Spring 2014

The effect of hearing aid program on the perceived sound quality of music

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THE EFFECT OF HEARING AID PROGRAM ON THE PERCEIVED SOUND QUALITY OF MUSIC

By

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Audiology

COLLEGE OF LIBERAL ARTS
LOUISIANA TECH UNIVERSITY

May 2014

LOUISIANA TECH UNIVERSITY

THE GRADUATE SCHOOL

March 21, 2014

Date

We hereby recommend that the dissertation prepared under our supervision by Kalyn Kennedy Bradford

entitled

The Effect of Hearing Aid Program on the Perceived Sound Quality of Music

be accepted in partial fulfillment of the requirements for the Degree of

Doctor of Audiology

Supervisor of Dissertation Research

Head of Department

Speech

Department

Recommendation concurred in:

Advisory Committee

Approved:

Director of Graduate Studies

Dean of the College

Approved:

Dean of the Graduate School

GS Form 13a
(6/07)

ABSTRACT

Hearing loss affects many aspects of people's lives, including both communication and their ability to enjoy music. Currently, however, there is very little research on patient perception of music through hearing aids; therefore, the purpose of this study was to determine if there was a difference in the perceived listener satisfaction for music between a standard music program and the commonly used option for programming hearing aids (i.e., an automatic program). Data was collected using fifteen participants with symmetrical mild to moderately-severe sensorineural hearing loss with normal to near normal low frequency hearing. Participants were asked to listen to a one-minute clip of music in two different hearing aid programs (Program1= standard automatic program; Program 2= manufacturer's music program). This process was completed listening to three clips of music: a classical selection ("Clair de Lune" by Debussy), a pop selection ("California Girls" by the Beach Boys), and a listener's choice selection, which included a choice of seven songs of varying genres. After listening to each clip for 30 seconds, the participant was asked to complete a questionnaire which required participants to rate softness, brightness, volume, clarity, fullness, nearness, spaciousness, and overall impression on a 10-point scale as well as an additional questionnaire which assessed participant opinion on volume, clarity, fullness, pleasantness, and overall impression of sound quality. Results of this study indicated that participants noticed no difference in sound quality for any of the song selections when comparing the automatic hearing aid program to the music program. Furthermore, the favored program was equally divided between participants. Clinical implications/ applications will be discussed.

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Author Kalyn Bradford

Date 5-5-14

GS Form 14
(5/03)

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ACKNOWLEDGEMENTS

I would like to thank everyone who helped with the completion of this dissertation. I would especially like to thank Dr. Melinda Bryan, Dr. Matt Bryan, and Dr. Steve Madix for their knowledge and guidance. I give my sincerest gratitude to my Savior, without whom nothing is possible. I also would like to thank my family, friends, and classmates for their continued encouragement and support.

CHAPTER I

Introduction

Hearing loss can have a profound effect on a patient's quality of life. For some, speech is the most important aspect of life that hearing loss affects. For others, music may be just as or even more important than understanding speech. Furthermore, hearing aid technology has made extensive improvements over the last few years in increasing sound quality and intelligibility for speech. While this is typically the main goal of hearing aid fittings, it is essential that audiologists broaden the research to include assessments of patient satisfaction for music as well.

To maximize speech understanding in quiet and noise, hearing aids are commonly programmed using either a fixed omnidirectional microphone program or an automatic program. These programs work in two different ways. When omnidirectional microphones are utilized, the hearing aid microphones are set so that they are equally sensitive to sounds from both the front and back of the patient (Valente, Hosford-Dunn & Roeser, 2007). On the other hand, if set to automatic, the microphone configuration automatically changes after surveying the patient's environment. Specifically, if the hearing aid determines that the desired signal is in front of the listener, it will utilize directional microphones to help filter out background noise. Likewise, omnidirectional microphones are utilized when the hearing aid determines that the patient needs signal input equally from the front and back of the patient.

These settings are implemented to provide the best sound quality and intelligibility for speech. Please note that these settings may not always be the best when listening to music.

Fundamentally, there are several differences between speech and music, which make it necessary to treat each uniquely in reference to hearing aids. First, the dynamic range of speech is approximately 30 dB, with the most intense presentations of speech rarely passing 90 dB SPL. For music, the dynamic range of a single piece of music may span across 100 dB, with the loudest parts of music hitting 120 dB. Another difference that must be considered is crest factors of speech and music. Speech has a crest factor of approximately 12 dB SPL, meaning that the peaks of speech may be 12 dB louder than the average presentation level (Cole, 2005). In music, crest factors may reach as much as 20 dB (Ross, 2009). Lastly, music may be produced from a wide variety of sources such as wind instruments, percussion instruments, stringed instruments, human voices, and many more. Each of these instruments has subtle differences, which add distinctive aspects to music. For example, the flute could be used to convey surprise while percussion can add a sense of drama to a song. Speech, while it varies as much as the speaker, is at its core still created from the same sources (i.e., lips, tongue, teeth, and vocal tract; Chasin, 2009).

Furthermore, music is important for reasons other than pure enjoyment. Recent studies have indicated that music has an impact on health as well. Specifically, research suggests that music has a positive effect on blood pressure regulation as well as heart and mental health (Sutoo & Akiyama, 2004; Trappe, 2010). Furthermore, Chan, Chan, and Mok (2009) found that music reduced the prevalence of depression in older adults. Still another study found that music is able to effect complex neurobiological tasks in the brain and that it may be used as an alternative therapy option for treating dementia, autism, schizophrenia, and other mental health disorders (Lin & Yang, 2011).

Little research has been completed evaluating the effects of hearing aid programming on music listening. In fact, one of the only studies available on this topic sought to determine the extent of difficulty of listening to music in hearing impaired listeners and the effect of hearing aids on listening to music (Leek, Molis, Kubli, and Tufts, 2005). For this study, 262 patients completed a survey detailing characteristics of hearing aid use and total hearing impairment, musical practice and habits, music sound quality, and hearing aids and music. The results showed that 30% of the interviewed participants felt that their hearing impairment had affected their enjoyment of music. These dissatisfied listeners reported problems with the volume of the music (too high or too low), difficulties understanding lyrics, and less clarity in the higher frequencies. Furthermore, research by Chasin (2009) has provided some parameters for programming hearing aids for both music and speech. Specifically, Dr. Chasin (2009) suggested that in order to program a hearing aid for music, the noise and feedback management systems should be turned off. He also recommended having more linear gain in order to preserve the fidelity of the music. Based on the research by Chasin (2009) hearing aid companies have developed hearing aid programs for music with specific parameters in an attempt to provide more ideal settings for listening to music versus speech. For example, in Oticon's music program, noise management, My Voice (i.e., occlusion effect manager), and multiband adaptive directionality are turned off. Additionally, the compression characteristics are set more linearly with an overall reduction gain of 5 to 7 dB (Oticon

Audiology, personal communication, March 24, 2011). Although Oticon provides the music program, an Oticon employee is quoted through email as saying that Oticon has "invested very little time in looking at the details of [the music] program" (D. Schum, personal communication, January 31, 2012). Furthermore, there has been little research a few clinical trials about the implementation of music programs in hearing aids.

In conclusion, there has been little research into the effect of hearing aid programming on music listening ability. Because of the fundamental differences between speech and music, more information in the area of the effects of hearing aid programming on music listening ability must be obtained. Therefore, this study seeks to determine if there is a difference in the perceived listener satisfaction for music between a standard music program and the commonly used option for programming hearing aids (i.e., an automatic program).

CHAPTER II

Review of Literature

Hearing Aid Fittings

There are several options to consider when programming the microphone features on a hearing aid. The most common of these microphone programming options includes programming a hearing aid to utilize either omnidirectional or directional microphones or utilizing both omnidirectional and directional microphones in the same automatic program. Each microphone programming option is described below. As noted, these microphone programming options treat listening environments very differently (Katz, Medwetsky, Burkard & Hood, 2009). Therefore, the audiologist must decide among these options to provide patients with a hearing aid that will best suit their lifestyle.

Omnidirectional microphones. One option the audiologist/patient has is the use of an omnidirectional microphone. An omnidirectional microphone is equally sensitive to sounds from all directions. In other words, all sound sources (i.e., those from the front, sides, and back) are presented to the listener equally. This type of microphone might be advantageous if, for example, a listener with hearing impairment is sitting at a table for a meeting and other talkers are sitting around the table. In this instance, it is equally important that he/she hear people talking not only in front but also to the sides, making omnidirectional microphones the best microphone programming option (Valente et al., 2007).

Directional microphones. Another microphone programming option audiologists have is the use of directional microphones. A directional microphone is a microphone which is more sensitive to sounds from a specific direction while suppressing sounds from other directions (Valente et al., 2007). Most of the time this sensitivity is towards the front of the listener in order to enhance the signal to noise ratio for talkers in front of the listener. Furthermore, there are three types of directional microphones: traditional directional microphones, dual microphones, and d-mics®. First, a traditional directional microphone consists of one microphone with two ports and utilizes internal and external delays in sound processing to improve the signal to noise ratio. The internal time delay is caused by the placement of an acoustic damper which "slows down" noise coming in the back port. The external delay is the time difference between the sound entering the front and back microphone ports. If the internal and external time delays are equal, the sounds will hit the diaphragm of the microphone at the same time and be canceled out. For example, sound coming from in front of the listener (i.e. the desired signal) will reach the front microphone port before it reaches the back microphone port (i.e., a delay due to the external time delay). The same sound will be delayed again at the back port as it goes through the acoustic damper. Thus, the two input sources do not strike the diaphragm of the microphone at the same time; therefore, the sounds will not cancel each other out. Sounds coming from behind the listener, however, will reach the back microphone port first and will be delayed as they pass through the acoustic filter. Likewise, sounds coming from the back will also take longer to reach the front microphone port, creating the external delay. If the external and internal time delays are equal, the noise should reach the diaphragm of the microphone at the same time and be canceled out (Kates, 2008).

