Preferred FM System Listening Levels of Children With Central Auditory Processing Disorders

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The use of FM systems as a form of classroom management for children with central auditory processing disorders and normal peripheral hearing was investigated by describing everyday FM usage patterns. The preferred listening levels for the 7 subjects were recorded. The amount of gain provided by the FM systems was measured using real ear insertion gain procedures. A wide range of preferred listening levels was evident, with a similarly wide range of peak gain measures being recorded. FM systems for children with central auditory processing disorders should be checked using real ear measures with each individual child and preset to ensure that appropriate amplification is delivered.

Deficiency in auditory processing skills has been given a number of terms including central auditory dysfunction, central dysacusis, central auditory processing disorder, language-learning disorder, and auditory processing problem (Gerber & Mencher, 1980; Keith, 1981; Musiek & Chermak, 1994). The variety of terms used and the vague definitions presented are indicative of the general lack of knowledge about such problems. Sloan (1991) reflects a widespread consen-

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sus in defining central auditory processing problems as involving "a difficulty in processing the acoustic speech signal that interferes with accurate and efficient perception of speech" (p. 35). These difficulties are often more apparent in poor acoustic environments, especially when language becomes more complex and less familiar, and the task becomes more challenging. Children with central auditory processing disorders (CAPDs), however, are routinely expected to learn under less than favorable acoustic conditions such as the "open classroom" (Willeford, 1980).

Treatment and management options for children with CAPD are limited. A common management approach is to counsel the child, parent, and teacher in how to modify the auditory and visual environments by reducing background noise, increasing the intensity and clarity of the primary signal, and maximizing the nonauditory cues. In the classroom, this may be done by preferential seating, using visual stimuli to supplement oral instructions, repeating and rephrasing instructions, checking the child's understanding, pretutoring, and presenting information in small segments. In addition, some authors have suggested the use of amplification devices such as frequency-modulated (FM) systems which provide a more favorable signal-to-noise (S/N) ratio in the classroom environment (ASHA, 1991; Pfeffer, 1992; Stach, Loiselle, Jerger, Mintz, & Taylor, 1987). Usually, these devices are designed to improve the S/N ratio of the teacher's voice in relation to background noise in the student's classroom. Kopun (1991) recommends that the FM system not be designed to amplify the teacher's voice, but to simply transmit it to the student at the same level as it has been received by the transmitter microphone. This is known as a "unity gain" or a "transparent" fitting.

As yet there has been limited research regarding the efficacy of fitting amplification devices, such as FM systems, to children with indications of CAPD and normal peripheral hearing. The optimal S/N ratio to be targeted (mainly determined by the transmitter microphone electroacoustic characteristics and microphone placement) has not yet been determined for children with CAPD. A typical FM system can provide an S/N ratio of approximately +20 dB (Hawkins, 1984). In addition, there have been no quantitative analyses of the actual gain provided by FM systems, and the preferred listening levels of such systems, when fitted to this group of children. This study was undertaken to monitor the preferred listening levels of FM systems fitted to children with CAPD and to provide information on the real ear gain associated with a system fitted to members of this group.

METHOD

Subjects

Seven subjects aged 8 to 13 years (mean = 10 years) were included in the study. Of the 7, there were 5 male and 2 female subjects. Six subjects attended different elementary schools and one attended a secondary college. The children were diagnosed as having indications of CAPD after testing at the University of Queensland Audiology Clinic. All children were given an audiological test battery, including tests of peripheral hearing, immittance audiometry, the Goldman-Fristoe-Woodcock Auditory Skills Test Battery (GFW), Synthetic Sentence Identification (SSI), and the Staggered Spondee Word Test (SSW). For children to be included in the CAPD study group they needed to (a) have normal pure tone audiometry and immittance results; (b) a history of observed educational difficulties over at least a 2-year period; and (c) show poor results on one or more of the GFW, SSI, and SSW tests. In particular, all children scored below the 20th percentile on the GFW Selective Attention subtest. In view of the high test-retest variability associated with this subtest (Baran & Gengel, 1984), the subtest was repeated on two occasions at least 2 weeks apart. Subjects were required to show poor results at both test and retest.

