FM for Adults

Chapter 11

Outcomes of FM System Usage in Places of Worship

Jay P. Sheehan[1] and Scott K. Griffiths[2]
[1] Beltone Headquarters, Glenview, IL
[2] University of Florida, Department of Communicative Disorders, Gainesville, FL

Jay recently accepted a role as a professional trainer for Beltone. His tenure with Phonak spanned 4 years. For the majority of that time, Jay trained hearing professionals through on-site clinical instruction and off-site continuing education seminars focusing specifically on Phonak FM products and compatibility with various hearing instrument manufacturers. More recently, Jay provided technical support for FM and hearing instrument products though the US call center in suburban Chicago. Jay earned his PhD in Communication Sciences and Disorders at the University of Florida, his Master of Health Science from Johns Hopkins Bloomberg School of Public health and his undergraduate degrees in Psychology and Deaf Studies at Rochester Institute of Technology.

Scott K. Griffiths, Ph. D. holds the positions of Associate Professor and Graduate Coordinator in the department of Communicative Disorders at the University of Florida. He also serves as Director of UF's Au.D. program. Having completed his MA and Ph.D at the University of Illinois, Dr. Griffiths has been on faculty at the University of Florida for 20 years, working in the areas of auditory and balance physiology, and attention. He is the author of over 100 peer-reviewed papers and presentations in these areas. Dr. Griffiths also currently serves as President of the Council of Au.D. Programs and Director on the Board of the Accreditation Commission on Audiology Education.

Outcomes of FM System Usage in Places of Worship

Jay P. Sheehan[1] and Scott K. Griffiths[2]

Abstract

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. The purpose of this study was to determine if an FM device would provide significant benefit for experienced hearing aid users who regularly attend religious services.

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 Inventory (HHI) for the 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.

Within the FM Group, the 6 personal FM users scored significantly greater on the Competence and Adaptability scales of the PIADS 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.

Introduction

Frequency modulation (FM) technology is a well recognized way to improve speech perception in adverse listening environments. In both personal and public FM systems, a microphone picks up the voice of the speaker near his or her mouth, where the deleterious effects of distance, noise, and reverberation are minimal. The voice is transmitted wirelessly to a receiver that is coupled to a hearing aid or cochlear implant in a variety of methods.

The increase in 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). 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). Specifically, personal FM systems have been shown to improve speech perception in persons with hearing impairment by as much as 20 decibels (dB) in the signal-to-noise ratio (SNR) over hearing aid alone (Hawkins, 1984; Fabry, 1994; Pittman et al., 1999; Crandell & Smaldino, 2000; M.S. Lewis et al., 2004).

Although the audiologic 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 et al., 1996; Boothroyd, 2004; M.S. Lewis et al., 2004) and exceptionally high where the participant did not incur the expense (Noe, McArdle, Hnath-Chisolm et al. 2004; Hnath-Chisolm, Noe, & McArdle et al., 2004). At first glance,

[1] Beltone Headquarters, Glenview, IL
[2] University of Florida, Department of Communicative Disorders, Gainesville, FL

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 necessary for an appropriate FM fitting (Boothroyd, 2004; Noe et al., 2004; Hnath-Chisolm et. al., 2004) complicate the interpretation.

Recently, certain public FM transmitters have been tuned so personal FM users can use their receivers directly. This is a more seamless approach than the indirect method, which requires that a user to patch into a public receiver with an audio cord to their personal microphone transmitter which will send the signal to their personal receivers. The seamless ability of a personal FM user to access the auditory signal through a public access system may prove to be a powerful advantage in terms of signal quality and convenience. An individual who is assertive about their hearing loss may ask the main presenter to wear a remote FM microphone but this interaction may be perceived as an awkward for some users. A large area transmitter may be purchased and permanently installed by plugging into the main sound mixer. To date, there has been no systematic investigation of large area FM system usage. With the merging of personal and public FM access, it will become more important to know what impact such a system has on the users who access the FM signal.

Recently, certain public FM transmitters have been tuned so personal FM users can use their receivers directly.

This investigation includes outcomes of FM system usage specifically in places of worship. Worship environments represent one of the most commonly reported listening situations that people with hearing aids still report listening difficulty (Gatehouse, 1999). It is also plausible that members of a congregation may view the interaction with the main presenter in the place of worship differently than interaction with others; that the remote microphone poses more inconvenience compared to other situations.

