Chapter 7

Assistive Devices for the Hearing-Impaired

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Professional practices and applied research needs relating to management of assistive devices for individuals with impaired hearing are addressed. Brief consideration is given to in-clinic needs assessment, evaluation, and dispensing practices. Implications for implementation of the Americans with Disabilities Act are reviewed. Emphasis is directed toward identification of research needs relating to measurement of assistive devices and user characteristics.

Assistive listening devices amplify sound, enhancing the opportunity for verbal communication in noisy and reverberant settings as well as over large areas.

Visual decoding devices provide a printed display of spoken messages, clarifying information for individuals with impaired hearing. Alerting devices respond to environmental sounds, serving as guideposts for navigating through life's experiences with less than optimal hearing. Collectively, assistive devices help compensate for a range of problems associated with hearing loss. Published descriptions of assistive device technologies and acccounts of advantages and limitations of various technologies and products are available in the professional literature (Compton, 1989a, 1989b). In this chapter, current practice in clinical management of assistive devices are reviewed. Implications for management under the Americans with Disabilities Act are reviewed and general research needs are addressed.

CURRENT PRACTICE

To identify ways to strengthen *future* clinical practice, it is helpful to examine *current* practice in assistive device management. Three aspects are reviewed: needs assessment, device evaluation, and dispensing.

Needs Assessment

Obviously, all hearing-impaired individuals are not in need of assistive devices. Consumers have choices based on available technologies and they are influenced by personal preference.

How are in-clinic choices made? The first step is to conduct a *needs assessment*. Areas to be considered may be categorized as follows (Garstecki, 1988).

1. User capabilities and preferences. It is important to determine the potential user's sensory and motor capabilities for independent and successful use of a device. Individuals with severe/profound hearing impairment may not benefit from *listening* devices, but will want to know about *visual decoding* systems. Some may not *require* a visual alerting system, but will *prefer* it to an auditory alerting system. Some devices substitute for hearing aids and others enhance their use.

2. Situational needs. Devices may be dedicated for use in personal communication situations, in large areas, for telephone communication, for television listening, and for alerting purposes. Communication problems encountered in specific situations such as at home, on the job, and in recreation and travel situations should be reviewed with the potential consumer (Compton, 1991). In focusing on situational needs, consideration should be given to potential benefit from use of multiple-function devices, such as personal communication systems that may be used for telephone *and* television listening as well.

3. Lifestyle considerations. The assistive device needs of sedentary, homebound individuals are different from those with active lifestyles. It would benefit both the dispenser and consumer to discuss the consumer's everyday communication demands and challenges, as well as successes and failures. This should be done with the intent of resolving as many difficulties as appropriate with

assistive technology.

4. Environment. Preferences for equipment location should be explored *with* the user. User input is vital as it is unlikely that the dispenser will physically observe the place where equipment will be used. Consideration should be given to ambient noise, light, and traffic patterns as these factors may influence success and/or privacy in use of telephone equipment or placement of television amplifying or alerting systems. Some devices require electrical current and depend on ancillary appliances necessitating location near electrical outlets. Warning devices must be placed in strategic locations where the individual with a hearing impairment is most likely to detect their signal. Power options and preferences must be explored, as well as the desirability and/or need for multiple function devices.

5. Independent management and cost. The user's ability to independently manage the daily operation and upkeep of a particular device should be determined before it is purchased. In-clinic demonstration and trial must be allowed. If independent management is not likely, availability of assistance should be ascertained. Independent management also relates to an individual's ability to cover initial payment and on-going maintenance costs.

6. Alerting needs. It is important to determine if an alerting device will serve a functional purpose for the intended user. Will a selected device's warning signal be audible to the user? Will auditory devices in current use need to be replaced or combined with visual or vibro-tactile systems? Will user mobility have an impact on the number and location of signaling devices? Will preferred systems be accepted by others in a given environment or are they likely to be considered obtrusive? Will selected systems address all alerting needs (e.g., security, smoke alarm, telephone, baby monitor, doorbell, and wake-up alarm)?

A needs assessment should address each of the above points. The result will provide a comprehensive blueprint for building an effective assistive technology support system.

Device Evaluation

There are few published reports on assistive devices in general and only a modest number address concerns in device evaluation (Palmer, 1992). Most reports focus on issues in performance and/or use of assistive listening devices. There are few published references on clinical evaluation of non-amplifying devices such as television captioning, text telephones, and alerting systems. Relatedly, at this time, device evaluation procedures are not uniform across clinics. However, efforts are underway to develop international standards and guidelines for clinical practice in measuring assistive listening devices. The American National Standards Institute has established a new writing group, S3/W681, on assistive devices. This group is attempting to develop standard procedures for evaluating assistive listening device performance. These standards will provide a uniform way of expressing objective performance attributes of an assistive device. However, the extent to which performance attributes relate to user-benefit must be determined by clinical trials.