Second, a dual microphone consists of two omnidirectional microphones. The dual microphone system works similarly to the traditional directional microphones but with electronic subtraction instead of the acoustic damper. The dual microphone allows for the microphones to be placed farther apart in the hearing aid which will enhance directivity. D-mics® consist of one omnidirectional microphone and one traditional directional microphone, each of which works independently of one another. Generally, directional microphone fittings allow for an increase in the signal to noise ratio from two to four dB (Katz et al., 2009).

Polar plots for directional microphones. The sensitivity of directional microphones is described by their polar plot (i.e., a graphical representation of the sensitivity of a microphone for sounds arriving at all angles around a fixed point; Sandlin, 2000). Furthermore, polar plots can be divided into four categories: cardioid, super-cardioid, hyper-cardioid, and bidirectional (Valente et al., 2007). First, cardioid polar plots are most sensitive towards the front (i.e., 0° azimuth) while sounds arriving at 180° azimuth receive the most attenuation (see Figure 1). Super-cardioid and hyper-cardioid polar plots are also most sensitive to the front; however, there is more sensitivity to the back than in a cardioid plot. Super-cardioid plots attenuate the most for sounds arriving at approximately 150° and 210° azimuth while hyper-cardioid attenuate most for sounds arriving at approximately 120° and 240°. Hyper-cardioid plots are more sensitive to sounds arriving from the back than super-cardioid plots (see Figure 1). Bidirectional polar plots provide equal sensitivity to the front and back while maximum attenuation is provided to the sides (see Figure 1). Furthermore, polar plots may be fixed or adaptive. Fixed polar plots are the implementation of only one polar plot in the directional program in a hearing aid while adaptive polar plots change based on the incoming signal to noise ratio, input level, and signal location to determine the best polar plot configuration (Valente et al., 2007).

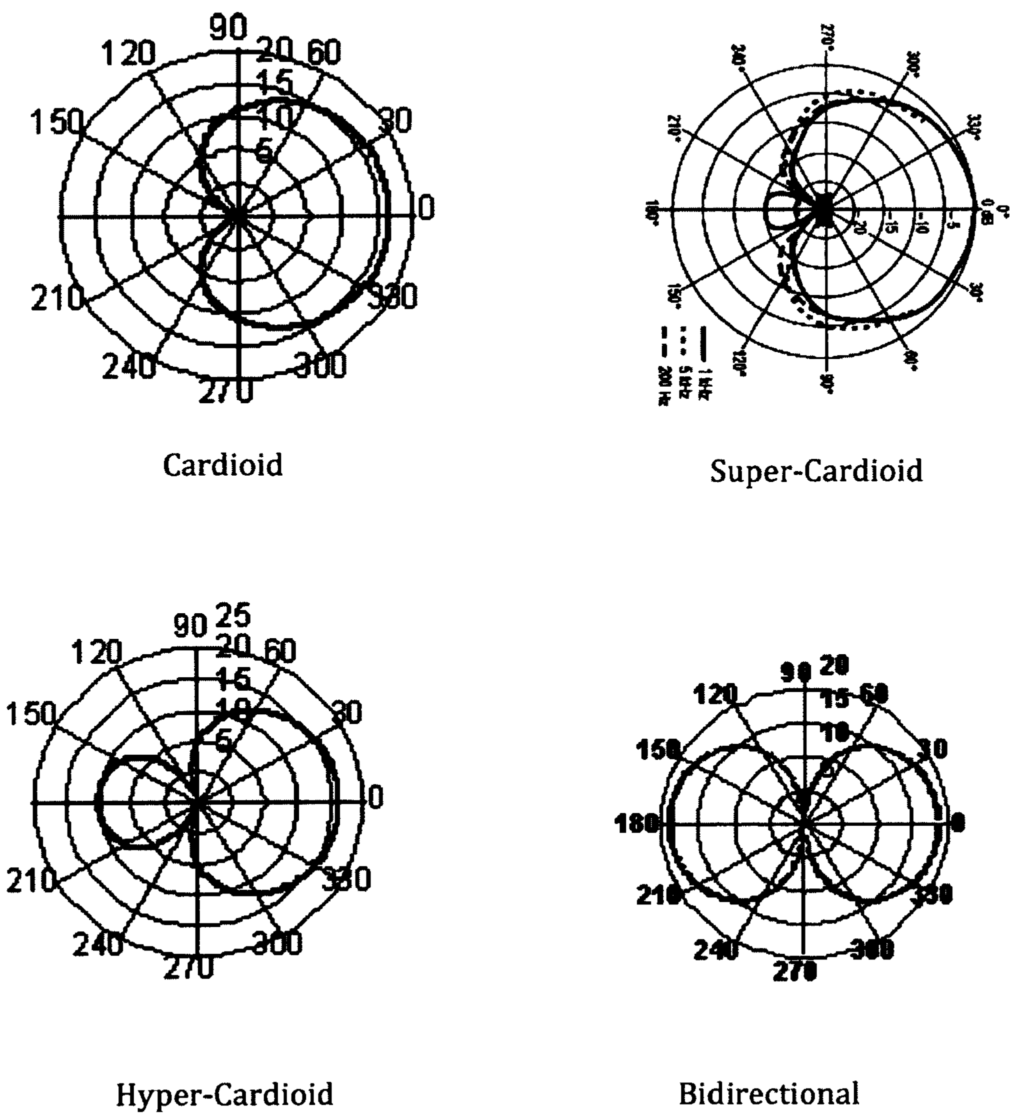

Figure 1: Cardioid, super-cardioid, hyper-cardioid, and bidirectional polar plots depicting the sensitivity of microphones around a central point.

Automatic program fittings. The third programming option for hearing aids is an automatic program. Automatic programs automatically choose between the different microphone options (i.e., omnidirectional or directional). Prior to the use of automatic programs in hearing aids, listeners were required to manually change the program on their hearing aid when they were in different listening environments; however, with the use of the automatic program, the hearing aid makes the decision. For example, in manual programming, a hearing impaired listener might change the hearing aid to a noise program which utilizes directional microphones in a noisy environment. When utilizing the automatic program, the hearing aid evaluates the environments' overall volume, mean frequency, fluctuations in volume, and fluctuations from mean frequency to determine which microphone option (i.e., omnidirectional or directional) should be utilized in this environment (Valente et al., 2007).

Differences in Speech and Music as a Signal for a Hearing Aid

Spectra and intensity of speech versus music. Speech does not stay at a constant intensity level but has fluctuations in volume, which are essential for normal prosody. The long-term average speech spectrum (LTASS) is defined as the average intensity over time for the speech frequencies (Valente et al., 2007). The LTASS considers the average intensity levels of speech over time as well as the peaks and valleys. While average conversational speech is approximately 65 dB SPL at one meter, the peaks of speech can be up to 12 dB above the average levels while the valleys of speech can be as much as 18 dB below the average level (Cole, 2005; Olsen, 1998). Furthermore, the dynamic range of speech is about 30 to 35 dB while the most energy is found in the frequency range from 250 to 8000 Hz (Chasin, 2007; Olsen, 1998). The main source of speech is human vocal cords; therefore, these speech spectrum averages will vary only marginally because the vocal tract can generate only a limited number of varying outcomes, no matter the age or gender of the speaker (Chasin & Russo, 2004).

On the other hand, the long-term intensity averages are difficult to define clearly for music because sources of music are highly variable. For example, sources of music can include the human voice, a spoon, a piano, a guitar, or one of many other objects. A single piano (a combination percussion and string instrument), for example, on *average* will produce decibels levels of 60 to 70 dB SPL while a single clarinet (a woodwind instrument) may produce decibel levels on *average* from 80 to 110 dB SPL (Chasin, 2008). Furthermore, it is very rare that a musical selection will have only one contributing instrument, which means an increase in the overall volume and peaks. For example, amplified rock music at 4 to 6 feet may have a root mean square of approximately 120 dB SPL with peaks up to 150 dB. Peaks for a symphonic presentation may range from 120 to 137 dB SPL (Chasin, 2008). In other words, music can range from extremely soft (i.e., about 20 dB SPL) to dangerously loud (i.e., 120 dB SPL) within a single bar of music. Therefore, the dynamic range of music can be estimated at approximately 100 dB SPL (Chasin, 2009; Ross, 2009).

With so many varying options for musical outputs, it becomes more complicated to predict the *average* music spectrum, although the spectrum most likely will have much of the energy in the low frequencies. For speech, however, these signals carry less useable information. On the standard piano keyboard, there are 88 total keys, each producing different frequencies, which can be divided into two equal categories: treble and bass clefts. Middle C (absolute middle pitch on the keyboard and the divider between treble and bass) on a keyboard measures at 262 Hz; however, information below this pitch is essential for the quality of music but would most likely be considered unimportant for a speech signal (Chasin & Russo, 2004). If sounds below 262 Hz were eliminated as noise, this would eliminate the entire bass cleft.

Limitations of hearing aid microphones for music. The louder intensities of music may create a distorted signal before the music is processed by the hearing aid because of front-end limiting. The peak input limiting level for a hearing aid is the highest intensity signal that can enter the hearing aid and is implemented by placing a limiter just after the microphone in the "front end" of the hearing aid (Chasin, 2006). Traditionally, this limiter has been set at intensity levels of 85 to 95 dB SPL, thus peak clipping signals above this intensity level (i.e., limiting signals from the "front end" of the hearing aid that are above 85 to 95 dB SPL). Likewise, front-end limiting occurs when the input stimulus is too intense for the hearing aid to process, thus overdriving the microphone and peak clipping or limiting the signal (Chasin, 2007). If front-end limiting occurs, distortion of the signal occurs at the hearing aid microphone (i.e., the front-end of the hearing aid). It is unlikely that speech is produced at intensities great enough to cause front-end limiting thus creating distortion for the speech signal. However, music is generally more intense than speech; therefore, music could activate the front-end limiter, distorting the music and altering the stimulus into low fidelity sound. When this change occurs, a hearing aid, no matter the capabilities of the music program, cannot overcome the distortion caused by the microphone. Because the distortion occurs before the music is processed by the hearing aid, low quality music is delivered to the listener.