The goal of this study was to determine if a six-month trial period with a large area frequency modulation (FM) system would have a significant benefit for individuals with hearing impairment who desired to hear better in their place of worship by using an FM device. Specifically, the benefit 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 of assistive devices, and 4) spiritual well being. It was hypothesized that usage of an FM system in addition to current personal amplification with hearing aids will improve each of dimensions (decreases in disability and handicap acores; increases in quality of life, psychosocial impact and spiritual well-being scores) on items pertaining to the worship listening environment.

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

It was also hypothesized that there would be no difference between those who used FM only during worship and those who used FM also in activities of daily living.

Methods

Recruitment

A total of 29 participants completed the study (Table 1). Participants were recruited through convenience sampling of various places of worship in Gainesville, FL, a mid-central Florida city of approximately 108,000 people (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.

Representatives from nine of fourteen places of worship (PW) contacted via telephone, were interested in learning more about

the study. Of those declining participation, two indicated their congregations were preoccupied with atypical activity, and one reported that their current sound system was fine. Two places of worship could not be reached for follow-up. An audio-visual Powerpoint presentation was recorded on digital video disc (DVD) and was delivered to interested representatives. Follow-up interviews were arranged to answer any questions.

Information sessions were organized on-site at each of the PW, with attendance ranging from 1 to 60 potential participants per session. The sessions were advertised in bulletins, newsletters and/or announcements. Candidates for the study included those who: 1) currently wore hearing aids; 2) attended worship services weekly; and 3) still perceived listening difficulty during the service. Seven of the nine PW agreed to participate with the information session. These included three Methodist churches, two Catholic churches, one Lutheran church and one Synagogue. The number of participants at each PW is summarized in Table 1.

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FM transmitters

Installations of Listen Technologies (LT-800) 216 MHz large area FM transmitters were arranged at the convenience of the representative. There are only two connections for installing the device: 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 audio 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 an XLR/microphone level input and one installation used a ¼ inch audio/line level input.

Procedure

Each participant came in for a clinic appointment which lasted 2 hours and 15 minutes on average. After signing the Informed Consent form, an audiological evaluation was performed including: case history interview, video otoscopy (Panasonic GRK 5162 and Sony Trinitron monitor), immittance audiometry (GSI Tympstar) and pure-tone air/bone conductance audiometry (GSI – 61audiometer) and speech audiometry (GSI-61 audiometer). None of the participants displayed symptoms of soreness or signs excessive cerumen, inflammation/redness, or perforation of the tympanic membrane. Ipsilateral acoustic reflexes at .5, 1, 2, and 4 kHz were measured. When reflexes were present, acoustic decay (10dB SL re: acoustic reflex threshold) was performed at .5 and 1 kHz. All of the enrolled participants presented immittance results consistent with sensorineural hearing loss. Pure tone 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 difference of 15 dB or greater at adjacent octave frequencies. Narrow band masking noise was routed contralaterally when indicated. Speech recognition threshold (SRT) was measured with spondees via monitored live voice. 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) in the following conditions: monaural left ear in quiet; monaural right ear in quiet; binaural in quiet; and binaural in noise. For noise testing, pink noise was delivered binaurally at 10dB below MCL. Stimuli were routed through Etymotic Research (ER-3A) insert earphones or TDH-50P headphones. Audiometric equipment was calibrated prior to and following the completion of this study.

Table 1. Enrollment Summary: Participant Selection of FM Receivers.

	Participants		Receiver Type		
Place of Worship	Enrolled	Completed	Ear Level	Body Worn	None
Catholic A	2	1	0	1	0
				(1) RX2 with earbuds	
Catholic B	6	4	3	0	1
			(3) ML8S, binaural		
Methodist A	4	4	2	2	0
			(1) ML8S, binaural (1) ML4, binaural	(2) RX2 with earbuds	
Methodist B	10	10	5	4	1
			(2) iLink, binaural (2) MLxS, binaural (1) ML9S, binaural	(2) RX2 with headphones (1) RX2 with earbuds (1) RX2 with neckloop	
Methodist C	2	2	1	1	0
			(1) ML8S, binaural	(1) RX2 with neckloop	
Lutheran	7	7	1	2	4
				(1) RX2 with headphones (1) RX2 with earbuds	
Synagogue	2	1	0	1	0
				(1) RX2 with neckloop	
TOTAL	33	29	12	11	6

Following the audiologic testing, the information from the on-site session was reviewed with each participant. All potential options for coupling FM receivers to current hearing aids were discussed. A differentiation matrix was used to outline the factors in selecting a receiver: signal quality, cosmetics and hypothetical financial consideration (payment for the devices was not required, except for iLink hearing aids). None of the participants chose Direct Audio Input (DAI).

