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Comparison of FM Auditory Trainers, CROS Aids, and Personal Amplification in Unilaterally Hearing Impaired Children

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Abstract

The effectiveness of FM auditory trainers, conventional hearing aids, and CROS aids in six children with varying degrees of unilateral hearing loss was compared. Word recognition unaided and with each of the forms of amplification was evaluated both in quiet and in noise in a classroom. With the conventional hearing aid and CROS aid fittings, word recognition actually decreased in noise. With the FM trainer, word recognition improved significantly in both quiet and noise. All six unilaterally hearing impaired (UHI) children experienced significantly better performance with the FM trainer. The children with the most loss derived the greatest benefit.

Key Words: Auditory discrimination, children, CROS amplification, FM auditory trainers, unilateral hearing loss

Of every 1000 school-aged children, as many as 3 may have a unilateral sensorineural hearing loss. Until recently, many physicians, audiologists, and special educators believed that a unilateral hearing loss would have little impact on a child's speech-language development and would cause no academic problems.

Giolas and Wark (1967) reported that unilaterally hearing impaired adults have difficulty understanding speech under both quiet and noisy conditions, regardless of the location of the sound source. Children with unilateral hearing loss also encounter similar listening problems in a background of noise, particularly within a classroom (Oyler et al, 1987). Such listening difficulties could lead to problems in maintaining attention and difficulty in following classroom instructions and discussions. Indeed, recent research does suggest that unilaterally hearing impaired (UHI) children may be at significant risk for academic failure. Bess and Tharpe (1986) examined the medical and educational status and auditory skills of children with unilateral hearing loss. They found that one third of the UHI children had failed at least one grade, and almost 50 percent of the UHI children had either failed a grade and/or needed resource assistance in the schools. Twenty percent of the children were described by their teachers as having some behavioral problems.

To date, the primary educational recommendation for UHI children is preferential classroom seating and possible use of a CROS hearing aid. However, many teachers move about the classroom during instruction and subsequently the child with preferential seating will not enjoy a favorable listening situation. Furthermore, Bess et al (1986) observed that many children do not benefit from the use of CROS amplification. These authors suggested the trial use of an FM system as an alternative management approach for the UHI child who is having difficulty with communication and/or school. They presented two case studies wherein they fitted two children with FM trainers and had the teachers and parents evaluate the children's behavior. They noted that the use of the FM system provided a significant benefit in the classroom setting.

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Kenworthy et al (1990) investigated the effectiveness of CROS amplification and FM systems upon the speech recognition ability of children with unilateral hearing loss. They observed that the FM system was the only system to produce consistently high speech recognition scores across all listening conditions, but only with children who had severe-to-profound unilateral hearing loss. These authors did note, however, that generalization of the conclusions was limited, due to the experimental nature of their test setting (they used speech recorded via a KEMAR manikin). They recommended the initiation of a field study conducted with UHI children within the context of a real classroom. Furthermore, they suggested further evaluation of FM systems, CROS amplification, and the use of conventional hearing aids with children having varying degrees of unilateral hearing loss.

The purpose of the present study was to evaluate the relative effectiveness of conventional hearing aids, CROS hearing aids, and FM auditory trainers on the word recognition ability of UHI children with varying degrees of hearing loss within a classroom situation.

METHOD

Subjects

Six children (three females, three males), aged 5 years, 10 months to 12 years, 11 months, served as subjects. Each child had normal hearing in one ear (defined as hearing threshold levels no poorer than 25 dB HL at the octave frequencies from 250 to 4000 Hz). Each child also had a sensorineural hearing loss in one ear, defined as at least three hearing threshold levels worse than 25 dB HL. All children had normal tympanograms on the day of testing to rule out conductive overlay.

There were one mild, one moderate, one moderately severe, one severe, and two profound UHI children (Table 1). Four subjects were performing at grade level in school, although two were reported by their teachers as having behavior difficulties. The remaining two were repeating a grade.

