HEARING CHARACTERISTICS: IMPLICATIONS FOR AUDITORY TRAINING AND HEARING AID USE

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In order to determine which students at NTID(National Technical Institute for the Deaf) are in need of Auditory Training, certain basic information on the individual students must be obtained. Toward this end, each student is given a complete audiometric assessment during his initial orientation at NTID. The tests administered include a pure tone audiogram to determine the amount and configuration of the student's hearing loss, and speech discrimination testing to determine how well the student utilizes his residual hearing for understanding speech. Evaluation of speech discrimination is performed using a battery of tests which are indicative of various levels of discrimination ability. "Spondee Discrimination" is the first test administered to a student. This test consists of familiarizing the student with 10 selected two-syllable (spondee) words*, and then administering 20 presentations of the words in random order. If the student can correctly identify 50% of the spondee words, a more difficult discrimination task, the CID Everyday Sentence Test (at NTID this is called CHABA, because it was originally developed by the Committee on Hearing and Bio-Acoustics) is administered (Davis and Silverman, 1970). If the student cannot identify 50% of the spondee words, he is evaluated again, using a more gross discrimination task, the "Same-Difference" test. This test instrument utilizes the same 10 selected spondees; however, the words are presented in pairs. The student responds "same" if the two words sound the same (for example: cowboy-cowboy) or "different" if the two words sound different (for example: cowboy-baseball). Discrimination testing is administered under earphones at MCL (most comfortable listening level) for each ear.

Each student is given a rating from 1 to 5 for the better ear based on the results of his speech discrimination testing. This number becomes the student's "Profile" rating for speech discrimination. Table 1 shows how the profile rating is developed from the student's raw scores on the various discrimination tests. Table 2 demonstrates that the Profile rating relates to a functional description of how well the

**The spondee words, baseball, birthday, cowboy, dishpan, eyebrow, foot stool, hotdog, ice cream, rainbow, and sunset were specially selected both because of their vowel representations and because they did not pose language problems for the young deaf adult population at NTID.*

student is using his hearing for aural communication. The student receives a similar profile score for each of his communication parameters including speech intelligibility, speechreading, receptive and expressive language, manual reception, etc. The combined picture of a student's profile ratings make up what is known as his "Communication Profile" and gives a total picture of the student's weaknesses and strengths in receptive and expressive communication. (For a more detailed explanation of the "Communication Profile", refer to the report given by Dr. Donald Johnson within the present proceedings).

TABLE 1: Rating system utilized by NTID, deriving levels of hearing (speech) discrimination ability of individual students.

Profile Rating	Level of Discrimination Functioning
V (5)	Correct identification of 90 to 100% of 50 key-words during administration of CID Everyday Sentence list
IV (4)	Correct identification of 50 to 88% of 50 key-words during administration of CID Everyday Sentence list
III (3)	50% level of recognition of 10 selected spondee words and 0 to 48% correct identification of 50 key-words during administration of CID Everyday Sentence list
II (2)	Correct identification of 15 or more of 20 items in a same-difference task utilizing 10 selected spondee words
I (1)	Less than 15 items correctly identified during a same-difference task utilizing 10 spondee words

TABLE 2: Rating system and functional descriptors utilized by NTID for defining student hearing discrimination ability.

Profile Rating	Functional Descriptor
V (5)	Student understands the complete message
IV (4)	Student understands most of the content of the message
III (3)	Student understands with difficulty about half of the message (understanding may improve with increased exposure)
II (2)	Student understands little of the content of the message, but does understand a few isolated words or phrases
I (1)	Student cannot understand any of the message

The results of the audiometric assessments carried out on students entering NTID over the past several years indicate that 90% of the population has some residual hearing. However, only 26% of these entering students have developed enough discrimination to follow a spoken message using audition only (achieving a Profile 4 to 5 in speech discrimination). Due to the great disparity between the number of students with residual hearing and the number who can use their hearing effectively for communication, Auditory Training is necessarily considered a high priority component of the total instructional picture in communication development for NTID students.