Of 32 initially enrolled participants, three were not compliant or failed to complete the study and were excluded from the results. One participant dropped out of the study due to an injury not related to the study (Lutheran, ML8S binaural). One participant dropped out due to lack of interest (Lutheran, RX2 with headphones). One participant was omitted due non-compliance after clinic appointment (Catholic B, RX2 with earbuds).

Of the 29 participants completing 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 ML4) and 11 chose body worn receivers (5 earbuds, 3 neckloops, 3 headphones). The selection of receivers by participants who completed the study is summarized in Table 1.

Participants who selected ear level receivers or body worn receivers with a neckloop were counseled on how to activate microphone inputs: hearing aid only, hearing aid plus FM (hearing aid plus telecoil for neckloop users), and FM only (telecoil only for neckloop users). Participants were also instructed that these three settings could be used in one or both ears. Suggestions were given on when it might be preferred to change the active microphone settings based on the type of listening situation.

Six participants in the sample used a personal FM system in addition to the large area FM system installed at their place of worship: three were fit prior to study enrollment (two with 2 years experience and one with 20 years experience); and three were fit during the study (two at baseline and one at approximately 12 weeks). The personal FM users were instructed to turn off their personal FM transmitters during the worship service. If the transmitting channel at the place of worship was different than the transmitting channel that the personal FM users used in everyday listening situations, they were instructed to synchronize or "tune in" their receivers to receive the signal and then shut off their personal transmitter immediately to prevent interference. One participant (Methodist A, ML4 binaural) had receivers that did not have the ability to change channels, so the transmitting frequency for that place or worship was selected to accommodate this individual. In sum, six participants had additional exposure to the FM signal in addition usage in the place of worship.

Dependent measures

All self-report outcome measures described above 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. The outcome measures booklet contained the following 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 Inventory (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).

The modifications to the Glasgow Hearing Aid Benefit Profile (GHABP) included the addition of three items to the open-ended section of the measure: Main Presenter [listening to the main presenter in a place of worship (pastor, priest, rabbi, etc.)]; Other Presenters [listening to other presenters in a place of worship (readers, guest speakers, assistant clergy, people who make announcements, etc.)]; and Music (lyrics) [listening to music in a house of worship (understanding the lyrics of people singing)].

All items of the Hearing Handicap Inventory for the Elderly (HHIE, Ventry & Weinstein, 1982) and Hearing Handicap Inventory for Adults (HHIA, Newman et al., 1990) were combined for a 28 item Hearing Handicap Inventory (HHI).

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. All administrations were written self-reports from each participant. During the initial administration, the investigator was present and provided assistance as needed. Each participant had an average of one request for clarification. 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. Baseline measurements reflected personal amplification of the hearing aid alone. The subsequent measurements at 12 and 24 weeks reflected personal amplification of the hearing aid and FM system combined (except for the 8 participants who had to remove their hearing aids to use the FM system). The subsequent administrations were mailed on Monday following the 12th and 24th weekend service. They were asked to complete and return in a postage-paid return envelope prior to their next weekend worship service.

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 and the FM users were permitted to keep their receivers at the completion of the study.

Non-audiological outcome measures

The Glasgow Benefit Inventory (GBI) is designed to assess the effect of an intervention on quality of life. The questionnaire consists of 18 items which allow for comparison across health conditions because it is generic in nature ("hearing aid fitting" or "FM fitting" may be substituted for "operation/intervention"). The GBI contains three subscales: a general subscale (12 items); a social support subscale (3 items) and a physical health subscale (3 items).

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 Information Package, 2006). The GBI items are listed in Appendix 1.

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 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 points total. It takes about 10–15 to complete. The SWBS items are listed in Appendix 2.

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 one, four, six and ten 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 are loaded on the religious factor and most existential items are loaded on the existential factor (Ellison, 1983).

