RESEARCH ON HEARING-AID DESIGN

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Rehabilitative audiology is an area of primary interest in our Auditory Research Laboratory. The research we do under our contract with the Veterans Administration is one of our major efforts in this regard. We have focused both on learning what potentials and limitations hearing aids hold in everyday life and on developing techniques for determining these potentials and limitations at the time a veteran's hearing is evaluated. We have investigated various topics ranging from effects of physical performance of hearing aids on intelligibility to factors operating when the hearing-aid user is in adverse environments. Our past findings have contributed to procedures now employed by the Veterans Administration in the procurement of hearing aids and to its clinical practices in the selection of hearing aids.

Our attention was originally directed toward problems of binaural hearing-aid use. Our current research employs only monaural listening since the problem currently to be solved can be most easily attacked using monaural presentation. The application of the solution to the binaural mode will be a straightforward extension of what we thus discover.

Our present research is influenced by two basic considerations which make hearing-aid use difficult. One basic consideration is that small amounts of background noise are much more disturbing to a hearing-aid user than one would expect from the listening experiences of normal hearers. The second basic consideration is that hearing aids deliver a broad range of relatively high intensities when adjusted to bring the fainter sounds of the world to the hearing-impaired user. Under such circumstances the stronger sounds in the environment are amplified well beyond the comfortable level. The price the user pays for being able to perceive the weaker sounds of his world is that its stronger sounds are made unmercifully loud.

Our current research for the Veterans Administration seeks to minimize the effects of these two considerations by modifying the pattern of sound reproduction to gain two advantages. First, we wish the

pattern of amplification to emphasize those components of speech which are most important to intelligibility while minimizing intense, relatively uninformative elements of speech. Second, we wish to force all sounds into a narrow dynamic range. This range will then be adjusted to be just adequately audible, thus achieving proper intelligibility. Concurrently, the intense sound elements will be kept from reaching unnecessary loudness.

A study by Thomas and Sparks suggests that a combination of filtering out lower frequencies and of clipping the peaks of the sound waves will achieve the signal needed to accomplish our goal. We are in the midst of investigations designed to discover whether this is the case.

We began the project by testing the effect of high pass filtering plus peak clipping on intelligibility as measured with the Oklahoma No. 6 test. At this preliminary stage, presentation was via a high quality conventional earphone. Each test item is a monosyllabic word. The listener knows the test word is one of four words differing only in final consonants. Every word in set of four is used with equal frequency as the test progresses, and there are five different sets of words. Both intelligibility as percent correct and specific consonantal confusions can be evaluated with this test.

The foregoing test has been administered to both normal hearers and elderly persons with presbycusis under three listening conditions: 1. high quality reproduction, 2. with the peaks of the signal clipped by 12 dB, and 3. with this same clipping plus filtering out of frequencies below 1100 Hz with 18 dB per octave slope. Broad band noise that was 10 dB weaker than the signal of the moment was present in each condition.

The study I am describing was delayed somewhat by the fact that we moved our contract research into new quarters during the year and that it took considerable time to construct, assemble, and calibrate portions of the equipment. At this writing we are just completing the testing of two groups of six subjects each. The results for these subjects of each type, expressed in terms of median scores, are shown in Table 1. We have here some evidence confirming the practical value of filtering plus clipping. Note that for both groups the filtered plus clipping conditions yielded best discrimination scores at the 10 dB and 20 dB sensation levels and that for the elderly this condition maintained its advantage at the 30 dB sensation level. Specifically for normals at the 10 dB sensation level, the clipped-filtered condition gave a median of 71.9 percent as opposed to 63.0 percent unclipped. For the elderly the absolute values were slightly lower but the advantage for clipped-filtered was greater, being 68.8 percent opposed to 59.4 percent. For each group the t test at this sensation level yielded a ratio with a probability of less than 0.05. This result leads us to interpret the differences as real.

TABLE 1.—*Median Scores in Percent*

	Sensation Level		
Normals	10	20	30
Unclipped	63.0	80.6	85.0
Clipped	67.0	78.8	86.3
Clipped-filtered	71.9	83.8	85.6
Elderly with loss			
Unclipped	59.4	71.9	78.1
Clipped	65.0	73.8	78.8
Clipped-filtered	68.8	73.8	82.5

We are still in process of analyzing the results of the foregoing study. One procedure will be to determine via confusion matrices what types of consonantal confusion predominate in the several listening conditions and for the two types of subjects.

Our next study will repeat the foregoing conditions with a three talker babble as the background. The test material will be monosyllabic words presented in triplets. Subjects will be 12 normals and 12 persons with sensorineural hearing loss. The latter will be audiologically defined as having inner ear involvement. We will retain the 12 dB clipping level. All signals will be reproduced via an insert receiver of the hearing-aid variety. Moreover, the filtering will be changed so as to yield a speech signal which is flat from 300 to 5000 Hz as defined by its spectrum level.

Provided that this filtering, plus 12 dB clipping, proves the superior condition, we will later increase the amount of clipping so as to discover the point where still further clipping causes enough deterioration in signal-to-competition ratio to affect intelligibility. Eventually, we plan also to explore the effect of variations in hearing loss upon this benefit and to look into the question as to whether tailoring of filtering and clipping for individual patients is desirable. Another important question is whether logarithmic compression is equally effective when combined with the same pattern of filtering.

In closing, I should mention that during the past year we have also been bringing several earlier projects to a conclusion. This work is being done primarily by Dr. Wayne Olsen. For one thing, he is making a retrospective analysis of the relation between the performance characteristics of 16 commerial hearing aids and our success with each instrument in the Northwestern Audiology Clinics. Secondly, he is evaluating results of a questionnaire on everyday hearing-aid experience. This questionnaire has been answered by patients from our clinics. Their experiences are being correlated with their scores on traditional tests for speech discrimination. Finally, Dr. Olsen completed a study on the

effects of head baffle and head shadow on the intensities of sounds reaching the microphones of ear-level hearing aids.

The projects I have mentioned illustrate the diversity of questions about hearing aids that we have investigated under our contract with the Veterans Administration. We anticipate similar diversity in the future.