Young-Adult Students' Ratings of the Relative Performance of Hearing Aids, FM, and Loop Amplification Systems

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This study reports the benefit of FM and loop classroom amplification systems as perceived by severely and profoundly hearing-impaired students. Eight instructors and 44 students each participated in one of three experiments. Questionnaire results indicated that more students preferred personal hearing aids than any classroom amplification systems. Among classroom systems, more students expressed preference for a loop than for an FM system. More students rated their teacher easier to "hear/understand" than they did their classmates regardless of system. While there was a general preference for hearing aids, a substantial minority preferred the classroom systems.

It is well documented that an amplification system which reduces distance between instructor and student by use of an instructor microphone improves the signal-to-noise ratio (S/N) and, thereby, discrimination ability of hearing-impaired students (Blair, 1977; Erber, 1971; Markides, Huntington, & Kettlety, 1980; Niemoeller, 1968; Ross & Giolas, 1971; Webster & Snell, 1983). Gengel (1971) recommended a S/N of at least +15-20 dB for hearing-impaired listeners using hearing aids. This S/N is difficult to attain in most classrooms; therefore, an instructor microphone must be used.

Several kinds of amplification systems are available to improve S/N, including wireless frequency modulation (FM) or amplitude modulation (AM), loop, infrared, and hard-wired systems. Freeman, Sinclair, and Riggs (1981) and Ross (1973) listed several important factors to consider for system selection including (a) educational needs of the school program, (b) service record of the manufacturer, (c) ease and flexibility of equipment operation, (d)

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acoustic flexibility, (e) student-to-student communication, and (f) self-monitoring capability.

Calvert (1964) has shown that a questionnaire format can assist selection of an amplification system. Instructors of deaf students rank-ordered factors similar to those mentioned above for various amplification systems. Results revealed no system as clearly superior, although personal aids were ranked best over-all. Bishop, Christopolus, and Nielson (1972) also used a rank-ordering technique to determine instructor and student preferences. They found use time was maximized if attitudes were positive toward an amplification system. Even a system with optimal electro-acoustic properties will be to no avail if it is not used.

The purpose of this study was to describe student perceptions of several classroom amplification systems at the National Technical Institute for the Deaf (NTID) at Rochester Institute of Technology (RIT) where students are severely and profoundly hearing-impaired young adults. To determine if some students would benefit more from a classroom amplification system than from personal hearing aids, three experiments were conducted. Assuming that attitudes toward these systems are critical to their acceptance, information on these attitudes was collected and supplemented by a daily log of a classroom observer (one of the authors) and follow-up interviews with students. Because the *N* was small and lengthy familiarization with classroom amplification systems was not possible, the reader is cautioned against generalizing beyond the conditions of this study. Subjects in all experiments were selected based on consistent hearing aid use and enrollment in representative classes rather than hearing characteristics although all were severely or profoundly hearing impaired.

EXPERIMENT 1

The purpose of the first experiment was to compare two manufacturers' FM systems with each other as well as with students' own hearing aids.

Method

Subjects. Subjects were seven male and five female students enrolled full-time at NTID and ranged in age from 20 to 26 years. Their mean pure tone average (500, 1000, 2000 Hz) for the better ear was 93 dB HL (range: 65-105 dB HL, ANSI, 1969). Their mean grade-equivalent score on the California Reading Comprehension Test (Junior High level) was 10.1 (range: 7.9-12.0).

Students' receptive communication skills, including auditory discrimination, speechreading with and without sound, sign language reception, and simultaneous reception (speech and sign language), represented a range from poor to excellent. In all experiments students wore hearing aids with self-reportedly functioning telephone switches.

Students were enrolled in one of three classes of hearing-impaired students.

One of the three instructors (one male, two female) was hearing-impaired; all used intelligible speech consistently in the classroom.

Apparatus. The Phonic Ear Model 441T/445R and the Telex Model TW4/TDR4 FM systems were used. Each instructor wore an FM transmitter with a lapel-style directional microphone attached 3-5 in. below the chin. An FM receiver was coupled to each student's hearing aid(s) via an induction neck-loop and was equipped with an environmental microphone. There were no controls on the Phonic Ear System; the Telex receivers were set at factory settings for tone and SPL, and at the midpoint on the FM trimmer which increased the FM signal gain relative to the environmental microphone gain. Factory settings were used on the transmitters.