The practical need for uniform standards and evaluation procedures is evidenced in two recent studies. Stein, Wilber, and Garstecki (1991) examined the electroacoustic characteristics of pocket amplifiers using probe microphone measures and the Knowles Electronics Manikin for Acoustic Research (KEMAR). The result not only demonstrated the efficiency and appropriateness of using real-ear measures to determine frequency response characteristics of these systems, but the desirability of applying these measures in clinical selection.

A second study examined telephone amplifiers (Fikret-Pasa & Garstecki, 1993). The result demonstrated that only selected amplifiers provided an increase in gain which was proportional to volume control rotation. At mid-on volume, several amplifiers demonstrated a narrower frequency range than that of an unamplified telephone receiver. Volume control linearity varied across amplifiers and, as in the previously reported study, no correlation was found between frequency response gain characteristics and cost.

Each of these studies suggest that dispensers would be well-advised to conduct real-ear measures before recommending pocket or telephone amplifiers. Existing international hearing aid measurement standards may offer a guide to those concerned with objective evaluation of listening devices and systems. The development of international standards for assistive device evaluation and guidelines for the selection and fitting of these devices should bring objectivity and efficiency to device evaluation.

Dispensing

Assistive devices may be acquired by mail order, from local pharmacies, radio supply stores, assistive device stores, private practicing audiologists or hearing aid dispensers, local hearing societies, and hospital and university hearing clinics. Some devices, such as text telephones, may be acquired directly from telephone company sales personnel, firms specializing in the manufacture of text telephones, or agencies managing their distribution. Television caption devices may be obtained from appliance centers and department stores. There can be no universal device dispensing system because the range of available devices extends from specialty items which are designed for and of interest primarily to individuals with a hearing impairment (e.g., text telephones) to items of interest and benefit to all individuals, regardless of hearing capabilities (e.g., listening aids). Individuals with a hearing impairment may choose from among all available options in obtaining the device of choice, with or without professional guidance.

Few audiologists engage in device dispensing (Palmer, 1992). However, dispensing audiologists should incorporate assistive listening device considerations in the selection of hearing aids. Furthermore, it is also true that many consumers choose not to seek professional advice in selecting certain types of devices, particularly alerting devices. Others expect a recommendation from the professional who purports to serve all of their rehabilitative needs.

While there are many successful free-standing and hospital- and university-affiliated dispensing programs, relatively few have been described in the professional literature (Fernandes, 1986; Friedman & Grimes, 1990; Parmiter-Jacobs, Black Kraemer, & Jared, 1988). One such program is offered by the Northwestern University Hearing Clinic. It consists of a 4-week series on hearing loss management for new hearing aid users. It addresses consumer interest in assistive devices through:

- administration of a communication needs assessment;
- demonstration and in-clinic trial-use of selected devices;
- discussion of advantages and limitations of selected devices;
- review of listening and stage-managing strategies for maximizing benefit from personal and large area amplification systems;
- review of tips on how to enhance hearing aid use with assistive listening devices;
- review of factors to consider in the selection and use of various types of devices;
- review of ways to determine benefit from use of assistive listening devices;
- review of information on availability of assistive devices in the community;
- review of device ordering information; and,
- review of federal regulations relating to hearing accessibility under the Americans with Disabilities Act.

In this program, new hearing aid users are not only provided with device-related information and experience, but also with an opportunity for professional guidance in making selection decisions.

FUTURE PRACTICE

Future management of assistive devices will be influenced by new federal legislation. Public Law #101-336 (Americans with Disabilities Act – ADA) will have an impact on hearing-impaired individuals, their employers, device dispensers, and society in ways that are unprecedented (Bebout, 1990). As Stromberg (1992) suggests, we are on the brink of a "Disability Revolution" in which assistive technology will become a routine way of life.

Former U.S. President George Bush signed the ADA into law on July 26, 1990 (Fox-Grimm, 1991). ADA legislation is intended to eliminate discrimination against all individuals with hearing disability by providing federally enforceable standards for addressing problems in employment, access to public accommodations, transportation, state and local government services, and telecommunications. Each of these concerns is addressed in separate sections of the law or "titles" (Rovner, 1990).

Title I – Employment

Under Title I, hearing-disabled individuals are protected against discrimination in job hiring, orientation, advancement, and dismissal (Equal Employment

Opportunity Commission [EEOC], 1991). Employers are allowed to question applicants about their ability to perform necessary job functions, but they may not screen potential employees on the basis of hearing handicap. For example, while it would be appropriate to judge an applicant's suitability for a position requiring telephone communication by observing or inquiring about their ability to understand telephone messages and to be understood by others, it is now illegal to inquire about a job applicant's hearing disability.

