Speech Intelligibility at Gain Settings Determined by Aided Acoustic Reflexes

Albert J. Jetty and Allen H. Tani
Louisiana State University
Baton Rouge, Louisiana

Clarence J. Freeman
Hearing Rehabilitation Service
Baton Rouge, Louisiana

For some potential hearing aid users, gain settings for maximal speech intelligibility are difficult to determine. The present study was designed to determine if the aided acoustic reflex could be used to establish these settings. The aided acoustic reflex level, comfort setting, and -10 dB and +10 dB of reflex threshold gain setting were used to determine gain settings for 18 hearing-impaired adults. Two types of speech intelligibility tests were utilized to determine speech discrimination ability at each experimental gain setting. The results indicated that the aided acoustic reflex setting may provide maximal intelligibility and therefore be a viable, objective procedure in determining the hearing aid gain setting.

The goal of a hearing aid evaluation is to help in the selection of a hearing aid which is appropriate for each person's hearing loss. Typically, the suitability of a hearing aid is determined by the hearing-impaired person's performance on tests of speech discrimination. The ideal hearing aid fitting is considered to be one which provides maximum speech discrimination while avoiding the problem of over-amplification and resultant reports of loudness discomfort by the hearing aid user. It has been shown that experienced adult hearing aid users are able to set the gain control to a level that allows them maximum speech intelligibility and comfort in most listening situations (Yantis, Miller, & Shapiro, 1976). However, for the child who is unable to make such a sophisticated judgment, the recommended gain setting is most often based upon subjective observations. A more objective and accurate method is

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Albert J. Jetty, Ph.D., is Director, Speech and Hearing Clinic, Louisiana State University (LSU), Baton Rouge, LA, 78003-2606. Allen H. Tani, Ph.D., is Assistant Professor, Speech Pathology and Audiology, LSU. Clarence J. Freeman serves on the staff of Hearing Rehabilitation Service, Baton Rouge, LA.

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needed, since maximum speech discrimination is crucial during the early years of speech and language acquisition.

The development of impedance measurements has focused attention on the effects of the acoustic reflex on speech intelligibility. Studies by Liden, Norland, and Hawkins (1963), Borg and Zakrisson (1973), and Mahoney, Vernon, and Meikle (1979) indicate that the middle ear reflex may extend the dynamic range of the ear by attenuating low-frequency energy and thus maintaining an adequate suprathreshold signal/noise ratio for the understanding of speech. Thus, it would appear that the acoustic reflex measurement could be used as an objective method of setting the use gain of amplification at the level that would yield maximum speech intelligibility. A study by Rappaport and Tait (1976) supports this statement. They compared aided comfort gain settings and reflex gain settings and found a significant improvement in speech intelligibility with the Rush Hughes PB-50 monosyllabic word lists (competing message of connected discourse recorded at a signal-to-noise ratio of +10 dB) in favor of the reflex threshold gain setting. While the reflex threshold gain setting was statistically significant, the actual mean score was only 7.3% higher. The authors suggest that a less difficult task may have shown greater differences among the four gain settings used in their study.

The purpose of the present research was to determine if various hearing aid gain settings relative to the aided contralateral acoustic reflex would yield significantly different speech discrimination scores on two auditory intelligibility tasks. One task was a traditional approach utilizing one-syllable words with a competing message: specifically, Northwestern University (N.U.) Auditory Test No. 20 (Jerger, 1964). The other discrimination task consisted of the Synthetic Sentence Identification Test (SSI) with 30 synthetic sentences presented under each test condition (Speaks & Jerger, 1965).

METHOD

Subjects

Aided speech discrimination scores were obtained from 18 adult subjects ranging in age from 28 to 71 years with a mean age of 48.7 years. All 18 subjects (ten males and eight females) had bilateral sensori-neural hearing losses and Type A tympanograms bilaterally. Unaided spondee thresholds for the experimental ears ranged from 28 dB to 55 dB HL with a mean of 42.7 dB HL. Pure tone averages (500, 1000, and 2000 Hz) in these same ears ranged from 28 dB to 58 dB HL with a mean of 46.3 dB HL.

Procedure

The subjects wore their own hearing aid or a stock aid during the testing procedures and scores were obtained for each of the speech discrimination tasks at the following four gain settings: (a) aided contralateral reflex threshold as determined by speech-noise stimulus; (b) +10 dB of acoustic reflex gain setting; (c) -10 dB of acoustic reflex gain setting; and (d) comfort level determined by the subject from recorded, cold-running speech. Test conditions were randomized to preclude order effects.