Factory settings were selected because of practical constraints precluding individual fittings. Also, students coupled the FM receivers to their personal hearing aids (which were individually fit), so that it was the hearing aids which ultimately modified the amplified signal. The midpoint of the FM trimmer was selected because Van Tasell and Landin (1980) found that environmental microphone gain was uniformly higher than FM gain for the FM receivers they tested.

Classroom Noise. Connected speech and noise measurements were made using two Bruel and Kjaer type 2203 and 2204 Sound Level Meters on the A-weighting scale. The classrooms were set up as they were during normal use with students and instructor present (door open or closed, overhead projector on or off, laboratory equipment on or off). In each of the three classrooms, the ambient noise and teacher's voice were measured at the position of the teacher's lapel microphone and at three representative student locations. In the first classroom, the S/N for the three student locations were -4 dB, +3 dB, and -2 dB, while at the location of the lapel microphone it was +15.5 dB (this teacher was a soft-spoken hearing-impaired person). In the second classroom the S/N at the student locations were +3 dB, +4 dB, and +4 dB, while at the lapel microphone it was +25 dB. In the third classroom, the S/N were +9 dB, +5 dB, and +5.5 dB, while at the lapel microphone it was +23 dB.

Questionnaires. Questionnaires were used to collect information on students' opinions about listening with each FM system and with their hearing aids alone. They were developed through pilot use at NTID and were based on factors that would be discriminating among systems (see Appendix A, B, C). Most of the items were statements to which students responded by checking the appropriate point on a rating scale. In other items students selected one answer from two or three alternatives. The questions were worded so that an average NTID student could understand them. Questions related to the factors of (a) loudness of teacher, self, and classmates; (b) ease of use; (c) cosmetic factors; and (d) general preference for type of amplification system. Questionnaires permitted addition of comments in open-ended questions.

Procedures. Students used each FM system for 2 weeks (four to six 50-minute class meetings) and then completed questionnaires. The order of use

of the three systems (including hearing aids) was counterbalanced across the three classrooms.

In introducing the experiment, the teacher allowed approximately 10 minutes for explanation of the goals of the project and equipment operation (also outlined in a printed handout). As all students were consistent aid users familiar with volume adjustment, each set the volume control on the FM receiver for most comfortable listening level. Students decided whether or not to use the environmental microphone to allow for different listening situations, for example, lecture or discussion. The teachers and observers (the authors) kept a written record of their observations, concerns, and successes. Follow-up interviews were conducted with students to clarify answers and comments on the questionnaires.

Results

Comparison of FM systems and hearing aids. Initial observation of the data suggested that no particular response pattern was unique to any one class; therefore, data were combined for the three classes. Table 1 presents responses to questions about loudness of the teacher's voice and ease in using the system. (In this table the *N* is reduced for the Telex questionnaire. In all tables where *N* is reduced, it is because students did not return questionnaires or did not respond to certain questions.)

Table 1

Students' Responses to Questions about Loudness and Ease of Use of Hearing Aids and FM Systems

Amplification System	Rating Categories[a]				Mean Rating
	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)	
Teacher's Voice Loud Enough?					
Hearing Aid	1	3	6	2	2.8
Telex	0	2	4	5	3.3
Phonic Ear	0	1	7	4	3.3
Easy to Use in Class?					
Hearing Aid	0	0	6	6	3.5
Telex	0	0	10	1	3.1
Phonic Ear	0	2	7	3	3.1

[a]Entries are number of students who checked each rating category.

As shown in Table 1, students perceived the FM systems to be louder than their hearing aids. More students selected *strongly agree* for the two FM sys-

tems than for their hearing aids. Although the sample size was small, repeated-measures analyses of variance (Dixon, 1983) were performed on mean ratings in order to identify trends. The mean ratings of the FM systems were higher than those of the hearing aids and the analysis of variance indicated that the difference in means was statistically significant, $F(2,20) = 3.86$, $p < .05$.

For the question about ease of use, more students responded with *strongly agree* for hearing aids than for the FM systems, but differences between means were not statistically significant.