Under Title I, employers are required to make existing facilities and equipment accessible and usable by individuals with hearing disabilities. Employers may need to consider use of signaling devices, interpersonal communication aids, telephone amplifiers, and text telephones. They also need to consider such factors as work area noise, lighting, and traffic patterns. While reasonable accommodations must be made, they are not *required* to be made if they impose undue hardship or expense for the employer (Ingebrigtsen, 1991). Obviously this is a judgment made by the employer and a potential loophole that may be contested by employees and their legal advisors.

Under Title I, hearing loss is a *potentially* disabling physical impairment, regardless of mitigating measures such as successful use of amplification and other assistive devices. Hearing impairment is not considered to be disabling unless it limits one or more of life's major activities, such as interpersonal communication, use of the telephone, or the ability to detect warning signals. An important implication for hearing-impaired individuals is that they must be informed of the full range of potential job responsibilities and be ready to make some pre-agreement decisions about their ability to carry out these responsibilities either with or without assistive devices. Job applicants must know what devices are available in a particular job setting or, more likely, what devices might need to be acquired or made available by an employer.

Title II – Public Services

Qualified hearing-disabled individuals are protected from exclusion or denial of services, programs, or activities sponsored by a public entity under Title II. Qualified individuals are those who are eligible for services, programs, and activities which may require modification of existing rules, policies, and practices; removal of architectural, communication, or transportation barriers; or provision of auxiliary agent services. A public entity is defined as any state or local department, agency of a state or local government, Amtrak, and any commuter rail authority (Department of Justice [DOJ], 1991a).

Auxiliary agent services are made available to ensure communication access which may be achieved through telephone amplifiers, personal communication systems (e.g., pocket amplifiers), hearing aid compatible telephones, text telephones, and closed- and opened-message captioning devices. Other options include use of telephone relay services, public address systems, transcription services, and written notice. Again, the individual with a hearing loss must be aware of available communication technology, special telephone communication services, and their ability to benefit from their use.

Title III – Public Accommodations

Title III of the ADA ensured non-discrimination toward hearing-disabled individuals in the employment of goods, services, and accommodations of any public entity unless undue burden would result (Department of Justice [DOJ], 1991b). In determining level of burden, the cost and nature of required action; financial resources of the providing facility; overall size of a business; and number, type, and location of facilities are considered.

Individuals with a hearing disability need to know about the types of assistive devices that guarantee communication access in such diverse settings as places of lodging, exhibition or entertainment centers, public gathering places, sales or rental establishments, stations used for public transportation, places of public display, places of recreation, places of exercise and education, and social service establishments. Besides personal and large area amplification systems, telephone amplifying or decoding devices, television amplifying or captioning devices, and alerting and warning devices should be considered.

In places that are equipped with audible emergency alarms, these alarms must exceed prevailing sound levels by 15 dBA or the maximum sound typically occurring in an area by at least 5 dBA. Under Title III it also is required that public accommodations allow use of service animals, such as hearing-ear dogs. Public telephones must be hearing aid compatible. Telephone amplifiers must allow for a 12 to 18 dBA signal gain and be identified by signs depicting a telephone handset with radiating soundwaves (see Figure 1). Text telephones (TT) used with public pay telephones must be permanently affixed to the telephone enclosure and identified by the international telephone communication device for the deaf symbol (see Figure 2).

Places of lodging and hospitals providing televisions in five or more guest rooms must provide a television caption decoder for patrons who are hearing-

Figure 1. Symbol used to identify amplified telephone handsets in public places. From *Assistive Devices: Doorways to Independence* (p. 34) by C.L. Compton, 1989, Washington, DC: Gallaudet University Press. Reprinted by permission.

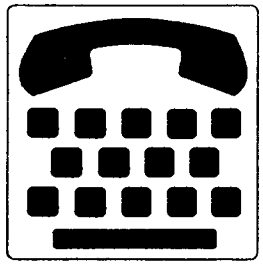

Figure 2. International text telephone symbol. From "Americans with Disabilities Act (ADA): Accessibility Guidelines for Buildings in Facilities" by United States Architectural & Transportation Barriers Compliance Board, 1991, *Federal Register, 56,* 144, July 26, 35512.

disabled. They must have a text telephone to receive calls from guests who use text telephones in their rooms. Hotels providing 1 to 25 sleeping rooms must equip a minimum of one room with appropriate assistive devices for individuals with a hearing disability, such as visual alarms and amplified or text telephones.

