MULTI-DIMENSIONAL OUTCOME MEASURES OF FM SYSTEM USAGE IN PLACES OF WORSHIP

By

JAMES P. SHEEHAN JR.

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LIST OF ABBREVIATIONS

ALD	Assistive Listening Device
ANOVA	Analysis of Variance
ANSI	American National Standards Institute
ASHA	American Speech, Language and Hearing Association
BTE	Behind-the-Ear
dB	Decibel
DAI	Direct Audio Input
DSL	Desired Sensation Level
NAL	National Acoustics Laboratories
NIDCD	National Institute of Deafness and other Communication Disorders
FM	Frequency Modulation
HA	Hearing Aid
HL	Hearing Level
PW	Place of Worship
SE	Standard Error
SNHL	Sensorineural Hearing Loss
SNR	Signal-to-Noise Ratio
SPL	Sound Pressure Level
SL	Sensation Level

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James P. Sheehan Jr.

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Places of worship are commonly reported environments where people with hearing impairment still have listening difficulty despite wearing hearing aids. The provision of an assistive listening device such as a Frequency Modulation (FM) system has been documented to improve speech perception in these adverse listening situations. However, research on the application of such devices in the real-world has been scarce. This study sought to determine if the device would impact a sample of 29 experienced hearing aid wearing adults who regularly attend religious services in various outcome measures.

Of the 29 enrolled, 23 elected to participate in the experimental group and were fit with an FM system and 6 decided to wear only their current hearing aids. All participants were administered the following outcome measures at baseline, 12 weeks and 24 weeks: Abbreviated Profile of Hearing Aid Benefit (APHAB) for assessment of disability; Glasgow Hearing Aid Benefit Profile (GHABP) with specified worship situations for assessment of disability and handicap; Glasgow Benefit Inventory (GBI) for assessment of health related quality of life, Hearing Handicap Inventories for the Elderly (HHIE) and for Adults, (HHIA) for assessment of

handicap; the Psychosocial Impact of Assistive Devices Scale (PIADS) and, the Spiritual Well-Being Scale (SWBS).

The participants in the FM experimental group had statistically greater satisfaction, reported benefit and derived benefit as measured by the GHABP worship specific items across time intervals. These effects were found for the main presenter, other presenters and music/lyrics and at 12 weeks and 24 weeks. The participants in the FM experimental group also exhibited a significant main effect for improvement in the Adaptability scale of the PIADS.

Within the FM Group, the 6 personal FM users scored significantly greater on the Competence and Adaptability scales at baseline, 12 weeks and 24 weeks than the FM users that were only exposed to the FM signal during the worship service.

The findings of this study indicate the FM systems in conjunction with hearing aids resulted in significantly greater outcomes than hearing aid alone. The adapted GHABP and PIADS measures were most sensitive to these differences.

CHAPTER 1
INTRODUCTION

Approximately 29 million Americans have a hearing impairment (National Institute of Deafness and other Communication Disorders [NIDCD], 2004). A major consequence of sensorineural hearing loss (SNHL) is difficulty communicating, especially in adverse listening situations such as those with a considerable distance between the speaker and listener or environments with excessive amounts of noise and reverberation (Duquesnoy & Plomp, 1980; Nabelek & Mason, 1981; Plomp & Duquesnoy, 1982; Dubno, Dirks & Morgan, 1984; Hawkins & Yacullo, 1984; Needleman & Crandell, 1995; Crandell & Smaldino, 2000; Crandell & Smaldino, 2002). The difficulty communicating may often lead to a reduced quality of life (Ringdahl & Grimby, 2000; Pugh & Crandell, 2002), but may be partially restored with the provision of hearing aids (Mulrow et al., 1990; Yueh et al., 2001).

Hearing aids have been successful in restoring the audibility of speech signals for listeners in quiet environments (Humes, 1991; Humes, & Christopherson, 1996). Hearing aids have also been successful in normalizing the limited dynamic range in those with SNHL. The dynamic range refers to the range at which a frequency or pitch is just noticeable and extends to a level at which the same frequency or pitch becomes intolerable. Those with SNHL have a reduced dynamic range. Therefore, a sound must be more intense to be perceived and then quickly becomes uncomfortable when the intensity is increased. However, restoring audibility and maintaining comfort are only part of rehabilitating hearing loss. Individuals with SNHL may also have other distortion factors such as reduced frequency resolution and reduced temporal resolution (Needleman & Crandell, 1995). These deficits show those with SNHL cannot distinguish frequencies and timing differences as well as those with normal hearing. Presumably for these reasons, hearing aids do not share the same success in improving speech perception for listeners in noisy and reverberant environments. To overcome these deleterious effects, the signal-to-noise ratio (SNR) must be increased. The SNR is the level at which the desired sound (i.e. speech) is presented above the undesired sound (i.e. noise). The critical SNR is the decibel (dB) value where 50% of speech is understood. Individuals with normal hearing may perceive speech when noise and speech signals are equal (0 dB SNR) or even negative (noise exceeds speech signal) but a person with SNHL needs a much greater advantage (higher SNR) to achieve the same level of speech perception performance.

Unfortunately, traditional hearing aids provide little or no improvement in the SNR because the environmental distortions have altered the signal by the time it is received at the level of the hearing aid microphone. Some hearing aids are equipped with directional microphone technology. With directional microphones, sound to the rear and sides of the hearing aid wearer are attenuated. By eliminating some processing of the competing noise, the directional microphone can enhance speech perception directly in front of the listener. This technology has shown improvement in speech perception in noise by 6-8 dB (Hawkins & Yacullo, 1984; Gravel, Fausel, Liskow, & Chobot, 1999; Preves, Sammeth, & Wynne; 1999; Ricketts, Henry, & Gnewikow, 2003). However, individuals with SNHL require the speech signal to be 4 to 12 dB louder than the background noise (Killion, 1997; Moore, 1997) and additional 3-6 dB louder in reverberation (Hawkins & Yacullo, 1984).

Assistive listening devices (ALDs) are devices that assist individuals with hearing loss to sounds they would otherwise not perceive or understand. A hearing aid can be considered an assistive listening device in the strict sense of the word, but typically the term ‘ALD’ is reserved for two types: listening for alerts and listening to speech. An alerting type of ALD would signal the user by tactile/vibratory motion or visual/flashing lights to a specific stimulus (e.g. doorbell).

An ALD designed for speech perception could be a stationary (e.g. amplified telephone) or remote (e.g. FM) system.

One specific remote ALD that is well recognized for improving speech perception in adverse listening environments is frequency modulation (FM) technology. With a personal FM system, a wireless microphone picks up the voice of the speaker near his or her mouth, where the affects of noise and reverberation are minimal. The acoustic signal is converted into a high frequency radio waveform that is transmitted via FM to a receiver that is operating on the same frequency band. If the FM system is designed for use by one user, it may be considered a 'personal FM system' because the sound is intended for one individual. It may also be considered a personal FM system because the user may own both parts: the transmitter and receiver(s). Even with a personal FM system, the transmitted sound may be received by other listeners if they are tuned into the same frequency of transmission. When the signal is intended for a number of listeners at the same venue, a large area FM transmitter may be used to intentionally relay the signal over a larger area to several FM receivers operating on the same frequency band. Typically, these users borrow FM receivers from the venue during a particular event but some FM users may use their own advanced equipment to scan and lock on to the transmitting FM frequency (e.g. Phonak Smartlink FM microphone/transmitter also serves as a synchronization device to access available channels with synthesized receivers).

When the signal is received at the receiver, it is transduced back into the acoustic waveform and presented at the level of the ear through any one of the various coupling strategies such as headphones or by connecting directly to a hearing aid. This process brings the relative sound that is desired closer to the listener, therefore minimizing the effects of distance (noise and reverberation). By eliminating these deleterious effects, the listener is able to perceive speech more effectively. Specifically, FM systems have been shown to improve speech perception in persons with hearing impairment by as much as 10-20 dB in the SNR over unaided conditions (Crandell & Smaldino, 2000) and 10-18 dB over hearing aid alone (Hawkins, 1984; Fabry, 1994; Pittman, D.E. Lewis, Hoover & Stelmachowicz, 1999; Crandell & Smaldino, 2000; M.S. Lewis, Crandell, Valente & Horn, 2004).

Traditional, body-worn, or box style FM systems consist of relatively large transmitters and receivers. Their size approximates an early 1990's era pager to a 1970's era garage door opener. Both boxes are clipped to a belt, placed in a pocket, or held in the hand of the user. Each box has a wire. The person speaking wears the transmitter box with a wire that extends to a microphone clipped on an article of clothing near the mouth (i.e. lapel or collar). The person listening wears the receiver box in similar fashion, but the wire extends to the ear(s) through any of a number of coupling devices (e.g. headphones or ear buds).

Among the advances in FM technology is the ability to receive the signal in a wireless, miniaturized unit. One wireless strategy is the incorporation of FM system receivers into behind-the-ear (BTE) hearing aids. The mini receiver may be ordered as a feature inside the hearing aid (Phonak iLink, AVR Sonovation Logicom, Phonic Ear Sprite) or it may be connected via an audio boot (Phonak Microlink or Phonic Ear Lexis). One manufacturer has streamlined the connection of the mini receiver and hearing aid to appear as a single unit (Phonak Claro, Perseo and Savia models represent first, second and third generations of development respectively). The remote microphone/transmitter worn by the person speaking may also be operated in a miniaturized, wireless fashion rather than a wired connection to the wired box unit. The small microphone/transmitter may be clipped to the lapel directly or worn around the neck with a lanyard. Behind-the-ear FM systems (BTE-FMs) provide similar benefit in speech perception as traditional body-worn FM systems (Boothroyd and Inglehart, 1998) and may be cosmetically more appealing than the traditional systems. This is particularly advantageous for many children (Madell, 1992) and adults who are concerned with the associated stigma of large electronic devices and noticeable wires. Behind-the-ear FM systems may also facilitate management of the units (e.g. storing in desk or locker) because the receiver is directly connected to the hearing aid rather than in a storage space. Furthermore, the electroacoustic variations (changes in the frequency response and electromagnetic interference) of FM systems when coupled to different devices (direct audio input, silhouette inductor, telecoil neck loop, etc) are markedly reduced. Because the FM signal is routed though the BTE hearing aid, it allows for finer amplification adjustments and overall electroacoustic flexibility (Crandell & Smaldino, 2002). Achieving acoustic transparency is important in fitting BTE-FMs because the addition of the FM receiver should be independent of the processing parameters and frequency response of the hearing aid. There are procedures for verifying this independence (discussed later).

When referring to the body-worn FM, the local microphone on the receiver box is often referred to as the environmental microphone, even though the system may be coupled to a hearing aid in various ways. When referring to the BTE-FM, the hearing aid microphone serves as the environmental microphone and the terms are often used interchangeably. In both BTE-FM and traditional body-worn FM systems, there are three typical microphone configurations: 1) FM-only, used to listen to an individual sound source such as a talker far away (the environmental microphone is attenuated); 2) FM/EM, used to listen to multiple sound sources such as talkers near and far (both the FM microphone and environmental microphones are used); and 3) EM-only, used to listen to a sound source such as a talker nearby (only the environmental microphone is used). Research has shown that speech perception performance from a favorable

SNR is best in the FM-only mode, least in EM only and with the FM/EM, performance is somewhere in between (Hawkins, 1984; Fabry, 1994; Pittman et al., 1999; M.S. Lewis, Crandell & Kreisman, 2004). Because noise and reverberation are included in the environmental microphone, the overall benefit of increased speech perception via FM is reduced. However, listeners may prefer to have the environmental microphone activated since they feel increasingly detached as their local microphone becomes less dominant. Therefore, it may be preferable to include the option that allows the user to select between FM, FM/EM and EM only. It may also be preferable to have adjustable gain on the FM and EM microphones to allow for changes to the FM advantage (the gain applied to the FM microphone vs. the EM microphone). The default setting on most Phonak Microlink receivers is a +10 dB. Synthesized FM technology allows for manipulation of the FM advantage from -6 to +24 dB if the user is experiencing difficulty with speech (increase FM gain) or comfort (decrease FM gain). The FM advantage can also be adjusted by decreasing the gain in the environmental microphone in the hearing aid fitting software. In the hearing aid only mode, the gain is actually reduced to a level below threshold instead of attenuating completely.

The development of FM technology has been quite remarkable and the audiological benefit of improving the acoustic signal is well documented. However, the acceptance of wireless technology has not been widespread (Ermann, 2006). Some postulated reasons include: cost; cosmetics; complexity; reduced clinical competence in fitting FM with hearing aids among professional; and, lack of sufficient counseling and coaching on appropriate usage to the FM use (Ermann, 2006). This study seeks to determine the impact that FM usage has on an experienced hearing aid wearer in their place of worship, a commonly reported environment in which users report listening difficulty despite wearing their hearing aids.

CHAPTER 2
REVIEW OF THE LITERATURE

Speech Perception in Children with FM Systems

The nature of the educational environment demands that students hear what is being said before the lessons can be learned. Classroom acoustics are critical variables to consider in the achievement of students with hearing impairment (Finitzo-Hieber & Tillman, 1978). For this reason, it is no surprise that pediatric fittings have dominated 80% of the FM market (Ermann, 2005). The benefit of increased speech perception performance for children using FM has been thoroughly validated (Hawkins, 1984; Moeller, Donaghy, Beauchaine, D.E. Lewis and Stelmachowicz 1996; Boothroyd & Englehardt, 1998; Pittman, D.E. Lewis, Hoover and Stelmachowicz, 1999).

Hawkins (1984) evaluated the effects of various hearing aid and FM systems on speech perception in noise. Subjects included 9 children ranging from 8 to 13 years of age with mild-to-moderate SNHL. The subjects wore Phonic Ear hearing aids (805CD Behind-the-ear, BTE) and a Phonic Ear FM system (441T transmitters, 445R receivers). Speech perception was assessed with spondaic words and phonetically balanced (PB-K) words presented at 65 decibels sound pressure level (dB SPL) at the subject's head in a classroom with a reverberation time of 0.6 seconds. Speech stimuli were presented via a loudspeaker at 2 meters from the subject at 0 degrees azimuth. Noise stimuli were presented at 4 meters from the subject at 180 degrees azimuth. In the conditions that used a frequency modulated (FM) system, the transmitter microphone was located 6 inches from the loudspeaker with the speech stimuli. An adaptive procedure was used where the level of the speech stimuli remained constant while the noise level was adjusted in 2 dB steps to a signal-to-noise (SNR) that resulted in 50% performance. Speech perception was assessed in the following conditions: 1) monaural hearing aid in omnidirectional microphone mode; 2) monaural hearing aid in directional microphone mode; 3) binaural hearing aids in omnidirectional microphone modes; 4) binaural hearing aids in directional microphone modes; 5) FM only in directional mode to monaural hearing aid via neck loop; 6) FM only in directional mode to monaural hearing aid via silhouette inductor; 7) FM only in directional mode to monaural hearing aid via direct audio input; 8) FM only in omnidirectional mode to monaural hearing aid via direct audio input; 9) both FM microphone in directional mode and hearing aid microphone in omnidirectional mode routed monaurally via direct audio input (DAI); 10) both FM microphone in directional mode and hearing aid microphone in omnidirectional mode routed binaurally via DAI and 11) both FM microphone in directional mode and hearing aid microphone in directional mode routed binaurally via DAI. Results revealed that directional microphones on the hearing aids provided significantly speech perception scores than the omnidirectional microphones (2.6 to 3.5 dB). There were no differences between binaural and monaural hearing aid fittings. The FM only condition provided significantly better speech perception scores than all hearing aid only conditions (11.8 to 18.4 dB, mean 15.3 dB). The 'FM only' condition provided significantly better speech perception scores than 'FM plus hearing aid' conditions (7.9 to 16.9 dB). There were no differences in speech perception performance between the coupling methods. On the FM transmitter, the directional microphone mode provided significantly better speech perception than the omnidirectional microphone mode (3.3 dB). Taken together, these results led Hawkins to recommend the option to switch between modes of FM microphone only, FM and hearing aid (FM+HA) microphones active simultaneously and hearing aid microphone only. He also recommended that when in the FM+ HA mode that a directional hearing aid microphone for an optimal classroom amplification.

The hearing aid fitting in the Hawkins (1984) study used the half-gain rule. This may provide too much amplification of the hearing aid microphone in the FM+HA mode, obscuring the benefit of the SNR. Also, noise was presented at 180 degrees azimuth. This may not reflect a realistic listening environment. The improved speech perception when the hearing aid was in the directional mode compared to the omnidirectional mode is not surprising because the target speech is originating from the FM microphone. The attenuation provided by directional microphones proximal to the hearing aid helps to improve the SNR but total attenuation (FM only) is the best way to preserve the advantage. The FM only configurations were superior to both configurations that incorporated the hearing aid microphone (HA only or FM+HA). If the goal were to perceive multiple speech signals simultaneously through the FM and hearing aid (e.g. an alerting situation such as a baby monitor), omnidirectional microphones at both levels may be beneficial to maximize the amount of acoustic input. However, if only two speech sources are desired, one near the FM microphone and one near the hearing aid microphone(s), it would appear that directional microphones at both ends would be most beneficial because it attenuates competing noise from the sides. Therefore, the polar plots (the graphic representation of microphone sensitivity) of both microphones should be considered with regard to the desired and competing sound sources.

Although improved speech perception ability in the classroom was found for students using FM systems, the effects of an improved signal over a longer period of time did not show similar benefit. Moeller et al., (1996) evaluated the effects FM system usage on language development in nonacademic settings. Subjects included ten children ranging in age from 2 to 4 (at the beginning of the study) with mild-to-severe sensorineural hearing loss (SNHL) who attended an aural/oral preschool where speech therapy was provided in the school setting only.

All subjects wore hearing aids and Phonic Ear (471 or 475) FM systems during school. Half of the subjects wore a Telex TDR-6 FM as often as possible outside the classroom setting while the other half wore their hearing aids only. Issues such as intermittent FM interference, multiple caregivers, family dynamics and device bulkiness made it difficult to expect full-time use. All subjects were followed for 2 years. The FM microphone was set 5 dB higher than the environmental microphone. Language was assessed with at least 200 play based conversational turns every 6 months. The conversations were recorded and scored with Systematic Analysis of Language Transcripts (SALT) and Developmental Sentence Scoring (DSS) procedures. Results did not reveal any differences in language development between the children who used the FM system outside of the school setting compared to those who did not. Parents reported that the child preferred to use the FM while listening to TV or story tapes and group situations with a primary talker. Parents also reported that they preferred to use the FM system with their children when visiting places such as stores, parks and the zoo because it facilitated parental control or discipline. Younger subjects also reported a greater sense of security when caretakers were not visible. Parents also reported negative aspects of using the FM system: it was bulky and cumbersome; interference; communicative delays and/or inabilities in passing and/or unwillingness to pass the transmitter microphone; and the wearer may serve as a messenger of private information to peers. The authors also point out the potential for violating pragmatically accepted distances for communicating (e.g. talking from another room). Despite training, the parents sometimes failed to activate the FM and environmental microphone setting in the presence of a third party because the unintentionally forgot or because they intentionally used the system to control their child's' behavior.

If body-worn systems are seen as bulky and cumbersome, the miniaturization of FM systems may be needed before a greater number of individuals can appreciate the benefit. Boothroyd and Inglehardt (1998) examined speech perception benefit of body-worn and ear-level FM systems and the effect of the level of the FM microphone sensitivity relative to hearing aid microphone sensitivity. Subjects included 13 teenagers ranging from 15 to 17 years of age (mean = 15.7 years) with severe to profound SNHL who attended an oral school for the deaf. All subjects were experienced users of personal and classroom FM systems. The Phonic Ear 471 T served as the transmitter, which was located at 12 inches from the speaker's mouth. Two transmitters settings were used: the standard setting which had a compression threshold of 75 dB SPL and the modified setting which had 15 dB less sensitivity than the standard unit, a 90 dB SPL compression threshold. Receivers included the Phonic Ear 471 R body-worn and the Phonic Ear Free Ear ear-level receivers. All subjects used both receivers and all but one subject were fit bilaterally. The FM systems were adjusted for equal gain via the remote FM microphone and built-in hearing aid microphones using 65 dB SPL sinusoidal inputs to both. Speech perception was assessed in a classroom designed for the education of those with hearing impairment. Speech stimuli included Arthur Boothroyd's isophonemic word lists, which were scored as a percentage of correct phonemes identified, in quiet and noise. Multi-talker babble served as the noise competition and was presented from four loudspeakers located 4 feet from and facing each of the corners of the room at a height of 30 inches. The uniform sound field of noise was adjusted to reach 55 dB SPL at the location of the teacher and student. Speech was presented via monitored live voice without visual cues with an intensity level measured at 75 dB SPL at the FM microphone and 60 dB SPL at the student's hearing aid microphone. Responses were written and scored by percent correct for initial consonants, vowels, final consonants and all phonemes. Phoneme omissions, substitutions and additions were counted as errors. The authors concluded that the addition of the remote FM microphone was equivalent, on average, to doubling the number of independent channels of information provided by the hearing aid alone. The result, on average, was a 25 percentage point improvement in phoneme recognition with the FM system in students who scored 40-60% in the aid-alone condition. This improvement was reduced for students with poorer scores in hearing aid alone condition. Subjects performed significantly better in quiet than in noise. However, the benefit was greater when the FM system was worn in noise (30%) than when it was worn in quiet (20%). There was no significant advantage of the body-worm FM system over the ear-level FM system. There were no significant differences in speech perception between the modified and standard FM microphone/transmitters.

Boothroyd and Inglehardt (1998) stated that although students with the most severe losses have the greatest need for FM, they would obtain the least help with the addition of FM, at least when expressed in terms of a percentage point increase in phoneme recognition. They found that proportional benefit of FM is independent of aid-alone phoneme recognition performance. There was greater benefit in the noise condition compared to the quiet condition because there was a greater need and ability to overcome the adverse effects associated with noise. The 20 dB SNR at the remote microphone (e.g. teacher) might not have been enough to eliminate interfering effects at the level of the environmental microphone in the aid + FM setting. However, the authors suggested that the 75dB SPL compression threshold of the FM microphone was probably exceeded because speech stimuli were used. Speech has a higher crest factor than pure tone stimuli (13 vs. 3 dB respectively) so it is possible that the amplitude peaks of the speech spectrum, while not reflected in the root mean square (rms) average, probably activated the compression algorithm. The FM advantage was virtually eliminated when the FM microphone was reduced to 15 dB to equalize the FM and HA outputs as recommended by the American Speech, Language and Hearing Association (ASHA, 1994). In this study, the equal output rationale was not supported for those with profound hearing loss. Since the audibility of conversational speech via the hearing aid microphone is limited, further reduction of the hearing aid microphone to achieve a 15 dB difference below the FM microphone would be detrimental. The ASHA guidelines now include a revised recommendation for FM fittings, stating that the FM microphone should be 10 dB greater than the hearing aid microphone (ASHA, 2000).

Investigations on FM system benefit in speech perception performance have utilized the same amplification scheme in both ears. To determine if the benefit of asymmetrical amplification schemes, Pittman, et al. (1999) assessed speech perception in four system configurations of hearing aid and FM microphones. Subjects included 11 children (mean age = 10.5) with bilateral moderate-to-severe SNHL and 8 children with normal hearing. All subjects with hearing impairment were experienced users of hearing aids and FM systems and were mainstreamed (oral communication). The children were fit with two different FM personal FM systems, the Phonak Microvox and the Phonic Ear Solaris used in conjunction with Phonak Pico-Forte C2 BTE hearing aids. Fitting was verified with the Desired Sensation Level (DSL) fitting formula. The children with normal hearing were tested without any amplification. Speech stimuli included four subsets of the Nonsense Syllable Test (NST) (Dubno & Dirks, 1982). Five loudspeakers were setup in a classroom with a reverberation time of 0.6 seconds. Speech stimuli were presented through three loudspeakers at 0, 90 and 270 degrees measured 66 dB SPL at a location of 2 meters from the subject. The FM microphone was positioned 20 centimeters from the front speaker, where the long term average speech spectrum (LTASS) measured 80 dB SPL.

Competing speech weighted noise was presented through four different loudspeaker positioned at 90, 135, 225 and 270 degrees azimuth to represent students within the classroom. The side loudspeakers presented the noise at 60 dB SPL at a distance of 1.7 meters. The loudspeakers located behind and to the sides of the subjects presented noise at 59 dB SPL at a distance of 1.9 meters. The hearing aid and FM microphones were activated in the following configurations: 1) FM and hearing aid binaurally; 2) FM and hearing aid binaurally simultaneously with a system giving precedence to the FM when the input exceeds 72 dB SPL; 3) FM and hearing aid monaurally and FM only monaurally; and 4) FM only monaurally and hearing aid only monaurally. The conventional FM system (no precedence) gave a 10 dB system advantage by setting the FM microphone output 5 dB above the DSL target and the hearing aid microphone output 5 dB below the DSL target. The FM precedence system automatically reduced the hearing aid microphone to 10 dB less than the FM microphone when it was activated. Results revealed significantly better speech perception when speech stimuli were presented via the front loudspeaker (with FM) than either of the side loudspeakers for both groups. There were no significant differences between the different HA/FM configurations. Regardless of the HA/FM condition, speech perception via the FM microphone (75%) was significantly greater than via the environmental microphone (55%). When the speech stimuli were presented to those with hearing impairment, initial consonants were perceived better than final consonants in both front and side loudspeaker conditions. The authors suggest that a variety of HA/FM system configurations may be used to provide speech perception benefit in noise, at least for a similar group of students with moderate-to-severe SNHL. Pittman et al. (1999) also suggested that an increase of 5 dB to the FM over the HA microphone was not large enough to improve speech perception performance when activated simultaneously; that the output levels were already sufficiently high to maximize performance in these children.

Speech Perception in Adults with FM Systems

Although children may use FM systems more often than adults, there is little reason to believe that adults could not benefit from an improved SNR. Speech perception benefit has also been documented in the adult population (Fabry, 1994; Jerger, Chmiel, Florin, Pirozzolo and N. Wilson, 1996; Boothroyd, 2004; M.S. Lewis, Crandell, Valente and Horn, 2004).

In addition to the fair SNR benefit in directional microphones and excellent SNR benefit in FM systems, attempts have been made to provide SNR benefit within a single microphone. Such methods rely on changes at the microchip processing level of the hearing aid. When the resultant frequency response is visualized, the reduction in low frequency gain is apparent; the stimulus is high pass filtered. To determine if high pass filtering of the hearing aid microphone would improve the SNR already provided by an FM system, Fabry (1994) assessed speech perception ability in listeners with hearing impairment using FM integrated hearing aids that were modified with this rationale. Subjects included five adults, ranging from 33 to 65 years of age, with moderate-to-severe SNHL. Each subject was fitted binaurally with Phonic Ear 471 hearing aids. Each subject was also fit monaurally with a Phonic Ear 471 FM transmitter and AT 595 Earmic environmental microphone receiver. Real-ear measures confirmed that hearing aid fittings were within 5 dB of National Acoustic Laboratories – Revised (NAL-R) targets for the frequency range 200-4000 hertz (Hz) with 60 db SPL composite noise. Saturation Sound Pressure Levels at 90 dB (SSPL-90) did not exceed unaided loudness discomfort levels (LDLs) at 750 and 2000 Hz, verifying that intensity levels were not uncomfortable. Speech perception was assessed with an adaptive speech reception threshold (SRT) procedure utilizing the Hearing in Noise Test (HINT) sentences (Nilsson, Sullivan & Soli, 1994) in five conditions: 1) FM only (standard FM system); 2) environmental microphone/hearing aid only with a high-pass filter (EM-HP); 3) environmental microphone/hearing aid only with a standard frequency response (EM-S); 4) both FM and environmental microphone/hearing aid microphones with a high-pass filter (FM/EM-HP) and 5) both FM and environmental microphone/hearing aid with a standard frequency response (FM/EM-S). Target speech and multi-talker noise were presented though loudspeakers at 0 and 180 degrees azimuth, respectively. The noise was presented at 56 dB and 66 dB on the A-weighted noise scale measured at the location of the subject. The subject was seated in the middle of sound suite measuring 10 square meters. The FM microphone was positioned 8 inches from the loudspeaker though which speech was presented. Results for both 56 dB A and 66 dB A noise levels were approximately the same. The results were plotted as SNRs corresponding to speech reception thresholds (SRTs) of 50% performance: 16 dB in the FM only mode; 13 dB in the FM/EM-HP; 9 dB for FM/EM-S; and about 6 dB for the EM-HP and EM-S modes. There were no significant differences in speech scores between the standard and the high-pass filtered in the EM (hearing aid only) conditions. However, when the EM was high pass filtered for the FM/EM conditions, speech perception scores were significantly greater (4 dB) compared to the standard EM of the FM/EM condition.

In the Fabry (1994) study, it was hypothesized that because the ambient environmental noise contains predominantly lower frequencies that the attenuation of the EM in this range would improve speech perception in the FM+EM mode over traditional FM+EM mode. This method has been commonly used as a noise reduction strategy in regular hearing aids with questionable success. This may cause a noticeable difference in listening comfort to the hearing aid user, but has yet to prove beneficial by increasing speech perception scores (Fabry & Van Tassell, 1990; Tyler & Kuk, 1989). The rationale is to differentially apply spectral changes to desired sound (speech) compared to compromised (noisy and reverberant) signals. The Fabry article stated that in addition to replicating these results with high-pass filtering or other spectral manipulations, that it is important to identify the appropriate level of attenuation of the EM of the FM/EM configuration for maximal speech perception in noise from both microphones. Although the high-pass filter looks promising because it maintains the SNR advantage for the FM microphone while allowing the occasional (environmental) inputs via the hearing aid to be perceived, it may be detrimental if those infrequent inputs are speech signals.

Jerger, Chmiel, Florin, Pirozzolo and N. Wilson (1996) compared the relative impact of adding a traditional monaural FM system to a conventional monaural hearing aid on audiological, neurophysiological and sociological outcome measures. Participants included 180 elderly adults, one hundred of which have previously worn hearing aids (average duration = 10.2 years). Ninety-four of the previous users had binaural fittings. The inclusion criteria included: 1) age greater than 60 years; 2) high frequency sensitivity loss, quantified as the average of the pure-tone average of threshold levels at 1000, 2000, and 4000 Hz greater than 15 dB in both ears 3) normal middle ear status by immittance audiometry; 4) average score of 3 or less on a self-report measure of physical health based on current health status, eyesight, extent to which daily life was limited by the subject's state of health, how many days the subject had been sick, and how often the subject had visited the doctor during the 6 months before the study; 5) a normal score (24 or more) on the Mini Mental State Exam (Folstein, Folstein & McHugh, 1975) and 6) no previous history of neurologic of psychiatric disorder. The experimental groups included: 1) hearing aid only; 2) FM only, 3) hearing aid and FM, and 4) no amplification. Each treatment condition lasted for 6 weeks. The order of treatments and the ear that received amplification were both randomized. The hearing aids were assigned according to degree of low frequency

(LF) hearing loss. Those with mild LF hearing loss received 3M Memory Mate and those with a greater LF hearing loss received Siemens Triton 3000. A Comtek personal FM system was used. In the FM only condition, an earbud was used. In the hearing aid with FM condition, a neckloop was used with the hearing aid telecoil activated. There were six test sessions. Session 1 measured pure-tone, speech and immittance audiometry and a series of screening measures of vision, physical health and mental status to determine if the inclusion criteria were met. If so, earmold impressions were taken and the 5 remaining sessions were scheduled. In session 2, a battery of tests was performed to measure central auditory status, neurophysiologic status and self-assessed hearing handicap. The first group of tests was referred to as subject descriptors: NEO Five-factor Inventory for personality (Costa & McCrae, 1986), California Verbal Learning Test for memory (Delis, Kramer, Kaplan & Ober, 1987); Time Sustained Attention Test for attention (Mahurin & Pirozzolo, 1986); Purdue Pegboard test for manual dexterity; Duke Social Support Index (DSSD; George, Blazer, Hughes, & Fowler, 1989). The second group of tests were referred to as the outcome measures: Hearing Handicap Inventory for the Elderly (HHIE, Ventry & Weinstein, 1982); Speech Perception in Noise Test (Kalikow, Stevens & Elliott, 1977); Brief Symptom Inventory (BSI; Derogatis, Rickels & Rock, 1976); Social Activity Scale (Graney & Graney, 1974); Life Satisfaction in the Elderly Scale (LSES; Salamon & Conte, 1986); Affect Balance Scale (Bradburn, 1969); and a use of amplification scale pertaining to the past 6 weeks. The outcome measures were repeated at sessions 3, 4, 5 and 6. Each session was scheduled 6 weeks apart. There was significant improvement in speech understanding in noise in the two FM conditions. No significant differences were noted in hearing handicap between the three amplification conditions. Despite the superiority of the FM conditions in noise and anecdotal report of improved sound quality with FM, participants overwhelmingly choose the conventional hearing aids as the amplification system they would use in daily life. Only five participants choose the ALD over the hearing aid. Interestingly, the participants who chose the hearing aid only perceived themselves to be more handicapped, tended to be less well adjusted psychological and were less satisfied with their quality of life. They also showed larger left ear deficits in dichotic listening ability, suggesting greater difficulty in the central processing of binaural input.

Boothroyd (2004) assessed the benefits and limitations of a remote wireless microphone as a hearing aid accessory for adults in laboratory and field tests (discussed later). Participants included 8 men and 4 women (mean age 73 years) with a better ear three frequency average of 48 dB. Six of the participants had a sloping audiogram, defined ad a 30 dB difference in pure-tone thresholds between 500 and 4000 Hz. Eleven were experienced hearing aid users. All participants were fit with behind-the ear hearing aids from (the Free Ear from Phonic Ear), linear, single-channel, analog aids with adjustable compression limiting. Participants also received a Free Ear microphone-transmitter. The FM transmitter contained a compression-limiting algorithm with a kneepoint of approximately 75 dB SPL. Gains for the hearing aid and FM microphones were adjusted to be equal for inputs below the kneepoint of the FM transmitter. Above this threshold, gain via the FM microphone was applied according to the parameters set for the hearing aid microphone. Otherwise, the hearing aid was programmed to NAL targets. Speech and noise were presented from digital stereo files via a laptop computer and amplified single-cone loudspeakers (Roland 12C). Speech was presented as a distance of 3 feet and 0 degrees azimuth. Noise was presented from two loudspeakers at 3 feet and +60 and -60 degrees azimuth. The two noises were desynchronized by a 200 ms delay. When testing via FM, the remote FM microphone was placed at a distance of 6 inches from the speech loudspeaker. Root mean square (RMS) noise level at both the listener's location and the FM microphone was 55 dB SPL. The speech level at the FM microphone was always 15 dB greater than at the level of the ear. Speech material included 20 isophonemic lists of 10 consonant-vowel-consonant words recorded by a female talker from the eastern United States. Spectrally matched noise was added and remained at a constant level. The speech was adjusted in 5dB steps from -10 dB to +20dB to generate seven sets of stimuli. Four different carrier phrases were prepared for each set: with and without noise. All stimuli were presented randomly via computer software. Each participant attended three sessions. In the first session, pure-tone audiometry and tympanometry were performed and earmold impressions were made. In the second session, a brief questionnaire was administered to assess non-audiometric benefit (field study). Speech performance was assessed unaided in quiet, aided with previous hearing aids in quiet, aided with experimental aids in quiet and noise, and aided with experimental aids in noise with the FM microphone activated (no hearing aid microphone). Counseling, demonstration and instruction in use of the FM system was provided. Participants were given illustrated written instructions on the use of the FM system and a diary for logging experiences with system. In the final visit (at least two weeks later), the questionnaire was administered again. Speech performance measures with the experimental hearing aids were conducted in quiet, noise and in noise with the FM microphone activated. Participants were also given materials describing all commercially available BTE FM systems at the time of the study. One subject was excluded because of unusually high noise susceptibility. Performance intensity functions were generated for all conditions. Analysis of variance and post hoc testing showed significant differences between aided performance in quiet and noise at all speech levels 45-60 dB SPL (SNRs of -10 through +5) ($p < .000$). There was no statistically significant difference between FM assisted performance in noise and aided performance in quiet. When typical FM inputs were analyzed, performance at a 75 dB SPL input at the FM microphone in a 55 dB SPL noise (SNR +20) was significantly greater than performance with an input of 45 db SPL at the listener's location ($p < .0012$).

