dealer to provide important information through a newsletter. This information will be specific to the hardware and perhaps general software (operating systems, word processing, etc.). With or without a newsletter, you should visit the computer dealer frequently to pick up new product literature. Several of the distributors of computerized audiological equipment provide a newsletter full of computer and audiological updates (e.g., Virtual Corporation's "Hear, Hear!" newsletter). Updates also are included in the Computer Applications in Audiology column in *Audiology Today* as appropriate. Take advantage of local computer users groups. This is a commitment of time with benefits. The most valuable information comes from those already using systems in which you are interested.

New Audiology Software Developments

The news of audiology software has been scattered, at best. Currently, the best places to look are in product reviews and new product announcements (*Asha*, *Hearing Instruments*, *The Hearing Journal*, and the *Computer Users in Speech and Hearing Journal*). Further, *The Hearing Journal* and *Hearing Instruments* provide yearly summaries of available products and are free to hearing healthcare professionals. See Appendix A for addresses of the sources listed in this section. With the 1991 advent of the Technology Track at the annual ASHA convention, audiologists are provided with a forum for compiling information about all of the latest software applications. Make sure you're on the mailing list of companies that distribute software (e.g., Parrot Software, Support Syndicate for Audiology). Catalogs from these companies can serve as updates. The Audiology Technical Assistance Section of the Professional Practices Department of the American Speech-Language-Hearing Association provides a continually updated list of available software to members who call and request the information.

CURRENT AUTOMATION POSSIBILITIES FOR THE AUDIOLOGIST

Introduction

In this section automation possibilities are discussed under several general headings. These sections are meant as an introduction to available technologies. Pros and cons of general applications will be offered whenever possible. For specific product information, consult Appendix B under the corresponding heading.

Clinic Management

Clinic management systems generally come from one of four sources: software/system producers (e.g., Swenson,

1988), hearing aid manufacturers (e.g., Danavox, 1991), diagnostic equipment manufacturers (e.g., Micro Audio-metrics' BioLink), or individuals who have created solutions for their own clinics (e.g., Margolis & Thornton, 1991). Margolis and Thornton (1991) describe two spreadsheets (one for the IBMTM and one for the MacintoshTM) that allow them to monitor patient flow in their respective clinics. The first three types of solutions generally limit you to a particular computer system or to particular diagnostic equipment. This may not be a problem if you already use the required equipment or if you were planning to update your office. The fourth solution is the most flexible, but requires some expertise in customizing either databases or spreadsheets. The inexperienced computer user may want to consider hiring a consultant to develop a clinic management system for his/her individual clinic if none of the packaged software fits the bill.

Try to look at the whole picture before you make clinic management software decisions. How complete do you want this system to be? Should it monitor patient flow and create a database of patient test results? Should it serve as a scheduling tool and a billing device? Do you use computerized diagnostic equipment (e.g., Virtual Corporation equipment) or diagnostic equipment that has the capability to transfer data to a nondedicated computer (e.g., Grason-Stadler equipment)? You may want to consider a clinic management system that would take diagnostic information directly from the diagnostic equipment as opposed to re-entering data into the clinic management system. Although several diagnostic equipment manufacturers are claiming that they have this type of transfer down to a science, many clinicians have run into problems (or at least expenses) in trying to do this (Hayes, 1991). Make sure you have a trial period to guarantee that all of the information transfers as promised. See the section entitled "Communication and Networks" for more details.

Hearing Aid Fitting and Dispensing Office Management

Clinic management systems that focus on dispensing come in two forms: independent dispensing office management software (e.g., MacHear), and hearing aid fitting software combined with dispensing office management software (e.g., Frye Electronics and Acoustimed HA-2000 II). The independent dispensing office management software is not linked to any particular hearing aid fitting equipment. Many clinic management systems have developed out of hearing aid fitting systems. With advanced hearing aid fitting strategies (e.g., real-ear measures), the clinician is forced to use a computer in the dispensing office and can take advantage of its more general functions.

Many of the hearing aid fitting equipment manufacturers wisely chose to use nondedicated computers (e.g., IBM compatible and/or Macintosh) coupled with their specific equipment. This allows the user to choose a nondedicated clinic management system by virtue of having the computer. Although manufacturers are promoting these non-

dedicated computers by pointing out that testing as well as clinic management functions can be performed on the same computer, this is true only if the computer is not being used for testing purposes. In a busy clinic, more than one computer is necessary.

When contemplating a dispensing office management system, consider whether you would like it to be separate from your diagnostic clinic or an integrated part of the whole clinic. Deciding between independent management software and equipment-linked software may be dictated by the hearing aid fitting equipment that you are presently using. As with clinic management systems, you need to decide if you would like automatic data transfer from hearing aid measurement equipment or if you will be re-entering results.

Sometimes it's hard to know what the actual possibilities are when you're trying to evaluate if a software management system is complete. The following list has been compiled to help give you an idea of what may be included in a software package: client record keeping, automated correspondence, battery club mailings, appointment reminders, repair tracking, business management reports, accounts receivable, direct mailings, cash flow accounts, referral source tracking, diagnostic information, scheduling capabilities, and tracking and analysis of marketing activities.

The following questions should be considered when deciding to invest in a particular software package: what is the installation time, does the software come in a modular format, is training available from the company, can the software be customized, is there free telephone support for a specified period of time, can I continue with paid telephone support, and is there a trial version to make sure the software works on my computer and with my clinic load? The clinic director is often the individual responsible for making software package decisions. Keep in mind that many solutions to information management require the insight of the people working closely with the data. Elicit information from the people who ultimately will be using the software as they work with the trial version.

Scheurer (1985) provides several suggestions that will help the consumer avoid problems in the future: buy equipment that is expandable, consider the importance of local support, use a consultant, and buy time-proven software. The fourth suggestion bears repeating. There is nothing like word of mouth. Ask the software distributor for names of several customers if you don't have friends who are using the software. Ask users what they like and dislike about the system and decide what you can and can't live with.

If you're trying to decide what type of investment is reasonable for your clinic, Pollack (1987) offers appropriate guidelines to use when considering the cost/benefit ratio for your dispensing office. He describes both revenue-generating uses that increase profits and operational efficiency uses that reduce expenses.

Data Storage and Analysis

The way your clinic/dispensing data are stored and the ability to analyze these data (i.e., how you can sort informa-

tion, what type of information can be retrieved, and in what format) will depend on the decisions that you make in the above two sections. Remember to consider how you would like to use the stored information in the future in order to avoid having a fancy data storage system that you can't access appropriately.

Other considerations in data storage are security/confidentiality and redundancy. If data can be accessed from several computers, you may want to make use of passwords (make sure this ability comes with your software package) to limit user access to confidential records. With computers there is always the risk of loss of information. Many clinics continue to keep a hard copy of patient results so they will have the information if the patient comes in, but re-entering all of this information in the event of a computer problem would be prohibitive. There are a variety of backup tape drives that can be used with most computers today. At the end of each day, the entire patient record system is copied onto the backup tape. The tape can be taken out of the office for extra security against vandalism and/or fire. Using this method, in the worst case, the clinic would lose one day's worth of entries. The rule of thumb is to decide how much time you can afford to waste and backup at intervals that equal this amount of time. In other words, if you can afford to waste a week, then backup only once a week.

Computerized Diagnostics

In 1966, Levitt presented information on psychophysical testing at a conference on computer-assisted evaluation. One of the conclusions from this paper was that the cost of computerized clinical testing was prohibitive and that software to facilitate such testing wasn't readily available. This is no longer true. Now the problem is deciding which type of system is best for you or how to make your current system part of a "computerized" system. There are two basic types of "computerized diagnostics." Yanz (1989) describes the two types as internal computer control and external computer control.

The internal computer control systems are dedicated pieces of diagnostic equipment that have the capability (given the correct software and connections) to transfer data after testing to a nondedicated computer where information can be stored and used. Internal computer control systems have the following advantages: you can buy a variety of equipment; if the computer fails, you still can test patients; you may have more choice when it comes to the type of nondedicated computer; and equipment can be used simultaneously. Possible disadvantages include finding software that will make all of the interfaces useful and finding software to integrate more than one module (i.e., getting results from several pieces of equipment into one database).

The external computer control system consists of several instruments connected to one nondedicated computer that controls the instruments and also can store data. Advantages to the external computer control system include full integration of test results, complete hardware network, one vendor, one maintenance contract, no hardware/software interface problems, easy updating, and consistency

for users. The disadvantages include limitations regarding the equipment that the particular vendor supplies and the inability to test simultaneously with different test modules without the use of another computer.

Yanz (1989) indicates several reasons to consider computerizing your diagnostic clinic. The computer saves time with repetitive tasks, accuracy and consistency are enhanced (i.e., meaningless signal and routing options are locked out), automation of tests that have rule-driven protocols is possible, and more sophisticated tests are incorporated into the test battery. Yanz (1989) provides a complete description of an external control computer system in a working audiology clinic. Radcliffe (1990) and Pay (1990) provide information about internal control computer systems (with a focus on the Madsen equipment) and give quite a bit of information about software used to "connect" the dedicated test equipment.

Recently, audiologic tests have been designed to be presented via a computer that may or may not be channeled through an audiometer. Stach (1990) describes a microcomputer-based speech audiometer that uses the Macintosh stereo output capability. The advantages of the computer-controlled speech tests as compared with traditional tapes and even the new compact disks are user control over interstimulus interval, randomization of stimulus presentation, easy repetition of speech targets, efficient data storage, and automatic data analysis. Clinical trials with this procedure have been carried out on more than 1,000 patients at The Methodist Hospital Audiology Services in the Neurosensory Center of Houston with good results.

Supervision and Staff Management

The use of microcomputer-based diagnostic audiometric equipment (referred to above as external computer control systems) provides a unique opportunity in supervision of a student's technical competence. The use of a local area network and instructional software allows a supervisor in an observation room or separate office to view the basic test procedures used by the student. The supervisor views the identical computer screen that the student is using in order to test the patient. This allows the supervisor to be privy to the exact test procedure and protocol that the student is using without needing to peer over his/her shoulder.

Microcomputer-based diagnostic audiometric equipment (e.g., the Virtual system) automatically compiles work record sheets that can provide valuable information about what types of patients a student has seen and what tests have been used. This type of record keeping is useful in any clinic to monitor productivity.

Any nondedicated computer system can be used for record keeping if someone is available to enter the data. Hood and Miller (1984) propose administrative uses of computer in graduate education. They developed a software application for reporting student clinical experiences in a format conforming to ASHA certification requirements.

Rehabilitation

Sims, Kopra, Dunlop, and Kopra (1985) provide an excellent survey of microcomputer applications in aural reha-

bilitation. The focus of their survey is on computer-managed instruction, computer-assisted instruction, and computer-assisted interactive video. They provide some essential tips about hardware and software considerations for computer-to-video interfaces. The individuals who have developed many of the available microcomputer applications in aural rehabilitation have published findings using these systems. This provides the reader with specific information that is not available for many of the other computer applications mentioned above. For further reading, the following references are suggested: Grossman, Siders, and Garraway (1983); Kopra, Dunlop, Kopra, and Abrahamson, (1985); Pichora-Fuller and Benguerel, (1991); Sims, Scott, and Myers (1982); Tye-Murray (in press); and Tye-Murray, Tyler, Bong, and Nares (1988).

One of the most recent advances in microcomputer-assisted aural rehabilitation is the advent of interactive programs that use commercially available videodiscs. Cochran (1990) unveiled the "Watch and Talk Clinical Toolkit." Cochran developed the computer software that is used by the clinician to control the videodisc. The clinician can use widely available, inexpensive videodiscs in conjunction with this software. This type of use is called "repurposing." This provides the language clinician with access to more than 50,000 high quality, moving pictures. The child who is hearing-impaired has opportunities for sequencing, story-telling, predicting, and using verb tenses.

As with the other categories, the computer can add efficiency in administrative activities. Scoring for several of the more popular hearing handicap scales is now computerized (see Appendix B). This type of scoring can reduce error and time as well as provide a database of results.

The organization and retrieval of large amounts of information are perfect applications for a computer. With this ability in mind, an interactive product locator for assistive devices was developed (see Appendix B). Many clinicians report the need for up-to-date information regarding assistive devices and distributors. This new product provides a complete database that is easily updated. The interactive quality of the program allows the user to select devices that meet particular patient criteria.

When purchasing rehabilitation software and/or hardware, make sure there is good written documentation to get you started and some sort of local or telephone support to keep you going.

Teaching Tools

The wide variety of teaching tools that are available have come directly from teachers who realize that the computer doesn't take their place but enhances the teaching process. The best overall description of the applications listed in Appendix B under teaching tools is computer-assisted instruction. This means that the programs provide direct instruction with feedback to learners on their performance. Several of the applications in other sections (e.g., Hearing Aid Selection, Interactive Product Locator for Assistive Devices), although not meant to be teaching tools, are valuable indirect teaching tools because of the amount of information contained in each program. Teaching programs are

not limited to the traditional student; Computer-assisted learning is ideal for continuing education purposes. The "Zwislocki Model" program is a perfect example. This program provides the resulting multiple frequency, multiple component tympanometry for any chosen disease process. For many practicing clinicians this type of information was not readily available during their school days. With the availability of computer-assisted learning, there is a fun and nonthreatening way to keep up.

When buying teaching tools, make sure a good manual is available. The manual allows the students to be independent. Also, check that there is an automatic scoring feature that will allow you to track when the exercises were done and how the student performed.

PURCHASING CONSIDERATIONS — HARDWARE, SOFTWARE, CONSULTING SERVICES

Palmer (1990a) suggests using the simple who, what, when, where, why, and how method in order to define exactly what is right for your clinical/educational center in terms of computer use. For those who are not experienced in computer applications and purchasing, the question "Who?" is most important. The right computer consultant can save you time and money in the designing of a computerized clinic. Most importantly, a computer consultant may offer a complete solution. Expect to pay a consultant for some up-front costs. These expenses are much less than making costly mistakes and oversights that could make the hardware/software less than ideal for your clinic situation. But no matter how competent the computer consultant is, you will have to provide him/her with a detailed picture of your clinic functions and needs as well as any information about commercially available software that is specific to audiology. To make the best use of a computer consultant, you have to do your homework. Write everything down in advance. Then save the written description for a 6-month review to see if you are doing what you set out to accomplish. The written objectives serve as motivation and protection.

When selecting software (on your own or through a consultant), try it in your office with your data and get an evaluation from the people in the office who will be using it. A systematic evaluation is always preferable. ASHA (1985) has provided an appropriate checklist to use when evaluating hearing aid selection software that is appropriate for any new software. The checklist includes questions about program description, program effectiveness, user friendliness, and support documentation. The results of the evaluation can be used to compare software programs that your clinic is considering.

When budgeting your computer purchasing, remember that the purchasing price of the software/hardware package is only part of the systems total cost. You must allow for the hours to learn to use the system, teaching others to use the system, entering a backlog of data if desired, training any new skills that may be required, theft insurance, and

cost of upgrades. A computer consultant will be able to predict these costs for you and provide most of these services. The consultant also will be able to outline where you will make up for these costs in the long run (i.e., fast, efficient record retrieval; automatic billing; better scheduling; etc.).

We recommend avoiding two costs: extended warranties and service contracts. If computers are going to break, it happens within the first 30 days while they are covered under the standard warranty. Misuse is never covered under a service contract. These two categories produce exorbitant profits for service providers. We highly recommend insurance against theft. More than one company has suffered when computer equipment has been stolen, which happens frequently.

When hiring a computer consultant, consider the following questions: Will you receive a cost estimate, will the consultant design software for your clinic, will training for the staff be provided, will documentation be provided for all hardware/software, will the consultant provide a competitive price for purchasing equipment or will you purchase it from a third party with his/her suggestions, will the consultant physically set up the equipment, will you receive long-term hardware and software support, will the consultant be easily reached, will you be charged for ongoing support, will you receive a periodic newsletter, will you receive the names of others who have used this consultant?

Make sure you have the answer to each question in the form of a written contract/agreement so that you and the consultant agree on what is expected. If you are associated with a university, you may have access to these services through your computer center.

COMPATIBILITY

Compatibility (noun): 1. capable of living together harmoniously, 2. able to exist or be used together" (Webster's New World Dictionary, 1970). Compatibility seems to be the issue of the 1990s for the world and for computers. The individual designing a computerized clinic will want to consider compatibility on two levels.

Within the clinic, compatibility is necessary between diagnostic equipment in the case of an internal computer-controlled system (see the section entitled Computerized Diagnostics for a description). In this case, the goal is to move all of the diagnostic information to one computer where the information is integrated into one database and can be used for record keeping and office purposes. This type of compatibility results from both hardware and software solutions. You will need the commitment of the diagnostic equipment manufacturers to ensure the ultimate compatibility of an internal computer-controlled system. Hayes (1991) expresses a variety of problems that have been encountered from a lack of interconnectivity between available diagnostic equipment, and estimates that the cost for solving these problems is over \$1,000. The potential user is wise to demand a firm commitment and price from the manufacturers before pursuing the integration of an internal computer-controlled system. Whenever possible,

it also is wise to contact those who have already been through the process; learn from their mistakes.

For the user of an external computer-controlled system, compatibility is still an issue for integrating the test results from a variety of modules. This will result from a software solution either from the manufacturer of the system, the computer-wise clinician, or a consultant.

The second level of compatibility comes from the desire to communicate with other professionals or use software designed for a computer system other than your own. Apple Computer has been responsive to the issue of compatibility (they use the term "connectivity"). The Macintosh enthusiast is able to use an "Apple File Exchange" program that comes with the system in order to read DOS (IBM system) files and to translate them for use with the Macintosh. The user also can save Macintosh word processed documents in the DOS format to give to an IBM user. The small IBM formatted disks can be inserted directly into the Macintosh disk drive when using Apple File Exchange. If you are trying to be compatible with a large floppy disk user, a hardware product called "DaynaFile" is available. This description appears to be one-sided (toward the Macintosh), but a compatibility solution has to go only one way. If the Macintosh is compatible with the IBM, it is not necessary for the IBM to be compatible with the Macintosh.

If the Macintosh user wishes to run "IBM" programs, a software program called "Soft PC" is available. Other software programs are becoming available that translate Macintosh programs for use with the IBM. All of these applications are new enough and general enough that it is essential to try to run the specific program in which you are interested before assuming it will work on your equipment.