Analyses

Data were analyzed with the Statistical Package for the Behavioral Sciences (SPSS) statistical analysis software program. For each subscale of each outcome measure a within-subjects, a repeated measures Friedman analysis of variance (ANOVA) was performed

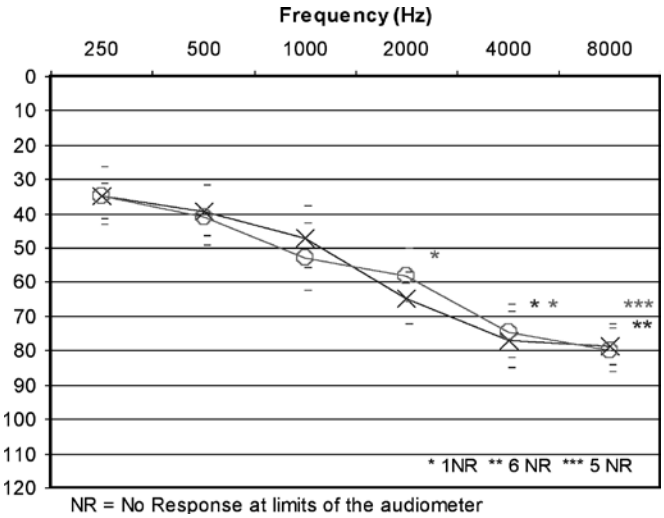

Figure 1. Mean Pure Tone Thresholds (+/- 2 SEM- unfilled bars for right ear, filled bars for left ear) for the FM Group (n = 23). Asterisks (*) indicate frequencies at which some participants had no measurable threshold at the limits of the audiometer (i.e., in the right ear of 1 participant at 2000 Hz, in each ear of 1 participant at 4000 Hz, and in the right ear of 5 participants and left ear of 6 participants at 8000 Hz.

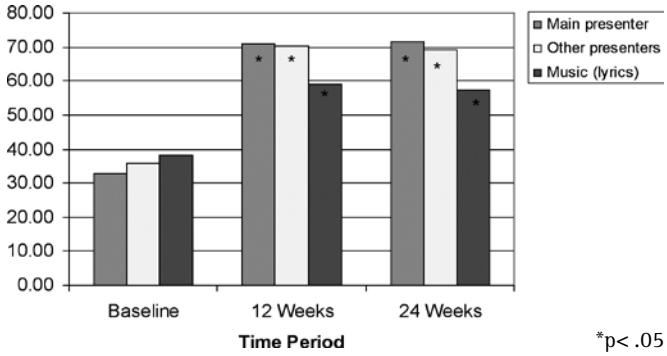

Figure 2. Mean Satisfaction Scores for Worship Related Items on GHABP for FM Users. Values at 12- and 24-weeks that are significantly different from baseline are marked with an asterisk (*).

on all 23 participants in the FM group to determine if there were any differences among scores at pre- (baseline), mid- (12 weeks) and post-trial (24 weeks) administrations 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 hearing aid only comparison group (n = 6); users with ear level receivers (n =12) and users with body worn receivers (n = 11); and users that used FM only in the place of worship (n = 17) and users that used personal FM in addition to worship FM (n = 6).

Results

Audiometrics

The pure tone air audiometric thresholds for the left and right ear for the participants in the FM experimental group are shown in Figure 1. Mann Whitney U analyses revealed no statistically significant differences between the FM experimental group and hearing aid only comparison group in pure tone audiometrics. Participants in both groups tended to display mild sloping to severe sensorineural hearing loss.

The average (and standard error, SE) word recognition scores at MCL for the FM experimental group were: 50.1 (6.0) % correct for the left ear; 54.9 (6.4) % correct in the right ear; 66.2 (6.0) % binaural in quiet; and 17.0 (2.5) % binaural in noise. Mann Whitney U analyses revealed no statistically significant differences between the FM group and the hearing aid only comparison group in word recognition scores in any of the test conditions.

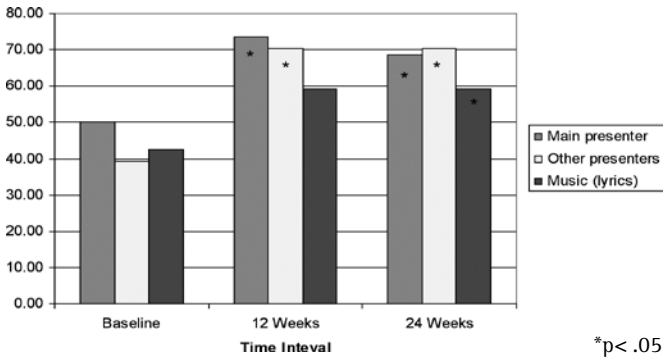

Figure 3. Mean Reported Benefit Scores for Worship Related Items on GHABP for FM Users. Values at 12- and 24-weeks that are significantly different from baseline are marked with an asterisk (*).

