PHYSICAL PERFORMANCE OF HEARING AIDS AS AFFECTED BY RECEIVER SUBSTITUTION

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INTRODUCTION

There are currently available several hearing aids which are provided with interchangeable receivers of different models for the purpose of altering the frequency response patterns of the instruments. The effect or change of electroacoustic characteristics of a given hearing aid resulting from a change of the frequency response has not been reported. Any such effect or change upon the nonlinear distortion characteristic which has been shown to influence listener intelligibility performance (Harris et al., 1961; Jerger, Speaks and Malmquist, 1966), or otherwise significant alteration of the hearing-aid performance in terms of gain or maximum power output is of direct concern to the audiologist for hearing-aid selection purposes.

Receiver substitutions may be made with a receiver of the same model which supposedly would not change the pattern of frequency response, or the substitution may be made by a receiver of a different model with the objective of altering the frequency response pattern of the hearing-aid output. The resulting substitution of receivers presents two important questions. First, does the replacement of a receiver of the same model as the one supplied with the hearing-aid transmitter provide the same electroacoustic performance characteristics of the hearing-aid output? This question is of particular interest with respect to hearing-aid repair which necessitates the replacement of a like receiver to make the instrument functional. For example, in a Veterans Administration pilot repair program of hearing aids at the Denver Prosthetics Distribution Center, of all the repairs accomplished during a 1-year period, 19.9 percent of these repairs included the replacement of receivers. The second question is, does the substitution of a different model receiver contribute to changes other than the frequency response pattern in the physical performance characteristics of a given hearing aid?

The purpose of this study was, therefore, to determine what changes in the physical performance characteristics of a hearing aid took place as a result of a change in the frequency response by the substitution of a different

model of receiver, and to determine the reliability of performance characteristics of a hearing aid among different receivers of the same model.

METHOD

Electroacoustic performance characteristics were measured for a strong-powered body-type hearing aid. To provide different frequency response patterns of the hearing aid, four different models of universal receivers were used as well as the standard receiver recommended by the hearing-aid manufacturer. The impedance of the universal receivers was the same as the standard receiver. To determine the variability of hearing-aid performance with a given receiver model, five samples each of the standard and universal receiver models were evaluated.

Apparatus

Sine wave signals were generated by a beat-frequency oscillator (B & K Model 1014) and fed into a hearing-aid test box (B & K Model 4212) by means of a loud speaker. A constant input level to the test box was maintained by the monitoring condenser microphone, microphone amplifier (B & K Model 2603), and compressor circuit of the beat frequency oscillator. The output of the hearing aid placed inside the test box was fed to an amplifier (B & K Model 2603) and a distortion analyzer (Hewlett-Packard Model 330B) through a 2 cc coupler and calibrated pressure microphone. The output of the amplifier was coupled to a graphic level recorder (B & K Model 2305) for automatic recording of frequency response.

Procedure

The following measurements were made using the same hearing-aid transmitter for each of the five samples of the standard and four universal receivers:

Maximum Power Output (MPO). MPO was measured at 500, 750, 1000, 1500, and 2000 Hz with the volume control of the hearing aid set at the full-on position. The input level to obtain MPO was also noted.

Gain. With a 70-dB sound pressure level (SPL) input signal, the volume control was adjusted until the output of the hearing aid was 3 dB below saturation at 1000 Hz. Gain was recorded for the same frequencies listed above for MPO measurements.

Response versus frequency. An automatic recording was made of the gain versus frequency curve from 200 to 5000 Hz. These curves were recorded with a 70-dB SPL input signal with the gain control set 3 dB down from saturation at 1000 Hz.

Distortion. Total nonlinear distortion was obtained for the same input level and volume control setting as for the response curve and gain determinations. Measurements were made at the five frequencies of 500, 750, 1000, 1500, and 2000 Hz.

Signal-Noise Ratio. With the volume control and input level as in the preceding, the output of the hearing aid was recorded at 1000 Hz for comparison of the output SPL due to electrical self-noise in the absence of a signal.

RESULTS

Means and standard deviations were determined at each frequency tested for maximum power output, total nonlinear distortion, and gain of each model of hearing-aid receiver.

Examination of Table 1 shows the saturation levels for each of the receiver models to be fairly constant as a function of frequency. On the other hand, the mean MPO at each frequency for universal receivers #2 and #4 is approximately 5–10 dB lower than for the other receivers.