There are, of course, many reasons why a student may be function-

ing at a low level of discrimination ability. For instance, it has been shown that a deaf person's ability to develop discrimination skills can be highly dependent on the degree and configuration of his hearing loss (Wedenberg, 1954). Moreover, Jerger has demonstrated that discrimination skills may also be dependent on the person's "site-of-lesion" within the auditory system: i.e., persons with VIIIth nerve damage may have a drastically reduced potential for discriminating speech sounds (Jerger, 1960). Also, recent research at NTID has shown that the speech discrimination skills of the young adult deaf may be directly related to the deaf person's adjustment to and use of amplification: that is, NTID students who use a hearing aid "seldom or never" generally have lower levels of discrimination achievement than those students who have similar hearing configurations and use a hearing aid "all or most" of the time (Johnson, 1974). For this reason, Auditory Training at NTID is limited to students who are already using amplification on a regular basis. Students who are not using a hearing aid regularly are offered special evaluation, counseling, and/or courses designed to discover why the student is not using amplification, fit the student with appropriate amplification, and encourage the student to use amplification on an "all or most" of the time basis. When this process is completed, the student is considered a potential candidate for Auditory Training.

The type and duration of previous Auditory Training may also affect the student's level of discrimination functioning. Yet another factor which may affect the student's discrimination ability, especially on a sentence test such as CHABA, is the student's knowledge of the English language. One cannot expect a student to recognize auditorily a word which is not in his vocabulary (Johnson, 1974). Also, as with Speechreading (Myklebust, 1964) and reading (Moores and Quigley, 1967), the student's familiarity with English semantics, syntax, and grammar may facilitate his ability to fill in or predict the parts of the sentence which are not actually discriminated.

Because of the complexities of examining each student in terms of all these parameters which may affect discrimination, and the lack of availability of information on some of the parameters (for example: testing for site of lesion cannot be completed on many NTID students due to the severity of their hearing losses), an attempt has been made at NTID to develop a technique for determining candidacy for Auditory Training which is based on both hearing loss configuration and attained level of speech discrimination. This analysis of residual hearing characteristics has made it possible to determine whether students are functioning at a realistic level of discrimination, or whether they need Auditory Training to try to improve their discrimination skills.

To accomplish this analysis, each student's residual hearing is analyzed in terms of "cut-off frequency" (the highest frequency tested at which the student responds to sound) and pure tone average (PTA). Pure tone averages are calculated using a classical three frequency

average for students who have responses at 500, 1000, and 2000 Hz. A two frequency average (averaging the thresholds at 500 and 1000 Hz) is calculated for students with a cut-off frequency of 1000 or 1500 Hz. A one frequency "average" is assigned to students with a cut-off frequency of 500 or 750 Hz using only their threshold at 500 Hz. Table 3 shows how students are broken into groups based on their cut-off frequency and PTA.

TABLE 3: Predicted discrimination achievement based on residual hearing for NTID students who use a hearing aid "all or most" of the time (N=258).

Cut-off Frequency (in Hz)	PTA (in dB)	Predicted Discrim. Level		Number of Students
6-8k Hz	65-84 dB	V	(90-100% CHABA)	87
6-8K	85-98	Lo IV	(50-68%)	42
6-8K	99+	Lo III	(0-18%)	4
3-4K	65-84	Hi IV	(70-88%)	13
3-4K	85-98	Lo IV	(50-68%)	35
3-4K	99+	Lo III	(0-18%)	9
2K	65-84	Lo IV	(50-68%)	8
2K	85-98	Lo III	(0-18%)	18
2K	99+	II	(Same Diff.)	5
1500	85-98	Lo III	(0-18%)	6
1500	99+	II	(Same-Diff.)	3
1K	85-98	Lo III	(0-18%)	6
1K	99+	II	(Same-Diff.)	12
750	85-98	II	(Same-Diff.)	1
750	99+	I		2
500	85-98	I		1
500	99+	I		2

Note that the PTA groupings used (65-84dB, 85-98dB, and 99+ dB) are those specified by the Office of Demographic Studies (1973) to indicate degree of hearing loss. These groupings are used with the NTID population in order to compare the students at NTID with a large cross-section of the deaf primary and secondary school population in the United States. In order to derive the prediction formula and establish candidacy for Auditory Training, a histogram was plotted for each consecutive hearing loss grouping found on Table 3, showing the distribution of discrimination achievement of the students with that cut-off frequency and PTA level who were using a hearing aid "all or most" of the time. Figure 1 demonstrates the histogram which was originally plotted for the first level on Table 3; i.e. those students with a cut-off frequency of 6-8K Hz and a PTA of 65-84dB, who use a hearing aid "all or most" of the time.

