Frequency Modulation (FM) Systems for Children with Normal Hearing

7/29/2002

Brian M. Kreisman, M.S., CCC-A and Carl C. Crandell, Ph.D., CCC-A, Department of Communication Sciences and Disorders, University of Florida

Research has demonstrated that many children with normal hearing (e.g., children with learning, reading, language, attentional and/or auditory processing disorders) experience difficulties understanding speech in typical classroom environments (see Crandell, Smaldino, & Flexer, 1995). Unfortunately, these perceptual difficulties can lead to diminished academic performance.

One well-recognized strategy for reducing the deleterious effects of noise and reverberation in such populations is the use of a Frequency Modulation (FM) system. With this in mind, the present article will present an overview of FM systems that can be used in the classroom for children with normal hearing. For further information about FM technologies, or FM technologies for children with hearing loss, the reader is directed to Crandell and Smaldino (2000, 2001).

PERSONAL FM AMPLIFICATION

There are two basic types of FM systems, personal (body-worn and behind-the-ear) and sound field. With a personal body-worn FM system, the speaker's voice is picked up via an FM wireless microphone near their mouth and is converted to an electrical waveform. The waveform is transmitted by an FM signal to a personal receiver worn by the listener. The electrical signal is converted back to an acoustic signal and transmitted to the listener's ear(s). The traditional body-worn FM system typically has the receiver coupled to walkman-style headphones or earbuds. Originally, the Federal Communications Commission (FCC) required that FM systems broadcast across the frequency region between 72.025 to 75.975 MHz. Unfortunately, other products (cellular phones, pagers, etc.) may also transmit in this frequency band, which can result in transmission interference or reception of an inappropriate signal. Changing the transmitting channel of the FM system (within this frequency band) can eliminate these problems. In addition, to avoid some of these interference problems, the FCC recently allocated a higher frequency region for FM transmission (216 to 217 MHz). Regardless of the transmitting frequency, body worn FM systems can provide a high signal-to-noise ratio to the listener, often 15 to 25 dB (Crandell, et al. 1995).

Behind-the-ear (BTE) FM systems have recently been introduced by several companies. Unlike traditional body-worn FM systems, BTE FM systems have an FM receiver built into a BTE hearing aid that is coupled to the wearer via the earmold (usually an open or free-field style earmold). One advantage of the BTE FM technology is elimination of cords, which body-worn FM systems require. Damaged cords are frequently the cause of malfunction of body-worn FM systems (Crandell & Smaldino, 2000, 2001). Therefore, it is possible that BTE FM systems would be more durable than the body-worn FM systems. Another advantage of BTE FM systems is they might reduced the stigma associated with the more visible body-worn FM systems and therefore, be more acceptable to more students. Unfortunately, while BTE systems may have important advantages over body-worn FM systems, there remains limited research demonstrating the effectiveness of such systems

We recently examined speech-perception benefits from a commercially available BTE FM system (Phonic Ear Sprite BTE FM) in noisy environments for listeners with normal hearing. The speech perception benefits of a body-worn FM system (Phonic Ear Easy Listener) were also measured for purposes of comparison.

The Phonic Ear Sprite BTE FM is a digitally programmable hearing aid with a built-in FM receiver in a BTE casing. The Sprite can be fit to individuals with normal hearing and hearing impairment and is programmed with the Phonic Ear PE 801 hand-held programmer. The FM system was coupled to the subject via Comply sound tube adapters connected to open-style Comply canal tips. The traditional body worn FM system consisted of a Phonic Ear Easy Listener FM system that was coupled to Phonic Ear AT 606 attenuated walkman-style headphones (to ensure that the output of the FM system would not reach an intensity level that can potentially cause damage to the ear). The microphone/transmitters for both FM systems are the same size and use a Phonic Ear AT513 microphone.