Title III also ensures that no hearing-disabled individual is discriminated against because of absence of assistive devices and special services, unless it can be demonstrated that taking such steps would result in undue hardship. For example, if a large area amplification system is used in a place with fixed seating, seats must be located within a 50-ft viewing distance of a target area. In areas where listening systems are permanently installed, they must be identified with signage that includes the international symbol of access for hearing loss (see Figure 3).

Title IV – Telecommunications

Title IV amends Title II of the Communications Act of 1934 by making available to all individuals an efficient communications service. The Federal Communication Commission ensures that inter- and intra-state telecommunica-

Figure 3. International symbol of access for hearing loss. From "Americans with Disabilities Act (ADA): Accessibility Guidelines for Buildings in Facilities" by United States Architectural & Transportation Barriers Compliance Board, 1991, *Federal Register, 56,* 144, July 26, 35512.

tion relay services will be made available to enable individuals with a hearing disability to communicate by wire or radio in a manner functionally equivalent to that of someone without a hearing impairment (Federal Communications Commission [FCC], 1991). Relay system providers are responsible for supplying communication assistants (CA) who meet the specialized needs of individuals with hearing disabilities. Communication assistants must be skilled in interpretation of American Sign Language (ASL) and familiar with the culture, language, and etiquette of individuals with a hearing disability.

Implementation of the ADA provides an opportunity to extend the scope of audiologic practice well beyond the confines of hearing clinics and into everyday settings. Because of the ADA, in the future it will become increasingly common for hearing professionals to establish working relationships with acoustical engineers, architects, transit authority officials, employers of individuals with a hearing disability, assistive device manufacturers and distributors, telecommunication service representatives, proprietors of businesses serving individuals with hearing disabilities, sign language interpreters, notetakers, and attorneys. It is also likely that with the implementation of the ADA, audiologists will assume greater responsibility than in the past for championing the rights of individuals with a hearing disability to access their community and workplace.

In summary, new federal legislation mandates provision of "accessibility aids" that are not likely to be objectively evaluated in clinical settings, uniformly fit in clinical practice, or of estimable long-term benefit to individuals with a hearing disability. Armed by the ADA, individuals with a hearing disability and their employers will demand use of these products. Therefore, it is incumbent upon technical researchers and skilled clinical practitioners to attempt to bring order to this circumstance where technology is advancing faster than the ability to measure its benefits. Access to this technology is being regarded by some hearing-disabled individuals as an inalienable right. To accommodate these individuals, it is important for hearing professionals to develop objective and reliable device evaluation procedures and guidelines for dispensing assistive devices as part of a comprehensive program of rehabilitative service. It also is important to investigate user benefit for all types of devices in order to be able to make informed and responsible clinical decisions in device selection and use.

RESEARCH

There is a need for fundamental information about device performance. Product research is needed to describe what an assistive device does in relation to what it is intended to do. This information potentially applies to selection and use considerations. There also is a need for demographic information in regard to consumer characteristics. This information may relate to device selection, use, and marketing considerations.

Research needs for three types of assistive devices will be considered: amplifying devices, decoding devices, and alerting devices.

Amplifying Device Measures

Concerns in amplifying device research focus on three areas: electroacoustic characteristics, microphone transducer characteristics and microphone usage, and device interactions.

According to the United States Food and Drug Administration (FDA), all hearing prostheses, *including* assistive listening devices, are considered to be "medical devices" in that their use is intended to address a human sensory deficit (Bove, 1992). As such, it is important to be able to specify device performance characteristics in clinical management of individuals with a hearing disability. In this way, it will be possible to ascertain the appropriateness of a particular device for a given individual.

Recent published reports indicate that American National Standards Institute (1987) is woefully inadequate for measuring non-linear amplifying devices (Revit, 1991). Recent research findings suggest that instead of using swept sinusoids, tests using speech-shaped noise may better describe an assistive listening device's performance. According to Stelmachowicz, Lewis, Seewald, and Hawkins (1990), complex noise may better represent combined speech and environmental noise than pure tones. Use of complex noise minimizes the standing wave problem in sound field measures and it may be useful in measuring higher order distortion products. In addition, use of complex noise allows study of the relationship between complex signal input and perceptual data (e.g., consonant confusions).