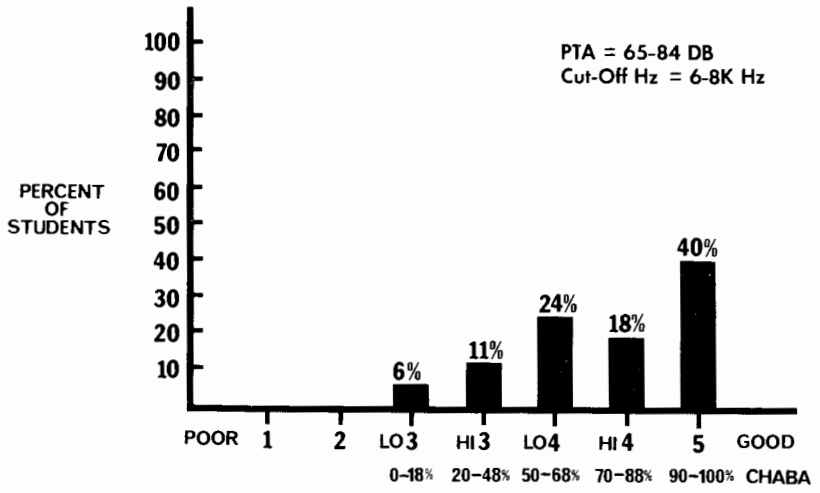

Figure 1. Distribution hearing discrimination (N = 87 students entering NTID 1972)

As can be seen in the figure, 40% of the students examined performed at the Profile 5 speech discrimination level. Because this was the highest skill level at which it appeared that a significant percentage of the students in that hearing loss category (6-8 Hz and 65-84dB PTA) could function satisfactorily, a Profile 5 rating was projected to be the "Predicted Discrimination Level" as indicated in column 3 of Table 3. In essence, students with similar hearing characteristics who are functioning below this level become candidates for Auditory Training.

A similar histogram was plotted for each consecutive cut-off frequency and PTA level. In each case, the Profile score which is listed in the column headed "Predicted Discrimination Level" demonstrates the highest level at which a large percentage of the students in that hearing loss category performed. This Profile rating and its concomitant speech discrimination level has thus been assumed to be the highest realistic expectation that can be attained by an NTID student with identical hearing characteristics.

The relationship between residual hearing and potential for speech discrimination achievement is graphically demonstrated in Table 4. For a given PTA category, the ability to discriminate speech appears to decrease as cut-off frequency decreases. Also, for each PTA category as a whole (regardless of cut-off frequency), discrimination potential generally decreases at PTA becomes worse.

This analysis of residual hearing in terms of discrimination potential has some important implications for Auditory Training. First, from

TABLE 4: Relationship between residual hearing characteristics and potential for speech discrimination (N=258).

PTA (in dB)	Cut-off Frequency (in Hz)	Predicted Discrim. Level	
65-84 dB	6-8K Hz	V	(90-100% CHABA)
	3-4K	Hi IV	(70-88%)
	2K	Lo IV	(50-68%)
85-98	6-8K	Lo IV	
	3-4K	Lo IV	
	2K	Lo III	(0-18%)
	1500	Lo III	
	1K	Lo III	
	750	II	(Same-Diff.)
	500	I	
99+	6-8K	Lo III	
	3-4K	Lo III	
	2K	II	
	1500	II	
	1K	II	
	750	I	
	500	I	

looking at the analysis, it becomes much easier to identify a potential candidate for Auditory Training; i.e. any student who uses a hearing aid "all or most" of the time, yet falls below his predicted level of discrimination achievement. The analysis also established a potential discrimination level which a student might be expected to achieve to exit from an individualized Auditory Training program.