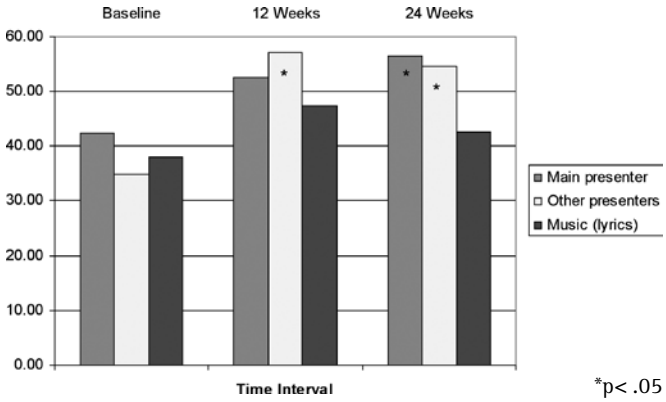

Figure 4. Mean Derived Benefit for Worship Related Items on GHABP for FM Users. Values at 12- and 24-weeks that are significantly different from baseline are marked with an asterisk (*).

Adapted outcome measures

Friedman Analysis of Variance (ANOVA) revealed statistically significant differences in all three worship-modified items in the *Satisfaction, Reported Benefit,* and *Derived Benefit* domains from the GHABP at the $\alpha = .05$ significance level. All three worship-modified items in the Handicap domain failed to reveal any significant differences at the $\alpha = .05$ significance level. The results for the GHABP are summarized in Table 2.

The *Satisfaction* domain simply asks, "How satisfied are you with your [amplification system]?" in a given situation. The mean Satisfaction scores are summarized in Figure 2. Friedman ANOVA of *Satisfaction* by the Main Presenter item revealed at least one statistically significant ($X^2 = 23.684$ df = 2, p =.000) difference across time intervals. Pairwise analyses with the Wilcoxon signed ranks test showed 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). Pairwise comparisons for listening *Satisfaction* with to Other Presenters and Music (lyrics) yielded similar significant findings.

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 Figure 3. Friedman ANOVA of *Reported Benefit* by the Main Presenter item revealed at least one statistically significant ($X^2 = 22.680$ df = 2, p =.000) difference across time intervals. Pairwise analyses with the Wilcoxon signed ranks test showed 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). Pairwise comparisons for listening *Reported Benefit* with to Other Presenters and Music (lyrics) yielded similar significant findings.

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

Table 2. Glasgow Hearing Aid Benefit Profile (GHABP) Results for FM Users during Worship Service: Mean Scores and Standard Errors (SE). Values at 12- and 24-weeks that are significantly different from baseline are marked with an asterisk (*).

DOMAIN and Listening Situation	Baseline	12 Weeks	24 Weeks
SATISFACTION			
Main Presenter	32.61 (19.69)	*** 71.05 (20.22)**	*** 71.59 (20.26)**
Other Presenters	35.87 (20.33)	*** 70.24 (20.56)**	*** 69.32 (20.37)**
Music (lyrics)	38.04 (19.82)	*** 59.21 (19.20)**	57.50 (19.84)
REPORTED BENEFIT			
Main Presenter	50.00 (20.28)	*** 73.68 (21.99)**	*** 68.48 (20.49)**
Other Presenters	39.13 (20.60)	*** 70.24 (20.56)**	*** 70.45 (20.76)**
Music (lyrics)	42.39 (20.17)	59.21 (17.79)	*** 59.21 (19.87)**
DERIVED BENEFIT			
Main Presenter	42.39 (21.34)	52.50 (18.24)	*** 56.52 (20.49)**
Other Presenters	34.78 (20.35)	*** 57.14 (18.99)**	*** 54.55 (20.76)**
Music (lyrics)	38.04 (21.53)	47.37 (18.99)	42.50 (18.44)
HANDICAP			
Main Presenter	60.87 (18.95)	57.89 (17.34)	48.91 (18.43)
Other Presenters	55.68 (19.08)	58.33 (18.94)	48.86 (18.32)
Music (lyrics)	45.65 (19.19)	45.00 (17.61)	39.77 (17.71)

system in addition to the hearing aid. The mean *Derived Benefit* scores are summarized in Figure 4. Friedman ANOVA of Derived Benefit by the Main Presenter item revealed at least one statistically significant (X^2 = 8.644 df = 2, p =.036) difference across time intervals. Pairwise analyses with the Wilcoxon signed ranks test showed a statistically significant increase 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). Pairwise comparisons for *Derived Benefit* with to Other Presenters and Music (lyrics) yielded similar significant findings.