The speech perception data in Boothroyd (2004) study provides valuable information for the ongoing development of a fitting protocol for FM used with hearing aids. It appears that the equal gain criterion that was recommended for the hearing aid/FM mode (ASHA, 2000) may have resulted in no perceived reduction of background noise switching from aid-only to FM-only mode. When the person speaking via FM microphone stops talking, the gain is increased. This would create a poor signal-to-non-simultaneous noise ratio. Reduction of FM gain may alleviate this complaint but the FM benefit may also be reduced. Contrary to earlier investigation (Boothroyd & Inglehardt, 1998), ideal initial settings might be closer to the equal output criterion. The establishment of a fitting protocol for an initial FM system fit remains challenging.

M.S. Lewis, Crandell, Valente and Horn (2004) compared speech perception in noise performance in directional microphones and wireless FM systems. Participants included 55 adults in Gainesville, FL (n = 22, 68% male, median age of 73 years) and St. Louis, MO (n = 23, 57% male, median age 73 years) with mild-severe SNHL. The Gainesville group had significantly higher pure-tone average thresholds than the St. Louis group. Despite this both groups had similar word recognition performance. Subject inclusion/exclusion criteria included: 1) ear inspection via otoscopy within normal limits; 2) Normal middle ear function bilaterally (+/- decaPascals [daPa] as indicated by tympanometry; 3) no evidence of conductive or retrocochlear pathology as indicated by pure-tone testing and immittance measurements; 4) no air-bone gap greater than 10 dB at any test frequency as indicated by pure-tone test results; 5) slight (20-40 decibels Hearing Level [dB HL]) to severe (65 to 85 dB HL) high frequency or flat sensorineural hearing loss as indicated by pure-tone test results (250-8000 Hz, including 3000 and 6000 Hz); 6) symmetrical hearing loss that does not differ by more than 15 dB at more than one audiometric test frequency as indicated by pure-tone test results; 7) word recognition scores of 50% or better in quiet as assessed by recorded version of Northwestern University, 6th version (NU-6) monosyllables at the subjects Most Intelligible Level (MIL); 8) motivated to try amplification as reported by the participant; 9) native speaker of English as reported by the participant; 10) intact mental status as measured by the Short Portable Mental Status Questionnaire (SPMSQ, Pfeiffer, 1975); 11) no history of chronic or terminal illness, psychiatric disturbance, or senile dementia as reported by the participant; 12) no history of being bedfast/chairfast as reported by the participant; 13) not home or nursing bound; 14) no history of stroke or cerebrovascular disorder with a paresis or aphasia as reported by the participant; and 15) willing and able to give informed consent to participate in this investigation. All participants were fit with Phonak Claro 311 digital Audio Zoom (dAZ) BTE hearing aids, select-a-vent earmolds with size #13 or 3 mm horn tubing, Phonak MicroLink 8th version (ML8) receivers attached directly to the hearing aid (no boot required) which can be worn in the FM only mode (hearing aid microphone is attenuated 20 dB) or FM plus hearing aid microphone mode. The Phonak TX3 handheld microphone transmitters were used. The TX3 allows the user to change the microphone settings in the following mode: 1) “wide angle” which amplifies sound from all directions equally; 2) “zoom” which provides less amplification to the signals originating from the rear, a cardioid polar plot); and 3) superzoom” which provides less amplification to signals originating from the sides and rear, a hypercardioid polar plot. The hearing aids were fit according to the Desired Sensation Level (DSL) prescriptive fitting rationale. Participants wore their hearing aid and FM systems for 30 days prior to testing. The Hearing in Noise Test (HINT, Nilsson, Soli & Sullivan, 1994) stimuli were presented at 0 degrees azimuth located one meter from the participant. The TX3 transmitter was positioned 0.5 meters in height at a distance of 7.5 cm from the loudspeaker. Correlated speech spectrum shaped noise was presented at 45, 145 225 and 315 degrees azimuth located one meter from the participant. Both signals were routed through a dual channel audiometer (GSI 61) . An adaptive procedure, the reception threshold for sentences (RTS), was used with the noise level held constant at 65 dBA and the intensity level of the sentences was varied to determine a 50% accuracy level. The RTS measures were measured in the following conditions: 1) unaided; 2) binaural hearing aids in omnidirectional microphone mode; 3) binaural hearing aids in directional microphone mode; 4) binaural hearing aids and one FM receiver (ear assigned at random); and 5) binaural hearing aids with binaural FM receivers. The FM receivers were set to the FM only mode (the hearing aid microphone was attenuated) and the Superzoom mode on the TX3 microphone transmitter. The order of the conditions and speech stimuli were randomized to avoid order and practice effects. Analysis of variance (ANOVA) and least significant differences tests revealed significant differences between conditions. Performance of hearing aids with binaural FM resulted was significantly better thresholds than binaural hearing aids with one FM ($p < .001$). Thresholds for hearing aids with monaural FM were significantly better than both hearing aid only conditions ($p < .001$). Thresholds for hearing aids in directional microphones mode were significantly better than omnidirectional microphone mode ($p < .001$). Thresholds for omnidirectional microphone mode were significantly better than the unaided condition ($p < .001$).

In the M.S. Lewis, Crandell and Kreisman (2004) study, one goal was to replicate the Hawkins (1984) study in adults with updated protocols that take into account the advances in digital signal processing and directional microphones (on both hearing aids and FM microphone/transmitters). A 3 dB binaural advantage was found in the binaural mode that was not found in the Hawkins study. The author suggested that this advantage was probably the result of being truly binaural (two ears, two receivers) rather than a diotic routing from one FM receiver. A separate analysis also showed that among FM transmitter settings, thresholds for speech performance through the FM microphone were best in the "zoom" setting and worst in the "wide angle" mode (M.S. Lewis, Crandell & Kreisman, 2004). Perhaps the "superzoom" setting is too directional to catch the voice of the speaker; that the acoustic focus is pointing to the neck or chin rather than the mouth.

In sum, FM systems are an effective means of improving speech perception in those with SNHL. Speech perception performance is best in the FM-only mode, least in EM only and with the FM/EM, performance is somewhere in between (Fabry, 1994; Jerger et al., 1996; Boothroyd, 2004; M.S. Lewis, Crandell & Kreisman, 2004, M.S. Lewis, Valente, Horn & Crandell, 2005).

When the environmental microphone is activated, the overall advantage of the FM is reduced by at least 3 dB due to the re-introduction of noise and reverberation. However, listeners may prefer to have the environmental microphone activated to maintain awareness around them. The process of achieving the ideal SNR in the FM/EM setting for optimal speech perception via both microphones remains a challenge. In addition to the FM/EM mixing consideration, attention should also be given to the appropriate placement and directionality settings of the FM microphone transmitter.

Electroacoustic Performance Factors in FM Systems

In addition to evaluating the performance of the FM device, the mechanism between the FM receiver and the hearing aid must also be considered. Electroacoustic variability has been found in FM receivers, hearing aids, and the coupling methods used to connect the two (Hawkins & van Tassell, 1982; Thibodeau & Saucedo, 1991; Hawkins & Schum, 1985).

Between FM systems, the volume control and frequency response have been found to vary. The “linear” scale of the volume control on the FM receiver does not always provide linear output (Hawkins & van Tassell, 1982; Hawkins & Schum, 1985). In addition to the nonlinearity, different frequency responses of hearing aids were noted when coupled to FM systems in the same manner (Hawkins & van Tassell, 1982; Hawkins & Schum, 1985; Kopun, Stelmachowicz, Carney & Schulte, 1992)). Differences have also been found within the FM system components. In a multi-center study, 30 units of the same FM system were analyzed and found to vary electroacoustically in the receivers, the lapel microphone, and the neckloops (Thibodeau & Saucedo, 1991). Neckloop couplers work by switching the hearing aid to the telecoil setting, which allows the signal to be processed through electromagnetic energy. By nature, this method is also susceptible to electromagnetic interference (Thibodeau & Saucedo, 1991). The strength of the signal is dependent on distance to the telecoil located inside the hearing aid. Changes in body position (head tilt/orientation) and physical fit (e.g. neck length) will have an effect (Hawkins & van Tassell, 1982). Silhouette inductors are another coupling method that minimizes the distance to telecoil by aligning between the hearing aid and the head or pinna (portion of outer ear that “hold” BTE hearing aid), but this method is still susceptible to internal noise (Hawkins & Schum, 1985).

The American National Standards Institute (ANSI) established a standard for electroacoustic characteristics of hearing aids (ANSI-2003, S3.22) but not for assistive listening devices such as FM systems. In the future, ANSI may develop standards similar to those of the International Electrotechnical Commission (IEC) that standardized the parameters for telecoil input (IEC 60-118-1), hand-held microphones, and wireless systems (IEC 60-118-3). Until then, the electroacoustic variability in FM systems and their coupling methods may cause these systems to be fit inappropriately.

D.E. Lewis, Feigin, Karasek and Stelmachowicz (1991) reviewed the three common methods of assessing FM systems: functional gain, coupler measures and probe tube measures. Functional gain is the difference between aided and unaided acoustic thresholds in sound field (no headphones). The functional gain method was not recommended because it does not allow for the measurement of input levels that are normally used with the system. Since it is a threshold measure, the input levels are generally lower than the necessary 60 and 75 dB inputs expected from conversational speech at the device microphone. Probe tube and coupler measures were recommended because they can provide important electroacoustic information such as the gain and maximum output. The authors preferred coupler measures because harmonic distortion may also be measured.

In sum, the electroacoustic analysis of FM systems showed great variability in a number of parameters both between and within the units and components. It is therefore, important to control for as much of this variability as possible. The BTE-FM system would be expected to have the most consistent response because the basic hearing aid parameters have been standardized for quite some time. Furthermore, BTE-FM systems allow for greater flexibility in fitting because the hearing aid has additional controls to allow for finer electroacoustic modifications. However, it remains to be seen if the hearing aid is transparent (no change in frequency or gain response when connected to the FM system). To ensure that the signal has not been modified, real-ear probe microphones and/or coupler measures should be used for verification, as recommended by D.E. Lewis et al. (1991).

Guidelines for Fitting FM Systems

Presently, there is no standard electroacoustic measurement procedure for FM systems (Thibodeau, 2006). The American Speech-Language Hearing Association (ASHA, 2000) set forth guidelines for fitting and monitoring personal FM systems, but does not specify recommendations for large area FM systems. The guidelines instruct the person testing the device to place the microphone/transmitter in the test box and deliver various input stimuli so that the output can be measured. A large area transmitter cannot be measured with this procedure because it does not have a microphone; it requires audio input from another audio output source

Unless indicated, the remainder of this section refers to key points set forth in the guidelines for fitting and verifying personal FM systems (ASHA, 2000). A similar procedure would be followed if the attempt to verify the large area systems is made (if a reference microphone was created for such testing).

It is assumed that the input arriving at the FM remote microphone (6-8 inches from the mouth of the talker) is at least 15 dB greater than the input to the hearing aid at a distance of 1-2 meters from the talker, which is typically 60 to 70 dB SPL. Therefore, in the testing situation it s recommended that the input level of the FM microphone be set 15 dB higher than the local microphone(s). The guidelines further suggest that manufacturer measurements provided with the device should be evaluated according to the ANSI S3.22 (1987) standard, which established parameters used in verifying hearing aid specifications. The authors on the ASHA ad hoc committee recommended that the FM and environmental (on receiver, hearing aid, or both) microphones be evaluated separately.

The FM microphone/transmitter may have a compression algorithm that modifies some aspect of the signal between receiving and transmitting. It is therefore recommended that the SSPL90 measure be made to the environmental microphone to reflect the true SSPL.

Some receivers have a volume control wheel for the FM signal and/or the environmental signal. Care should be taken to control for these various combinations of output because undesired effects may result. The user may also become confused as to what the appropriate adjustment should be made so reducing the number of volume control options may facilitate ease of use.

The general steps for adjusting gain to an FM system include: 1) measure output of the hearing aid into a 2cc coupler for an input of 65 dB SPL at a frequency of 1000 Hz; 2) couple the FM system with the respective method of coupling and activate the FM setting; 3) adjust the volume on the FM system to match the output in step #1 with a 65 dB, 1000 Hz input (mark the location on the FM volume control wheel); 4) increase the input of the test box to 80 dB SPL. If the hearing aid output via FM increased by a step of 10 dB, the fitting is complete. If the hearing output via FM increased beyond 10 dB, adjust the FM volume control to decrease the output to 10 dB. If the hearing aid via FM output is increased by a step that is less than 10 dB, adjust the FM volume control to increase the output by 2 or 3 dB to provide a 7 or 8 dB advantages rather than a 10 dB advantage. If there was no increase in output when the input changed from 65 to 80 dB SPL, you may assume that the FM transmitter has a very low compression threshold. In this case, increase the volume control of the FM transmitter to provide a 5 dB increase of output (giving a 5 dB advantage).

It the user chooses to wear a self-contained system (e.g. earbuds), adjust the characteristics of the environmental microphone to match the settings of the user's personal hearing aid.

A swept tone or speech-weighted noise may be used rather than a 1000Hz pure tone. In this case, the focus should be on the 500-2000 Hz range.

In some systems, there is an automatic reduction of gain in the local microphone when the FM microphone is activated. This feature helps to maintain the signal-to-noise ratio benefits for speech received via the FM microphone. Unfortunately, it also reduces the audibility of other talkers not wearing the FM microphones. If simultaneous use of the FM and local (typically, the hearing aid) microphones is the rule rather than the exception for a given individual, then the adjustment of gain via the local microphone should be made with the FM channel on, but receiving no input.

Current FM microphone transmitters and hearing aids both exhibit some type of compression (typically when input exceeds 72-75dB). This causes difficulty in measuring and validating the FM advantage because it affects the output measurement. Different approaches to this dilemma have been proposed. Appendix B of the ASHA (2000) guidelines listed three criteria for adjusting the FM gain during the simultaneous (FM and hearing aid) inputs: the equal output criterion; the equal gain criterion; and, the +10 dB FM advantage criterion. The equal output criterion was not recommended for simultaneous inputs because there is no SNR advantage (this procedure can be used for 'FM only" verification). The equal gain criterion was partially recommended because it provided an excellent SNR (+17 dB) but caution was expressed because when no speech is present via FM, there would be an increase in noise at the hearing aid microphone. The '+10 dB FM advantage' criterion was recommended as the basis for adjusting gain in the FM channel because it offered a compromise between the limitations of the two earlier criteria and a favorable SNR of +14. The FM advantage is the loudness of the FM microphone relative to the hearing aid microphone. The SNR advantage is the difference of

SNR with and without the presence of an additional component (here, the FM system). The FM advantage can therefore be considered the subjective correlate of the measurable SNR advantage.

The verification of simultaneous inputs remains challenging because typical clinical equipment can only conduct sequential tests that estimate the activity at each microphone separately. Recently, the Phonak Offset Protocol (POP), a manufacturer initiated guideline for verifying simultaneous inputs was announced. Similar to the aforementioned criteria in the ASHA (2000) guidelines, this procedure involves measurements taken in sequential fashion with standard clinical equipment (Platz, 2006). However, this procedure has been compared to results from a rigorous protocol with sophisticated equipment that allowed for Fourier analysis (separation of simultaneous sound source contributions in a complex acoustic signal). The POP calls for a 65 dB input to be delivered to the HA microphone with the FM receiver connected and set to the FM+M (inside test box) and the FM transmitter off (outside test box). The output of the HA at 750Hz, 1 kHz and 2 kHz is noted. Then, the same 65dB stimulus is delivered to the microphone of the FM transmitter (inside test box) and the HA (in also connected and set to FM+M position). The output of the HA at the same 3 frequencies is noted again. The first measurement is subtracted from the second measurement. If the difference or offset between the two measurements lies within +/- 2dB, the FM has achieved acoustical transparency. If the offset value is greater than 2 dB, the recommendation is to reduce the FM gain by the offset value. If the offset value is less than 2 dB, the recommendation is to increase the FM gain by the offset value. It remains to be seen if this procedure has gained or will gain widespread acceptance among FM audiologists. But the POP has been validated by two proofs: 1) the offset is influenced by the parameters of the input at the HA microphone and not by signal processing scheme); and, 2) that the offset remains constant for any FM transmitter, FM receiver and hearing aid (Platz, 2006).

FM System Usage and Satisfaction

Although the audiometric benefit of FM systems is well established, the acceptance of this technology among adults remains low in some studies where the participant had to pay for the device at the end of the trial (Jerger, Chmiel, Florin, Pirozzolo and N. Wilson, 1996; Boothroyd, 2004, M.S. Lewis, Crandell, Valente & Horn, 2004) and exceptionally high where the participant did not incur the expense (Noe, McArdle, Hnath-Chisolm et al. 2004; Hnath-Chisolm, Noe, & McArdle, 2004). At first glance, cost appears to be the determining factor in the decision to retain FM systems. However, other factors such as cosmetics, inconvenience (M.S. Lewis et al. 2004) and level of counseling (Boothroyd, 2004; Noe et al., 2004; Hnath-Chisolm, 2004) complicate the findings.

While most people prefer the sound quality when the FM system was added to their hearing aids, but the overwhelming majority of individuals preferred to wear only their own hearing aid (Jerger et al., 1996). The author concluded that the strong preference for conventional hearing aids in everyday life "undoubtedly reflects the fact that elderly users usually are not willing to endure the difficulties associated with the use of remote-microphone systems" if such systems involve a relative large transmitters and receivers with their respective microphone and coupling wires.

Sanford and Kierkhaefer (2002) evaluated the subjective benefit of Phonak Microlink system in 28 adults with various BTE hearing aids and degrees of hearing loss. After a 3-5 week trial, participants were asked to rate nine listening situations with hearing aid only and hearing aid and FM on a 4 point Likert scale: 1) poor, 2) fair, 3) good, and 4) excellent. All participants reported that the addition of the FM improved their self-perceived hearing ability. Twenty of the

28 participants elected to purchase their FM system at the end of their trial. The participants who purchased the FM reported greater benefit (1.2 point improvement) than those who did not (.5 point improvement) in the four most difficult listening situations. This finding may be statistically significant, but an analysis was not reported. It was also unclear if the both groups identified the same situations as being most difficult.

In the Boothroyd (2004) field study, all participants reported some or considerable overall perception of benefit. The questions were designed to identify difficult listening situations and their importance to the subject (if they experience those situations). The following situations were described: 1) one person in quiet at a distance; 2) one person in noise at a distance; 3) in the car; 4) one person in noise close; 5) watching TV; 5) in a meeting (including church); 6) in a restaurant; 7) one person in quiet close; 8) listening to the radio, and 9) overall. The responses were ordered: not used, worse, no help, some help, a lot of help. The results after at least two weeks of FM usage showed that there were no situations in which participants felt that the FM system made their communication worse. Benefit was reported as numbered above. Situations 1 and 2 involving distance in quiet and in noise were rated as most beneficial. A quasi-parametric procedure in which numerical values were applied to the categorical/ordinal data: 0 for “no use/no help”, 1 for “some help” and 2 for “a lot of help”. The seven beneficial listening situations were summed. Listening to one person close by and listening to the radio, situations where FM would not be expected to provide benefit were excluded. There was no significant correlation between the benefit metric and pure-tone thresholds, speech perception performance (aided in quiet and noise, FM assisted in noise) and age. Various comments were reported about the FM microphone and typically involved sensitivity to soft sounds and occasional static interference. One complained of localization difficulty and another was uncomfortable asking a friend to wear the microphone. None of the 12 participants decided to purchase the hearing system (FM integrated hearing aid and remote FM microphone). None of the participants, most of who have worn in-the-ear hearing aids, expressed concern over the large size of the hearing aid or the noticeable antenna. Nobody expressed concern about cost. It was not clear if the participants were explicitly asked about these features. The author points out that some situations were not beneficial because the listener did not experience them. They may have altered their lifestyle because of the communicative difficulty this situation posed.   The author concluded that there is, "the need for considerable counseling, instruction and coaching, extended over several sessions, if remote wireless microphones are to become widely accepted as hearing aid accessories by adults with hearing loss" (p.32).

While the need for FM counseling and training seems essential, further investigation into other aspects of the device and the behavior of the device user are needed. For example, if the participants did not want to incur the monetary expense or believe that the device drew attention to them, these questions should have been asked. Furthermore, the benefit data are only reported for post-FM use. The differences between pre- and post- benefit scores would have been informative to factor out the contribution of the non-experimental hearing aids that the individuals were wearing prior to the experimental trial.

Noe, McArdle and Hnath-Chisolm et al. (2004) identified criteria for candidacy of FM systems and Hnath-Chisolm, Noe, and McArdle (2004) reported the outcomes of a 7-week trial of ear-level FM systems that were fit according to those criteria. Forty-three participants from the Veteran Affairs Medical Center (VAMC) in Bay Pines, FL and Mountain Home, TN were enrolled. Of the 43 enrolled, 31 have completed the protocol, 4 were still in the protocol at the time of writing, seven withdrew from the study for various personal reasons and one withdrew because he did not like the FM system. The inclusion criteria included: 1) at least a moderate adult onset hearing loss with no evidence of retrocochlear pathology; 2) at least 6 months of hearing aid experience; 3) dissatisfaction with their current hearing aids in at least one listening environment in which an FM system would be beneficial; 4) appropriate reading and cognitive skills to participate in the study as determined by informal clinical assessment, and 5) no known neurological, psychiatric, or co-morbid disease. Participants were seen in five sessions over seven weeks. In the first session, the hearing aid functioning was verified and initial outcome measures were administered. First, goals for FM usage were established. Participants were asked to identify situations that they most wanted to improve with the use of an FM system. Using the Client Oriented Scale of Improvement (COSI, Dillon, James & Ginnis, 1999) the audiologist categorized each of the open-ended situations identified into the 16 typical listening situations. Seven situations were categorized: one or two people in quiet, one or two in noise, conversation with a group in quiet, conversation with a group in noise, TV/radio at a normal volume, familiar speaker on the telephone and church/meeting. The church/meeting was identified most often as the first listening priority and often as the second (and overall) listening priority. Although the responses were both arranged in a 5-point Likert scale, the degree of change was termed differently between sites. Mountain Home used “degree of improvement” to which the responses included: “worse”, “slightly worse”, no change”, “slightly better”, and “better”. Bay Pines used “final ability” to which the responses included “hardly ever (10%)”, “occasionally (25%), half the time (50%), most of the time (75%), and “almost always (95%). The second outcome measure was 18 selected items from the Communication Profile for the Hearing Impaired (CPHI, Demorest & Erdman, 1987; Erdman & Demorest, 1990). The items asked the respondent to indicate how well they communicate in various situations, in which they responded in a Likert scale from: “1 rarely, almost never”, “ 2 occasionally, sometimes”, 3 “about half the time”, “4 frequently, often” and usually, almost always”. The third outcome measure administered was a group of selected items from the Marketrak surveys (Kochkin 2000, 2003) to assess hearing aid satisfaction in specific listening situations and device features. Respondents were asked to rate “very dissatisfied” to “very satisfied” in 12 situations: one-on-one, small groups, large groups, outdoors, concerts, worship, TV, music, leisure activities, restaurants, cars and telephones. Another question was added to the Marketrak survey, “How often do you find yourself embarrassed, ridiculed or rejected because you wear an FM system?”. Participants returned a week later for the second session when they were fit binaurally with the Phonak Microlink FM system. The transmitters included the TX2 (body worn with lavaliere microphone), TX3 (Handymic hand held unit), and TX4 (TV/phone) and were dispensed according to communication needs. The MLx and ML8 ear-level receivers were used depending on hearing aid compatibility (analog and digital). The FM was fit and verified with real ear measures according to the method described by Hawkins (1984). Educational instruction was provided in writing (with picture support) and verbal instruction on how to use the FM systems according to their respective goals. Participants returned at 2 week intervals (sessions 3-5) to report their perceived performance in achieving their listening goals and to receive additional instruction as needed. At the end of the 6 week trial, mean perception of hearing ability was significantly better (“better” or “much better”) in all 7 situations identified by the COSI ($p<.05$). The mean CPHI score increased one point with the addition of FM (hearing aid only = 2.44, hearing aid with FM = 3.44, $p< .00005$). There was an improvement in Marketrak satisfaction across all listening situations and a statistically significant improvement in small groups ($p < .000$), worship ($p< .005$), T> ($p < .002$), restaurants ($p < .02$), cars ($p < .02$), and telephones (p

<.000). The device feature items pertaining to cosmetics ("visibility to others" and the embarrassment-ridicule-rejection item both showed that 90% were satisfied with these aspects. Of the 31 participants who completed the study, all decided to keep their FM system. Participants were also asked at the end of the trial how much they would be willing to pay for the FM system had it not been provided free of charge. Using an anchor of hearing aid cost ("about $4000 a pair") the participants indicated that they would be willing to pay approximately $2300 for the FM system. The high level of acceptance could be attributed to several factors: the FM systems were provided at no personal cost to the participant; the participants received rigorous counseling, coaching and instruction; the device has reached a level of acceptability in terms of cosmetic appearance, ease of use or performance (M.S. Lewis, Valente, Horn and Crandell (2005) used the complete version of the CPHI on the sample of 23 participants described in Site II of M.S. Lewis et al. (2004). The CPHI is a 145-item self-assessment inventory that measures hearing handicap, adjustment to hearing loss, and communication strategies. There are 25 subscales that are categorized in four areas: 1) communication performance; 2) communication environment; 3) communication strategies; and 4) personal adjustment. Responses are arranged in 5-point Likert ordering on a continuum of frequency of agreement/disagreement. The sample was randomized into hearing aid only and hearing aid plus FM groups. There was crossover of experimental groups at 3 months. The interviewer did not fit the participants and was thus blinded from knowing group assignment. Note: The Phonak Claro 311 daZ BTE with ML8 matching receivers were used. These units have the streamlined design that was mentioned earlier in this paper. The FM receivers were actually attached in the hearing only mode but the FM was not activated. The CPHI was administered at baseline (hearing aid only) and once per month during the hearing aid plus FM experimental condition. Repeated measures ANOVA

showed statistically significant differences between the hearing aid only and hearing aid plus FM group for the following subscales: 1) importance of communication at work; 2) importance of communication at social situations; 3) importance of communication at home; 4) problem awareness; 5) behavior of others 6) verbal strategies and 7) stress. Communication partners made less accommodations and participants used less verbal strategies with the utilization of FM amplification. Despite statistical significance, all but one subscale (work) failed to reach clinical significance because the differences did not exceed the 90% confidence interval established in the original sample of 101 active duty military (Demorest & Erdman, 1988). The fact that many of the adults were older (retired) made the significance in the work subscale questionable. None of the 23 participants elected to purchase the hearing system. The difficulties that were reported were: 1) expense 2) inconvenience (e.g. need to charge the transmitter each night); 3) cosmetic issues (e.g. need to point the transmitter near the mouth of the talker).

It remains to be seen if the use of extensive counseling and coaching with the cosmetically advanced devices may have an impact on the penetration of FM technology into the population of adult hearing aid wearers. When factoring in personal expense, only one study (Sanford and Kierkhaefer, 2002) reported a substantial uptake rate (>70%). Perhaps their clientele enjoyed a greater socioeconomic status. While market influences are beyond the scope of this paper, further investigation of satisfaction and benefit in multiple dimensions via subjective measures in this population is needed.

Outcome Measures

The World Health Organization convened a group of experts known as the International Classification of Functioning, Disability and Handicap (or ICF) to provide a unified and standard language and framework for the description of health and health-related states (WHO, 2001). There are two broad domains, one stated in a positively grammatical sense, “functioning” and another that take on a potentially negative connotation, “disability”. Functioning encompasses all body functions, activities and participation. Disability encompasses all impairments, activity limitations or participation restrictions. Impairments refer to problems with body function or structure such as a significant deviation or loss. Activity refers to the execution of a task or action by an individual. Participation refers to involvement in a life situation. Within the framework, functioning and disability domains also interact with environmental (external) and personal (internal) factors.

Validity refers to the approach of measuring whether a scale measures what it purports to measure. In other words, do the quantifiable constructs tell you something about a concept? Responses to the outcome measures described in the following section are the primary data sources in the proposed study. However, audiometric data (e.g. degree and configuration of hearing loss) demographics (e.g. age, socioeconomic status, etc) and medical history (e.g. previous hearing aid usage etiology) information will also be important factors to consider when interpreting the scale values. The goal in audiologic rehabilitation is to maximize the functional abilities associated with hearing loss. Clearly that involves more than the provision of a hearing aid to “make things louder”. Audiologists must also take into account these non-audiological factors. Vanity, for example, is a very prominent barrier to providing appropriate amplification. If a young man is not willing to wear a BTE hearing aid because he fears being embarrassed and stigmatized, that issue needs to be addressed. Some audiologists may take a cognitive approach to counseling and would respond that without amplification, the concerned person might be more embarrassed and stigmatized for a different reason; that the effects of the hearing loss are more apparent than the sight of the hearing aid. If an elderly woman can be fit audiologically with a completely in the canal (CIC) hearing aid, but she cannot insert and remove the device because of limited manual dexterity, the audiologist has failed to maximize her functional ability.

There are a number of converging constructs that may lead to the valid measurement of hearing benefit: age; years with hearing loss with and without amplification; hours of daily use; subjective ratings of device satisfaction; severity of hearing loss; activity requirements, etc. Investigation of seemingly generic variables may also lead to the development of operational constructs that are sensitive detecting a change. For examples, you might not expect to see a relationship of inter-ear differences in speech perception scores, hearing loss by gender, or inland vs. coastal dwellings. When operational constructs are identified, the relationship to the latent variable may be supported. In the previous examples, such operational constructs could be the detection of lesion in corpus colosum (physiological), a history of noise exposure (occupational), and the common report of wind noise interference to the hearing aid microphone (environmental) respectively.

In the proposed study, it is believed that the following outcome measures validly assess the dimensions involved with using an FM system. It is believed that the worship specific items on these outcome measures validly assess the dimensions involved with using an FM system in a place of worship.

Abbreviated Profile of Hearing Aid Benefit (APHAB)

The Abbreviated Profile of Hearing Aid Benefit (APHAB) is a scale that examines the disability (or activity limitation) domain specifically. Developed by Cox and Alexander (1995), it is a 24-item scale with four sub-scales: 1) Ease of Communication; 2) Reverberation; 3) Background Noise; and 4) Aversiveness to Sound. The items include phrases or sentences to which there is a 7-point Likert response scale indicating how often each situation is experienced: always (99%), almost always (87%), generally (75%), half-the-time (50%), occasionally (25%), seldom (12%) and never (1%). There is a response column for both unaided and aided conditions. The difference score between unaided and aided is referred to as the benefit provided by the hearing aid. Each subscale contains an average of the responses for 6 items with item values corresponding to the percentage of time the situation is experience. To minimize response bias, 6 items have been phrased in a positive communication context and 18 in a negative communication context. The responses for all items remained the same. Prior to data analysis, the 6 positive item values are reversed before the subscale score is calculated (APHAB Scoring Instructions, 2006). Scores range from 1%-99%.

The APHAB was normed on 128 elderly, experienced, successful hearing aid users (defined as wearers for greater than four hours per day) with mild-to-moderate sloping or flat sensorineural hearing loss (Cox & Alexander, 1995). It typically takes 10 minutes or less to complete. The APHAB was developed from the 66-item Profile of Hearing Aid Performance (PHAP) and Profile of Hearing Aid Benefit (PHAB) (Cox & Gilmore, 1990; Cox & Rivera, 1992). Item total correlations of the original PHAB subscales were conducted in aided, unaided and benefit scores to reduce the number of items to 6 per category. Test-retest reliability was assessed with comparisons from the same items with a previously administered PHAP (Coz & Gilmore, 1990) and sister measure PHAB (Cox & Rivera, 1992). The correlations for unaided subscales ranged from .65 to .80 with the APHAB (there were no unaided measurements with PHAP or PHAB). The correlations with the aided subscales ranged from .77 to .84 with the PHAP and .70 to .81 with the APHAB. The correlations of benefit (difference scores) scales ranged from .54 to .72 with the PHAB and .48to.71 with the APHAB. The lower correlations of the benefit subscales were expected because of the combined random error with both unaided and aided scores (Cox and Alexander, 1995). Corrected item total correlations ranged from .54

to .66, indicating homogeneity within each subscale (Cox & Alexander, 1995). Cronbach's alpha scores ranged from 0.78 to 0.97 indicating fairly high internal consitency (Cox & Alexander, 1995).