These product names and applications are mentioned here in order to highlight the endless possibilities for compatibility that are available in 1991. This description is not meant to be complete and we urge you to stop in at a full-service computer store for more information about the products mentioned or to question a computer consultant about your compatibility needs.

COMMUNICATION AND NETWORKS

A network can provide the audiologist with internal clinic communication, between-department communication, between-referral communication, and professional communication. The type of network that you choose will be based on your needs, boundary lines, cost, and equipment ability.

For a detailed description of one internally networked clinic, see Margolis and Fornier (1991). Their description will help the novice understand the possibilities as well as the problems of a clinic network.

Between-department communication often arises when the audiologist is working within a larger organization (e.g., hospital or university) that already has a computer system. See Palmer (1990b) for a description of some of the essential considerations when contemplating tying into an existing computer network.

Between-referral communication is supported by the use of a modem. This means that your clinic computer can send information over the telephone lines to another clinic. The second clinic also needs a modem that allows it to access the information that you send. Again, selecting a modem and software package for transmitting information is best achieved with the advice of a knowledgeable person. If you are part of a university system, you most likely have access to "electronic mail." Call your computer center to find out how it may be of benefit to you.

Professional communication can be assisted by the use of a modem that can access a "bulletin board." A computer (electronic) bulletin board is simply a "place" where individuals can call. They leave messages for other users or post general notices to all users. Several audiology product distributors have identified the possible benefits of supporting electronic bulletin boards and provide this service for people who purchase their products. In this way they can disseminate information to all of their customers quickly and their customers can problem-solve together. MacHear™, Madsen™, and Acoustimed™ all provide electronic bulletin boards for their users. Before signing on for bulletin board use, make sure you understand how you will be charged for the privilege. Is it part of the original equipment cost, or will you be billed separately? Keep in mind that you will incur the cost of your telephone calls.

When contemplating a network, the user must consider the necessary software for communication, the type of "wiring" that will be used, and the maintenance of the network. Once you have decided exactly what you want from a network, figuring out how to achieve the correct communication is best done with the help of an expert (your own consultant or an individual associated with a computer store). Apple Computer™ supplies a detailed handbook for networking hardware from a variety of vendors (ask for this handbook from an authorized Apple dealer). This type of book can help highlight the possibilities open to the clinician.

CONCLUSIONS

The above information is meant to spark your curiosity, expand your horizons, and perhaps point you in the right direction. The most important thing that you will do for yourself and your clinical/ educational center is define your needs and desires in detail. Your challenge is to find a complete solution to this detailed description. Just as you would expect someone needing expert advice about hearing conservation to consult you, you should expect to consult an expert in computer solutions. Through this process, don't be dazzled by technology. Although technology is marvelous, you are not buying technology. You are buying a solution to very specific problems that you have identified in your work place. Do your homework. Find out what has worked for other people and know what's available specific to audiology (Appendix B). Armed with this information you can expect the payoff of the computer as a valuable tool in your clinical/educational center.

REFERENCES

- American Speech-Language-Hearing Association. (1985). Software review checklist. *Asha*, 27, 71.
- Cochran, P. (1990). Paper presented at the Building Bridges Demonstration. Annual Convention of the American Speech-Language-Hearing Association, Seattle, WA.
- Danavox. (1991). *Information Seminar*. Presentation at the annual convention of the American Academy of Audiology. (April, 1991).
- Grossman, K., Siders, J., & Garraway, H. (1983). Sign teacher: A microcomputer application for the teaching of sign language. *American Annals of the Deaf*, 128, 577-584.
- Hayes, D. (1991). Forum—Soft Hardware. *Audiology Today*, 3, 5-6.
- Hood, S. & Miller, L. (1984). Administrative application for microcomputers. In A.H. Schwartz (Ed.), *The handbook of microcomputer applications in communication disorders* (pp. 219-245). San Diego: College Hill Press.
- Kopra, L., Dunlop, R., Kopra, M., & Abrahamson, J. (1985). *Computer-assisted instruction in lipreading with a laser videodisc interactive system*. Paper presented at the computer conference of the American Speech-Language-Hearing Foundation, New Orleans, L.A.
- Levitt, H. (1966). *Psychophysical testing*. Proceedings of a conference on computer-assisted testing. Princeton, NJ: Educational Testing Service.
- Margolis, R. & Fournier, E. (1991). A microcomputer networked audiology clinic. *Audiology Today*, 3, 28-31.
- Margolis, R. & Thornton, A. (1991). Spreadsheet systems for tracking audiology patients. *Audiology Today*, 3, 22-23, 31.
- Palmer, C. (1990a). Computer applications in audiology. *Audiology Today*, 2, 27-28.
- Palmer, C. (1990b). Computer applications in audiology. *Audiology Today*, 2, 25-26.
- Pay, G. (1990). Technology in the service of audiology—a personal view point. *Special supplement to the Hearing Journal*, 43, 31, 33-34.
- Pichora-Fuller, M. & Benguerel, A. (1991). The design of CAST (Computer-Aided Speechreading Training). *Journal of Speech and Hearing Research*, 34, 202-212.
- Pollack, M. (1987). The computer in a dispensing office. *Hearing Instruments*, 38, 15-18, 67.
- Radcliffe, D. (1990). Beyond number-crunching: The marriage of computers and audiology. *Special Supplement to the Hearing Journal*, 43, 31, 36-37.
- Scheurer, R. (1985). Computer applications in a hearing aid office. *Hearing Instruments*, 36, 15.
- Sims, D., Kopra, L., Dunlop, R., & Kopra, M. (1985). A survey of microcomputer applications in aural rehabilitation. *Journal of the Academy of Rehabilitative Audiology*, 18, 9-26.
- Sims, D., Scott, L., & Myers, T. (1982). Past, present, and future computer-assisted communication training at NTID. *Journal of the Academy of Rehabilitative Audiology*, 15, 103-115.
- Stach, B. (1990). *Building Bridges Project: Innovative Software for Communication Disorders*. Paper presented at the Building Bridges Demonstration. Annual Convention of the American Speech-Language-Hearing Association, Seattle, WA.
- Swenson, C. (1988). Office automation as a competitive edge. *Hearing Instruments*, 39, 10, 13-14.
- Tye-Murray, N. (in press). Repair strategy usage by hearing-impaired adults and changes following communication therapy. *Journal of Speech and Hearing Research*.
- Tye-Murray, N., Tyler, R., Bong, B., & Nares, T. (1988). Computerized laser videodisc programs for training speechreading and assertive communication behaviors. *Journal of the Academy of Rehabilitative Audiology*, 21, 143-152.
- Webster's New World Dictionary, 2nd ed. (1970). Englewood Cliffs, NJ: Prentice-Hall.
- Yanz, J. (1989). The computerized audiology clinic. *Otolaryngologic Clinics of North America*, 22, 89-103.

APPENDIX A

Following are sources for updated information.

Asha

10801 Rockville Pike
Rockville, MD 20852
Product reviews in monthly issues.

Audiology Division

Professional Practices Department
American Speech-Language-Hearing Association
10801 Rockville Pike
Rockville, MD 20852

Audiology Today

Journal of the American Academy of Audiology
"Computer Applications in Audiology" (column)

CUSH—Computer Users in Speech-Language-Hearing Journal

Attention: William Seaton
PO Box 2160
Hudson, OH 44263
Runs new product listings and reviews each edition.

Hearing Instruments

PO Box 6019
Duluth, MN 55806-9719
Runs new product listing each month. Yearly product directory.

The Hearing Journal

Runs new product listing each month. Yearly product directory.

APPENDIX B SOFTWARE SYSTEMS

HEARING AID DISPENSING OFFICE MANAGEMENT

ACODAT HA2000II Real Ear and Office Management System

Description: Automated real-ear measurement and office management system. Database for hearing aid dispensing.

Options: Can get access to Bulletin Board for application notes and updates on software (need modem).

Can use remote terminal (PC-Anywhere) to control system from Acoustimed headquarters for troubleshooting, etc.

Can interface with GSI 10 or GSI 16 audiometers for direct data transfer.

Computer: IBM compatible, hard drive recommended, 1.2MB disk drives okay. (\$950)

Contact: Acoustimed, 2801 Youngfield, Suite 128, Golden, CO 80401, 303-232-1226

AudioPro 2

Description: Management system for the dispensing office. The program includes marketing, accounting, office management, filing system, calendar, etc.

Computer: IBM compatible

Contact: Oticon, 29 Schoolhouse Road, Somerset, NJ 08873

Computerized Hearing Aid Retail Marketing System (CHARMS)

Description: Client management and accounting system designed for hearing aid dispensers. Includes patient chart, audiograms and information for follow-up and servicing. Point-of-sale invoicing, insurance billing, multi-practice capability, client management, audiograms, user-defined testing, user-specified follow-up dates, user-defined follow-up codes, client charts that include complete notes, fully integrated accounting, serialized inventory, menu-driven query language, client listings to use with Mailmerge/accounts payable, accounts receivable, and general ledger.

Computer: IBM or compatible. Can be used as single-user or multi-user system (up to 100 workstations). (\$1,995)

Contact: Computer Center of Upper Darby, Inc., 6786 Market Street, Upper Darby, PA 19082, 215-734-1600

EARS2YOU

Description: Database management system for managing business operation of hearing aid dispensing practice. Option: Version for use in the schools also available.

Computer: IBM compatible with 512K and hard disk. (\$795)

Contact: EARPRESSIONS, INC., EARS2YOU Software, 8901 W. 74th Street, Suite 150, Shawnee Mission, KS 66204, 913-384-5880, 800-227-9440

Fonix 6500 Quik-Probe II

Description: Software to use with the Fonix 6500 that allows the user to complete all the calculations for 2-cc full-on gain and SSPL-90 targets.

Computer: IBM Compatible

Contact: Frye Electronics, PO Box 23391, Tigard, OR 97223

Hearing Aid Office System

Description: Dispensing management software.

Computer: IBM compatible

Contact: RJS Acoustics, Inc., PO Box 30749, Portland, OR 97230, 800-826-3180

HearWare Computer Systems

Description: Record management and marketing software. Available as complete system or as modules for client management, devices manager, clinical records manager, billing and inventory (general ledger, accounts payable, and payroll modules also available). Modules are fully integrated so data has to be entered only once. Options: Master Module-client and prospect tracking. Coding of clients for mailings and follow-up. Form letters, labels (zip code order by selection criteria), lists. Battery club records. (\$395)

Billing and Accounts Receivable Manager—works with master to produce single-entry integrated system. Tracks billing, cash and check receipts and open receivables. Tracks inventory and sales history of each item or service. Print or view unlimited number of user-definable reports. (\$395)

Devices, Repairs and Visits Manager—tracks client device history, repair history and records of visits. Print or view records based on purchase dates, manufacturer, model and serial number, repair records and warranty expiration reminders. (\$395)

Audiogram/Clinical Records Manager—tracks audiogram history. Print or view audiogram, generate testing report and letters for follow-up. (\$395)

Demo disks available \$19.95 (\$24.95 for all 4 modules)

Computer: MS-DOS compatible with 512K RAM and a hard disk. (dBase)

Contact: Software And Systems, 1169 Main Street, Branford, CT 06405, 800-234-0160

MacHear

Description: MacHear is an office client, marketing, and financial management software system for the Macintosh computer. It was designed in a modular way so that a dispensing office is free to use any or all parts of the software.

Computer: Macintosh, 1 MB RAM (\$2,000 for the complete software modules)

Contact: MacHear, Hearing Centers' Network, 426 Virginia Street, PO Box 7189, Vallejo, CA 95590, 800-544-8484

Office Management Applications

Description: Office practice management, patient management, word processing, spreadsheet, electronic mail, and business graphics.

Computer: IBM compatible

Contact: INFODYNE Corp., 13 Inverness Way South, Englewood, Colorado 80112, 303-790-1311

Patient Management System

Description: Relational database management system for hearing aid dispensing. Mailing labels, prepared reports and user-definable reports for individual/group and all variables. Merge other mailing lists into database to generate letters to prospects. Letters include automatically generated sales thank yous, referral thank yous, one-year appointment reminders, upcoming warranty expiration, provider-eligible renewal letters and overdue test letters. Tracks client device history, prescription, and balances.

Computer: IBM PC compatible with 640K and a hard disk. (\$995)

Contact: SOFTWARE RESEARCH, LTD., 2526 Binghamton Drive, Auburn Hills, MI 48057, 313-335-8173 for sales and technical information, 313-485-0122 (Venice Hearing Aid Center I) for other questions

ProHear Marketing and Management System

Description: A complete office system featuring tracking ability, sales functions, sales reports, hearing aid pricing information, automatic battery club, accounts receivable, accounts payable, general ledger, data table printed reports, hearing aid review screen, repair and review screen, real-ear interface, audiogram retention, and direct mail.

Computer: IBM compatible

Contact: Starkey Labs, 6700 Washington Ave. S., Eden Prairie, MN 55344

Swenson Client Management System (CMS)

Description: Database management of client information, scheduling, and follow-up; clinical records, and device purchases and repairs. Modules available for battery club, billing and company ledger, and prospect marketing.

Demonstration/30-day trial period for \$59.

Computer: IBM compatible with 640K and hard disk (3–10 MB or 20 MB if thousands of database entries). Essential Client Management System-\$995, Master Edition-\$1,350, Battery Club Module-\$100, Client Billing Module-\$350, Prospect Management Module-\$250

Contact: Swenson Associates, Inc., Riverbend Bldg, Nine Galen Street, Watertown, MA 02172, 800-441-1960

Swenson CMS Jr.

Description: A streamlined version of CMS. Stores client information, automates correspondence and reporting functions, and provides a means to analyze business functions.

Computer: IBM Compatible. Cost: Demo Disks available for \$15.

Free telephone support for 30 days. Monthly newsletter provided free to purchasers with technical support information, tips for users, answers to commonly asked questions, and announcements and calendar of events.

Contact: Swenson Associates, Inc., Riverbend Bldg, Nine Galen Street, Watertown, MA 02172, 800-441-1960

Delta Patient Management/Billing System

Description: The software makes patient appointments, stores patient records, and provides billing. It also handles payment analysis and report generation.

Computer: Macintosh Plus or higher with hard drive

Contact: Delta Medical Shareware, Inc., 9170 Ellen Davies Dr., Bartlett, TN 38133, 901-372-4789

HEARING AID FITTING (PRESCRIPTION AND SELECTION)**Aurora**

Description: Computer-controlled system with a full-function audiometer, hearing aid analyzer, real-ear measurement functions with optional middle ear analyzer.

Has database management functions.

Computer: IBM-PC compatible

Contact: Nicolet, Biomedical Division, 5225-4 Verona Road, Madison, WI 53711, 608-271-3333

Berger Prescriptive Method

Description: User enters pure-tone air and bone and LDL. Program calculates aided sound-field thresholds, SSPL-90, full-on gain (for ITE, BTE and body aid). Provides correction for conductive component of hearing loss. Will select hearing aid if you input data and will print out full-on gain requirements, SSPL-90 and sound-field-aided results.

Computer: Apple II or IBM-PC compatible

Contact: Herald Publishing House, 647 Longmere Drive, Kent, OH 44240

Chameleon

Description: System of measurement and simulation of hearing aids. Requires additional signal processing and electronic equipment.

Computer: Apple II

Contact: Harry Levitt, City University of New York (CUNY)

CHAP-1

Description: Computerized hearing aid program to interface with real-ear measurement and hearing aid test software. Stores, retrieves, and displays in color—hearing aid curves and data. Uses windows. Compatible with dBase and FoxBase for user programming capability.

Computer: IBM AT or PS2, EGA/VGA, 20MB hard disk, mouse, 640K memory, RS232 option.

Contact: Frye Electronics, Inc., Tigard, OR, 800-547-8209

deJong Hearing Aid Selection Strategy

Description: User enters pure-tone data, MCL and LDL. Program calculates SSPL-90, use gain, estimated speech intelligibility, and compression characteristics.

Computer: Apple II

Contact: Robert deJong, Department of Speech Pathology and Audiology, Central Missouri State University, Warrensburg, MO 64093

Edition 3.11

Description: User inputs audiometric data. Generic hearing aid fitting and selection program. Provides style, gain, output, trim pot features, tubing and mold configurations, dampers and other electroacoustic characteristics.

Computer: Apple II and IBM. (\$600)

Contact: Katz

Hearing Aid Worksheet

Description: Lotus© worksheet for calculating real-ear and coupler gain for ordering hearing aids. The formulas from NAL and Libby are used.

Computer: IBM compatible, Lotus© spreadsheet

Contact: Michael Valente, Washington University, St. Louis, MO

Hearing Aid Selection

Description: This is a complete hearing aid selection program—perfect for a clinic or for teaching purposes. The user enters the threshold levels and any MCL or UCL data they have. The user selects the type of aid (BTE, ITE, etc.), the type of earmold (there is a hidden tutorial with pictures of all the types of earmolds and their acoustic results), type of prescriptive formula (e.g., NAL, POGO, etc.). The program automatically calculates desired real-ear gain, coupler gain, SSPL-90, etc. The calculations are presented in an easy-to-read format, perfect for ordering the hearing aid. For the student or interested clinician, a change in earmold selection, damping, or venting results in a graph showing the resulting change in frequency response.

Computer: Macintosh, HyperCard© program (\$130)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

MSU Hearing Instrument Prescription Procedure

Description: User enters pure-tone data. Program calculates gain requirements, LDLs and SSPL-90.

Computer: IBM compatible

Contact: Robyn Cox, Memphis State University, Speech and Hearing Center, 807 Jefferson Avenue, Memphis, TN 38105

New National Acoustic Laboratories (NAL) Hearing Aid Prescription Kit

Description: Set of three sliderules to calculate required coupler gain, required real-ear gain, required aided threshold. Takes into account both 2cc coupler and real-ear measures. Provides for ITE, BTE and body aids.

Computer: N/A (\$78.50)

Contact: E. Robert Libby, Associated Hearing Instruments, 6796 Market St, Upper Darby, PA 19082, 215-528-5222, 215-352-8383

Phase IV Hearing Aid Selection and Evaluation Program

Description: User enters pure-tone data, MCL, LDL, aided and unaided sound field thresholds. Prescriptive program that uses graphics to display speech spectrum with aided and unaided conditions.