TABLE 1.—*Mean Maximum Power Outputs and Standard Deviations (in dB) of Standard and Universal Receivers*

Receiver		Hz				
		500	750	1000	1500	2000
Standard	M	130.8	131.4	131.8	131.4	130.2
	SD	2.0	1.0	.7	1.4	.4
Universal #1	M	130.0	129.0	131.0	134.4	130.6
	SD	2.7	3.1	3.4	2.4	2.9
Universal #2	M	126.2	124.4	125.2	129.4	125.6
	SD	1.0	7.1	1.8	1.8	3.1
Universal #3	M	130.6	132.0	135.2	132.4	128.0
	SD	1.6	1.0	1.8	2.3	.6
Universal #4	M	128.0	126.8	128.8	133.0	124.8
	SD	.6	1.0	1.1	1.2	2.9

Inspection of Table 2 indicates extremely low total nonlinear distortion found in this hearing-aid output regardless of the receiver used or the frequency considered.

Mean gain (relative to 1000 Hz) values are reported in Table 3. These values reflect the frequency response patterns of each receiver model. The general pattern of the universal receivers was a rising (high frequency emphasis) pattern somewhat sharper in slope to the standard receiver.

TABLE 2.—*Mean Total Nonlinear Distortion (in %) and Standard Deviations of Standard and Universal Receivers (the Input Signal was 70 dB SPL and the Volume Control of the Hearing Aid was Adjusted 3 dB Down from the Saturation Level at 1000 Hz)*

Receiver		Hz				
		500	750	1000	1500	2000
Standard	M	3.3	3.7	4.1	4.6	4.1
	SD	.5	0.0	2.0	1.8	1.7
Universal #1	M	4.3	4.1	4.0	4.9	2.1
	SD	3.7	1.8	2.8	2.7	.3
Universal #2	M	3.3	5.8	2.5	5.0	2.4
	SD	.7	2.3	1.3	3.1	.6
Universal #3	M	3.8	4.0	4.6	2.0	2.3
	SD	2.5	3.2	1.6	1.0	.7
Universal #4	M	2.5	3.5	2.3	4.0	2.3
	SD	.7	1.5	1.1	1.1	.3

TABLE 3.—*Mean Gain (in dB) Relative to the Gain at 1000 Hz and Standard Deviations of Standard and Universal Receivers*

Receiver		Hz			
		500	750	1500	2000
Standard	M	−8.0	−3.8	1.6	1.4
	SD	2.9	1.3	1.0	1.0
Universal #1	M	−7.0	−4.6	2.8	−2.2
	SD	4.1	2.3	5.0	3.0
Universal #2	M	−4.5	−3.0	7.0	−1.8
	SD	3.2	1.9	2.8	2.3
Universal #3	M	−8.6	−6.0	.2	−4.8
	SD	4.1	1.2	3.0	1.7
Universal #4	M	−5.2	−5.0	7.2	−.8
	SD	5.0	1.8	1.0	2.4

Performance Variability

To determine variability among the standard and universal receivers as well as the variability among the samples of each receiver model, analyses of variance were conducted for the four electroacoustic performance characteristics of maximum power output, nonlinear distortion, mean gain, and signal-noise ratio.

Maximum Power Output (MPO). Separate analyses of variance were conducted at each frequency tested (500, 750, 1000, 1500, and 2000 Hz). In each analysis the main effects were receiver models and model samples. The summaries of these analyses are reported in Table 4.

At three frequencies (500, 750, and 1000 Hz) significant differences in MPO were demonstrated among the receiver models. At 1500 and 2000 Hz, the F values were extremely close to the significance level. However, among the receivers of the same model, no differences approaching significance appeared at any frequency. From these analyses it is apparent the use of different models of receivers may produce different MPO's with the same hearing aid, particularly at lower frequencies with little likelihood of significant differences occurring among receivers of the same model.

TABLE 4.—*Summary of Analyses of Variance for Maximum Power Output*

Source	Sum of squares	df	Mean square	F
Models:				
500 Hz	77.8	4	19.4	[a] 4.97
750 Hz	201.9	4	50.5	[a] 15.78
1000 Hz	274.8	4	68.7	[a] 17.17
1500 Hz	69.8	4	17.4	4.70
2000 Hz	137.4	4	34.4	4.69
Samples:				
500 Hz	15.8	4	3.9	1.0
750 Hz	21.1	4	5.2	1.6
1000 Hz	22.8	4	5.7	1.4
1500 Hz	27.6	4	6.9	1.7
2000 Hz	30.2	4	7.5	1.0
Error:				
500 Hz	63.0	16	3.9	
750 Hz	52.1	16	3.2	
1000 Hz	64.4	16	4.0	
1500 Hz	59.2	16	3.7	
2000 Hz	117.3	16	7.3	
Total (all groups)	1235.2	24		

[a] Significant at .01 level (4.77).

Nonlinear Distortion. As in the case of MPO, separate analyses of variance were conducted at each test frequency to determine variability of total nonlinear distortion among different receiver models and receivers of the same model. The summaries of the analyses are reported in Table 5. No statistically significant differences in total distortion appeared either among different models or among receivers of the same model. These results indicate that the substitution of a receiver, either of the same or different model, will not significantly change the amount of total nonlinear distortion at the output of a hearing aid.