Second, the analysis allows the potential candidates for Auditory Training to be prioritized. Due to time constraints and personnel limitations at NTID, it may not always be possible to service all potential candidates for Auditory Training at the same time. Therefore, the students with the most residual hearing and the highest predicated discrimination levels are labled as having a higher priority for Auditory Training than other candidates.* They should have the most potential for obtaining good aural communication skills. Table 5 demonstrates the various priority groupings. Note that students who fall into Group 1 have been assigned a higher priority for Auditory Training than those in Group 8.

Experience with Auditory Training during the past year at NTID demonstrates that although only 20% of all students in Auditory Training have made gains of 10% or more on a post-test of CHABA after one quarter of instruction, 85% of all these students were in Priority Group 1. This supports prioritizing the candidates for Auditory Train-

**However, students who have been enrolled in the NTID course, Orientation in Hearing Aids and have elected to utilize amplification on an "all or most" of the time basis are number one priority candidates for Auditory Training as soon as they have been fitted with proper hearing aids.*

TABLE 5: Priorities for Referral for Auditory Training at NTID (N=258).

Priority Group	Predicted Discrim. Level		Cut-off Frequency (in Hz)	PTA (in dB)
	V	(90- 100%)	6-8K Hz	65-84 dB
	Hi IV	(70-88%)	3-4K	65-84
1	Lo IV	(50-68%)	6-8K	85-98
	Lo IV		3-4K	85-98
2	Lo IV		2K	65-84
	Lo III	(0-18%)	6-8K	99+
3	Lo III		3-4K	99+
4	Lo III		2K	85-98
	Lo III		1500	85-98
5	Lo III		1K	85-98
	II	(Same-Diff.)	2K	99+
6	II		1500	99+
	II		1K	99+
7	II		750	85-98
	I		750	99+
8	I		500	85-98
	I		500	99+

ing. Data from pre-and post-tests utilizing materials on which the students practice in the Auditory Training program do indicate, however, that students can make great gains toward increasing their discrimination skills for those particular speech stimuli practiced, even though this improvement does not necessarily generalize to other materials.

Third, this analysis of residual hearing has implications for the kind of Auditory Training to be used with a particular student. In the NTID population, a student who is deemed to have good potential for discrimination may be selected for an intensive, auditory only, training program. Another student, who has a low potential for discrimination achievement, may benefit more from a combined program of Auditory Training and Speechreading, or an Auditory Training program which emphasizes gross phoneme discriminations to aid the student in improving his speech production. As in most aural rehabilitation programs, it is very important to identify the student's exact communication needs and tailor an individualized program which will allow those needs to be met as quickly as possible. At NTID, the average student completes his academic program in two and one half years and exits to find a job. Therefore, in this short time span, it would seem to be most efficient to develop that communication mode in which the student has the greatest potential to best prepare him for communicating on the job.

The implications for training with deaf children are similar. The Auditory Training Program should be tailored to the child's amount of

residual hearing. If the child has very little residual hearing, other forms of receptive communication should be emphasized in training. However, when working with a child, more time is usually available to help him develop his speech discrimination as well as the other receptive and expressive communication skills. Further study is indicated to determine whether those students involved in this analysis of residual hearing, who had early Auditory Training, show generally higher achievement levels for speech discrimination upon arrival at NTID than those students who did not have early Auditory Training.

This analysis of hearing characteristics also has implications for hearing aid use in the deaf. The study supports the finding that the use of amplification is a prerequisite for developing good discrimination skills (Johnson, 1974). Fifty-nine percent of those students who wear their hearing aids "all or most" of the time are functioning at their predicted discrimination levels; whereas, only 32% of the less than "all or most" of the time hearing aid users are achieving their predicted level. "All or most" of the time hearing aid use does not, however, guarantee that good discrimination skills will develop. This is evident from the 41% of the "all or most" hearing aid users who fall below their predicted discrimination levels. The implications here are first, that some students need a structured Auditory Training program to develop to their fullest discrimination potential, even when they are using a hearing aid "all or most" of the time; and second, that there is a definite need to study the other parameters such as site of lesion, previous Auditory Training or adequate English language skills which may influence discrimination potential and achievement.