The *Handicap* domain probes how much difficulty in a given situation "worry, upsets or annoys you". The items for Main Presenter, Other Presenters and Music did not reveal any *Handicap* score differences of statistical significance throughout the trial. The mean *Handicap* scores are summarized in Figure 5.

Unadapted outcome measures

The GHABP is the only measure in this investigation that examined several domains with specific worship listening sitiations. The remainder of outcomes did not have any worship specified items or only had 1-2 worship items of a single dimension.

The mean scores for the Competence, Adaptability and Self-esteem scales of the Psychosocial Impact of Assistive Devices Scale (PIADS) measure are listed in Table 3. None of the PIADS scale scores revealed score differences of statistical significance throughout the trial.

The mean scores for the Total, General, Social and Physical subscales of the Glasgow Benefit Inventory (GBI) are listed in Table 4. None of the GBI scales revealed score differences of statistical significance throughout the trial.

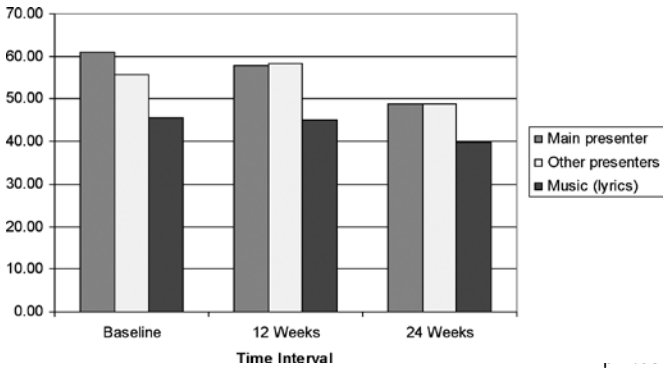

Figure 5. Mean Handicap Scores for Worship Related Items on GHABP for FM Users.

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 5. None of the APHAB scales or the two APHAB worship-specific items revealed score differences of statistical significance throughout the trial.

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 6. None of the HHI scales or the single HHIE worship-specific item revealed score differences of statistical significance throughout the trial.

The mean scores for the Spiritual Well Being Scale (SWBS) are listed in Table 7. None of the SWBS scales revealed score differences of statistical significance throughout the trial.

Between-subject comparisons on selected outcome measures

Although the study was designed as a within-subject longitudinal investigation, comparisons were made to explore other relationships within the data set. Two between-subject comparisons

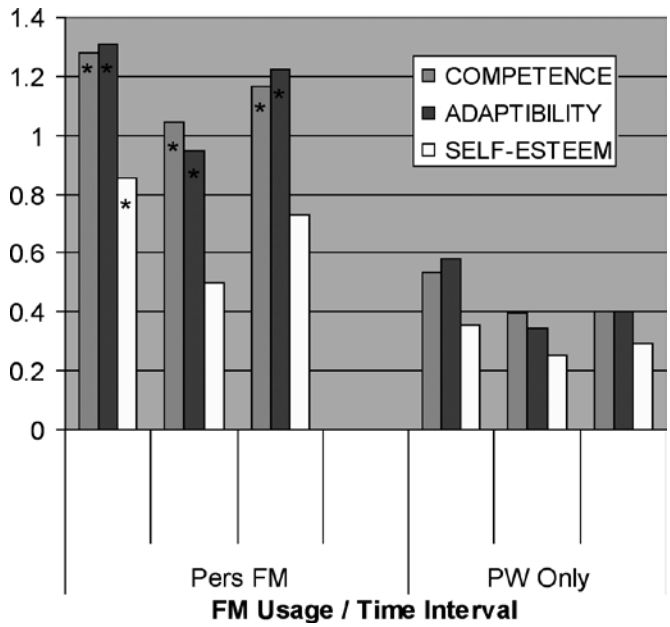

Figure 6. Between-subject comparisons on PIADS between Personal FM Users (Pers FM) and FM Users only in Place of Worship (PW Only). Significant differences between values obtained from Pers FM users and those from PW Only users are marked with asterisks (*).

yielded meaningful results: 1) FM/experimental group (n = 23) vs. hearing aid only/comparison group (n = 6); and 2) 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.