Equipment

Eight versions of the Goldman-Fristoe-Woodcock Test of Auditory Discrimination (GFWTAD) were devised so that word recognition ability under eight different listening conditions could be evaluated.

The GFWTAD was designed to evaluate speech and sound discrimination ability for children as young as 4 years of age. The test words were chosen on the basis of high familiarity and meaningfulness to young children. The test has two subtests: a quiet subtest, which provides a measure of auditory discrimination in the absence of background noise, and a noise subtest, which evaluates auditory discrimination in the presence of distracting background noise. There are separate norms for each subtest from ages 3 years, 8 months to 70+ years. The GFWTAD includes a set of training plates and test plates and a cassette tape with the prerecorded test stimuli. Each plate contains four line drawings. The four words pictured on each test plate are similar in sound except for a single phoneme. During the test, the subject is asked to point to the picture representing the stimulus word. The revised test forms used in this study consisted of the same 25 items, with the same contrasts but in different orders as the original GFWTAD quiet subtest. To determine the test item order in each revised list, the words were randomly selected. These lists were tape recorded by a female speaker, on separate tapes for ease of administration, using a Technics RS-T11 tape recorder interfaced with a Beltone 2000 clinical audiometer microphone.

The Telex TDR-7 FM auditory trainer with circumaural earphones was used to evaluate word recognition ability in quiet and in noise.

Table 1 Description of Subjects

Subject	*Age*	*Gender*	*Poorer Ear*	*PTA of Poorer Ear (dB)*	*PTA of Better Ear (dB)*
1	8 – 11	Female	Right	37	5
2	6 – 0	Male	Left	42	3
3	12 – 11	Female	Left	63	0
4	5 – 10	Female	Left	85	0
5	12 – 10	Male	Right	110+	20
6	5 – 11	Male	Left	110+	7

The Telex 334 (CROS) hearing aid was used to evaluate word recognition in noise and in quiet using a CROS hearing aid.

The study was conducted in a regular classroom at Ball State University. The intrinsic noise level of the room was 24.8 dBA as measured by a sound level meter. Three tape recorders were arranged around the subject: one in front and one on either side. Two Panasonic RQ-2739 tape recorders, which presented the speech noise, were located equidistant from the subject, who sat in the center of the classroom. The Marantz PMD 430 tape recorder presenting the test stimuli was located in the center of the front of the classroom, 15 feet from the subject. The volume controls on each tape recorder were adjusted so that 71 dB SPL speech noise and 77 dB SPL speech arrived at the subject's location, creating a +6 dB S/N. Sanders (1971) found that this signal-to-noise ratio closely approximates the typical classroom acoustic set-up.

Procedure

There were two background listening situations: quiet and noise (+6 dB S/N). There were four amplification conditions: unaided, aided with a conventional hearing aid, CROS amplification, and an FM auditory trainer with circumaural earphone. This created a total of eight experimental conditions for each subject. The electroacoustic characteristics of each of the amplification systems were adjusted to meet the individual subject's needs (Table 2).

Presentation of the eight stimulus tapes was randomized independently for each child. Each child was instructed to listen to the taped speech and then to point to the appropriate picture from a set of four.

Table 2 Electroacoustic Characteristics of the Various Amplification Devices Fitted to Each Subject

Subject	*Ear*	*Hearing Aid*	*CROS Aid (Telex 340)**	*FM Trainer (Telex TDR-7)*
1	Right	Unitron UM 60 HF Gain: 32 dB HF SSPL: 105 dB	Microphone	Gain: 1 Tone: 1 SPL: 3
	Left	None	Receiver	Gain: 1 Tone: 1 SPL: 3
2	Right	None	Receiver	Gain: 1 Tone: 1 SPL: 3
	Left	Unitron UM 60 HF Gain: 50 dB HF SSPL: 118 dB	Microphone	Gain: 1 Tone: 5 SPL: 5
3	Right	None	Receiver	Gain: 1 Tone: 1 SPL: 3
	Left	Unitron UM 60PP HF Gain: 57 dB HF SSPL: 105 dB	Microphone	Gain: 2 Tone: 6 SPL: 5
4	Right	None	Receiver	Gain: 1 Tone: 1 SPL: 3
	Left	Unitron UM 60PP HF Gain: 60 dB HF SSPL: 127 dB	Microphone	Gain: 4 Tone: 8 SPL: 8
5	Right Left	None None	Receiver Microphone	Gain: 1 Tone: 1 SPL: 3
6	Right Left	None None	Receiver Microphone	Gain: 1 Tone: 1 SPL: 3