In order to establish the gain control setting for each of the conditions, the subjects were seated in a double-walled test booth 1.5 meters from the loudspeaker at zero degrees azimuth wearing an auricular-type hearing aid. Each subject set the gain control on her/his hearing aid to a comfortable level while listening to recorded cold-running speech presented at 65 dB sound pressure level (SPL) at the listener's ears. When the comfort level adjustment had been made, the hearing aid was removed from the subject and placed in a Phonic Ear, model 2000 hearing aid test chamber, and an output curve obtained with a 60 dB SPL input and recorded on a Phonic Ear model 2200 strip chart recorder. The aid was then placed back on the subject. The probe tip of the American Electromedics model 83 Impedance Bridge was placed in the contralateral ear and the aided contralateral acoustic reflex was determined using speech noise calibrated to 65 dB SPL at the ears of the subject. Again, the aid was removed from the subject and placed in the hearing aid test chamber where an output curve was recorded. The hearing aid was then placed at the location it would be when on the subject, but connected to the 2 cc coupler of the test chamber. With the speech noise at 65 dB SPL at the microphone of the hearing aid, the gain control was rotated to +10 dB and -10 dB of the reflex threshold gain as indicated by the output reading of the test chamber, and output curves obtained at each of these settings.

Once the gain levels had been determined the aid was set to one of the four gain settings depending on the sequence of test conditions for a particular subject. The two speech discrimination tasks were presented at each of the four gain settings at 65 dB SPL. A hearing aid output curve was again obtained immediately following each test condition. The first condition was then repeated in order to obtain an indication of test reliability.

RESULTS

Mean speech intelligibility scores for N.U. Auditory Test No. 20 at the four hearing aid gain settings are presented in Table 1. The table shows that, except for the -10 dB of reflex gain setting, the mean scores are essentially the same. The highest mean score was obtained at the comfort gain setting, but this was only 1% higher than the mean score at the reflex setting and less than 2% higher than the +10 dB of reflex gain setting. The mean score at the -10 dB of reflex gain setting was 8% lower than the mean score at the comfort gain setting. The -10 dB test condition was often accompanied by complaints that the stimuli were not loud enough. Variability between subjects and

Table 1
Speech Discrimination Scores on
N.U. Auditory Test No. 20 at the Four Hearing Aid Gain Settings

Gain Setting	Mean	Range	Standard Deviation
Reflex	50.9	26-80	18.2
+10 dB reflex	50.2	26-80	17.3
-10 dB reflex	33.9	0-80	20.2
Comfort	51.9	28-76	15.1

overlapping intelligibility scores are revealed by the range and standard deviation for each gain setting.

Speech intelligibility scores for the SSI at the four hearing aid gain settings are shown in Table 2. Again, except for the -10 dB of reflex gain conditions, the mean scores are not clinically significantly different. This time the highest mean score was obtained at the reflex gain setting, but this was only 3% higher than the mean score for the +10 dB of reflex gain setting and less than 3% higher than the comfort gain setting. The mean score at the -10 dB of reflex gain setting was 9% lower than the mean score of the reflex gain setting. As with N.U. Auditory Test No. 20, the range and standard deviation for each gain setting indicates variability between subjects and overlapping intelligibility scores on the SSI.

Table 2
Speech Discrimination Scores on the SSI
at the Four Hearing Aid Gain Settings

Gain Setting	Mean	Range	Standard Deviation
Reflex	67.9	17-97	21.7
+10 dB reflex	64.8	13-100	25.9
-10 dB reflex	58.5	0-97	27.5
Comfort	65.2	33-100	22.7

The analysis of variance for effect of hearing aid gain setting on aided speech discrimination for N.U. Auditory Test No. 20 is shown in Table 3. The treatment effect is statistically significant at the .0001 level of confidence. Duncan's Multiple Range Test was applied to the differences between treatment means for N.U. Auditory Test No. 20 and is summarized in Table 5. From the table it is clear that the only significantly different mean is for the

Table 3

Analysis of Variance for Effect of Hearing Aid Gain Setting on Aided Speech Discrimination for N.U. Auditory Test No. 20

Source	df	Sum of Squares	f ratio	Probability
Gain Setting	3	3978.00	18.61	.0001
Subject	17	17830.44	-	-
Subj*Treat	51	3634.00	-	-

Table 5

Duncan's Multiple Range Test Applied to the Differences Between Treatment Means for N.U. Auditory Test No. 20

Alpha Level = .05 *Grouping	df = 51 Mean	M.S. = 71.25 Treatment
A	51.9	Comfort
A	50.9	Reflex
A	50.2	+10 dB reflex
B	33.9	-10 dB reflex

*Means with the same letter are not significantly different.