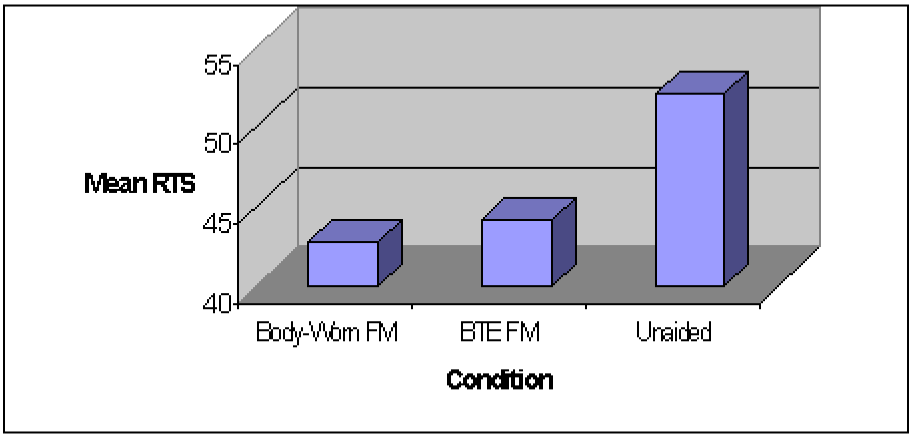
The Hearing In Noise Test (HINT) was used as the speech stimuli with speech spectrum noise from the HINT CD as the noise competition. The HINT sentences were presented to subjects in three conditions: 1) unaided; 2) with a BTE FM receiver on both ears; and 3) with a body-worn FM system.

Twenty subjects, ranging from 18-29 years old, were used for the study. All subjects had normal hearing sensitivity from 250-8000 Hz, English as their primary language, no reported learning disabilities, no history of attention deficit or auditory processing disorders, and no significant medical problems or visible ear abnormalities.

The presentation order for all conditions and the HINT lists were randomized. An adaptive procedure, as recommended by Nilsson et al. (1994), and which results in a reception threshold for sentences (RTS) of 50 percent correct performance level, was utilized to administer the HINT sentences. The speech stimuli was presented through a loudspeaker positioned at 0 degrees azimuth and 1 meter from the subject's head. The Phonic Ear AT 513 microphone/transmitter was fixed at a distance of 3 inches from the front speaker to simulate normal FM microphone position (Crandell et al., 1995). The competing noise was presented through a loudspeaker positioned at 180 degrees azimuth and 1 meter from the subject's head. In all conditions, the speech-spectrum noise was presented simultaneously with the speech stimuli at a level of 60 dB SPL.

Mean RTSs were obtained for each listening condition as follows:
unaided (RTS = 52.08 dB SPL)
binaural BTE FM (RTS = 44.23 dB SPL), and
body-worn FM (RTS = 42.88 dB SPL) (see Figure 1).

Figure 1: Mean RTS (in dB SPL) as a function of listening condition (unaided, binaural BTE FM, body-worn FM). The lower the RTS, the better the speech-recognition performance.



Overall, these findings illustrate several trends. First, while subjects were using either binaural BTE FM or body-worn FM systems, they obtained better speech-recognition scores than in the unaided listening condition. These differences were statistically significant. These data also suggest that either of the FM configurations examined in this investigation can improve the signal-to-noise ratio (SNR) in noisy environments by approximately 8 to 9 dB. Importantly, a 1-dB change in SNR for the HINT sentences equates to a change of approximately 10% in percentage-correct scores (Nilsson et al., 1994). These data clearly suggest that either FM system can significantly improve speech recognition for normal hearing listeners in noisy environments, such as classroom settings. Finally, these data indicated that speech perception differences were not statistically significant between the two FM systems. In other words, while both FM fitting configurations improved speech-recognition performance, neither FM system statistically outperformed the other. These data suggest that children at risk for listening deficits in the classroom could utilize either configuration for SNR improvement.

SOUND-FIELD FM AMPLIFICATION

Another established form of FM technology is sound-field FM amplification. Similar to personal FM systems, the sound-field FM system consists of a microphone and transmitter that the speaker wears. However, the speaker's voice is transmitted to listeners in the room via strategically-placed loudspeaker(s). Sound-field systems vary from permanently-mounted multiple loudspeaker systems powered by alternating current (AC) to very compact and portable battery-powered units with a single loudspeaker. Sound field systems may also use a ceiling speaker array. A number of studies have shown that when sound-field FM systems are placed within a classroom, psychoeducational and psychosocial improvements occur for children with normal hearing sensitivity (see Berg, 1993, Crandell et al., 1995, Crandell & Smaldino, 1996).