* HF gain: 37 dB; HF SSPL: 105 dB.

RESULTS

Data Analysis

Table 3 shows the word recognition scores of the six subjects for the various test conditions. The unaided speech recognition scores were sometimes better than the scores obtained with either the hearing aid or CROS amplification, especially in the noise condition. Conversely, there was usually a marked improvement in word recognition ability when the FM auditory trainer was fitted. An analysis of the improvement in word recognition scores made by individual subjects was conducted using the Raffin and Thornton (1980) model.

Individual Analyses

Case 1

This 8-year-old female had only a mild loss (37 dB) in the right ear. She showed about the same word recognition ability in quiet but much less difficulty in noise than the children with severe and profound unilateral hearing loss. This result could perhaps be predicted, since the mild UHI child has the binaural advantage and should therefore be better able to cope under adverse listening conditions.

It appears that this mild UHI child did not experience any significant decrease in word recognition ability when noise was present (Fig. 1, Table 3). However, when she was fitted with a conventional hearing aid, a CROS aid, and the FM trainer, her performance was significantly improved in quiet (Table 4). Her word recognition in noise also improved significantly when the FM trainer was fitted, but there was no improvement in noise with the hearing aid and CROS aid. For the mild UHI child, then, the fitting of the FM auditory trainer yielded the best overall advantage in both quiet and noise. While the conventional hearing aid and CROS aid fitting did help improve word recognition in quiet, there was no significant gain in noise.

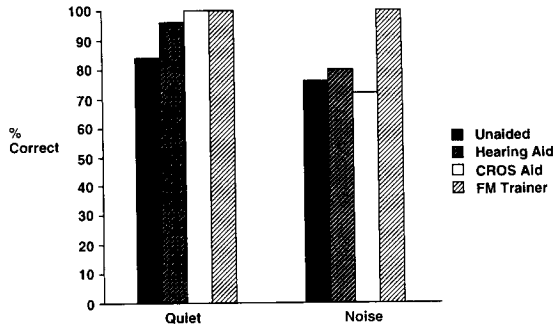

Figure 1 Mild UHI child's word recognition scores in the various listening conditions (case 1).

Case 2

This 6-year-old male had a moderate (42 dB) loss in the left ear. He showed significantly greater difficulty in word recognition when noise was added ($p < .01$, Tables 3 and 4). The fitting of amplification of any type yielded no significant improvement in scores in quiet (Fig. 2). There were significant differences in performance in noise when the CROS aid and the conventional hearing aid were fitted; unfortunately, rather than an improvement in scores, as expected, there were significant decreases ($p < .01$) with both types of amplification. The fitting of the FM auditory trainer effected a significant improvement in word recognition, especially in noise ($p < .01$).

Case 3

This 12-year-old female had a moderately severe loss (63 dB) in the left ear. She experienced significant difficulty in word recognition

Table 3 Comparison of Word Recognition Scores in Unaided and Aided CROS Amplification and FM Auditory Trainer Conditions

	Unaided		*Aided*		*CROS Aid*		*FM Auditory Trainer*	
Subject	*Q*	*N*	*Q*	*N*	*Q*	*N*	*Q*	*N*
1	84	76	96	80	100	72	100	100
2	88	20	24	0	80	4	88	88
3	80	20	32	8	40	16	80	76
4	42	20	64	28	60	24	80	72
5	88	56	CNT	CNT	76	32	100	100
6	72	42	CNT	CNT	60	44	96	88

Q = quiet; N = noise; CNT = could not test.

