ECOLOGICALLY VALID MEASURES OF HEARING AID PERFORMANCE

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*Tempora mutantur, nos et mutamur in illis. …Lothair I**

Whenever technology advances at a rate faster than its consumers can accommodate to it, there is likely to be trouble. No better example is the fact that, beginning in 1945, scientists provided governments around the world with nuclear tools capable of destroying all life forms on the planet, but there is still no general agreement on how to halt the march to Armageddon. Nor has a mountain of scientific evidence produced a coordinated worldwide effort to counter global warming.

We have similar, if less dramatic, problems in audiology. The technologies associated with digital signal processing, directional microphones, remote microphones, and adaptive testing techniques have made giant strides in the past two decades, but our ability to measure the benefits that individuals with hearing-impairment derive from these advances has not matched their rapid pace. We are still, as a field, mired in the hearing aid evaluation testing philosophies and paradigms devised following the second World War more than 60 years ago. The client is seated in a relatively small, dimly lit, sound-treated chamber. A loudspeaker directly facing the client delivers speech materials, syllables, words, or sentences at a constant level, measured in sound pressure level (SPL), sensation level (SL), or most comfortable listening level (MCL). In addition, some sort of competition, either constant noise, temporally or spectrally modulated noise, or multi-talker babble, may be presented. The competition may be presented either via the same loudspeaker or from one or two other loudspeakers oriented at various angles relative to the front loudspeaker. This is not greatly different from the procedure devised by Ray Carhart at the Deshon General Military Hospital in the early 1940s and later at Northwestern University in the late 1940s.

Perhaps it is time to reevaluate this auditory scene. If we think about how individuals who use hearing aids function in real life, the following conclusions seem inevitable:

1. They don't spend a great deal of time listening in small sound-treated chambers.
2. They are not always facing the source of the speech message.
3. When they do face the talker, they enjoy the benefits of a rich panoply of helpful visual cues.
4. The sources of competition are more likely to be the speech of other persons than temporally or spectrally modulated noises.
5. The level of the speech to which they are attending may vary over time rather than remaining constant.

Within the past decade, there has been a growing movement to bring a more ecologically valid perspective to testing and evaluation, and, indeed, to auditory research in general (Cf., Neuhoff, 2004). The goal is to evaluate a listener's performance, not in artificially constrained laboratory environments, but in the situations characteristic of real-life

*Translation: "The times change and we change with them" from Lothair the First, grandson of Charlemagne and Emperor of the Holy Roman from 817 – 855.

listening. What, then, would an ecologically valid approach to the evaluation of performance with amplification be like?

We might begin by moving the entire operation out of the sound booth and into a simulated ordinary living room. It is perhaps instructive to ask why we do this sort of testing in sound-treated booths in the first place. The great audiological pioneers who arose from schools and departments of speech in the universities more than half a century ago were greatly influenced by the model of the radio broadcasting studios of the 1930s and 1940s. In the typical radio studio on a college campus in those days, a control room was linked by microphone to a sound-treated room in which one or more artists performed. The performance was, in turn, picked up by one or more microphones and fed into the control room for distribution to the airwaves. This arrangement became the model for speech audiometry. The tester was seated before a microphone in the control room and delivered test stimuli, via live voice, to a listener in the sound-treated chamber. In subsequent years, technological advances, including disc recording, tape recording, and digital recording made it possible to deliver the test items in a more standardized fashion, but as we are reminded by Fred Martin's periodic surveys (Martin, Champlin & Chambers, 1998), 60 years later the majority of clinicians still cling to the live-voice testing model carried over from the radio studio so many years ago.

It was only a short step from this radio studio concept to modification of the walls of the sound-treated space to attenuate the intensity of external sounds transmitted to the interior in order to facilitate threshold audiometric procedures under earphones. In the early days these sound-treated test chambers were locally constructed using plans available in the acoustic control literature. But now the divergence from the radio studio model began. The typical radio studio was often large enough to contain an entire orchestra, but, because of cost and space limitations, these locally constructed audiologic test chambers were considerably smaller than their radio studio progenitors. At the time, it seemed that since only one person at a time would occupy the room, excessive size was not a requirement. They were, additionally, usually limited in height by the vertical space available in existing buildings. As the need for sound-treated booths increased, commercial organizations specializing in acoustical control systems and hardware began to offer prefabricated sound rooms for use by audiologists. But in order to mass-produce such rooms, they had to agree on standard sizes for the prefabricated panels, and here the limitation was the typical vertical clearance of the space in which the room was to be installed. The net result, after allowance for floor and ceiling panels, was a standardized chamber with an interior vertical dimension of six feet six inches. But the vertical dimension of most rooms in typical residences ranges from about 8 feet to 12 feet. In most office and business spaces the vertical dimension is even greater. Normal illumination, in these small sound booths, is difficult to achieve. Hence they are typically dimly lit. Another legacy of the radio studio is wall and ceiling treatment. In radio recording studios, just as in anechoic chambers, it is important to limit the input for the recording microphone to the direct sound source without contamination by reflections from hard-surfaced walls, floor, and ceiling. Hence the inner surfaces of the room are lined with sound-absorptive materials like acoustical tiles, wedges, and the like. This preoccupation with sound absorption survives in our sound-treated rooms. It gives the interior of the booth an acoustically "dead" quality, important for sound recording but very unlike the acoustical environment in the real world. Being shut up in a small, dimly-lit, and acoustically dead room is a claustrophobic's worst nightmare.