There are two main objectives when placing a sound-field FM system in a classroom. The first objective is to amplify the speaker's voice by approximately 8-10 dB, thus improving the SNR of the listening environment. The second objective is to provide amplification uniformly throughout the classroom regardless of the position of the teacher or students.

There are many reported advantages of sound-field FM amplification in classrooms for children with normal hearing. These advantages include the following;

1. Sound-field FM amplification provides benefit to virtually *all* children in a classroom, thus, such technology is extremely cost effective.
2. Sound-field systems are the most inexpensive technology for improving speech perception in the classroom. For example, if the average cost of a sound-field system is approximately $1,000.00 and this is divided by 25 students-per-class, all of the children in the classroom benefit, at a cost of $40.00 per child. If this cost per student is prorated over a 10-year period (the estimated average life span of a sound-field system), the annual unit cost per child is only $4.00.
3. Use of a sound-field system does not stigmatize children, which can be the situation with some auditory assistive technologies.
4. Teachers accept sound-field amplification systems overwhelmingly once they have received in-service training on the instrumentation or have actually utilized the equipment.
5. Teachers report lessened stress and vocal strain during teaching activities with sound-field FM amplification.
6. Students willingly accept sound-field amplification systems. Moreover, by passing around the sound-field microphone (for oral reports, oral reading, and asking/answering questions) students reported improved classroom interaction and participation.
7. Sound-field systems can be used to enhance other instructional equipment, such as televisions, cassette tape recorders, and compact disc players to make the output more audible in the classroom.
8. Parents willingly accept sound-field amplification systems. Crandell et al (1995) reported that more than 97% of parents willingly accept the concept of sound-field technology, even if they have not actually seen the instrumentation in use within the classroom.

Conclusion:

Audiologic counseling, demonstration and instruction are important components of a successful FM amplification system. The child, parent(s) and teacher(s) need to be involved in the decision-making process regarding FM systems, to determine the most appropriate FM system for a particular child. If cosmetics are a major concern, the BTE FM system may be a more appropriate choice. If the child has attentional or cognitive deficits, the parents and teachers may prefer the body-worn FM system that has a lesser chance of being lost. Clearly, providing a choice between the two styles of FM systems empowers the child to select which system he or she would prefer to use. Empowerment may lead to the child's increased acceptance and use of the FM system.

Future research with BTE FM technology should focus on efficacy in actual classroom settings, trials across different manufacturers, benefits for specific populations of normal hearing and hearing impaired children and should address cost effectiveness comparisons between BTE FM systems and body-worn FM systems in terms of use and repair.

REFERENCES:
Berg F. (1993). *Acoustics and Sound Systems in Schools*. Boston: College-Hill Press.

Crandell, C. & Smaldino, J. (1996b). Sound field amplification in the classroom: Applied and theoretical issues. In: Bess, F., Gravel, J., & Tharpe, A. (Eds.) *Amplification for Children with Auditory Deficits*. Nashville: Bill Wilkerson Center Press. 229-250.

Crandell, C., & Smaldino, J. (2000). Room acoustics for listeners with normal-hearing and hearing impairment. In M. Valente, H. Hosford-Dunn, & R.J. Roeser (Eds.), *Audiology treatment* (pp. 601-637). New York, NY: Thieme.

Crandell, C., & Smaldino, J. (2001). Auditory rehabilitation technology and room acoustics. In J. Katz (Ed.), *Handbook of audiology* (5th ed.) (pp. 607-630). Baltimore, MD: Willaims & Wilkins.

Crandell, C., Smaldino, J., & Flexer, C. (1995). *Sound field FM amplification: Theory and practical applications.* San Diego: Singular Press.

Flexer C. (1989). Turn on sound: An odyssey of sound field amplification. *Educ Audiol Assoc News* 5: 6-7

Flexer C. (1992). Classroom public address systems. In Ross M, ed. *FM auditory training systems: Characteristics, selection & use* (pp. 189-209). Timonium, MD: York Press.

Nillson, M., Soli, S.D., & Sullivan, J. (1994). Development of the Hearing In Noise Test for the measurement of speech reception thresholds in quiet and in noise.

Back to top