Kates (1991) stated that a swept sinusoid serves as a most appropriate test signal when measuring a linear amplification system. However, when measuring a non-linear system, it may lead to "blooming" or activation of a device's compression circuit during a portion of the measured frequency response range (Preves, Beck, Burnett, & Teder, 1989). Kates provides two examples of blooming. One example relates to measuring devices equipped with automatic gain control (AGC) detection circuits. These circuits are most sensitive to high frequencies, therefore the device may appear to be linear at low frequencies and compressive at high frequencies. The result is that the test signal bears little relationship to how the device may enhance speech perception. A second example pertains to a similar effect created by amplifier saturation, that is, a personal amplification system's gain generally is lower at low frequencies than at high frequencies. To resolve these test signal problems, Kates recommended using a speech-shaped noise signal (Burnett, Bartel, & Roland, 1987). Such a signal would consist of white Gaussian noise, limited to the speech band (200 Hz to 5000 Hz) with a 6 dB roll-off per octave beyond 900 Hz to resemble a long-term speech spectrum. The rationale for using speech-shaped noise as the test signal in hearing aid measurement applies equally to assistive listening device measurement. In either case, using such a test signal is a more complicated procedure than obtaining hearing aid output on a chart recorder. However, Kates offers insight and suggestions for accomplishing this task.

Kates (1991) also reviewed concerns in measurement of distortion characteristics in hearing aids. First, he acknowledged that ANSI Standard S3.22 is limited in that it specifies only harmonic distortion measures at 500 Hz, 800 Hz, and 1600 Hz. According to Kates, distortion and gain factors are intertwined throughout a hearing aid's circuitry. Therefore, when measuring a high frequency emphasis amplification system, for example, distortion properties occurring before the frequency response shaping in the circuit may serve to disproportionately increase the gain given to distortion components. Secondly, existing measures do not indicate how distortion at the highest frequencies affects low frequency speech signals which may occur simultaneously.

A number of issues remain to be addressed concerning the use of complex noise to measure the electroacoustic characteristics of assistive listening devices. First, in regard to the proposed complex noise test signal, the average spectral characteristics of everyday speech stimuli need to be defined. Next, the interaction between hearing aid signal processing and noise signal characteristics needs to be understood (Stelmachowicz et al., 1990).

While these questions are being addressed, other more basic concerns will remain. For example, it will be important to know the power and gain functions of the range of commercially-available listening devices and how these measures can be efficiently made in the clinical setting. It will be beneficial to know the volume control characteristics of commercially-available devices and the potential drawbacks of using non-linear systems in everyday communication environments. Moreover, it should be possible to measure the distortion characteristics of commercially-available instruments. The range and limits of all adjustable controls such as gain controls, tone/frequency shaping/frequency limiting controls, "sound enhancer" controls, and others must be measurable. The relationship between adjustable control settings and their labeling should be known. These and related questions need to be resolved in order to control product quality and to effectively manage device evaluation and selection.

Assistive Listening Device Component Design

Microphone systems. In selecting a microphone to be used as part of an assistive listening device, Brandt (1989) recommended an electret condenser microphone for its superior sound clarity over alternative microphones. For best performance, input impedance should match output impedance. If it is not possible to match input-output impedance, then input impedance should be higher than output. If output impedance is higher than input, the signal will be distorted and low frequency information will be lost. In high output impedance systems the length of the microphone wire will affect the frequency response of the microphone. If the impedance of the microphone is low, the length of the external microphone wire in an assistive listening device will not have an effect on the frequency response of the microphone's output (Brandt, 1989). In selecting a microphone for an assistive listening device where performance is a key factor, Brandt recommended a microphone with a low output impedance (50 to 500 ohms) and he warned that inexpensive microphones generally demonstrate high impedance.

A final consideration is microphone pickup pattern. Omnidirectional pickup patterns favor sound from all directions equally. Bi-directional microphones favor signals from the front or back. Cardioid patterns favor sound from the front. According to Brandt (1989), omnidirectional microphones are most often used in assistive listening devices, primarily because they are less expensive than other types. Improper use of other types of microphones can increase intensity of low frequency signals and result in creation of extraneous noise. For general listening conditions, Brandt recommended use of omnidirectional microphones. For large group or distance listening, cardioid microphones are preferred.

While a considerable amount of information exists in regard to performance characteristics and pickup patterns of microphones in general, comparatively little is known about the practical application of this information to clinical judgments regarding device selection or configuration. As such, there is a need for new information regarding performance differences with alternate types of microphones. For example, given the number and range in quality of commercially-available and consumer-configured pocket amplifiers, it would be important to know how device performance changes with different microphones. It also would benefit those inclined to "enhance" their pocket amplifiers with "higher quality" microphones to know how the amplifying system might limit the advantages of using microphones with broad frequency ranges.

There is a need to understand the relationship between microphone-amplifier impedance characteristics and microphone wire length. A clear advantage to using a pocket amplifier is to improve the SN ratio. However, it would be important to know the point of diminishing returns where an increase in microphone wire length has a noticeable impact on the performance characteristics of a microphone for a given system. Finally, it would be helpful to know the relationship between alternate microphone pickup patterns and device user performance in a variety of everyday listening conditions. Is it beneficial to use something other than an omnidirectional microphone in a noisy listening situation? Performance data would contribute to clinical decision making.