Computer: Apple II with 640K RAM or IBM-PC

Contact: Gerald Popelka, Central Institute for the Deaf, St. Louis, MO

Selecting Hearing Aids for Patients Effectively (SHAPE)

Description: User enters pure-tone data and LDLs, and selects prescriptive fitting formula to be used (POGO, NAL-R or COX). Program calculates SSPL-90, insertion gain, full-on coupler gain and sound field predicted aided thresholds.

Computer: IBM compatible (\$120)

Contact: Venture 4th, 2003 Montclair Avenue, Bloomington, IN 47401

3M Master Fit HEAR System

Description: Expert fitting system that integrates prescriptive fitting methods (1/3 gain, 1/2 gain, POGO, NAL, CID, Berger or user-define method), programming, database management system, real-ear measurement functions.

Computer: IBM PS/2 50 system w/80286 CPU chip

Contact: 3M Hearing Health, 76-2W-02, 3M Center, St. Paul, MN 55514-1000

COMPUTERIZED DIAGNOSTICS/DATA STORAGE AND ANALYSIS**Audiometric Evaluation System (AES)**

Description: Part of modular, medical diagnostics system. Developed from Infodyne's Audiometry Application System (AAS). AES extends capabilities of AAS. In addition to collecting and storing patient information and audiograms, AES automatically evaluates each audiogram and assigns it to a Hearing Loss Category. Analysis and report functions for single patient or groups. Can be used for hearing conservation program.

Other applications from Infodyne: Medical Diagnostic Applications

Computer: IBM compatible

Contact: INFODYNE Corp., 13 Inverness Way South, Englewood, Colorado 80112. 303-790-1311

Auditory/Visual Word-identification Materials

Description: This software provides a computer-based approach for administering an auditory/visual word-identification task wherein auditory stimuli and visual response foils (pictures) are configured in computer memory such that an auditory stimulus is presented to a patient in conjunction with a visual response display on the computer monitor.

Computer: Macintosh II series, two color monitors, 2 MB RAM, 40 MB hard drive

Contact: June Antablin McCullough, 6168 Springer Way, San Jose, CA 95123, 408-924-3683

AUDIOCOM

Description: Computer software program for automatic acquisition, processing, display, and storage of data transmitted directly from Madsen instruments and into organized patient profile.

Computer: IBM AT or compatible PC

Contact: Madsen Electronics, 908 Niagara Falls Blvd., North Tonawanda 14120-2060, 800-268-5151

Biocoustics

Description: Audiologic software for recording, storing, and data-basing patient test results, and generating reports. Accepts data from most microprocessor audiometers and related audiologic equipment with RS-232 capability.

Interface with other major clinical software, e.g., evoked potentials, real-ear measures. Operates as applications manager.

Computer: IBM and compatibles

Contact: Biocoustics Instruments, Inc., 6925-H Oakland Mills Road, Columbia, MD 21045, 301-621-8161

BioLink

Description: Audiometric data base acquisition/management system. Data acquired with Earscan, Microlab, or Biometer can be stored directly. Records can hold thresholds for 250Hz-8kHz for both ears, acoustic immittance data and comprehensive identification data. Up to 64 retests stored per individual. Threshold shifts automatically calculated. User-customized report forms from templates. Demo Disk Available

Computer: IBM XT, AT or compatible, 640k RAM. 20 MB hard disk.
(\$995)

Contact: Micro Audiometrics, 3749-B S. Nova Road, Port Orange, FL 32119-4233, 904-788-9332

Customized Report Generation

Description: A BASIC program permits the clinician to input identifying information and audiometric data, the program displays a wide variety of test calculations on-screen and writes the data to an ASCII data-file. By using merging capabilities of most commercially available word-processors, the clinician can integrate the information from the data-file into customized report templates.

Computer: IBM compatible, 640K RAM, 20 MB hard drive

Contact: Stephen Oshrin, Southern Station, Box 5092, University of Southern Mississippi, Hattiesburg, MS 39406-5092, 601-266-5216

Digital Hearing Systems Corp.

Description: Computer-controlled audiometers and software for clinical and industrial audiologic applications. Custom development.

Computer: IBM compatible

Contact: Digital Hearing Systems Corp., 2934 Shady Lane, Ann Arbor, MI 48104, 313-973-2658

ICS Vestibular Software

Description: Software for vestibular evaluations.

Computer: IBM compatible

Contact: ICS Medical Corp., Schaumburg, IL, 312-397-2150

Intelligent Hearing Systems

Description: Computerized visual response audiometry and evoked potential hearing screening and testing equipment. Computerized speech discrimination testing (IVRSD)

Contact: Intelligent Hearing Systems, Inc., North Miami, FL, 305-547-5981

MacCAD

Central Auditory Diagnostics for the Macintosh

Description: MacCAD is a HyperCard program that makes it possible to set up, run, and analyze the results of listening tests, based on a selection of parameters (e.g., sound set, monaural or dichotic, which ear to test, etc.).

Computer: Macintosh

Contact: Judith Lauter, Department of Speech and Hearing Sciences, University of Arizona, Tucson, AZ 85721, 602-621-1367

MAICO System 2400

Description: Database storage and acquisition system with modules for real-ear measures, prescription methods, audiometric data, patient info. Patient records and tests can be recalled while in any testing mode.

Computer: IBM compatible, 512K RAM, graphics card, 20-40MB hard disk

Contact: MAICO, 612-835-4400, 800-328-6366

Microcomputer-Based Speech Audiometer

Description: A variety of standard audiometric speech tests on disk. The software is flexible and allows for efficient clinic testing and research. A Macintosh computer is used as the external input to a standard audiometer.

Computer: Macintosh, 2 MB RAM

Contact: Brad Stach, The Methodist Hospital, 6501 Fannin, NA 200, Houston, TX 77030

Virtual Audiometric Instrumentation

Description: Computer-operated audiometer, immittance system (multiple-frequency, multiple-component), and probe microphone and standard hearing aid test equipment. Data are stored in a way compatible with a database or spreadsheet program. Software upgrades are included, dealer support.

Computer: Macintosh, 1 MB RAM

Contact: Virtual Corporation, 521 S.W. 11th Avenue, Portland, OR 97205, 503-226-3000

AURAL REHABILITATION**Aural Rehabilitation on Video Disk**

Description: Video disk interactive aural rehabilitation program

Computer: IBM compatible (see contact for more specific information)

Contact: Nancy Tye-Murray, Department of Otolaryngology—Head and Neck Surgery University of Iowa Hospitals, Iowa City, IA 52242

Computerized Audiologic Habilitation Program with the NST

Description: The program provides systematic opportunities to enhance the ability of the person with hearing impairment in the auditory, visual, and auditory/visual conditions with user feedback features. The program includes monitoring of patient confidence level, utilization of a confusion matrix, and measurement of patient response time to speech stimuli. Data are analyzed automatically and the patient can receive immediate feedback.

Computer: Macintosh SE/30, MacRecorder, Mac'N'Touch computer screen, Hypercard© program

Contact: Henry Tobin, Veteran Affairs Medical Center (566/126), Fort Howard, Maryland 21052-3018, 301-687-8852

CPHI Services

Description: Hard copies of the Communication Profile for the Hearing Impaired Questionnaires, response sheets, a database system for scoring and storing data, and a manual of instructions.

Computer: IBM compatible. Cost: Questionnaires—\$6.25 per package, Response Sheets—\$3.75 per package, Database System—\$5.00 per package, Manual—\$10.00, (reduced prices for bulk orders)

Contact:

CPHI Services

PO Box 444

Simpsonville, MD 21150-0444

Hearing Handicap Inventory for the Elderly: Computerized Scoring

Description: a program for scoring and reporting the HHIE data. Can transfer data to a database. User-friendly program.

Computer: Macintosh computer, 1 MB RAM, Hypercard© program. (\$25)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Hearing Performance Inventory: Computerized Scoring

Description: a program for scoring and reporting the HPI data. Can transfer data to a database. User-friendly program.

Computer: Macintosh computer, 1 MB RAM, Hypercard© program. (\$25)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Interactive Product Locator of Assistive Devices for Hearing-Impaired Individuals

Description: Designed to present the user with appropriate devices for specific listener and situational/environments characteristics. The stack is used in several ways. The user is asked a variety of questions in order to identify the needs of the individual. Supplied with this information, the user selects the appropriate product locator. The locator identifies the specific problem, the signal to be used, the preferred technology, the coupling method, whether the device must be portable, and if no installation is preferred. Armed with this information, the product database automatically is searched. Any devices matching the identified characteristics are presented in a summary stack to the user for review. Additional information and a picture of the device is provided.

The distributors who supply the device are shown automatically. If the user selects a device for the patient, the device and distributor information automatically are placed in the patient file. Any of the databases can be searched individually. Updates provided.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$50)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Performance Inventory for Profound and Severe Loss: computerized scoring

Description: a program for scoring and reporting the PIPSL data. Can transfer data to a database. User-friendly program.

Computer: Macintosh computer, 1 MB RAM, Hypercard© program. (\$25)

Contact: The Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Watch and Talk Clinical Toolkit Project

Description: Software for commercial videodisc access. The stories on videodisc can be used to elicit and practice language (i.e., the child can see verbs in action, future, past tense, etc.).

Computer: Macintosh, 2 MB RAM, video monitor, videodisc player

Contact: Paula Cochran, Department of Communication Disorders, Northeast Missouri State University, Kirksville, MO 63501

TEACHING TOOLS

Acoustic Transduction in the Auditory Periphery

Description: Animation of the motion of the tympanic membrane and ossicular chain, the travelling wave pattern of the basilar membrane, the cochlear micromechanics, inner hair cell depolarization, tonotopic organization and the place principle of frequency coding, and temporal coding of frequency. This is an interactive program with quizzes. Acoustic simulation of hearing impairment presented with audiometric charts and postmortem cochlear sections.

Computer: Macintosh II series or Macintosh LC, 8 MB RAM, 30 MB hard drive, color monitor (640 × 480 pixels or larger), Macintosh-compatible CD-ROM player. (\$95)

Contact: Steven Greenberg, Department of Neurophysiology, 273 Medical Sciences Building, Madison, WI 53706, 608-262-5896

Anatomy Tutorial

Description: An interactive program that reveals the detailed anatomy of the ear in stages. All structures are labeled. The user clicks on the structure with the mouse and can see the name. There is a self-test that allows the user to be quizzed. A record of the score is kept.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$50)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Audiogram Interpretation through Computer-Aided Instruction

Description: Users of the software practice and learn audiogram interpretation within a question-answer format that incorporates response-sensitive feedback. Help files are available and the program tracks students' responses for later review by instructors.

Computer: Macintosh IIcx or IIci

Contact: Suzanne Quigley, University of Washington, 1029 Springbrook Road, Lake Stevens, WA 98258, 206-543-0597

Audio PC

Description: An audiometer simulation allows students to test hearing while interacting with a "patient." A masking model allows the student to understand when he/she is over/undermasking.

Computer: IBM compatible with color (\$300)

Contact: Robert Turner, Department of Otolaryngology, Director, Audiology and Speech Clinic, University of California—San Francisco, San Francisco, CA

Damping Tutorial

Description: This program demonstrates the effects of damping with graphics. Nice for the beginning hearing science student.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$20)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

dB Calculator and More

Description: This tutorial illustrates the decibel and scientific notation. Interactive screens allow for a variety of conversions and practice. Ideal learning tool for the beginning hearing science student.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$50)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Decibel Scale

Description: The Hypercard introduces and explains the decibel scale. Reference levels are explained as the differences between sound pressure and sound intensity are explained. The emphasis is on understanding as opposed to working complex mathematical problems. Example problems and feedback are provided.

Computer: Macintosh, Hypercard© program

Contact: Thomas Kneil, Wichita State University, c110 Edinburg, Wichita, KS 67220

Dynamic Acoustics

Description: See the fundamental concepts of sound and sound transmission demonstrated. Text and easy-to-use computer program.

Computer: IBM compatible. (\$149.50, \$19.50 each additional copy)

Contact: Parrot Software, PO Box 1139, State College, PA 16804-1139, 1-800-Parrot1

Harmonic Motion

Description: This program is a tutorial in harmonic motion with graphic illustration.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$10)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Hearing Aid Selection

Description: This is a complete hearing aid selection program—perfect for a clinic or for teaching purposes. The user enters the threshold levels and any MCL or UCL data they have. The user selects the type of aid (BTE, ITE, etc.), the type of earmold (there is a hidden tutorial with pictures of all the types of earmolds and their acoustic results), type of prescriptive formula (e.g., NAL, POGO, etc.). The program automatically calculates desired real-ear gain, coupler gain, SSPL-90, etc. The calculations are presented in an easy-to-read format, perfect for ordering the hearing aid. For the student or interested clinician, a change in earmold selection, damping, or venting results in a graph showing the resulting change in frequency response.

Computer: Macintosh, HyperCard© program (\$130)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Hooke's Law

Description: This interactive program demonstrates Hooke's Law with graphics.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$10)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Impedance Calculator

Description: This program illustrates results of equations that relate to calculations of mechanical impedance. The user enters the values for mass, spring, resistance, and frequency. The program calculates all of the impedance and admittance values as well as resonant frequency.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$20)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Masking Model

Description: The user enters values for the tones, occlusion effect, crossover, etc., or uses default values and can see what is happening within (and across) the individual's head. Nice interactive model for beginning audiology students.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$30)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Ohm's Law

Description: This interactive model illustrates Ohm's law for the student. Perfect for beginning hearing science and hearing aid students.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$10)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Oscilloscope

Description: Enter up to three tones (including amplitudes and phases). The display gives you the graph of what you would see on an oscilloscope if the tones were mixed or added together.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$10)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Pure-Tone Simulation

Description: A computer program that can simulate virtually any hearing pathology. User manipulates the "audiometer," animated listener responds, and one of three plots are viewed—an audiogram, a masking curve, or a Hughson-Westlake response curve.

Computer: IBM compatible (\$149.50, \$19.50 each additional copy)

Contact: Parrot Software, PO Box 1139, State College, PA 16804-1139, 1-800-Parrot1

Tube Resonance

Description: This interactive model illustrates a variety of tube resonances. The user can enter data and see the influence of the tube.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$20)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

Understanding Decibels

Description: This software provides knowledge of the theoretical and practical aspects of decibel computations.

Computer: IBM compatible \$149.50, \$19.50 each additional copy)

Contact: Parrot Software, PO Box 1139, State College, PA 16804-1139, 1-800-Parrot1

Zwislocki Model

Description: The user is presented with the electrical Zwislocki model of the middle ear in graphic form. The values can be changed or the user can select a common pathology from a menu. The user then is able to view the resulting audiogram based on the middle ear information and multiple-frequency, multiple-component tympanometry results. The user also is able to change ear canal length. Perfect for the beginning and advanced student of immittance measures.

Computer: Macintosh, 1 MB RAM, HyperCard© program (\$100)

Contact: Support Syndicate for Audiology, 1739 E. Carson Street, Suite 1650, Pittsburgh, PA 15203, 800-869-0758, 412-481-2497

HEARING CONSERVATION**HCS Hearing Conservation System Database Management Software**

Description: Database management system for audiogram storage, retrieval, comparison, scheduling, notices, and custom analysis reports. Analysis of patterns (threshold shift) by location and shift schedules. Extended subject history file (factors affecting employee's hearing, e.g., off-the-job noise exposure, medical complications).

Full color display (optional) with windows.

Data Transfer Option Program—direct transfer of data into existing sw programs.

Military Program—includes extra provision for printing 2215 and 2216 demographic reporting forms.

Computer: IBM PS/2, PC/XT, PC/AT or compatible. 640K RAM and min. 20MB hard disk. (\$2,900)

Contact: Tracor Instruments Austin, Inc., 6500 Tracor Lane, Austin, TX 78725-2100, 512-929-2027

Health Care Management System

Description: Comprehensive database system for hearing testing, spirometry testing, blood pressure monitoring and physical examination including data storage, retrieval, comparison, report writing, notice writing and scheduling functions. Data can be transferred directly from audiometer to PC or entered manually.

Geared for industrial uses/OSHA regs.

Menu driven.

Special transfer option program—transfer of data directly to other existing sw programs.

Computer: IBM PC/XT or PC/AT or compatible. Min. of 10 MB hard disk. (\$3,450)

Contact: Tracor Instruments Austin, Inc., 6500 Tracor Lane, Austin, TX 78725-2100, 512-929-2027

HEAR/TRAK

Description: Database management system for data storage, comparison and reporting. Analysis of trends for individual or groups. Available for single or multi-user. Provides analysis by OSHA and AAO medical criteria analysis, state compensation impairment calculations, speech and high-frequency type audiogram analysis. Audiometric data can be input directly through interface or manually on-line in batch mode.

Options: Multiple audiometer interface van program (\$1,500), trained data entry personnel (\$14/hr), data conversion program (\$495), data conversion custom system and consulting (\$75/hr), maintenance contract (after first six months, \$825/yr), phone and remote support (\$60/hr), and on-site consulting services (expenses and hourly rate).

Computer: IBM AT compatible 640K RAM, 5 1/4" disk drive, 30 MB hard disk and 2400 Baud modem. Compatible with dBase but does not require user to have dBase. Compiled with Nantucket's Clipper to run as standalone at rates 2 to 20× faster than dBase III. Cost: \$4,400 includes system updates and on-site training for 6 months; remote site and phone support up to 12 months.

Contact: Software Resources & Marketing a Division of a.m. SPEECH, Inc., PO Box 33, Waterford, WI 53185-0033, 414-895-6376, 800-356-5239

N.A.N

A computer program for estimating a population's hearing threshold characteristics. The program makes predictions of threshold levels from age-related hearing loss or combination of noise-induced hearing loss and age-related hearing loss.

Computer: IBM compatible, 512 K RAM, 30 MB hard drive required

Contact: Environmental Noise Consultants, Inc., PO Box 30698, Raleigh, NC 27622-0698, 919-782-1624

Savear

Description: Hearing conservation database system

Contact: Savear, Inc., 44 Elm St., Huntington, NY 11743, 800-HEARS-2-U

System 1

Description: Computer-based audiometer with microcomputer, audiometer, and software. Designed to allow technicians to perform OSHA-required tests, store audiologic records on single diskette and enter noncomputer records.

Password protected keyboard audiometer calibration protection.