Glasgow Hearing Aid Benefit Profile (GHABP)

The Glasgow Hearing Aid Benefit Profile (GHABP) is an audiological outcome measure that measures both activity limitations and disability/participation restrictions in the same scale. The GHABP was designed to evaluate the efficacy of aural rehabilitation services for adults with hearing loss (Gatehouse, 1999). Four of which situations include: 1) listening to the television with other family or friends when the volume is adjusted to suit other people; 2) having a conversation with one other person when there is no background noise; 3) carrying on a conversation in a busy street or shop; and 4) having a conversation with several people in a group. There are four items in which the respondent can write in the listening situations that are specific to their needs. Questions are formulated in each of the following dimensions: 1) initial disability (How much difficulty do you have in this situation?); 2) handicap (How much does any difficulty in this situation worry, annoy or upset you?); 3) reported hearing aid usage (In this situation, what proportion of the time do you wear your hearing aid?); 4) reported benefit (In this situation, how much does your hearing aid help you?); 5) residual disability (In this situation, with your hearing aid, how much difficulty do you now have?); and 6) satisfaction (For this situation, how satisfied are you with your hearing aid?). For each situation, the respondent is first asked if the event occurs in their life, to which they can reply: no or yes. If it does not apply, all subsequent questions for that situation are omitted from analysis. The collection of data for frequency of occurrence in these lifestyle events can serve as an indirect measure of situation specific usage of amplification; only the pertinent environments are assessed. The responses for each of the seven questions within each situation are arranged in Likert fashion and include a choice “0) N/A” for instances where the item may occur only infrequently and/or is an event that s/he does not consider to be. Five additional response choices are included that are relevant to each scale dimension. For example, the responses for question one (initial disability) include: 1) no difficulty; 2) only slight difficulty; 3) moderate difficulty; 4) great difficulty; 5) cannot manage at all. The responses are coded in the same order with discrete values 1-5. Items for each scale are average by the number of applicable responses and converted to a 0 to 100 range (by subtracting one and multiplying by 25) (GHABP Information Package, 2006).

The GHABP was normed on 293 adults (median age = 69 years) and has a block matrix design in which a variety of listening situations were used. The GHABP was derived from the Hearing Disability and Aid Benefit Interview (HDABI, Gatehouse, 1999), a scale that contained 14 listening situations. The method to reduce the number of items without loss of discriminatory power was to rank difficult listening situations according to frequency of occurrence (for the whole population) and importance of listening in the given situation (for the individual) without duplication. For criterion analysis, the assumption was made that increased perceptions of improved outcome of those with hearing loss should be systematically related to increasing improvements in the audibility of the speech signal as measured by the Speech Intelligibility Index (SII). Multiple comparison analyses of the 14 listening situations were analyzed. The four specified 4 situations with the highest statistical power and four open-ended situations were used in the final version of the GHABP. The reduction of situations resulted in only a minor loss of discriminatory power.

The assumption was made that situations that were not specified would be specified by the user according to importance. All respondents included at least one open-ended situation, 89.8% included at least two, 80.2% included at least three and 65.9% included four situations in addition to the pre-specified situations. Of the open-ended situations, ‘listening in church’ was listed by 33.2% of the respondents, second overall only to ‘listening on the telephone’ cited buy 35.2% of the respondents. Examination of the order of responses to the open-ended situation revealed that the ‘listening in church’ situation was ranked third as the first response (12.3%), third as the second response (9.6%) and first as the third response, and never as the fourth response. If the assumption is made that the order of responding to open-ended questions reflects precedence of perceived need, then ‘listening in church’ might be considered one of the top priorities for auditory rehabilitation in the normative sample.

The internal reliability of the GHABP is high (alpha > 0.7) but the authors warn that in may be inflated because the structure of the measure identifies situations that exist only in a listeners experience and are of relevance. Test re-test reliability assessed at three weeks show high correlation (all greater than r = .86). The validity assessment of the GHABP could not be assessed because there is no similar measure that has subscales that are similar to the dimensions measured.

Glasgow Benefit Inventory (GBI)

The Glasgow Benefit Inventory (GBI) is a measure that assesses the effect of an intervention on quality of life. The questionnaire consists of 18-items which allows for comparison across health conditions because it is generic in nature (“hearing aid fitting” or “FM fitting” ” may be substituted for “operation/intervention”). The pilot version of the GBI consisted of 38 items that were based on interviews with patients and surgical staff. Questions that were condition specific and difficult to understand were eliminated and the GBI was reduced to 18 questions. Factor analysis using principal components extraction with orthogonal rotation and yielded a three-factor solution that explained 69% of the variance. Each factor represented a loading coefficient above .55. The three factors make up the GBI 3 subscales: a general subscale

(12 questions, numbers 1, 2, 3, 4, 5, 6, 9, 10, 14, 16, 17, and 18); a social support subscale (3 questions, numbers 7, 11 and 15) and a physical health subscale (3 questions, numbers 8, 12, 15).

The questions for the GBI are as followed: 1) Has the result of the operation or intervention* affected the things you do? 2) Have the results of the operation/intervention* made your overall life better or worse? 3) Since your operation or intervention*, have you felt more or less optimistic about the future? 4. Since your operation or intervention*, do you feel more or less embarrassed when with a group of people? 5) Since your operation or intervention*, do you have more or less self-confidence? 6) Since your operation or intervention*, have you found it easier or harder to deal with company? 7) Since your operation or intervention*, do you feel that you have more or less support from your friends? 8) Have you been to your family doctor, for any reason, more or less often, since your operation or intervention*? 9) Since your operation or intervention*, do you feel more or less confident about job opportunities? 10) Since your operation or intervention*, do you feel more or less self-conscious? 11) Since your operation/intervention*, are there more or fewer people who really care about you? 12. Since you had the operation or intervention*, do you catch colds or infections more or less often? 13. Have you had to take more or less medicine for any reason, since your operation/intervention*? 14. Since your operation or intervention*, do you feel better or worse about yourself? 15. Since your operation or intervention*, do you feel that you have had more or less support from your family? 16. Since your operation/intervention*, are you more or less inconvenienced by your health* problem? 17. Since your operation or intervention*, have you been able to participate in more or fewer social activities? 18. Since your operation or intervention*, have you been more or less inclined to withdraw from social situations? For each quality, responses are arranged in a quantitative Likert fashion ranging from: 1) Much worse; 2) A little or somewhat worse; 3) No change 4) A little or somewhat better; and 5) Much better. To control for response bias, half of the questions are arranged from a large improvement to a large deterioration. The five ordinal responses are coded with discrete values 1-5 and converted to a range of –100 to +100 (averaging the responses, subtracting 3 and multiplying this value by 50) (Glasgow Health Status Questionnaire Manual, 2006).

The GBI has been used to assess the following otorhinolayngological interventions in Scotland: middle ear surgery to improve hearing (n=181), cochlear implantation (n=184), middle ear surgery to eradicate ear activity (n=138), rhinoplasty (n=96) and tonsillectomy (n=61) (Robinson, Gatehouse & Browning, 1996). Each intervention had a different criterion for defining a success varied between each intervention (e.g. tonsillectomy success meant sore throat was better or cured).

The GBI has since been used extensively in otoloaryngological interventions since its inception, including: quality of life studies (Morzaria, Westerberg, & Anzarut, 2003); middle ear implantation (Sterkers et al., 2003); bone-anchored hearing aids (McLarnon, Davison, & Johnson, 2004); Hol Bosman, Snik, Mylanus, & Cremers, 2005; cochlear implantation (Lassaletta, Castro, Bastarrica,de Sarria, & Gavilan, 2005); tumor surgery (Eikelboom, Eager, & Atlas, 2005; Myrseth et al., 2005; Subramaniam, Eikelboom, Eager, & Atlas, 2005); septum surgery (Konstantinidis et al., 2003; Konstantinidis, Triaridis S, Triaridis A, Karagiannidis & Kontzoglou, 2005; Uppal, Mistry, Nadig, Back, & Coatesworth, 2005); sinus surgery (Mehanna, Mills, Kelly, & McGarry, 2002; Salhab Matai, & Salam, 2004) and surgery to treat snoring (Uppal, Nadig, Jones, Nicolaides, Coatesworth, 2004) .

Hearing Handicap Inventories (HHI)

There are two versions of the Hearing Handicap Inventory (HHI), one for the Elderly (HHIE) (Ventry & Weinstein, 1982) and another for adults (HHIA) (Newman, Weinstein, Jacobson, & Hug, 1990). Both are 25-item measures designed to assess the perceived emotional and social/situational consequences of activity limitations resulting from hearing loss which are not apparent from the audiogram. Perceived handicap is an important measure because it emerges as a construct that is separate than more ojective measures such as hearing sensitivity, speech perception and central auditory processing (Jerger & Chmiel, 1997). They have high internal consistency and high test-retest reliability. They are relatively easy to administer, score and interpret. For each item the responses are: yes (4 points), sometimes (2 points), and no (0 points). Therefore, scores range from 0 (no handicap) to 100 (significant perceived handicap). The HHIA was slightly modified from the HHIE to assess adults less than 65 years of age (Newman, Weinstein, Jacobson, & Hug, 1990). Three items were changed in the HHIA: one emotional question regarding occupation, one social question regarding occupation, and one social question regarding leisure activities. Both scales take 10 minutes or less to complete.

Initial development of the HHIE items was generated by questions from five audiologists in various clinical settings with experience working with older adults. They intended to identify situational difficulties in their patients and probed the effect the difficulty had on limiting or reducing the involvement of the individual in these situations (Ventry & Weinstein, 1982). A total of 42 items comprised the original version. Preliminary data collection on 42 participants (> 65 years) generated reliability coefficients were .93 for the emotional subscale, .83 for the social/situational subscale and .24 for the sensitivity subscale. A few items in each group were eliminated due to low inter-item and item total correlations and those with a high rate of "not applicable" responses. Due to a low reliability coefficient, all but two items on the sensitivity subscale were eliminated. Multiple regression analysis revealed two items from the sensitivity subscale that contributed significantly toward the overall variance and were incorporated into the final version: one social item and one emotional item. The final version of the HHIE comprised a 25-item scale with a reliability coefficient of .95 including a 13-item emotional and 12-item social/situational subscales with reliability coefficients of .93 and .88 respectively.

A subsequent study on mode of administration showed that reliability was maintained in face-to-face (r = .96) and pencil-and-paper (r = 0.84) formats (Demorest and Walden, 1984). Demorest and Walden conceded that if the HHIE was to be used as an index of change due to an intervention, it should have low standard error. Test-retest reliability at 6 weeks was evaluated in a sample of 27 elderly adults with hearing loss and 95% confidence intervals were calculated to determine the necessary change in HHIE scores for such an attribution to occur (Weinstein, Spitzer & Ventry, 1986). The face-to-face and paper-and-pencil versions resulted in confidence intervals (and standard errors) of 18.7% (SE = 6.6) and 36% (SE = 13) respectively. Therefore, the required difference in HHIE score to attribute a true change with 95% confidence using the written administration is approximately double of the verbal administration. Audiometric data were not reported in the Weinstein et al, 1986) article, but the authors caution that there may have been lesser variability in the verbal administration because of yea or nea saying; the respondent may have offered more consistent responses because the question was misheard. In such a situation, it is plausible that the respondent elected repetition instead of requesting clarification prior to responding. The recently cited critical difference for paper-and-pencil administrations is 19.2% (Weinstein, personal communication 2006) indicates that these constructs leading to the measurement of handicap have long term stability (only a .5% difference since 1986).

The HHIE has shown significant differences in hearing aid outcomes at 3 weeks (Malinoff & Weinstein, 1989) and at one year post-fitting (Newman & Weinstein, 1988).

Twenty-two of the 25 questions between the HHIE and the HHIA are identical. Three questions have been modified. In the HHIE, the following questions were targeted for change: 1) Does a hearing problem cause you to feel "stupid" or "dumb"? 2) "Do you have difficulty hearing when someone speaks in a whisper? and 3) "Does a hearing problem cause you to attend church services less often that you would like?. Instead, the HHIA omitted the above questions and included the following: 1) Does a hearing problem cause you to feel frustrated when talking to coworkers, clients, or customers? 2) Does a hearing problem cause you difficulty in the movies or theater? and, 3) Does a hearing problem cause you difficulty hearing/understanding coworkers, clients or customers?.

The balance of 13 emotional and 12 social questions remains the same between versions. The HHIA has high internal reliability with a Cronbach's alpha value of .93 for the entire measure, and .88 and .85 for the emotional and social subscales respectively (Newman, Weinstein, Jacobson, & Hug, 1990a). The HHIA has high test-retest reliability with Pearson product-moment correlations of .97 for the entire measure and .93 and .95 for the emotional and social subscales respectively (Newman, Weinstein, Jacobson, & Hug, 1990b).

The combination of HHIE and HHIA items will be called the Hearing Handicap Inventory (HHI), a 28-item collection that administered to all adults and analyzed according to their age (above and below age 65) and compared to their respective version (HHIE or HHIA).

Psychosocial Impact of Assistive Technology Scale (PIADS)

The Psychosocial Impact of Assistive Technology Scale (PIADS) was developed as an outcome measure to investigate the reasons for abandonment of assistive devices (Day & Jutai, 1996; Day, Jutai, Woolrich & Strong, 2001). The 26-item measure was developed on two premises the authors believed were central to retaining an assistive device: 1) that the assistive device (AD) improves function, and, 2) that the AD must function to improve the quality of life of its adopter. The authors make the distinction between these two effects because although a user may be satisfied with the AD, they may be unhappy overall with the AD for other reasons (e.g. they are embarrassed when using the device).

Device abandonment presents a monetary concern from a service delivery standpoint. Identification of recipients who retain and use their devices may be critical for appropriate spending from the perspectives of public and private service providers (Phillips & Zhao, 1993). The assumption had been that adoption of a working AD, not necessarily an appropriate AD, contributed to an improvement in quality of life. Vash (1983) noted that personality, motivation, perceived and desired roles, and the amount of effort expended in using ADs compared to the rewards experienced in using them, are psychosocial factors that appear to affect satisfaction.

There existed no widely known mechanism to operationalize or measure the constructs toward AD satisfaction that were centered on sustaining an improvement in quality of life (Day & Jutai, 1996). Through focus groups of people with disabilities, constructs were devised and tested on a sample of eyeglass and contact lens wearers. Item analysis reduced the number of items based on extreme distribution and redundancy. To account for the potential for a negative impact on an individual's quality of life, the scale was revised to reflect a bi-directional Likert type scale ranging from –3 (decreases) to +3 (increases) points. There are three subscales that comprise the overall PIADS score: the competence subscale (which reflects items such as productivity, usefulness, performance and independence); adaptability (which reflects items such as ability to participate, willingness to take chances and eagerness to try new things); and the self –esteem subscale (which reflects items such as emotional health and happiness). Each subscale derives a score from -3 to +3. To control for response bias, one item in each scale was reversed and these items are adjusted before averaging scores.

The directions state: “Each word or phrase below describes how using an assistive device may affect a user. Some might seem unusual, but it is important that you answer every one of the 26-items. So, for each word or phrase, put an “X” in the appropriate box to show how you are affected by using the (device name)”. The items include the following words/phrases: 1) competence 2) happiness; 3) independence; 4) adequacy; 5) confusion; 6) efficiency; 7) self-esteem; 8) productivity; 9) security; 10) frustration; 11) usefulness; 12) self-confidence; 13) expertise; 14) skillfulness, 15) well-being, 16) capability; 17) quality of life; 18) performance; 19) sense of power; 20) sense of control; 21) embarrassment; 22) willingness to take chances; 23) ability to participate; 24) eagerness to try new things; 25) ability to adapt to the activities of daily living; 26) ability to take advantages of opportunities. The PIADS can be completed in 5-10 minutes.

The PIADS has shown high internal consistency with a Cronbach's alpha values of .95 for the total scale. The reliability of each subscale was also high as alpha coefficients were .92, .88, and .87 for competence, adaptability, and self-esteem respectively (PIADS manual version 4.21, 2006; Scherer, 1996; Day, Jutai & Campbell, 2002; Demers, Monette, Descent, Jutai & Wolfson, 2002. These values indicate that the three constructs mentioned above represent a large proportion of the latent variable of interest, psychosocial impact. The PIADS has shown high test-retest reliability (Scherer, 1996; Jutai & Campbell, 2002; Demer, Monette, Descent, Jutai & Wolfson, 2002) demonstrating temporal stability within the measure. The PIADS is also sensitive to device stability in that the effect of the AD intervention shows long-term repeatability (Scherer, 1996; Jutai & Day, 2000; Day, Jutai & Campbell, 2002). The PIADS has been used as a generic outcome measure for hearing aid trials (Jutai & Saunders, 2003; Jutai & Saunders 2003; Jerger, 2004; Saunders & Jutai, 2004).

Concurrent validity of the PIADS was assessed on a sample of 157 eyeglass wearers with the Pleasure, Arousal and Dominance (PAD) (Mehrabian & Russell, 1974), a measure used to evaluate emotional responses to a diversity of conditions. The Pearson correlation coefficients were significant ($p < .05$) for the pleasure ($r = .46$-$.59$)and dominance ($r = .21$ to $.34$) subscales, but not the arousal subscale ($r = .06$-$.17$). These correlations indicate that the PIADS and the PAD may theoretically predict the relationship of one another. Construct validity was evaluated using principal components analysis. From a sample of 307 subjects with eyewear devices, the three sub-scales account for 61.1% of the variance (Day & Jutai, 1996).

Spiritual Well-Being Scale (SWBS)

The Spiritual Well-Being Scale (Paloutzian & Ellison, 1982; Ellison, 1983) was developed as a global psychological measure of one's perception of spiritual well-being. The authors borrowed terminology from Moberg and Brusek (1978) and developed a scale based on two dimensions: a vertical dimension that refers to one's sense of well-being in relationship to God and a horizontal dimension that refers to one's perception of the purpose of life and life satisfaction apart from any specifically religious preference. The two sub-scales were based on these concepts: the former dimension was conceptualized as religiosity spiritual well-being and the latter dimension as existentiality. Collectively, the total score is intended to reflect the construct of spirituality.

An independent review contended that the SWBS is not a measure of spiritual health or spiritual maturity (Boivin, Kirby, Underwood & Silva, 1999). The SWBS is a psychological, rather than theological measure that is nonsectarian and can be used in a variety of religious, health and research contexts (Boivin et al., 1999). The 20-item scale consists of evenly divided items that are believed to measure religious and existential dimensions. The items in the religious subscale mention "God" in the item. The items in the existential subscale do not mention "God", instead asking about life purpose, satisfaction and relations with other people and situations. Each Item is rated in a 6-point Likert scale ranging from: SA "strongly agree"; MA "moderately agree"; A "agree"; D "disagree", MD "moderately disagree" and SD "strongly disagree". Approximately half of the items are worded in a reverse direction so that disagreement with the item reflects higher well-being. Point values range from 1-6 with the higher number representing higher well-being. The range is 10-60 points per subscale and 20-120 total. It takes about 10-15 to complete.

The SWBS was normed on 206 college student and additional studies employing over 500 of various age, gender and geographical representations. Subsequent investigations have used the SWBS on participants with various physical and mental disorders. The internal reliability, based on data from over 900 participants, ranged from .89-.94 for the total score, .82-.94 for the religious subscale and .78 to .86 for the existential subscale (Boivin et al, 1999). Test-retest reliability coefficients for four different samples with 1, 4, 6 and 10 weeks between administrations ranged from .82-.99 for the total SWBS, .88-.99 for the religious subscale and .73-.98 for the existential subscale (Boivin et al., 1999). The vertical/religious and horizontal/existential approach to conceptualizing the construct of spirituality appears to be valid. An initial factor analysis revealed that all religious items loaded on the religious factor and most existential items loaded on the existential factor (Ellison, 1983). The scores on the SWBS have been positively correlated with measures of physical well-being such as ideal body weight and perceived health and negatively correlated with pain (frequency, intensity and duration) (Granstrom, 1987).

CHAPTER 3
METHODS

Research Question

The goal of this study was to determine if a six month trial period with a large area frequency modulation (FM) system had an impact on individuals with hearing impairment who desired to hear better in their place of worship by using an FM device. Specifically, the impact, if any, was assessed in self-reported measures of: 1) auditory functioning (disability/activity limitation and handicap/participation restriction); 2) health related quality of life; 3) psychosocial impact to assistive devices, and 4) spiritual well being. It is hypothesized that usage of an FM system in addition to current amplification with hearing aids will improve each of dimensions that are measured with their respective metrics. In this experiment, it is expected that only items related to the place of worship will exhibit the increase in score. Therefore, the specific hypothesis for this study is that the FM users in this study will show significant increases in their scores pertaining to worship related items. Worship related items include: items 18 and 21 of the Abbreviated Profile of Hearing Aid Benefit (APHAB), the customized listening situations (discussed later) on the Glasgow Hearing Aid Benefit Profile (GHABP); item S11 on the Hearing Handicap Inventory for the Elderly (HHIE); and, all items on the Spiritual Well-Being Scale (SWBS). The remainder of items in the previously listed measures, all items on the Glasgow Benefit Inventory (health-related quality of life) and Psychosocial Impact of Assistive Devices (PIADS) measures are expected to show increases in mean scores, but are not expected to reach significance as they are more generalized, global measures.

Pilot Investigation

To estimate current usage and potential need of assistive listening devices (ALDs), a self-addressed, stamped envelope was mailed with a letter and questionnaire to the 227 places of worship in the Gainesville area listed in the yellowpages.com (accessed 9/1/05) website with complete, unduplicated addresses. The letter briefly explained about ALDs and their function. The questionnaire portion of the mailing asked about the representative's general knowledge and provision of ALDs, the estimated physical dimensions of place of worship, and a description of the listening experiences of the members including how many were reported difficulty. The questionnaire was anonymous. Of the 227 letters sent, 27 were returned from the postmaster as undeliverable. Of the 200 mailings, 43 were returned for a response rate of 21.5%. One questionnaire was omitted from the analysis because most questions did not contain responses.

The results of the pilot investigation are summarized in Table 3-1. In the 42 completed questionnaires, 40 of 42 (95.2%) respondents reported the provision of an amplified public address (PA) system during their services. Sixteen of the 40 (38.1%) places of worship with a PA system also reported having assistive listening devices (ALDs). Of the 16 places of worship with ALDS: 11 (68.8%) described the ALD as an FM system; 3 (18.8%) did not know or specify the type of ALD; and 2 (12.5%) described the ALD as an infrared system.

Among all 42 respondents: 33 (78.8%) reported awareness of ALDs; 7 (16.8%) reported no awareness of ALDs; and 2 (4.8%) reported being "somewhat aware". The two respondents that did not have a public address system also reported being unaware of ALDs.

When asked if there is a need for ALDs in their house of worship: 24 representatives (57.1%) indicated that there is a need, 9 (21.4%) responded that there is not a need; and 8 (19%) responded that there might be a need. The majority of places of worship surveyed reported awareness/limited awareness (83.3%) and reported need/potential need for ALDs (76.1%). However, only 38.1% reported having ALDs. This finding suggests that places of worship are knowingly not providing the listening accommodations for all of their congregants.

When the respondent was asked if congregants with normal hearing experience difficulty hearing the presenter during the service: 28 (66.7%) believed that they do not experience difficulty; 6 (14.3%) believed that they experience difficulty “sometimes”; 4 (9.5%) believed they experience difficulty; and 4 (9.5%) were “not sure” if they experience difficulty. When asked if congregants with hearing impairment experience difficulty hearing during the service: 16 (38.1%) believed that they experience difficulty; 9 (21.4%) believed they experience difficulty “sometimes”; 9 (21.4%) believed they did not experience difficulty; and 8 (19%) were “not sure” if they experience difficulty. Collapsed into a binary question, the respondents believed that 23.8% of congregants with normal hearing and 59.5% of congregants with hearing impairment have experienced difficulty hearing the service.

Two of the questions were aimed toward estimation of the physical space of the venue. When the respondents were asked to estimate the physical volume inside the main area of the place of worship: 16 (38%) described the space as “medium (20,000-100,000 cubic feet)”; 12 (28.6%) described the space as “small (less than 20,000 cubic feet)”; 7 (16.7%) could not estimate the volume; and 6 (14.3%) described the space as “large (more than 100,000 cubic feet)”. When asked to estimate the seating capacity in the main area of the place of worship: 20 (47.6%) estimated less than 200 people; 12 (28.6%) estimated between 200-399 people; 8 (19%) estimated between 400-799 people; and 2 (4.8%) estimated 800 or more people. The majority of the places of worship in Gainesville were estimated to have physical volumes of less than 100,000 cubic feet (66.7%) and less than 400 people (76.1%).

Correlational analyses were conducted by Pearson chi-square tests. Responses were collapsed into binary responses (“yes” and “maybe” treated as “yes”; and “no” and not sure” treated as “no”). Results of the comparisons are shown in Table 3-1. Four of the 10 relationships were significantly correlated (α = .05). Respondents that reported a need for ALDs were also likely to report that: congregants with normal hearing were perceived to have difficulty during the service; congregants with hearing loss were perceived to have difficulty during the service; and the estimated seating capacity was high in their place or worship. Respondents that reported greater awareness of ALDs were also likely to report that congregants with hearing loss had difficulty during the services. It appears that when the respondents suspect a need for ALDs that they are aware of their existence and that the congregants with different hearing abilities have listening difficulty during the service, particularly when congregating in a larger venue. It is unclear if the congregants were perceived to have residual difficulty when using the ALD because the questionnaire did not probe this dimension.

Main Investigation

Participants were recruited through convenience sampling of various places of worship in Gainesville, FL, a mid-central Florida city of approximately 100,000 (U.S. Census, 2006). Larger facilities were targeted first because they had a greater pool of potential participants and a greater likelihood of adverse acoustical characteristics. An attempt was made to contact places of worship of different faiths and denominations. The Christian and Jewish faiths were represented in the sample. The Islamic faith could not be represented because there was no such place of worship listed in the yellowpages.com search. Each place of worship was contacted via telephone and a representative was identified. The questionnaire data from the previous mailing was not used to identify any potential participants/venues because it was anonymous.

Of the 14 place of worship (PW) contacted, 9 were interested in learning more about the study and 5 declined to participate. Although the representatives were not asked for reasons for declining participation, 3 offered explanations. Two representatives believed that their congregations were preoccupied with atypical activity: one congregation was moving to a different location and the other was participating in a series of retreats. The third representative reported, “we are managing the [FM system] fine. We have a device for people with hearing aids and for people without hearing aids so we don’t need your help”. Of the two PW that declined without reason, one representative simply stated that they were not interested and the other representative did not return phone calls.

A slide presentation was created on Microsoft Powerpoint and burned to digital video disc (DVD) to disseminate information about the research study. The DVD was delivered to each interested representative and they were asked to review its contents.

Interviews with interested representatives were arranged to answer questions, clarify the purpose of the study and arrive at mutual agreement on the terms of the participation. Nine interviews were conducted. One PW declined to participate two weeks after the interview. The representative explained that he polled the congregation informally and determined that there was no interest in participating.

The remaining 8 PW agreed to participate. One PW had only one potential participant and he decided to attend another PW instead, one that had already been enrolled in the study. The participant conveyed that his decision was not made on the basis of the study but that, “it is something we [he and his wife] had been meaning to do anyway so we could join our daughter and her family [at the other PW]”.

A total of 7 PW were enrolled in this study. The participants by place worship are summarized in Table 3-2. Installations of Listen Technologies (LT-800) large area FM transmitters were arranged at the convenience of the representative. The procedure for installing the device is similar to installing a home electronic component (e.g. DVD player) in that there was only a couple of necessary connections: one for the audio input and another for a power supply. The audio input possibilities included: an XLR microphone cable, a ¼ inch stereo connection, or RCA connections. The principal investigator installed four large area transmitters and the remaining three were installed by either the music minister or house manager of the respective PW. Six of the installations used XLR inputs and 1 used a ¼ inch audio input.

The 7 PW that were enrolled in the study included 3 Methodist churches, 2 Catholic churches, 1 Lutheran church and 1 Synagogue. The PW that chose not to participate included 3 Baptist churches, 2 non-denominational Christian churches, 1 Catholic church, and 1 Episcopal church.

All participating PW agreed to allow the CD presentation to be shared with interested members of the congregation during an information session. An announcement was made in the weekly bulletin and an on-site location was reserved. One PW included the information session in their newsletter (Methodist A) and another PW (Methodist B) invited the principal investigator to make announcements during two Sunday services, one week prior to the information session. Five places of worship arranged weekday evening meeting times. One place (Lutheran) reserved time during the day because it facilitated transportation for the primarily senior population. One place (Methodist B) conducted the informational session on Sunday following their most heavily attended service. Meeting attendance varied from one person (Catholic B) to approximately 60 people (Synagogue).

The information session included the same Microsoft Powerpoint slides as the informational CD, projected on screen or white wall. The principal investigator narrated the presentation in person to facilitate speech reading and to offer clarifications to several questions.

The session outlined that each participant may use an FM system for a 6 month trial without any monetary obligation. Those who were current hearing aid wearers at the time of the information session and still perceived difficulty listening to the services in their place of worship were eligible to participate. A sign-up sheet was made available and the potential participants were contacted via their preferred means (phone or email) to schedule a clinic appointment.

The clinic appointments were scheduled for two hours. The average length of each appointment was 2 hours and 15 minutes. At the beginning of the clinic visit, the participant read and signed the Informed Consent form approved by the Institutional Review Board at the University of Florida. A copy of the Informed Consent form was provided to each participant.

An audiological evaluation was performed including: otoscopy, immittance audiometry and pure-tone air/bone conductance audiometry and speech audiometry. These measures reflect functional aspects of outer ear, middle ear, inner ear and central processing respectively (but not exclusively). A medical case history form was also administered.

Video otoscopy (Panasonic video camera GRK 5162, Panasonic power supply #521248, Sony Trinitron monitor) was performed to rule out excessive cerumen and to ensure the integrity of the ear canal and tympanic membranes. None of the participants displayed symptoms of soreness or signs excessive cerumen, inflammation/redness, or perforation of the tympanic membrane. One participant was referred to an otolaryngologist for follow-up because of the presence of glue-like substance in ear canal of one ear.

Immittance audiometry was performed on a Grason Stadler Instruments (GSI) Tympstar immittance bridge. A computer monitor was attached to TympStar for ease of viewing. Immitance testing included ipsilateral (tone presented and measured in same ear) acoustic reflexes at .5, 1, 2, and 4 kilohertz (kHz). If acoustic reflexes were present at .5 kHz or 1 kHz, acoustic decay was measured at the same frequencies. Acoustic decay is the reduction in response magnitude within 10 seconds from a pure tone stimulus presented at 10dB SL (decibels Sensation Level re: acoustic reflex threshold). The presence of decay indicates a positive finding, and would be grounds for exclusion from participating in this study. None of the enrolled participants presented abnormal immittance results.

Pure tone audiometry was performed on a GSI-61 dual channel audiometer. Thresholds were defined as the lowest level at which the participant responded to the presence of a tone 50% of the time. Thresholds were obtained at .25, .5, 1, 2, 4 and 8 kHz. Inter-octave thresholds at .75, 1.5, 3 and 6 kHz were obtained when there was an inter-ear difference of 15 dB or greater at adjacent octave frequencies. Narrow band masking noise was routed to the contralateral ear via the second channel of the audiometer when indicated; when crossover auditory perception was possible.

Speech recognition threshold (SRT) was defined as the lowest level that speech is understood half of the time and was measured using spondaic words (bi-syllabic words with equal stress on each syllable, e.g. toothbrush). Speech perception performance was measured as a percent correct score on the Northwestern University auditory test #6 (NU-6) monosyllabic word lists. The 50-item word lists were spoken by a female talker on a compact disc recording produced by the Department of Veteran's Affairs in Mountain Home, TN (version 2.0, lists 17-24). Fifty words were presented at the most comfortable level (MCL) for each condition. The conditions included: monaural left ear in quiet; monaural right ear in quiet; binaural in quiet; and binaural in noise (pink/speech noise at + 10dB signal-to-noise ratio (SNR). Pure-tone and speech audiometry was performed in a single walled sound booth. Stimuli were routed through Etymotic Research (ER3A) insert earphones or TDH-50P headphones.

A routine professional calibration was performed March 8th, 2006. The technician recommended usage of headphones because the calibration ensured that the impedence of the transducer matched that of the audiometer. Participants evaluated prior to noon on March 8, 2006 used insert earphones and those evaluated afternoon on March 8, 2006 used headphones. Insert earphones were initially used instead of headphones because they are more hygienic, facilitate ease of testing because need for masking is reduced, and avoids erroneous thresholds due to ear canal collapse. To ensure that the insert earphones thresholds were accurate, two individuals (one with normal hearing and one with a moderate to profound sensorineural hearing loss) were tested with both inserts and headphones in the research sound booth and in the regular clinic sound booth. There were no differences in the thresholds obtained; all thresholds were within test-retest reliability (+/- 5 decibels).

FM receiver selection

Following the audiologic testing, the information from the on-site session was reviewed with all 32 participants. All options for coupling FM receivers to hearing aids were discussed and differentiated. The participant was provided a paper handout that listed the advantages and disadvantages of each. The decision matrix included factors such as signal quality, cosmetics and financial considerations for using the device(s) during and after the trial (Appendix A). None of the participants chose Direct Audio Input (DAI).

The participants were reminded (from informational session) that they could purchase, at the end of the 6-month study, any new Phonak FM product available at a significantly reduced cost. One hearing aid model, the Phonak iLink with completely integrated FM, was also included as an option for purchase. This particular hearing aid model was made available because the FM receiver could not be separated from the hearing aid because it was an internal component. Because this unit was primarily a hearing aid with FM as a feature, payment was required at the beginning of the study. However, the standard trial period that allowed the user to return the hearing aid-FM system within 45-days for a full refund (including reimbursement for the purchased earmolds) was extended for the duration of the study. The price quotes for all FM products, including the iLink hearing aid were given only when the participant asked.

Of the 29 participants who completed the study, 23 chose to use an FM system and to participate in the experimental group and 6 chose not to use an FM system and to serve in the comparison group. Of the 23 participants in the experimental group, 12 chose ear level receivers (5 ML8S, 2 iLink hearing aids, 2 ML9S, 2 MLxS, 1 ML4S) and 11 chose belt level receivers (5 earbuds, 3 neckloops, 3 headphones). The selection of receivers is summarized in Table 3-2.

The three participants who chose the iLink hearing aid-receiver were fit by a licensed, certified audiologist. The fittings were conducted at the University of Florida Speech and Hearing Clinic in Dauer Hall. The fitting fee for each of these participants was paid using the research grant, funded by Phonak Hearing Systems. One participant was initially fitted with the iLink but during her hearing aid trial upgraded to a more sophisticated Phonak Eleva behind-the-ear (BTE) hearing aid with ML9S receiver. This participant was the only monaural fit of the sample.

Participants were counseled on how to change between their microphone mode settings. A hearing aid wearer that uses an FM system in conjunction with their hearing aid can choose to have their hearing aid microphone activated, their remote FM microphone activated and both hearing aid and FM microphones activated simultaneously. Suggestions were given on when it might be preferred to change the active microphone settings based on the type of listening situation (Appendix B). A hands-on demonstration was given and the participant was asked to repeat the steps to demonstrate understanding.

The participants were counseled on the appropriate use of the FM system. They were instructed to wear the FM system each week during their worship service(s). Traditional users were given one AA battery and were instructed to replace the battery every 6 weeks. Wireless users were reminded that the receiver will draw more power from the hearing aid battery. Both groups were advised to bring replacement batteries with them to their weekly services.

Enrollment by place of worship

The procedure for advertising the study, enrollment of participants, and selection of receivers are summarized in Table 3-2.