Ratings of difficulty listening to classmates are presented in Table 2. The distribution of responses indicates greater difficulty listening to classmates with the FM systems than with hearing aids. An analysis of variance of the mean responses was statistically significant, $F(2,20) = 5.79, p < .05$. Newman-Keuls pairwise comparisons (Kirk, 1968, p. 91) indicated that the mean rating for hearing aids was significantly lower (better) than those for the Phonic Ear ($p < .05$), and Telex systems ($p < .01$).

Table 2

Students' Rating of Difficulty Listening to Classmates with Hearing Aids and FM Systems

Amplification System	Rating Categories[a]					Mean Rating
	No Problem (1)	(2)	Moderate Problem (3)	(4)	Big Problem (5)	
Hearing Aid	6	4	2	0	0	1.7
Telex	1	4	3	2	1	2.8
Phonic Ear	1	4	5	2	0	2.7

[a]Entries are number of students who checked each rating category.

Responses to questions about "hearing/understanding" teacher and classmates are presented in Table 3. More students rated understanding the teacher to be easy than they did their classmates, regardless of system. Students did not appear to favor one system over the other. For each question, analysis of variance results were not statistically significant.

Monitoring of Voice. Students were asked to indicate the extent of difficulty in monitoring their voice with the two FM systems on a *no problem* (1) to *big problem* (5) scale. Five out of ten students using the Telex and 8 out of 12 using the Phonic Ear system reported a *moderate* to *big* problem in monitoring their own voice. (This question was not addressed in the hearing aid questionnaire because it was assumed that voice monitoring would not be a problem.)

Table 3

Students' Rating of Ability to Hear/Understand Teacher and Classmates with Hearing Aids and FM Systems

Amplification System	Rating Categories[a]				Mean Rating
	Excellent (4)	Well (3)	Poorly (2)	Very Poorly (1)	
	How well hear/understand teacher?				
Hearing Aid	4	7	0	1	3.2
Telex	3	8	0	0	3.3
Phonic Ear	4	7	1	0	3.3
	How well hear/understand other students?				
Hearing Aid	2	6	3	1	2.8
Telex	0	7	3	1	2.5
Phonic Ear	0	6	6	0	2.5

[a]Entries are number of students who checked each rating category.

Cosmetic factors of FM systems. Questions were asked about (a) size, (b) cords, and (c) appearance. For each question the most frequent rating across the two systems was 1 (*no problem*) or 2 (*less than moderate problem*).

Relative preference for hearing aids and FM systems. On the Phonic Ear questionnaire, seven students noted a preference for their hearing aids; five preferred the FM. On the Telex questionnaire, seven preferred their aids and four preferred the FM. A second question asked about continued use of the system. For Telex, there were five *yes,* three *maybe,* and two *no* responses; for Phonic Ear there were four *yes,* five *maybe,* and three *no* responses. Thus there was considerable variation in students' preferences. While slightly more preferred their own aids, a substantial number preferred an FM system.

EXPERIMENT 2

The original purpose of this experiment was to compare the superior FM system from Experiment 1 with a loop system, as well as with hearing aids; however, there were no clear differences in students' perceptions of the two FM systems. Telex was selected due to greater flexibility of equipment operation.

Method

Subjects. Subjects were 13 male and 7 female NTID students 20 to 33 years of age who had not participated in Experiment 1. Their mean pure tone average (500, 1000, 2000 Hz) for the better ear was 81 dB HL (range = 67-108 dB HL, ANSI, 1969). Their mean grade-equivalent score on the California Reading Test was 10.0 (range = 7.9-12.0). As in Experiment 1, students' receptive

communication skills represented a range from poor to excellent.

Students were enrolled in one of three classes of hearing-impaired students. The instructors (two male, one female) were normally-hearing.

Apparatus. The Telex FM system was used as described in Experiment 1. The loop system consisted of components designed to be portable and laid out on the floor of a room and included a Radio Shack model MPA-35A amplifier (35 watts), Radio Shack model 32-1220 FM transmitter and receiver, and differing lengths of 4-conductor, 24-gauge wire which could be coupled to fit around each classroom. The teacher clipped the lapel-style microphone 3-5 in. below the chin. There was also a hard-wired microphone connected through the amplifier, available to pick up the students' voices.