Interfacing systems. Hearing aid users accept amplification because of self-perceived benefit in everyday communication. Assistive listening device users accept amplification for the same reason. While some assistive device users may not as readily accept hearing aids, many hearing aid users choose to use a wide range of assistive devices. For example, hearing aid wearers also use telephone amplifiers, television amplifiers, pocket amplifiers, as well as the available array of room amplification systems while wearing their hearing aids. In some instances, hearing aid users may be coupled to other systems by inductive technology (e.g., neck loops). In other instances they are coupled by means of a direct, wired connection. In addition, it is not uncommon for some amplifying devices to be used in tandem. That is, through acoustic coupling of amplifier units in series, such as when using a hearing aid (in the microphone mode) *and* a standard telephone amplifier. It is well-documented that the electroacoustic characteristics of hearing aids change when used under microphone, telecoil, and direct audio input (DAI) conditions. In clinical management, therefore, it behooves the audiologist to determine the effect of interfacing amplification systems on signal output and user performance.

Inductive coupling technology allows hearing aids equipped with telecoils to pickup magnetic field leakage generated by hearing aid compatible telephones, assistive listening devices, and loop amplification systems. In order for these systems to function effectively, the magnetic field must have sufficient energy to energize the induction coil and the hearing aid circuitry must be able to accommodate and amplify coil output effectively (Beck & Nance, 1989). Induction coil pickup sensitivity is proportional to size; the larger the coil, the greater the pickup strength. Smaller hearing aids typically house smaller telecoils (if any), reducing the likelihood of an effective inductive system. Unfortunately, it is not possible to characterize the functional adequacy of an induction coil from information required by the present standard.

Direct audio input (DAI) coupling provides a direct electrical connection between a hearing aid and some attached appliance such as an external microphone, television, or radio. Care must be taken to ensure a proper impedance match between the hearing aid and any attached system. If there is a significant mismatch, the audio signal from the assistive listening device may be weakened or the hearing aid may be overdriven, distorting the amplified signal. Some hearing aids may operate using both microphone and DAI technology simultaneously.

Acoustic coupling provides an open-field connection between a hearing aid and some other amplifying device such as telephone amplifier. The most common contraindication to such an arrangement is the occurrence of acoustic feedback. If feedback can be successfully controlled, the amplified signal from the initial system (i.e., telephone) is boosted by the second amplifier (e.g., hearing aid). While the result may be somewhat additive, it could be that the second system is overdriven by the first which, again, will result in a distorted final output.

In regard to research needs, clinical studies are necessary to provide in situ data on hearing aid induction coil performance. For example, currently there are no specifications for telephone handset performance with telecoils. However, Public Law #101-336, the Americans with Disabilities Act, ensures telephone accessibility for hearing-disabled individuals. There also is a need for information on the influence of power lines, transformers, and fluorescent lights on telecoil performance. Hearing aid compatible telephones may be rendered useless because of their placement near interfering sources.

Clinical investigations are needed to define changes in hearing aid performance associated with use of DAI coupling. Hearing aid fitting protocols should include measures of performance with and without the aid used in the DAI mode when it is coupled with an accompanying device (Beck & Nance, 1989). In addition, the effect of acoustic coupling on signal output remains to be quantified.

EXPERIMENTAL DESIGNS

Amplifying Device Research

Contemporary approaches to the investigation of hearing aid measurement procedures also apply to the study of assistive listening devices. Differences in device electroacoustic characteristics, microphone types, microphone pickup patterns, and configuration (e.g., single unit or interfaced units) can be evaluated using paired comparison judgments or single-subject experimental designs. Paired comparison judgments are known to be more sensitive than speech recognition tests for demonstrating differences between amplification systems (Studebaker, 1982). For example, Byrne (1991) reported on successful use of paired comparisons for measuring differences between frequency response curves in hearing aids. The result demonstrated a statistically significant preference for one response curve over another in 70 to 80% of the cases. Another advantage to the use of a paired comparison approach is that it avoids the problem of ceiling effects. One output signal or frequency response can usually be judged as "better" than another even when both are highly intelligible (or unintelligible). Paired comparison measures also allow for comparisons along parameters other than signal intelligibility. Signal quality, pleasantness, and naturalness have been judged using this technique. In all, paired comparison measures indicate what the assistive listening device user would choose, regardless of their reason for making a selection. Future studies of system differences would benefit from use of paired comparison experimental designs.

