Effects of Coupling Hearing Aids to FM Systems Via Neck Loops

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The electroacoustic response of 12 hearing aids was measured when coupled to each of two different FM systems via teleloops placed on KEMAR. There were relatively small changes in SSPL90 or harmonic distortion in the aid + FM condition relative to the aid alone. There was an increase in equivalent input noise which varied across FM systems. There was generally a reduction in the low frequency information in the aid + FM condition that was related to the frequency response of the hearing aid telecoil. Differences in output as great as 20 dB were observed as KEMAR's head was rotated from left to right. The results support the need for electroacoustic evaluation of hearing aids in conjunction with personal FM-neckloop systems to determine if the desired electroacoustic characteristics are achieved.

An increasingly popular option for the delivery of a frequency-modulated (FM) signal is the use of a neckloop coupled to the FM receiver in conjunction with a personal hearing aid. Although this arrangement may be preferable cosmetically because the loop may be hidden under clothing, there are several electroacoustic factors which warrant consideration when choosing this arrangement over other signal delivery options.

Hawkins and Van Tasell (1982) raised concern regarding these systems because of significant differences between the telecoil and microphone modes of a hearing aid (Sung & Hodgson, 1971). They evaluated three hearing aids in conjunction with an FM system and found significant differences in the frequency responses in the aid + FM condition relative to the aid alone. Furthermore, there were substantial differences in the electroacoustic response as the distance and orientation of the aid relative to the loop varied. Similar electro-

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acoustic variations were reported by Hawkins and Schum (1985) and Van Tasell and Landin (1980).

Despite these findings, neckloops are still advocated by some. Van Tasell, Mallinger, and Crump (1986) found no significant reduction in word identification when using a neckloop and personal aid as compared to using an FM system only for eight of the nine children they evaluated. However, performance with the personal hearing aid alone was not evaluated.

The degree to which the electroacoustic characteristics of a variety of hearing aids are altered by different FM neckloop systems is unknown. It is the authors' contention that audiologists who dispense hearing aids or make recommendations regarding purchase of FM systems should consider those hearing aid-FM system combinations that result in the least amount of alteration in the hearing aid output. Furthermore, those who dispense to children must consider the inevitable need for FM amplification in educational situations and the potentially wide range of performance of telecoil aids with neckloop coupling. The purpose of this research was to provide practical information to aid in these decisions. The electroacoustic performance of 12 hearing aids in the telecoil mode was measured with each of two different neckloop systems and is reported below.

METHOD

Hearing Aids

Twelve behind-the-ear hearing aids were selected as representative of available clinic stock at a university speech and hearing clinic (see Appendix). All of the aids were set to provide the widest frequency response and greatest maximum power output. All aids were tested according to ANSI S3.22 (1982) procedures to ensure they were functioning according to manufacturers' specifications in the microphone and telecoil modes. Results were consistent with manufacturers' specifications and are summarized in Table 1.

FM Systems

The two FM systems used in the study were designed especially for use with personal hearing aids (see Appendix). Each transmitter had an omnidirectional lapel microphone. Only one of the FM receivers had output controls; these were set to provide the widest frequency response and the highest gain. This receiver also had environmental microphones which were deactivated during all of the testing.

Procedures

All electroacoustic measurements were conducted with a calibrated Fonix 5500 Z or Fonix 6500 hearing aid measurement system in a quiet room. The lapel microphone of the FM transmitter was placed in the test box and the transmitter placed outside of the box. The neckloop was placed on a Knowles

Table 1
Electroacoustic Characteristics of Hearing Aids Evaluated for FM Coupling

Aid	SSPL90	FOG	RTG	Freq. Range	EIN	Telecoil Sensitivity
1	121	60	44	500-5300	28	104
2	121	53	44	300-5200	28	101
3	127	50	50	390-6600	27	100
4	117	47	40	120-5600	25	100
5	117	49	40	300-5600	25	100
6	124	53	47	200-4800	30	107
7	129	72	52	440-6000	26	123
8	120	50	43	200-5800	27	100
9	130	66	54	90-4900	27	120
10	123	54	46	140-6100	27	105
11	131	62	54	160-5200	25	117
12	123	54	46	80-6200	27	107

Note: SSPL90 = high frequency average saturation sound pressure level (dB SPL); FOG = high frequency average full on gain (dB); RTG = reference test gain (dB); Freq. Range = frequency range (Hz); EIN = equivalent input noise (dB); Telecoil Output is in dB SPL.