Table 4 Amount of Improvement in Word Recognition (%) with the Various Types of Amplification Relative to Unaided Listening

	Quiet			Noise		
Subjects	HA	CROS	FM	HA	CROS	FM
1	12	16*	16*	4	–4	24*
2	64*	8	0	–20*	–16*	68*
3	–48*	–40*	0	–12	–4	56*
4	22*	18	38*	8	4	52*
5	CNT	–12	12	CNT	–24*	44*
6	CNT	–12	24*	CNT	2	46*

HA = conventional hearing aid; CROS = contralateral routing of signal amplification; FM = FM auditory trainer; CNT = could not test.

* $p < .01$.

in noise as compared to a quiet background (a 60% decrease, $p < .01$, Table 4). The fitting of amplification of any nature did not yield significant improvement in word recognition in quiet (Fig. 3). In fact, for the CROS aid, it produced a 40 percent decrease in scores ($p < .01$), and for the hearing aid fitting, it resulted in a 48 percent decrease in scores ($p < .01$). The same trend toward decrease in performance was evident in noise with both the CROS aid and conventional hearing aid. However, when the FM trainer was fitted, there was a significant gain in word recognition of about 60 percent ($p < .01$). For the moderately severe UHI child, then, the FM auditory trainer provided significant benefit in noise while the hearing aid and CROS aid did not help and, indeed, were detrimental to performance.

Case 4

This 5-year-old female had a severe-to-profound loss (85 dB) in the left ear. She experienced significantly more difficulty discriminating speech in noise than in quiet ($p < .01$, Tables 3 and 4). The fitting of the hearing aid and CROS amplification did not significantly improve the word recognition scores in quiet (Fig. 4). The fitting of the FM auditory trainer did, however, improve performance significantly (38% increase, $p < .01$). The conventional hearing aid and CROS fitting did not improve word recognition ability in noise; however, there was a significant increase in scores in noise with the FM auditory trainer (approximately 52% increase, $p < .01$). For the severe to profoundly UHI child, then, the FM trainer provided a significant advantage in word recognition in both quiet and noise, while the hearing aid and CROS aid provided no significant benefit.

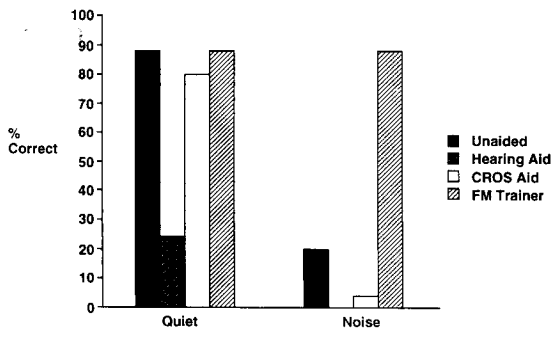

Figure 2 Moderate UHI child's word recognition scores in the various listening conditions (case 2).

Cases 5 and 6

These two profoundly UHI children experienced a significant decrease in word recognition scores in noise versus quiet (about a 32% decrease, $p < .01$). Neither child could be fitted with a hearing aid, due to the severity of the hearing losses. The CROS aid was fitted but yielded no significant benefit to either child (Figs. 5 and 6). Indeed, the word recognition scores in quiet and noise for both children decreased when the CROS aid was worn. The use of the FM auditory trainer, however, yielded favorable results for both children in both quiet and noisy backgrounds. For case 5, there was approximately a 12 percent increase in quiet and a 44 percent increase in noise ($p < .01$). For case 6, there was about a 24 percent increase in quiet and a 50 percent increase in word recognition ability in noise ($p < .01$). For both of the profoundly UHI children, then, the FM auditory trainer significantly improved performance in quiet and in noise, while the CROS aid did not help and, indeed, was a hindrance for word recognition.