-10 dB of reflex gain control setting.

An analysis of variance for effect of hearing aid gain setting on aided speech discrimination for the SSI is summarized in Table 4. The treatment effect is statistically significant at the .05 level of confidence. Duncan's Multiple Range Test applied to the differences between treatment means for the SSI and is shown in Table 6. Again, the only significantly different mean is for the -10 dB of reflex gain control setting.

Figure 1 shows the number of times each different gain setting yielded the highest aided speech discrimination score for N.U. Auditory Test No. 20.

Table 4

Analysis of Variance for Effect of Hearing Aid Gain Setting on Aided Speech Discrimination for the SSI

Source	df	Sum of Squares	f ratio	Probability
Gain Setting	3	855.22	2.72	.05
Subject	17	35652.61	-	-
Subj*Treat	51	5339.27	-	-

Table 6

Duncan's Multiple Range Test Applied to the Differences Between Treatment Means for the SSI

Alpha Level = .05	**df = 51**	**MS = 104.69**
***Grouping**	**Mean**	**Treatment**
A	65.2	Comfort
A	67.9	Reflex
A	64.8	+10 dB reflex
B	58.5	-10 dB reflex

*Means with the same letter are not significantly different.

Nine subjects (50%) obtained their highest score at the comfort gain setting, while no subject obtained her/his highest score at the -10 dB of reflex gain condition. Five subjects (28%) obtained their highest score at the +10 dB of reflex gain setting, and three subjects (17%) obtained their highest score at the reflex gain setting. One subject obtained his highest scores at both the reflex gain setting and the -10 dB of reflex gain setting.

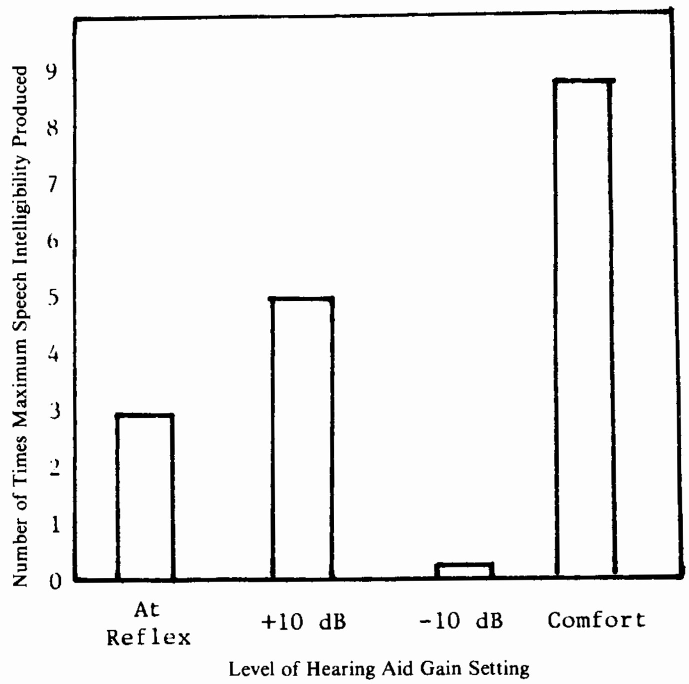

Figure 1. Number of times each hearing aid gain setting produced maximum speech intelligibility on N.U. Auditory Test No. 20 (N = 17).

Figure 2 shows the number of times each different gain setting yielded the highest aided speech discrimination score on the SSI. In this case, seven subjects (39%) obtained their highest score at the reflex gain setting. The next highest scores were obtained at the +10 dB of reflex gain setting by 5 (28%) subjects. Highest scores were obtained by 2 subjects at the comfort gain setting and by only one subject at the -10 dB of reflex gain setting.