Classroom noise. Connected speech and noise measurements were performed as in Experiment 1. In the first classroom, the S/N for the three student locations were +11 dB, +1 dB, and +8 dB; at the lapel microphone, it was +28 dB. In the second classroom, the S/N were +13 dB, +9 dB, and +5 at the student locations and +22 dB at the lapel microphone. Technical difficulties prohibited completion of these measurements in the third classroom.

Data collection. The questionnaires to evaluate the FM system and personal hearing aid were identical to those in Experiment 1. The questionnaire about the loop was analogous to the others (see Appendix C). Students in each classroom used the loop, FM system, and their hearing aids for 2 weeks in counterbalanced order.

Results

Analyses of variance of mean responses to the questionnaires yielded no

Table 4

Students' Responses to Questions about Loudness and Ease of Use of Hearing Aids, FM, and Loop Systems

Amplification System	Rating Categories[a]				Mean Rating
	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)	
Teacher's Voice Loud Enough?					
Hearing Aid	0	2	16	2	3.0
FM	0	2	11	6	3.2
Loop	0	0	15	5	3.3
Easy to Use in Class?					
Hearing Aid	1	2	12	5	3.1
FM	1	3	13	2	2.8
Loop	0	1	14	5	3.2

[a]Entries are number of students who checked each rating category.

significant differences in the students' ratings of the three systems evaluated. Trends and comments of note follow.

Comparison of FM system, loop system, and hearing aids. Table 4 displays ratings of loudness of the teacher's voice and of ease in using the systems. These data show that most students did not perceive one system as more effective than another in amplifying the teacher's voice. We also see in Table 4 that most students did not perceive one system as easier to use in class than the others.

Students' ratings of difficulty in listening to classmates are shown in Table 5. The ratings were similar across all three systems.

Table 5

Students' Rating of Difficulty Listening to Classmates with Hearing Aids, FM, and Loop Systems

Amplification System	Rating Category[a]					Mean Rating
	No Problem (1)	(2)	Moderate Problem (3)	(4)	Big Problem (5)	
Hearing Aid	2	7	6	4	1	2.8
FM	3	4	7	3	2	2.8
Loop	2	5	7	5	1	2.9

[a]Entries are number of students who checked each rating category.

Table 6

Students' Rating of Ability to Hear/Understand Teacher and Classmates with Hearing Aids, FM, and Loop Systems

Amplification System	Rating Category[a]				Mean Rating
	Excellent (4)	Well (3)	Poorly (2)	Very Poorly (1)	
	How well hear/understand teacher?				
Hearing Aid	4	14	1	1	3.1
FM	6	8	5	0	3.1
Loop	9	8	3	0	3.3
	How well hear/understand other students?				
Hearing Aid	0	8	11	1	2.4
FM	0	5	10	4	2.1
Loop	1	3	15	1	2.2

[a]Entries are number of students who checked each rating category.

Table 6 displays ratings of others' voices. As in Experiment 1, more students indicated they could "hear/understand" the teacher better than they could their classmates, regardless of system. Differences between systems were not apparent.

Monitoring of Voice. Thirteen out of 20 students using the loop system and 8 out of 19 using the FM systems reported *no problem* or only a small one in hearing their own voice.

Relative preference for hearing aid, FM, and loop systems. On the loop questionnaire, 11 students indicated preference for their hearing aids; nine preferred the loop system. On the FM questionnaire, 14 preferred their hearing aids; five preferred the FM system. Preferences for the FM and loop systems were compared using a Wilcoxon signed ranks test (Dixon, 1983, p. 437). Students favored the loop system over the FM system at a marginal level of significance, $p = .059$. When asked if they would use the system again in the following quarter, there was somewhat more willingness to use the loop system than the FM system. For the loop system, eight marked *yes;* nine, *maybe;* and three, *no.* For the FM system, five marked *yes;* six, *maybe;* and seven, *no.* However, these distributions were not significantly different from each other. As was the case in Experiment 1, we saw a general preference for hearing aids, but with some students favoring the classroom amplification system.

EXPERIMENT 3

In the course of the first two experiments it was apparent that the students' major difficulty was communicating with each other. In Experiment 3 a new system (VOX) was designed to facilitate communication between students as well as self-monitoring. It was compared with the loop system from Experiment 2 and personal hearing aids.