Electronics Manikin for Acoustic Research (KEMAR) and the FM receiver was placed at the waist. The hearing aid attached to the 2-cc coupler was placed on KEMAR's left pinna with a sling supporting the coupler.

Because there is no standard for the electroacoustic measurement of FM systems, the measurement procedures were designed to approximate the ANSI S3.22 (1982) protocol. For saturation sound pressure level (SSPL90) and full on gain (FOG) measurements, the volume controls of both the hearing aid and the FM receiver were set full on and input levels were 90 and 50 dB SPL respectively. For the remaining measurements the hearing aid was set to its reference test gain (RTG) position when operating in the microphone mode. It was then returned to KEMAR's ear and set to telecoil mode. The volume control of the FM receiver was adjusted to achieve RTG relative to the aid + neckloop SSPL90 level previously determined. In some cases, even with the FM receiver full on, RTG could not be achieved. In that event, the hearing aid was set to full on and the FM receiver was adjusted to achieve the desired gain. While in the RTG setting, frequency response curves were generated with a 60 dB SPL input. Frequency range was derived from these curves following ANSI procedures. Another set of frequency response curves was obtained when KEMAR's head was turned 90° right and left.

Harmonic distortion and equivalent input noise (EIN) were measured using the frequencies and input levels specified in the ANSI S3.22 standard. The final set of measurements involved comparison of the frequency response of the aid when in telecoil and microphone modes. The telecoil measurement was made according to ANSI specifications. The hearing aid was then switched to the microphone mode and the volume control reduced until the output at 1000 Hz was the same as that observed in the telecoil mode, and another frequency response curve was generated. As a reliability check, the electroacoustic evaluation was repeated with five aids with FM System #1.

RESULTS AND DISCUSSION

Basic Electroacoustic Measurements

Results were evaluated according to three measurement conditions for each aid: the aid alone, and the aid in combination with neckloop system #1 and in combination with neckloop system #2. For each measurement, difference scores were calculated. A difference score equaled the value in the aid + neckloop condition minus the value in the aid alone condition.

For the first measurement, high frequency average SSPL90, all of the aids had difference scores within ±5 dB. Regarding harmonic distortion, there was often an increase in harmonic distortion when the aid was used in conjunction with the neckloop systems relative to the aid-alone conditions. The largest increase in distortion occurred at 800 Hz and was 3.42% averaged across aids for System #1, and 6.08% for System #2. Two aids, #9 and #11, had difference scores of 19% and 16%, respectively, with System #2.

The difference scores for FOG and EIN are shown in Figure 1. There was always an increase in FOG for System #1 and often a decrease in FOG for System #2. As shown on the right in the top panel, the average difference scores were 18 dB and -2 dB, respectively. There was generally an increase in EIN for both FM systems. As shown on the right in Figure 1B, System #2 resulted in an average increase in EIN that was nearly twice that for System #1.

With respect to frequency response, there were a variety of patterns observed across the aids as illustrated in the left portion of Figure 2. Two of the aids (#5 and #11) had little difference among the aid-alone and aid + neckloop curves. The frequency response curves for one of these aids, #5, are shown in panel A. However, two of the aids (#6 and #10) had primarily a decrease in the low frequency output with both of the FM systems as illustrated by aid #6 in panel B. For the remaining aids there were substantial changes in the frequency response in both the high and low frequencies which usually occurred with both FM systems. The most dramatic change was for aid #8 as illustrated in panel C. These differences were related to changes in hearing aid frequency response between microphone and telecoil mode. The right panel of Figure 2 shows the same pattern of slight differences (aid #5), low-frequency reduction (aid #6), and high- and low-frequency reduction (aid #8) for the three representative aids when switched from microphone to telecoil mode.