Computer: IBM-PC/XT or compatible with min. 256 K RAM, dual floppy drives.

Contact: Monitor/Demlar, ELB Associates, Inc., Chapel Hill, NC

Chapter 13

THE OFFICE OF THE FORUM FOR QUALITY AND EFFECTIVENESS IN HEALTHCARE: STANDARDS OF PRACTICE

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*Office of the Forum for Health Care Quality and Effectiveness
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The Agency for Healthcare Policy and Research (AHCPR) was established December 19, 1989, by Title IX of the Omnibus Budget Reconciliation Act of 1989. This legislation gave the new agency a broad mandate that expands upon the activities of its predecessor, the National Center for Health Services Research and Healthcare Technology Assessment (NCHSR). The new and expanded responsibilities include medical treatment effectiveness research, guideline development, data standardization, and dissemination of research findings and guidelines. The administrator of the agency is appointed by the secretary of the Department of Health and Human Services, Dr. Louis Sullivan. J. Jarrett Clinton is currently administrator of the agency.

AHCPR is one of the eight agencies of the Public Health Service. The other seven are well known: the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA); the National Institutes of Health (NIH); the Health Resources and Services Administration (HRSA); the Food and Drug Administration (FDA); the Indian Health Service (IHS); the Centers for Disease Control (CDC); and the Agency for Toxic Substances and Disease Registry.

The AHCPR reports to Secretary Sullivan through the assistant secretary for health, Dr. James Mason. AHCPR's appropriation level increased from \$50.7 million in FY 89 to \$116 million in FY 91.

The purpose of the AHCPR is to enhance quality, appropriateness, and effectiveness of healthcare services and to enhance access to healthcare services. The focus is on quality. When we consider costs, it is in terms of how cost impacts quality. The agency's purpose is achieved through establishment of a broad base of scientific research and promotion of improvements in clinical practice and organization, financing, and delivery of healthcare services.

The agency consists of four offices and four centers responsible for a variety of activities including intramural and extramural research, demonstration projects, evaluation of demonstration projects and practice guidelines, training

and conferences, practice guideline development, dissemination of research findings and practice guidelines, and data development. Our activities are achieved with the participation of professional specialty organizations, such as ASHA, the American Medical Association (AMA), and the American Nursing Association (ANA); academic health centers; standards-setting organizations such as the Joint Commission for Accreditation of Healthcare Organizations (JCAHO); research-based organizations; and consumer advocates.

The Medical Treatment Effectiveness Program or MEDTEP was developed to focus on the improvement of effectiveness and appropriateness of medical practice and to increase our understanding of the effects of variations in healthcare practices on patient outcomes. MEDTEP research emphasizes the evaluation of "outcomes" of healthcare services rather than the "process" or what was done. MEDTEP involves several of the offices and centers within AHCPR and consists of four elements: (a) research on patient outcomes and clinical effectiveness, (b) collection and development of databases for outcomes research, (c) development of clinical practice guidelines, and (d) dissemination of research findings and clinical practice guidelines.

The Office of the Forum for Quality and Effectiveness in Healthcare (or "the Forum," as it is known within the agency) was mandated to arrange for the development, review, and updating of clinically relevant guidelines. The Forum is also responsible for facilitating the development of standards of quality, performance measures, and medical review criteria.

AHCPR has contracted with the Institute of Medicine (IOM) to advise on guideline development. The IOM has defined guidelines as "systematically developed statements to assist practitioner and patient decisions about appropriate healthcare for specific clinical circumstances." Guidelines are tools to change patient and provider behavior. They will identify areas in which additional research is needed. The IOM also has defined standards of quality as

“authoritative statements of minimum levels of performance or results, excellent levels of performance or results, or the range of acceptable performance or results.”

Guidelines are being developed to reduce inappropriate or unnecessary variation in practice style and uncertainty about clinical effectiveness. Guidelines will convert science-based knowledge to clinical action, allowing more informed clinical judgment to set the research agenda and clarify healthcare choices for the consumer. The two processes for developing guidelines and standards include convening panels of experts and awarding contracts with public and private nonprofit entities.

The IOM has defined 11 attributes of guidelines: credibility, disclosure, validity, reliability/reproducibility, scheduled review, applicability, research relevance, clinical adaptability, flexibility, clarity, and inclusion of many disciplines. One of the hallmarks of the guideline development process is the requirement that it be a multidisciplinary approach including physicians, nurses, allied health, and other health and consumer involvement as appropriate.

The process for developing guidelines includes topic selection, panel selection, extensive literature search, review and analysis, and formatting of the guideline. There will be several versions of the provider format of the guideline (technical, short, and a flow chart or an algorithm), and a patient version. Each guideline will be peer-reviewed for science, content, and issues, and will undergo pilot review for feasibility.

There are currently seven guideline development panels: diagnosis and treatment of benign prostatic hyperplasia, urinary incontinence in adults, acute post-operative pain management (acute post-operative), pressure ulcers prediction, prevention and early intervention of diagnosis and treatment of depressed outpatients in primary care settings, visual impairment due to cataracts in the aging eye, and processing of comprehensive care of sickle cell disease. It is anticipated that guidelines for these conditions will be disseminated to the public beginning in the fall of 1991 through early spring 1992.

New guideline development panels will be formed for the following conditions: management of cancer-related pain, treatment of pressure ulcers, HIV/AIDS, low back disorders, and development of quality determinants of mammography. A request for proposal will also be written to solicit proposals to develop guidelines by contract for the following conditions: otitis media in children, diagnosis and treatment of heart failure secondary to coronary vascular disease, and post-stroke rehabilitation.

In selecting guideline topics, AHCPR considers a number of factors:

- Adequacy of scientific-based evidence on which to develop guidelines
- Number of individuals affected by the clinical condition
- Amenability to prevention
- Expected potential for reducing inappropriate variations in the prevention, diagnosis, treatment, or management of a particular disease or condition

- Specific needs of the Medicare and Medicaid populations
- Cost of the condition to all payers including patients.

When guideline topics are chosen, a Federal Register Notice announcing the guideline development panel and soliciting nominations is published, and interested organizations of healthcare practitioners are invited to submit names of candidates for panel chair and panel membership. Criteria for consideration of candidates for panel chair(s) include the following:

- Relevant training and clinical experience
- Demonstrated interest in quality assurance and research on the clinical condition including publication of relevant peer-reviewed articles
- Commitment to the need to produce clinical guidelines
- Recognition in their field with a record of leadership in relevant activities
- Broad public health view of the utility of the particular procedure or clinical service
- Demonstrated capacity to respond to consumer concerns
- Prior experience in developing guidelines for the clinical conditions in question.

The panel chair provides leadership to the panel regarding methodology, literature review, panel deliberations, and formation of the final product. Panel chairs are appointed by the AHCPR.

In selecting members for panels, AHCPR seeks recommendations from a broad range of interested individuals and organizations, including physicians representing specialty and general practices, nurses, allied health and other healthcare practitioners, and consumers with experience or information pertinent to the guideline being developed. Individuals with experience in developing guidelines are particularly sought. The panel chair(s) is responsible for recommending proposed members for the panel to AHCPR for appointment.

Guidelines developed by AHCPR require that all scientific evidence be considered, the consequences of different options be weighed, and the scientific evidence and subjective judgments supporting the chosen options be described explicitly. The methodology emphasizes the importance of a comprehensive evaluation of empirical evidence of effectiveness and all significant outcomes (especially those important to patients), benefits, and harms. The methodology emphasizes explicit documentation of methods, rationale, and assumptions.

It is expected that the guideline development process will help identify needed research and thus provide additional guidance to AHCPR's medical treatment effectiveness research agenda. Similarly, the research on treatment effectiveness and outcomes will contribute to the development and revision of guidelines.

As guidelines are completed, AHCPR will promote and

support their dissemination to practitioners and other users. Organizations of healthcare practitioners, healthcare consumers, peer reviewers, accrediting bodies, academic medical centers, medical educators, researchers, payers, and other appropriate groups will be encouraged to disseminate the guidelines to their members and constituents. Guidelines will be made available through medical libraries and indexing services.

In July 1990, AHCPR's Forum convened an allied health workshop to examine the role of allied health professions in MEDTEP activities, with an emphasis on guideline development. Three multidisciplinary subgroups were established to facilitate discussion and consensus. Plenary sessions provided opportunities to share viewpoints and refine issues. Representatives were invited from the allied health disciplines included in the 1988 study of the role of allied health personnel in healthcare delivery that was conducted by the Institute of Medicine. Those 10 professions included clinical laboratory science, dental hygiene, dietetics, emergency medical services (prehospital care), medical record administration, occupational therapy, physical therapy, radiologic technology, respiratory therapy (respiratory care), and speech-language pathology and audiology. In addition, representatives of surgical technology, electroneurodiagnostic technology, and ophthalmic medical technology were invited because their activities are particularly pertinent to discussion of the clinical guidelines under development. Representatives from psychology and medical social work were also invited.

In general, workshop participants were nominated by their respective national organizations. Nominees were identified as leaders in their disciplines with recognized expertise as clinicians, researchers, educators, and administrators who could represent the organizations. Forty-eight individuals participated, representing 14 of about 85 diverse professions commonly identified as allied health professions.

Participants identified a number of clinical conditions for future guideline development. Through group consensus, the following conditions were identified as priorities:

- Stroke rehabilitation
- Chronic obstructive pulmonary disease (COPD)
- Mobility impairment secondary to osteoporosis
- Diabetes management in the elderly
- Alzheimer's disease
- Otitis media in children

The following are among the other recommendations made by workshop participants:

- Guideline development should be the responsibility of the healthcare professions, not the government.
- The allied health community needs to pursue vigorously the continuing development and expansion of clinical effectiveness research.
- A task force of allied health experts should be identified by the allied health professions to provide continuing counsel to AHCPR.
- A coalition is needed to address public health policy issues and activities from an informed, multidisciplinary perspective because of the diversity of allied health professions and their varying degrees of autonomy and scopes of practice.

Allied health professionals are currently involved with five of the seven guideline development panels. An audiologist has been invited to peer review the final draft of the Depression Guideline. Additionally, it should be noted that two of the recently announced conditions (otitis media and post-stroke rehabilitation) for guideline development by contract are recommendations from the Allied Health Workshop sponsored by the Forum in July 1990 and affect the practice of audiologists and speech-language pathologists.

This overview of the AHCPR, the guideline development process, and allied health involvement in the guideline development process is based on the following AHCPR publications: the August 1990 AHCPR program note, *Clinical Guideline Development*, and the November 1990 AHCPR factsheet, *Allied Health Perspectives on Guideline Development*

Chapter 14

CONTINUOUS QUALITY IMPROVEMENT: A MANAGEMENT STRATEGY FOR THE 1990s

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In the past two decades we have witnessed marked changes and increased demands on our healthcare system: the cost of healthcare is rising, the competition among healthcare providers has never been greater, and today's consumer of healthcare services is more knowledgeable, seeking the best possible care for the most reasonable cost. Other specific examples of changes and demands on healthcare:

- Healthcare costs in the United States continue to rise and represent about 12% of the gross national product.
- More hospitals in the United States are closing.
- Americans believe that the healthcare system is poorly organized and inefficient.
- Americans believe that rising healthcare costs can be reduced without cutting the quality of care.
- Americans are losing confidence in the leaders of medicine and healthcare institutions.

If healthcare providers are to succeed in the future they will need to respond to these changes and demands. It is becoming increasingly apparent that the only way to distinguish the services of competitors is through quality—not simply quality assurance but a program that focuses on getting better. The concept of quality improvement has long been part of business and industry. Only in the past few years, however, have quality improvement programs found their way into the healthcare arena.

DEMING'S 14 PRINCIPLES

Some healthcare professionals have turned to the work of W. Edwards Deming, a well-recognized statistician who was called upon by MacArthur to help the Japanese rebuild their economy following World War II (Gillem, 1988). Deming believes the best way to become productive and competitive is to rivet one's attention on quality. To do so,

an organization must identify the customer's perceived needs and then design services to meet those needs. The general plan is to design the best value service, provide the service according to some set specifications, offer the services to all populations, and then assess the quality of that service based on customers' judgments. To help accomplish this goal, Deming developed 14 guiding principles considered essential for quality and continuous improvement (Walton, 1986; Gillem, 1988). A brief description of these principles follows.

1. Create Constancy of Purpose for Service Improvement

This principle is considered the most important. Deming speaks specifically to the leader's role in quality improvement of a healthcare institution. That is, the leaders of the organization *must* have a total commitment toward a quality improvement process. Deming also places emphasis on long-term goals rather than near-term goals. Too often we dwell on day-to-day issues and spend insufficient time on where the organization is going 5, 10, and 15 years into the future. Deming tells us that healthcare institutions need to define goals for the future and then communicate these goals to all employees if we expect to be competitive and maintain a quality organization. In programs of communication disorders, we have the challenge of developing quality improvement processes and moving our staffs to share a single long-term commitment to higher productivity and better patient care.

2. Adopt the New Philosophy

Every institution must learn that work-related functions can be performed correctly the first time. When a hearing aid is selected for a client who is hearing impaired, we ex-

pect that it will be the most appropriate instrument and that the instrument will lead to hearing aid success. When a speech-language pathologist conducts a diagnostic test, we expect that it will be accurate and that an appropriate recommendation will be made. When a client is billed for services we expect the bill to be timely and accurate. Interestingly, a significant amount of what takes place within any healthcare facility, including hearing and speech centers, is not performed correctly the first time. This brings about the cost of rework and waste. Because it is possible to do things right the first time, Deming tells us that nothing less should be accepted. He believes that doing it right the first time around should become routine practice. In the past, quality programs were thought to result in excessive cost. Today there is a trend toward accepting the fact that gains in quality attract new customers and result in gains in efficiency and productivity, which in turn translates to lower cost. This is the new philosophy.

3. *Cease Dependence on Inspection to Achieve Quality*

Our current system of quality healthcare in communication disorders focuses on inspection: inspection of files, inspection of people and inspection of people's performance. Deming suggests to us that this is not the best way in which to improve quality. We must move away from the inspection concept and develop methods to improve processes and to measure objectively whether the changes introduced produce an effect. The focus, then, is on the entire process—a system of care that promotes cooperation, coordination and *esprit de corps* among all staff, both professional and nonprofessional.

4. *End the Practice of Awarding Business on Price Alone—Make Partners Out of Vendors*

Too often we emphasize price alone. It is standard practice for a healthcare facility to send a requisition to a group of bidders to obtain the best cost possible. Sometimes, however, such a practice can be expensive. There can be late delivery, poor installation, inappropriate setup and lack of design. It is important that, once a healthcare facility develops a focus and a strategy for quality improvement, vendors be made aware of such a program.

5. *Constantly Improve Every Process for Planning, Production and Service*

To improve quality, every employer must know how and feel free to make improvements within the process. The "perks" for performance must come from finding ways to improve the process. Too often suggestions are totally disregarded within an institution. Ideas are often disregarded because leadership does not believe workers understand what the institution is about and what the institution is try-

ing to accomplish. Our responsibility here is to ensure that all employees know the mission, vision, and definition of quality and then encourage them and provide them with the know-how to make improvements in the process. Deming tells us that several basic steps are needed for continuous improvement (Walton, 1986; Moen & Nolan, 1987; Perry, 1988). First, we must *plan*. That is, we study the process, and we look for an opportunity to improve that process. Second, we *do*. We make improvements, we collect data, and we carry out data analysis. Third, we *check* or *analyze*. That is, we look at the data for process improvement, for customer outcomes, and for lessons learned. And finally, we *act*. We learn from the process, and we continue to improve the process wherever possible.

6. *Institute Training and Retraining on the Job*

Continuous education is critical to the improvement process. Employees need to learn ways to measure quality improvement. They not only need to be trained to do the job but to know why and how to improve it.

7. *Institute Leadership for System Improvement*

Deming believes that most of the time problems lie within the process, not people. People want to do well; however, too often the process will not allow it. To improve performance we *must* learn to improve the system. The manager or department head must be the leader for the improvement of the system's performance. The manager must serve as the coach to help prepare, improve, and cheer the successes of employees.

8. *Drive Out Fear*

Workers must feel free to improve the system. Often, institutions create an atmosphere in which employees are afraid to suggest change. Here again, the importance of leadership is emphasized—that is, developing a constancy of purpose and assuring employees that the leadership is committed to a quality improvement program.

9. *Break Down Barriers Between Staff Areas*

This principle is perhaps one of the most difficult areas in any healthcare facility. Oftentimes departments function in isolation, like boxes on the organization chart. They are interested in their own well-being. They are interested in trying to improve their own departmental situation. A great example in healthcare facilities is the barrier that typically exists between the business office and professional departments. Business office staff have job responsibilities 180° out of phase with the responsibilities of professional staff. One group cares for people, the other group collects money. Hence, it is not unusual to find a lack of cooperation between the business office and other departmental

staffs. This results in excessive cost, time waste, bad feelings, and reworking of assignments. Mechanisms must be established to break down barriers that exist between various departments.

10. *Eliminate Slogans, Exhortations and Targets for the Workforce*

It is not unusual to see slogans in business settings such as "Do a better job!" "Make it happen!" and "Teamwork!" Such slogans, according to Deming, are not helpful. In fact, they are sometimes insulting. Please keep in mind that employees are interested in doing the very best job they can. They don't need to have signs telling them what they should believe.

11. *Eliminate Numerical Quotas for the Workforce and Numerical Goals for the Management*

If the focus is on quantity, there will be a tendency to disregard quality. Many centers for communication disorders have quotas for patient contact hours. The emphasis here is on meeting that quota. If the focus is on quality—that is, to see as many patients as possible in the most efficient way, to do your very best—then quality will no doubt result. If your goal is to meet a quota, you typically will get that quota.

12. *Remove Barriers to Pride of Workmanship*

All employees should take pride in the work they do. Performance appraisals should take into consideration how the individual works with the team and whether the person is concerned with the overall mission and vision of the institution.

13. *Institute a Vigorous Program of Education and Self-Improvement for Everyone*

A highly educated workforce is an institution's most valued asset. Deming tells us that quality begins and ends with education. An excellent example of the importance of education is seen with Nissan Motor Manufacturing Corporation USA. Nissan spent \$63 million dollars on 20,000 employees before the company even began to manufacture a car! Nissan wanted the people to feel good about their work and to provide them with the resources to do the best job possible. Typically, educational programs of this nature are the very first items eliminated when budget restraints occur. Hence, we find that employees begin to seek other ways to learn that are not related to the organization or its goals.