Materials

The children included in the study were all motivated to try FM units which were initially loaned for a 3-month period, after which the FM units could be purchased. All children in this study had been wearing the FM systems, with parental support, for a period of at least 2 months. The FM system fitted comprised a Toa (WM-320) transmitter and monaural receiver unit. All fittings were monaural, using a simple non-custom ear tip attached to the receiver transducer unit. The frequency response as measured by the manufacturer was essentially flat (±3 dB between 70 Hz and 12000 Hz). The system response was linear except for high level signals when the MPO was limited to 115 dB SPL using an AGC output circuit. The sole user adjustable control was the combined volume/on-off control wheel. The system is typical of many such FM assistive devices that are designed to be used independently of personal hearing aids. The units were only worn at school and the main use was for language intensive classes such as English and mathematics. As part of the initial counselling of children, parents, and teachers, the children were told to wear the receiver with the volume at a level that was comfortable for them. Although the FM receiver volume control wheel was coded from *1* to *10* the children were counselled not to use a setting greater than 7. The transmitter lapel microphone was worn 20 cm from the mouth of the teacher.

Procedure

Preferred listening level real ear insertion gain measures were collected from each subject on two occasions during a 6-month study timeframe. The second measures were taken between 2 and 3 months after the first data set. On both occasions real ear measures were taken with each child's FM receiver volume control wheel at the setting it was noted to be on when the classroom visit was made.

Real ear gain was measured using a Rastronics portaREM-20 insertion gain system, version 4.0, in quiet interview rooms in the schools' administration buildings. Probe calibration was carried out before all testing at each school. Each subject's real ear insertion gain was calculated by subtracting the unaided from the aided SPL in the ear canal. The positioning of the FM system was the same as the method described by Hawkins (1987). The FM receiver was placed on the child and the FM microphone was positioned next to the reference microphone on the probe assembly. This placement allowed a flat input across all frequencies delivered to the FM microphone. A warble tone at 75 dB SPL was emitted from the speaker, as recommended by Lewis, Feigin, Karasek, and Stelmachowicz (1991), for the test range 10.5 kHz to 125 Hz. The FM system operated in a linear mode at this input level.

Audiometric monitoring of the subjects' pure tone thresholds took place on three occasions, before, during, and at the end of the study This was performed initially in a sound-treated test booth and later in the same environment as the real ear gain measurements. Thresholds were obtained at 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 6 kHz, and 8 kHz for both right and left ears with a portable audiometer calibrated to ANSI S3.6-1989 specifications. Audiometric monitoring was carried out to ensure that any significant threshold shift associated with amplification would be detected. During visits to each subject's school, sound level measures were also taken of the noise level associated with regular activities in the subjects' main classroom. This was conducted to enable comparison of the noise levels in the present study with published reports from other school systems. Readings were taken using the dB A scale three times at 2 min intervals on a slow meter setting, using a Rion Sound Level Meter (NA-23) calibrated to ANSI SI.4-1983 standards.

RESULTS AND DISCUSSION

The FM receiver volume wheel levels used by the subjects ranged from 4 to 10, with a mean setting of 6. Table 1 summarizes the preferred listening level findings for each subject on the two occasions measures were made. The mean real ear gain and the range of gain provided by the FM systems for selected frequencies in all subjects is shown in Figure 1. Frequency response graphs showing the preferred listening level real ear insertion gain for Subjects 1 and 2 are displayed in Figure 2 (a) and (b) respectively. The two subjects selected showed changes in preferred listening level over time that typically occurred in this sample of CAPD children.