At the Lutheran church, 8 people expressed interest at the session on 2/1/06 and 7 enrolled (5 experimental, 2 comparison). Of the 5 enrolled participants in the experimental group, 3 chose a Microvox belt level receiver (2 with headphones and 1 with neckloop) and 2 chose ear level receivers (ML8S and ML9S). Two participants in the experimental group at Lutheran church dropped out of the study. One participant, who wore ML9S ear level receivers, dropped out because he experienced a serious, unrelated injury and could not attend services. The other individual, who wore the belt level receiver with headphones, dropped out because he lost interest in participating since enrollment.

At Catholic Church A, 7 people expressed interest at the information sessions on 2/5/06 and 2 of them were enrolled (1 experimental, 1 comparison). The participant in the experimental group chose a Microvox belt level receiver with earbuds.

At Catholic church B, 1 person expressed interest at the session on 2/7/06 and was enrolled (experimental) but participant decided to attend Catholic church C instead. Catholic Church B was then dropped from the potential list of study sites. This person was omitted from the final data set because they did not return the 12 or 24 week questionnaire booklet.

At the synagogue, 4 people expressed interest at the session on 2/8/06 and 2 of them were enrolled (one experimental, one comparison). The participant in the experimental group chose a Microvox belt level receiver with a neckloop. The participant in the comparison group initially chose and was fit with MLxS ear level receivers but within the first week, reported too much anxiety about losing them and chose to participate in the comparison group instead.

At Methodist church A, 5 expressed interest 2/9/06 and 4 were enrolled. All 4 participated in the experimental group: 2 wore ear level receivers (ML4S and ML8S) and two chose Microvox belt level receivers with earbuds. The two participants with the ear level receivers were experienced FM users: one for 2 years and the other for 20 years. However, neither experienced user used their FM system during their worship service until this study.

At Methodist church B, 13 expressed interest at the session on 2/26/06 and 10 were enrolled. Of the 10 enrolled participants, 5 chose ear level receivers (2 MLxS, 2 iLinks, and 1 ML9S) and 5 chose belt level receivers (2 earbuds, 2 headphones, 1 neckloop). The participant with the ML9S receivers was fit at the VA medical center in Gainesville during the enrollment period. He was also fit with a Smartlink microphone/transmitter. Two participants were fit binaurally with Phonak iLink hearing aids. One of the iLink users was also fitted with an Easylink microphone/transmitter.

At Catholic church C, 5 people expressed interest at the session on 2/27/06. A total of 6 participants were enrolled (including one participant from former site Catholic B). Five participants elected to be in the experimental group and one elected to serve in the comparison group. Of those enrolled in the experimental group, 3 chose ML8S ear level receivers, one chose a Microvox belt level receiver with earbuds and one withdrew from the study before choosing an FM receiver. The participant who withdrew did not feel comfortable answering the questions on the Spiritual Well Being Scale and cited this reason for declining further participation. The participant in the comparison group decided not to use FM because he developed a strategy to compensate for his hearing difficulty. Because he served as an usher, he was able to position himself near the loudspeaker in the crying room at various times during the service. This member of the comparison group may therefore not be representative as a suitable comparison unit as he no longer experienced listening difficulty.

At Methodist church C, 4 expressed interest at the session on 3/1 and 2 were enrolled in the experimental group. One participant chose to be fit monaurally with an iLink monaural hearing aid but later switched to Phonak Eleva BTE hearing aid with a ML9S receiver and a Smartlink microphone/transmitter. The other participant chose a belt level receiver with neckloop.

Hearing aid adjustments

Current hearing aid settings were downloaded with the HI-PRO hearing aid hardware device and Noah software program and saved with a code (no participant identifiers). If hearing aid adjustments were desired, they were made according to patient preference. Five participants requested changes to their hearing aid programs. Frequency response changes included: a 4 dB increase in high frequency gain; a 2 dB decrease in low frequency gain; and an increase in the compression threshold (kneepoint) for quiet sounds. Program changes included: activation of the telecoil (as T-only) for one participant and activation of the hearing aid microphone in addition to the telecoil (T+M) for another participant. The final program settings were saved to the Noah database with and the hearing instrument.

The three within-program hearing aid adjustments were verified with real-ear acoustic measurements. Using the Audioscan Verifit, the gain and output was be measured in the main program of the hearing aid at soft (55 dB SPL), average (65 dB SPL) and loud (70 dB SPL) inputs of speech weighted noise. This procedure did not assess the gain or output of the FM receiver through the large area transmitter. There are currently no guidelines for evaluating such a system (Thibodeau, 2006 personal communication).

Quality control protocol for verifying large area FM

In effort to validate the electroacoustic variability of a sample of FM receivers used in this study, a quality control protocol of a sample of the equipment was developed. Using the same procedure described in American Speech Language Hearing Association (ASHA, 2000), a sample of 3 Phonak Microvox receivers, 3 Monacor MD-300 headphones and 3 Radio Shack earbuds were randomly selected. Each of nine receiver/coupler combinations were verified at 55, 70, 75 dB sound pressure levels (SPLs) of speech-shaped noise from the Audioscan Verifit real-ear loudspeaker at 2 receiver volume settings (corresponding to dial positions 3 and 6). A Phonak Smartlink microphone transmitter was placed 10 inches from the Verifit loudspeaker. The headphones and earbuds were positioned on the Knowles Electroacoustic Manikin for hearing Aid Research (KEMAR) which was positioned 3 feet from the Verifit loudspeaker. The average output data for the left and right ears have been collapsed. The real–ear outputs at the level of the ear canal for earbuds at volume settings 3 and 6 are presented in Figures 3-5 and Figure 3-6 respectively. The real–ear outputs at the level of the ear canal for headphones at volume settings 3 and 6 are presented in Figures 3-7 and Figure 3-8 respectively. In all four figures, the output lines are not symmetrical which indicates variable operation of a compression algorithm across the frequency range. More importantly, none of the outputs at any frequency exceeded 90 dB SPL in any of the four conditions, which verifies that the sound pressure level in the ear canal is not excessive. Despite this, users of FM systems in this study were instructed to adjust their volumes to a comfortable level.

Questionnaire booklets

A number of relevant self-report outcome measures were compiled into a Microsoft Word document with 14-point size text and Times New Roman font. All measures were printed and tape-bound into booklets. All measures were arranged in a Likert response format that quantifies or orders the attribute being measured. All responses were arranged vertically in the original yet unnumbered order. The questionnaire booklet for the FM group is included in Appendix C. All administrations were written self-reports from each participant. During the initial administration, the investigator was present and provided assistance with completing the forms as needed. Each participant typically had one question or request for clarification. The most common request for clarification occurred during the administration of the Abbreviated Profile of Hearing Aid Benefit (APHAB) when respondents were asked to answer each question in the situation where they are not wearing hearing aids. The respondents reported stated that they are not in these situations without their hearing aids. They were instructed to imagine that they were in that given situation today without their hearing aids and to response hypothetically. The glossary for the items in the Psychosocial Impact of Assistive Devices Scale (PIADS) was also provided during the initial administration to clarify any meaning of definitions used in the measure, as recommended by Pauloutzian and Ellison (1982). Participants were instructed to respond to all items.

Subsequent administrations were also written self-report measures that were nearly identical to the initial administration. The only difference to the repeated measures was the type of amplification. In subsequent administrations, the amplification pertained to the hearing aid and FM system combined. It was identified by a teal booklet cover. If the participant was part of the comparison group, s/he received another copy of the initial administration (beige booklet) that pertained to amplification that was limited to hearing aid only.

The subsequent administrations were mailed to arrive on Monday following the 12th and 24th weekend service. They were asked to complete and return in the postage-paid return envelope prior to their next weekend service.

All clinic administrations referred to outcomes experienced by the participant when using the hearing aid alone. For the comparison group, the mailed versions referred to outcomes experienced by the participant when using the hearing aid alone. For the FM group, the mailed versions referred to outcomes experienced by the participant when using the FM in addition to their hearing aid.

Six participants in the sample used a personal FM system in addition to the large area FM system installed at their place of worship: 3 were fit prior to study enrollment (two with 2 years experience and one with 20 years experience); and 3 were fit during the study (two at baseline and one at approximately 12 weeks). Therefore, 6 participants had additional exposure to the FM signal in addition usage in the place of worship. Three of the 6 personal had cumulative FM exposure prior to the study. Additional analyses were performed on the ‘personal FM’ participants (discussed later).

The outcome measure booklet contained the following measures, in order : the Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox & Alexander, 1995); the Glasgow Hearing Aid Benefit Profile (GHABP) (Gatehouse, 1999); the Glasgow Benefit Inventory (GBI, Robinson, Gatehouse & Browning, 1996); the Hearing Handicap Inventories (Ventry & Weinstein, 1982; Newman, Weinstein, Jacobson, & Hug, 1990); the Psychosocial Impact of Assistive Devices Scale (PIADS) (Day & Jutai, 1996); and the Spiritual Well-Being Scale

(SWBS) (Paloutzian & Ellison, 1982). Where applicable, the terms “hearing aid only” and “hearing aid with FM” were used for their respective versions. The “hearing aid with FM” or experimental version of the outcome measure booklet is included in Appendix C**.**

Adaptations to outcomes measures

The original version of the Glasgow Hearing Aid Benefit Profile (GHABP) was administered at baseline. A revised version of the GHABP reflecting the addition of FM was administered at 12 and 24 weeks. For both versions, a total of 9 listening situations were described: items 1-4 were pre-specified (previously mentioned) and items 5-9 were created specifically to address listening in the place of worship. Recall that in the normative sample, ‘listening in church’ was listed by 33.2% of the respondents, second overall only to ‘listening on the telephone’ cited buy 35.2% of the respondents. It could be assumed that if the number of pre-specified items in the GHABP measure were expanded, an item pertaining to the place of worship would likely be included. Because listening in this situation is commonly reported as difficult and because FM exposure in this investigation is limited to the place of worship, five items have been specified. Item 5 describes, “listening to the main presenter in a house of worship (e.g. pastor, priest, rabbi, etc.)”. Item 6 describes, ‘listening to other presenters in a house of worship (readers, guest speakers, people who make announcements, etc.). Item 7 describes, “listening to music in a house of worship (understanding the lyrics of people singing).” Item 8 describes, “having a one-on-one conversation in a house of worship <u>before or after</u> the service (many people speaking simultaneously).” Item 9 describes, “having a one-on-one conversation in a house of worship <u>during</u> the service (while one presenter is speaking).” For all listening situations, the following domains were investigated: handicap, reported usage, reported benefit, derived benefit (residual disability minus initial disability) and satisfaction. The Abbreviated Profile of Hearing Aid Benefit (APHAB) was administered at baseline. For each item on this administration, the participant was asked to respond as if they were unaided and aided with only their hearing aids. A revised version of the APHAB reflecting the addition of FM was administered at 12 and 24 weeks. For each item on this administration, the participant was asked to respond as if they were aided only with their hearing aids and also aided with their hearing and FM system. Benefit scores were derived by subtracting the aided score from the unaided score. Benefit scores in the positive direction showed the listening difficulty was experienced less often and scores in the negative direction showed that listening difficulty was expressed more often.

In the baseline administration of the APHAB, the 'unaided' response column asked the participants (who were experienced hearing aid users) to state hypothetically the amount of time they would experience difficulty in the given situation without their hearing aids, and the 'aided' response column asked the participants to state how much difficulty they experienced in the given situation with their hearing aids until the time of administration. In the subsequent administrations, 'unaided' reflected amplification with hearing aid only and 'aided' reflected amplification with hearing aid and FM system.

The 28 items from the Hearing Handicap Inventory for Adults (HHIA) and Hearing Handicap Inventory for the Elderly (HHIE) were combined and administered at baseline, 12 weeks and 24 weeks. The 25-item HHIA and the 3 items that differed on the 25-item HHIE version were combined to form the HHI section. However, the HHIA and HHIE were analyzed separately as their original 25-item scales.

For the baseline administration, the intervention in the Glasgow Hearing Benefit Inventory (GBI) was "since your hearing aid fitting". The intervention in the GBI at 12 and 24 weeks was "since your FM system fitting".

For the Psychosocial Impact of Assistive Devices Scale (PIADS), the assistive device was specified as an FM system in the directions.

Compensation/Other Benefit

To enhance participant compliance, the participants were compensated monetarily ($50) at the completion of the study. The place of worship was permitted to keep the transmitter if there was a perceived need. All places of worship were expected to keep their FM transmitters because at least one participant from each venue expressed interest in ongoing use. Participants were sent a letter prior to the completion of the study that gave the purchase price of the receiver(s) if they decided to keep after the trial. Collection of FM items is ongoing so a summary of purchases and returns cannot be completed at the time of this writing.

Analyses

Data were analyzed with the Statistical Package for the Behavioral Sciences (SPSS) statistical analysis software program. For the Stage 1 pilot questionnaire data, Pearson chi-square analyses were run between items for each respondent. The remainder of the analyses was conducted for the Stage 2 main investigation. For each subscale of each outcome measure a within-subjects, a repeated measures Friedman analysis of variance (ANOVA) was performed on all 23 participants in the FM group to determine if there are any differences between scores at pre- (baseline), mid- (12 weeks) and post-trial (24 weeks) administration at $\alpha = .05$ significance level. If significant differences were found, Wilcoxon rank sum tests were performed on the pairwise comparisons to determine if the significance remained at a specific time interval.

Between-subject comparisons with the Mann Whitney U test were performed to determine if there were differences between FM group ($n = 23$) and the comparison group ($n = 6$) on: pure tone audiometry results, speech audiometry results, items 5-9 of the GHABP, the PIADS measure and the three original religious items (Items 18 and 21 on APHAB and Item S11 on the HHIE) to determine if there were any significant differences at the α =.05 level:

Between subject comparisons with the Mann Whitney U test were performed for items 5-9 on the GHABP, the PIADS measure and the three original religious items (Items 18 and 21 on APHAB and Item S11 on the HHIE) to determine if there were any significant differences at the α =.05 level: 12 users with ear level receivers and 11 users with belt level receivers; 12 poor performers (<20%) and 11 fair performers (>/= 20%) on word recognition performance in noise at + 10dB SNR; and the 17 users that used FM only in the place of worship and the 6 users that used personal FM systems.

Hypotheses

It was hypothesized that a 24 week trial of an FM system used in the place of worship will have a significant effect on: 1) disability (lesser); 2) handicap (lesser); 3) quality of life (greater); 4) psychosocial impact (more positive); and, 5) spiritual well-being (greater); as measured with their respective metrics in items pertaining to the place of worship listening environment.

It was also hypothesized that FM users with ear level receivers will have significantly greater (more positive) psychosocial scores than FM users with belt level receivers as reflected in the PIADS measure.

It was also hypothesized that the 24 week trial with an FM system used in a place of worship will have no difference on worship specific outcome measures between: the poor and fair performers of speech perception in noise; and between FM users that were exposed to the FM signal only in the place of worship and FM users who were exposed to the FM signal in more than the worship setting.

Table 3-1. Pilot investigation data summary: pearson inter-item chi-square values.

	Seats	Need	Awareness	Normal hearing	Hearing impaired
Seats	---				
Need	** 9.79	---			
Awareness	2.64	2.65	---		
Normal hearing	8.02	** 12.89	4.93	---	
Hearing impaired	6.31	*** 31.45	** 9.82	* 14.86	---

Seats	Informant estimate of seating capacity.
Need	Informant estimate of the need for Assistive Listening Devices (ALDs)
Awareness	Informant estimate of awareness of Assistive listening devices (ALDs)
Normal Hearing	Informant estimate of perception of listening difficulty among congregants with normal hearing
Hearing Impaired	Informed estimate of perception of listening difficulty among congregants with hearing impairment
*	$p \leq 0.10$
**	$p \leq 0.05$
***	$p < 0.001$

Table 3-2. Main investigation enrollment summary: participant selection of FM receivers and transmitters.

Date (2006)	Denomination	Interested Participants	Enrolled Participants	Ear Level Receivers (type-quantity)	Belt Level Receivers Selected (coupling-quantity)	Personal FM Users (Transmitter model)
2/1	Lutheran	8	7	2 (ML8S-1) * (ML9S-1)	3 ** (headphones-2) (earbuds-1)	0
2/5	Catholic A	7	2	0	1 (earbuds-1)	0
2/7	◊ Catholic B	1	0	0	0	0
2/8	Synagogue	4	2	0	1 (neckloop-1)	0
2/9	Methodist A	5	4	2 (ML4S-1) (ML8S-1)	2 (earbuds-2)	2 (Smartlink) (HandyMic)
2/26	Methodist B	13	10	5 (iLink-2) (MLxS-2) (ML9S-1)	5 (headphones-2) (earbuds-2) (neckloop-1)	2 (Smartlink) (Easylink)
2/27	Catholic C	5	*** 6	3 (ML8S-3)	1 ◊◊ (earbuds-1)	2 (Smartlink-2)
3/1	Methodist C	4	2	1 (ML9S-1)	1 (neckloop-1)	0
	TOTAL	47	33	13	14	6

* This participant dropped out due to non-study related injury.
** One participant dropped out due to lack of interest.
*** One participant dropped out during clinic visit prior to FM receiver selection. Also, another participant from Catholic B joined Catholic C.
◊ Participation site eliminated due to lack of enrolled attendees. No FM installed.
◊◊ Omission due to non-compliance (no 12 or 24 week data).

Table 3-3. Individual participant data for the 23 participants in the FM group: amplification history and audiometrics.

Participant	Age	Yrs HA Use	Age 1st HA	PTA	Word Recognition: Left Ear	Right Ear	Binaural	Binaural +10 SNR
1	79	11	68	52	54	76	88	32
2	84	23	61	27	CNT	86	92	24
3	93	26	67	40	32	58	58	0
4	71	5	66	27	48	70	70	20
5	93	4	89	52	50	70	78	16
6	61	39	22	88	0	18	18	0
7	74	NR	NR	65	8	6	16	0
8	91	1	90	38	80	66	70	10
9	81	20	61	63	16	0	38	0
10	74	6	68	48	28	36	40	8
11	71	8	63	32	70	34	76	32
12	82	NR	NR	52	76	0	70	30
13	86	21	65	47	58	60	60	22
14	74	9	65	35	76	58	74	12
15	80	8	72	50	80	84	86	22
16	88	10	78	37	56	64	76	24
17	76	21	55	47	42	46	44	4
18	78	4	74	38	48	12	72	26
19	66	31	35	58	34	58	48	14
20	75	2	73	22	74	100	96	22
21	56	13	43	58	18	78	68	26
22	77	36	41	38	88	84	88	8
23	63	1	62	15	82	98	96	40
Mean	77.18	14.24	62.25	44.67	50.09	54.86	66.17	17.04
SE	10.06	2.54	3.65	3.35	5.97	6.40	6.02	2.46

Age	In years
Yrs HA Use	Years of hearing Aid use
Age 1st HA	Age at first hearing aid
PTA	Pure tone averageof thresholds at 500, 1000 and 2000 Hz
Word Recognition	Percent of correctly repeated words
Left	Left ear only in quiet at most comfortable level
Right	Right ear only in quiet at most comfortable level
Binaural	Both ears in quiet at most comfortable level
Binaural +10 SNR	Both ears in noise at most comfortable level with competing pink noise at 10 decibels hearing level (dB HL) below speech level
NR	No response
CNT	Could not test

Table 3-4. Individual participant data for 6 participants in the comparison group: amplification history and audiometrics.

					Word Recognition			
Participant	Age	Yrs HA Use	Age 1st HA	PTA	Left Ear	Right Ear	Binaural	Binaural +10 SNR
1	81	25	57	35	32	60	44	18
2	77	6	71	48	48	74	92	24
3	81	NR	NR	62	72	98	96	42
4	53	10	43	33	88	32	82	22
5	71	5	66	38	18	28	46	0
6	76	3	73	63	82	82	82	12
Mean	73.17	9.80	62.00	46.50	56.67	62.33	73.67	19.67
SE	22.52	3.29	17.69	8.48	4.88	5.47	7.88	3.46

Age	In years
Yrs HA Use	Years of hearing Aid use
Age 1st HA	Age at first hearing aid
PTA	Pure tone averageof thresholds at 500, 1000 and 2000 Hz
Word Recognition	Percent of correctly repeated words
Left	Left ear only in quiet at most comfortable level
Right	Right ear only in quiet at most comfortable level
Binaural	Both ears in quiet at most comfortable level
Binaural +10 SNR	Both ears in noise at most comfortable level with competing pink noise at 10 decibels hearing level (dB HL) below speech level
NR	No response
CNT	Could not test

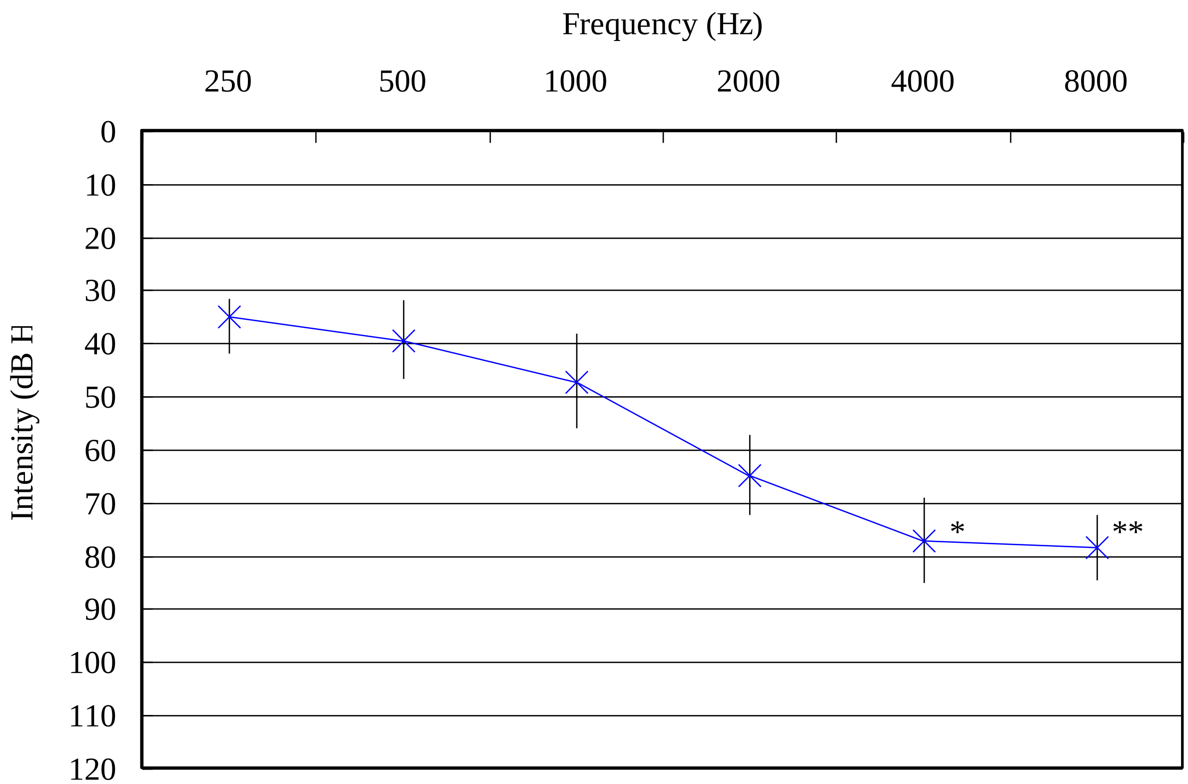

Figure 3-1. Left ear pure tone air thresholds (dB HL) by frequency (Hz) for the 23 participants in the FM group: means (+/- 2 standard errors). * indicates no response at 4000 Hz for 1 particpant. ** indicates no response at 8000 Hz for 6 partcipants.

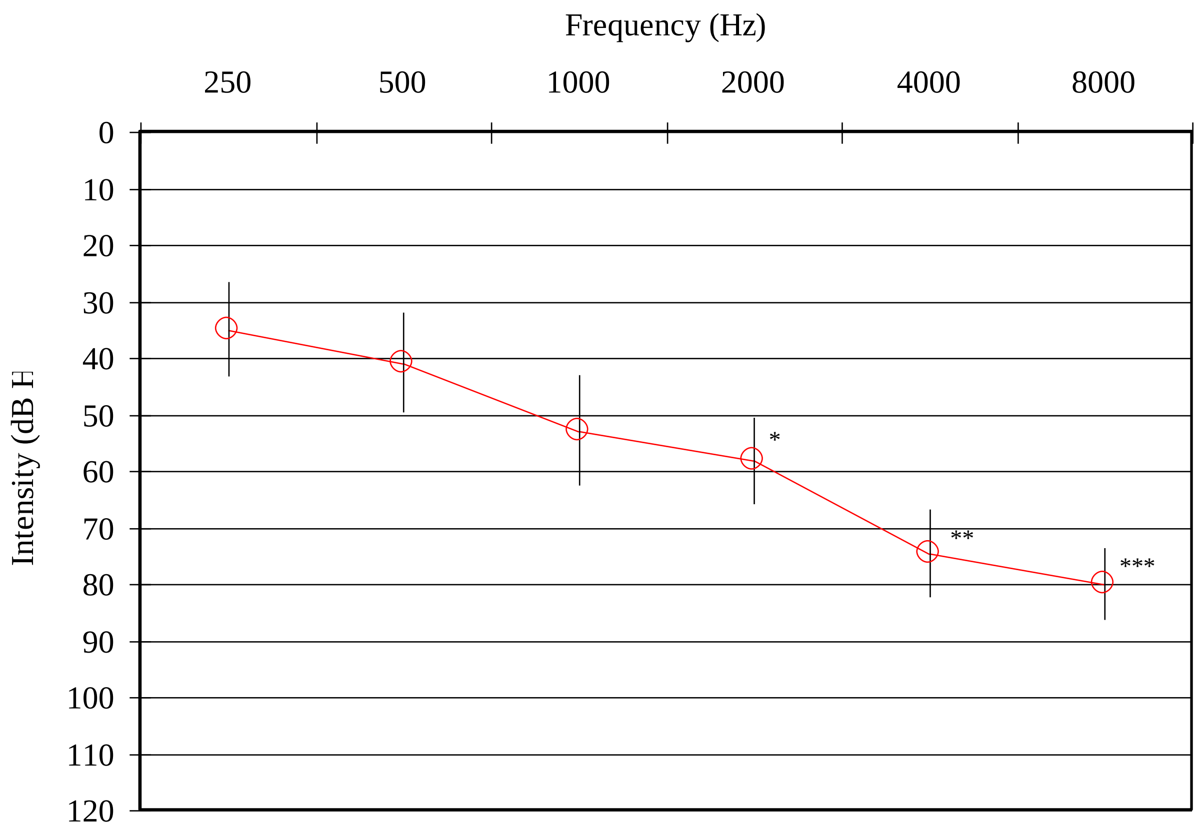

Figure 3-2. Right ear pure tone air thresholds (dB HL) by frequency (Hz) for the 23 participants in the FM group: means (+/- 2 standard errors). * indicates no response at 2000 Hz for 1 particpant. ** indicates no response at 4000 Hz for 1 participant. *** indicates no response at 8000 Hz for 5 participants.

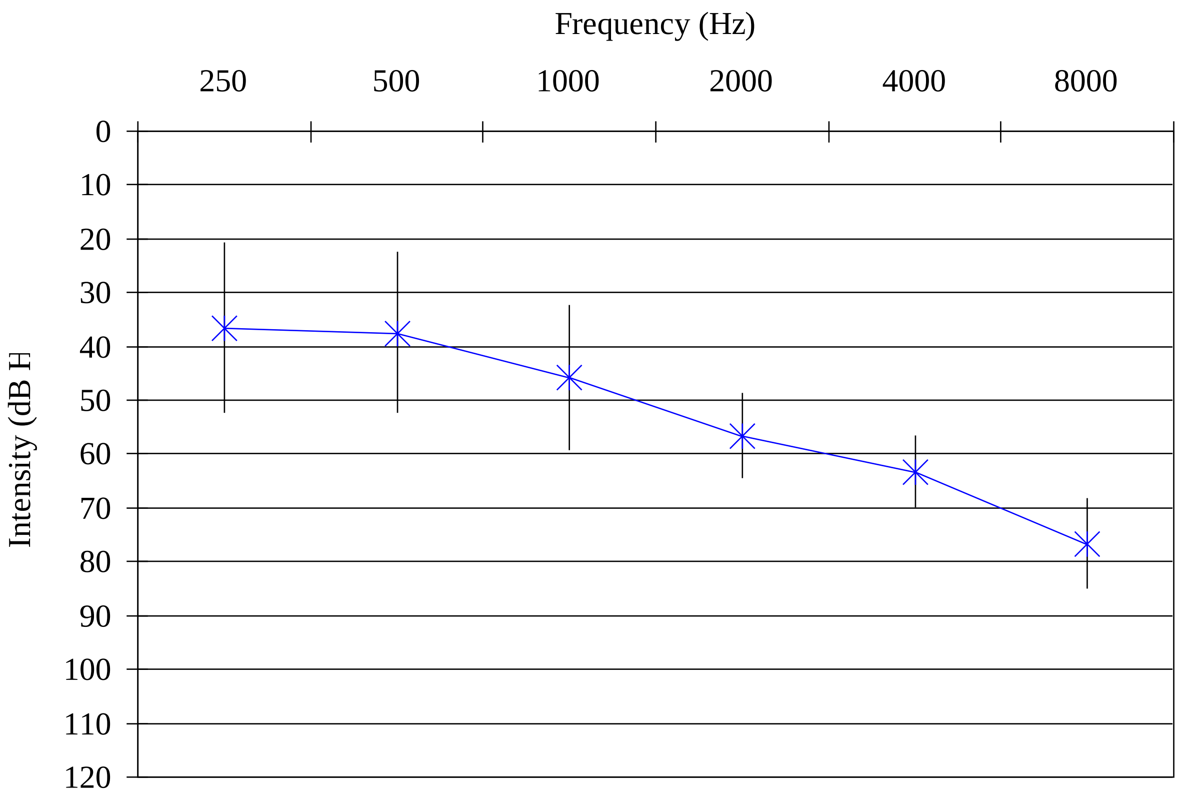

Figure 3-3. Left ear pure tone air thresholds (dB HL) by frequency (Hz) for the 6 participants in the comparison group: means (+/- 2 standard errors).

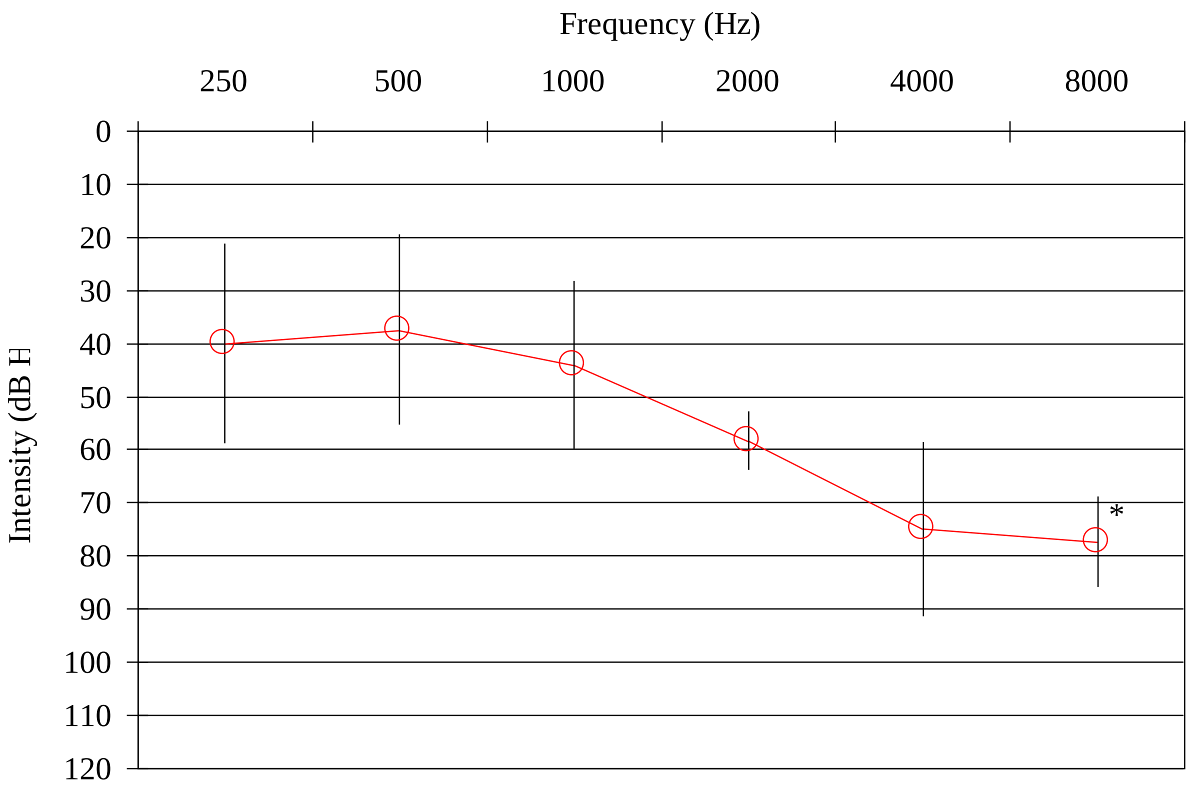

Figure 3-4. Right ear pure tone air thresholds (dB HL) by frequency (Hz) for the 6 participants in the comparison group: means (+/- 2 standard errors). * indicates no response no response at 8000 Hz for 2 particpants.

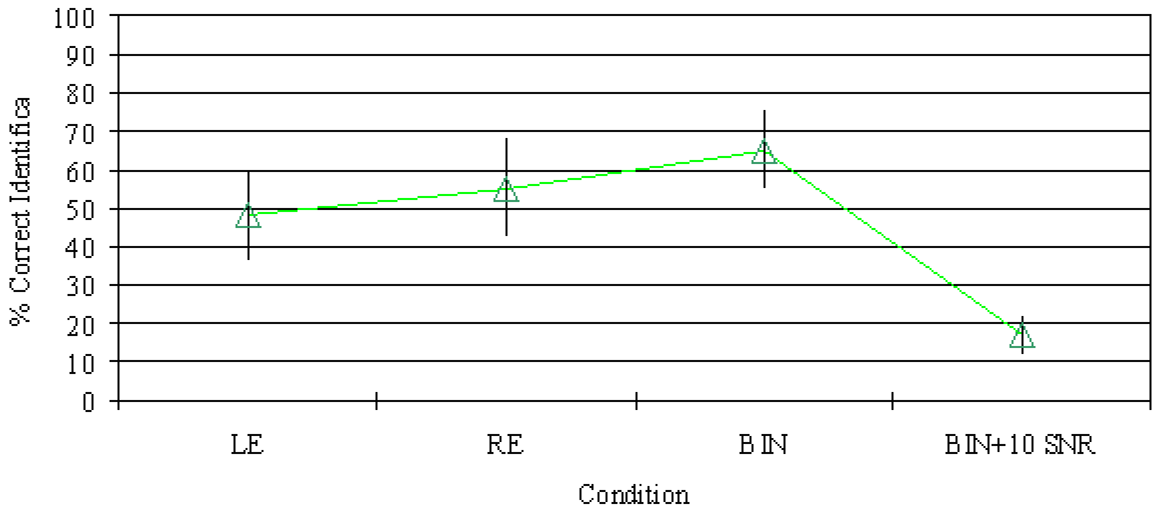

Figure 3-5. Word recognition performance in percent correct scores on Northwestern University word list #6 (NU-6) for the 23 participants in the FM group. LE) Left Ear in Quiet at Most Comfortable Level (MCL). RE) Right Ear in Quiet at MCL; Binaural in Quiet at MCL. BIN) Binaural at MCL. BIN +10 SNR) Binaural with Pink Masking Noise at 10 decibels below Binaural MCL for a +10 dB Signal-to-Noise Ratio.