TABLE 5.—*Summary of Analyses of Variance for Total Nonlinear Distortion*

Source	Sum of squares	df	Mean square	F
Models:				
500 Hz	6. 85	4	1. 71	. 54
750 Hz	15. 89	4	3. 97	. 73
1000 Hz	42. 20	4	10. 55	2. 29
1500 Hz	29. 93	4	7. 48	1. 22
2000 Hz	13. 96	4	3. 49	4. 41
Samples:				
500 Hz	12. 18	4	3. 04	. 95
750 Hz	20. 63	4	5. 13	. 94
1000 Hz	14. 44	4	3. 73	. 81
1500 Hz	19. 35	4	4. 83	. 79
2000 Hz	3. 24	4	. 81	1. 02
Error:				
500 Hz	50. 90	16	3. 18	
750 Hz	87. 09	16	5. 44	
1000 Hz	73. 56	16	4. 59	
1500 Hz	97. 53	16	6. 09	
2000 Hz	12. 64	16	. 79	
Total (all groups)	500. 39	24		

Mean Gain. The mean gain at 1000, 1500, and 2000 Hz was determined for the samples of receiver models. An analysis of variance was conducted using these means and is reported in Table 6. Neither the variance among the models nor the variance among the samples of the same model was significant. This would suggest, in the case of different models, that the frequency response pattern change due to the substitution of a receiver is not significant enough to influence the mean gain of the instrument in the mid-frequency range. The same is true if the mean gain of 750, 1000, and 1500 Hz is obtained and subjected to the same statistic (Table 7).

TABLE 6.—*Summary of Analysis of Variance of Mean Gain (1000, 1500, and 2000 Hz)*

Source	Sum of squares	df	Mean square	F
Models	142.6	4	35.6	2.80
Samples	30.5	4	7.6	.59
Error	204.1	16	12.7	
Total	337.2	24		

TABLE 7.—*Summary of Analysis of Variance of Mean Gain (750, 1000, and 1500 Hz)*

Source	Sum of squares	df	Mean square	F
Models	130.8	4	32.7	4.24
Samples	23.2	4	5.8	.75
Error	123.2	16	7.7	
Total	277.2	24		

Signal-Noise (S/N). An analysis of variance of S/N at 1000 Hz using receiver models and model samples as main effects was conducted. The summary (Table 8) shows no statistically significant differences for either receiver models or samples of the same model.

TABLE 8.—*Summary of Analysis of Variance of Signal-Noise Ratio at 1000 Hz*

Source	Sum of squares	df	Mean square	F
Models	194.0	4	48.5	1.28
Samples	38.0	4	9.5	.25
Error	606.0	16	37.8	
Total	838.0	24		

DISCUSSION

Aside from the fact that the frequency response patterns of a hearing aid may be changed by the substitution of a different model receiver, significant changes of other electroacoustic characteristics as measured in this study do not occur except with regard to MPO at the lower frequencies. Even though these differences in MPO occur statistically, it is questionable whether these differences are clinically significant while the other physical performance characteristics remain constant.

The lack of physical performance differences occurring with the use of different receivers on the same hearing aid again presents the proposition, which has been supported by Shore, Bilger, and Hirsh (1960) and Harris et al. (1961), that little or no influence on listener intelligibility occurs resulting in a change of the frequency response pattern of a hearing aid. That is, a frequency response pattern which is suppressed at one end of the frequency spectrum by the substitution of a receiver, will not either enhance or degrade the fidelity or change other electroacoustic charactistics of the instrument enough to improve or reduce speech intelligibility. This being the case, the clinical concern should be whether such a substitution of a receiver will provide an instrument which "sounds better" or "sounds worse" to the user, rather than will such a substitution provide more or less intelligible speech with a given hearing aid. The clinical concern thus becomes a quality judgment on the part of the listener following the selection of the aid by the audiologist according to his criterion. It therefore appears that the use of universal receivers can be made without contributing significant effects upon the physical performance characteristics of the hearing aid other than the frequency response pattern, and this change of pattern is in effect probably influential only as a tone control.

The absence of variability among receivers of the same model indicates a relatively good quality control in the manufacture of receivers. Clinically, this is of importance when it is necessary to replace an existing receiver because of damage or inoperative condition. Such a change can therefore be accomplished without influencing the user's intelligibility performance or necessary usable gain expected with his hearing aid.

SUMMARY

Physical performance characteristics of a hearing aid were measured using five samples of a standard receiver and five samples each of four different models of universal receivers. The only significant statistical differences found among different models of receivers was for MPO at the lower frequencies. Statistical differences among receivers of the same model were not found at any frequency for any electroacoustic characteristic measured.

The results indicate that the substitution of hearing-aid receivers (matched to the impedance of the output of the hearing aid) do not alter physical performance characteristics other than frequency response, and therefore should not affect listener intelligibility performance.

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