14. *Put Everyone to Work on the Transformation*

Once the commitment has been made, all possible energy needs to be focused on a transformation, which requires the total involvement of everyone. It is a major

transformation that starts with the leadership and involves everyone within the facility.

DEVELOPMENT OF A QUALITY IMPROVEMENT PROCESS

Many organizations believe that because they have a quality assurance program, the institution is totally committed to and effectively carrying out a quality program. In all likelihood, this is not the case. Importantly, there are distinctive differences between what is meant by quality improvement and what is meant by quality assurance. Quality assurance usually means that you are trying to meet some minimum standard. Quality improvement, on the other hand, implies trying to do a better job all the time. For a quality improvement process to exist, administrators of healthcare facilities should be able to answer the following questions:

- Does your organization have a mission and vision statement as well as a summary of principles and values?
- Does everyone in your facility know the definition of quality and how to measure quality? Do they know the tools that are needed to measure and improve quality?
- Do you know who your customers are? Do you know your customers' needs and expectations? Does everyone in the organization know who their customers are?

If leaders of healthcare facilities are unable to answer these questions positively, there is probably a need for improvement in their quality focus.

The Bill Wilkerson Center recently began the development of a quality improvement process. The conceptual framework underpinning the center's quality improvement strategy is shown in Figure 1. This figure, based on the work of Deming (1986) and others (Nelson, Caldwell, Quinn & Rose, 1991) shows the Bill Wilkerson Center as a system for managing the organization through systematically assessing customer knowledge and feedback. The dashed line enclosing the general area represents the internal environment of the Bill Wilkerson Center; those areas outside the circle represent the external environment. In the words of Nelson and co-workers (1991), "The process is . . . a means of transforming the organization from a reactive, product-driven culture to the proactive, customer-minded culture necessary for successful quality improvement." It is seen that the process begins with the need. The overall thrust, then, is to match the services and/or products of the organization to that need. The need answers the question, "What do our customers need, regardless of what services or products our organization, or other ones, provide?" The vision, mission, and values answer the questions, "Who are we, what needs do we meet, and what business are we in?" To clearly define the need of the Bill Wilkerson Center as well as to delineate our businesses we rewrote our mission; developed a statement on principles, values, and quality; and developed a vision statement that projected where we wanted to be in the future. After con-

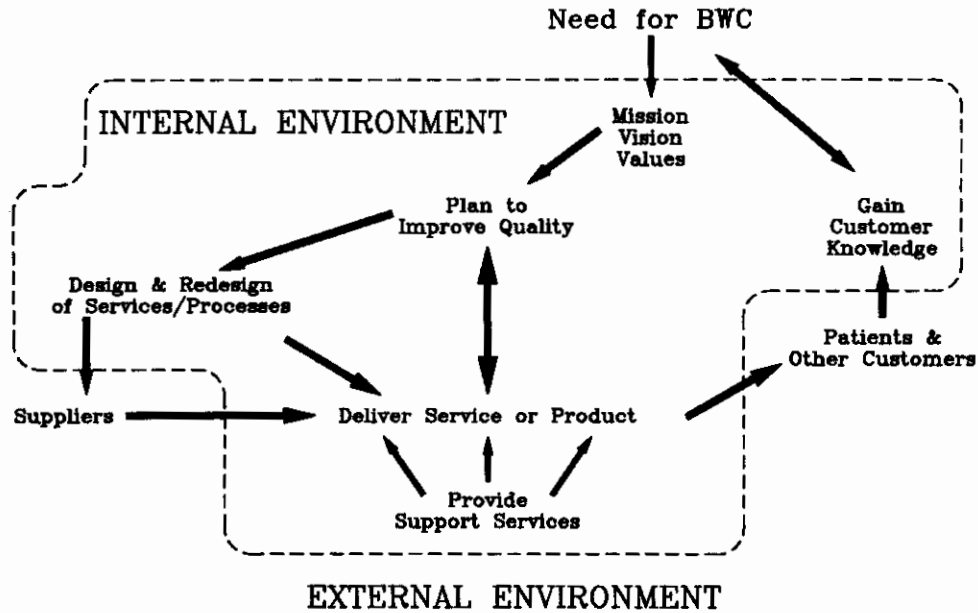


FIGURE 1. The Bill Wilkerson Center viewed as a process. The dashed line encloses an area that represents the center's internal environment; areas outside the circle represent the external environment.

siderable discussion, debate, and revision by all employees and board members at Bill Wilkerson we finalized these various documents. The mission statement of the Bill Wilkerson Center is presented in the Appendix.

The process also emphasizes customer knowledge. An organization must clearly identify the customers' needs and then develop a program designed to meet those needs with services and products. That is, we must continually seek the opinions and perceptions of our customers if we expect to develop a quality improvement process. The development of customer knowledge along with a mission, vision, and values provides us with the basis for developing a plan to improve quality. The plan provides us with the

short- and long-term goals of the organization, but most importantly it is a long-term strategy. It takes into consideration the need and the customers' requirements, and allows us to focus on specific services/products that best meet the needs of the customers. It also represents a balance of both external and internal environments.

As discussed earlier, the focus is to find a system or process to improve and to describe that process and to determine what is important and who benefits. The second step is to organize a team of employees who know that process, that is, to assemble individuals from various components of the process. For example, examining the hearing aid repair process probably would involve a number of important peo-

TABLE 1. Basic steps in the old process and the new process of hearing aid repair at the Bill Wilkerson Centers.

<i>Old Process</i>	<i>New Process</i>
Forms required: Repair Form to repair vendor to dispensary file to medical records	Forms required: Repair Form only, modified to contain all information needed by all participants in the process. Form will be printed on carbonless multipart form to eliminate need for copying, with the name of the recipient of each copy clearly marked on the printed form. Saves time and avoids errors in completing multiple forms.
Purchase Order to accounts payable to dispensary file Speedy Bill to accounts receivable to dispensary file	
Repair records One set in dispensary (kept for 2 years) One set in accounts payable One set in medical record	Repair Records Dispensary file will be eliminated and accounts payable records will serve as general repair records as well. Reduce filing time and saves space.

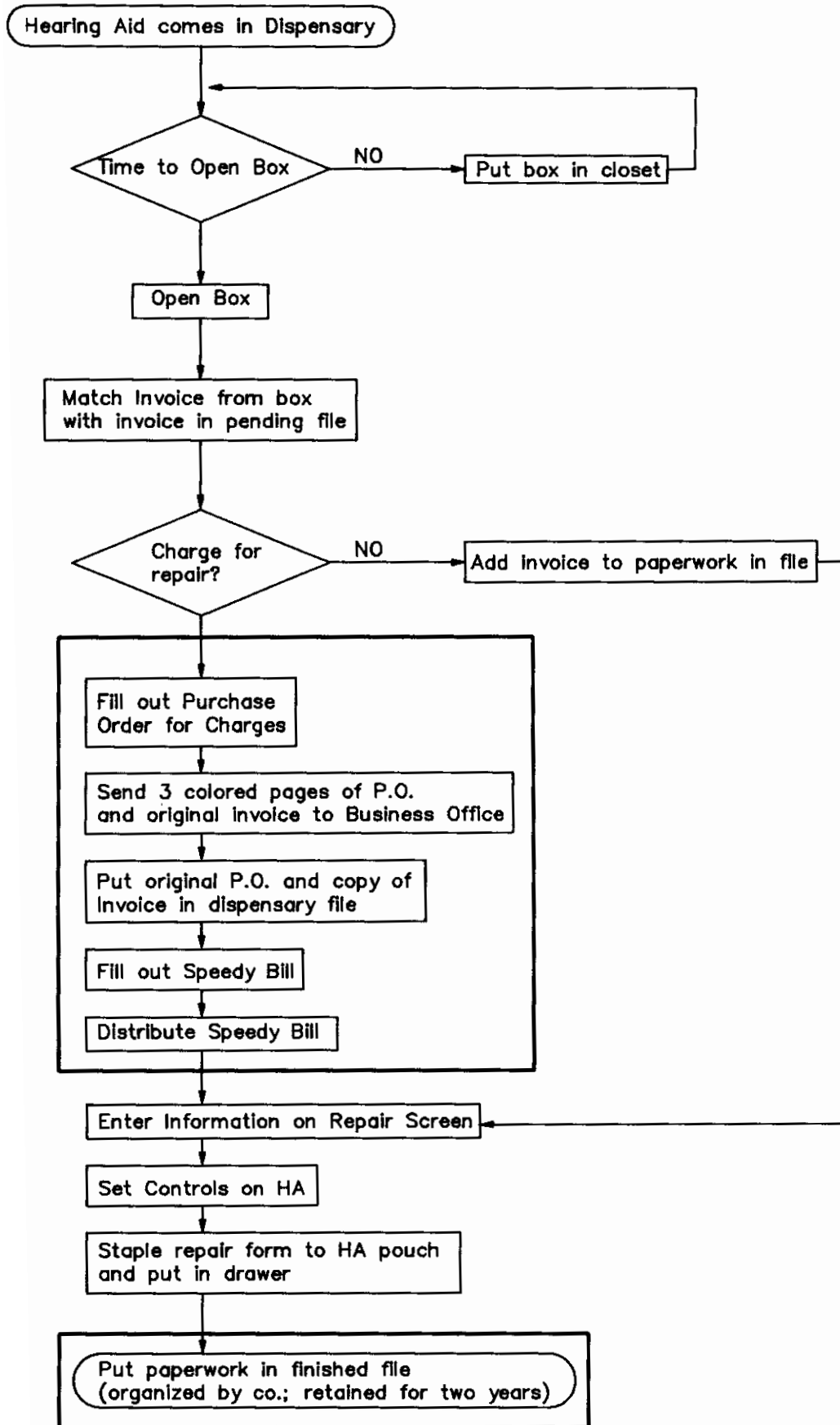


FIGURE 2. The Bill Wilkerson Center: Flowchart of one stage of the hearing aid repair process.

ple from various departments concerned with that process (i.e., business office, hearing aid clinic, etc.). The next step is to clarify current knowledge of the process. What do we know about the process? What is it about the process that works? What is it that doesn't work? Is there redundancy that can be eliminated? Next, there is a need to understand the cause of process variation. Process variation is simply identifying normal variation and differentiating normal variation from abnormal variation. Finally, one selects the process for improvement—that is, the development of some strategy or intervention to improve the overall process.

To illustrate, the Bill Wilkerson Center first identified the hearing aid repair process as an opportunity for improvement. A quality improvement team was then assembled to study the various activities involved in hearing aid repair. A flow diagram of the hearing aid process was developed and one stage of this process is shown in Figure 2. It was noted that this repair was extremely lengthy and, as a result, was causing time loss, excessive cost, and duplication of effort. After reviewing the various steps involved in the hearing aid process, it was easy to reduce much of the redundancy. In fact, those steps outlined in bold were eliminated. A summary of the basic steps in the previous process and in the current process is detailed in Table 1. We will continue to work on improving this process. Objective methods (i.e., control charts, scatter diagrams, Pareto analysis) can be developed to monitor the strategies designed for improving the process.

S U M M A R Y

Healthcare is undergoing significant change and the importance of continuous quality improvement is paramount.

We have reviewed some of the basic characteristics central to the Deming form of management for quality improvement. The primary thrust, of course, is to build knowledge of the customer in an effort to continually plan, design, improve, and monitor processes. In this way, we have our best chance of improving quality. The Bill Wilkerson Center is currently working to set up various quality improvement teams consistent with the long-term goals of the Bill Wilkerson Center. Our objective is to link the center's mission and vision to a quality improvement plan that focuses on the needs and perceptions of all who benefit from our services.

R E F E R E N C E S

- Deming, W.E. (1986). *Out of the crisis*. Cambridge, MA: Massachusetts Institute of Technology.
- Gillem, T.R. (1988). Deming's 14 points and hospital quality: Responding to the consumers' demand for the best value healthcare. *Journal of Nursing Quality Assurance*, 2, 70-78.
- Moen, R.D., & Nolan, W. (1987, September). Process improvement. *Quality Progress*, 62-68.
- Nelson, E.C., Caldwell, C., Quinn, D., & Rose, R. (1991). Gaining customer knowledge: Obtaining and using customer judgments for hospitalwide quality improvement. *Topics in Health Record Management*, 11, 13-26.
- Perry, L. (1988). The quality process. *Modern Healthcare*, April, 30-34.
- Reece, R. (1987). Quality of medicine—The view from Hospital Corporation of America. *Minnesota Medicine*, 70, 678-684.
- Scholtes, P.R., & Hacquebord, H. (1987). *A practical approach to quality*. Madison, WI: Joiner Associates.
- Walton, M. (1986). *The Deming management method*. New York: Dodd, Mead and Company.

APPENDIX

BILL WILKERSON CENTER
MISSION STATEMENT

The Bill Wilkerson Center is a private, not-for-profit corporation designed to serve individuals with communicative and related disorders through service, education, and research.

We strive to:

- Achieve excellence in providing services to our patients.
- Advance the quality of service available to individuals with communicative and related disorders through education and research.
- Achieve international leadership in the field of communication disorders and related disciplines.
- Promote public awareness of communicative and related disorders.
- Enhance our knowledge of the nature of communicative and related disorders.
- Encourage continuous improvement of operations and staff through personal and professional development.
- Generate measurable benefits for our community, employees, and patients.

Chapter 15

CONSUMER SATISFACTION MEASURES—AN INTEGRAL COMPONENT OF SERVICE DELIVERY

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This manuscript focuses on consumer satisfaction measures as they relate to people who are hearing impaired. The discussion derives from the healthcare marketing literature, which suggests that healthcare behavior and consumer satisfaction are integrally related. Prior to beginning the discussion, an understanding of certain terms is necessary. First, we must agree on the term *consumer* or *individual buyer*. This person is the target of our marketing efforts and his or her characteristics will influence product pricing, distribution, and promotion (Kotler & Clarke, 1987). The term *consumer satisfaction* refers to a state felt by a person who has experienced an outcome that has fulfilled his or her expectations (Kotler & Clarke, 1987). To validly measure consumer satisfaction, we healthcare professionals must be *market-centered*; that is we must come to know the core product the consumer is actually seeking (Kotler & Clarke, 1987). Specifically, we must come to know the consumer's *wants, needs and perceptions/preferences* (Kotler & Clarke, 1987). In the case of people who are hearing impaired, we must, from the outset, gain a grasp of their wants, needs, and perceptions as they relate to the hearing impairment, the hearing handicap, and rehabilitation.

Motivational Factors Influencing Healthcare Behavior

Understanding what motivates healthcare behavior is a first step toward uncovering the needs we must satisfy to ensure a satisfied consumer, namely people who are hearing impaired. The motivation behind seeking hearing healthcare services is dependent on the complex interplay among four variables: wants, beliefs, rewards, and costs (Kemp, 1990). The audiologist must understand the consumer's wants or needs (Kemp, 1990), because this will help us understand the needs to be best served by the product(s) we have to deliver (e.g., hearing aids, assistive listen-

ing devices, etc.) (Kotler & Clarke, 1987). Maslow's (1954) hierarchy of needs typology details the order in which individuals seek to satisfy their basic needs (Kotler & Clarke, 1987). The needs, in the order in which they define the individual's motivational orientation, are as follows:

1. Physiological needs: to restore hearing sensitivity or word-recognition ability
2. Relate-to-safety needs: to remove hearing loss as a threat to safety at home or at work
3. Social needs: to enable people with hearing impairment to communicate better with family and friends
4. Self-esteem needs: to minimize the emotional consequences of hearing loss, which often are damaging to one's self-concept.

Use of hearing aids and assistive listening devices accommodates some or all of these basic needs; thus, the audiologist must attempt to understand and activate the needs of each person so as to influence his or her buying behavior (Kotler & Clarke, 1987).

Next, we must uncover our consumer's beliefs or expectations as they relate to the product we have to offer (Kemp, 1990). According to Kemp, beliefs reflect the consumer's subjective view of his or her expectations and perceptions and often run counter to a professional's opinions. Consumer expectations are formed on the basis of past experience, statements by age cohorts, family, and health professionals (Kemp, 1990). We have an obligation to ensure that the consumer's expectations/beliefs regarding the hearing aid/assistive listening device are realistic. If the task the person sets out to achieve appears feasible, he or she will approach it with optimism and energy (Kemp, 1990; Kotler and Clarke, 1987). In the case of a hearing aid purchase, the professional should avoid making exaggerated claims about the device to be dispensed (Kotler & Clarke, 1987). Specifically, Kotler and Clarke argue in fa-

vor of understating hearing aid performance so that the hearing-impaired consumer experiences higher than expected satisfaction with the unit.

The next component of motivation is reward (Kemp, 1990). The hearing-impaired consumer must be convinced that the hearing aid or assistive listening device will result in some type of reward or he or she is not likely to try to use it (Kemp, 1990). The consumer of a hearing healthcare product may expect some or all of the following rewards:

- Reduction in the emotional and social consequences of hearing loss
- Improved communication with family, friends, and co-workers
- Improvements in the ability to understand TV/radio and telephone communication
- Greater independence
- Enhanced safety
- Improved pure-tone levels and improved speech recognition ability.

It is imperative that the consumer have objective evidence that use of a hearing aid/assistive listening device does in fact result in at least one of the above rewards. The consumer will have confidence in the professional rendering the service and in enhanced satisfaction if, in fact, the outcomes (i.e., rewards) they experience are made real to them (Kotler & Clarke, 1987).

Finally, the social, physical, and psychological costs associated with handicapping hearing loss are integral to the person's motivation to use a hearing healthcare product and, ultimately, to their satisfaction (Kemp, 1990). In short, these costs must be outweighed by the long-term benefits of use of the hearing aid/assistive listening device. For example, a major obstacle to hearing aid use is the excessive cost associated with purchasing a hearing aid and related services. Accordingly, it is incumbent on the professional to acquaint the hearing-impaired consumer with information regarding the cost of a hearing aid relative to its long-term utility and benefit (Weinstein, 1991).