The subjects in this study showed a wide range of preferred volume settings for their FM systems. Individual children also varied markedly in their preferred listening levels on different occasions. When following a consistent procedure, the test-retest measurement variability associated with insertion gain instrumentation and this type of assistive listening device is very likely to be small, with an in-

Table 1

Observed Peak Real Ear Insertion Measures at Preferred Listening Levels

Subject	Test occasion	Volume setting	Peak gain (dB SPL)	Peak frequency (Hz)
1	a	10	11	1500
	b	6	10	1700
2	a	8	24	1400
	b	4	12	1500
3	a	10	26	1400
	b	5	16	1300
4	a	6	8	1700
	b	4	6	1600
5	a	8	10	1400
	b	7	12	1700
6	a	9	19	1700
	b	4	17	1500
7	a	5	8	1800
	b	4	8	1500

trasubject standard deviation for test-retest differences of between 2.48 and 3.33 dB SPL (McPherson, Hickson, & Baumfield, 1992). The variability noted from occasion to occasion was, at times, much greater than this range. Moreover, the actual real ear gain provided by the systems was not always accurately reflected in the volume setting of the receiver unit. For example, Table 1 indicates a real

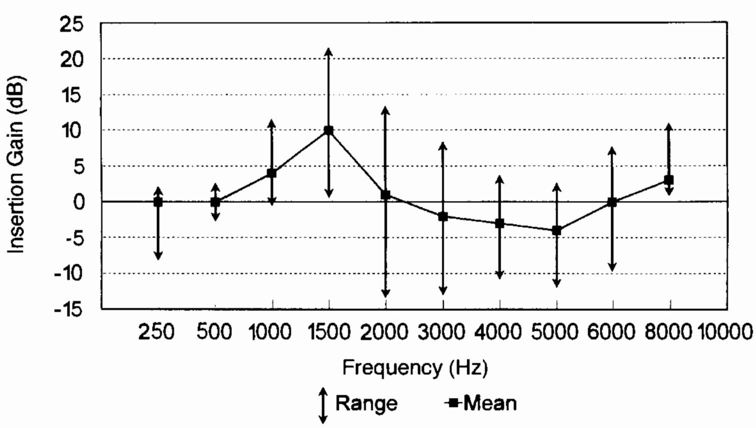

Figure 1. Mean real ear gain and gain range over all subjects.

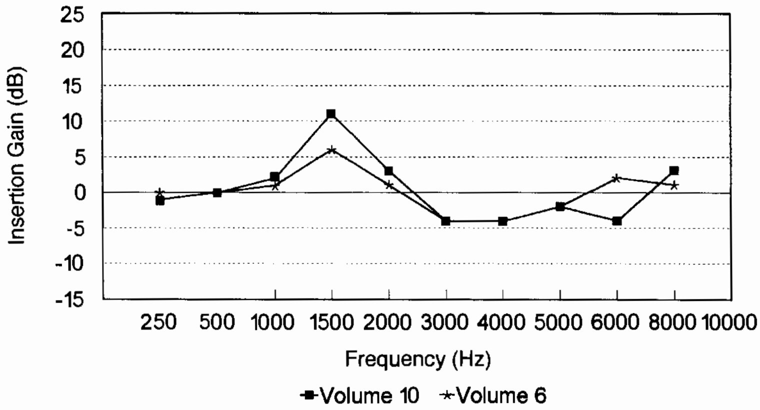

Figure 2(a). FM preferred listening level frequency response for Subject 1 on two occasions.

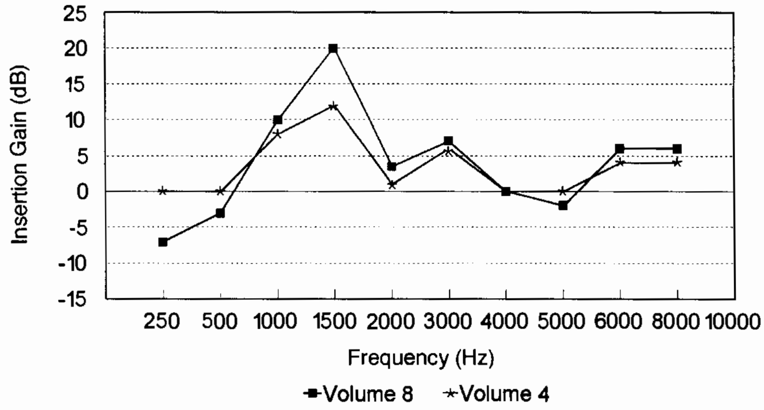

Figure 2(b). FM preferred listening level frequency response for Subject 2 on two occasions.

ear peak gain difference of 15 dB SPL between subjects 1 and 3 for an identical volume setting. This disparity indicates the need to undertake real ear gain measures to gauge actual gain in such fittings.