DISCUSSION

The results of this study suggest that UHI children with varying degrees of involvement all experience significant difficulty in word recognition in a typical classroom environment. These results agree with those of Bess et al (1986b). Furthermore, neither the fitting of a conventional hearing aid to the impaired ear nor the use of CROS amplification enhances speech understanding. In fact, they appear to have detrimental effects, particularly in a noisy environment.

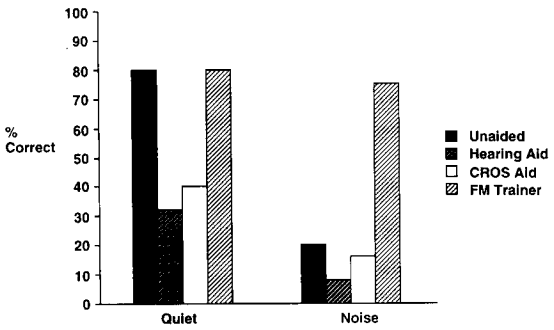

Figure 3 Moderately severe UHI child's word recognition scores in the various listening conditions (case 3).

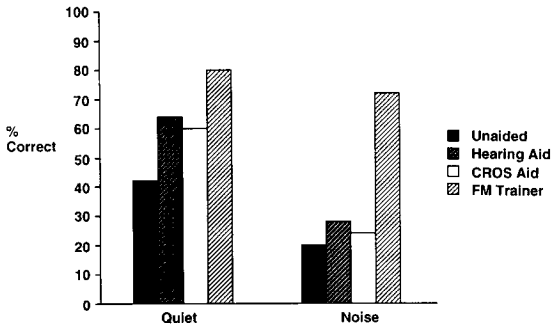

Figure 4 Severe-to-profound UHI child's word recognition scores in the various listening conditions (case 4).

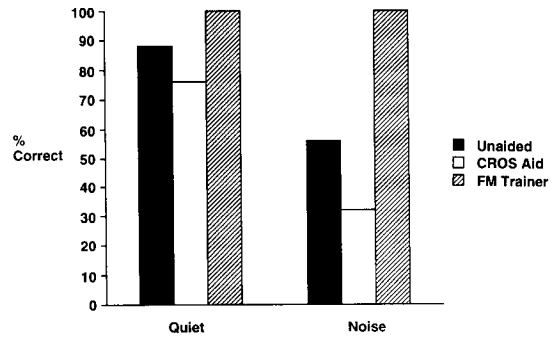

Figure 5 First profound UHI child's word recognition scores in the various listening conditions (case 5).

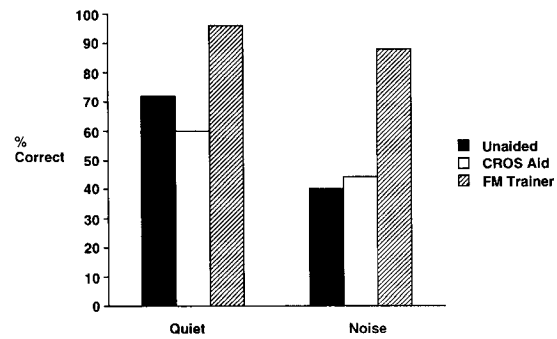

Figure 6 Second profound UHI child's word recognition scores in the various listening conditions (case 6).

The fitting of an FM auditory trainer, however, does improve word recognition for this population, particularly in background noise. The degree of improvement in word recognition appears to depend upon the degree of involvement in the impaired ear. The more severely involved UHI children derive the greatest benefit from the FM auditory trainers. In this study, even the mild UHI child experienced a significant improvement in word recognition when she was fitted with the FM auditory trainer. These findings were not observed with the mild UHI child in the Kenworthy et al (1990) study. The discrepancy in observations may be due to the different test materials used in each study.

The findings of this pilot study suggest that an FM system should be considered seriously for children with varying degrees of unilateral hearing loss who may be experiencing some academic or attending problems in a classroom situation.

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