In their study of quality of life changes associated with hearing aid use, Mulrow et al. (1990) provided the reader with data that can serve as a powerful impetus for purchasing a hearing aid (Weinstein, 1991). Mulrow et al. (1990) projected the average cost of a hearing test, hearing aid selection, hearing aid and hearing aid dispensing to be \$1,000. Using these calculations, they performed a cost-benefit analysis wherein the economic impact of a hearing aid was considered in the context of financial outlay and psychosocial benefit to the hearing-impaired consumer (Weinstein, 1991; Mulrow et al. 1990). Specifically, they computed the cost of a hearing aid in terms of hearing quality adjusted life years (HQALYS), which considers the actual financial outlay for hearing healthcare services, along with some measure of benefit (Mulrow, et al. 1990).

Using percent improvement in score on the Hearing Handicap Inventory for the Elderly (HHIE), a self-report instrument that quantifies the emotional and social consequences of hearing loss in the elderly, Mulrow et al. (1990) projected the actual cost-effectiveness estimate for an individual receiving a hearing aid to be \$200. In short, the

hearing aid reduced the perceived psychosocial handicap in their subjects to such a degree that theoretically the cost to the consumer could be projected to be considerably less. Information of this nature should be shared with the consumer as it may truly influence the decision to purchase a hearing aid.

The Measurement of Consumer Satisfaction

Having outlined some of the internal and external triggers that may motivate the behavior of the hearing-impaired consumer, we are one step closer to judging post-purchase hearing aid satisfaction, because knowing the hearing-impaired consumer is the basis for effective product delivery (Kotler & Clarke, 1987). Our goal in determining consumer satisfaction is twofold: to measure objectively the efficacy or efficiency of our service and to communicate to our clients the outcomes we believe have been achieved through the intervention (Kotler & Clarke, 1987). As noted earlier, the latter point is critical, yet because of time constraints, clinicians often forget to communicate outcomes of intervention to the consumer. Finally, to ensure continued consumer satisfaction, postpurchase communications in the form of newsletters, packets of information about hearing healthcare technology, and periodic consumer satisfaction questions can cut the rate of dissatisfaction and should be pursued with vigor (Kotler & Clarke, 1987).

Three general methods of consumer satisfaction analysis are used by healthcare organizations to ensure that the product is performing according to the consumer's expectations (Kotler & Clarke, 1987). These include sales-related methods, which are indirect methods used by healthcare organizations wherein satisfaction is judged according to service utilization; complaint or suggestion systems wherein the consumer is encouraged to complete comment cards regarding the service; and consumer satisfaction questionnaires/surveys.

Because the hearing-impaired consumer is purchasing a product that will alleviate the self-perceived communication, social, and emotional handicaps deriving from the hearing loss, my bias is the use of the latter category of measures. Using this approach, consumers are asked to report directly on their level of satisfaction with a particular product in the situation they specifically described as being problematic from the outset. The goal, of course, is to determine if we can measure any improvement that is directly attributable to the product. Self-assessment techniques have been used successfully to demonstrate to consumers the ability of hearing aids to reduce the handicaps they attribute to the hearing impairment. Below is a synopsis of selected studies that have documented the sensitivity of self-assessment tools as measures of outcomes with hearing aid intervention.

Newman and Weinstein (1988) successfully demonstrated the benefit/ satisfaction derived from hearing aids in selected domains of function in a sample of elderly male veterans after 1 year of hearing aid use. Specifically, each subject and spouse completed the HHIE prior to the hearing aid evaluation and 1 year after the hearing aid fitting.

Differences between scores on initial and readministration of the total scale, the emotional subscale, and the social subscale of the HHIE were statistically significant. Such a difference suggests that the handicap experienced prior to intervention was significantly reduced 1 year after using a hearing aid. The spouses also rated the handicap in the emotional and social domains to be reduced as a result of the hearing aid intervention. Similarly, while prior to hearing aid use there was a gap between the scores of hearing-impaired subjects versus the scores of their spouses regarding the psychosocial impact of the hearing loss, following hearing aid use, the mean HHIE scores were quite similar, suggesting that the hearing-impaired subjects and their spouse's perceptions were more compatible (Newman and Weinstein, 1988).

Garstecki, Hutton, Nerbonne, Newman, and Smoski (1990) presented a case study demonstrating the utility of the HHIE as a tool for monitoring a patient's adjustment to different style hearing aids. Specifically, a 78-year-old woman with a bilaterally symmetrical high-frequency sloping sensorineural hearing loss completed the HHIE prior to obtaining a behind-the-ear hearing aid (Garstecki et al. 1990). Her HHIE score 3 weeks post-hearing aid use was essentially unchanged, and the patient admitted having considerable difficulty adjusting to the unit (Garstecki et al. 1990). In light of her reported difficulties, a trial period with an in-the-ear hearing aid with a comparable frequency response was attempted, and the HHIE was completed 3 weeks post-hearing aid use. A dramatic improvement (30%) in HHIE scores emerged following merely 3 weeks with the in-the-ear unit (Garstecki et al. 1990). The patient also reported that she easily adjusted to the in-the-ear hearing aid and was once again enjoying participation in social activities at her retirement center. This case dramatically demonstrates the use of self-assessment tools to monitor consumer dissatisfaction as well as satisfaction.

Malinoff and Weinstein (1989) presented data to support the use of the HHIE as a consumer satisfaction measure sensitive to longitudinal adjustment to amplification. Malinoff and Weinstein (1989) monitored adjustment to hearing aid use in a sample of 25 older adults over a period of 1 year. The HHIE was completed prior to hearing aid use, and at 3 weeks, 3 months, and 1 year after obtaining the hearing aid. The findings were as follows:

- A significant reduction in self-perceived hearing handicap on the HHIE and its subscales emerged after 3 weeks of hearing aid use.
- Differences between HHIE scores before and 3 months after the hearing aid fitting were statistically significant.
- A slight statistically significant increase in mean HHIE scores emerged between 3 weeks and 3 months of hearing aid use.
- Differences between mean HHIE scores obtained on the HHIE and its subscales after 3 months and 1 year of hearing aid use were not statistically significant.

Malinoff & Weinstein (1989) concluded that self-report measures such as the HHIE hold promise as indices of perceived satisfaction with hearing aids over an extended interval of time.

Handicap scales may also be used to demonstrate to clients the differential effect of intervention versus nonintervention in a sample of older adults with hearing impairment over an extended time interval. Mulrow et al. (1990) conducted a randomized controlled trial to evaluate whether hearing aids are efficacious treatments for improving the quality of life of hearing-impaired individuals. Approximately half of their subjects were assigned to a waiting list group and the other half received hearing aids. Each group of subjects completed a series of disease-specific and generic measures of quality of life at the beginning of the trial and at a 6-week and a 4-month time interval. Treatment effects of hearing aids from baseline to 6 weeks and from baseline to 4 months were clinically and statistically significant on the HHIE and its subscales. In contrast, in the waiting list group, scores on the total, emotional, and social scales of the HHIE remained stable at these same time intervals (Mulrow et al. 1990). Once again it is apparent that self-assessment tools such as the HHIE can demonstrate to the consumer the effects of long-term intervention versus nonintervention with hearing aids.

Finally, Von Wedel, Von Wedel, and Streppel (1991) demonstrated the sensitivity of the Social Hearing Handicap Index (SHHI) as a measure of the efficacy of the hearing aid fitting in older adults. A sample of 121 older subjects wearing hearing aids for at least 3 months completed the SHHI. Social hearing ability as measured on the SHHI showed dramatic improvement after a brief trial with hearing aids, leading the authors to conclude that "information obtained from tests such as the SHHI enables longitudinal studies on the course of a hearing disability or the effectivity of a particular therapy" (Von Wedel et al., 1991, p. 270).

In summary, Kotler and Clarke (1987) contend that the acid test of a health professional's effectiveness is the satisfaction a particular intervention, therapy, or device creates within the consumer. Further, Kotler and Clarke (1987) reason that responsive healthcare professionals must make use of satisfaction indices, because these are vehicles for matching consumer performance to consumer expectations, thereby creating high levels of satisfaction (Kotler & Clarke, 1987). Hearing healthcare professionals are urged to consider the advice of Kotler and Clarke in an effort to better meet the needs of the consumer with hearing impairment.

REFERENCES

- Garstecki, D., Hutton, C., Nerbonne, M., Newman, C. & Smoski, W. (1990). Case study examples using self-assessment. *Ear and Hearing*, 48S-57S.
- Kemp, B. (1990). The psychosocial context of geriatric rehabilitation: Toward a therapeutic model. In B. Kemp, K. Brummel-Smith, and J. Ramsdell, (Eds.), *Geriatric Rehabilitation*. Boston: College-Hill Press.
- Kotler, P. & Clarke, R. (1987). *Marketing for healthcare organizations*. New Jersey: Prentice Hall.
- Malinoff, R. & Weinstein, B. (1989). Measurement of hearing aid benefit in the elderly. *Ear and Hearing*, 10, 354-356.
- Maslow, A. (1954). *Motivation and Personality*. New York: Harper & Row.
- Mulrow, C. Aguilar, C., Endicott, J., Tuley, M., Valez, R., Charlip,

- W., Rhodes, M., & Hill, J. (1990). Quality of life changes and hearing impairment: Results of a randomized trial. *Annals of Internal Medicine*, 113, 189-194.
- Newman, C. & Weinstein, B. (1988). The Hearing Handicap Inventory for the Elderly as a measure of hearing aid benefit. *Ear and Hearing*, 9, 81-85.
- Von Wedel, H., von Wedel, U., & Streppel, M. (1991). Monitoring the efficiency of hearing aid fitting in the aged by the social hearing handicap index. *Acta Otolaryngologica Supplement*, 476, 270-278.
- Weinstein, B. (1991). Hearing aids and the elderly: Audiologic and psychologic considerations. In G. Studebaker, L. Beck, & F. Bess, (Eds.), *The Vanderbilt Hearing Aid Report II*. Parkton, Maryland: York Press.

Chapter 16

CONTRACTING PROFESSIONAL SERVICES

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Contractual agreements form the basis of our service relationships whether they are with patients, physicians, hospitals, cities, insurance companies, lawyers, school districts, universities, service clubs, industries, or county, state, or federal agencies. The observations in this presentation regarding these contractual agreements are based on 20 years of experience with these agencies plus hundreds of industrial companies, and 10 years of experience with major cities in southern California and a giant aerospace company.

This presentation's purpose is to review contractual agreements that have worked over the past 20 years and those that have not. The intent of the presentation is to focus critical thinking on avoiding catastrophes, on self-protection, on caution, and most of all on ensuring profit and peace of mind. Altruism, untempered by reality, should be abandoned when entering into agreements to provide professional services.

It is crucial to anticipate problems when we form contractual service relationships, although the myriad of possible financially disastrous events can never be totally predicted or prepared for. However, some predictable occurrences can be anticipated, such as death, illness, mental problems, substance abuse, change of ownership, professional business buy-outs, changes in administration, and a collapse and/or moving of an industry. If properly anticipated, buy-sell agreements, termination clauses, performance definitions, statements regarding the breach of those performances, specifications of financial duties and responsibilities, and consequences, can all be spelled out in a contract. Why is this not done more often? Why do we enter into agreements that are unilateral, verbal, nonspecific, and open for future interpretation? Several factors may influence our judgment:

- We may not want to spoil the positive feeling of an early business relationship or temper our enthusiasm with reality by specifying potential problems;
- Our academic background, clinical training, and experience may train us to be of service to others, meaning that we expect to give more than we receive;
- Audiologists rarely receive business or managerial

training, and hence naively enter into contractual relationships that are more serious than marriage and more difficult to dissolve, with financial implications that are more far-reaching and can affect our real marriage partner, family, and colleagues in disastrous ways;

- Agreements may reflect the level of our self-esteem at the time of the negotiations. If our self-esteem is low, or if we have great personal upheavals or financial crises, we may not exercise our best, conscious, prudent judgment. The scrutiny of agreements by another critical party may avoid obvious problems. Such parties could be attorneys, professional associates, business people, or financial advisors. As Mackay (1987) says, urging his readers to anticipate such problems, "Why spend time and money to try to anticipate a problem you never had? For the same reason you get a checkup at the doctor's when you're feeling fine: Take the trip today; it may save your life tomorrow."

Basic Definitions

Please bear in mind that this is not a legal course in contracts.

Neubert and Withiam (1991) enumerate the essential elements of a valid contract and discuss the complexities in a clear and concise fashion, especially in the area of partnerships and business agreements. Their text is an excellent basic source for drafting contractual agreements. Again, contracts should always be reviewed by a business attorney with the specific purpose of avoiding problems that could later result in unanticipated hardships.

If there is no instrument to sign—if the agreement is verbal—then the contract is usually worth the paper it is not printed on. Experienced business leaders will tell you that if an agreement is not expressed in writing, it simply does not exist.

A *valid contract* exists when two or more parties have agreed to do or not to do something that the law will uphold. Muraski (1982) points out that in order to have a valid contract, the parties must meet certain requirements:

- Have sufficient intellectual capacity to know what they are doing;
- Be in mutual agreement and assent to the terms of the contract;
- Not commit anything illegal;
- Exchange a consideration (something of value).

Mutual assent means that the two parties have agreed upon terms without any misunderstandings. There usually has been an offer and an acceptance.

In providing mutually assented to services to clients, the audiologist commits himself or herself to a service relationship with readily understood standards of care. If there is a problem, the courts look to the usual and customary standard of care nationwide, consider whether that standard has been violated, and what the damages are. In short, this usually falls into the area of tort law known as negligence or malpractice, and the courts look to the doctrine of reasonable care, and to the licensed professional.

Audiologists need to be aware that even if there is no formal written contract between them and their clients, they may nevertheless be responsible for any injury they cause to those clients. In-depth discussion of this subject is outside the purpose of this presentation.

Objectives of Contractual Agreements

Before discussing contractual agreements with various agencies it may be helpful to say why we bother with contractual agreement in the first place. Although our original viewpoint might have been that contracts are written to ensure success, I now would say that contracts serve to avoid the pitfalls in managing your practice/company. Some principles involved in planning and operations, therefore, need to be kept in mind to avoid such pitfalls.

"The key to keeping any company well and profitable is the same: We advocate for ourselves: Preventive care. That is, we must remain lean and trim." (Davis, 1987). The proper way to operate a new or old company is to be "lean and trim" all the time. Our practice has experienced the fat-lean cycle that (Davis, 1987) describes in such vivid detail. Avoiding the "sick" company is now the main objective of all agreements. When things are good, the company management is perhaps noncritical and lax. When mismanagement occurs because of diminished capacity, for example, it may not be recognized for a long period of time. Once recognized, it then is difficult to handle expeditiously. The object of all agreements is to be financially profitable and to avoid running into problems. Setting up contractual relationships can help to avoid the "sick company syndrome" exemplified by White's (1977) stages, as described below.

- Stage 1. Causes for the sickness are not recognized or defined, and corrective actions therefore don't take place.
- Stage 2. The first effects of the illness become observable. Now enter alibis and wishful thinking.
- Stage 3. Sales and profits decrease.

Stage 4. Buck passing begins.

Stage 5. The best people exit, innovation is stifled.

Stage 6. Management by objectives systems degrade and third generation of effects are born.

Stage 7. The classical corrective actions no longer even have a cosmetic effect as nothing seems to work and real surgery is essential.

Stage 8. Management-by-exceptions controls totally break down as the exceptions become the rule and labor grievances begin to consume far too much time and energy.

Stage 9. Both sales and profits continue their downward plunge and nothing seems to work in reversing them.

Stage 10. The venture capitalists and investors have completely lost confidence in management and band together to replace you and your management team with a team that they hope can perform. Your company is then either turned around, sold, or forced into bankruptcy proceedings.

White (1977) points out that the sick company syndrome exists in a major percentage of established companies. The key, according to White (1977), is to select founders, managers, and key employees who face your problems squarely, define them honestly, and solve them permanently. It is the goal of these comments to avoid problems at each of these stages.

The contracts formed, if prudent, will allow the necessary surgery when it must be exercised. This avoids major upheavals, huge legal expenses, and catastrophic downturns in production or performance.

The mechanics of identifying the "sick" and unacceptable are readily available but need to be spelled out initially so that action can be taken when the time comes. This includes planning and preparation for action in the case of "sickness" nonperformance, ineptitude, unprofessional conduct, and so forth. We need to know the bottom line that will terminate contracts. The problem is that we are not trained in management and control initiatives and cannot even anticipate the bottom line if, indeed, we can articulate it in the first place.

Those experienced in management talk about the "price of doing business." What they mean is that there is a percentage of failure of functions, ideas, operations, and business relationships with people that is acceptable in the routine operation of a business. Experienced business people will tell you that if you can manage an 80% successful track record with agreements and business contractual dealings, you are doing well.

It appears then that we should plan for the unpalatable. First, we should acknowledge that the agreements we make at a particular time mirror the self-image that we have of ourselves at that time. We may not strike a bargain that really is a bargain for us in the long run. It is not uncommon, therefore, that we will look at this action in the future and say incredulously, "How could I ever have made that agreement?"

TYPICAL CONTRACTS IN AUDIOLOGY

Hospital-Based (long-term)

Example: Establish clinical program for in- and out-patient load, neonates, trauma center, rehabilitative services.

Advantages: Immediate cash flow, no overhead or billing expense, high visibility, existing public relations department, ease of publicity.

Disadvantages: When successful, may be too busy to be staffed on a part-time basis; full-time staff may then be employed directly by the hospital. This may force a short-time contract if administration changes or if administrative hierarchy is reorganized.

Most hospital contracts have a 30-day cancellation clause. If exercised, a dependable source of cash flow may disappear despite years of devoted service, public relations, educational efforts, and research contributions. Once hospitals realize how much money an audiology department can make, they may seek to acquire the practice and administer it. Contractual services and relationships have to be so valuable and successful that they cannot reasonably be severed.

Question: What would your payoff have been if your efforts had been directed toward building your own private practice? Would you be better off? Was the profit large enough to offset the negative cash flow now? In the past 20 years, we developed audiology departments for five large city hospitals. In one case, we purchased the entire program from the hospital and moved it into an adjoining private office setting that is still in business. All the other programs are self-staffed, functional, and all are profitable, but not for us. Sense of achievement: Yes. Accumulated profits: none. Ownership: None.