Table 6 demonstrates that for the portion of NTID population studied, as the range of available frequencies is narrowed (based on

TABLE 6: Cut-off frequency and percentage of NTID students using hearing aids "all or most" of the time (N=258).

Cut-off Frequency (in Hz)	N of Total Population at each cut-off Frequency (N=530)*	% of Total Population at each Cut-off Frequency	N Who Use HA's "All or Most" of the time (N=258)	%f Students at each cut-off Hz Who Use a HA "All or Most" of the Time
6-8K Hz	182	34%	133	73%
3-4K	97	18	57	59
2K	72	14	31	43
1500	27	5	9	33
1K	79	15	18	23
750	29	6	3	10
500	18	3	3	17
250 or NR	26	5	4	15

*Approximately 477 of that population studied alledgedly own their own nearing aids. Of this total, only 258 use them on an "all or most" of the time basis.

cut-off frequency), the number of students who use a hearing aid "all or most" of the time decreases. This is not surprising since the less hearing a person has, the less likely it is that he will receive tangible benefit from amplification. It is interesting to note, however, that the predicted discrimination level for students with a high frequency cut-off of 1000 Hz and a PTA of 85-98dB is a low 3 (0-18% on CHABA). This means that these individuals can only discriminate a few words in connected speech. However, with proper training they might derive some benefit from amplification as an aid to Speechreading. The limited residual hearing is present.

Table 6 also indicates that as the available frequency range narrows (i.e., lowered cut-off frequency), the percent of students in the total population with that narrowed range diminishes. Approximately one third have a high frequency cut-off of 1K Hz or lower. Data is not available to compare these trends with the overall deaf population.

A comparison of residual hearing characteristics of NTID students to a larger population can be made on the basis of PTA. Table 7 shows the relationship of PTA threshold levels of NTID students to students studied by the Office of Demographic Studies (1973).

TABLE 7: Comparison of residual hearing characteristics of NTID students and ODS (Office of Demographic Studies) students.

PTA (in Db)	% of Total Population ODS (N=24,345)	% of Total Population NTID (N=488)	% of NTID students for each PTA who use a HA "All or Most" of the Time (N=248)
65-85 (dB)	32%	25%	81%
85-98	32	46	65
99+	36	29	38

It must be remembered when comparing the two populations that PTA is calculated in a different manner by ODS than for the NTID population. NTID calculates a three, two, or one frequency "average" (as described earlier in this paper) whereas ODS calculates only a three frequency average. If there is no response at any of the three frequencies to be averaged, ODS substitutes the value of 120dB (ISO) as the threshold at that frequency. This difference in calculation methods may affect the distribution in the 85-98dB and 99+dB ranges, but would not affect the 65-84dB range as no student in the NTID population with a two or one frequency "average" falls into these ranges (see Table 3). In future studies at NTID, an effort will be made to calculate PTA using the ODS method for more accurate comparison of NTID students to the overall deaf population.

In conclusion, the above research undertaken at NTID has established a means of predicting appropriate levels of discrimination achievement based on the residual hearing characteristics of that population. The prediction formula cited above allows for ease of identifi-

cation of those students who are in need of Auditory Training. Moreover, it establishes criteria for entrance and exit achievement levels for the Auditory Training program at NTID, as well as providing insights into the particular kinds of instruction which should be provided for individual students. This prediction formula has also made it apparent that there is a need for additional research into the other parameters which influence the potential for the development of discrimination skills of the deaf, and once again, has pointed out the importance of continual use of amplification for the development of good discrimination skills in this population.

As more students are admitted to NTID each year, their residual hearing will be analyzed in the same manner and further research concerning the appropriateness of this technique for calculating predicted discrimination levels will be obtained. In this way, changes in the character of the NTID population will be continually monitored and a broader data base will be developed from which to make inferences concerning the deaf population in general.

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