In general, the fittings provided a relatively flat, transparent transmission of the microphone input. For CAPD children with normal peripheral hearing, this is desirable (Kopun, 1991) to give a natural reproduction of the speech signal. There was typically little gain at low frequencies or above 2000 Hz. Indeed, for high frequencies, the real ear gain was often negative due to the effects of occluding the ear with a low-gain device. A nonoccluding coupling technique may be desirable in such cases. The peak real ear gain frequency ranged from 1300 Hz to 1700 Hz for the 7 subjects, with gain ranging from 6 dB to 26 dB SPL. The maximum preferred SPL output in the ear canal in the highest volume control condition (subject 3, Table 1), therefore, showed a peak of slightly over 100 dB SPL for the 75 dB input signal.

It was interesting to observe the consistent finding with all children of a reduced volume control setting on the second test occasion. This may be a function of their greater experience with the system over time. Familiarity with the FM system may have led to the realization that high gain levels did not give greater clarity (in terms of teacher's voice S/N ratio). However, with this small subject group it should be noted that the difference did not reach statistical significance ($t(6) = 1.79, p = .12$).

No change in audiometric status associated with overamplification was found in any of the 7 subjects over the period of the study. A paired t-test was used to determine if there were any significant differences for the subject group, at any frequency, between the initial baseline hearing thresholds and the thresholds obtained during the final audiometric assessment. No significant differences were noted for any test frequency in the 1 kHz to 8 kHz range. Significant differences were obtained at 250 Hz ($t(6) = 2.52, p < .05$) and 500 Hz ($t(6) = 3.36, p < .05$) and were very likely to have been due to the ambient noise found in the school test environment.

Classroom noise measures ranged from 52 dB A to 62 dB A. Noise measures were consistent with those obtained for occupied U.S. classrooms by Bess, Sinclair, and Riggs (1984), who found mean ambient noise to be 56 dB A. Such high noise levels indicate the desirability of improving the S/N ratio in the classroom for children with CAPDs. There was no consistent relationship noted between the children's FM gain settings and their classroom noise levels.

Anecdotal reports from teachers tended to be positive. The reported advantages of FM system usage were: more on-task behavior, more independent learning, portability, and ease of use. Service difficulties and maintenance were the cited disadvantages of the FM system.

CONCLUSIONS

Although the number of subjects in the present study was small, the findings do suggest a need for further research in this area. In particular, studies involving larger numbers of subjects and a more detailed, perhaps daily, monitoring of preferred listening levels would be of value. In the present study the wide variability of preferred listening levels found among children, and at different times for the same child, indicates that a number of considerations may need to be made in any CAPD management program involving FM amplification. These are:

1. The gain of the FM system should be checked using real ear measures with

each individual child.

2. The use of a standard recommended volume setting in such cases is not valid. A wide peak real ear gain range was seen among subjects for similar volume control wheel settings. An individual setting that will provide a relatively transparent fitting needs to be selected.

3. The preferred listening levels of CAPD children with FM systems in the classroom environment may be greater, at least some of the time, than desired by an audiologist and a means should be found to ensure that the volume wheel cannot be adjusted above the prescribed level. FM systems for children with normal peripheral hearing should have a convenient means for achieving a fixed gain reduction setting, to reduce the possibility of a system causing damage to hearing. This has been recommended even for compression-limiting amplification devices (Macrae, 1993).

4. Consideration needs to be given in some cases to the selection of alternative nonoccluding couplings, such as custom open earmolds that reduce the extent of negative real ear gain.

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