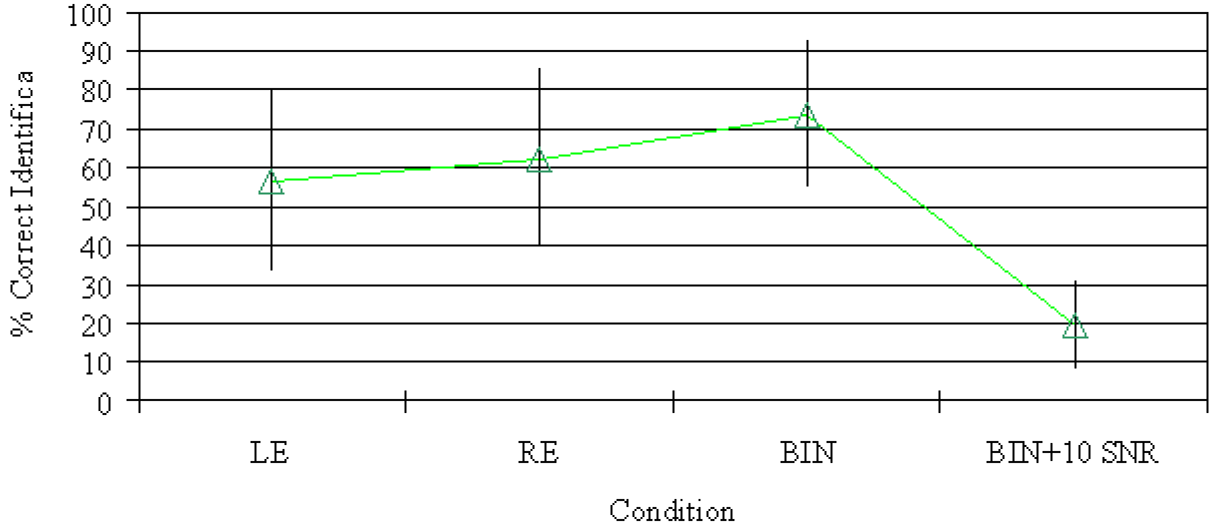

Figure 3-6. Word recognition performance in percent correct Scores on Northwestern University word list #6 (NU-6) for the 6 participants in the comparison group. LE) Left Ear in Quiet at Most Comfortable Level (MCL). RE) Right Ear in Quiet at MCL; Binaural in Quiet at MCL. BIN) Binaural at MCL. BIN +10 SNR) Binaural with Pink Masking Noise at 10 decibels below Binaural MCL for a +10 dB Signal-to-Noise Ratio.

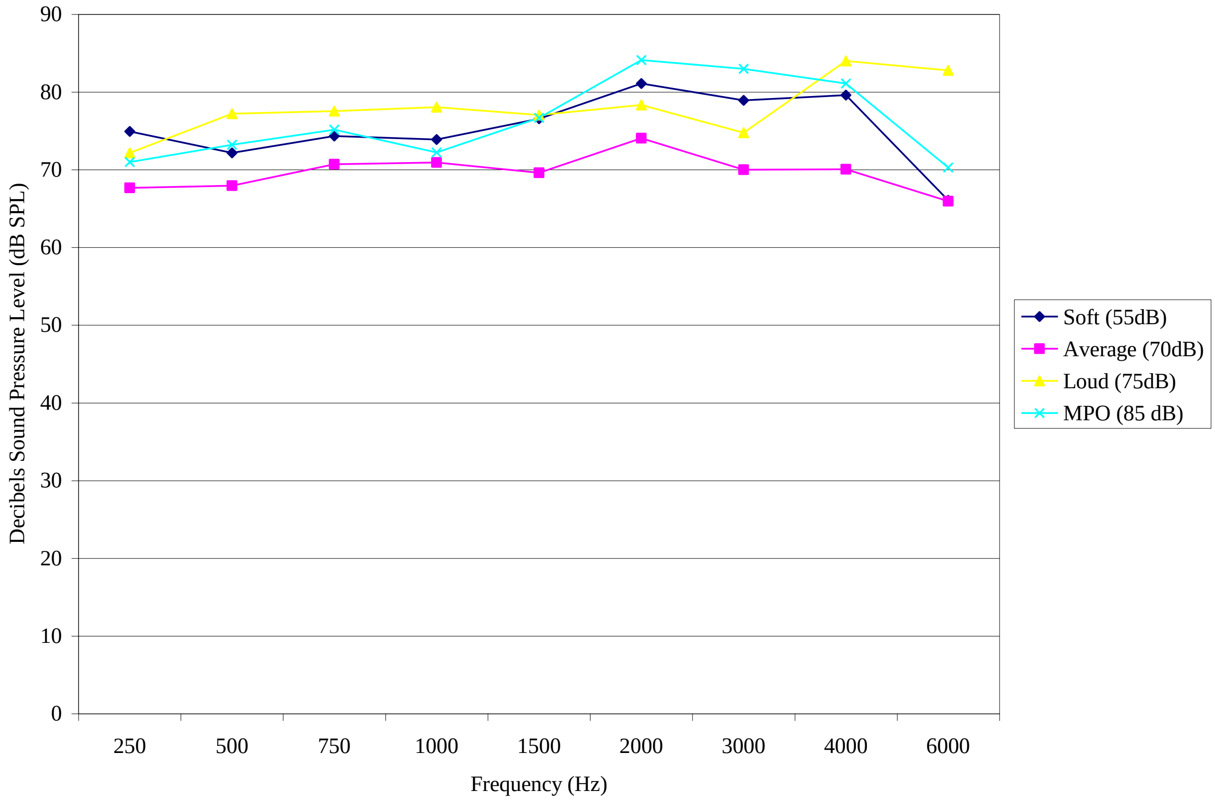

Figure 3-7. Quality control measures for electroacoustic verification: average acoustic output (dB SPL) by frequency (Hz) of earbuds at volume 3. The outputs correspond to 4 input stimuli at the same frequency (Hz): soft speech weighted noise (55 dB SPL), average speech weighted noise (70 dB SPL), loud speech weighted noise (75 dB SPL) and Maximum Peak Ouput (MPO) narrowband signals. The averages represent 18 conditions: 3 Microvox Receivers (1, 2, 3); 3 Transducer Pairs (A, B, C); and 2 Ears (Left and Right).

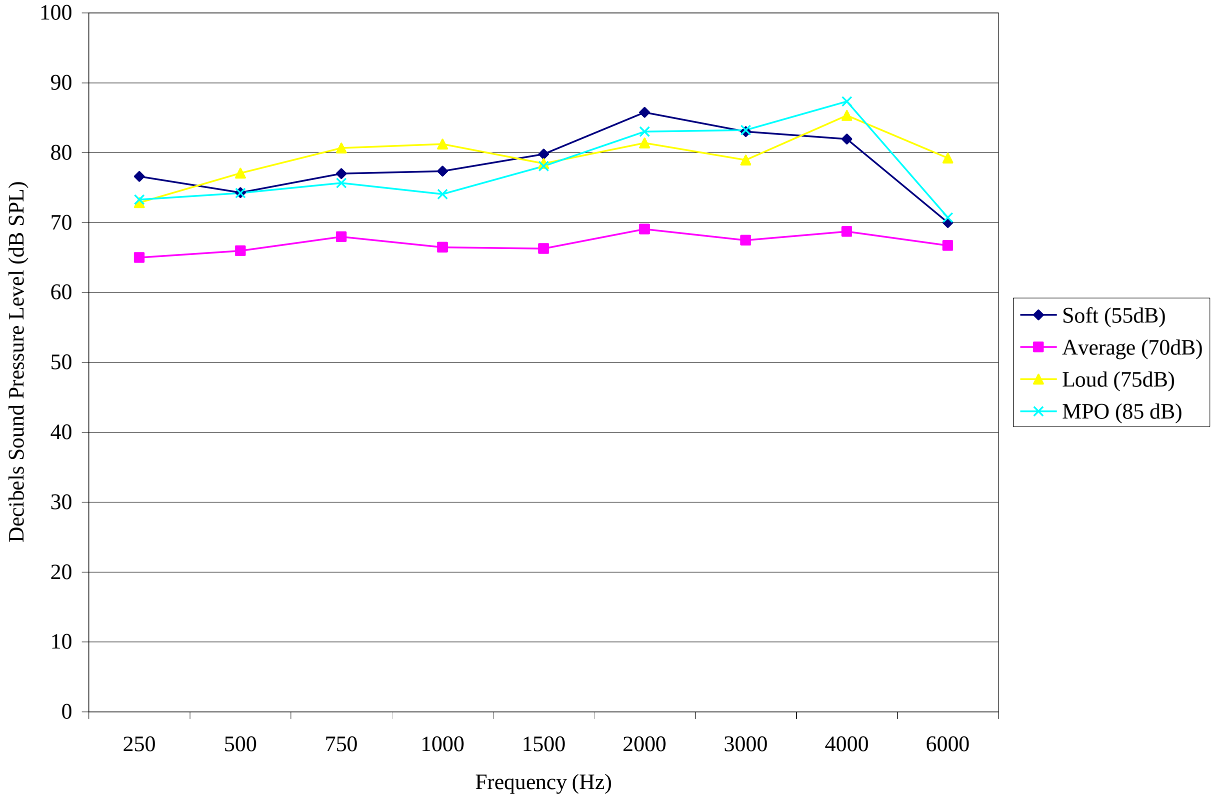

Figure 3-8. Quality control measures for electroacoustic verification: average acoustic output (dB SPL) by frequency (Hz) of earbuds at volume 6. The outputs correspond to 4 input stimuli at the same frequency (Hz): soft speech weighted noise (55 dB SPL), average speech weighted noise (70 dB SPL), loud speech weighted noise (75 dB SPL) and Maximum Peak Ouput (MPO) narrowband signals. The averages represent 18 conditions: 3 Microvox Receivers (1, 2, 3); 3 Transducer Pairs (A, B, C); and 2 Ears (Left and Right).

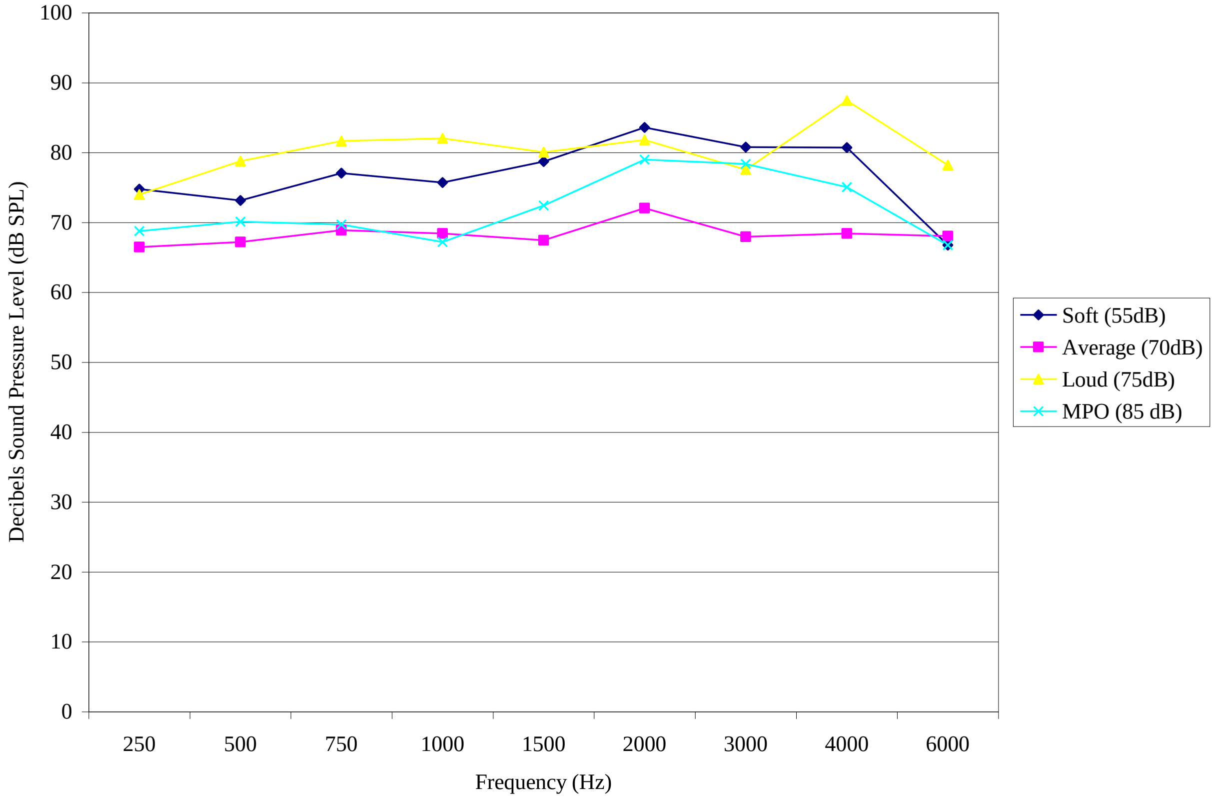

Figure 3-9. Quality control measures for electroacoustic verification: average acoustic output of (dB SPL) by frequency (Hz) of headphones at volume 3. The outputs correspond to 4 input stimuli at the same frequency (Hz): soft speech weighted noise (55 dB SPL), average speech weighted noise (70 dB SPL), loud speech weighted noise (75 dB SPL) and Maximum Peak Ouput (MPO) narrowband signals. The averages represent 18 conditions: 3 Microvox Receivers (1, 2, 3); 3 Transducer Pairs (X, Y, Z); and 2 Ears (Left and Right).

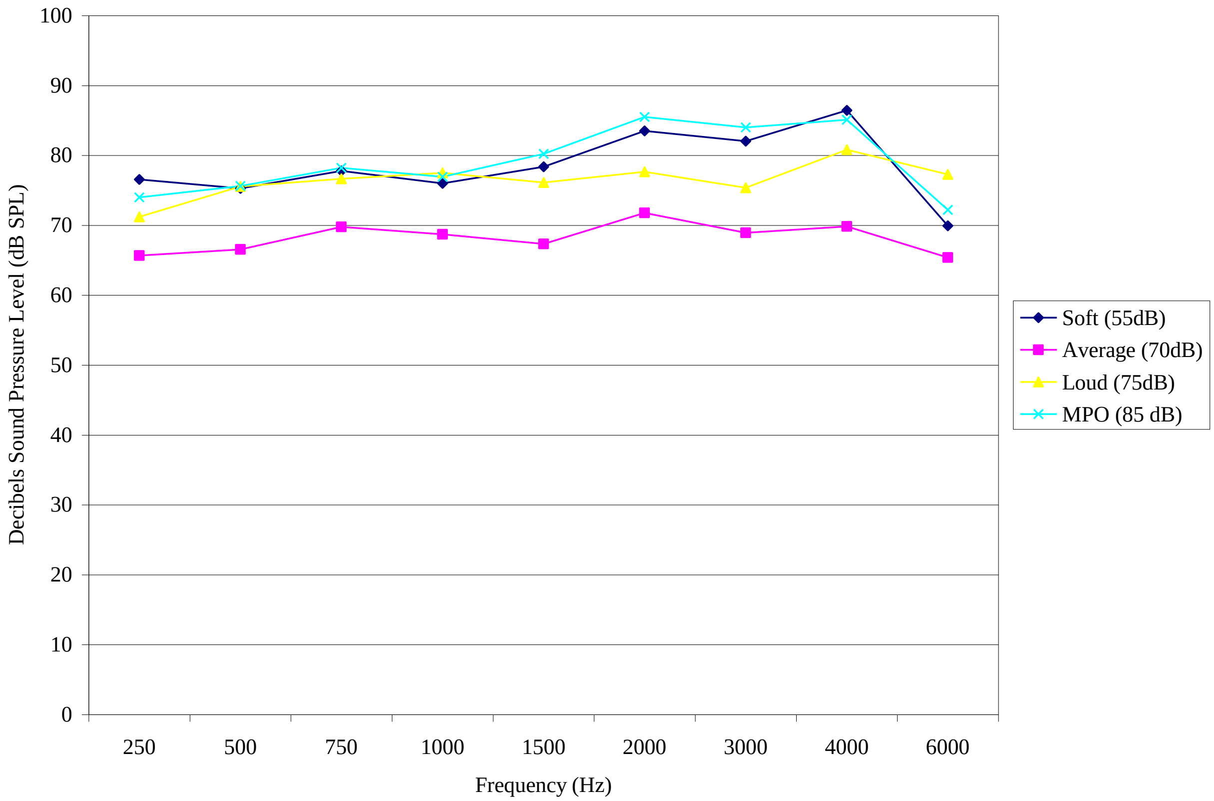

Figure 3-10. Quality control measures for electroacoustic verification, average acoustic output of (dB SPL) by frequency (Hz) of headphones at volume 6. The outputs correspond to 4 input stimuli at the same frequency (Hz): soft speech weighted noise (55 dB SPL), average speech weighted noise (70 dB SPL), loud speech weighted noise (75 dB SPL) and Maximum Peak Ouput (MPO) narrowband signals. The averages represent 18 conditions: 3 Microvox receivers (1, 2, 3); 3 transducer Pairs (X, Y, Z); and 2 ears (Left and Right).

CHAPTER 4
RESULTS

Between-Subject Comparisons on Audiometric Data at Baseline

The pure tone air audiometric thresholds for the left and right ear for the participants in the experimental group (n = 23) are shown in Figures 3-1 and Figure 3-2 respectively**.** The pure tone air audiometric thresholds for the left and right ear for the participants in the comparison group (n = 6) are shown in Figures 3-3 and Figure 3-4 respectively**.** Mann Whitney U analyses revealed no statistically significant differences between FM and comparison groups in pure tone air thresholds (Appendix D). Participants both groups tended to display mild sloping to severe sensorineural hearing loss.

The word recognition scores (in percent correct) for the left ear condition, the right ear condition, the binaural in quiet condition and the binaural in noise (+10 decibels signal-to-noise ratio [dB SNR]) condition for all participants in the experimental group (n = 23) and comparison group (n = 6) are presented in Table 3-5 and Table 3-6 respectively. Mann Whitney U analyses revealed no statistically significant differences between FM and comparison groups in word recognition scores in any of the test conditions

Within-Subject Comparisons on Outcomes Measures across Time Intervals

Glasgow Hearing Aid Benefit Profile (GHABP)

Friedman Analysis of Variance (ANOVA) was conducted for each scale and pre-specified listening situation combination of the Glasgow Hearing Aid Benefit Profile (GHABP). Statistically significant differences were revealed in some worship specific items within the Satisfaction, Reported Benefit, Derived Benefit and Use scales. All worship specific items in the Handicap scale failed to reveal any significant differences at the α =.05 level. None of 20 listening combinations (5 domains * 4 pre-specified situations) revealed intervals revealed any statistically significant within-subject differences between time intervals at the α =.05 level.

The Satisfaction domain simply asks, "How satisfied are you with your [amplification system]?" in a given situation. The mean Satisfaction scores are summarized in Table 4-1 and for worship specific items, in Figure 4-1.

For item 5, (listening to the main presenter, pastor, priest, rabbi, other), the mean (and standard error, SE) Satisfaction scores were: 32.61 (19.69) at baseline; 71.05 (20.22) at 12 weeks; and, 71.59 (20.26) at 24 weeks. Friedman ANOVA of Satisfaction by Item 5 revealed a statistically significant (X^2 = 23.684 df = 2, p =.000) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in satisfaction scores for listening to the main presenter in a place of worship between baseline and 12 weeks (Z = -3.627, p = .000) and baseline and 24 weeks (Z = 3.822, p = .000) but not between 12 and 24 weeks (Z= 0.000, p = 1.000).

For Item 6, (other presenters, readers, guest speakers, other), the mean (SE) Satisfaction scores were 35.87 (20.33) at baseline; 70.24 (20.56) at 12 weeks; and 69.32 (20.37) at 24 weeks. Friedman ANOVA of Satisfaction by Item 6 revealed a statistically significant (X^2 = 23.273, df = 2, p =.000) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in Satisfaction scores for listening to other presenters in a place of worship between baseline and 12 weeks (Z = 3.769, p = .000) and baseline and 24 weeks (Z = 3.713, p = .000) but not between 12 and 24 weeks (Z= 0.000, p = 1.000) at the α = .05 level.

For Item 7 (listening to music, understanding lyrics), the mean (SE) Satisfaction scores were: 38.04 (19.82) at baseline; 59.21 (19.20) at 12 weeks; and, 57.50 (19.84) at 24 weeks. Friedman ANOVA of Satisfaction by Item 7 revealed a statistically significant (X^2 = 10.857, df

= 2, p = .004) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in satisfaction scores for listening to music in a place of worship between baseline and 12 weeks (Z = 2.769, p = .006) but not between baseline and 24 weeks (Z = 1.805, p = .071) or between 12 and 24 weeks (Z= .535, p = .593) at the α = .05 level.

For Item 8 (one-one-one conversation <u>before or after</u> service), the mean (SE) Satisfaction scores were: 43.48 (19.74) at baseline; 58.33 (15.68) at 12 weeks; and, 36.54 (16.69) at 24 weeks. Friedman ANOVA of Satisfaction by Item 8 revealed a statistically significant (X^2 = 7.929, df = 2, p = .019) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increase in listening during a one-on-conversation before or after a service at a place of worship between baseline and 12 weeks (Z = 2.124, p =.034) but not between baseline and 24 weeks (Z = .243, p = .808) or between 12 and 24 weeks (Z= 1.518, p = .129) at the α = .05 level.

For Item 9 (one-on-one conversation <u>during</u> the service), the mean (SE) Satisfaction scores were: 43.33 (21.17) at baseline; 38.89 (13.89) at 12 weeks; and, 39.29 (17.26) at 24 weeks. Friedman ANOVA of Satisfaction by Item 9 did not reveal a statistically significant (X^2 = 1.900 df = 2, p = .387) main effect..

The Reported Benefit domain probed, “how much does the [amplification system] help you?” in a given situation. The mean Reported Benefit Scores are summarized in Table 4-2 and for worship specific items, in Figure 4-2.

For item 5, (listening to the main presenter, pastor, priest, rabbi, other), the mean (SE) Reported Benefit scores were: 50.00 (20.28) at baseline; 73.68 (21.99) at 12 weeks; and, 68.48 (20.49) at 24 weeks. Friedman ANOVA of Reported Benefit by Item 5 revealed a statistically significant (X^2 = 22.680 df = 2, p =.000) main effect.. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in reported benefit scores for listening to the main presenter in a place of worship between baseline and 12 weeks (Z = 3.52, p = .000) and baseline and 24 weeks (Z = 3.019, p = .003) but not between 12 and 24 weeks (Z = 1.414, p = .157).

For Item 6, (other presenters, readers, guest speakers, other), the mean (SE) Reported Benefit scores were: 39.13 (20.60) at baseline; 70.24 (20.56) at 12 weeks; and 70.45 (20.76) at 24 weeks. Friedman ANOVA of Reported Benefit by Item 6 revealed a statistically significant (X^2 = 30.333, df = 2, p =.000) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in Reported Renefit scores for listening to other presenters in a place or worship between baseline and 12 weeks (Z = 3.817, p = .000) and baseline and 24 weeks (Z = 3.729, p = .000) but not between 12 and 24 weeks (Z=-0.000, p = 1.000) at the α = .05 level.

For Item 7 (listening to music, understanding lyrics), the mean (SE) Reported Benefit scores were: 42.39 (20.17) at baseline; 59.21 (17.79) at 12 weeks; and, 59.21 (19.87) at 24 weeks. Friedman ANOVA of Reported Benefit by Item 7 revealed a statistically significant (X^2 = 10.651, df = 2, p = .005) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in Reported benefit Ccores for listening to music at a place or worship between baseline and 24 weeks (Z = 2.310, p = .021) but not between baseline and 12 weeks (Z = 1.888, p = .059) or between 12 and 24 weeks (Z= 1.265, p = .206) at the α = .05 level.

For Item 8 (one-one-one conversation <u>before or after</u> service), the mean (SE) Reported Benefit scores were: 44.57 (20.57) at baseline; 36.36 (17.19) at 12 weeks; and, 32.69 (17.31) at

24 weeks. Friedman ANOVA of Reported Benefit by Item 8 did not reveal a statistically significant (X^2 = 2.545, df = 2, p = .280) main effect.

For Item 9 (one-on-one conversation during the service), the mean (SE) Reported Benefit scores were: 41.67 (20.33) at baseline; 34.09 (13.68) at 12 weeks; and, 31.67 (17.11) at 24 weeks. Friedman ANOVA of Reported Benefit by Item 9 did not reveal a statistically significant (X^2 = .231, df = 2, p = .891) main effect.

The Derived Benefit score is the difference between the Initial Disability domain, "how much difficulty do you have" in a given situation and the Residual Disability domain, "With your [amplification system] how much difficulty do you now have". For the baseline measure, the difference reflects the benefit derived as a change in difficulty from the provision of the hearing aid. For the 12 and 24 week measures, the difference reflects the benefit derived as a change in difficulty from the provision of the FM system in addition to the hearing aid. The mean Derived Benefit Scores are summarized in Table 4-3 and for worship specific items, in Figure 4-3.

For Item 5, (listening to the main presenter, pastor, priest, rabbi, other), the mean (SE) Derived Benefit scores were: 42.39 (21.34) at baseline; 52.50 (18.24) at 12 weeks; and, 56.52 (20.49) at 24 weeks. Friedman ANOVA of Derived Benefit by Item 5 revealed a statistically significant (X^2 = 8.644 df = 2, p =.036) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in Derived Benefit scores for listening to the main presenter in a place of worship between baseline and 24 weeks (Z = 2.041, p = .041), but not between baseline and 12 weeks (Z = 1.624, p = .104) or between 12 and 24 weeks (Z = .758, p = .449).

For Item 6, (other presenters, readers, guest speakers, other), the mean (SE) Derived Benefit scores were: 34.78 (20.35) at baseline; 57.14 (18.99); and, 54.55 (20.76) at 24 weeks. Friedman ANOVA of Derived Benefit by Item 6 revealed a statistically significant (X^2 = 14.632, df = 2, p = .001) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant increases in Derived Benefit scores for listening to other presenters in a place of worship between baseline and 24 weeks (z = 2.41, p = .016) but not between baseline and 12 weeks (Z = 2.58, p = 0.10) or 12 and 24 weeks (Z = 0.418, p = .676).

For item 7 (music/understanding lyrics), the mean (SE) Derived Benefit scores were: 38.04 (21.53); 47.37 (18.99); and, 42.50 (18.44) at 24 weeks**.** Friedman ANOVA of Derived Benefit by Item 7 did not reveal any statistically significant (X^2 = 2.178, df = 2, p = .337) main effect.

For Item 8 (one-one-one conversation <u>before or after</u> service), the mean (SE) Derived Benefit scores were: 42.39 (21.01) at baseline; 47.73 (15.80) at 12 weeks; and, 34.62 (18.34) at 24 weeks. Friedman ANOVA of Derived Benefit by Item 8 did not reveal a statistically significant (X^2 = 1.448, df = 2, p = .485) main effect.

For item 9 (one-on-one conversation <u>during</u> the service), the mean (SE) Derived Benefit scores were: 36.67 (18.61) at baseline; 30.00 (11.16) 12 weeks; and, 35.71 (17.26) at 24 weeks. Friedman ANOVA of Derived Benefit by Item 9 did not reveal a statistically significant (X^2 = .636 = 2, p = .727) main effect.

The Use domain probes, “what proportion of the time” the amplification system is being used in a given situation. The mean Use scores are summarized in Table 4-4 and for worship specific items, in Figure 4-5.

For item 5, (listening to the main presenter, pastor, priest, rabbi, other), the mean (SE) Use scores were: 93.48 (21.08) at baseline; 96.05 (22.85) at 12 weeks; and, 92.05 (21.56) at 24 weeks. Friedman ANOVA of Use by Item 5 did not reveal a statistically significant (X^2 = 1.333, df = 2, p =.513) main effect.

For Item 6, (other presenters, readers, guest speakers, other), the mean (SE) Use scores were: 92.39 (21.01) at baseline; 92.86 (22.47) at 12 weeks; and, 90.22 (21.58) at 24 weeks. Friedman ANOVA of Use by Item 6 did not reveal a statistically significant (X^2 = .722, df = 2, p =.697) main effect.

For Item 7 (music/understanding lyrics), the mean (SE) Use scores were: 92.39 (21.01) at baseline; 90.00 (19.44) at 12 weeks; and 82.14 (18.07) at 24 weeks. Friedman ANOVA of Use by Item 7 did not reveal a statistically significant (X^2 = .867, df = 2, p = .648) main effect.

For Item 8 (one-one-one conversation <u>before or after</u> service), the mean (SE) Use scores were: 91.30 (20.39) at baseline; 51.79 (12.31) at 12 weeks; and, 54.41 (14.67) at 24 weeks. Friedman ANOVA of Use by item 8 revealed a statistically significant (X^2 = 8.897, df = 2, p = .012) main effect. Pairwise analyses with the Wilcoxon signed ranks test revealed statistically significant decreases in Use scores for listening before or after a service at a place of worship between baseline and 12 weeks (Z = 2.598, p = .009) and baseline and 24 weeks (Z = 2.855, p = .004) but not between 12 and 24 weeks (Z = .412, p = .680) at the α = .05 level.

For Item 9 (one-on-one conversation <u>during</u> the service), the mean (SE) Use scores were: 93.33 (19.84) at baseline; 77.27 (14.63) at 12 weeks; and, 85.00 (16.98)) at 24 weeks. Friedman ANOVA of Use by item 9 did not reveal a statistically significant (X^2 = 2.00, df = 2, p = .368) main effect.

The Handicap domain probes how much difficulty in a given situation “worry, upsets or annoys you”. The mean Handicap scores are summarized in Table 4-5 and for worship specific items, in Figure 4-5.

For item 5, (listening to the main presenter, pastor, priest, rabbi, other), the mean (SE) scores were: 60.87 (18.95) at baseline; 57.89 (17.34) at 12 weeks; and 48.91 (18.43) at 24 weeks. Friedman ANOVA of Handicap by Item 5 did not reveal a statistically significant (X^2 = 2.375, df = 2, p =.305) main effect. For Item 6, (other presenters, readers, guest speakers, other), the mean (SE) scores were: 55.68 (19.08) at baseline; 58.33 (18.94) at 12 weeks; and, 48.86 (18.32) at 24 weeks. Friedman ANOVA of Handicap by Item 6 did not reveal a statistically significant (X^2 = 3.435, df = 2, p =.180) main effect. For item 7 (listening to music, understanding lyrics), the mean (SE) scores were: 45.65 (19.19) at baseline; 45.00 (17.61) at 12 weeks; and, 39.77 (17.71) at 24 weeks. Friedman ANOVA of Handicap by Item 7 did not reveal a statistically significant (X^2 = 0.000, df = 2, p = 1.0) main effect. For Item 8 (one-one-one conversation before or after service), the mean (SE) scores were: 52.17 (19.14) at baseline; 48.75 (18.86) at 12 weeks; and, 41.67 (17.41) at 24 weeks. Friedman ANOVA of Handicap by Item 8 did not reveal a statistically significant (X^2 = .591, df = 2, p = .744) main effect. For Item 9 (one-on-one conversation during the service), the mean (SE) scores were: 56.67 (18.80) at baseline; 59.09 (15.91) at 12 weeks; and, 51.67 (15.72) at 24 weeks. Friedman ANOVA of Handicap by Item 9 did not reveal a statistically significant (X^2 = .105, df = 2, p = .949) main effect.

Glasgow Benefit Inventory (GBI)

The mean scores for the total GBI and General, Social and Physical subscales of the GBI are listed in Table 4-6. The GBI total scale and general subscale showed a significant decrease in scores throughout the trial.

The mean (SE) scores for the GBI total were: 24.21 (3.72) at baseline; 17.35 (3.85) at 12 weeks; and, 17.41 (5.10) at 24 weeks. Friedman ANOVA of total GBI scores revealed a statistically significant (X^2 = 9.694, df = 2, p = .008) main effect. Pairwise comparisons with the Wilcoxon Signed Ranks test revealed a significant decrease in GBI total scores between 12 and

24 weeks ($Z = 2.061$, $p = .039$) but no difference between baseline and 12 weeks ($Z = 1.610$, $p = .107$) or between baseline and 24 weeks ($Z = 1.773$, $p = .076$).

The mean (SE) scores for the GBI general subscale were: 32.93 (4.98) at baseline; 23.45 (4.69) at 12 weeks; and, 21.42 (5.93) at 24 weeks. Friedman ANOVA of the general subscale of the GBI revealed a statistically significant ($X^2 = 8.149$, df = 2, $p = .017$) main effect.. Pairwise comparisons of GBI general scores with the Wilcoxon Signed Ranks test revealed a significant decrease between 12 and 24 weeks ($Z = 2.024$, $p = .043$) but no difference between baseline and 12 weeks ($Z = 1.372$, $p = .170$) or between baseline and 24 weeks ($Z = 1.811$, $p =.070$).

The mean (SE) scores for the GBI social subscale were: 3.30 (0.08) at baseline; 3.20 (0.09) at 12 weeks; and, 3.24 (0.09) at 24 weeks. Friedman ANOVA of the social subscale of the GBI did not reveal a statistically significant ($X^2 = 4.647$, df = 2, $p = .098$) main effect.

The mean (SE) scores for the GBI physical subscale were: 2.94 (0.03) at baseline; 3.00 (0.00) at 12 weeks; and, 3.00 (0.02) at 24 weeks. Friedman ANOVA of the physical subscale of the GBI did not reveal a statistically significant ($X^2 = 4.625$, df = 2, $p = .099$) main effect.

Psychosocial Impact of Assistive Devices Scale (PIADS)

The mean scores for the Competence, Adaptability and Self-esteem scales of the PIADS are listed in Table 4-7. None of the scale scores showed statistically significant differences throughout the trial.