An example of the appropriateness and advantage of using a single-case experimental design in assistive listening device evaluation was provided by Stein, McGee, and Lewis (1989). In their study, each subject served as his/her own control. Each experienced both the "no treatment" and "treatment" condition. The simplest analysis strategy in a single-case experiment is the A-B-A design where, in the A condition, performance is measured without the treatment variable. The B condition represents the treatment variable. Stein and his colleagues used a variation of this strategy by replicating the A-B pattern in an A-B-A-B-A series. In this way, the treatment variable (B) was repeated to study possible learning, practice, or fatigue effects. This work demonstrated that studies of behavior change lend themselves well to single case experimental designs.

Alerting Device Research

Alerting devices monitor sounds by use of sensor microphones, inductive pickup, or direct electrical connection. They transmit signals using either hardwired or wireless technology and by visual (e.g., strobe light), auditory (e.g., low pitched signals), or tactile (e.g., wrist vibrators, pocket pagers, bed shakers) stimuli (Compton, 1989b). Wireless systems can be used to monitor small areas, homes, and office buildings. Portable vibratory paging systems may span thousands of miles through inter-linking telephone lines, satellite systems, and local pager antennae. Wake-up and telephone alerting systems include use of strobe lights, fans, or shakers. Fire and emergency alarms use visual alerting technology. Strobe lights are required to meet a minimum effective intensity of 100 candela according to National Fire Protection Association and Illuminating Engineering Society criteria.

As with amplifying devices, studies measuring alerting devices may employ paired comparison or single-case experimental designs. Questions regarding alerting technology, for example, may be addressed by using paired judgments of the effectiveness of auditory, visual, and tactile wake up alarms. Answers to such questions may relate to the relative differences among signaling modalities. Questions regarding the candlepower of alerting lights, frequency range of fire alarms, and vibrating power of bed shakers, for example, may lend themselves well to single-case designs. Answers to these questions may relate to behavioral differences within subjects.

Decoding Device Research

Decoding devices have essentially two applications that are of primary importance to individuals with a hearing disability: telephone and television access. The term Telecommunication Device for the Deaf (TDD) or Text Telephone (TT) applies to a typewriter-like device that translates keyboard input into an acoustic (Baudot) code that is transmitted by telephone line to a compatible receiver (another TDD/TT) and displays the message as printed text. Other telephone message decoding systems include personal computers equipped with modems and used with telecommunications software as well as facsimile machines.

Closed captioned television decoders enable viewers to read text associated with televised programs and messages. While the printed text does not match the spoken text verbatim, it does relay the intent of spoken text in somewhat abbreviated form. This enables individuals with a hearing disability to fill-in information that is not perceived through listening or viewing.

As noted above, research relating to evaluation of decoding devices and user behaviors lends itself well to paired comparison and single-case experimental design. Questions regarding the value of captioning technology, for example, may be addressed by using paired judgments of the relative difference in message understanding using captioned systems versus non-captioned systems. Questions regarding the legibility and visibility of printed word displays on various captioning systems lend themselves to single-case investigations or well designed surveys for preference and function. Answers to these questions may relate to behavioral differences within subjects as well as to differences between systems. (Also see Stuckless, in press.)

Demographic Research

Demographic data are vital for forming clinical service and assistive device marketing plans. Goldstein (1984) and Kochkin (1993) reviewed factors considered to have an impact on hearing aid consumption. These included the stigma associated with hearing loss, cost of obtaining and using a hearing aid, behavior of hearing care professionals, hearing aid delivery systems, and the "medical funnel." Each of these factors may relate to use of assistive devices as well.

Handicapping stigma associated with hearing loss may be dependent on age at onset. If hearing loss occurs in mid-life, it may create a deterrent to occupational success and social prowess. If it occurs in later life, hearing loss is more likely to be accepted as inevitable and unremediable (Humphrey, Herbst, & Faurqui, 1981). Regardless of when it occurs, Barcham and Stephens (1980) as well as Bevan (1981) reported embarrassment with poor hearing and with visibility of the hearing aid as the most frequently cited problems in hearing aid acceptance and use by adults. Kochkin (1993) reported that hearing aids communicate apparent "weakness" to others. Hearing-impaired individuals feel that hearing aids draw attention to hearing loss and may serve as a sign that one is growing older, weaker, disabled, or handicapped (Kochkin, 1993). Studies by Blood, Blood, and Danhauer (1978) and others have reported a "hearing aid effect" among those who use hearing aids. They are perceived by others to be less intelligent, lower achieving, less attractive, and more likely to demonstrate negative personality traits than others.