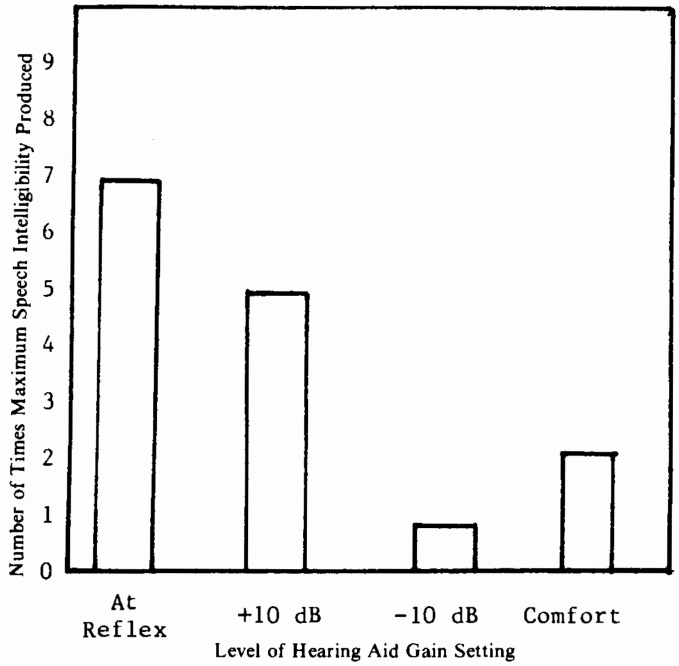

Figure 2. Number of times each hearing aid gain setting produced maximum speech intelligibility on the SSI (N = 15).

For each subject the first test condition was repeated on each of the speech intelligibility tasks. A Pearson Product Moment Correlation Coefficient of .81 was obtained for N.U. Auditory Test No. 20 and .85 for the SSI. Both coefficients indicate a high degree of reliability.

An idea of intensity differences among the test conditions can be gained from an examination of the hearing aid output curves shown in Figures 3, 4, and 5. Figure 3 shows the maximum that the comfort level was set above the reflex level (7.0 dB at 1000 Hz), whereas Figure 4 shows the maximum that the comfort gain level was set below the reflex gain level (5.5 dB at 1000 Hz). Figure 5 is typical of the usual relationship between the comfort gain and reflex gain positions. These levels were usually within 2 or 3 dB of one another with either comfort set slightly above or below the reflex gain setting.

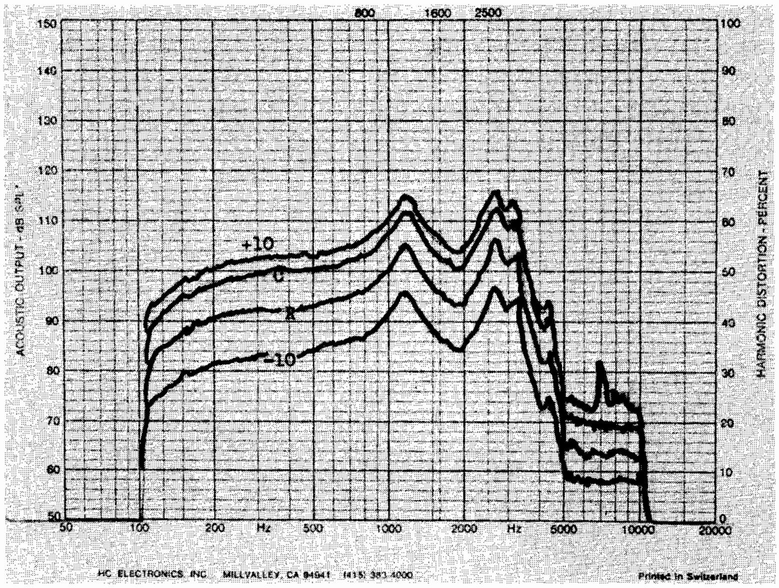

Figure 3. Hearing aid output curves illustrating the maximum that the comfort level gain was set above the reflex gain level.

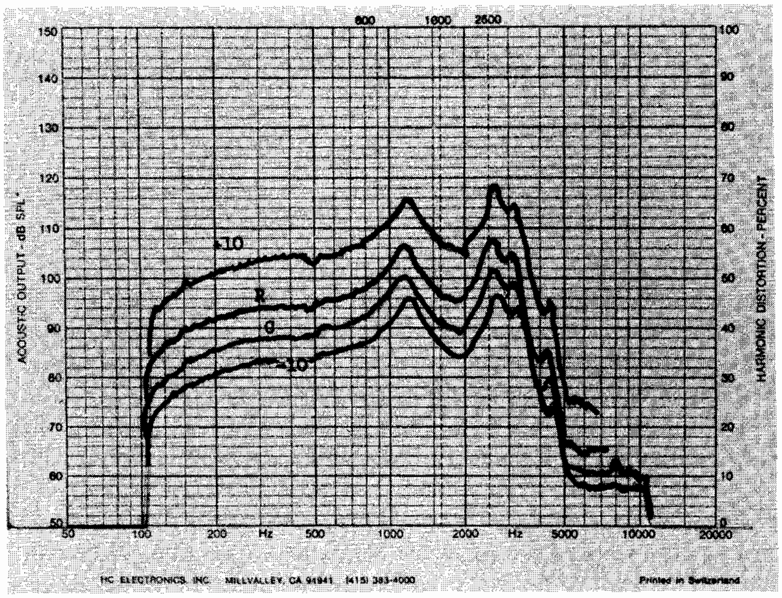

Figure 4. Hearing aid output curves illustrating the maximum that the comfort level gain was set below the reflex gain level.