In 2004, Chasin and Russo conducted a study to determine the total harmonic distortion (THD) of the hearing aid output when using front-end limiters set at four different limiting values. Participants for this study included 53 professional musicians (16 women, 37 men) ranging in age from 33 to 81 years. An experimental hearing aid was used with front-end limiters set to 115, 105, 96, and 92 dB SPL. Average conversational speech and 2 intense music stimuli were presented to each participant at 65 dB SPL and 90 and 100 dB SPL, respectively. THD was measured at 1600 Hz in a 2-cc coupler and on the real ear, and a sound quality measure was obtained using 5 perceptual scales pertaining to music. Listeners were asked to assess fullness, crispness, naturalness, loudness, and overall fidelity on a five point scale (1 = poorest and 5 = best).

The results revealed that distortion was decreased as the front-end limiters were increased. It should be noted that distortion for high fidelity music should be 10 % or less. For limiters set to 115, 105, 96, and 92 dB SPL, THD recordings for a 90 dB SPL signal were 2, 3, 12, and 25%, respectively. For limiters set to 115, 105, 96, and 92 dB SPL, THD recordings for a 100 dB SPL signal were 4, 4, 48, and 68%, respectively. The subjective results indicated a preference for the higher limiters (115 and 105 dB) over the lower limiters (96 and 92 dB), with the overall preference for the 115 dB SPL limiter. Furthermore, on the subjective quality rating scale, participants indicated no preference between the higher limiters (115 and 105 dB) or the lower limiters (96 and 92 dB); however, during the post assessment interview patients verbally reported that with the highest limiter (115 dB) music sounded more "natural." Lastly, these results confirm that front end limiters must be set sufficiently high enough to not degrade the music signal at the microphone.

Crest factors for speech and music. Crest factors are differences between the peaks in a waveform and the root mean square (RMS) or average portions of the waveform (Chasin, 2009). For example, the RMS (i.e., average) of speech is approximately 65 dB SPL with a crest factor of 12 to 15 dB, indicating that speech intensities on average do not produce levels of volume which exceed 12 to 15 dB above the RMS. Instruments, on the other hand, commonly have a crest factor of 18 to 20 dB SPL. This difference is because instruments are made of rigid materials in comparison to the softer, more pliable vocal tract (Chasin, 2007). Specifically, the softer tissues along the vocal tract cause a natural "dampening" effect, which decreases the crest factor for speech by about 6 to 8 dB.

For hearing aid users, increases in crest factors for music can pose a problem. Since the crest factors in music are approximately 6 dB larger than those of speech (i.e., 18 dB versus 12 dB), hearing aids may go into compression at lower intensity levels, altering harmonic relationships. This altering of harmonic relationships can decrease the fidelity of music. For example, the relationship between middle C and A, a minor chord, has the ability to incite a different emotional response than that of middle C and E, a major chord (Bowling, Gill, Choi, Prinz & Purves, 2010). To combat this problem, the hearing aids' maximum output should be increased by at least 6 dB so that the music signal is not compressed, making it sound somewhat distorted (Chasin, 2009).

Speech and music: implications for hearing aid users. After determining the fundamental differences in music and speech, it is important to evaluate how the enjoyment of music is altered because of hearing impairment. The following studies evaluate the effect of hearing loss on the enjoyment of music, the effect of music on acceptable noise levels, the effect of personality on music preference, and the effect of circuitry on speech and music perception.

First, Leek, Molis, Kubli, and Tufts (2008) attempted to determine the extent of difficulty of listening to music in hearing impaired listeners and the effect of hearing aids on listening to music. Participants for this study were chosen from the patient pool of the Army Audiology and Speech Center in Portland, Oregon and had had an audiogram within the previous year. Of the 262 patients contacted to participate, 68 agreed to be interviewed for the study. Participants had a mean age of 75 years with an average degree of impairment ranging from mild to moderately-severe bilaterally. Most of the participants' losses were sensorineural in nature. Of the total participants, 68% wore hearing aids bilaterally. The majority of the included participants had in-the-ear (ITE) aids. The requests to participate and survey were both conducted over the phone. Three interviewers, who were given a randomly complied list of patients to contact, used a script to insure that all participants were asked the same questions. The entire survey consisted of 37 questions which were divided into four categories: 1) characteristics of hearing aid use and total hearing impairment, 2) musical practice and habits, 3) music sound quality, and 4) hearing aids and music.

Results of this study indicated that approximately 30% of the interviewed participants felt that their hearing impairment had affected their enjoyment of music. This percentage showed a decrease from one identified in a study conducted two decades earlier, a change which indicated that improvements in technology have increased satisfaction when listening to music. Researchers also noted that the two most common complaints when listening to music were volume (either too loud or too soft) and difficulty understanding the speech within music. These findings indicated that when patients experience decreased satisfaction for music through hearing aids, each case should be treated individually, taking into consideration the needs of the patient.

Furthermore, Davies-Venn, Souza, and Fabry (2007) examined music and speech quality in with three types of hearing aid circuitry, one nonlinear circuitry type (i.e., WDRC) and two linear circuitry types (i.e., peak clipping and compression limiting). Eighteen adults (mean age = 69.8 years, range = 28-86) with bilateral mild to severe sensorineural hearing loss participated in this study. Most participants had no previous formal musical training, and half of the participants had at least six months of full-time hearing aid experience. All participants had binaural WRS at 80% or above at 30 dB SL.

All participants completed two experimental testing sessions. The initial visit included a full audiological evaluation including the assessment of UCLs. Earmolds were also made during this visit. At the second visit, all participants were fit with the two Phonak Valeo 211 AZ behind-the-ear (BTE) hearing aids with three programs (all set with omnidirectional microphones) and were administered aided speech testing. The volume control, program button, noise suppression, and feedback suppressor were deactivated in all three programs. The aids were set with linear peak clipping in program one, compression limiting in program two, and WDRC in program three.

In a sound-treated booth, participants were asked to assess four detentions of speech quality in five conditions in each of the hearing aid programs. Three of the conditions were conducted in quiet at 50, 65, and 80 dB SPL. The remaining two were conducted in noise with a +10 and +6 dB SNR. Participants were instructed to listen to 10 sentences. After the first five, they were cued to begin the quality ratings. The Speech Intelligibility Rating Test (SIR) was used to assess speech quality in terms of overall impression, pleasantness, intelligibility, and loudness. The SIR uses a 10-point scale where 10 represents the optimal rating for all scales except loudness. Loudness is evaluated on a 10 point scale with 10 being "very loud," 0 being "not loud at all," and 5 being the optimum rating. Each of the five speech quality assessments were tested in all three processing conditions.

Participants were also asked to determine music quality. One-minute sections of an instrumental Mozart piece and a vocal piece by Virginia Rodriguez were presented at 65 dB SPL. The vocal piece was sung in Portuguese to decrease the chance of rating being made for word comprehension rather than music quality. Participants were instructed to listen to the first 30 seconds and rate the music for loudness, sharpness, fullness, pleasantness, and overall impression for the remaining 30 seconds. Music quality ratings were made in all three processing conditions.

Results of the study were analyzed using a two-way repeated measures ANOVA. The results showed that there was no effect of amplification type for any of the quality judgments including loudness, pleasantness, intelligibility, or overall impression for speech presentations in quiet. For speech in noise, the + 6 SNR condition was rated louder, less pleasant, and of poorer overall quality than the +10 SNR condition. For music ratings, participants indicated no preference for circuitry choices in terms of sharpness, fullness, or loudness. Participants reported a significant effect for pleasantness and overall impression with a preference for WDRC over either linear circuitry option. In addition, participants indicated a preference for the instrumental presentation over the vocal presentation because the instrumental selection was less loud, less sharp, and more pleasant. These findings indicated a preference for WDRC over either linear circuitry option when listening to music. The authors stated that this study would have had more impact if the music selections were more varied in genre; therefore, the study could include a more substantial look into music quality and hearing aids (Davies-Venn et al., 2007).

Thirdly, in 2007, Gordon-Hickey and Moore conducted a study to determine if acceptable noise levels (ANLs) were the same when music was the background noise versus 12-talker babble. This study also attempted to determine if ANLs were affected by music preference among participants. These researchers hypothesized that there would be a change in ANLs with music as the background noise stimuli versus 12-talker babble. They also hypothesized that music preference would influence ANLs.

Twenty-four females (age range 20 to 29 years) with normal hearing sensitivity and no history of speech disorders, tinnitus, middle ear dysfunction, and/or neurological disorders served as the participants for this study. Conventional ANLs were assessed using 12-talker babble and music stimuli in the soundfield. The music stimulus was a selection of six instrumental clips (created for this study) and were all within the rock genre. After completion of ANLs, participants were interviewed to determine overall familiarity with music samples, enjoyment of music samples, and experience with music in daily life.

Results from this study showed that ANLs obtained when music was the background noise were significantly better than ANLs when 12-talker babble was the background noise stimuli. These results indicated that participants were able to accept higher levels of background noise when the background noise was music rather than 12-talker babble. Results from this study also showed that there was no significant correlation between music preference and ANLs. Based on these results, the researchers speculated that better ANLs for music could be due to the differences in the ways that music and speech are processed in the brain. These results further support the idea that music and speech are processed differently within the brain and are treated differently in terms of acceptance of background noise.

Lastly, Kopacz (2005) conducted a study to evaluate the effect of personality traits on music preferences. The personality traits that were evaluated in this study included liveliness, social boldness, vigilance, openness to change, and extraversion. The 145 randomly selected Polish college students indicated a fondness for music but no professional training. Participants were given the *16 Personality Factor Questionnaire* to determine personality traits and the *Questionnaire of Musical Preferences* (created by the researcher) to determine music preferences. The *16 Personality Factor Questionnaire* allowed researchers to identify seven primary personality traits which may determine musical preferences: warmth, liveliness, social boldness, abstractedness, self-reliance, openness to change, and vigilance. The *Questionnaire of Musical Preferences* included a set of instructions which required participants to complete a list detailing their favorite music choices and relevant information about each selection including performer, title, composer (for classical selections), and title of album. To analyze each musical selection, researchers created a disk made of every song indicated on the submitted questionnaires. The chosen songs were evaluated in terms of tempo, changes in tempo, number of melodic themes, rhythm, sound voluminosity, meter, sound dynamics over the course of the piece, melodies, and leading instrument timbre.