The between-subject comparison of GHABP scores between the FM experimental group and hearing aid only comparison group revealed one significant difference throughout the trial. For the Main Presenter Item of the GHABP, 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 only group.

The between-subject comparison of the PIADS scores between the FM users in only the place of worship and the personal FM

Table 3. Psychosocial Impact of Assistive Devices Scale (PIADS) Results for FM Users during Worship Service: Mean Scores and Standard Errors (SE).

Scale	Baseline	12 Weeks	24 Weeks
Competence	0.73 (0.14)	0.77 (0.16)	0.48 (0.10)
Adaptability	0.57 (0.13)	0.50 (0.14)	0.32 (0.09)
Self-Esteem	0.60 (0.13)	0.62 (0.15)	0.41 (0.10)

Table 4. Glasgow Benefit Inventory (GBI) Results for FM Users during Worship Service: Mean Scores and Standard Errors (SE).

Scale	Baseline	12 Weeks	24 Weeks
General	32.93 (4.98)	23.45 (4.69)	21.42 (5.93)
Social	3.30 (0.08)	3.20 (0.09)	3.24 (0.09)
Physical	2.94 (0.03)	3.00 (0.00)	3.00 (0.02)
Total	**24.21 (3.72)**	**17.35 (3.85)**	**17.41 (5.10)**

Table 5. Abbreviated Profile of Hearing Aid Benefit (APHAB) Results for FM Users during Worship Service: Mean Scores and Standard Errors (SE). 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". Values at 12- and 24-weeks that are significantly different from baseline are marked with an asterisk (*).

Scale/Item	Baseline	12 Weeks	24 Weeks
Ease of Communication	29.64 (4.16)	22.47 (5.26)	17.82 (4.08)
Reverberation	29.96 (3.33)	29.20 (5.35)	29.90 (4.51)
Background Noise	24.54 (3.45)	17.46 (6.53)	23.24 (7.22)
Aversiveness to Sounds	28.41 (4.10)	*** 5.15 (7.30)**	***3.64 (9.20)**
Item 18	32.65 (4.71)	40.50 (5.87)	36.77 (5.82)
Item 21	39.95 (4.20)	35.55 (5.96)	37.81 (5.81)

users revealed 7 statistically significant differences. The results are summarized in Figure 6. 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.

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 ratio (17.6 % correct identification).

Glasgow Hearing Aid Benefit Profile (GHABP)

There were several, consistent and significant within-subject differences for participants in the FM group over the FM trial. All three of the adapted items of the GHABP (Main Presenter, Other Presenters, Music (lyrics)) showed significant increases in Satisfaction, Reported Benefit and Derived Benefit domains. However, none of three adapted items showed differences in the Handicap

Table 6. Hearing Handicap Inventory (HHI) for FM Users during Worship Service: Mean Scores and Standard Errors (SE).

Scale/Metric	Baseline	12 Weeks	24 Weeks
Social			
HHIA	22.17 (2.00)	22.00 (2.51)	20.26 (2.26)
HHIE	21.91 (1.89)	21.00 (2.25)	19.13 (2.07)
Emotional			
HHIA	19.09 (2.43)	19.73 (2.52)	16.35 (2.57)
HHIE	18.22 (2.44)	17.48 (2.48)	15.04 (2.46)
Total			
HHIA	41.26 (4.43)	41.73 (5.03)	36.61 (4.83)
HHIE	40.13 (4.32)	38.48 (4.73)	34.17 (4.53)
Religious Item of HHIE	0.87 (0.30)	0.36 (0.25)	0.45 (0.23)

domain. This may be considered an indirect measure of compliance; participants were consistent in their worship attendance pattern with and without the provision of the FM system.

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. Only one of the proposed hypotheses has been supported by the results with 95 % confidence: the reduction in disability as reflected by the adapted items of the GHABP.

Table 7. Spiritual Well Being Scale (SWBS) Results for FM Users during Worship Service: Mean Scores and Standard Errors (SE).