Partnerships

Although partnerships may create the most satisfactory professional relationships, they may also have the most complex and immense problems. Partners can overrule your opposition in binding financial contracts and other venture agreements. Usually the contractual relationships and limitations are poorly defined. Although theoretically a good partnership can far out-perform a single-person practice, it may result in long-term problems, infighting, and lack of ability to respond immediately to opportunities and crises. In our experience, multilevel partnerships have not been as successful as anticipated because we were naive and inexperienced, and did not have binding agreements.

Advantages: Many, from the gathering of complementary professional skills and talents, pooling of financial resources, coverage, and increased overall earning capacity.

Disadvantages: Inflexibility, unpredictable problems, cost of dissolution, questionable long-term personal profit. Liability is assumed for the acts or failure to act in agree-

ment made by other partners. The professional is more vulnerable to legal action.

Corporations

Corporations are established to provide some insulation from legal action, to maximize growth, and secure venture capital. In most instances, the founders make the following key mistakes:

- Stock ownership is on a 50% basis without a buy and sell agreement. This can be an altruistic and naive arrangement.
- The belief that the new entity does not encumber personal financial assets when agreements are broken. Most banks now seek security from the individual owners/officers. It is difficult to escape personal financial responsibility for all corporate obligations when they involve taxes.
- The owner-stockholder is an employee and should have specific performance specifications spelled out.
- It is difficult to remove an incompetent or incapacitated 50% stockholder without further additional legal and financial hardships.

Advantages: Requires corporate function and discipline. The extra financial costs are offset by the corporate minutes and accounting and reporting requirements. The public view is easier to establish, make grow, and sell. There is the possibility to go public and increase income.

Disadvantages: Costs for formation, accounting, reporting, and state and federal taxes. Tax liabilities are borne by the officers personally, if not properly met. In the case of nonperformance on tax obligations, the other officers-owners-stockholders become personally liable. That means their families, spouses, homes, and other property become attachable by the taxing authorities. An unsuspecting person can therefore become 50% liable for the acts or improprieties of a spouse's previous corporate officers, stockholders, owners. Insulation is not provided for the tax obligations. For example, 100% IRS penalties for one officer's failure to file payroll taxes can become a nightmare for other officers and their families. Recourse exists for willful acts of mismanagement, but is expensive to enforce.

Contracting Services as a Sole Proprietor

In contracting services, care must be taken not to compete with yourself. For example, when contracting to provide services for a local hospital, physician's office, or medical group, it is conceivable that in the course of building that practice, that entity's reputation grows at your eventual future expense. You have traded immediate cash flow advantages for long-term self-competition and future financial loss. When providing services to potential self-competing entities, ensure profitability. Build in unforeseen expenses not anticipated in fee-for-service.

Contracts with cities. Include expenses for travel, meetings, educational training costs on an hourly basis, public relations costs on an hourly basis, costs for attending staff and committee meetings, and news conferences. In short, a significant amount of time will be spent in activities that have nothing to do with a fee-for-service basis and recovery for that time may be impossible if not spelled out.

There may be an "understanding" of who will provide support staff when the program grows. "We'll help you with that" usually does not work when the need for data processing, materials preparation, workshop planning, and administration occurs. You can spend extra days per week without remuneration. You can travel for hours a day for a single hourly administrative meeting without reimbursement.

Contracts with hospitals. Unforeseen costs include administrative, support, educational, public relations, and problem-solving expenses. These need to be spelled out in the contract with some flexibility for what is unknown but usually predictable. One example is that of promotional materials that can take weeks of meetings to prepare.

We usually do not plan for success but rather for immediate cash flow. Success makes additional demands, but those problems can be anticipated and spelled out. They can be accompanied by planned solutions for each case. A business plan should include increased expenses, not merely statements of accounts generated. Most hospitals want a 30-day mutual cancellation clause. A long-term contract for a minimum period of 5 years is more advantageous. However, the contract should include all of the possible predictable costs for interaction with healthcare workers, medical staff, speeches to medical staff, participation in healthcare, lectures, public appearances, and so forth. It is prudent, despite the contractual agreements and cash flow, never to rely totally on a hospital contract. When the hospital administration changes, "the ball game" changes. When they have made the relationship profitable, administration may want more of the profits and parts of the program, including equipment, staff, and income. Since they own the premises, recourse to avoid such action is rarely available.

Contracts with companies. Providing hearing healthcare, screening services, baseline tests, diagnostic evaluations, or rehabilitation services must include administrative costs and the costs of setting up and providing equipment. In one situation with a national company, the provision of services contract was not clear as to who was going to do the scheduling. Since it was not spelled out, administrative costs had to be borne by us for more than 18,000 employees, and the profits evaporated. Despite a contract, the company can fail, move from the state, or be acquired by some other entity, causing the contract to be terminated. Such events can and do happen and, therefore, it is smart not to count on any one contract. Other professional planning activities must be carried out at the same time to offset possible future losses.

Working for a medical entity. "Work for me, help me build this center (institute, clinic) and we'll take care of you." There may not be a written contract or even a written agreement to provide one. You must ask, When em-

ployment agreements and contracts are standard, why can't I get one here?

The answers should be obvious. The offering party does not want to be legally obligated in case the relationship turns sour. However, a contract will exist by performance (pro forma) and if you rely on the promises and act in a reasonable, usual, and customary professional fashion, you may have some legal recourse. The bottom line should be clear so that you are not hurt, demoralized, or discouraged when it happens. *You* may be the practice, *you* may have built the entity, *but it is not yours*. Despite your "life's blood" and reputation it will continue on without you quite well. It is not unusual for a professional to be asked to leave, to be replaced by a colleague who has been offered less money, so that the contracting party has more control and more income. Even one of your staff providing services with your equipment under your agreement may be hired directly. Such are the outcomes of quick, verbal agreements. Verbal agreements may work, but the bottom line is that changes occur, and when they do, the terms should be very clear.

Joint Ventures

Joint ventures may be an attractive, effective, and highly profitable contractual arrangement, combining assets, facilities, and professional practices, thereby creating a very powerful agency. It may also be very complicated and even impossible to maintain a contract between parties that does not spell out the following critical factors:

- Lease obligations. Whoever owns the property and pays the lease is the party that controls the premises and/or the property and can exercise dominion and control over them.
- Professional competence. What do you do if the other party provides less-than-competent professional services? Do you have a written agreement as to procedures to be employed to solve such a problem? You may find yourself in danger of joint malpractice lawsuits.
- Does a buy-sell agreement exist? If it does not, you may simply have to walk away from the situation, leaving your investment behind if you have no agreements regarding buying and selling your equipment. Demands for increased rents may soar with the intent to force you out. Legal costs to carry this to resolution may outweigh the investment that you have made. Getting out and walking away may be cheaper. Have we done it? Yes, we have. Our initial investment was about \$15,000, but that was roughly equivalent to legal costs for a breach of contract suit, conversion of property, and so forth.

Employment Agreements/Contracts

No matter whom we provide services for, we usually cannot avoid hiring additional personnel. Employment con-

tracts, therefore, should include specific items. When hiring professional personnel, two basic tools should be included in the contract to ensure clear understanding, cooperation, and performance. The two "basic tools" are job descriptions and job specifications (Blanding, 1991). Job descriptions should be mutually rewritten and confirmed. It is wise to include some future job responsibilities that are easily predictable. This avoids familiar statements, such as, "But it's not in my job description."

Job specifications include an enumeration of all the qualifications that the person is expected to have. Blandon (1991) cautions, "Under equal employment laws, the skills and qualifications you list must be relevant to the job and must be required of all candidates for that particular job." Performance-based salary structure can also be articulated in such a fashion that all terms are clear and not contingent on uncommunicated conditions.

When periodic review suggests that the agreed-upon aspects of performance are not being met, a progressive series of events should occur.

First, the problem should be reviewed and answers to the problems determined. Perhaps that person can be used more productively in a different capacity, and someone else can be moved into that position. If this does not work, Davis (1987) suggests that peer pressure will cause those who can't perform to leave.

But if the staff person has had a chance to improve performance and is trying harder, then perhaps more training and more support are needed. If it is clear that the person cannot achieve his or her potential, or is lazy and uncooperative, then termination looms. Davis (1987) suggests the following scenario:

1. Assignment of tasks
2. Failure to perform
3. Heart-to-heart talk in private
4. Failure to perform
5. Ultimatum
6. Failure to perform
7. Termination

It must be kept in mind, however, that "unlawful termination" lawsuits are a growing area of litigation. The "paper trail" must be clearly established and communicated prior to any such act. The reasons for termination must be credible, based on documented meetings that have discussed the problems, and failures of performance must be specified.

The supervisor of the person being terminated, in the presence of someone else from the managerial team, should inform that employee of the reasons for termination, what benefits he or she may have accrued, and an immediate time for departure. Notes should be taken of the meeting, but basic documents, once again, must include a written agreement that spells out all expectations.

Summary

Contracts must be drafted with a view toward the future, anticipating any imaginable potential conflict or problem. No matter how distasteful it may be to spell out in writing the remedies for anticipated problems, not doing so can be catastrophic. Being concerned about protecting yourself or your practice is not "bad," it is wise. Having other professionals review contracts provides an objective opinion perspective that is more financially knowledgeable and critical.

We do learn from mistakes. Even though MacKay (1984) is right when he states, "In fact, if you want to double your success ratio you have to double your failure rate." I personally prefer to avoid contractual mistakes. It is less stressful, affects fewer people whom we care about, and is financially prudent.

REFERENCES

- Blanding, Warren. (1991). *Customer service operations: The complete guide*. New York: American Management Association.
- Davis, M. A. Turn around. (1987). *The no-nonsense guide to corporate renewal*. Chicago: Contemporary Books.
- Eliot, Robert S., & Breo, Dennis L. (1989). *Is it worth dying for?* New York: Bantam Books.
- MacKay, Harvey. (1990). *Beware the naked man who offers you his shirt*. New York: William Morrow and Company.
- Neubert, C., & Withiam, J. (1991). *How to handle your own contracts*. New York: Sterling Publishing Company.
- White, Richard M. (1977). *The entrepreneur's manual*. Radnor: Chilton Book Company.

RECOMMENDED READING

- Henry, Donald L. (1985). *The profitable professional practice*. Englewood Cliffs, New Jersey: Prentice-Hall.
- Colmery, H. W. (1988). *Successful Business Management*. Atlanta: Hume Financial Education Services.

Chapter 17

MARKETING AND THE AUDIOLOGIST

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What is marketing? According to Webster, that all-knowing word scribe, marketing is the “act or process of selling or purchasing in a market,” or the “aggregate of functions involved in moving goods from producer to consumer.” For the marketing academician who takes pride in a command of lingo and principles, marketing is a component of strategy matrixes, marketing audits, and other types of manufacturing-oriented charts and graphs.

But all this means little to the audiologist or, for that matter, to any provider of healthcare or social services.

Do you need an MBA to market your services? Do you have to outmarket the hearing aid dealers to have a successful practice? Do you need to hire a marketing professional for assistance and guidance? Are there others in the profession whom you can rely on for assistance? What is marketing? How do you go about it? Answers to these questions are the basis of an “up-front” discussion of audiology marketing.

Because of the changing nature of healthcare competition, most healthcare professionals are vulnerable to exaggerated promises of success from those who pronounce themselves to be “marketing experts.” Audiologists, in particular, are vulnerable because their training does not include business and practice management aspects of the profession.

Do you need an MBA to market your practice? No. You need an MBA if you want a job as a product marketing specialist in American industry. And to paraphrase the CEO of one major American company, the only reason you need an MBA to work in private industry is to get your foot in the door and compete with all the other MBA candidates seeking such jobs. An MBA confers no special magic marketing formula. The academic coursework, however, will provide you with an understanding of basic marketing principles—the same type of understanding you can develop from continuing education programs on marketing and from the best teacher possible: your own marketing experiences, both the successful efforts and the not-so-successful efforts.

Do you have to outmarket the hearing aid dealers to have a successful practice? Again, the answer is no. Competition

is part of business when and only when you and your competitor offer the same product or service. The consumer decides if you are in competition with another service (or product) provider. When you enter into competition, you tacitly acknowledge that your services and products are no different from your competitor’s. If your service is better, if your products are better, you are not competing. Once you recognize how different you are from a hearing aid dealer, you will feel more comfortable in marketing your services actively instead of marketing against your perceived “competition.” Once you feel comfortable knowing you are different—that you provide a higher standard of professional service—you can focus on maximizing your client caseload instead of worrying about the seemingly unlimited financial resources of the hearing aid dealer.

Do you need to hire a marketing professional? Many people without marketing backgrounds market their services very effectively. You can, too. Don’t be shy about seeking help when you are confused; hire somebody if you have the resources and you think he or she can help you. But a little marketing experience goes a long way, so you might want to give yourself a chance to be your own best marketing professional.

Are there others in the profession who can help? Of course. Again, they are experts at their own practice. Every practice is unique. Recognize that marketing has few strategies that are universally applicable. What works in one area for one type of practice might not (and probably won’t) work in another area. If you are well grounded in the basic principles of marketing, you will be in a position to accept the advice that is good for you (whether it comes from a professional colleague or a marketing professional) and reject the advice that does not seem appropriate.

What is marketing and how do you go about it? If anybody could truly answer that question with authority based on a universal consensus, there would be few companies trying to get people from all walks of life to part with some of their finances to learn the magical steps to successful marketing. In essence, the true meaning of marketing puts the meat on the bones of Webster’s definition. Marketing means getting more visibility for your profession, a greater

awareness of your practice within your community, a maximum client load, and revenue to match.

Marketing is something that you and only you can do for yourself. Other resources, including books, seminars, and advisors can help steer you down a strategic marketing path, but ultimately you are in the driver's seat. Although it means more responsibility, more work, and more chance, it also means more opportunities, more benefits, and more control over your professional life.

So, then, how do you do it? There is universal agreement on this aspect of marketing. Develop a realistic marketing plan—not in your head, on paper. A marketing plan is a combination of the conceptualization of a strategy and the implementation of the strategy. A realistic marketing plan is one that recognizes your strengths and your limits and therefore is a plan within your capacity to implement.

The best way to begin is with a thorough understanding of the basics of marketing principles and theory. This chapter will introduce you to the world of marketing and offer some practical commentary along the way.

What is Marketing, Anyway?

In the simplest language possible, marketing is nothing more than getting into the minds of your target audiences. It is making connections with those you seek to reach. Marketing is all about creating an image, developing the types of messages that can enable you to communicate that image, and then disseminating those messages.

Prior to sending those messages, you must understand and admit your marketing objectives. That is, why engage in marketing? How you answer that question will influence the strategies and tools you use. Your reasons should be to do one or a combination of the following:

- Educate your public about hearing disorders and the effect of hearing disorders on daily living
- Educate your public about the role of audiologists in treating hearing disorders
- Educate professional colleagues (other than audiologists) about hearing disorders and the profession that provides treatment
- Expand the number of sources who are familiar with your services to increase referrals
- Improve your working relationships with professional colleagues and potential referral sources
- Build support within institutional settings for the services you provide
- Preserve and expand the funding base of your current operations
- Retain existing clients
- Increase your client caseload.

If your reasons for marketing are not covered in this list, you may need to reassess your marketing objectives.

The Marketing Plan

The purpose of understanding marketing principles and theory is to enable you to develop a marketing plan that

meets your needs. However, a marketing plan combines the principles of marketing theory with the practical realities of our lives and the market forces encountered in the real world on a daily basis—better known as your marketing reality. The knowledge of theory alone will not ensure an effective marketing plan. Rather, a successful marketing plan is tempered by your marketing reality.

Traditional marketing theory suggests you adhere to the following three phases to develop a marketing plan. The first phase is your preliminary work:

- Define your goals
- Determine your audience(s)
- Conduct research
- Define potential marketing tools.

Phase 2 is the most painstaking and the most detailed part, and requires the most work to do:

- Develop your marketing pitch, your marketing message, or what textbooks would call your *market position* (in simpler language—determine what you want your target audiences to think, know, read, see, and hear about you)
- Select the marketing tools you need to implement the plan
- Establish timelines to complete your work.

Phase 3 is the final step in the process:

- Assess the financial impact of the plan, that is, how much it will cost to implement
- Implement your strategy
- Evaluate the effectiveness.

Expect to refine your marketing plan. No marketing plan is either perfect or permanent. In fact, a good marketing strategy is always changing and responding to new market conditions and new information. In a sense, marketing is a continuum of care—always responding to changing conditions, events, and times.

This three-phase process represents the broad conceptualization of your marketing plan. Your marketing reality is what helps to shape the plan and its outcome.

What is marketing reality? Marketing reality is about limits—the realities of daily living that make it impossible for you to assume a marketing role 24 hours a day. Your marketing reality is driven by dollars; that is, how much you can afford to spend on marketing. It is affected by how you make your money, influenced by your competition, and influenced by your professional self-image.

Marketing and Self-Image

As part of ASHA's continuing commitment to provide marketing services for audiologists, the Association embarked on the development of a supplement or second kit of marketing materials for audiologists to customize and use in their communities. To ensure that ASHA was responding to the needs of audiologists, several focus groups

were conducted throughout the nation on the marketing needs of audiologists. The focus groups were convened and conducted by an outside public affairs/survey research firm.

As a result of these focus groups, ASHA learned that audiologists' view of their profession affects their interest and commitment to marketing. More specifically, we learned that audiologists have a problem with professional self-esteem as related to autonomy of practice, have limited knowledge of marketing practices, tend to define their primary audience to be physicians, have little experience in direct consumer marketing, and strongly believe that advertising "cheapens" the profession. Consequently, once an audiologist's marketing effort did not meet the anticipated level of success, marketing as a whole was abandoned.

Now for a moment of commentary: Marketing is both an art and a science. Even the marketing "whiz-kids" of corporate America do not succeed 100% of the time. Successful marketing is the result of perseverance, patience, and a willingness to change direction. Rigidity has few dividends. There is no magic marketing formula. Neither dollars nor the theoretical quality of a marketing plan ensures success. Your best guide is the least expensive one—your common sense—but confidence and pride go hand in hand. You cannot project a positive image of yourself or your profession if you do not have one. Yet this is the type of "marketing reality factor" over which you have absolute control.

Practice Management

Although often ignored, a critical component of a marketing plan is the area of practice management—how you run your business. Seven key areas of practice management require your attention:

- The location of your practice
- Basic office operations, such as your hours, method of payment (Do you accept credit cards?), parking, staffing (Is there a receptionist who greets your clients warmly?)
- Clinical recall system (How you get your clients to return and how often)
- Business cards, newsletters, patient handouts
- Fee strategy
- Written explanation of your fee structure
- The overall presentation of your practice.