To evaluate the extent to which the frequency response changed across the 12 aids, the range determined in the aid-alone condition was subtracted from that obtained in the aid + neckloop condition. System #1 resulted in a mean reduction of 400 Hz in the frequency range, whereas System #2 increased the

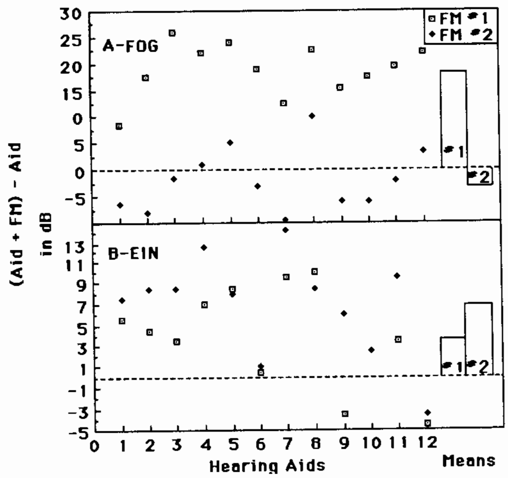

Figure 1. A: Difference scores for full on gain (FOG). A positive number reflects an increase in FOG in the aid + neckloop condition relative to aid alone. The bars at the right indicate the average difference score for each FM system. B: Difference scores and means for equivalent input noise (EIN).

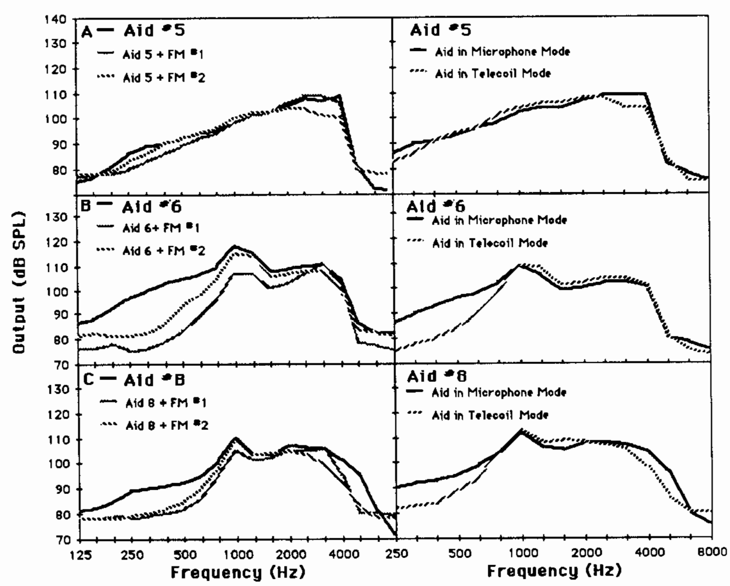

Figure 2. A: Frequency response curves for aid-alone and aid + neckloop conditions for three representative aids with two FM systems. B: Frequency responses for three aids when operating in microphone and telecoil modes.

frequency range by 150 Hz on the average.

Difference scores were calculated separately for the low- and high-frequency cutoff values. For the low-frequency cutoff, the difference scores were nearly always positive, as shown in Figure 3A, indicating a narrower range for the aid + FM compared to the aid alone. For the high-frequency cutoff shown in Figure 3B, the difference score was highly dependent on the hearing aid.

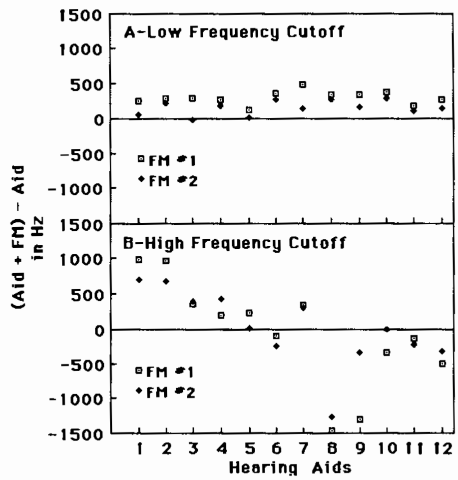

Figure 3. A: Difference scores for low-frequency cutoff of hearing aids with and without two FM systems. A positive number indicates a narrower range for aid + FM compared to aid alone. B: Difference scores for high-frequency cutoff.