To be sure, sound booths serve very important functions in audiometric screening and in threshold

audiometry, and for these purposes the small dimensions of the space are an acceptable compromise with the reality of listening in the real world. But we need not make such compromises when presenting test stimuli to hearing aid users at suprathreshold levels. Why not, then, move the hearing aid testing procedure into a more comfortable space in which the realities of real-life listening can be more adequately simulated? I suggest a well-lit ordinary room with doors, windows, furniture, pictures on the wall, a television set, and rugs on a wooden floor. Let the client be comfortably seated in the approximate center of the room, and let reflection and reverberation play their realistic roles.

Next we should set up an array of at least eight loudspeakers surrounding the client. This will permit us to present both speech targets and competition from various directions. We should also set up an array of video monitors, one just above or below each loudspeaker, so that the auditory signal may, if desired, be supplemented by the face of the talker. The fact that individuals who use hearing aids live in a visually abundant world can no longer be ignored. In the case of speech communication, especially in the presence of competition, the importance of visual cues as supplements to the stream of auditory information can hardly be overstated. One need only consult colleagues in deaf education and in cochlear implant rehabilitation.

In such a surrounding, it is possible with a modicum of imagination to devise test protocols more representative of actual everyday life than the formulaic procedures with which we are currently burdened. There is a need to develop tasks that tap not only the client's ability to achieve fine-grain discriminations among the phonemic elements of the message but also the client's ability to benefit from the context in which the message is presented. One can thus make a persuasive argument for sentences rather than isolated words or syllables as the test materials.

Repeating back what is heard is a time-honored component of contemporary test protocols, but, again, is not very representative of actual communication. In real life instead of repeating back what was heard, the listener typically responds to a speech message by either a meaningful message in reply or by some appropriate overt motor response. The reply can be as simple as a "yes" or "no," and as complex as "The capitol city of New Mexico is Santa Fe." Another approach is to frame test items as questions, which can be answered by selection from among multiple choices, as is often done in children's testing (e.g., point to the "dog").

Within this framework, we should eschew competing noises and multi-talker babble in favor of the information-rich discourse of one or more competing speakers. In real life, continuous noise, whether modulated or not, is seldom as bothersome to communication as the interfering speech of one or two individuals. Years ago, it was thought that the actual speech of a single talker would not be a very effective competitor because the listener would be able to pick up cues during the silent intervals between words and sentences. But, we now know that masking by real speech is actually more effective than masking by a continuous noise at the same level, a condition attributable to the additional "informational masking" content of the real speech (Cf., Hornsby, Ricketts & Johnson, 2006). A good example of this is the common experience of the passenger on an airplane flight. The constant roar of the jet engines is only a minor distraction compared to the annoyance and interference with communication when a nearby passenger talks loudly on a cell phone.

Finally, one ought to vary the presentation levels of both speech targets and competition in quasi random fashion over a range of perhaps 10-12 dB to simulate the variation one is likely to encounter in real-life listening situations.

An additional dividend arising from testing in a realistic acoustic environment would be the effect on subjective measures of satisfaction based on questionnaires and similar scales. The client would be able to judge benefit in the kinds of listening situations ordinarily encountered in real-life listening rather than in the sterile confines of the sound-treated booth.

Many colleagues will undoubtedly raise a chorus of negative reactions to such a radical proposal. Here is just a short list of the objections that might be raised:

1. Once you leave the sound-treated booth, the acoustic environment is uncontrolled. It is now subject to reverberations, reflected waves, variation in absorption, etc. *I counter that such a realistic listening environment is exactly what we seek, an environment characteristic of the rich world of sounds. In discussing the impact of an ecological approach on traditional psychoacoustic research, John Neuhoff (Neuhoff, 2004, p. 4) recounts an old joke:*
   "A bar patron who has had too much to drink… is on his hands and knees beneath the streetlight looking for his car keys. A police officer happens by and asks, 'Well, where did you lose them?'
   'Across the street' is the reply.
   'Then why not look over there?'
   'Because the light is better here.'"

2. Current test instruments have been carefully normed under a number of specified conditions. This new approach would void such norms. *I counter that this might very well be helpful if it would stimulate the development of new protocols and procedures not dependent on arbitrary norms, but designed so that the client serves as his/her own control through the use of relative rather than absolute measures of performance.*

3. What you are proposing would take too much time, time one can ill afford in today's busy practices. *I counter that if we cannot take the time to ensure reasonable accountability for what we do, then we are not the professionals we purport to be.*

In summary, perhaps it is time to move hearing aid evaluation into the new millennium in an ecologically valid manner.

References

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