Method

Subjects. Subjects were six male and seven female NTID students 19 to 25 years of age who had not participated in Experiments 1 or 2. Their mean pure tone average (500, 1000, 2000 Hz) for the better ear was 87 dB HL (range: 62-105 dB HL, ANSI, 1969). Their mean grade equivalent score on the California Reading Test was 9.0 (range: 6.5-10.7). Again, as in Experiments 1 and 2, students' receptive communication skills ranged from poor to excellent. Students were enrolled in one of three classes with a male or female instructor. Two classes met in the same room and were taught by the same teacher.

Apparatus. The conventional loop system was set up as in the second experiment. The VOX system added to this a JBL automatic microphone mixer, model 7510A, and four floor-model voice-actuated microphones. This required each student to be no more than 6 in. from a microphone in order to be heard clearly through the loop system.

Classroom Noise. Connected speech and noise measurements were per-

formed as in Experiments 1 and 2. In the first classroom, the S/N for the three student locations were +11.5 dB, +15.5 dB, and +22 dB; at the lapel microphone it was +31.5 dB. Technical difficulties prohibited completion of these measurements in the second classroom.

Data Collection. The questionnaires were identical to those used in Experiment 2 for hearing aids and loop systems (see Appendix C). For 2 weeks each, students used the loop, VOX system, and hearing aids in counterbalanced order, completing questionnaires after each interval.

Results

Comparison of loop and VOX systems and hearing aids. Table 7 presents responses pertaining to loudness of teacher's voice and ease in using the systems. The distribution of responses indicates that most students did not perceive the teacher's voice as being louder with one system than with the others. This is consistent with findings of Experiment 2. Table 7 also indicates that more students perceived their hearing aids as easier to use in class than they did the loop or VOX systems. This result is similar to that for the same question in Experiment 1. (Statistical analysis was not attempted because some questionnaires were incomplete, reducing the N to less than 10.)

Table 7

Students' Responses to Questions about Loudness and Ease of Use of Hearing Aid, VOX, and Loop Systems

Amplification System	Rating Category[a]				Mean Rating
	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)	
	Teacher's Voice Loud Enough?				
Hearing Aid	0	1	5	6	3.4
VOX	1	1	5	3	3.0
Loop	0	0	7	4	3.4
	Easy to Use in Class?				
Hearing Aid	0	0	3	8	3.7
VOX	0	4	4	2	2.8
Loop	0	3	8	0	2.8

[a]Entries are number of students who checked each rating category.

Students' ratings of student-to-student communication are displayed in Table 8. As was the case in Experiment 1, fewer students indicated problems listening to classmates with their hearing aids than they did with the other systems.

Table 8

Students' Rating of Difficulty Listening to Classmates with Hearing Aids, FM, and Loop Systems

Amplification System	Rating Category[a]					Mean Rating
	No Problem (1)	(2)	Moderate Problem (3)	(4)	Big Problem (5)	
Hearing Aid	5	4	2	1	1	2.2
VOX	0	4	4	1	1	2.9
Loop	2	1	3	0	4	3.3

[a]Entries are number of students who checked each rating category.

Table 9

Students' Rating of Ability to Hear/Understand Teacher and Classmates with Hearing Aids, VOX, and Loop Systems

Amplification System	Rating Category[a]				Mean Rating
	Excellent (4)	Well (3)	Poorly (2)	Very Poorly (1)	
	How well hear/understand teacher?				
Hearing Aid	8	3	1	0	3.6
VOX	6	4	0	0	3.6
Loop	4	6	1	0	3.3
	How well hear/understand other students?				
Hearing Aid	2	7	3	0	2.9
VOX	2	3	4	0	2.8
Loop	1	6	3	0	2.8

[a]Entries are number of students who checked each rating category.

Table 9 presents data on reported ability to "hear/understand" teacher and classmates. Once again most students could "hear/understand" their teacher better than fellow classmates.

Monitoring of voice. When asked about monitoring their own voice, 8 out of 13 students using the VOX and 9 out of 11 using the loop reported a *moderate* to *big* problem.