Practice management also means you should know the competition. An effective marketer always keeps current on the competition. Know your competition. Know what services they offer. Know their fee structure. Keep track of the locations of others in your area who provide similar services and know from which communities they draw their clients. Try to analyze their strengths and their weaknesses.

Targeting Your Audience(s)

Like most healthcare professionals, audiologists can divide their potential audiences into three groups: referral sources, the general public, and your current clients.

Referral sources include physicians, other healthcare social service providers, current clients, and community sources, including organizations.

The general public includes all people with hearing impairment and the people who are close to them.

Of course, your current clients are your best potential audience. Encourage them to refer friends, relatives, and business acquaintances and establish a program of care and maintenance for them, which ensures they return to your office on a routine basis through a systematic office recall system.

Selecting your audience is critical to the development of your marketing message. Your message should be applicable to your audience, especially if your audience is consumers. For example, if your primary objective is to expand the number of elderly people in your client caseload, it may be necessary to appeal to their adult children.

Targeting the Consumer Audience

Direct marketing to consumers is important if you do not want to rely solely on referral sources for your clients. However, marketing to referral sources and marketing directly to consumers require two different strategies. Because the consumer market is so diverse (and because few people think alike), marketing to consumers can be tricky, to say the least. Developing a marketing strategy that includes consumers will require more work on your part. But marketing is work and nobody said work was easy. (As the CEO of one internationally recognized PR/marketing firm recently told me: "Why do you think they call it work?")

ASHA's 1990 focus group research also targeted consumers. This research provides some important anecdotal information for audiologists interested in direct consumer marketing.

Although many of the consumers who participated in the focus groups had hearing disorders or friends or relatives with hearing disorders (some of whom had received treatment from audiologists), these consumers often had little recognition of the role of the audiologist. This underscores the importance of providing your current clients with information about the profession of audiology and the services provided by audiologists. Your best marketing "tools" are the people you treat who are satisfied with the quality of service and can tell others about you and your practice. In other words, it is not adequate just to assess or treat a hearing disorder; you also must explain what you are doing and what the consumer can gain from you as a professional. This requires subtle communication, which can be done in the form of brochures or handouts. Our finding underscores the importance of effective practice management as a fundamental marketing strategy.

The focus group members also indicated that consumers are suspicious of nonphysicians who provide healthcare services. In other words, consumers will not automatically trust the abilities and qualifications of the audiologist to provide healthcare services. This lack of trust indicates a more pronounced need to educate consumers about the profession of audiology. Although some of this education can happen at a national level (and be conducted by na-

tional organizations such as ASHA), it requires maximum saturation to be effective. It also must happen at the local community level and emanate from audiologists who live and practice in the community.

Consumers also believe that healthcare marketing should be educational. They view healthcare as a service, not a product. Consumers rely on salespeople to sell them cars, not quality healthcare. If you promote yourself by promoting your product(s), that is, hearing aids, you become a salesperson concerned about your profit margin; if you promote yourself by promoting your services, that is, the assessment and treatment of hearing disorders, you are a healthcare provider concerned about the health and well-being of your target audience(s). Being a healthcare provider does not mean you feign lack of concern about profits and the "bottom line." It means only that you do not communicate that concern to your audience. After all, we live in a society that requires you to be financially viable to provide needed services.

Finally, consumers rejected aggressive advertising as "unprofessional." They believed advertising should focus on educating consumers about the services and the disorder, not selling a product. That does not mean that audiologists should not advertise. Rather, it suggests special attention should be given by audiologists to the message of the advertising.

Marketing Tools

Marketing tools are the building blocks of a marketing plan. How you market yourself (the tools you use) should be compatible with your message and consistent with the sociological patterns of your target audience(s). The 10 tools of marketing include the following:

- Market research, such as surveys (telephone or print), focus groups, competitor files, client response cards
- Handouts for current and prospective clients, such as brochures, newsletters, fact sheets
- Paid advertising, both print and electronic
- Public service advertising/education, both print and electronic
- Direct mail to referral sources and consumers
- Public speaking
- Community service
- Proactive media relations
- Person-to-person contact with referral sources
- Give-away items.

How to Get Started and How Much You Should Spend

To get started in a marketing effort, first establish your marketing goal. Select the tools you want to use and then begin developing your plan. You will also have to develop a marketing message. To do so, answer these questions:

- What makes me different?

- What makes me special? My location? My hours? My area of specialty?

Your answers will tell you how to position yourself in the marketplace. Basically, this is your marketing message—your marketing pitch.

Prior to implementing a marketing strategy, you must balance the theoretical aspects of your marketing strategy with your own marketing reality. In other words, you should ensure that your plan is practical. You can do this by adhering to the following four steps. The first two relate to money; the other two relate to time.

First, assess your financial resources—how much money you can spend on marketing. Money will dictate what you are able to do. Second, assess the long-term and short-term costs of your marketing strategy. Third, assess how much time you are prepared to commit to marketing yourself and your services. And fourth, assess your long-term and short-term expectations.

Strike a balance even before you start. Your financial resources and your long-term and short-term expectations should be equivalent to your long-term and short-term costs and your time commitment.

So, how much should you spend? If there was a magic answer to this, marketing would be easy and require little work or creativity—just lots of money. There is no formula. Instead, you should commit the resources that you think prudent from a business perspective, and this varies from person to person. Remember, the amount of money spent does not ensure success or doom you to failure. How the money is spent is a more critical factor.

ASHA, Marketing, and You

ASHA is working hard to make marketing a little easier for its members. In addition to the ASHA Audiology Marketing Kit introduced in late 1989 and the ASHA Audiology Marketing Supplement available in 1991, the Association also is working to provide direct marketing services to audiologists. These direct services include a Marketing Audiology Assistance Service and a series of marketing workshops conducted in various regions of the country.

Conclusion

Marketing is part theory and part common sense. The language of marketing might be new and confusing to you, but the process is basic to human communication. Ultimately, your marketing goals are elementary:

- To educate a defined sector (a target audience) about your practice and the profession of audiology
- To promote the services you offer
- To explain why people should use you
- To show how you can make a difference in their lives.

In its simplest form, marketing is about empowerment: empowering you to reach out to your audiences no matter what your marketing budget; empowering the public to learn about what you do and how to choose a service provider; and empowering you as a healthcare professional to seize and maintain your marketing advantage.

I suggest, then, three nonnegotiable marketing principles to guide you through your marketing efforts. You can call them your Empowerment Protection Plan, if you like,

because they give you maximum control over the welfare of your practice.

First, you are a healthcare professional, not a salesperson.

Second, an effective marketing plan is a product of common sense.

And third, marketing is no more than the function of mastering the art of communication.

Happy marketing!

Chapter 18

HEARING SCREENING IN THE ELDERLY: WHAT TO DO?

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Preventive healthcare for aged adults is an area of active concern in geriatric medicine (Rubenstein, Josephson, Seamons & Robbins, 1986). The most widely used preventive activity is screening, which is typically designed to identify individuals with unrecognized remediable conditions (e.g., hearing impairment), or to identify persons with established disorders deserving intervention so as to avoid disability. The focus of the former activities is considered to be a form of secondary prevention, whereas the focus of the latter is tertiary prevention (Rubenstein et al. 1986; Kane, Ouslander, & Abrass, 1989). Screening activity should be viewed as a health promotion strategy designed to promote early diagnosis of asymptomatic disorders, to maintain health and to prevent disability.

Aged individuals are frequently the target of screening activities aimed at identifying individuals with conditions giving rise to functional disabilities. Screening to uncover functional limitations (i.e., ability to manage daily routines) is at the heart of geriatric screening protocols (Lachs et al., 1990; Kane et al., 1989) for the following reasons:

- Eighty percent of aged persons have chronic diseases that cannot be eliminated.
- Functional disabilities often derive from chronic conditions that are not treated.
- For many aged persons, functional disabilities are a much more important problem in daily life than the specific chronic disease causing the limitation.
- Functional disabilities deriving from the chronic condition, if recognized, can often be improved or remediated.

According to the World Health Organization (1990), target disorders for screening activities in the aged include those impairments that if identified early enough can be prevented from progressing toward a disability. Recently, the American College of Physicians Subcommittee On Aging (1990) recommended that hearing screenings be per-

formed routinely on older adults using simple, practical, and sensible techniques. Similarly, the U.S. Preventive Services Task Force advocated routine hearing screening of aged adults by physicians (UPSTF, 1990). While there seems to be agreement among healthcare organizations regarding the importance of screening for hearing problems, there is little consensus on the approach to be used, on the frequency of screenings (e.g., annually), and on the referral criteria for identifying individuals requiring some form of intervention.

Along with vision, urinary incontinence, mental status, depression, and activities of daily living, hearing is considered a target for screening, because it meets several of the following guidelines set forth by epidemiologists to decide upon the appropriateness of screening efforts for a particular disorder (Sackett, Haynes & Tugwell, 1985):

- Efficacious treatments are available for aged persons with hearing impairment.
- The burden of suffering posed by handicapping hearing impairments warrants screening efforts. That is to say, unremediated hearing loss does in fact interfere with the quality of life of aged persons.
- Screening programs at hearing health fairs, at senior citizen centers, and in physician's offices certainly will reach those aged adults who could benefit from audiologic services.
- The hearing healthcare delivery system can cope with an increased caseload of aged adults with handicapping hearing impairments. To date, the elderly comprise only approximately 30% of the audiologist's caseload.

Because hearing loss is an important target area for screening, the real issue is whether there is a good screening test available to identify persons requiring audiologic services. I believe the best answer to this question can be determined by examining the efficacy of existing screening

programs employing selected protocols. In general, a screening program is considered to be effective if diagnostic and treatment services are used by screened persons or their families, and if compliance with treatment recommendations provided by these services occurs (Sackett, Haynes, & Tugwell, 1985).

Compliance with recommended treatment is critical because of the economic implications of mounting a screening program. Compliance seems to correlate with the client's perception of the seriousness of the condition (e.g., they are less likely to follow up on conditions they do not consider to be serious or on conditions that are an inevitable consequence of age) (Rubenstein et al., 1986). Unfortunately, there is ample evidence to suggest that persons with chronic conditions demonstrate poor compliance with recommended interventions (Sackett et al., 1985). Be it hypertension, vision, or hearing, compliance with screening outcomes is poor, irrespective of the screening protocol and irrespective of the setting. However, there are differences in compliance, depending on the recommended intervention at the time of the follow-up evaluation.

Fino, Bess, and Lichtenstein (1989) examined outcomes on a sample of aged persons undergoing a hearing screen in a primary care practice and a follow-up audiological evaluation at Bill Wilkerson Hearing and Speech Center. All subjects were screened using the screening version of the Hearing Handicap Inventory for the Elderly (HHIE-S), which assesses self-perceived emotional and social handicaps deriving from hearing loss and pure-tones delivered at 40dBHL at 1 and 2KHz. Fifty-nine percent of the 304 individuals screened underwent a follow-up audiological evaluation. Thirty-nine percent (69) of those undergoing a hearing test were considered hearing aid candidates by the audiologist administering the audiological evaluation. Eighty-four percent (58) of the hearing aid candidates declined hearing aids. Eleven (16%) purchased hearing aids—a humbling outcome at best (Fino et al., 1989). Overall, the people who elected not to seek rehabilitation had milder degrees of hearing loss and lower HHIE-S scores than those purchasing hearing aids (Fino et al., 1989).

Weinstein (1990) recently completed a study funded by the American Association of Retired Persons (AARP) looking at the efficacy of the HHIE-S as a tool for screening large numbers of aged people at senior citizen centers. One hundred ninety-seven people completed the HHIE-S. Seventy-five (38%) of them underwent a free hearing test at a university hearing and speech clinic. Thirty-eight (51%) of those undergoing the hearing test were considered hearing aid candidates. The mean hearing level of the hearing aid candidates was 41–42 dBHL, and the mean HHIE-S score was 18.6. Weinstein's (1990) data were comparable to Fino et al. (1989) in that only 16% (6) of the subjects actually purchased a hearing aid, whereas of the 27 (36%) subjects referred for medical intervention of some sort, 70% complied with the recommendation to see a physician.

Jupiter (1989) screened 843 older adults with a mobile van that visited senior citizen centers in a large metropolitan area. Half of the subjects underwent a pure-tone screen and the other half a combined pure-tone and handicap screen using the HHIE-S. Despite a failure rate of approxi-

mately 66% for both groups, only 13% of the subjects underwent an audiological evaluation, 7% of the subjects obtained a hearing aid and approximately 6% were undergoing hearing aid selection at the time of the data collection. Compliance, which was consistently low, did not seem to vary with the protocol.

Finally, Koike and Johnston (1989) screened 177 adults over the age of 58 at senior citizen centers and public health fairs using the protocol described by Ventry and Weinstein (1983). Overall, 73% of their sample passed the pure-tone screen at 40dBHL and 58% of these subjects reported no handicap (Koike & Johnston, 1989). Thirty-eight subjects (22%) of the sample were referred for further audiological evaluation. The majority of subjects could not be contacted to determine compliance with the recommendation to seek an audiological evaluation. Of the 25 persons contacted, 14 (56%) did not obtain the recommended treatment and did not seek further evaluation. The authors concluded by recommending that in light of the barriers to older adults who require any form of medical/audiological intervention, "audiologists should be self-reflective in how we provide services to those individuals who are in need of help and how we can make ourselves more easily accessible to the geriatric population" (Koike & Johnston, 1989, p. 253).

The aforementioned studies suggest a hit rate of approximately 15%, about the same hit rate reported by Rubenstein et al. (1986) in their analysis of a comprehensive health screening program conducted on a sample of healthy aged individuals. It is therefore incumbent on audiologists to develop strategies that can supplement routine screenings of older adults with a goal of increasing compliance with recommended interventions.

My scrutiny of data on the efficacy of hearing screening programs suggest that compliance-improving strategies are vital if screening efforts are to be justifiable from the point of view of manpower and economics.

In general, aged people are likely to comply with recommendations for follow-up treatment if the following conditions are met (Rubenstein et al., 1986):

1. People perceive themselves to be susceptible to the condition. For this reason, audiologists need to communicate to those persons undergoing the screen that age is the primary risk factor for hearing loss, yet not all aged adults suffer from hearing loss (Moscicki et al., 1985).
2. The person believes the condition has potentially serious consequences. The fact that unremediated hearing loss poses a threat to quality of life and to physical health status and correlates with depression and declines in cognitive status should be communicated to persons with hearing impairment at the time of the screen (Bess, Lichtenstein, Logan, et al., 1989; Uhlman, Rees, Psaty & Duckert, 1989).
3. The person undergoing the screen must come to understand that there is a course of action available to offset hearing loss via hearing aids and assistive devices, delivered in the context of an aural rehabilitation program.

4. Finally, the person must believe that the cost of taking action is outweighed by the benefit of the intervention. Quotes from or encounters with satisfied consumers of the same age cohort have significant potential as a tool for marketing audiology services.

In summary, the dearth of epidemiologic studies in the area of screening precludes a recommendation as to an ideal screening protocol for identifying aged persons requiring audiologic services. In reality, the nature of the screening protocol may not be as critical as incorporating compliance-improving strategies into all screening programs, irrespective of the design of the program. Clinical experience suggests that the use of videotape materials and the distribution of literature at the screening site, specifically designed to trigger a concern about one's hearing healthcare and to motivate the consumer to seek assistance, have potential as a most effective marketing and screening tool.

REFERENCES

- Bess, F., Lichtenstein, M., Logan, S., Burger, M., & Nelson, E. (1989). Hearing impairment as a determinant of function in the elderly. *Journal of the American Geriatrics Society*, 37, 123-128.
- Fino, M., Bess, F., & Lichtenstein, M. (1989). *Factors differentiating elderly hearing aid users and nonusers*. Poster session at Annual Meeting of the American Academy of Audiology.
- Jupiter, T. (1989). A community hearing screening program for the elderly. *The Hearing Journal*, 14-17.
- Kane, R., Ouslander, J., & Abrass, I. (1989). *Essentials of clinical geriatrics*, (2nd ed.). New York: McGraw-Hill Information Services Company.
- Koike, K., & Johnson, A. (1989). Follow-up survey of the elderly who failed a hearing screening protocol. *Ear and Hearing*, 10, 250-253.
- Lachs, M., Feinstein, A., Cooney, I., Drickamer, M., Marottoli, R., Pannill, F., & Tinetti, M. (1990). A simple procedure for general screening for functional disability in elderly patients. *Annals of Internal Medicine*, 112, 699-706.
- Moscicki, E., Elkins, E., Baum, H., & McNamara, P. (1985). Hearing loss in the elderly: An epidemiologic study of the Framingham Heart Study Cohort. *Ear and Hearing*, 6, 184-190.
- Rubinstein, L., Josephson, K., Seamons, M., & Robbins, A. (1986). Comprehensive health screening of well elderly adults: An analysis of a community screening program. *Journal of Gerontology*, 41, 342-352.
- Sackett, D., Haynes, R., & Tugwell, P. (1985). *Clinical epidemiology: A basic science for clinical medicine*. Boston, Toronto: Little, Brown.
- Uhlmann, R., Rees, T., Psaty, B., & Duckert, L. (1989). Relationship of hearing impairment to dementia and cognitive dysfunction in older adults. *Journal of the American Medical Association*, 261, 1916-1919.
- U.S. Department of Health and Human Services, Public Health Service (1990). *Healthy People 2000: National health promotion and disease prevention objectives*. Washington, D.C.: U.S. Government Printing Office.
- Ventry, I., & Weinstein, B. (1983). Identification of elderly people with hearing problems. *Asha*, 25, 37-42.
- Weinstein, B. (1990). *Improving hearing healthcare for the elderly*. Final report submitted to AARP Andrus Foundation.
- World Health Organization (WHO). (1980). International classification of impairments, disabilities, and handicaps: A manual of classification relating to the consequences of disease. *World Health Organization*, 25-43.
- Woolf, S., Kamerow, D., Lawrence, R., Medalie, J., & Estes, H. (1990). The periodic health examination of older adults: The recommendations of the U.S. Preventive Services Task Force. *Journal American Geriatrics Society*, 38, 933-942.