Results from this study showed that there is a significant correlation between personality and musical preference. For example, there was a positive correlation between the personality traits of liveliness and openness to change and the number of melodies present in preferred music. Furthermore, there was a negative correlation between vigilance and number of melodic themes. There was also a positive correlation between social boldness and tempo, meter, and number of melodic themes. Social boldness was the personality trait which showed the most significant correlation to musical preferences. Specifically, participants who scored high in social boldness were more likely to prefer fast tempos, high numbers of melodic themes, and asymmetric tempos in music. Those who had median scores in social boldness preferred median tempo, median number of musical themes, and more symmetrical meter. Those who scored lowest in social boldness preferred the slowest tempos, fewest numbers of melodic themes, and the more symmetrical tempo. These results indicate that there is a definite relationship between personality and musical preference. In other words, a person's musical preferences can be determined by his/her dominant personality traits.

Music Programs in Hearing Aids

In an attempt to find the best sound quality for listening to music through hearing aids, several adjustments have been suggested for hearing aid programming. Current research indicates that the differences in hearing aid programs for speech and music should address compression ratios, channels, overall gain, feedback management, and noise reduction (Chasin, 2009).

Compression in hearing aids. WDRC hearing aids should work well at amplifying music as long as several factors are considered. As a review, hearing aids utilize compression to ensure soft sounds and medium sounds remain soft and medium, while loud sounds remain tolerable. Compression systems also attempt to put the dynamic range of the signal into the dynamic range of the listener. Furthermore, hearing aids tend to focus on amplifying speech; therefore, two factors must be taken into account when programming hearing aids. First, the different crest factors of speech (i.e., 12 dB) and music (i.e., 18 dB) should be considered (Chasin, 2007). Second, the dynamic range of speech (i.e., 30 to 35 dB) and music (i.e., 100 dB) are vastly different.

Although the dynamic range (30-35 dB vs. 100 dB) and crest factors (12 dB vs. 18 dB) for music are much greater than those of speech, WDRC hearing aids should work for listening to both speech and music. The difference in success for WDRC for speech and music depends on what type of detector (peak detectors vs. RMS detectors) the hearing aid uses to determine the starting points of compression. A peak detector assesses the highest amplitudes of the incoming sounds. If the highest points in the stimuli or the "peaks" are greater than the kneepoint for compression, the hearing aid compresses the signal to bring the peak below the kneepoint (Sandlin, 2000). An RMS detector for compression systems looks at the average intensity of the incoming signal overtime. When the average signal surpasses the kneepoint for compression, gain is reduced (Sandlin, 2000). If the compression system in the music program uses a peak detector to determine at which level compression should be implemented, the peak detector should be set five to eight dB higher than that of speech to insure that compression does not go into effect before necessary. If the compression system uses an average (i.e., RMS) detector, there are no needed changes for the music program (Chasin, 2009).

Hearing aid channels. High frequencies are essential for speech as well as music. For speech, the high frequencies provide necessary details to make speech whole and understandable. For music, high frequencies serve to make the presentation whole. When pieces of the overall musical signal are missing, the presentation, much like speech, becomes less understandable and incomplete. However, being able to hear all the pieces of musical sound is not enough to ensure that the fidelity or quality of the music is preserved. To have a high fidelity musical signal, it is essential that the intensity, timing, and frequency relationships are preserved. Poor fidelity results when these relationships in the music are altered (Chasin, 2009). Therefore, the optimal hearing aid programming choice for listening to music would be a one-channel hearing aid or a hearing aid with all channels set with the same characteristics including the same compression thresholds and ratios (Chasin and Russo, 2004). This is because if one uses a hearing aid with multiple channels with different compression thresholds and ratios may alter the relationship between the low and high frequency harmonics of music.

Disabling specific hearing aid features. Disabling both the noise reduction and feedback management/cancellation systems is recommended in a hearing aid when music is the stimulus of interest (Chasin, 2009). This is because these programs are set to filter out non-speech like signals. Specifically, feedback management/cancellation systems are designed to reduce the occurrence of feedback by either reducing gain or presenting a similar but opposite signal to cancel out the feedback. Therefore, if the hearing aids perceive a music signal to be feedback, the hearing aids will make adjustments to cancel out the perceived feedback. Likewise, digital noise reduction is designed to increase listener comfort by decreasing stimuli which have noise-like characteristics. These reductions, however, in the lower frequencies can be detrimental to the fidelity of the musical stimuli because it will alter the frequency relationships.

In some hearing aids, it may be impossible to disable the feedback management/cancellation and/or the noise reduction systems. If the feedback system in a hearing aid cannot be disabled, a gain reduction method will work better than both notch filtering and the phase cancellation approach. This is because notch filtering may cause a frequency-hopping artifact while phase cancellation may introduce a chirping sound because the system may consider the music signal to be feedback (Chasin, 2009). If the noise reduction system cannot be disabled, Chasin (2009) recommends using slow attack and fast release times for compression.

Manufacturer's music program. In most cases hearing aid manufacturers offer the option of a music program. However, each hearing aid company handles the music program differently in terms of programming the instruments. Three major manufacturers' music programs are compared below. First, Oticon implements its music program by deactivating the My Voice (i.e., occlusion effect manager), noise management, and multiband adaptive directionality options. Additionally, gain for the music program is more linear, and about 5 to 7 dB less overall gain is applied as compared to amplification of speech (Oticon Audiology, personal communication, March 24, 2011). Second, in Siemens' music program, the noise management system is turned off, and the feedback reduction rates are changed from moderate to slow. Furthermore, compression characteristics are the same as those used for speech processing but with increased kneepoints (Siemens Audiology, personal communication, March 24, 2011) Third, Unitron has different protocols for different types of music. For classical music, the hearing aids provide gain with a 3 dB bump in the mid frequencies. For Rock/Pop, the gain has a 3 dB boost in the lows and a 3 dB boost in the high frequencies. For Jazz/Blues, the gain is similar to Rock/Pop but has broader bands of frequencies for which gain is increased. Unitron reported that they find patients enjoy the Rock/Pop and Jazz/Blues programs more than the Classical (Unitron Audiology, personal communication, March 24, 2011).

Rationale for the Present Study

Very little research has been conducted on the perception of music for hearing impaired listeners using a manufacturer's music program. In fact, an Oticon employee is quoted as saying that Oticon has "invested very little time in looking at the details of [the music] program" (D. Schum, personal communication, January 31, 2012). How can audiologists implement the use of a hearing aid program when even the manufacturer has no research to support its use? According to the principles of evidenced based practice, every aspect of amplification should be researched in order to more efficiently provide useful intervention (Robey et al., 2004). Therefore, the ultimate purpose of this study is to provide more research concerning the use of a music program within a hearing aid for the purpose of finding the best fitting for the quality of music.

CHAPTER III

Methods

Participants

Sixteen adults participated in this study. Because data for one participant was omitted from data collection due to a failure to answer all questions, the participants included six men (mean age=79.3) and nine women (mean age=74.6). The inclusion criteria included participants with (1) symmetrical mild, moderate, or moderately-severe sensorineural hearing loss with normal to near normal lows (i.e., participants should have thresholds at 35 dB or better at 250, 500, and 1000 Hz and should slope to no greater than 65 dB at 6000 Hz); (2) native English speakers with no known neurological, learning, or cognitive deficits; and (3) full-time, binaural users with at least three months hearing aid experience. Figure 2 shows mean data for participant audiograms. Furthermore, Figure 3 displays the musical experience of the participants. Please note that participants were asked to indicate all that apply.

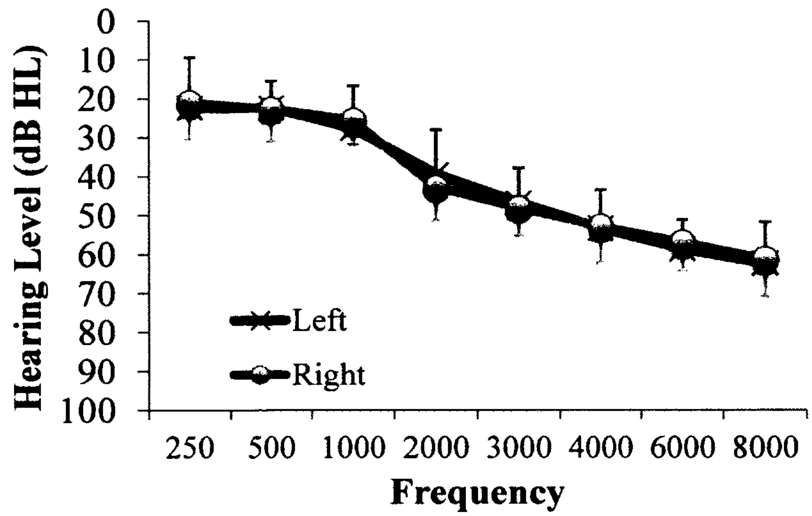

Figure 2: Audiometric means and standard deviations for participants.