Scale	Baseline	12 Weeks	24 Weeks
Religious	52.48 (1.31)	46.65 (3.68)	52.52 (1.52)
Spiritual	50.43 (1.56)	45.35 (3.43)	50.43 (1.44)
Total	**102.91 (2.56)**	**92.00 (7.00)**	**102.96 (2.60)**

The 23 FM users in the study scored significantly greater Satisfaction at 12 and 24 weeks than the hearing aid only 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. 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.

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). 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.

Psychosocial Impact of Assistive Devices Scale (PIADS)

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 body worn receivers as reflected in the PIADS measure. The results did not support this hypothesis.

Only one difference between these groups was apparent. Users with ear level receivers had significantly greater Competence scale scores at 24 weeks than the users of body worn 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. The rationale for the hypothesis is that the ear level FM receivers could be expected to draw less attention to the individual and therefore make the device more acceptable to the individual. It appears that regardless of the device chosen, the participants measured similarly. It is possible that the selection process may have had an impact on these findings. Had the participants been assigned ear and body worn devices at random, perhaps the measurements for each device class would have been different. It is also possible that the other considerations such as sound quality and financial consideration were prioritized greater than the cosmetic factor.

It was also hypothesized that the trial with an FM system used in a place of worship will have no difference on worship specific outcome measures 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. Although there were no differences between these groups in worship specific items, there were strong and consistent differences in the PIADS measure.

The 6 personal FM users exhibited significantly greater scores on Adaptability and Competence scales of the PIADS at baseline, at 12 weeks and at 24weeks, than the 17 users who were only exposed to the FM signal in the place of worship. Therefore, it appears that personal FM users exhibit greater Adaptability characteristics (ability to adapt, willingness to take chances and eager to try new things) and Competence characteristics (productivity, usefulness, performance and independence. It is unclear whether these individuals developed these characteristics as a result of using their personal FM system or if these characteristics are apparent in FM candidates.

None of the mean within-subject differences between time intervals in the 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. Perhaps if the FM users had greater daily exposure to their FM assistive device the change in adaptability would be more apparent. It is possible that the 6 personal FM users inflated the overall adaptability scores to exhibit a main effect.

The lack of a significant within-subjects finding on the Competence scale 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.

Glasgow Benefit Inventory (GBI)

Although the potential of the FM system to restore auditory function is apparent, the extent to which the FM system can improve the quality of life remains contested. The length of exposure remains a potential confounder. The difference between wearing a hearing aid throughout the day and on a daily basis is much different than accessing the FM signal for about an hour once per week 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", therefore 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 (a = .05) 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 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 (Hawthorne & Hogan, 2002; Glasgow Health Status Questionnaires Information Package, 2006); 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.

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. 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) was 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. As with the GHABP Handicap, this lack of a difference 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.

It is interesting to note that the mean scores for the religious item decreased from baseline indicating less handicap at 12 and 24 weeks.

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.

Summary

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.

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. These changes were reflected in the adapted items of the Glasgow Hearing Aid Benefit Profile (GHABP) that were specific to the place of place of worship.

The participants who had greater access to the FM signal through personal use also exhibited characteristics reflected in the Psychosocial Impact of Assistive Devices Scale (PIADS). Subsequent investigations may therefore benefit from assessment of fewer, 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 1.

Glasgow Hearing Aid Benefit Profile (GHABP) adapted items.

1. Listening to the main presenter in your place of worship (e.g. pastor, priest, rabbi, etc.)
2. Listening to other presenters in your place of worship (e.g. readers, guest speakers, people who make announcements, etc.)
3. Listening to music in your place of worship (understanding the lyrics of the people singing)

a. With your HEARING AID ONLY, how much difficulty do you have in this situation?
0___Not applicable
1___No difficulty
2___Only slight difficulty
3___Moderate difficulty
4___Great difficulty
5___Cannot manage at all

b. With your FM SYSTEM, how much does any difficulty in this situation worry, annoy or upset you?
0___Not applicable
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
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
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 FM SYSTEM

e. In this situation, with your FM SYSTEM, how much difficulty do you now have?
0___Not applicable
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
1___Not satisfied at all
2___A little satisfied
3___Reasonably satisfied
4___Very satisfied
5___Delighted with aid

Appendix 2.

Psychosocial Adjustment of Assistive Devices Scale (PIADS) Items.

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

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