Cost is a common deterrent to hearing aid consumption. Goldstein (1984) described a loose relationship between hearing aid cost and "take-up rate." Citing increasing hearing aid sales during times of severe recession, coupled with a decrease in third-party reimbursement for hearing aid purchases, he stated that economic stress should not be considered to be a critical factor in explaining low hearing aid consumption. In fact, only 5% of the hearing-impaired individuals interviewed in the 1980 Gallup Poll complained of hearing aid cost. However, Kochkin (1993) reported that the results of a 1990 Hearing Industries Association's focus group survey indicated hearing aids cost more than their perceived value in compensating for hearing loss.

Behavior of hearing professionals is another factor to consider. Goldstein (1984) commented on the complex feelings some audiologists have about dispensing hearing aids. Some audiologists may be skeptical of the degree of assistance provided by an aid in comparison with its cost. Audiology textbooks and examples from clinic files suggest a conservative attitude toward hearing aid dispensing on the part of the audiology profession at large. However, in recent years, this situation has changed as an increasing number of audiologists include hearing aid dispensing in their professional practice.

Hearing aid marketing strategy may contribute to low consumption. The hearing aid dispenser risks being regarded as a high pressure salesperson, particularly when compared with other health care professionals whose products (e.g., eyeglasses) "sell themselves," not only because their use eliminates handicap, but it may also send a desired fashion statement. Elderly adults, in particular, are skeptical of high-pressure sales techniques and this may manifest itself in a negative attitude toward use of a hearing aid.

The hearing aid delivery system is another potential factor. Not long ago, procuring a hearing aid within the "system," that is, not through newspaper ads, flea markets, or another's discard, required a visit to a referring physician, a second visit to an ear specialist or otologist, a visit to an audiologist, and finally a visit to a hearing aid salesperson. However, in the past 20 years, this process has been streamlined and currently involves only a two- and sometimes a single-visit procedure.

Another factor is the "medical funnel" (Haggard, 1982; Kochkin, 1993). The purchaser of a hearing aid in the United States must first receive a medical examination from a physician (United States Food and Drug Administration [FDA], 1977). Certain conditions apply to waiver of this examination, but only after expressed admonition from the dispenser. This service delivery process often creates a bottleneck in the flow of services to potential hearing aid users.

Finally, hearing aid sales practices must be considered as a possible contributing factor. The hearing aid industry's response to low sales typically has been to persuade the potential consumer to purchase the aid with promises of improved products, free hearing exams, and discounted prices rather than by attempting to understand the underlying motivational differences between users and non-users. Clearly, emphasis is directed toward moving the hearing aid from the manufacturer's warehouse to a potential user's home. This may help explain why some aging adults do not use their hearing aids (Smedley & Schow, 1990). If so, data estimating the low consumption of hearing aids may actually overestimate the number of hearing aid users.

Concerns relating to acceptance of hearing aids potentially apply to acceptance and use of all assistive devices developed to address problems related to hearing loss: listening, alerting, and decoding devices. This supports a need for survey data to better define individuals who are candidates for using assistive devices. There is a need for information describing the potential consumer's age, gender, hearing loss, hearing handicap, history of device ownership, mindset in considering purchase of devices, satisfaction with owned devices, lifestyle, education level, and discretionary income level. From this information, underserved groups of hearing-impaired individuals can be identified. If, for example, personal amplification systems are not purchased by those with mild hearing loss, the advantages of using these devices in selected situations should be made known to them. Public education programs may prove necessary and beneficial. If the consumption of television captioning devices is low among potential user groups (e.g., severely hearing-impaired, ethnic minorities, elderly, hearing-disabled adults, etc.), these individuals can be targeted for informational literature and educational programs. User preferences also can be documented. Once it is known that consumers within certain age, hearing loss, and income levels prefer multi-function to single-purpose equipment, one sound transmission technology over others, and selected product brands over others, then prospective consumers with similar pedigrees can be approached accordingly.

Useful information may be obtained by consumer survey methods. Survey data may be synthesized to develop user profiles that describe hearing loss characteristics for individuals who elect to use various types of assistive devices. Personal factors that influence success in use of various devices may be identified and the effect of device use on quality of life and lifestyle may be defined. The differences between hearing aid users and non-users in their decisions to use listening devices should be investigated. Answers to these and related questions are important to know in assistive device management and they can be readily attained using standard survey research methods.

SUMMARY

Assistive devices should be an integral part of the hearing-impaired individual's armamentarium. Their popularity and use is expected to increase with new legislation mandating public access for individuals with a hearing disability. However, little is understood about available products or their potential consumers. Research is needed to determine the performance characteristics of available devices and changes in behavior that accompany their use. In addition, there is a need to identify those individuals who demonstrate the best potential for benefitting from specific types of assistive devices.

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