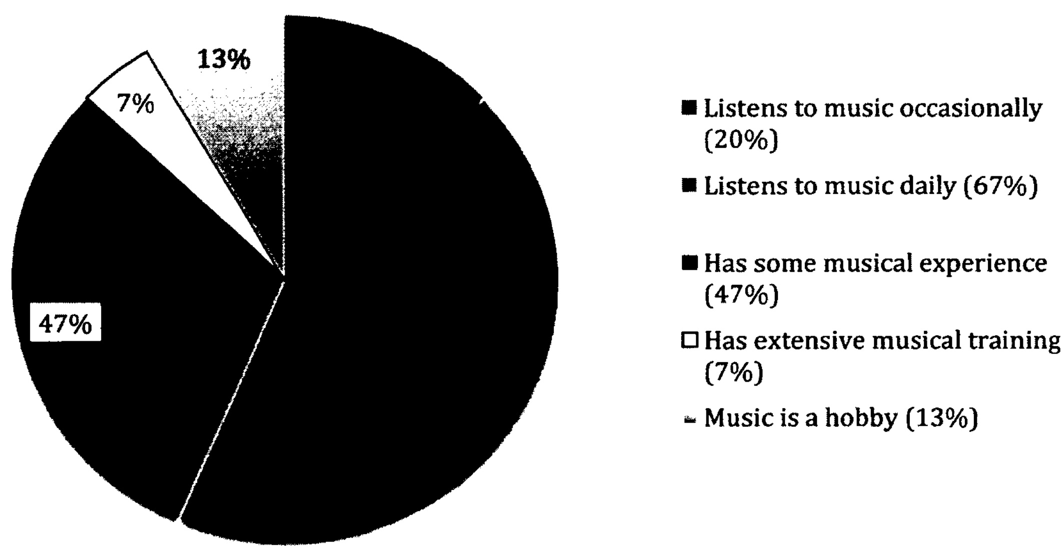

Figure 3: Participant experience with music.

Hearing Aids

Two Oticon Agil Pro receiver-in-the-ear hearing aids with multi-program capabilities were utilized in this study. The hearing instruments were coupled to the ear using the coupler recommended by the Oticon software (i.e., open domes, plus domes, power domes, etc.), which was based on the subjects' audiometric data. The aids were first fit using the Oticon Genie software in NOAH for each participant's hearing loss with two programs: Program 1 in *General* automatic adaptive/trimode directionality and Program 2 in Oticon's proprietary music program (see Appendix A for programming instructions for hearing aids). The identity was set to the recommended level. All fitting parameters for Programs 1 and 2 were identical excluding the following: For Program 1, the noise management, multi-band adaptive directionality, and My Voice systems were turned on; for Program 2, My Voice, noise management, and multi-band adaptive directionality were turned off as is recommended by the two programs settings.

Materials/Procedures

Upon arrival, each participant completed an informed consent document detailing the risks and benefits of this study. Audiological testing was completed at this time in the sound treated suite (IAC, Model 30 9'3 x 9'7). Audiometric testing included otoscopy; air conduction pure tone testing at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz; bone conduction thresholds at 500, 1000, 2000, and 4000 Hz; speech reception thresholds and word recognition scores (WRS) in quiet. Participants with discrimination scores lower than 75% in either ear were disqualified from the study. The two Oticon Agil Pro receiver-in-the-ear hearing aids were first fit on each patient using the procedures listed under *Hearing Aids* above.

In a sound treated booth, music was presented from an iPod running through a Bose SoundDock® Series II digital music system, iPod speaker (model #: 310583-1100), which was placed one meter in front of the participant with the participant at zero degrees azimuth. The music was presented at 60 dB SPL from the loudspeaker and was verified using a handheld sound level meter. First, the participant was asked to listen to a clip of music (i.e. "Clair de Lune" by Debussy) for one minute without hearing aids to have a baseline for comparison with hearing aid programs. After listening, the clip was played while the hearing aids were on the participant in Program 1, and the participant was asked to complete a questionnaire, which required participants to rate softness, brightness, volume, clarity, fullness, nearness, spaciousness, and overall impression on a 10-point scale (see Appendix B for Sound Quality Questionnaire). Participants were instructed to listen to the music with the aids for 30 seconds before beginning the questionnaire; the participant was alerted when it was time to complete the questionnaire. Then in Program 2, the clip was played while the participant rated the sound quality using the same questionnaire (see Appendix B). These steps were completed again with two additional clips of music (i.e., "California Girls" by The Beach Boys and one of the listener's choice) for each hearing aid Program. Please note the participants were given the option to choose from a list of seven songs listed by genre. Table 1 displays the song choices made by participants. Once both programs had been rated for each clip of music, the researcher completed a final interview to discuss the participant's thoughts concerning the sound quality for music in each program. The interview also assessed the participant's level of experience with music and their music preference (see Appendix C for interview form). The order of presentation and hearing aid program choice was randomized for each participant.

Table 1

A list of songs which listeners could choose from and their genre for the listener's choice song.

Genre	Song Title	# of Selections
Jazz	*Luck Be a Lady Tonight* by Frank Sinatra	6
Country	*Ring of Fire* by Johnny Cash	4
Rhythm & Blues	*Respect* by Aretha Franklin	2
Classic Rock	*Hey Jude* by The Beatles	3
Pop	*Thriller* by Michael Jackson	0
Hard Rock	*I Don't Want to Miss a Thing* by Aerosmith	0
Salsa	*Sway (Quien Sera)* by Pablo Beltran Ruiz	0

CHAPTER IV

Results

As previous stated, the purpose of this study was determine if there is a difference in the perceived listener satisfaction for music between a standard music program (Program 2) and the commonly used automatic program (Program 1) for hearing aids. Fifteen patients were asked to complete two sound quality measures in two different hearing aid programs for three different music selections: pop, classical, and listener's choice from a select list. For both questionnaires, individual data was averaged to produce a median score for each hearing aid program and musical selection for each sound quality rating.

Sound Quality Questionnaire

This study was completed in order to determine if there were any perceived differences in sound quality for music between an automatic hearing aid program and a program designed by the manufacturer for music. The Sound Quality Questionnaire (see Appendix B, pg. 1) asked participants to rate perception of softness, brightness, clarity, fullness, nearness, loudness, spaciousness, and total impression on a scale of 1 to 10. Table 2 displays the mean and range data for the Sound Quality Questionnaire.

Table 2

Median values (and range data) for the Sound Quality Questionnaire

Sound Quality Scale	Music Section and Hearing Aid Program					
	Pop		Classical		Listener's Choice	
	Automatic	Music	Auto	Music	Auto	Music
Softness	5 (4-7.5)	5 (4.5-9)	7 (4-10)	5 (1-10)	5 (4-9)	5 (3-7)
Brightness	5 (3-9)	6 (3-9)	7 (4-9)	6 (2-10)	7 (3-8)	6 (4-9)
Clarity	6 (4-9)	6 (4-9)	7 (4-9)	7 (3.5-9)	7 (3-10)	7 (5-10)
Fullness	5 (3-10)	6 (3-8)	7 (3-9)	7 (3-10)	7 (3-9)	7 (3-10)
Nearness	5 (3-8)	6 (3-9)	7 (3-9)	7 (2.5-9)	7 (1-9)	7 (3-9)
Loudness	5 (1-7)	5 (3-7)	5 (0-5.5)	7 (3-6)	5 (3-6)	5 (2-8)
Spaciousness	5 (3-8)	6 (2-8)	7 (3-9)	7 (3-9)	5 (2-10)	6 (3-9)
Total Impression	7 (4-8)	7 (4-9)	8 (5-9)	7 (3-9)	7 (3-9)	7 (4-9)

Three different groups of Wilcoxon Signed Ranks Tests were completed to evaluate the effect of hearing aid program on sound quality ratings. The three groups of tests were utilized because there were three song selections for each participant (pop, classical, and listener's choice). The within subject variable for each group of tests was hearing aid program with two levels (automatic and music). These variables were evaluated using eight musical descriptors (softness, brightness, clarity, fullness, nearness, loudness, spaciousness, and total impression). In the first, second, and third groups of Wilcoxon Signed Rank Tests, eight paired Wilcoxon Signed Rank tests were conducted to determine the effect of hearing aid program on sound quality for the pop, classical, and listens' choice music selections, respectively. For each group, a Bonferroni adjustment was completed for multiple comparisons (i.e., significance ≥ 0.006). The results indicated no significant main effect for hearing aid program for any of the sound quality ratings for the pop, classical, and listener's choice selections (see Table 3). This reveals that patients perceived no measurable difference for the eight qualifiers between the automatic and music programs when listening to any of the three musical selections.

Table 3

Significance and Z values for the pop, classical, and listener's choice music selections.

Sound Quality Rating	Pop Music		Classical Music		Listener's Choice	
	Z	Significance	Z	Significance	Z	Significance
Softness	-.357	.721	-2.302	.021	-.774	.439
Brightness	-1.271	.204	-.144	.886	-.450	.653
Clarity	-.958	.338	-.339	.734	-.853	.394
Fullness	-.045	.964	-.154	.878	-1.028	.304
Nearness	-1.081	.280	-.990	.322	-2.238	.025
Loudness	-1.513	.130	-.957	.339	-.660	.509
Spaciousness	-1.209	.227	-1.128	.259	-.224	.823
Total Impression	-1.078	.281	-1.239	.215	-1.215	.224

Self-Developed Sound Quality Questionnaire

A second self-developed questionnaire (see Appendix B, pg. 2) asked participants to answer questions regarding the musical selection's volume, clarity, fullness, pleasantness, overall satisfaction with sound quality. Furthermore, participants were asked to choose the best descriptive word for the selection from a list of choices (see Appendix B, Pg. 2). Figures 4-8 show the trends for participant response to the questions along with how each answer was quantified.