Relative preference for hearing aids, VOX and loop. There was a clear preference for hearing aids over a loop system. In comparing the loop system to hearing aids, seven students preferred their aids and two preferred the loop system. In considering the VOX system, seven preferred their aids and three preferred the VOX system. When asked if they would use the VOX or loop

systems again, the most frequent response was *maybe*. For the loop system, there were two *yes*, five *maybe*, and four *no* responses; for the VOX system, there were two *yes*, six *maybe*, and one *no* responses.

DISCUSSION

In all three experiments more students preferred their personal hearing aids than any of the other amplification systems. In Experiments 1 and 3, more students rated their own aids as easier to use and better for hearing their classmates. This preference for hearing aids is consistent with the findings of Calvert (1964) who found that instructors rated hearing aids more favorably than other amplification systems. This preference for personal hearing aids may have been influenced by several factors: (a) the status of students' telecoils was not determined electro-acoustically; (b) classroom amplification systems were not fit individually; and (c) time was not allotted for familiarization with the different systems selected. Another area that warrants further investigation is the effect of different FM receiver controls on the amplified signal when the FM unit is used in conjunction with hearing aids.

There was somewhat greater preference for the loop than for the FM system. In Experiment 2 more students preferred the loop than the FM system when asked to compare each of these with their hearing aids. One factor that could account for this result is that the loop system requires fewer changes from normal classroom functioning as students do not use any additional equipment.

It is interesting that, in all three experiments, more students rated the teacher as easier to "hear/understand" than their classmates under any condition. Students may have been rating simultaneous communication when answering these questions and, thus, the teacher's better positioning and conscious effort to sign and speak clearly. Nevertheless, the potential benefits of amplification in facilitating students' understanding of classmates should continue to be explored even though the results of these experiments suggest that current systems are inadequate. Follow-up interviews with 22 students included a question about the effectiveness of the environmental microphone during FM system use. Students who used this option still experienced difficulty in monitoring classmates and themselves. Representative comments included:

1. "I would use the device if they could find a way to improve the device such that I could pick up the class questions and so forth."
2. "I will use my own hearing aid because I will hear the student's voice and the teacher's voice."
3. I couldn't hear myself talk so I don't know if I'm talking loud or not.... and couldn't hear the classmates."
4. "Other students were very soft and couldn't hear my voice."

One problem was that the environmental microphones were body-borne

rather ear level, producing undesirable clothing noise and altered frequency response caused by body baffle. A study by Ross and Giolas (1971) found that using a binaural auditory trainer as a body-borne hearing aid decreased auditory discrimination ability of hearing-impaired subjects in comparison to their functioning in their usual listening condition, whether that was aided or unaided. Three students in the present study reported they were bothered by background noises picked up by the environmental microphone and complained they could not hear as well as in the FM-only mode. This observation is consistent with the findings of Hawkins (1984) which showed detrimental effects of activating an environmental microphone when using an FM system, thereby losing the improved S/N in the FM-only mode. It also supports the results of Hawkins and Schum (1985), which showed that microphone distance (FM or environmental) must be considered when determining signal strength. Therefore, the decision to "boost" the FM signal above the environmental microphone signal, based on Van Tassel and Landin's (1980) study, was not necessary. However, the present investigation had already been completed prior to the publication of the Hawkins and Schum data.

Problems were encountered with listening to classmates when using loop systems also. The loop system had one hard-wired student microphone that could be passed around, but this was quickly found to be too cumbersome in most situations, so the student microphone was either taped to a desk in a central location or not used at all. One student stated that, although the loop system permitted him to hear the teacher more clearly, he preferred to use his hearing aid alone because he could not hear other students with his hearing aid on T. Two other students attempted to facilitate hearing classmates by switching thier hearing aids from T to M during classroom discussion.

A major goal in implementing classroom amplification systems is to improve S/N to at least +15-20 dB (Gengel, 1971). This goal was achieved in all instances at the teacher microphone. At the student positions S/N was less than ideal for 16 of 18 measurements, representing the listening condition students would face using only their hearing aids. The acceptable S/Ns at two student positions were obtained in a classroom acoustically treated against noise and reverberation. The worse S/N of +11.5 dB at a student position was for a seat under a ventilation fan. The benefit of a teacher microphone for improving signal level was clearly demonstrated in these three experiments.