The mean (SE) scores for the Adaptability scale of the PIADS were: 0.57 (0.13) and 2.37 at baseline; 0.50 (0.14) and 1.67 at 12 weeks; and, 0.32 (0.09) and 1.96 at 24 weeks. Friedman ANOVA of the PIADS Adaptability scale revealed a statistically significant ($X^2 = 6.907$, df = 2, $p = .032$) main effect. Pairwise analysis with the Wilcoxon Signed Ranks Tests did not reveal any significant differences between baseline to 12 weeks ($Z = 1.462$, $p = .144$), baseline to 24 weeks ($Z = 1.270$, $p = .204$), or 12 to 24 weeks ($Z = 1.188$, $p = .235$)

The mean (SE) scores for the Competence scale of the PIADS were: 0.73 (0.14) at baseline; 0.77 (0.16) at 12 weeks; and, 0.48 (0.10) at 24 weeks. Friedman ANOVA of the PIADS Competence scale did not reveal a statistically significant (X^2 = 1.435 df = 2, p = .488) main effect.

The mean (SE) scores for the self-esteem scale of the PIADS were: 0.60 (0.13) at baseline; 0.62 (0.15) at 12 weeks; and, 0.41 (0.10) at 24 weeks. Friedman ANOVA of the PIADS self-esteem scale did not a statistically significant (X^2 = 1.537, df = 2, p = .464) main effect.

Abbreviated Profile of Hearing Aid Benefit (APHAB)

The benefit scores of all four scales and two worship specific items of the Abbreviated Profile of Hearing Aid Benefit (APHAB) results are presented in Table 4-8. None of the scale scores showed statistically significant differences throughout the trial.

The mean (SE) scores for the Aversiveness to Sound scale were: 28.41 (4.10) at baseline; 5.15 (7.30) at 12 weeks; and, 3.64 (9.20) at 24 weeks. Friedman ANOVA revealed a statistically significant (X^2 = 12.452, df = 2, p =.002) main effect. Pairwise analyses with the Wilcoxon Signed Ranks test failed to reveal any statistically significant differences in the Aversiveness to Sound subscale between baseline and 12 weeks (Z = 0.261, p = 0.794), baseline and 24 weeks (Z = 0.049, p = 0.961) or between 12 and 24 weeks (Z = 0.161, p =0.872). None of the differences between the mean scores exceeded the 95% critical difference (37 points) for the benefit score on the Aversiveness to Sound scale (Cox & Alexander, 1995).

The mean (SE) scores for the Ease of Communication scale were: 29.64 (4.16) at baseline; 22.47 (5.26) at 12 weeks; and, 17.82 (4.08) at 24 weeks. Friedman ANOVA of the Ease of Communication scale did not reveal a statistically significant ($X^{2 =}$ 4.00, df = 2, p = .135) main effect. None of the intervals between the three time points exceeded the 95% critical difference (31 points) for the benefit score on the Ease of Communication scale (Cox & Alexander, 1995).

The mean (SE) scores for the Reverberation scale were: 29.96 (3.33) at baseline; 29.20 (5.35) at12 weeks; and, 29.90 (4.51) at 24 weeks. Friedman ANOVA of the Reverberation scale did not reveal a statistically significant ($X^2 = 2.354$, df = 2, p =.308) main effect. None of the intervals between the three time points exceeded the 95% critical difference (33 points) for the benefit score on the Reverberation scale (Cox & Alexander, 1995**).**

The mean (SE) scores for the Background Noise scale were: 24.54 (3.45) at baseline; 17.46 (6.53): at 12 weeks; and, 23.24 (7.22) at 24 weeks. Friedman ANOVA of the Background Noise scale did not reveal a statistically significant ($X^2 = .905$, df = 2, p = .636) main effect**.** None of the intervals between the three time points exceeded the 95% critical difference (33 points) for the benefit score on the Background Noise scale (Cox & Alexander, 1995),

Items 18 and 21 are worship-specific items on the APHAB and were analyzed separately. Item 18 states, “It is hard for me to understand what is being said at lectures or church services”. The mean (SE) responses for item 18 were: 32.65 (4.71) at baseline; 40.50 (5.87) at 12 weeks; and 36.77 (5.82) at 24 weeks. Friedman ANOVA of Item 18 did not reveal a statistically significant ($X^2 = 3.800$, df = 2, p = .150) main effect. Item 21 states, “I can follow the words of a sermon when listening to a religious service”. The mean (SE) responses for Item 21 were: 39.95 (4.20) at baseline; 35.55 (5.96) at 12 weeks; and, 37.81 (5.81) at 24 weeks. Friedman ANOVA of Item 21 did not reveal a statistically significant ($X^2 = 3.484$, df = 2, p = .175) main effect.

Hearing Handicap Inventories (HHI)

The mean scores for the 28 items of the Hearing Handicap Inventories (HHI) are summarized by the two original 25-item Hearing Handicap Inventories: for Adults (-A) and for the Elderly (-E) scales in Table 4-9**.** None of the HHI scale scores showed statistically significant differences throughout the trial.

The mean (SE) scores for the HHIA total were: 41.26 (4.43) at baseline; 41.73 (5.03) at 12 weeks; and, 36.61 (4.83) at 24 weeks. Friedman ANOVA of HHIA total scores did not reveal a statistically significant (X^2 -= 3.13, df = 2, p = .209) main effect.

The mean (SE) scores for the HHIA social subscale were: 22.17 (2.00) at baseline; 22.00 (2.51) at 12 weeks; and, 20.26 (2.26) at 24 weeks. Friedman ANOVA of the HHIA social subscale did not reveal a statistically significant (x^2 = .220, df = 2, p = .896) main effect.

The mean (SE) scores for the HHIA emotional subscale were: 19.09 (2.43) at baseline; 19.73 (2.52) at 12 weeks; and, 16.35 (2.57) at 24 weeks. Friedman ANOVA of the HHIA emotional subscale did not reveal a statistically significant (x^2 = 1.537, df = 2, p = .464) main effect.

The mean (SE) scores for the HHIE total were: 40.13 (4.32) at baseline; 38.48 (4.73) at 12 weeks; and, 34.17 (4.53) at 24 weeks. Friedman ANOVA of HHIE total did not reveal a statistically significant (x^2 -= 2.966, df = 2, p = .227) main effect.

The mean (SE) scores for the HHIE social subscale were: 21.91 (1.89) at baseline; 21.00 (2.25) at 12 weeks; and, 19.13 (2.07) at 24 weeks. Friedman ANOVA of the HHIE social subscale did not reveal a statistically significant (x^2 = 2.385, df = 2, p = .304) main effect..

The mean (SE) scores for the HHIE emotional subscale were: 18.22 (2.44) at baseline; 17.48 (2.48) at 12 weeks; and, 15.04 (2.46) at 24 weeks. Friedman ANOVA of the HHIE emotional subscale did not reveal a statistically significant (x^2 = 2.214, df = 2, p = .331) main effect.

One item on the HHIE specifically referred to places of worship, “Does a hearing problem cause you to attend religious services less often than you would like?”. This item was analyzed separately. The mean (SE) scores for the religious item of the HHIE were: 0.87 (0.30) at baseline; 0.36 (0.25) at 12 weeks; and, 0.45 (0.23) at 24 weeks. Friedman ANOVA of the religious item on the HHIE did not reveal a statistically significant (x^2 =5.200, df = 2, p = .074) main effect.

Spiritual Well Being Scale (SWBS)

The SWBS mean scores are listed in Table 4-10. None of the SWBS scores or SWBS scale scores showed statistically significant differences throughout the trial.

The mean (SE) scores for the Total score of the SWBS were: 102.91 (2.56) at baseline; 92.00 (7.00) at 12 weeks; and, 102.96 (2.60) at 24 weeks. Friedman ANOVA of the total SWBS did not reveal a statistically significant (X^2 = 1.281, df = 2, p = .527) main effect.

The mean (SE) scores for the Spirituality scale of the SWBS were: 50.43 (1.56) at baseline; 45.35 (3.43) at 12 weeks; and, 50.43 (1.44) at 24 weeks. Friedman ANOVA of the Spirituality scale of the SWBS did not reveal a statistically significant (X^2 = 1.326, df = 2, p = .515) main effect. .

The mean (SE) scores for the Religiosity scale of the SWBS were: 52.48 (1.31) at baseline; 46.65 (3.68) at 12 weeks; and, 52.52 (1.52) at 24 weeks. Friedman ANOVA of the Religiosity scale of the SWBS did not reveal a statistically significant (X^2 = 1.537, df = 2, p = .464) main effect.

Between-Subject Comparisons on Selected Outcome Measures

Because there were significant positive findings on many of the GHABP worship specific items and the PIADS Adaptability scale, and because there were 3 original religious items on the APHAB and HHIE, additional analyses were conducted to determine if there were differences in response scores between the participants. Four binary comparisons of responses were made between: 1) FM/experimental group (n = 23) vs. hearing aid only/comparison group (n = 6); 2) FM users with ear level receivers (n = 12) vs. FM users with belt level receivers (n = 11); 3) FM users with poor (n =12) vs. FM users with fair (n =11) word recognition performance in noise; and, 4) users of FM in place of worship only (n = 17) vs. personal FM users (n = 6). Comparisons were analyzed with the Mann Whitney U test.

Glasgow Hearing Aid Benefit Profile (GHABP)

The between-subject comparison of GHABP scores between the FM experimental group and hearing aid only comparison group revealed 5 statistically significant differences within Items 5-9. For item 6 (listening to other presenters in the place of worship), Mann Whitney U analyses revealed that the FM group reported statistically greater Satisfaction scores at 12 weeks ($Z = 2.489$, $p = 0.013$) and at 24 weeks ($Z = 2.344$, $p = 0.019$) than the hearing aid group; and statistically greater Reported Benefit than the hearing aid only group at 24 weeks ($Z = 2.344$, $p = 0.019$).

The between-subject comparison of GHABP scores between the ear level receivers and belt level receivers revealed 4 statistically significant differences within Items 5-9. For Item 8 (listening one-on-one before or after a worship service), Mann Whitney U analyses revealed that the participants with belt level receivers reported statistically greater Reported Benefit at 12 weeks ($Z = 2.250$, $p = .024$); greater Use at 12 weeks ($Z = 2.858$, $p = 3.237$) and 24 weeks ($Z = 0.004$, $p = 0.001$) than the participants with ear level receivers. For Item 9 (listening one-on-one during the service) Mann Whitney U analyses revealed that the participants with ear level receivers reported significantly greater Derived Benefit during the service at 24 weeks ($Z = 2.103$, $p = 0.035$) than participants with belt level receivers.

The between-subject comparison of GHABP scores between the poor and fair performers of word recognition in noise testing revealed 4 statistically significant differences within Items 5-9. For Item 5 (listening to the main presenter), Mann Whitney U analyses revealed that participants with fair word recognition in noise reported significantly greater Reported Benefit scores at 12 weeks (Z = 2.220, p = 0.026) than the poor participants with poor word recognition ability in noise. For Item 9 (listening one-on-one during the service) Mann Whitney U analyses revealed that the participants with poor word recognition in noise reported significantly greater Satisfaction scores at 24 weeks (Z = 2.164, p = 0.030), significantly greater Reported Benefit scores at 24 weeks (Z = 2.122, p = 0.034) and significantly greater Derived Benefit scores at 24 weeks (Z = 2.122, p = 0.034) than participants with fair word recognition ability in noise.

The between-subject comparison of GHABP scores between the FM users in the place of worship only and personal FM users revealed 3 statistically significant differences within GHABP Items 1-9. For Item 8 (listening one-on-one before or after a worship service), Mann Whitney U analyses revealed that the participants with FM system in the place of worship only reported statistically greater Satisfaction at 12 weeks (Z = 1.979, p = 1.744) and Reported Benefit at 24 weeks (Z = 0.048, p = 0.081) than the personal FM users. For Item 9 (listening one-on-one during the service) Mann Whitney U analyses revealed that participants with a personal FM system reported significantly less handicap at 24 weeks (Z = 2.292, p = 0.022) than users that were exposed to FM only in the place of worship.

Psychosocial Impact of Assistive Devices Scale (PIADS)

The between-subject comparison of the PIADS scores between the FM users in only the place of worship and the personal FM users revealed 7 statistically significant differences. For the Competence scale, Mann Whitney U analyses revealed that personal FM users scored significantly greater at baseline (Z = 2.281, p = 0.023), 12 weeks (Z = 1.938, p = 0.053) and 24 weeks (Z = 2.430, p = 0.015) than the FM users that were exposed to FM only in the place of worship. For the Adaptability scale, Mann Whitney U analyses revealed that personal FM users scored significantly greater at baseline (Z = 2.075, p = 0.015), 12 weeks (Z = 1.938, p = 0.038) and 24 weeks (Z = 2.119, p = 0.053) than the FM users that were exposed to FM only in the place of worship. For the Self-esteem scale, Mann Whitney U analyses revealed that personal FM users scored significantly greater at baseline ($Z = 2.083$, $p = 0.037$) than the FM users that were exposed to FM only the place of worship.

Two-way ANOVA was conducted with time interval as the within-subject variable. The results confirm Mann Whitney U findings. All time intervals of Adaptability were significantly greater ($F = 14.615$, $p = 0.001$) in the Personal FM users with no interaction ($F = 0.143$, $p = 0.709$). All time intervals of Competence were significantly greater ($F = 15.692$, $p = 0.001$) in the Personal FM users with no interaction ($F = 0.101$, $p = 0.754$). The baseline interval of Self-Esteem was significantly greater ($F = 6.899$, $p = 0.016$) in the Personal FM users with no interaction ($F = 0.644$, $F = 0.431$).

The between-subject comparison of the PIADS scores between the participants with the ear level receivers vs. belt level receivers revealed 1 statistically significant difference. For the Competence scale, participants with ear level receivers reported significantly greater scores at 24 weeks ($Z = 2.384$, $p = 0.017$) than participants with belt level receivers.

The between-subject comparisons of the PIADS scores between the FM experimental group and hearing aid only comparison group did not reveal any statistically significant differences within the trial.

The between-subject comparison of the PIADS scores between the poor performers and fair performers in speech recognition in noise did not reveal any statistically significant differences within the trial.

Religious Items

The between-subject comparisons of the three original religious items (Items 18 and 21 on the Abbreviated Profile of Hearing Aid Benefit, APHAB and Item S11 on the Hearing Handicap Inventory for the Elderly, HHIE) are listed in Appendix D. Mann Whitney U analyses revealed only one statistically significant difference within the trial on these three items. For HHIE Item S11, the participants in the FM group reported significantly lower scores at 24 weeks ($Z = 2.130$, $p = 0.033$) than the participants in the hearing aid only comparison group. A lower score on HHIE S11, “Does a hearing problem cause you to attend religious services less often than you would like?” means lesser handicap.

Table 4-1. Satisfaction scale results of the Glasgow Hearing Aid Benefit Profile (GHABP) for the FM group: mean scores and standard errors (SE).

Listening Situation		Baseline	12 Weeks	24 Weeks	0 to 12 Week Difference	0 to 24 Week Difference	12 to 24 Week Difference
1) Listening to television with family & friends							
	Mean	42.39	75.00	55.56	32.61	13.16	-19.44
	SE	19.92	20.28	13.38	0.35	6.54	6.90
2) One-on-one in quiet							
	Mean	53.26	75.00	64.29	21.74	11.02	-10.71
	SE	20.47	18.32	11.80	2.15	8.67	6.52
3) One-on-one in noise							
	Mean	36.90	55.00	58.33	18.10	21.43	-3.33
	SE	19.65	20.00	12.50	0.35	7.15	7.50
4) Conversations with a group of people							
	Mean	35.23	63.89	46.43	28.66	11.20	-17.46
	SE	19.38	17.65	14.90	1.73	4.49	2.75
5) Main presenter during service							
	Mean	32.61	71.05	71.59	***38.44	***38.98	0.54
	SE	19.69	20.22	20.26	0.53	0.58	0.05
6) Other presenters during service							
	Mean	35.87	70.24	69.32	***34.37	***33.45	-0.92
	SE	20.33	20.56	20.37	0.23	0.04	0.19
7) Music during service (lyrics)							
	Mean	38.04	59.21	57.50	**21.17	*19.46	-1.71
	SE	19.82	19.20	19.84	0.62	0.02	0.64
8) One-on-one before and after service							
	Mean	43.48	58.33	36.54	**14.86	-6.94	-21.79
	SE	19.74	15.68	16.69	4.05	3.04	1.01
9) One-on-one during the service							
	Mean	43.33	38.89	39.29	-4.44	-4.05	0.40
	SE	21.17	13.89	17.26	7.28	3.90	3.37

The baseline measure reflects only hearing aid amplification. The 12 and 24 week measures reflect hearing aid and FM amplification. Items 1 to 4 represent pre-specified general listening situations. Items 5-9 represent listening situations specified to the place of worship.

* $p < .1$
** $p < .05$
*** $p < .01$

Table 4-2. Reported Benefit scale results of the Glasgow Hearing Aid Benefit Profile (GHABP) for the FM group: mean scores and standard errors (SE).

Listening Situation		Baseline	12 Weeks	24 Weeks	0 to 12 Week Difference	0 to 24 Week Difference	12 to 24 Week Difference
1) Listening to television with family & friends							
	Mean	51.14	63.89	56.25	12.75	5.11	-7.64
	SE	20.81	16.55	14.70	4.26	6.11	1.85
2) One-on-one in quiet							
	Mean	59.78	65.63	50.00	5.84	-9.78	-15.63
	SE	20.63	18.42	12.80	2.20	7.83	5.62
3) One-on-one in noise							
	Mean	42.86	41.67	47.22	-1.19	4.37	5.56
	SE	19.78	14.46	13.63	5.32	6.15	0.83
4) Conversations with a group of people							
	Mean	42.05	40.00	35.71	-2.05	-6.33	-4.29
	SE	20.53	17.36	12.98	3.17	7.55	4.39
5) Main presenter during service							
	Mean	50.00	73.68	68.48	*****23.68**	*****18.48**	-5.21
	SE	20.28	21.99	20.49	**1.71**	**0.21**	1.50
6) Other presenters during service							
	Mean	39.13	70.24	70.45	*****31.11**	*****31.32**	0.22
	SE	20.60	20.56	20.76	**-0.04**	**0.16**	0.20
7) Music during service (lyrics)							
	Mean	42.39	59.21	59.21	***16.82**	****16.82**	0.00
	SE	20.17	17.79	19.87	**.38**	**0.31**	2.07
8) One-on-one before and after service							
	Mean	44.57	36.36	32.69	-8.20	-11.87	-3.67
	SE	20.57	17.19	17.31	3.37	3.26	0.11
9) One-on-one during the service							
	Mean	41.67	34.09	31.67	-7.58	-10.00	-2.42
	SE	20.33	13.68	17.11	6.65	3.22	3.42

The baseline measure reflects only hearing aid amplification. The 12 and 24 week measures reflect hearing aid and FM amplification. Items 1 to 4 represent pre-specified general listening situations. Items 5-9 represent listening situations specified to the place of worship.

* $p < .1$

** $p < .05$

*** $p < .01$

Table 4-3. Derived Benefit scale results of the Glasgow Hearing Aid Benefit Profile (GHABP) for the FM Group: mean scores and standard errors (SE).

Listening Situation		Baseline	12 Weeks	24 Weeks	0 to 12 Week Difference	0 to 24 Week Difference	12 to 24 Week Difference
1) Listening to television with family & friends							
	Mean	47.73	60.71	54.17	12.99	6.44	-6.55
	SE	17.30	17.57	17.32	0.26	0.02	0.25
2) One-on-one in quiet							
	Mean	31.52	50.00	42.86	18.48	11.34	-7.14
	SE	18.29	20.83	14.49	2.54	3.81	6.35
3) One-on-one in noise							
	Mean	39.29	55.00	72.50	15.71	33.21	-17.50
	SE	19.39	20.00	14.17	0.61	5.22	5.83
4) Conversations with a group of people							
	Mean	42.05	58.33	58.33	16.29	16.29	0.00
	SE	21.18	19.11	12.64	2.08	8.54	6.47
5) Main presenter during service							
	Mean	42.39	52.50	56.52	10.11	****14.13**	4.02
	SE	21.34	18.24	20.49	0.10	**0.84**	2.26
6) Other presenters during service							
	Mean	34.78	57.14	54.55	****22.36**	****19.76**	-2.60
	SE	20.35	18.99	20.76	**1.37**	**0.41**	1.77
7) Music during service (lyrics)							
	Mean	38.04	47.37	42.50	9.32	4.46	-4.87
	SE	21.53	18.99	18.44	2.55	3.10	0.55
8) One-on-one before and after service							
	Mean	42.39	47.73	34.62	5.34	-7.78	-13.11
	SE	21.01	15.80	18.34	5.22	2.67	2.54
9) One-on-one during the service							
	Mean	36.67	30.00	35.71	-6.67	-0.95	-5.71
	SE	18.61	11.16	17.26	7.45	1.34	6.11

The baseline measure reflects only hearing aid amplification. The 12 and 24 week measures reflect hearing aid and FM amplification. Items 1 to 4 represent pre-specified general listening situations. Items 5-9 represent listening situations specified to the place of worship.

* $p < .1$

** $p < .05$

Table 4-4. Use scale results of the Glasgow Hearing Aid Benefit Profile (GHABP) for the FM group: mean scores and standard errors (SE).

Listening Situation		Baseline	12 Weeks	24 Weeks	0 to 12 Week Difference	0 to 24 Week Difference	12 to 24 Week Difference
1) Listening to television with family & friends							
	Mean	86.96	54.55	56.82	-32.41	-30.14	2.27
	SE	18.74	11.18	11.06	7.56	7.67	0.11
2) One-on-one in quiet							
	Mean	81.52	56.25	60.00	-25.27	-21.52	3.75
	SE	19.29	11.85	11.98	7.44	7.30	0.14
3) One-on-one in noise							
	Mean	81.25	67.86	47.73	-13.39	-33.52	-20.13
	SE	18.49	10.86	-11.75	7.63	6.74	0.88
4) Conversations with a group of people							
	Mean	86.36	72.22	58.33	-14.14	-28.03	-13.89
	SE	19.61	13.63	10.57	5.98	9.05	3.07
5) Main presenter during service							
	Mean	93.48	96.05	92.05	2.57	-1.43	-4.01
	SE	21.08	22.85	21.56	1.77	0.47	1.30
6) Other presenters during service							
	Mean	92.39	92.86	90.22	0.47	-2.17	-2.64
	SE	21.01	22.47	21.58	1.46	0.57	0.90
7) Music during service (lyrics)							
	Mean	92.39	90.00	82.14	-2.39	-10.25	-7.86
	SE	21.01	19.44	18.07	1.57	2.94	1.37
8) One-on-one before and after service							
					***_	***_	
	Mean	91.30	51.79	54.41	**39.52**	**36.89**	2.63
	SE	20.39	12.31	14.67	**8.08**	**5.72**	2.36
9) One-on-one during the service							
	Mean	93.33	77.27	85.00	-16.06	-8.33	7.73
	SE	19.84	14.63	16.98	5.21	2.86	2.35

The baseline measure reflects only hearing aid amplification. The 12 and 24 week measures reflect hearing aid and FM amplification. Items 1 to 4 represent pre-specified general listening situations. Items 5-9 represent listening situations specified to the place of worship.

*** $p < .01$

Table 4-5. Handicap scale results of the Glasgow Hearing Aid Benefit Profile (GHABP) for the FM group: mean scores and standard errors (SE).

Listening Situation		Baseline	12 Weeks	24 Weeks	0 to 12 Week Difference	0 to 24 Week Difference	12 to 24 Week Difference
1) Listening to television with family & friends							
	Mean	65.00	47.37	48.44	-17.63	-16.56	1.07
	SE	18.61	17.87	17.27	0.74	1.34	0.60
2) One-on-one in quiet							
	Mean	48.86	31.25	27.38	-17.61	-21.48	-3.87
	SE	18.96	19.91	18.80	0.95	0.16	1.11
3) One-on-one in noise							
	Mean	57.50	50.00	47.50	-7.50	-10.00	-2.50
	SE	18.96	18.61	18.00	0.35	0.96	0.61
4) Conversations with a group of people							
	Mean	65.91	59.09	54.41	-6.82	-11.50	-4.68
	SE	19.92	18.73	17.50	1.19	2.42	1.23
5) Main presenter during service							
	Mean	60.87	57.89	48.91	-2.97	-11.96	-8.98
	SE	18.95	17.34	18.43	1.61	0.52	1.09
6) Other presenters during service							
	Mean	55.68	58.33	48.86	2.65	-6.82	-9.47
	SE	19.08	18.94	18.32	0.14	0.76	0.62
7) Music during service (lyrics)							
	Mean	45.65	45.00	39.77	-0.65	-5.88	-5.23
	SE	19.19	17.61	17.71	1.58	1.49	0.10
8) One-on-one before and after service							
	Mean	52.17	48.75	41.67	-3.42	-10.51	-7.08
	SE	19.14	18.86	17.41	0.28	1.72	1.44
9) One-on-one during the service							
	Mean	56.67	59.09	51.67	2.42	-5.00	-7.42
	SE	18.80	15.91	15.72	2.89	3.08	0.19

The baseline measure reflects only hearing aid amplification. The 12 and 24 week measures reflect hearing aid and FM amplification. Items 1 to 4 represent pre-specified general listening situations. Items 5-9 represent listening situations specified to the place of worship.

Table 4-6. Glasgow Benefit Inventory (GBI) results for the FM group: mean scores and standard errors (SE).

	Baseline	12 Weeks	24 Weeks	Baseline to 12 Week Difference	Baseline to 24 Week Difference	12 to 24 Week Difference
General Subscale						
Mean	32.93	23.45	21.42	-9.49	-11.51	****-2.03**
SE	4.98	4.69	5.93	0.29	0.96	**1.24**
Social Subscale						
Mean	3.30	3.20	3.24	-0.10	-0.07	0.04
SE	0.08	0.09	0.09	0.01	0.01	0.00
Physical Subscale						
Mean	2.94	3.00	3.00	0.06	0.06	0.00
SE	0.03	0.00	0.02	0.03	0.01	0.02
Total Scale						
Mean	24.21	17.35	17.41	-6.85	-6.80	****0.05**
SE	3.72	3.85	5.10	0.13	1.37	**1.24**

The baseline measure reflects change in health related quality of life since the hearing aid fitting. The 12 and 24 week measures reflect change in health related quality of life since the FM fitting.
** $p < .05$

Table 4-7. Psychosocial Impact of Assistive Devices Scale (PIADS) results for the FM group: mean scores and standard errors (SE).

	Baseline	12 Weeks	24 Weeks	Baseline to 12 Week Difference	Baseline to 24 Week Difference	12 to 24 Week Difference
Competence Scale						
Mean	0.73	0.77	0.48	0.04	-0.24	-0.28
SE	0.14	0.16	0.10	0.01	0.04	0.05
Adaptability Scale**						
Mean	0.57	0.50	0.32	-0.07	-0.25	-0.18
SE	0.13	0.14	0.09	0.01	0.04	0.05
Self.Esteem Scale						
Mean	0.60	0.62	0.41	-0.01	0.19	0.21
SE	0.13	0.15	0.10	0.02	0.03	0.05

** $p < .05$ (Friedman Analysis of Variance revealed overall main effect)

Table 4-8. Abbreviated Profile of Hearing Aid Benefit (APHAB) results for the FM group: mean scores and standard errors (SE).

		Baseline	12 Weeks	24 Weeks	Baseline to 12 Week Difference	Baseline to 24 Week Difference	12 to 24 Week Difference
Ease of Communication							
	Mean	29.64	22.47	17.82	-7.18	-11.82	-4.64
	SE	4.16	5.26	4.08	1.10	0.08	1.18
Reverberation							
	Mean	29.96	29.20	29.90	-0.75	-0.06	0.70
	SE	3.33	5.35	4.51	2.03	1.18	0.85
Background Noise							
	Mean	24.54	17.46	23.24	-7.08	-1.30	5.78
	SE	3.45	6.53	7.22	3.07	3.76	0.69
Aversiveness to Sound							
	Mean	28.41	5.15	3.64	*****-23.26**	****-24.81**	1.51
	SE	4.10	7.30	9.20	**3.20**	**5.10**	1.90
Item 18							
	Mean	32.65	40.50	36.77	-7.85	4.12	-3.73
	SE	4.71	5.87	5.82	1.16	1.11	0.05
Item 21							
	Mean	39.95	35.55	37.81	-4.40	-2.15	2.26
	SE	4.20	5.96	5.81	1.77	1.61	0.16

The baseline measure reflects only hearing aid amplification. The 12 and 24 week measures reflect hearing aid and FM amplification. Item 18 states, "It is hard for me to understand what is being said at lectures or church services". Item 21 states, "I can follow the words of a sermon when listening to a religious service".

** $p < .05$

*** $p < .01$

Table 4-9. Hearing Handicap Inventory (HHI) results for the FM group: mean scores and standard errors (SE).

		Baseline	12 Weeks	24 Weeks	Baseline - 12 Week Difference	Baseline- 24 Week Difference	Baseline- 24 Week Difference
Social Subscale							
HHIA							
	Mean	22.17	22.00	20.26	-0.17	-1.91	-1.74
	SE	2.00	2.51	2.26	0.51	0.26	0.25
HHIE							
	Mean	21.91	21.00	19.13	-0.91	-2.78	-1.87
	SE	1.89	2.25	2.07	0.36	0.18	0.17
Emotional Subscale							
HHIA							
	Mean	19.09	19.73	16.35	0.64	-2.74	-3.38
	SE	2.43	2.52	2.57	0.09	0.15	0.06
HHIE							
	Mean	18.22	17.48	15.04	-0.74	-3.17	-2.43
	SE	2.44	2.48	2.46	0.04	0.02	0.02
Total Score							
HHIA							
	Mean	41.26	41.73	36.61	0.47	-4.65	-5.12
	SE	4.43	5.03	4.83	0.60	0.40	0.20
HHIE							
	Mean	40.13	38.48	34.17	-1.65	-5.96	-4.30
	SE	4.32	4.73	4.53	0.40	0.21	0.19
Religious Item of HHIE							
	Mean	0.87	0.36	0.45	-0.51	-0.42	0.09
	SE	0.30	0.25	0.23	0.05	0.08	0.03

The baseline measure reflects handicap perceived by the participant while using a hearing aid. The 12 and 24 week measures reflect handicap perceived by the participant while using a hearing aid and FM system.

Table 4-10. Spiritual Well Being Scale (SWBS) results for the FM group: mean scores and standard errors (SE).

	Baseline	12 Weeks	24 Weeks	Baseline to 12 Week Difference	Baseline to 24 Week Difference	12-24 Week Difference
Religious Scale						
Mean	52.48	46.65	52.52	-5.83	0.04	5.87
SE	1.31	3.68	1.52	2.37	0.22	2.15
Spiritual Scale						
Mean	50.43	45.35	50.43	-5.09	0.00	5.09
SE	1.56	3.43	1.44	1.86	0.13	1.99
Total Scale						
Mean	102.91	92.00	102.96	-10.91	0.04	10.96
SE	2.56	7.00	2.60	4.44	0.04	4.40

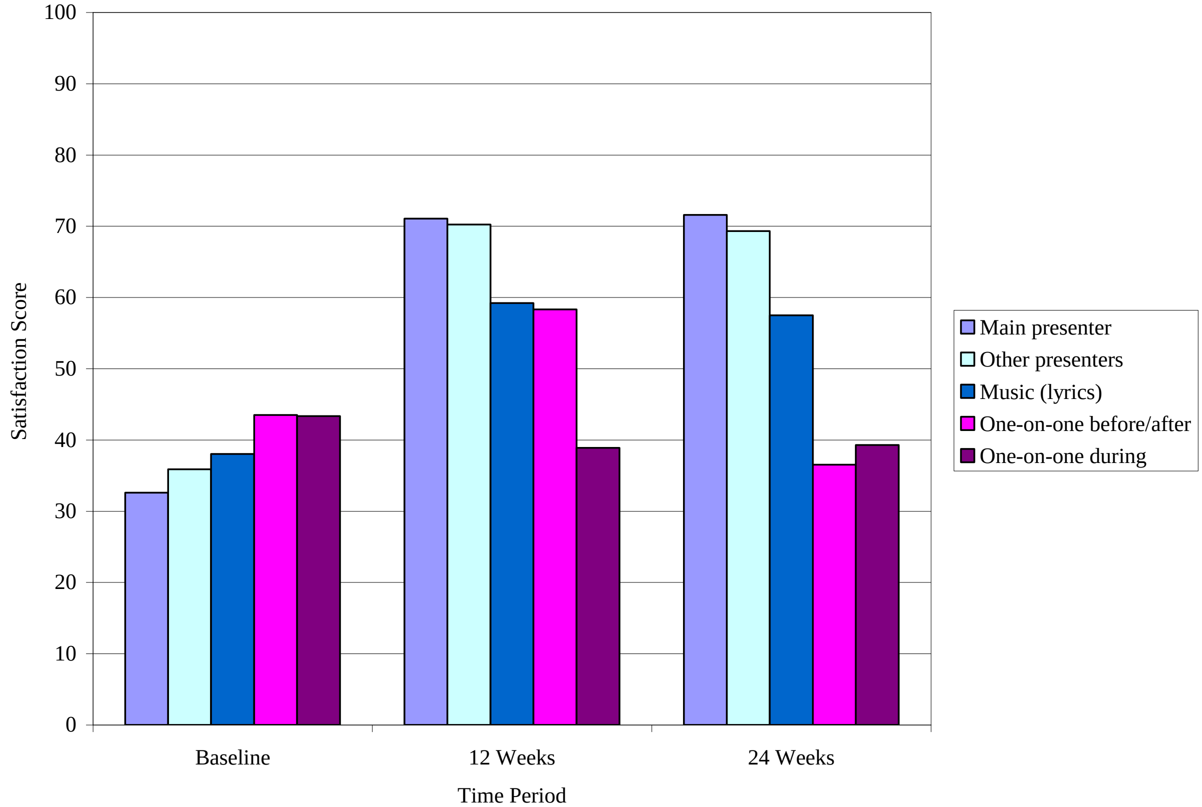

Figure 4-1. Satisfaction scores from items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) for the 23 participants in the FM group. Baseline measure refects Satisfaction with hearing aid only. The measures at 12 and 24 weeks reflect Satisfaction with hearing aid and FM system.