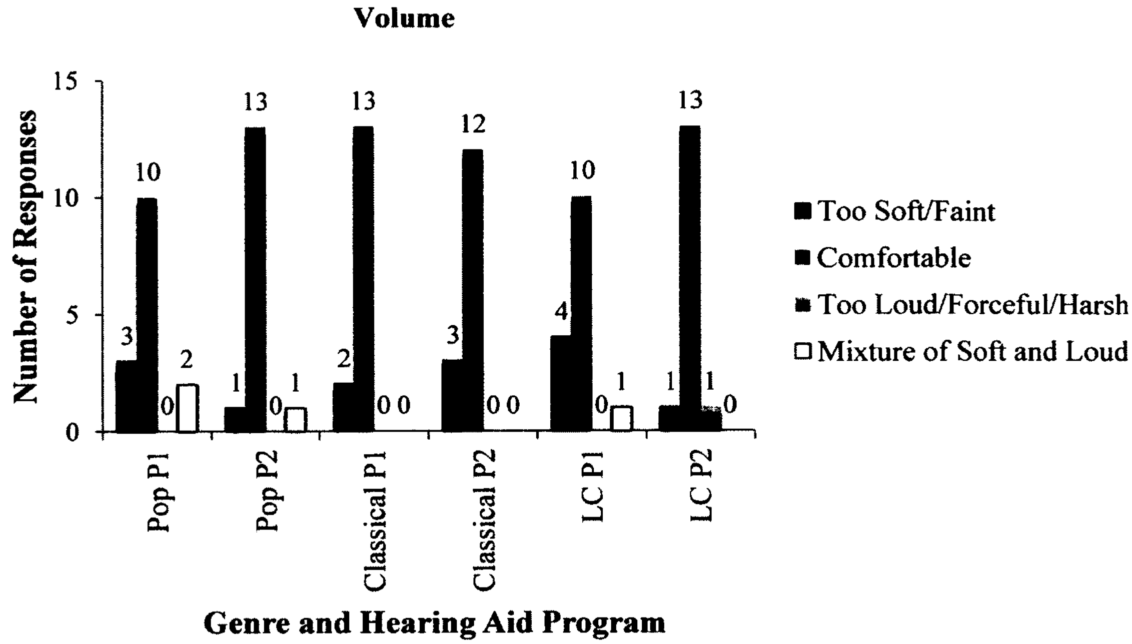

Figure 4: Participant response to inquiry of volume for each musical selection in the automatic hearing aid program (P1) and the music program (P2).

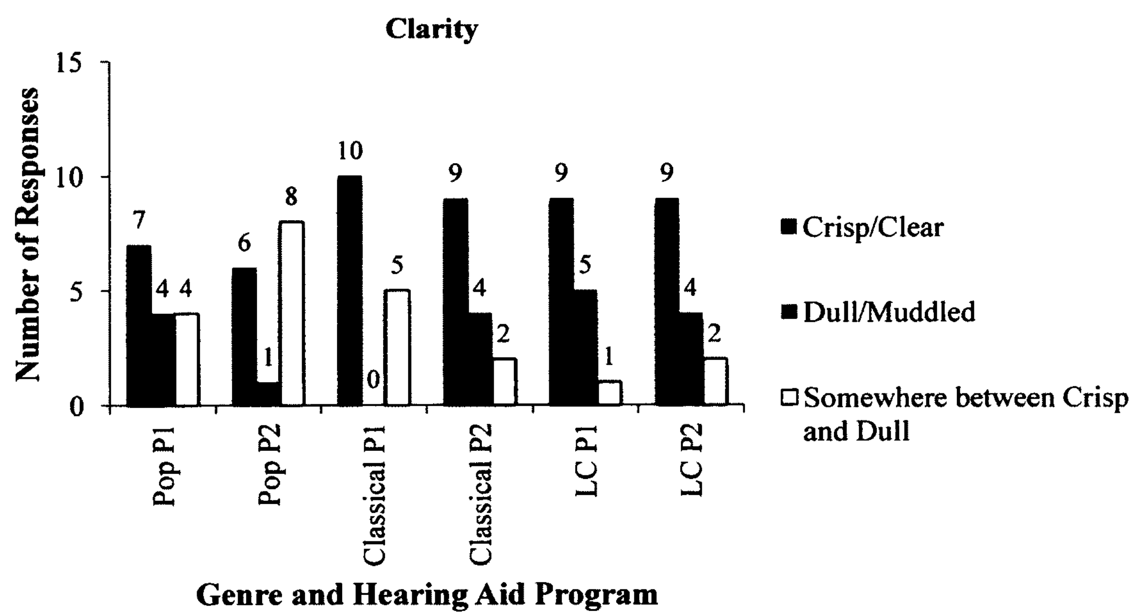

Figure 5: Participant response to inquiry of clarity for each musical selection in automatic hearing aid program (P1) and music program (P2).

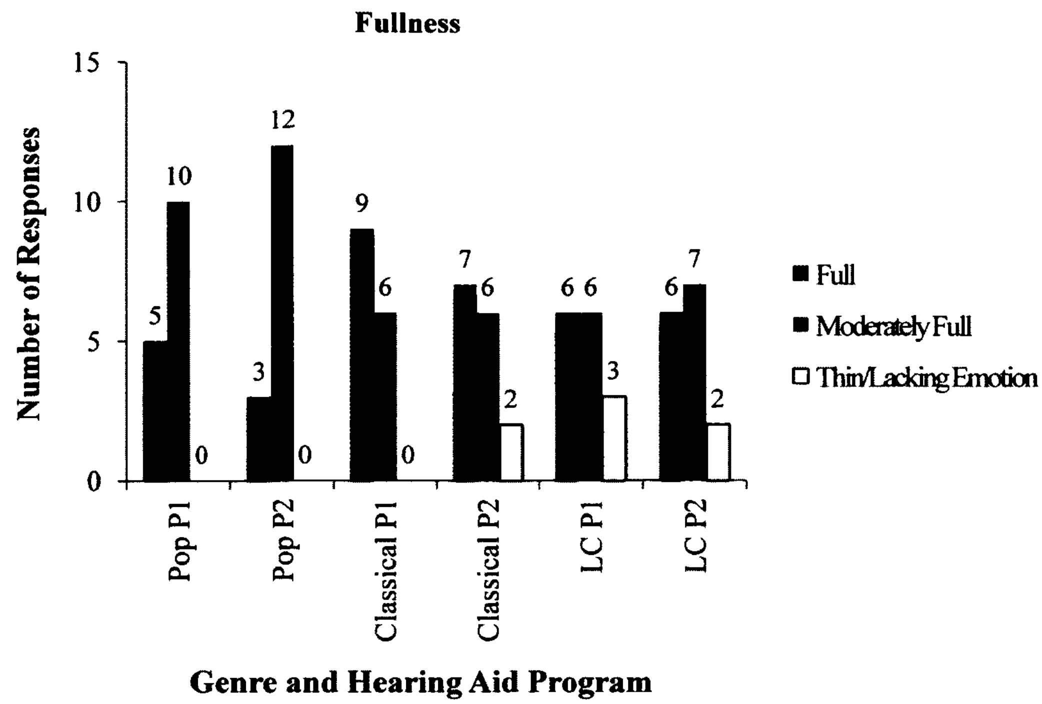

Figure 6: Participant response to inquiry of fullness for each musical selection in automatic hearing aid program (P1) and music program (P2).

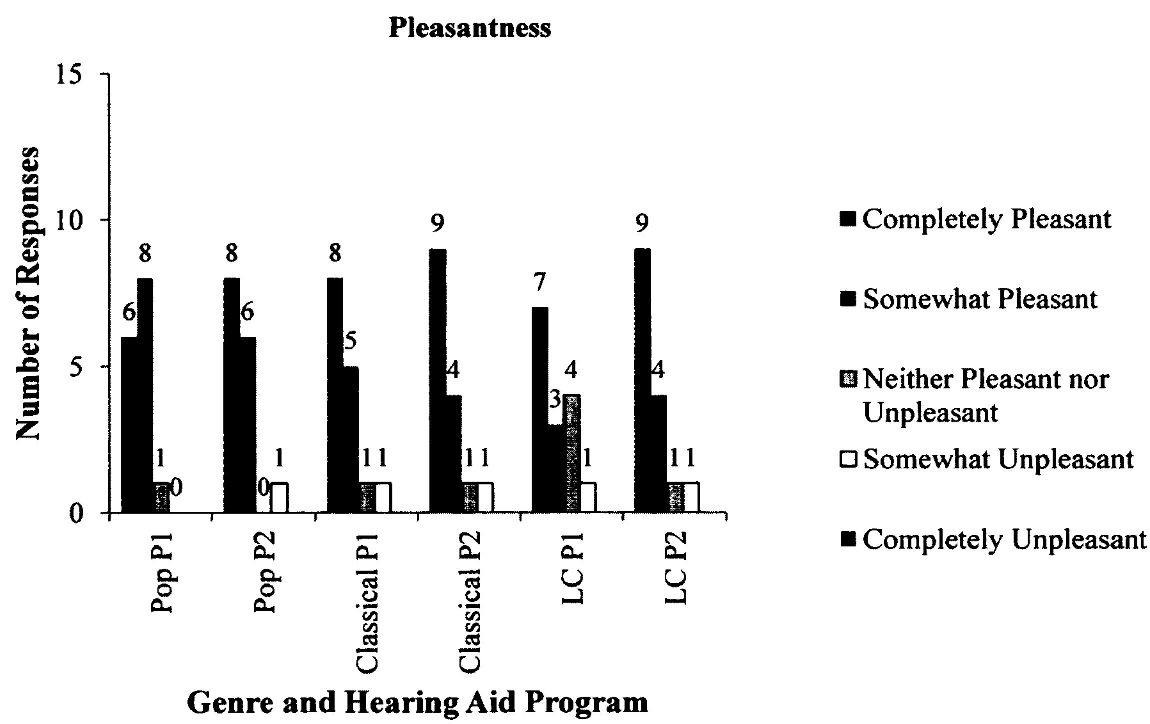

Figure 7: Participant response to inquiry of pleasantness for each musical selection in automatic hearing aid program (P1) and music program (P2).