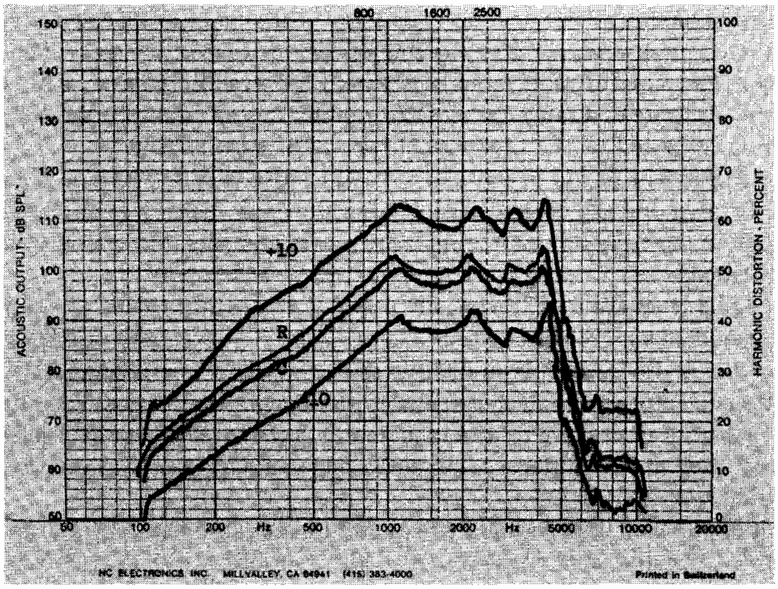

Figure 5. Hearing aid output curves illustrating the typical intensity relationship between the comfort gain setting and the reflex gain setting.

This being the case, it is understandable that the mean scores between these two test conditions were not statistically or clinically significant.

The hearing aid output curve obtained immediately following a test condition was virtually identical to the one obtained when the gain control position was set prior to beginning the testing, thus indicating that this was a highly reliable method of setting the gain control for the various experimental conditions.

DISCUSSION

While the reflex gain setting did not yield mean scores on the two intelligibility tests that were significantly better, the important point is that the discrimination scores were not adversely affected by using this objective measure. Thus, reflex gain setting appears to be a viable option to comfort gain setting in determining the gain necessary to obtain maximum speech intelligibility. This being the case, it is a useful method for any patient too young and/or unfamiliar enough with amplification to set the hearing aid to a comfort level.

Unless a person displays a significant tolerance problem, discrimination is not significantly affected by a higher gain setting than that which would ordinarily be perceived as comfortable. However, we found that such a setting is often accompanied by complaints that the stimuli are, if not intolerably loud, at least uncomfortably so. It should be noted that the reflex gain setting was never perceived as being either too loud or too soft. The data suggest that comfort and reflex are often very close in intensity and, since comfort is more of a range rather than a point, it is understandable why they are not perceived by the hearing aid user as being different.

Setting a hearing aid to a level of -10 dB relative to reflex threshold has an adverse affect on the obtained intelligibility scores. Speech is just not loud enough to yield maximum intelligibility scores and such low settings should be avoided.

Judging from the mean scores obtained, N.U. Auditory Test No. 20 could be considered a more difficult test than the SSI. However, although absolute mean scores differed between the two tests, the relative performance at each of the gain settings remained essentially the same for both measures. Either they are both insensitive to differences among the three higher gain settings, or real intelligibility differences in performance do not exist at these hearing aid gain settings.

Although the contralateral acoustic reflex measurement appears to be a reliable, objective approach to setting the gain of hearing aids, it is by no means useful for every patient. Some hearing-impaired people with no measureable middle ear involvement and moderate sensori-neural hearing loss have no acoustic reflexes under both aided and unaided conditions. Also, because the acoustic reflex may be obscured by even minor middle ear disorders, the reflex gain setting is not always attainable.

Finally, further experimental evidence should be obtained with young children using specially constructed discrimination tasks at various gain settings as determined by the aided acoustic reflex in order to further validate this procedure.

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