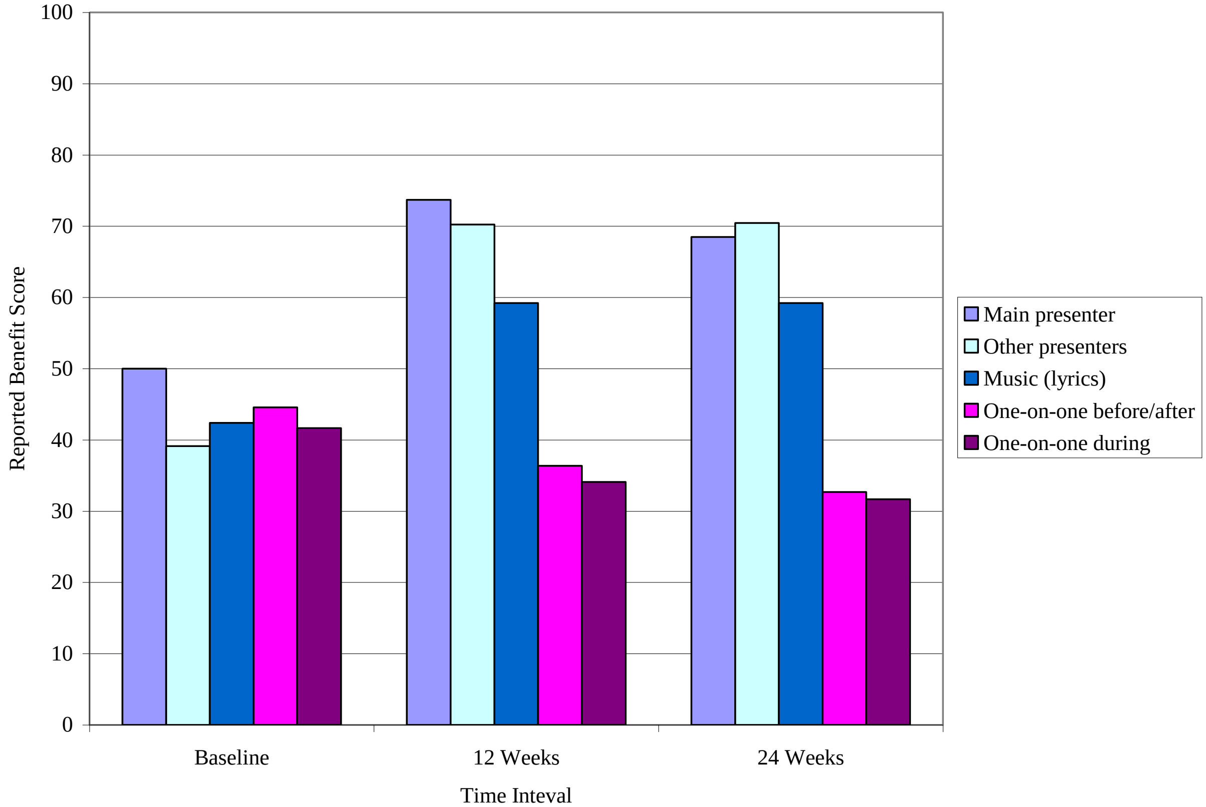

Figure 4-2. Reported Benefit scores from items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) for the 23 participants in the FM group. Baseline measure refects Reported Benefit with hearing aid only. The measures at 12 and 24 weeks reflect Reported Benefit with hearing aid and FM system.

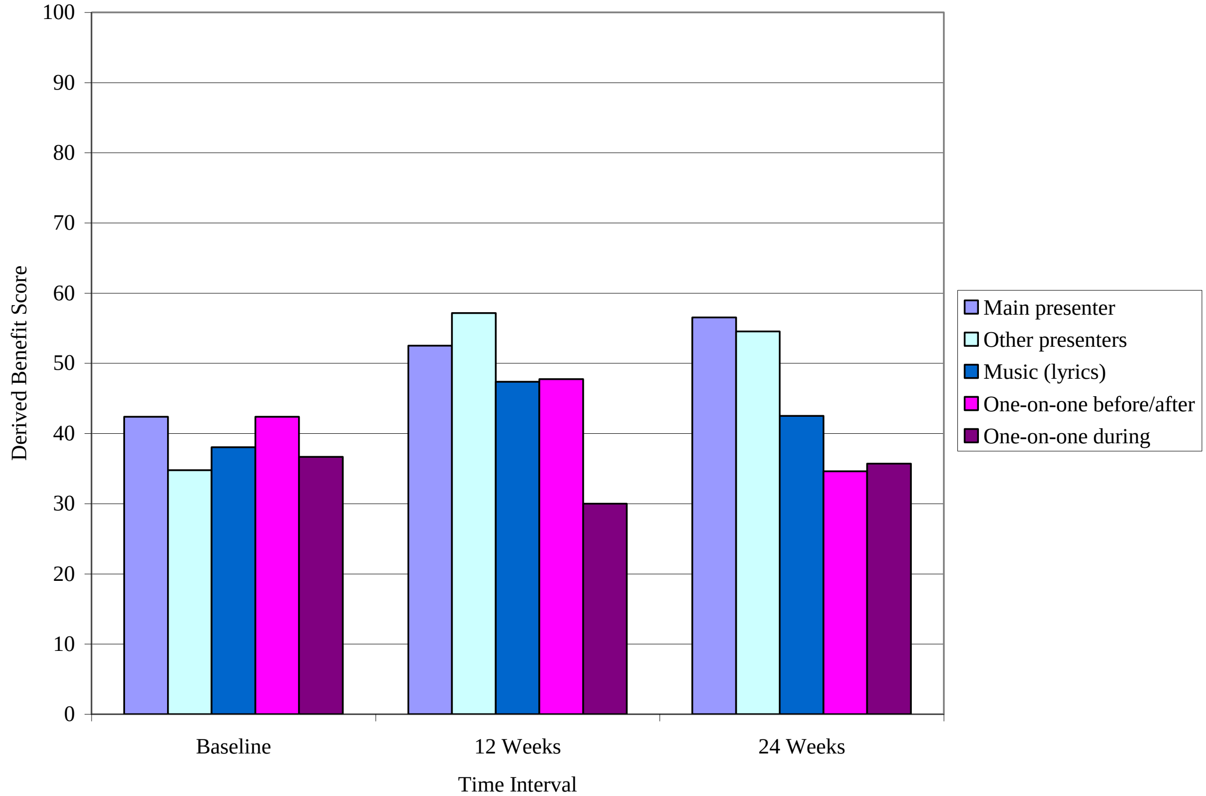

Figure 4-3. Derived Benefit scores from items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) for the 23 participants in the FM group. Baseline measure refects Derived Benefit with hearing aid only. The measures at 12 and 24 weeks reflect Derived Benefit with hearing aid and FM system.

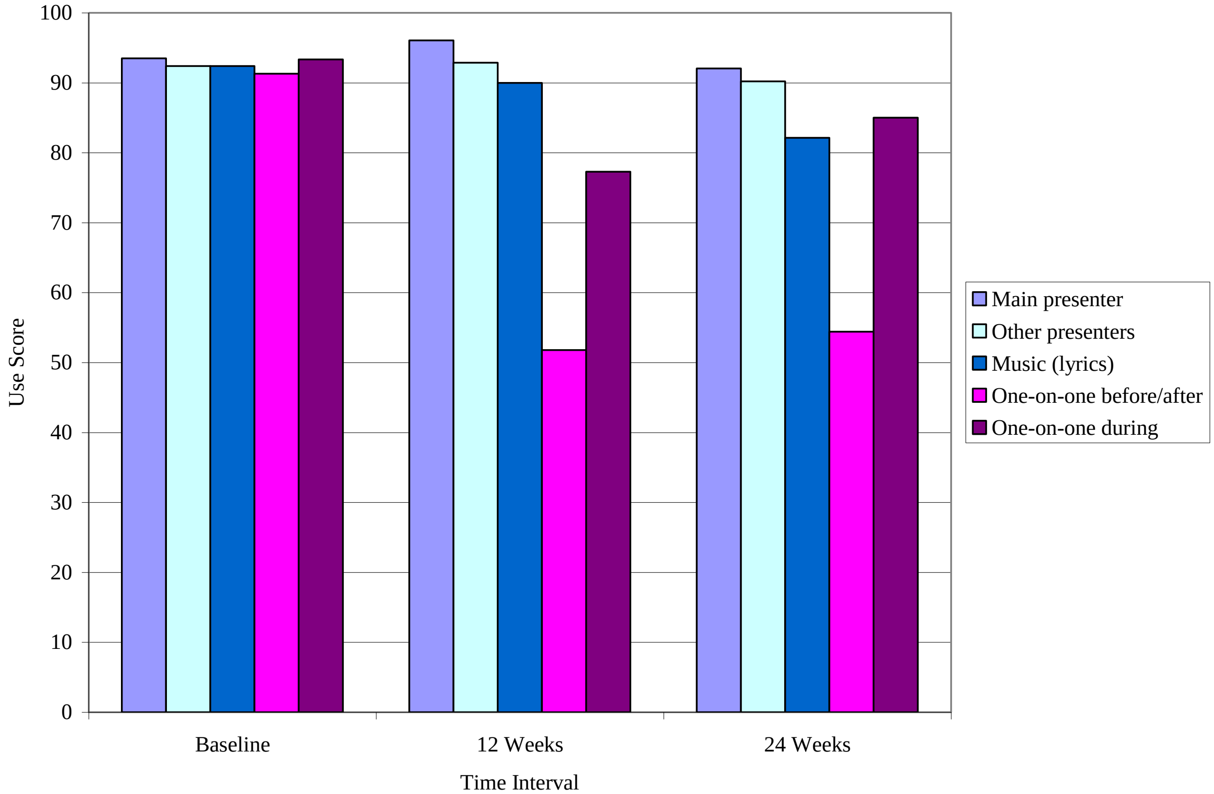

Figure 4-4. Reported Use scores from items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) for the 23 participants in the FM group. Baseline measure refects Use of amplification with hearing aid only. The measures at 12 and 24 weeks reflect Use of amplification with hearing aid and FM system.

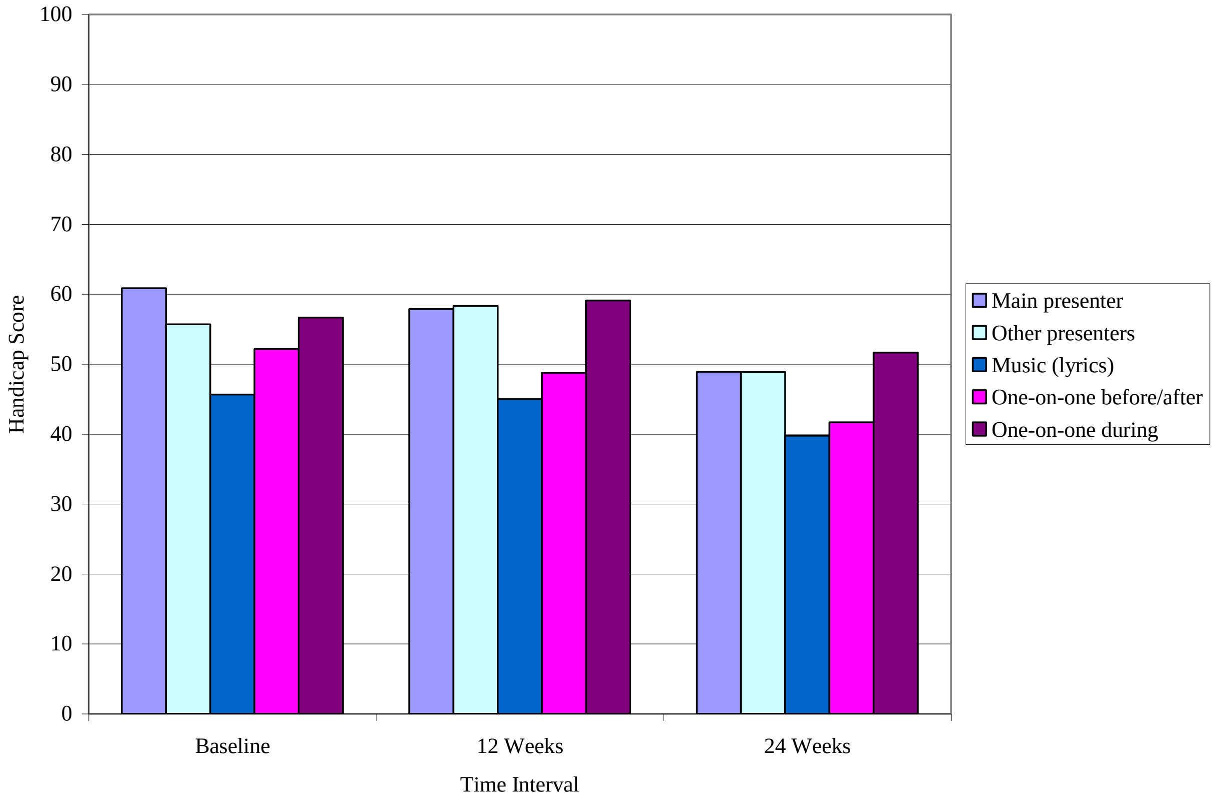

Figure 4-5. Handicap scores from items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP), Items 5-9 for the 23 participants in the FM group. Baseline measure refects Handicap with hearing aid only. The measures at 12 and 24 weeks reflect Handicap with hearing aid and FM system.

CHAPTER 5
DISCUSSION

The purpose of this investigation was to determine what differences, if any, would be revealed in multi-dimensional outcome measures during a 24 week trial with a Frequency Modulation (FM) system used in conjunction with a hearing aid in the place of worship. The typical participant in this investigation was a male (66%) whose age was in the mid-70s (mean = 76.3 years, range = 53-93 years) and had bilateral mild sloping to severe sensorineural hearing loss (pure tone average [PTA] of 54.6 decibels [dB]) and poor binaural word recognition ability in quiet (67.7% correct identification) and poor binaural word recognition ability in noise at a +10 dB signal-to-noise ration (17.6% correct identification.

Within the study, the results for the participants that were exposed to FM system amplification have shown several significant differences in subjective responses to written items that were created to assess outcomes in the place of worship. The results for listening situations or dimensions that were not specific to the place of worship did not reveal many significant differences. This is not surprising because for the majority (17/23 = 73.9%) of participants in the FM experimental group and none of the participants in the hearing aid only comparison group had exposure to the FM auditory signal outside the place of worship.

It was hypothesized the addition of the FM system to an individual's hearing aid amplification would significantly: decrease their hearing-related disability, decrease their hearing related handicap, improve their health related quality of life, improve their psychosocial impact toward assistive devices and improve their spiritual well-being, as reflected by their respective metrics. Two of the proposed hypotheses have been supported by the results with 95% confidence: the reduction in disability reflected by the GHABP and the improvement in psychosocial impact toward assistive devices reflected by the PIADS. Three of the proposed hypotheses have not been supported by the results: reduction in handicap, improvement in health related quality of life, and improvement in spiritual well-being.

It was also hypothesized that within the FM group, users with ear level receivers would have significantly greater (more positive) scores on psychosocial impact than users with belt level receivers as reflected in the PIADS measure. The results do not support this hypothesis at the 95% confidence level (only one of nine combinations or 11.1% of Mann Whitney U measures was significant). The results marginally support this hypothesis at the 90% confidence level (four of nine combinations, or 44.4% of Mann Whitney U measures were significant).

It was also hypothesized that the 24 week trial with an FM system used in a place of worship will have no difference on worship specific outcome measures between: the poor and fair performers of speech perception in noise; and between FM users that were exposed to the FM signal only in the place of worship and FM users who were exposed to the FM signal in more than the worship setting. The results support the null hypotheses of no significant differences ($\alpha = .05$) for: the word recognition in noise factor (70/75 combinations or 93.3% of Mann Whitney U comparisons were not significant) and the FM exposure factor (72/75 combinations or 96% of Mann Whitney U comparisons were not significant).

Glasgow Hearing Aid Benefit Profile (GHABP)

The GHABP was the most robust of all outcome measures in this investigation because it afforded the opportunity to specify situations that were unique to the place of worship while retaining the psychometric properties of the original measure. The worship listening situation was the second most common open-ended listening situation cited in the normative data of the GHABP (Gatehouse, 1999). In this study, five worship specific items were added to the GHABP. These results of these items provide useful data that support the potential inclusion of s worship specific item is the GHABP pre-specified conditions. However, most of the worship items constituted a valid addendum in this sample because each participant regularly attended worship services. From these outcome results, it appears that in the hearing related disability domain, that FM systems are capable of restoring functional listening ability according to subjective report.

Users of the FM system reported significant improvement in listening to the main presenter in the place of worship at 12 weeks in reported benefit ($p<.01$) and satisfaction ($p<.01$). At the 24 week assessment, improvement in reported benefit ($p<.01$) and satisfaction ($p < .01$) were maintained and improvement was also apparent for derived benefit ($p<.05$).

Users of the FM system reported significant improvement in listening to the other presenters in the place of worship at 12 weeks in reported benefit ($p < .01$), derived benefit ($p < .01$) and satisfaction ($p < .01$). At the 24 week assessment, improvement in reported benefit ($p < .01$), derived benefit ($p < .05$) and satisfaction ($p < .01$) were maintained..

Users of the FM system reported significantly greater satisfaction in listening to music during the worship service at 12 weeks ($p < .01$) and the satisfaction was maintained at 24 weeks ($p < .05$). Improvement was also apparent for reported benefit ($p<.05$) at 24 weeks.

Users of the FM system reported significantly greater use before and after the worship service at 12 weeks ($p < .01$) and 24 weeks ($p < .01$). It appears that users attribute the process of activating and deactivating the FM system as more active Use compared to just listening without manual manipulation because there were no significant findings of Use during the service. It is unlikely that these measures represent turning the system off before the service and turning the system on after the service because it conflicts with the improvements in listening during the service.

The four pre-specified listening situations (items 1-4) were not expected to change because there was, for the most part, no change in the amplification used in those situations. So, the lack of significant findings is not surprising. The results are actually encouraging because it validates that the open-ended portion of the GHABP measure was sensitive to measuring benefit while specific enough to resist spurious inflation of scores in unrelated situations.

Glasgow Benefit Inventory (GBI)

It is highly expected that using an FM system properly would enable the hearing aid wearer who experiences listening difficulty in the place of worship to hear better. Although the potential of the FM system to restore auditory function is quite high, the extent to which the FM system can improve the quality of life remains contested.

The GBI assesses the impact of an intervention on health related quality of life. At the baseline administration, the phrase, "since your HEARING AID fitting" took the place of the intervention. At the 12 and 24 week administrations, the phrase "since your FM SYSTEM fitting" took the place of the intervention. Participants were fit with hearing aids at various times and therefore had different levels of exposure to conventional amplification. Despite this, hearing aids were worn for a number of hours on a daily basis but FM amplification was worn for only about an hour on a weekly basis. The much greater GBI scores at baseline compared to 12 and 24 weeks showed a relatively small impact of FM amplification compared to hearing aid amplification. This effect may be viewed collectively or exclusively. The intent was for the question to be interpreted collectively and that any difference in scores could be attributed to the difference in amplification. However, the item terminology did not read "since your FM system was added to your hearing aid", we cannot be certain that participants interpreted similarly.

A closer look at response patterns to the 12 and 24 week administrations seems to indicate that the participants may have responded exclusively The difference between 12 and 24 weeks is significant (at the a = .05 level) on the non-parametric Wilcoxon test, but not on the parametric t-test for unmatched pairs. This indicates that, regardless of whether the FM was interpreted as part of the amplification system or as a separate amplification system, the significant change was evident in the within-subject comparison but not the between subject comparison. In other words, the potential misunderstanding of the items could have introduced enough variability in the responses to obscure the real difference, if one existed

Although it cannot be determined from the current investigation, it is reasonable to expect that the addition of FM to hearing aid amplification did not decrease the impact of the hearing aid intervention. The measures at 12 and 24 weeks both reflect an overall positive impact for the FM device. It can be seen from comparisons of the GBI mean scores on Table 4-6 decreased from baseline to 12 weeks and baseline to 24 weeks but they remained in the positive (non-negative) direction in the -100 to +100 range.

An alternative way to assess the total amplification system would be to utilize the Glasgow Health Status Inventory (GHSI, Glasgow Health Status Questionnaires (GHSQ) Information Package (2006). Hawthorne & Hogan, 2002) and to examine the effects of the hearing loss in general at different time intervals but not necessarily "since your intervention". This approach may avoid the pitfalls if misinterpreting the question; that the amplification system as a whole would be collectively assessed.

Psychosocial Impact of Assistive Devices Scale (PIADS)

None of the mean differences between intervals in PIADS scales reached statistical significance. Furthermore, none of the differences reached a clinically meaningful difference of at least 0.5 point (Jutai, 2006 personal communication). All of the mean scores on the PIADS measures ranged between 0 and 1 (within in a total range of -3 to +3), a small but positive psychosocial impact from their hearing aid at baseline and their FM at subsequent measures.

Although psychosocial impact did not improve with the FM system, it is reassuring to know that the impact did not decrease with the addition of another external device.

The mean scores on the adaptability subscale revealed a statistically significant main effect during the 24 week trial. However, post hoc testing did not reveal a significant difference at any of the time intervals. This was unexpected because the participants demonstrated the key constructs of the adaptability measure by taking part in the study: ability to adapt, willingness to take chances and eager to try new things. Perhaps if the FM users had greater daily exposure to their FM assistive device the change in adaptability would be more apparent. It is likely that the 6 personal FM users inflated the overall Adaptability scores to exhibit a main effect because they had Adaptability scores that were significantly greater than participants that were only exposed to FM in the place of worship.

The competence subscale purported to measure productivity, usefulness, performance and independence (Day & Jutai, 1996). The lack of a significant finding may not be very surprising because the descriptors used to describe the latent variable seem irrelevant in the context of the worship environment. It is possible that during this time of the worship service there is an introspective deactivation of the need to be resourceful or productive.

The self–esteem subscale purported to measure emotional health and happiness (Day & Jutai, 1996). It may be possible that the participants are attending worship services because they are secure in their emotional health or happiness; that they are not handicapped enough to stay at home (consistent with lack of findings in GHABP handicap and Hearing Handicap Inventory handicap measures) . It may also be that their mere presence at the worship service, not their speech perception of the spoken message is sufficient to maintain the same level of this construct.

Abbreviated Profile of Hearing Aid Benefit (APHAB)

None of the APHAB subscales of the Abbreviated Profile of Hearing Aid Benefit were significantly different during the FM trial. This is not surprising because for the majority of the sample (17 of 23), the FM system was only used in one venue, their place of worship. Another analysis of the 6 personal FM users compared to the main group is presented later.

Two items specifically pertained to listening experiences in the place of worship (items 18 and 21). Unexpectedly, neither item 18 nor item 21 revealed any significant differences. It is possible that these two items alone are not sensitive enough to detect a difference if one exists. Because the benefit scores (difference between aided and unaided scores) was used, it may be also be possible that additional variance was introduced in the derivation, causing potential real differences to be obscured. Another alternative is that the tendency to select the same non-applicable responses could have been more pronounced toward the end of the 24-item measure where items 18 and 21 were positioned.

Hearing Handicap Inventories (HHI)

None of the subscales or total scores on the Hearing Handicap Inventory for Adults (HHIA) or Hearing Handicap Inventory for the Elderly (HHIE) were statistically different during the FM trial. This was not surprising because all 25 items on the HHIA and 24 of the 25 items on the HHIE were not specific to listening in places of worship. The one item that asked if people attended religious services less often than they would like was also not statistically different. This was expected because we knew that these individuals were regularly attending their worship services. It may be considered as an indirect measure of compliance with the study protocol as attendance at the worship service precludes usage of a device during the service. It is interesting to note that the mean scores for the religious item decreased from baseline indicating less handicap at 12 and 24 weeks. The Analysis of Variance (ANOVA) result of the HHIE religious item ($x^2 = 5.20$, $p = 0.07$) was near significance.

The HHI is a detailed measure of handicap that isolates social and emotional examples of activity limitation whereas the GHABP measure of handicap asks “how much does this situation worry, upset or annoy you?” in a specified context. Despite differing definitions, both measures of handicap are corroborated because they both failed to find significant differences in this sample.

Spiritual Well-Being Scale (SWBS)

It was hypothesized that the FM system would facilitate communication during the worship service and that the more efficient auditory exposure would lead to a self-perceived improvement in the individual’s relationship with oneself and with God. This hypothesis was not supported by the results of the SWBS.

The baseline scores on the SWBS were fairly high (52.5 of 60 points for the religious scale, 50.4 of 60 points for the spirituality scale, and 102.9 of 120 points for the total SWBS scale). This finding suggests that these participants may have already had an optimal relationship with themselves and with God. A ceiling effect may present in certain religious groups such as those who regularly attend church. Bufford, Paloutzian & Ellison (1991) pointed out that the measure does not discriminate well in people above the 50th percentile. Visual inspection of mean scores in the current study with various normative samples of evangelical church goers confirms that our sample is functioning at the highest level of spiritual well being that can be assessed by the SWBS measure. It would be interesting to repeat this study in a group of hearing aid users that do not regularly attend religious services because of their hearing loss.

Between-Subject Comparisons on Selected Outcome Measures

At baseline, the 23 FM users and the 6 hearing aid only users did not differ in any of the objectively measured audiometrics or any of the subjectively rated outcome measures. This was not expected because it was surmised that the participants who opted out of the FM group did not experience as much listening difficulty and the respective dimensions associated with listening difficulty as the participants who opted to undergo the FM trial. However, because both groups were similar, it provided the opportunity to compare preliminary results between the FM experimental group and the hearing aid only comparison group.

The 23 FM users in the study scored significantly greater Satisfaction at 12 and 24 weeks, Reported Benefit at 24 weeks, and lesser HHIE handicap at 24 weeks than the 6 hearing aid only users in the comparison group. Although the unequal comparison groups and limited sample sizes limit the clinical significance of these findings, these results serve as a partial control for type of amplification group. It is therefore unlikely that the participants in the comparison group exhibited a response bias or a tendency to select responses to items that were perceived to be socially desirable had they used the FM system. These findings warrant further investigation with a larger sample of evenly divided groups in a randomized clinical trial design to further validate the listening improvement of the FM users experienced compared to the non-FM users.

Within the FM group, the most striking findings between the four binary comparisons occurred with the FM exposure variable with the Psychosocial Impact of Assistive Devices Scale (PIADS). The 6 personal FM users reported significantly greater Competence and Adaptability scores at baseline, 12 and 24 week intervals and Self Esteem at baseline than the 17 FM users who were only exposed to FM in the place of worship. The two-way ANOVAs with time interval as the within-subject variable cofirmed these findings. It appears that changes in psychosocial impact toward assistive devices become apparent when the exposure to the listening system is more commonly used in everyday listening situations.

Within the FM group, the personal FM users reported significantly less handicap during the service than the FM users that were only exposed only to FM in the place of worship at 24 weeks. Because the response rate for Item 9 “during service” questions was so low, a statement cannot be reliably made. If this relationship was backed by greater numbers, it appears that the addition of FM access to the place of worship with the everyday listening situations of personal FM users (who were not exposed to FM in the PW prior to the study) caused significantly less “worry, upset, or annoyance”. The PW-only FM users scored significantly greater Satisfaction and Reported Benefit before and after the service at 12 weeks then did the personal FM users. This may represent a small honeymoon effect of the new FM users because they did not exhibit the same effect at 24 weeks.

Within the FM group, the 11 users that wore belt level receivers reported significantly greater Use before and after the service at 12 and 24 weeks and Reported Benefit at 24 weeks than the 12 users that wore ear level receivers. This is likely attributed to the active process of putting the FM system on before the service and taking the FM system off at the end of the service. The users of ear level receivers had to push a button or flip a switch on their current hearing aid with FM receiver attached, but this process may have been viewed as more passive and less cumbersome than placement or removing headphones, earbuds or a neckloop.

The users with ear level receivers had significantly greater Competence scale scores at 24 weeks than the users of belt level receivers. This is consistent with the proposed hypothesis of greater PIADS outcomes with ear level receivers compared to belt level receivers. Despite this being the only significant finding in the PIADS, the 12-item Competence scale comprises the largest number of items in the 26-item total measure.

Within the FM group, the 12 poor performers in speech in noise testing (<20%) scored significantly greater in Satisfaction, Reported Benefit and Derived Benefit during the service at 24 weeks than the 11 fair performers in speech in noise testing (>/= 20%). Although the limited responses in the during the service category limit the finding, it appears that those with the poorest word recognition in noise are experiencing more positive effects during one-on-one communication during the service than those with fair word recognition. This may be because they were so far detached from their immediate environment prior to the trial that a clearer signal within the main message of the congregation facilitated more subtle communication nearby (eye contact, facial expressions, etc.). The fair performers reported significantly greater Reported Benefit in listening to the main presenter at 12 weeks than the poor performers. This effect would be expected because these users have greater word discrimination abilities to facilitate their understanding. Because the effect is not sustained at 24 weeks, it appears that the honeymoon effect may also occur in this measure; that the fair performers may have thought they were getting more benefit than they actually were. If the Derived Benefit measure showed effects at 24 weeks it would have confirmed that the benefit was real, at least under the assumption that this item/scale is valid.

Study Limitations

While the primary intent of this study was to investigate within subject changes associated with FM use in places of worship, the acquisition of data from several people who elected not to use the FM systems provided something of a comparison group. The use of these between group comparisons yielded some interesting findings. However, these findings could have been more robust had the control group been equal in size to the experimental group, randomly assigned, and matched for age, hearing loss, overall health, and perhaps even mental status.

Although all administrations of the outcome measures used in this study were made in the written mode, the response rate to the number of individual items was much lower in the 12 and 24 week administrations compared to the baseline administration. The participant was able to request clarification from the administrator during the clinic visit when the baseline measure was obtained. Because the administrator was not readily available when clarification was needed on the mailed administrations, it is possible that the questions were misinterpreted more often. Examination of the response patterns indicated that the majority of the missing items occurred on the same pages, suggesting that pages were sticking together and participants were unknowingly skipping a number of items.

None of the participants chose direct audio input (DAI) as a coupling method to use with the belt level receiver. It is possible that the design of the decision matrix inadvertently affected the selection process. There were two bullet points highlighted information on the ear level receiver that should have also been presented on the belt level via DAI option, “sounds the same as hearing aid” and “compatible with multiple transmitters”.

Summary

This investigation involved the addition of an FM system to conventional hearing aid amplification in a small sample of experienced hearing aid users and the determination of whether the addition had an impact on subjectively reported outcomes after 6 months of usage in a place of worship. For the group of participants that used the FM system, there was a significant improvement in a number of domains across time intervals. The majority of these changes were reflected in two outcome measures: the Glasgow Hearing Aid Benefit Profile (GHABP) that was adapted to assess the listening environment in the place of worship; and the

Psychosocial Impact of Assistive Devices Scale (PIADS). Subsequent investigations may therefore benefit from assessment of fewert, more pertinent outcomes measures such as the worship adapted GHABP and the PIADS. Because the place of worship continues to be one of the most commonly cited environments where people with hearing loss experience listening difficulty, the outcomes of amplification through subjective report will continue to gauge the success of the audiologic rehabilitative efforts.

APPENDIX A
DECISION MATRIX FOR SELECTION FM RECEIVERS

FM receivers/couplers	Benefits	Limitations
Wireless	• cosmetically appealing (wireless) • excellent signal strength • sounds the same as hearing aid • compatible with multiple transmitters	• cost
Traditional via Direct Audio Input (DAI)	• excellent signal strength • inexpensive	• visible wire to hearing aid
Traditional Via Telecoil + neckloop	• semi-discrete wire placement, visible from neck down • inexpensive	• fair signal strength • susceptible to interference

APPENDIX B
BEHAVIOR MATRIX FOR MICROPHONE ACTIVATION

Microphones activated	Benefits	Limitation	Preferred Situation
FM only	• can hear far away • can hear through noise • can hear through reverberation	• cannot hear nearby	• large areas • noisy areas • reverberant areas • no desire to hear sound nearby
FM and Hearing Aid	• all sound sources may be heard	• nearby sound interferes with perception of far away sound	• desire to hear occasional sound nearby
Hearing Aid only	• nearby sound	• no FM advantage	• both ears →one-on-one in quiet • one ear → combinations are alternate method to hear far (FM) and near (hearing aid)

APPENDIX C
QUESTIONNAIRE BOOKLET FOR THE FM GROUP

Abbreviated Profile of Hearing Aid Benefit (APHAB)

The following directions were included in the APHAB:

> Please place a check mark by the answers that come close to your everyday experience. Notice that each choice contains a percentage. You can use this to help you decide on your answer. For example, if the statement is true about 75% of the time, check C for that item. Please select only one choice per question.

The following listening situtations were included as items in the APHAB:

1. When I am in a crowded grocery store, talking with the cashier, I can follow the conversation.
2. I miss a lot of information when I'm listening to a lecture.
3. Unexpected sounds, like a smoke detector or alarm bell are uncomfortable.
4. I have difficulty hearing a conversation when I am with one of my family at home.
5. I have trouble understanding the dialogue in a movie or at the theater.
6. When I am listening to the news on a car radio and family members are talking, I have trouble hearing the news.
7. When I'm at the dinner table with several people, and am trying to have a conversation with one person, understanding speech is difficult.
8. Traffic noises are too loud.
9. When I'm talking with someone across a large empty room, I understand the words.
10. When I'm in a small office, interviewing or answering questions, I have difficulty following the conversation.
11. When I'm in the theater watching a movie or play, and people around me whisper and rustle paper wrappers, I can still make out the dialogue.
12. When I'm having a quiet conversation with a friend, I have difficulty understanding.
13. The sounds of running water, such as a toilet or shower, are uncomfortably loud.
14. When a speaker is addressing a small group, and everyone is listening quietly, I have to strain to understand.
15. When I'm in a quiet conversation with my doctor in an examination room, it is hard to follow the conversation.
16. I can understand conversations even when several people are talking.
17. The sounds of construction work are uncomfortably loud.
18. It is hard for me to understand what is being said at lectures or church services.
19. I can communicate with others when we are in a crowd.
20. The sound of a fire engine close by is so loud that I need to cover my ears.
21. I can follow the words of a sermon when listening to a religious service.
22. The sound of screeching tires is uncomfortably loud.
23. I have to ask people to repeat themselves in one-on-one conversation in a quiet room.
24. I have trouble understanding others when an air conditioner or fan is on.

The following response choices were included for each item of the APHAB:

WITH HEARING AIDS ONLY (choose one)

a ___ always (99%)
b ___ almost always (87%)
c ___ generally (75%)
d ___ half-the-time (50%)
e ___ occasionally (25%)
f ___ seldom (12%)
g ___ never (1%)
h ___ not applicable (N/A)

WITH HEARING AIDS AND FM SYSTEM (choose one)

a ___ always (99%)
b ___ almost always (87%)
c ___ generally (75%)
d ___ half-the-time (50%)
e ___ occasionally (25%)
f ___ seldom (12%)
g ___ never (1%)
h ___ not applicable (N/A)

Glasgow Hearing Aid Benefit Profile (GHABP)

The following listening situations were included as items in the GHABP:

1. Listening to the television with other family or friends when the volume is adjusted to suit other people
2. Having a conversation with one other person when there is no background noise
3. Carrying on a conversation in a busy street or shop
4. Having a conversation with several people in a group
5. Listening to the main presenter in a house of worship (e.g. pastor, priest, rabbi, etc.)
6. Listening to other presenters in a house of worship (e.g. readers, guest speakers, people who make announcements, etc.)
7. Listening to music in a house of worship (understanding the lyrics of the people singing)
8. Having a one-on-one conversation in a house of worship immediately before or after the service (many people speaking simultaneously)
9. Having aone-on-one conversation in a house of worship during the service (while one presenter is speaking)

The following response choices were included for each item of the GHABP:

Does this situation happen in your life?