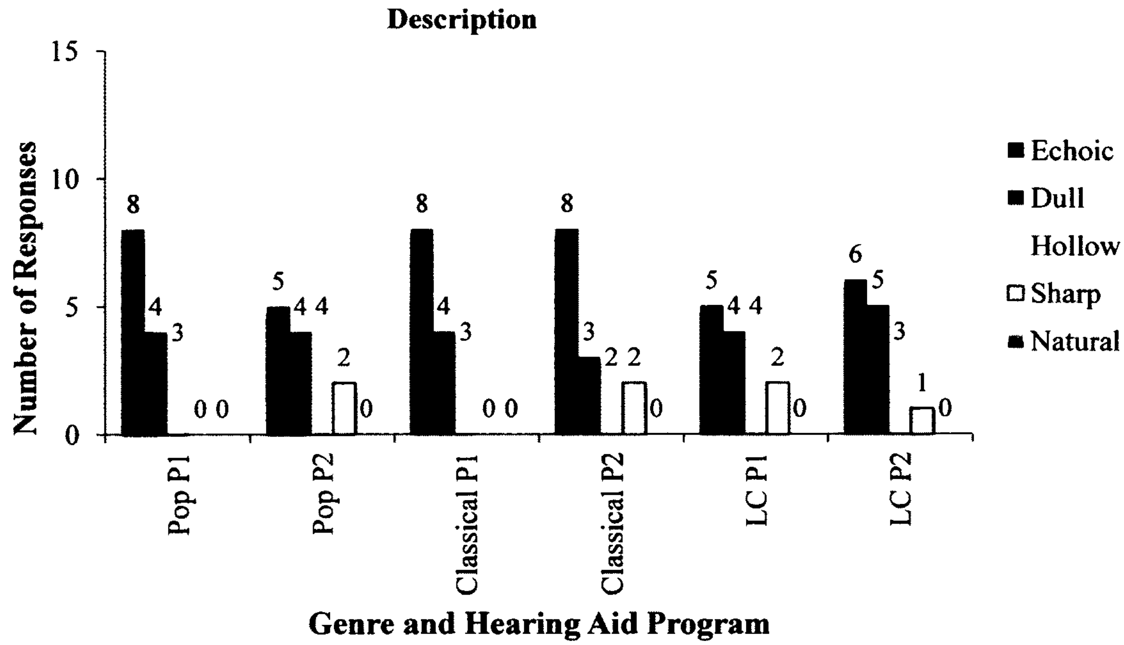

Figure 8: Participant response to inquiry of description for each musical selection in P1 and P2.

Again, three different groups of Wilcoxon Signed Ranks Tests were completed to evaluate the effect of hearing aid program on sound quality ratings for the self-developed sound quality questionnaire. Three groups were utilized because there were three song selections for each participant (pop, classical, and listener's choice). The within subject variable was hearing aid program with two levels (automatic and music). This variable was evaluated using five musical descriptors (volume, clarity, fullness, pleasantness, satisfaction, and description). For each group of Wilconxon Signed Rank Tests, eight paired Wilcoxon Signed Rank tests were conducted to determine the effect of hearing aid program on sound quality for the pop, classical, and listener's choice music selections, respectively. A Bonferroni adjustment was completed for multiple comparisons (significance ≥ 0.01). The results indicated no significant main effect for hearing aid program for any of the sound quality ratings for the pop, classical, or listener's choice selections (see Table 4). This reveals that patients perceived no measurable difference for the six descriptive qualifiers between the automatic and music programs when listening to any of the three musical selections.

Table 4

Significance and Z values for the self-developed sound quality questionnaire for the pop, classical, and listener's choice musical selections.

Sound Quality Rating	Pop Music		Classical Music		Listener's Choice	
	Z	Significance	Z	Significance	Z	Significance
Volume	-.138	.890	-1.000	.317	-.707	.480
Clarity	-1.518	.129	-1.000	.317	-1.342	.180
Fullness	-1.000	.317	-1.633	.102	-.577	.564
Pleasantness	-.378	.705	-.447	.655	-1.406	.160
Satisfaction	-1.134	.257	-.905	.366	-1.155	.248
Description	-1.089	.276	-.172	.863	-.272	.785

Hearing Aid Preference

Furthermore, participants were asked to indicate which hearing aid program they preferred when they were listening to music (see Figure 9). A one-sample chi-square test was completed to assess user preference for sound quality of music between the automatic and music programs. The hypothesized proportion of listeners that were expected to prefer the automatic program (P1), the music program (P2), or no preference for hearing aid program was 0.33. The results showed no significant preference for HA program ($\chi = 0.00$, $p = 1.00$). These results indicate that overall, patients did not consistently find one program to be have better sound quality for music.

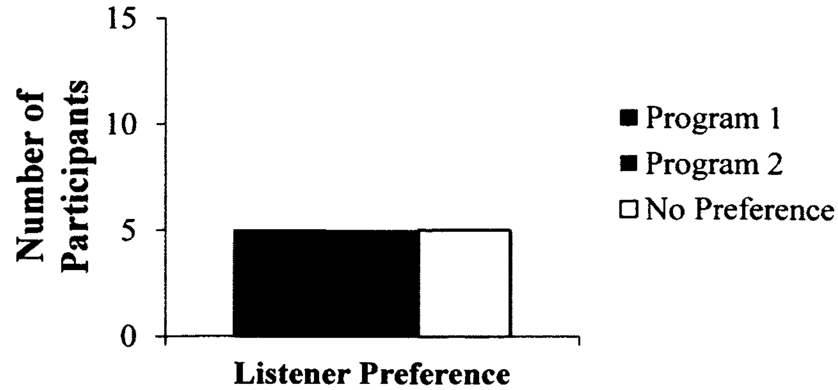

Figure 9: Hearing aid program preference for sound quality.

CHAPTER V

Discussion

The main purpose of this study was to determine if there is a difference in a listener's perception of music between an automatic hearing aid program and a standard music hearing aid program. Participants were asked to complete two sound quality assessments for three music choices in both automatic and music hearing aid programs. Results of the present study indicated that participants noticed no difference in sound quality for any of the song selections when comparing the automatic hearing aid program to the music program. Furthermore, the favored program was equally divided between patients with five participants indicating that they had no preference between programs, five indicating preference for Program 1 (i.e., automatic program), and five indicating that they preferred Program 2 (i.e., music program). This finding could be due to the fact that there is very little difference in terms of programming between the automatic and music program.

The results of the present study were somewhat unexpected due to the differences in how Program 1 and Program 2 treated the input signals. We expected participants to notice some degree of difference between the two programs and have a preference as to which program provided the best sound quality for music. Specifically, it was hypothesized that there would be a noticeable difference in the categories of Total Impression and Fullness as the goal of the music program should be to help provide listeners with a more natural music listening experience. Furthermore, if patients notice no improvement when using the music program, there may be no reason to utilize the music program as it is currently set. It should be noted that some of these similarities in preference and sound quality could have been due to the testing situation as participants were tested in a sound treated booth. It is possible that the participants would have noticed a difference if background noise was introduced or if music was presented in a less controlled environment (i.e., live music).

It should also be noted that of the 15 participants who completed this study, there were varying degrees of musical experience. Forty-seven percent (7 of 15) of participants indicated that they had some musical training, seven percent (1 out of 15) said that they had extensive musical training, and sixty-seven percent (10 out of 15) of participants indicated that they listened to music daily. For the seven participants with some musical training, median values for total impression in Programs 1 and 2 for each of the song selections was compared. Median values for Programs 1 and 2 were 6 and 7 for the pop selection, 7 and 7 for the classical selection, and 6 and 7 for the listener's choice selection, respectively. A comparison of this data seems to indicate no true preference between the automatic and standard music program, even for listeners with musical training.

Furthermore, previous research has indicated that there is a difference between speech and music as an input signal to the hearing aid and that hearing aids should be programmed differently for speech and music. This research indicates that with the current hearing aid parameters for music, patients do not perceive a change in sound quality when listening to music in the standard music program versus the commonly used automatic program. Based on these results, further research should focus on effective ways to program hearing aids for music. Specifically, one might focus research on the effect of environment on the overall listening experience for music as well as the ability of hearing aids to naturally process various sources of music (i.e. voices, percussive instruments, strings, etc.). Other research could focus on the effect of compression parameters and/or prescriptive formulas on the sound quality of music.

APPENDIX A

PROGRAMMING THE HEARING AIDS

Programming the Hearing Aids

- Update patient audiogram in patient information on NOAH.
- Put hearing aids with fresh batteries within the hook of the Nearcom which should be set to ON.
- Click on the Oticon Genie 2012.1 module.
- Click to the Family screen
    - Click Detect Aids in the center of the screen
- Click to the Selection screen
    - Click Personal Profile to the left of the screen
        - i. Select the appropriate age and gender
        - ii. Select long-term listed under experience level
    - Click Program Manager to the left of the screen
        - i. Program 1 (Automatic Directional Microphone)
            1. Select general
                - a. Select NAL-NL1 prescriptive formula
                - b. Select recommended identity
            2. Auto Phone should be set to not active
        - ii. Program 2 (Music)
            1. Select Add, choose music
    - Click Acoustics to the left of the screen
        - i. Select the recommended coupler to the hearing aid (open dome, plus dome, power dome)
- Click to the Fitting screen
    - Click Adaptation Manager to level 3
    - Click Automatic Features (in P 1) to the left of the screen
        - i. Directionality should be set to Tri-Mode
        - ii. Noise Management should be set to On
        - iii. My Voice should be set to On
        - iv. Binaural Broadband should be On
- Click to the End Fitting screen
    - Click the Buttons and Indicators option to the left side of the screen
        - i. Ensure that Binaural volume control is on
        - ii. Ensure that Mute is off
- Click Save, Program and Exit at the bottom of the screen

APPENDIX B

SOUND QUALITY QUESTIONNAIRES

Sound Quality Questionnaire

Instructions: Please judge the sound quality of the information that you are about to listen to. Describe how the information sounds using the scale below. The scales refer to various properties of the sound reproduction. Please judge the sound on a scale from 10 (maximum) to 0 (minimum). The integers 9, 7, 5, 3, and 1 on the response form are defined. For instance, in the scale for clarity 10 means maximum (highest possible) clarity, 9 means very clear, and 0 minimum clarity.