Effects of Head Orientation

Changes in frequency response with changes in the orientation of KEMAR's head for one representative aid are shown in Figure 4. With both FM systems coupled to aid #2, the highest output was obtained when KEMAR's head was turned to the right; however, the magnitude of the changes was not consistent across the two FM systems. With System #1 (top panel), there was approximately a 10-dB difference between the mid frequencies of the right and left output curves, whereas with System #2, a 20-dB difference was seen in the mid frequencies. Across all of the aids, System #2 resulted in greater differences in output between right and left head orientation than System #1.

Reliability

Comparison of SSPL90, FOG, RTG, and EIN values obtained on two different occasions for five aids with FM system #1 revealed differences of 3 dB or less except for one aid for which the differences were up to 7 dB. Frequency range values varied less than 100 Hz in three comparisons and 350-650 Hz in the remaining two comparisons.

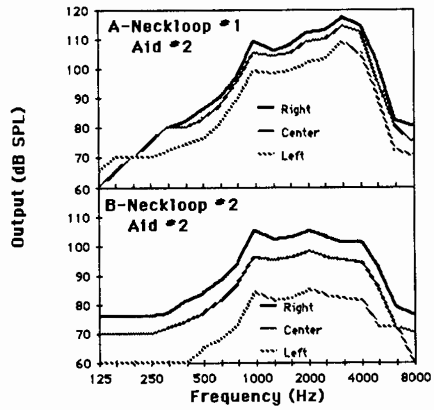

Figure 4. Variations in frequency response with head orientation for aid #2 with neckloop system #1 (A) and system #2 (B).

SUMMARY AND CONCLUSIONS

In summary, there was not one FM system-hearing aid combination that consistently resulted in low difference scores. However, some trends were observed. For example, if one does not need low-frequency amplification, the results with System #1 would be preferable because of the smaller increase in EIN and smaller head orientation differences. Consideration of these relative head orientation effects is particularly important when these systems are used with young children who are typically very active and probably not cognizant of the need to maintain a favorable orientation.

When maintenance of low-frequency amplification is desired, results such as those obtained from System #2 with aids #9, #11, or #12 would be recommended because of the extended low-frequency response and the minimal changes in the low-frequency cutoff. This would be particularly important when recommending amplification for children with residual hearing primarily in the low frequencies. The reduction in low-frequency amplification can be estimated by considering the telecoil response of an aid. If the telecoil reduces low-frequency amplification, another aid should be considered because use of that aid with an FM system might exaggerate that low-frequency reduction. The attempt to predict low-frequency reduction is especially important if the aid is to be used with a system like System #1 that consistently reduced low-frequency amplification.

When maintaining high-frequency amplification is important, one would prefer results as from aids #1, #2, #3, #4, #5, or #7 with either FM system or aid #10 with System #2. Aids that produced the least desirable results in this study with respect to high-frequency amplification are aid #8 with either FM system and aid #9 with FM system #1.

It is strongly suggested that everyone who uses a neckloop system have his or her hearing aid evaluated in the telecoil and microphone modes and in conjunction with the FM system and microphone to be used. Once the electroacoustic characteristics of the aid alone and the aid + neckloop system are compared, decisions can be made regarding the appropriateness of the system and alternatives explored if necessary.

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APPENDIX

KEY TO INSTRUMENTS

FM System #1: Telex TDR4 and TW5
FM System #2: Phonic Ear 475R and 471T

Aid	1:	Bernafon	T87
	2:	Bernafon	T85
	3:	Danavox	115 PP PCW
	4:	Oticon	E35F
	5:	Oticon	E37F
	6:	Telex	353C
	7:	Telex	372AI
	8:	Unitron	UM60-PP
	9:	Unitron	EIPL
	10:	Unitron	UE7
	11:	Widex	G2T
	12:	Widex	G6T