An FM "Duplex" system was (informally) attempted in an effort to allow both student-to-student communication and self-monitoring capability with the same improved S/N as when listening to the instructor. There was a traditional wireless FM system with a transmitter for the instructor and a compatible frequency receiver for each student. In addition, every student had an FM transmitter, each on a different frequency with spacing of 100 kHz. The signals from all the transmitters were mixed (in a receiver "bank") and sent back to the student receivers on a master frequency (which matched the frequency of the student receivers). It was not successful because of certain tech-

nical problems. For example, because the transmission frequencies were closely spaced, unacceptable levels of harmonic distortion occurred. Also, due to the number of antennae involved to connect the receivers to the mixer in the receiver bank, the system picked up outside signals (e.g., a neighboring 1000-watt radio station).

Unfortunately the VOX system was also unsuccessful at facilitating students' monitoring of self and classmates. It was rated as poorer than personal hearing aids for listening to classmates even though, in theory, voice-actuated student microphones should have alleviated the problem of student-to-student communication. Sharing still created difficulties. Also, mobility was restricted because students had to remain close to the microphones in order for the voice to activate the circuit. Representative comments from students included:

1. "I couldn't hear what the other students were saying."
2. "[It] needs a bigger microphone so things can be heard all over the room."
3. "I wish I could hear my voice and student voices too."

Although there was a general preference for personal hearing aids in all three experiments, a substantial minority of students did prefer the classroom amplification systems to hearing aids. This suggests that preference for amplification system may be related to students' preferred communication modality. Those who depend heavily upon audition and speechreading with sound are probably more likely to rate a classroom amplification system favorably than those who depend less on speech for communication. These relationships need further investigation. Also, given the importance of hearing self and classmates, classroom amplification must solve the dilemma of transmitting *all* participants' speech while still maintaining a desirable S/N.

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REFERENCES

American National Standard Specifications for Audiometers (ANSI S3.6-1969). (1970). New York: American National Standards Institute.

Bishop, M.E., Christopolus, T., & Nielson, M.A. (1972). A study of amplification systems used in schools for the deaf. *Volta Review, 74,* 111-121.

Blair, J.C. (1977). Effects of amplification, speechreading and classroom environments on reception of speech. *Volta Review, 79,* 443-449.

Calvert, D.R. (1964). A comparison of auditory amplifiers in the classroom in a school for the deaf. *Volta Review, 66,* 544-547.

Dixon, W.J. (Ed.). (1983). *BMDP statistical software.* Berkeley, CA: University of California Press.

Erber, N.P. (1971). Auditory and audiovisual reception of words in low-frequency noise by children with normal hearing and by children with impaired hearing. *Journal of Speech and Hearing Research, 14,* 496-512.

Freeman, B.A., Sinclair, J.S., & Riggs, D.E. (1981). Classroom amplification: Consideration for system selection. *Hearing Instruments, 32*(6), 16, 18, 23.

Gengel, R.W. (1971). Acceptable speech-to-noise ratios for aided speech discrimination by the hearing-impaired. *Journal of Auditory Research, 11,* 219-222.

Hawkins, D.B. (1984). Comparisons of speech recognition in noise by mildly-to-moderately hearing-impaired children using hearing aids and FM systems. *Journal of Speech and Hearing Disorders, 49,* 409-418.

Hawkins, D.B., & Schum, D.J. (1985). Some effects of FM-system coupling on hearing aid characteristics. *Journal of Speech and Hearing Disorders, 50,* 132-141.

Kirk, R.E. (1968). *Experimental design: Procedures for the behavioral sciences.* Belmont, CA: Brooks/Cole.

Markides, A., Huntington, A., & Kettlety, A. (1980). Comparative speech discrimination abilities of hearing-impaired children achieved through infrared, radio and conventional hearing aids. *Teacher of the Deaf, 4*(1), 5-14.

Niemoeller, A.F. (1968). Acoustical design of classrooms for the deaf. *American Annals of the Deaf, 113,* 1040-1045.

Ross, M., & Giolas, T. (1971). Effect of three classroom listening conditions on speech intelligibility. *American Annals of the Deaf, 116,* 580-584.