The scales are described as follows:

- ***Softness***. How soft and gentle is the reproduction - in opposition to sharp, hard, keen, and shrill.
- ***Brightness***. How bright is the reproduction - in opposition to dull and dark.
- ***Clarity***. How clear, distinct, and pure is the reproduction – in opposition to sounding diffuse, blurred, thick, and the like.
- ***Fullness***. How full is the reproduction - in opposition to thin.
- ***Nearness***. How close to you does the reproduction sound – in opposition to at a distance.
- ***Loudness***. How loud is the reproduction - in opposition to soft or faint.
- ***Spaciousness***. How open and spacious does the reproduction sound – in opposition to closed and shut up.
- ***Total impression***. What is your overall judgment of how good you think the reproduction is?

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	SOFTNESS
	VERY SHARP		RATHER SHARP		MIDWAY		RATHER SOFT		VERY SOFT		[___ ___.___]

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	BRIGHTNESS
	VERY DULL		RATHER DULL		MIDWAY		RATHER BRIGHT		VERY BRIGHT		[___ ___.___]

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	CLARITY
	VERY UNCLEAR		RATHER UNCLEAR		MIDWAY		RATHER CLEAR		VERY CLEAR		[___ ___.___]

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	FULLNESS
	VERY THIN		RATHER THIN		MIDWAY		RATHER FULL		VERY FULL		[___ ___.___]

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	NEARNESS
	VERY DISTANT		RATHER DISTANT		MIDWAY		RATHER NEAR		VERY NEAR		[___ ___.___]

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	LOUDNESS
	VERY SOFT		RATHER SOFT		MIDWAY		RATHER LOUD		VERY LOUD		[___ ___.___]

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	SPACIOUSNES
	VERY CLOSED		RATHER CLOSED		MIDWAY		RATHER OPEN		VERY OPEN		[___ ___.___]

0 MIN	1	2	3	4	5	6	7	8	9	10 MAX	TOTAL IMPRESSION
	VERY BAD		RATHER BAD		MIDWAY		RATHER GOOD		VERY GOOD		[___ ___.___]

Subject #: ____________________ Date:_____________

Investigator to Circle One: Program 1 Program 2

Mark the answer that you feel most closely describes your opinion on the music presentations.

1. As a whole this clip
   ( ) was too soft/ faint.
   ( ) was a comfortable volume.
   ( ) was too loud/ forceful/harsh.
   ( ) had sections that were too soft and sections that were too loud.

2. As a whole, I would rate this clip as
   ( ) crisp/clear.
   ( ) dull/ muddied.
   ( ) somewhere between crisp and dull.

3. In terms of fullness (opposite of thin/thread) this clip was
   ( ) full.
   ( ) moderately full.
   () thin (lacking emotion normally present in music).

4. In terms of sound quality, how pleasant was this clip?
   ( ) completely pleasant
   ( ) somewhat pleasant
   ( ) neither pleasant nor unpleasant
   ( ) somewhat unpleasant
   ( ) completely unpleasant

5. In terms of your overall impression of this presentation, what do you think of the sound?
   ( ) completely satisfying (great)
   ( ) moderately satisfying (good)
   ( ) average (just ok)
   ( ) moderately unsatisfying (disappointing)
   ( ) completely unsatisfying (bad)

6. Which of the following words most closely describes the sound?
   ( ) Echoic
   ( ) Dull
   ( ) Hollow
   ( ) Sharp
   ( ) Natural

APPENDIX C

PARTICIPANT INFORMATION SHEET

Participant Information Sheet

Subject #: ____________________ Date:____________

Date of Birth:__________________ Gender: M F

1. Please mark the answer or answers that most closely describe your experience with music:
   - ( ) I listen to music occasionally.
   - ( ) I listen to music almost daily.
   - ( ) I have had some musical training.
   - ( ) I have extensive musical training.
   - ( ) Music is part of my job.
   - ( ) Music is a hobby of mine.

2. Between the two genres of music that were used in this study, I enjoyed
   - ( ) the classical selection the most.
   - ( ) the more upbeat selection the most.
   - ( ) the selection I choose the most.
   - ( ) all selections equally.

3. Which listening situation provided the most satisfying listening situation?
   - ( ) Program 1
   - ( ) Program 2
   - ( ) No difference between Program 1 and Program 2
   - ( ) Other

     Explain:

4. Did you utilize your volume control?
   - ( ) Yes
   - ( ) No

   If so, when and in what direction?

Comments:

APPENDIX D

APPROVAL MEMO FOR HUC 1081

LOUISIANA TECH
UNIVERSITY

OFFICE OF UNIVERSITY RESEARCH

MEMORANDUM

TO: Ms. Kalyn Bradford and Dr. Melinda Bryan

FROM: Dr. Stan Napper, Vice President of Research & Development

SUBJECT: Human Use Committee Review

DATE: March 13, 2014

RE: Approved Continuation of Study HUC 1081

TITLE: **"The Effect of Hearing Aid Program on the Perceived Sound Quality of Music"**

HUC 1081

The above referenced study has been approved as of March 13, 2014 as a continuation of the original study that received approval on March 18, 2013. **This project will need to receive a continuation review by the IRB if the project, including collecting or analyzing data, continues beyond March 13, 2015.** Any discrepancies in procedure or changes that have been made including approved changes should be noted in the review application. Projects involving NIH funds require annual education training to be documented. For more information regarding this, contact the Office of University Research.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the university for three years after the conclusion of the study. If changes occur in recruiting of subjects, informed consent process or in your research protocol, or if unanticipated problems should arise it is the Researchers responsibility to notify the Office of Research or IRB in writing. The project should be discontinued until modifications can be reviewed and approved.

If you have any questions, please contact Dr. Mary Livingston at 257-5066.

References

Bowling, D. L., Gill, K., Choi, J. D., Prinz, J., & Purves, D. (2010). Major and minor music compared to excited and subdued speech. *Journal of Acoustical Society of America, 127*(1), 491-503.

Chan, M. F., Chan, E. A., & Mok, E. (2009). Effect of music on depression levels and physiological responses in community-based older adults. *International Journal of Mental Health Nursing, 18*(4), 285–294. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1447-0349.2009.00614.x/abstract;jsessionid=BFEF5A9D0710B241B4C9FBE8E4D4DA3B.f01t02?deniedAccessCustomisedMessage=&userIsAuthenticated=false

Chasin, M. (2006). Can your hearing aid handle loud music? A quick test will tell you. *The Hearing Journal, 59*(12), 22-23.

Chasin, M. (2007, February 12). *Music as an input to a hearing aid.* Retrieved from http://www.audiologyonline.com/articles/article_detail.asp?article_id=1759

Chasin, M. (2008, January 28). *Musicians and the prevention of hearing loss: An introduction* . Retrieved from http://www.audiologyonline.com/articles/musicians-and-prevention-hearing-loss-926

Chasin, M. (2009). *Hearing loss in musicians: prevention and management*. San Diego, CA: Plural Publishing.

Chasin, M., & Russo, F. A. (2004). Music and hearing aids. *Trends in Amplification, 8*, 35-37.

Cole, B. (2005). *A brief history of "speechmapping" at audioscan*. Retrieved from http://www.audioscan.com/resources/audionotes/audionote11lowrez.pdf

Davies-Venn, E., Souza, P., & Fabry, D. (2007). Speech and music quality ratings for linear and nonlinear hearing aid circuitry. *Journal of the American Academy of Audiology, 18*, 688-699.

Gordon-Hickey, S., & Moore, R. (2007). Influence of music and music preference on acceptable noise levels in listeners with normal hearing. *Journal of the American Academy of Audiology, 18*, 417-427.

Kates, J. M. (2008). *Digital hearing aids*. (pp. 75-109). San Diego, CA: Plural Publishing Inc.

Katz, J., Medwetsky, L., Burkard, R., & Hood, L. (2009). *Handbook of clinical audiology*. (6th ed., pp. 751-752). Philadelphia: Lippincott Williams and Wilkins.

Kopacz, M. (2005). Personality and music preferences: the influence of personality traits on preferences regarding musical elements. *Journal of Music Therapy, 42*(3), 216-239.

Leek, M., Molis, M., Kubli, L., & Tufts, J. (2008). Enjoyment of music by elderly hearing-impaired listeners. *Journal of the American Academy of Audiology, 19*, 519-526.

Lin, S., & Yang, P. (2011). Mental health implications of music: Insight from neuroscientific and clinical studies. *Harvard Review of Psychiatry*, *19*(1), 34-46. Retrieved from http://informahealthcare.com/doi/abs/10.3109/10673229.2011.549769

Olsen, L. (Designer). (2002). *Polar plots*. [Web Graphic]. Retrieved from http://www.audiologyonline.com/askexpert/display_question.asp?question_id=95

Polar pattern: Supercardioid in the horizontal plane; half-supercardioid in the vertical plane. [Web Graphic]. Retrieved from http://www.bartlettmics.com/specs.html

Olsen, W. O. (1998). Average speech levels and spectra in various speaking/listening conditions: A summary of the pearson, bennett, and fidell (1977) report. *American Journal of Audiology*, *7*, 21-25.

Robey, R., Apel, K., Dollaghan, C., Ellmo, W., Hall, N., Helfer, T., Moeller, M. P., & Threats, T. (2004). Report of the joint coordinating committee on evidence-based practice. Retrieved from http://www.asha.org/uploadedFiles/members/ebp/JCCEBPReport04.pdf

Ross, M. (2009, May/June). The "music" program. *Hearing Loss*, 30(4), 26-29.

Sandlin, R. E. (2000). *Textbook of hearing aid amplification.* (2nd ed., pp. 241-242). San Diego, CA: Singular Publishing Group Thomson Learning.

Sutoo, D., & Akiyama, K. (2004). Music improves dopaminergic neurotransmission: demonstration based on the effect of music on blood pressure regulation. Retrieved from http://www.sciencedirect.com/science/article/pii/S000689930400736X

Trappe, H. J. (2010). The effects of music on the cardiovascular system and cardiovascular health. *Heart*, *96*(23), 1868-1871. Retrieved from http://heart.bmj.com/content/96/23/1868.short

Valente, M., Hosford-Dunn, H., & Roeser, R. J. (2007). *Audiology treatment.* (2nd ed, pp., 97, 127-128). New York, NY: Thieme Medical Pub.