0 ___ No (please proceed to the next question) 1 ___ Yes

a. How much difficulty do you have in this situation?
(WITH YOUR HEARING AID ONLY)

0___Not applicable, N/A
1___No difficulty
2___Only slight difficulty
3___Moderate difficulty
4___Great difficulty
5___Cannot manage at all

b. How much does any difficulty in this situation worry, annoy or upset you?
(WITH YOUR HEARING AID ONLY)

0___Not applicable, N/A
1___Not at all
2___Only a little
3___A moderate amount
4___Quite a lot
5___Very much indeed

c. In this situation, what proportion of the time do you wear your FM SYSTEM?

0___Not applicable, N/A
1___Never / Not at all
2___About ¼ of the time
3___About ½ of the time
4___About ¾ of the time
5___All the time

d. In this situation, how much does your FM SYSTEM help you?

0___Not applicable, N/A
1___FM SYSTEM no use at all
2___FM SYSTEM is some help
3___FM SYSTEM is quite helpful
4___FM SYSTEM is a great help
5___Hearing is perfect with aid

e. In this situation, with your FM SYSTEM, how much difficulty do you now have?

0___Not applicable, N/A
1___No difficulty
2___Only slight difficulty
3___Moderate difficulty
4___Great difficulty
5___Cannot manage at all

f. For this situation, how satisfied are you with your FM SYSTEM?

0___Not applicable, N/A
1___Not satisfied at all
2___A little satisfied
3___Reasonably satisfied
4___Very satisfied
5___Delighted with aid

Glasgow Benefit Inventory (GBI)

The following listening situtations were included as items in the GBI:

1. Has the result of the FM SYSTEM fitting affected the things you do?
2. Have the results of the FM SYSTEM fitting made your overall life better or worse?
3. Since your FM SYSTEM fitting, have you felt more or less optimistic about the future?
4. Since your FM SYSTEM fitting, do you feel more or less embarrassed when with a group of people?
5. Since your FM SYSTEM fitting, do you have more or less self-confidence?
6. Since your FM SYSTEM fitting, have you found it easier or harder to deal with company?
7. Since your FM SYSTEM fitting, do you feel that you have more or less support from your friends?
8. Have you been to your family doctor, for any reason, more or less often, since your FM SYSTEM fitting?
9. Since your FM SYSTEM fitting, do you feel more or less confident about job opportunities?
10. Since your FM SYSTEM fitting, do you feel more or less self-conscious?
11. Since your FM SYSTEM fitting, are there more or fewer people who really care about you?
12. Since you had the FM SYSTEM fitting, do you catch colds or infections more or less often?
13. Have you had to take more or less medicine for any reason, since your FM SYSTEM fitting?
14. Since your FM SYSTEM fitting, do you feel better or worse about yourself?
15. Since your FM SYSTEM fitting, do you feel that you have had more or less support from your family?
16. Since your FM SYSTEM fitting, are you more or less inconvenienced by your hearing problem?
17. Since your FM SYSTEM fitting, have you been able to participate in more or fewer social activities?
18. Since your FM SYSTEM fitting, have you been more or less inclined to withdraw from social situations?

The following response choices are representative of items of the GBI (here, responses to item #1 shown):

1___ much worse
2___ a little or somewhat worse
3___ no change
4___ a little or somewhat better
5___ much better

Hearing Handicap Inventory (HHI)

The following directions were included in the HHI:

> The purpose of this scale is to identify the problems your hearing loss may be causing you. Check ONE RESPONSE: Yes, Sometimes, or No for each question. Do not skip a question if you avoid a situation because of a hearing problem.

The following listening situtations were included as items in the HHI:

1. Does a hearing problem cause you to use the phone less often than you would like?
2. Does a hearing problem cause you to feel embarrassed when meeting new people?
3. Does a hearing problem cause you to avoid groups of people?
4. Does a hearing problem make you irritable?
5. Does a hearing problem cause you to feel frustrated when talking to members of your family?
6. Does a hearing problem cause you difficulty when attending a party?
7. Does a hearing problem cause you difficulty hearing/understanding coworkers, clients, or customers?
8. Do you feel handicapped by a hearing problem?
9. Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?
10. Does a hearing problem cause you to feel frustrated when talking to coworkers, clients, or customers?
11. Does a hearing problem cause you difficulty in the movies or theater?
12. Does a hearing problem cause you to be nervous?
13. Does a hearing problem cause you to visit friends, relatives, or neighbors less often than you would like?
14. Does a hearing problem cause you to have arguments with family members?
15. Does a hearing problem cause you difficulty when listening to TV or radio?
16. Does a hearing problem cause you to go shopping less often than you would like?
17. Does any problem or difficulty with your hearing upset you at all?
18. Does a hearing problem cause you to want to be by yourself?
19. Does a hearing problem cause you to talk to family members less often than you would like?
20. Do you feel that any difficulty with your hearing limits or hampers your personal or social life?
21. Does a hearing problem cause you difficulty when in a restaurant with relatives or friends?
22. Does a hearing problem cause you to feel depressed?
23. Does a hearing problem cause you to listen to TV or radio less often than you would like?
24. Does a hearing problem cause you to feel uncomfortable when talking to friends?
25. Does a hearing problem cause you to feel left out when you are with a group of people?
26. Does a hearing problem cause you to feel “stupid” or “dumb”?
27. Do you have difficulty hearing when someone speaks to you in a whisper?
28. Does a hearing problem cause you to attend religious services less often than you would like?

The following response choices were included for each item of the HHI:

___ Yes

___ Sometimes

___ No

Psychosocial Impaact of Assistive Devices Scale (PIADS)

The following directions were included in the PIADS:

> Each word or phrase below describes how using an assistive device may affect a user. Some items might seem unusual but it is important that you answer every one of the 26 items. So for each word or phrase, check ONE RESPONSE for the appropriate box to show how you are affected using your FM SYSTEM.

The following items were included in the PIADS:

1. competence
2. happiness
3. independence
4. adequacy
5. confusion
6. efficiency
7. self-esteem
8. productivity
9. security
10. frustration
11. usefulness
12. self-confidence
13. expertise
14. skillfulness
15. well-being
16. capability
17. quality of life
18. performance
19. sense of power
20. sense of control
21. embarrassment
22. willingness to take chances
23. ability to participate
24. eagerness to try new things
25. ability to adapt to the activities of daily living
26. ability to take advantage of opportunities

The following response choices were included for each item of the PIADS:

___ increases +3
___ increases +2
___ increases +1
___ no change 0
___ decreases –1
___ decreases –2
___ decreases –3

Spiritual Well Being Scale (SWBS)

The following directions were included in the SWBS:

For each of the following statements, check the choice that best indicates the extent of your agreement or disagreement as it describes your personal experience.

The following items were included in the SWBS:

1. I don't find much satisfaction in private prayer with God.
2. I don't know who I am, where I came from, or where I'm going.
3. I believe that God loves me and cares about me.
4. I feel that life is a positive experience.
5. I believe that God is impersonal and not interested in my daily situations.
6. I feel unsettled about my future.
7. I have a personally meaningful relationship with God.
8. I feel very fulfilled and satisfied with life.
9. I don't get much personal strength and support from my God.
10. I feel a sense of well-being about the direction my life is headed in.
11. I believe that God is concerned about my problems.
12. I don't enjoy much about life.
13. I don't have a personally satisfying relationship with God.
14. I feel good about my future.
15. My relationship with God helps me not to feel lonely.
16. I feel that life is full of conflict and unhappiness.
17. I feel most fulfilled when I'm in close communication with God.
18. Life doesn't have much meaning.
19. My relationship with God contributes to my sense of well-being.
20. I believe there is some real purpose for my life.

The following response choices were included for each item of the PIADS:

___ strongly agree
___ moderately agree
___ agree
___ disagree
___ moderately disagree
___ strongly disagree

APPENDIX D
TEST STATISTIC SUMMARIES

Friedman Analysis of Variance Tests

Table D-1. Friedman Analysis of Variance (ANOVA) statistics for Worship Specific Items on the Glasgow Hearing Aid Benefit Profile (GHABP).

Item		Handicap	Use	Reported Benefit	Derived Benefit	Satisfaction
5						
	N	19.000	18.000	**19.000**	**18.000**	**18.000**
	X^2	2.375	1.333	**22.680**	**23.684**	**23.684**
	p	0.305	0.513	**0.000**	**0.000**	**0.000**
6						
	N	19.000	21.000	**20.000**	**20.000**	**20.000**
	X^2	3.435	0.722	**30.333**	**23.273**	**23.273**
	p	0.180	0.697	**0.000**	**0.000**	**0.000**
7						
	N	19.000	18.000	**16.000**	17.000	**17.000**
	X^2	0.000	0.867	**10.651**	2.178	**10.857**
	p	1.000	0.648	**0.005**	0.337	**0.004**
8						
	N	19.000	**12.000**	9.000	9.000	**8.000**
	X^2	0.591	**8.897**	2.545	1.448	**7.929**
	p	0.744	**0.012**	0.280	0.485	**0.019**
9						
	N	7.000	8.000	8.000	8.000	7.000
	X^2	0.105	2.000	0.231	0.636	1.900
	p	0.949	0.368	0.891	0.727	0.387

Sub-sample size, chi-square statistic and p-value included in each analysis. Statistics in boldface type are significant at α = .05 level and were further analyzed with Wilcoxon Signed Ranks tests.

Table D-2. Friedman Analysis of Variance (ANOVA) statistics for the Glasgow Benefit Inventory (GBI).

Total Scale		
	N	19.000
	X^2	9.694
	p	0.008
General Scale		
	N	19.000
	X^2	8.149
	p	0.017
Social Subscale		
	N	19.000
	X^2	4.647
	p	0.098
Physical Subscale		
	N	19.000
	X^2	4.625
	p	0.099

Sub-sample size, chi-square statistic and p-value included in each analysis.

Table D-3. Friedman Analysis of Variance (ANOVA) statistics for the Psychosocial Impact of Assistive Devices Scale (PIADS).

Adaptability Subscale		
	N	**23.000**
	X^2	**6.907**
	p	**0.032**
Competence Subscale		
	N	23.000
	X^2	1.435
	p	0.488
Self-esteem Subscale		
	N	23.000
	X^2	1.537
	p	0.464

Sub-sample size, chi-square statistic and p-value included in each analysis. Results in boldface type are significant at □ = .05 level and were further analyzed with Wilcoxon Signed Ranks tests.

Table D-4. Friedman Analysis of Variance (ANOVA) statistics for the Abbreviated Profile of Hearing Aid Benefit (APHAB).

Ease of Communication Subscale		
	N	10.000
	X^2	4.000
	p	0.135
Reverberation Subscale		
	N	20.000
	X^2	2.354
	p	0.308
Background Noise Subscale		
	N	11.000
	X^2	0.905
	p	0.636
Aversiveness to Sound Subscale		
	N	**8.000**
	X^2	**12.452**
	p	**0.002**
Item 18		
	N	19.000
	X^2	3.800
	p	0.150
Item 21		
	N	18.000
	X^2	3.484
	p	0.175

Sub-sample size, chi-square statistic and p-value included in each analysis. Results in boldface type are significant at α = .05 level and were further analyzed with Wilcoxon Signed Ranks tests.

Table D-5. Friedman Analysis of Variance (ANOVA) statistics for the Hearing Handicap Inventory (HHI).

HHIA Social Subscale		
	N	23.000
	X^2	0.220
	p	0.896
HHIE Social Subscale		
	N	23.000
	X^2	2.385
	p	0.304
HHIA Emotional Subscale		
	N	23.000
	X^2	1.537
	p	0.464
HHIE Emotional Subscale		
	N	23.000
	X^2	2.214
	p	0.331
HHIA Total Scale		
	N	23.000
	X^2	3.129
	p	0.209
HHIE Total Scale		
	N	23.000
	X^2	2.966
	p	0.227
HHIE Item S11		
	N	22.000
	X^2	5.200
	p	0.070

Sub-sample size, chi-square statistic and p-value included in each analysis. The Hearing Handicap Inventory used in this study included the combined items of the Hearing Handicap Inventory for Adults (HHIA) and the Hearing Handicap Inventory for the Elderly (HHIE). Results and analyses were grouped in their original order to permit comprisons of total scale and sub-scales. Item S11 was also analysed separately because it specifically pertained to attendance at religious services.

Table D-6. Friedman Analysis of Variance (ANOVA) statistics for the Spiritual Well Being Scale (SWBS).

Religious Subscale		
	N	23.000
	X^2	1.537
	p	0.464
Spirituality Subscale		
	N	23.000
	X^2	1.326
	p	0.515
Total Scale		
	N	23.000
	X^2	1.281
	p	0.527

Sub-sample size, chi-square statistic and p-value included in each analysis.

Wilcoxon Signed Ranks Tests

Table D-7. Wilcoxon Signed Ranks test statistics for worship specific items that exhibited a significant main effect (α = .05) on Analysis of Variance (ANOVA) in the Glasgow Hearing Aid Benefit Profile (GHABP).

Item		Baseline to 12 Weeks	Baseline to 24 Weeks	12 to 24 Weeks
5				
	Reported Benefit			
	Z	**3.520**	**3.019**	1.414
	p	**0.000**	**0.003**	0.157
	Derived Benefit			
	Z	1.624	**2.041**	0.758
	p	0.104	**0.041**	0.449
	Satisfaction			
	Z	**3.627**	**3.822**	0.000
	p	**0.000**	**0.000**	1.000
6				
	Reported Benefit			
	Z	**3.817**	**3.729**	0.000
	p	**0.000**	**0.000**	1.000
	Derived Benefit			
	Z	**2.582**	**2.412**	0.418
	p	**0.010**	**0.016**	0.676
	Satisfaction			
	Z	**3.769**	**3.713**	0.000
	p	**0.000**	**0.000**	1.000
7				
	Reported Benefit			
	Z	1.888	**2.310**	1.265
	p	0.059	**0.021**	0.206
	Satisfaction			
	Z	**2.769**	1.805	0.535
	p	**0.006**	0.071	0.593
8				
	Use			
	Z	**2.598**	**2.855**	0.412
	p	**0.009**	**0.004**	0.680
	Satisfaction			
	Z	**2.124**	0.243	1.518
	p	**0.034**	0.808	0.129

The Z statistic and p-value are listed for each time interval. The significant statistics ($p < .05$) are indicated in bold face type.

Table D-8. Wilcoxon Signed Ranks test statistics which exhibited a significant main effect(α = .05) on Analysis of Variance (ANOVA) in the Psychosocial Impact of Assistive Devices Scale (PIADS).

		Baseline to 12 Weeks	Baseline to 24 Weeks	12 to 24 Weeks
Adaptability subscale				
	Z	**1.837**	1.097	1.438
	p	**0.066**	0.273	0.151

The Z statistic and p-value are listed for each time interval. The significant statistics ($p < .05$) are indicated in bold face type.

Table D-9. Wilcoxon Signed Ranks test statistics for items that exhibited a significant main effect (α = .05) on the Analysis of Variance (ANOVA) in the Glasgow Benefit Inventory (GBI).

		Baseline to 12 Weeks	Baseline to 24 Weeks	12 to 24 Weeks
Total Scale				
	Z	1.610	1.773	**2.061**
	P	0.107	0.076	**0.039**
General Scale				
	Z	1.372	1.811	**2.024**
	P	0.170	0.070	**0.043**

The Z statistic and p-value are listed for each time interval. The significant statistics ($p < .05$) are indicated in bold face type.

Table D-10. Wilcoxon Signed Ranks test statistics for items that exhibited a significant main effect (□ □= .05) on the Analysis of Variance (ANOVA) in the Abbreviated Profiled of Hearing Aid Benefit (APHAB).

		Baseline to 12 Weeks	Baseline to 24 Weeks	12 to 24 Weeks
Aversiveness to Sound Subscale				
	Z	**2.803**	**2.401**	0.169
	p	**0.005**	**0.016**	0.866

The Z statistic and p-value are listed for each time interval. The significant statistics ($p < .05$) are indicated in bold face type.

Mann Whitney U Tests

Table D-11. Mann Whitney U test statistics for comparison of audiometrics between the FM group and comparison group.

Audiometric		Left	Right	Binaural in Quiet	Binaural in Noise (+10 SNR)
PTA					
	Z	0.404	0.404	-	-
	p	0.686	0.686	-	-
250 Hz					
	Z	0.189	0.216	-	-
	p	0.850	0.829	-	-
500 Hz					
	Z	0.163	0.352	-	-
	p	0.871	0.725	-	-
1kHz					
	Z	0.054	0.838	-	-
	p	0.957	0.402	-	-
2 kHz					
	Z	0.947	0.226	-	-
	p	0.343	0.821	-	-
4kHz					
	Z	1.439	0.141	-	-
	p	0.150	0.888	-	-
8 kHz					
	Z	0.482	0.452	-	-
	p	0.630	0.651	-	-
Word Recognition					
	Z	0.505	0.431	0.917	0.27
	p	0.614	0.666	0.359	0.787

Audiometrics include pure tone air audiometry and speech audiometry. Included are pure tone air (PTA) thresholds for the left ear in quiet, pure tone air (PTA) thresholds for the right ear in quiet; binaural word recognition percent correct score in quiet; and binaural word recognition percent correct score in noise (+ 10 dB SNR).

Table D-12. Mann Whitney U test statistics for comparison between FM group and comparison group on the Glasgow Hearing Aid Benefit Profile (GHABP).

		Satisfaction			Reported Benefit			Derived Benefit		
Item		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
5										
	Z	0.692	1.355	1.030	0.692	1.355	1.030	0.000	0.180	0.318
	p	0.489	0.175	0.303	0.489	0.175	0.303	1.000	0.857	0.750
6										
	Z	1.104	**2.489**	**2.344**	1.104	2.489	**2.344**	1.178	1.841	1.169
	p	0.270	**0.013**	**0.019**	0.270	0.013	**0.019**	0.239	0.066	0.242
7										
	Z	0.688	1.464	**1.909**	0.688	1.464	**1.909**	0.357	0.579	0.423
	p	0.491	0.143	**0.056**	0.491	0.143	**0.056**	0.721	0.562	0.872
8										
	Z	0.766	0.625	0.353	0.766	0.625	0.353	1.176	0.758	0.610
	p	0.444	0.532	0.724	0.444	0.532	0.724	0.240	0.448	0.542
9										
	Z	**1.714**	0.626	0.113	1.714	0.626	0.113	1.297	0.460	0.492
	p	**0.087**	0.532	0.910	0.087	0.532	0.910	0.194	0.646	0.623

The Z statistic and p-value are included for each analysis. The analyses for Satisfaction, Reported Benefit and Derived Benefit scales of created items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) included.

Table D-12 Continued

Item		Use Baseline	Use 12 Weeks	Use 24 Weeks	Handicap Baseline	Handicap 12 Weeks	Handicap 24 Weeks
5							
	Z	1.892	0.710	0.675	0.479	1.602	1.631
	p	0.059	0.478	0.500	0.632	0.109	0.103
6							
	Z	1.258	0.135	1.332	0.294	1.794	1.239
	p	0.208	0.893	0.183	0.769	0.073	0.215
7							
	Z	1.258	1.414	1.280	0.028	1.033	0.552
	p	0.208	0.157	0.201	0.978	0.302	0.581
8							
	Z	1.259	**2.858**	**3.237**	0.224	0.960	0.180
	p	0.208	**0.004**	**0.001**	0.823	0.337	0.857
9							
	Z	0.398	0.302	0.446	0.405	0.673	0.363
	p	0.690	0.763	0.655	0.686	0.501	0.716

The Z statistic and p-value are included for each analysis. The analyses for Use and Handicap scales of created items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) included.

Table D-13. Mann Whitney U statistics for comparison between Ear level receivers and Belt level receivers within the FM Group on the Glasgow Hearing Aid Benefit Profile (GHABP).

Item		Satisfaction			Reported Benefit			Derived Benefit		
		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
5										
	Z	0.842	0.475	1.639	0.389	1.269	1.892	0.934	0.317	0.424
	p	0.400	0.635	0.101	0.697	0.205	0.059	0.350	0.751	0.671
6										
	Z	0.831	1.456	0.970	0.067	1.456	0.576	0.858	1.498	0.988
	p	0.406	0.145	0.332	0.946	0.145	0.565	0.391	0.134	0.323
7										
	Z	0.601	0.261	1.208	0.662	1.103	0.000	0.581	**1.799**	0.895
	p	0.548	0.754	0.201	0.508	0.270	1.000	0.561	**0.072**	0.371
8										
	Z	0.789	0.275	**1.841**	0.598	**2.250**	**1.841**	0.602	0.855	0.680
	p	0.430	0.784	**0.066**	0.550	**0.024**	**0.066**	0.547	0.393	0.496
9										
	Z	1.361	0.000	1.025	0.773	0.096	**1.698**	1.206	1.214	**2.103**
	p	0.174	1.000	0.305	0.439	0.923	**0.090**	0.228	0.225	**0.035**

The Z statistic and p-value are included for each analysis. The analyses for Satisfaction, Reported Benefit and Derived Benefit scales of created items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) included.

Table D-13. Continued

Item		Use Baseline	Use 12 Weeks	Use 24 Weeks	Handicap Baseline	Handicap 12 Weeks	Handicap 24 Weeks
5							
	Z	1.892	0.710	0.675	0.852	1.036	0.950
	p	0.059	0.478	0.500	0.394	0.300	0.342
6							
	Z	1.258	0.135	1.332	1.200	0.150	0.745
	p	0.208	0.893	0.183	0.230	0.881	0.456
7							
	Z	1.258	1.414	0.807	0.700	1.513	1.051
	p	0.208	0.157	0.420	0.484	0.130	0.293
8							
	Z	1.259	**2.858**	**3.237**	1.274	1.079	1.444
	p	0.208	**0.004**	**0.001**	0.203	0.281	0.149
9							
	Z	0.398	0.302	0.446	0.869	1.229	1.614
	p	0.690	0.763	0.655	0.385	0.219	0.107

The Z statistic and p-value are included for each analysis. The analyses for Use and Handicap scales of created items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) included.

Table D-14. Mann Whitney U Statistics for comparison between Personal FM Users and Worship only FM users on the Glasgow Hearing Aid Benefit Profile (GHABP).

		Satisfaction			Reported Benefit			Derived Benefit		
Item		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
1										
	Z	0.481	0.000	0.136	0.746	1.342	1.195	0.265	0.000	0.316
	p	0.631	1.000	0.892	0.456	0.180	0.232	0.791	1.000	0.752
2										
	Z	0.999	0.935	0.995	0.491	0.316	0.648	0.874	0.000	0.398
	p	0.318	0.350	0.320	0.623	0.752	0.517	0.382	1.000	0.691
3										
	Z	0.206	0.500	0.266	0.754	0.984	0.143	0.000	0.500	0.654
	p	0.836	0.617	0.790	0.451	0.325	0.886	1.000	0.617	0.513
4										
	Z	0.505	1.303	0.203	0.449	0.657	0.597	0.604	1.207	0.603
	p	0.614	0.193	0.839	0.654	0.511	0.550	0.546	0.227	0.546
5										
	Z	1.033	0.719	**1.937**	1.033	0.719	1.937	0.157	0.046	0.817
	p	0.301	0.472	**0.053**	0.301	0.472	0.053	0.875	0.963	0.414
6										
	Z	0.383	0.522	0.429	0.383	0.522	0.429	1.238	0.395	0.552
	p	0.702	0.602	0.668	0.702	0.602	0.668	0.216	0.693	0.581
7										
	Z	0.979	0.247	0.844	0.979	0.247	0.844	0.117	0.202	1.001
	p	0.328	0.805	0.398	0.328	0.805	0.398	0.907	0.840	0.317
8										
	Z	0.340	**1.979**	**1.744**	0.340	**1.979**	**1.744**	0.076	0.189	0.168
	p	0.734	**0.048**	**0.081**	0.734	**0.048**	**0.081**	0.939	0.850	0.866
9										
	Z	0.428	0.398	1.505	0.428	0.398	1.505	0.843	0.993	**1.709**
	p	0.668	0.690	0.132	0.668	0.690	0.132	0.399	0.321	**0.087**

The Z statistic and p-value are included for each analysis. The analyses for all items are included because items 1-4 may be petinent to Personal FM users.

Table D-14 Continued.

		Use			Handicap		
		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
1							
	Z	0.212	0.864	0.679	1.337	**1.847**	1.571
	p	0.832	0.388	0.497	0.181	**0.065**	0.116
2							
	Z	1.078	1.911	0.651	0.405	1.298	1.645
	p	0.281	0.056	0.515	0.686	0.194	0.100
3							
	Z	1.116	1.826	0.946	0.311	1.443	1.376
	p	0.264	0.068	0.344	0.756	0.149	0.169
4							
	Z	0.658	1.162	1.291	0.039	1.379	0.618
	p	0.510	0.245	0.197	0.969	0.168	0.537
5							
	Z	1.076	1.098	0.755	1.044	0.917	**1.657**
	p	0.282	0.272	0.450	0.297	0.359	**0.098**
6							
	Z	1.272	1.581	0.303	**1.840**	1.151	**1.858**
	p	0.203	0.114	0.762	**0.066**	0.250	**0.063**
7							
	Z	1.272	1.250	0.047	0.109	1.532	1.402
	p	0.203	0.211	0.963	0.914	0.126	0.161
8							
	Z	1.273	1.429	0.931	0.797	1.111	1.270
	p	0.203	0.153	0.352	0.425	0.267	0.204
9							
	Z	0.883	0.208	0.252	0.000	1.860	**2.292**
	p	0.377	0.835	0.801	1.000	0.063	**0.022**

The Z statistic and p-value are included for each analysis. The analyses for all items are included because items 1-4 may be petinent to Personal FM users.

Table D-15. Mann Whitney U statistics for comparison between participants that scored below 20% and above 20% on word recognition in noise within the FM Group in the Glasgow Hearing Aid Benefit Profile (GHABP).

		Satisfaction			Reported Benefit			Derived Benefit		
Item		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
5										
	Z	1.230	1.371	1.080	0.357	**2.220**	0.605	0.968	1.316	**1.664**
	p	0.219	0.170	0.280	0.721	**0.026**	0.545	0.333	0.188	**0.096**
6										
	Z	1.197	0.890	1.194	1.009	1.537	0.729	0.198	0.562	1.124
	p	0.231	0.374	0.233	0.313	0.124	0.466	0.843	0.574	0.261
7										
	Z	1.269	1.393	0.244	0.662	0.000	1.019	0.923	1.023	0.399
	p	0.204	0.164	0.807	0.508	1.000	0.308	0.356	0.306	0.690
8										
	Z	1.052	0.261	1.036	0.765	1.250	1.628	1.237	1.229	0.410
	p	0.293	0.794	0.300	0.444	0.211	0.103	0.216	0.219	0.682
9										
	Z	0.680	0.000	**2.164**	1.611	0.962	2.122	1.611	0.962	**2.122**
	p	0.496	1.000	**0.030**	0.107	0.336	0.034	0.107	0.336	**0.034**

The Z statistic and p-value are included for each analysis. The analyses for Satisfaction, Reported Benefit and Derived Benefit scales of created items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) included.

Table D-15 Continued.

		Use			Handicap		
		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
5							
	Z	0.631	0.710	0.900	0.262	0.598	0.190
	p	0.528	0.478	0.368	0.793	0.550	0.849
6							
	Z	0.093	1.079	0.799	1.377	0.000	0.204
	p	0.926	0.281	0.424	0.169	1.000	0.838
7							
	Z	0.093	0.272	0.042	0.350	0.507	0.338
	p	0.926	0.786	0.966	0.726	0.612	0.736
8							
	Z	0.093	0.277	-0.200	0.000	0.354	1.083
	p	0.926	0.782	0.842	1.000	0.723	0.279
9							
	Z	0.199	0.201	0.074	0.434	1.229	0.657
	p	0.842	0.840	0.941	0.664	0.219	0.511

The Z statistic and p-value are included for each analysis. The analyses for Use and Handicap scales of created items 5-9 of the Glasgow Hearing Aid Benefit Profile (GHABP) included.

Table D-16. Mann Whitney U statistics for all four between subject comparisons on the Psychosocial Impact of Assistive Devices Scale (PIADS).

		Competence			Adaptability			Self-Esteem		
		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
FM+ HA & HA Only										
	Z	0.701	0.309	0.151	0.649	0.248	1.009	0.489	0.347	0.153
	p	0.483	0.757	0.880	0.516	0.804	0.313	0.625	0.728	0.878
Ear & Belt Level Receiver										
	Z	1.327	0.929	**2.384**	1.947	1.081	1.863	2.172	0.847	1.819
	p	0.185	0.353	**0.017**	0.051	0.28	0.063	0.300	0.397	0.069
PW Only & Personal FM										
	Z	**2.281**	**1.938**	**2.43**	**2.075**	1.938	**2.119**	**2.083**	0.536	1.534
	p	**0.023**	**0.053**	**0.015**	**0.038**	0.053	**0.034**	**0.037**	0.592	0.125
Poor & Fair Word Recognition										
	Z	1.080	0.681	0.588	0.155	0.681	0.093	0.341	0.91	0.533
	p	0.280	0.496	0.556	0.877	0.496	0.926	0.733	0.363	0.594

FM+HA & HA Only (FM group compared to hearingaid only group). Ear & Belt Level Receiver (selection by user). PW Only & Personal FM (regular participants and participants who have personal FM system also). Poo & Fai Word Recognition (participants who scores below and above 20% word recognition).

Table D-17. Mann Whitney U statistics for the Religious Items (Item S11 on the Hearing Handicap Inventory for the Elderly (HHIE) and Items 18 and 21 on the Abbreviated Profile of Hearing Aid Benefit (APHAB).

		HHIE Item S11			APHAB Item 18			APHAB Item 21		
		Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks	Baseline	12 Weeks	24 Weeks
FM+ HA & HA Only										
	Z	1.385	**2.130**	**2.130**	0.845	0.86	0.525	1.451	1.058	0.385
	p	0.166	**0.033**	**0.033**	0.398	0.39	0.600	0.147	0.290	0.700
Ear & Belt Level Receiver										
	Z	1.139	**2.068**	1.553	0.744	0.344	1.062	0.437	0.922	1.35
	p	0.255	**0.039**	0.120	0.457	0.731	0.288	0.662	0.356	0.177
PW Only & Personal FM										
	Z	0.216	1.379	0.862	0.740	0.833	1.150	0.376	1.104	**2.542**
	p	0.829	0.168	0.389	0.459	0.405	0.250	0.707	0.270	**0.011**
Poor & Fair Word Recognition										
	Z	0.697	0.558	0.794	0.324	0.429	1.281	0.247	0.372	0.248
	p	0.486	0.577	0.427	0.746	0.668	0.200	0.805	0.71	0.804

FM+HA & HA Only (FM group compared to hearingaid only group). Ear & Belt Level Receiver (selection by user). PW Only & Personal FM (regular participants and participants who have personal FM system also). Poo & Fai Word Recognition (participants who scores below and above 20% word recognition).

APPENDIX E
IMAGES OF FM EQUIPMENT USED IN STUDY

Figure E-1. Phonak TX-300V large area transmitter. Note: The actual model used in study was a Listen Technologies LT-800 large area transmitter. Although these transmitters cvary internally, they have identical external appearances except for logo on upper left side.

Figure E-2. Phonak ML9S ear level receiver. Receiver is circled and displayed ith Phonak Savia model Behind the Ear (BTE) hearing aid.

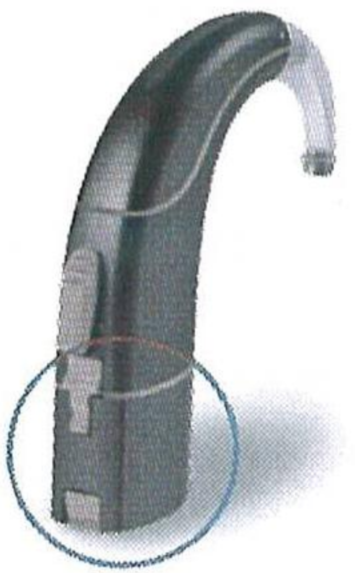

Figure E-3. Phonak ML8S ear level receiver. Receiver is circled and shown with Phonak Perseo model Behind the Ear (BTE) hearing aid.

Figure E-4. Phonak MLxS universal ear level receiver. This receiver is shown enlarged (left) and coupled to a generic hearing aid with an audio shoe (right).

Figure E-5. Phonak Microvox belt level receiver. The receiver is shown without coupling (left) and coupled to a generic hearing aid with a direct audio input wire and audioshoe (right). Note: Only induction neckloops, headphones and earbuds were used as coupling methods in this investigation.

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BIOGRAPHICAL SKETCH

James Patrick Sheehan Jr. was born the middle of three children on March 12, 1975 in Buffalo, NY. He moved to southern California in 1987, only to return to the Buffalo area about four years later. He graduated from West Seneca East Senior High School with a diploma from the New York State Board of Regents. He earned his Bachelor of Science degree in Psychology and Certificate in Deaf Studies at Rochester Institute of Technology in 1998. He went on to earn his Master of Health Science (MHS) degree from Johns Hopkins Bloomberg School of Public Health in 2002, where he focused on newborn hearing screening.

Between his graduate work experiences, Jay worked for the March of Dimes in Cleveland where he had the opportunity to organize a legislative breakfast to educate state Congressmen about the need for a Birth Defects Surveillance System, which was eventually signed into law. During his graduate work at Johns Hopkins, Jay testified at the Maryland General Assembly in Annapolis on a bill that was also signed into law that required private insurers to cover expenses for hearing aids and related services for children. After completing his MHS degree, he worked with states on development of universal newborn hearing screening programs at the Health Resources and Services Administration, Maternal and Child Health Bureau in Washington, DC.

Recently, Jay joined Phonak Hearing Systems in Chicago where he works enthusiastically as an FM Product Specialist. His role is to train audiologists and dispensing professionals how to implement FM technology into their everyday scope of practice.

Upon completion of his PhD, Jay will continue to work with assistive listening technology. He hopes to bridge the gap of auditory access for those with hearing impairment in various locations where hearing aids may not be sufficient in restoring functional hearing abilities. His priority areas include helping those in places of worship, retirement communities and entertainment venues.