Ross, M. (1973). Considerations underlying the selection of classroom amplification systems. *Journal of the Academy of Rehabilitative Audiology, 6,* 33-42.

Webster, J.C., & Snell, K.B. (1983). Noise levels and the speech intelligibility of teachers in classrooms. *Journal of the Academy of Rehabilitative Audiology, 16,* 234-255.

Van Tassel, D.J., & Landin, D.P. (1980). Frequency response characteristics of FM mini-loop auditory trainers. *Journal of Speech and Hearing Disorders, 25,* 247-258.

APPENDIX A

FM EVALUATION QUESTIONNAIRE FOR STUDENTS

1. What is the make and model of the hearing aid you used with the FM system? (Example: Oticon E22P)
2. Was the "T" switch on your hearing aid working well?
   YES NO
   Explain if NO:
3. The teacher's voice was loud enough. Circle one.
   strongly agree agree disagree strongly disagree
4. How well did you hear/understand the teacher? Circle one.
   excellent well poorly very poorly
5. How well did you hear/understand other students in class? Circle one.
   excellent well poorly very poorly

6. This FM system was easy to use. Circle one.

   strongly agree agree disagree strongly disagree

7. Did these things bother you when you used the FM system? Circle one number on the line.

   a. Size

no problem		moderate problem		big problem
1	2	3	4	5

   b. Cords

no problem		moderate problem		big problem
1	2	3	4	5

   c. Listening to classmates

no problem		moderate problem		big problem
1	2	3	4	5

   d. Listening to your own voice

no problem		moderate problem		big problem
1	2	3	4	5

   e. Appearance

no problem		moderate problem		big problem
1	2	3	4	5

   f. Do you have any other problems? YES NO

   What is your problem? _____

no problem		moderate problem		big problem
1	2	3	4	5

8. Would you use this system again next quarter? Circle one.

   yes maybe no

   Explain: _____

9. Which do you prefer to use? Check one.

   ___ My own hearing aid by itself

   ___ FM system

10. Comments:

APPENDIX B

HEARING AID EVALUATION QUESTIONNAIRE FOR STUDENTS

1. What is the make and model of the hearing aid you used in class? (Example: Oticon E22P)
2. Was your hearing aid working well? YES NO

   Explain if NO: _____

3. The teacher's voice was loud enough. Circle one.
   strongly agree agree disagree strongly disagree
4. How well did you hear/understand the teacher? Circle one.
   excellent well poorly very poorly
5. How well did you hear/understand other students in class? Circle one.
   excellent well poorly very poorly
6. My hearing aid is easy to use in class. Circle one.
   strongly agree agree disagree strongly disagree
7. Do these things bother you when you use your hearing aid in class? Circle one number on the line.
   a. Hearing background noises

no problem		moderate problem		big problem
1	2	3	4	5

   b. Listening to classmates

no problem		moderate problem		big problem
1	2	3	4	5

8. Comments:

APPENDIX C

LOOP EVALUATION QUESTIONNAIRE FOR STUDENTS

1. What is the make and model of the hearing aid you used with the FM system? (Example: Oticon E22P)
2. Was the "T" switch on your hearing aid working well? YES NO
   Explain if NO:
3. The teacher's voice was loud enough. Circle one.
   strongly agree agree disagree strongly disagree
4. How well did you hear/understand the teacher? Circle one.
   excellent well poorly very poorly
5. How well did you hear/understand other students in class? Circle one.
   excellent well poorly very poorly
6. This loop was easy to use. Circle one.
   strongly agree agree disagree strongly disagree
7. Did these things bother you when you used the loop? Circle one number on the line.
   a. "Dead Spots" (there are some places in the room where you can't hear)

no problem		moderate problem		big problem
1	2	3	4	5

   b. Listening to classmates

no problem		moderate problem		big problem
1	2	3	4	5

c. Listening to your own voice

no problem		moderate problem		big problem
1	2	3	4	5

d. Do you have any other problems? YES NO

What is your problem? _____

no problem		moderate problem		big problem
1	2	3	4	5

8. Would you use this system again next quarter? Circle one.

yes maybe no

Explain:

9. Which do you prefer to use? Check one.

___ My own hearing aid by itself

___ Loop

10. Comments: