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COLLEGE OF GRADUATE STUDIES AND RESEARCH

THE EFFECTS OF REAL WORLD BACKGROUND NOISE, SONG SELECTION, AND IPOD VOLUME LEVELS ON THE AUDIBILITY OF SONGS TO BYSTANDERS

By

Melina Ecos

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THESIS APPROVAL PAGE

This is to certify that the thesis prepared by Melina Ecos Entitled "Effects of Real World Background Noise, Song Selection, and Volume Level of iPods on Audibility to Bystanders" has been approved by the thesis committee as satisfactorily completing the thesis requirements for the degree Doctor of Audiology.

Brian Kreisman, PhD., Chair, Thesis Committee — Date 5/6/11

Brian Fligor, Sc.D., Committee Member — Date 5/6/11

Stephen Pallett, Au.D., Committee Member — Date 5/6/2011

Lawrence Shirley, Associate Dean
College of Graduate Studies and Research — Date

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ABSTRACT

THE EFFECTS OF REAL WORLD BACKGROUND NOISE, SONG SELECTION, AND IPOD VOLUME LEVELS ON THE AUDIBILITY OF SONGS TO BYSTANDERS

Melina Ecos

This research study investigated the effects of real world background noise, song selection, and volume level on audibility of a song as a bystander. The background noises included quiet (31.6 dB(A) of ambient noise), 45 dB(A) of speech babble, 60 dB(A) of restaurant noise, and 75 dB(A) of airplane noise. The five songs included “Boom Boom” by The Blackeyed Peas, “I Gotta Feeling” by The Blackeyed Peas, “Love Game” by Lady GaGa, “You Know You Want Me” by Pit Bull, and “Fire Burning” by Sean Kingston. The volume levels on an iPod touch included 0, 12.5, 25, 37.5, 50, 62.5, 75, 87.5, and 100%. The purpose of the research study was to determine if audibility of a song by a bystander indicated that the volume level was set at a dangerously loud level of greater than or equal to 85 dB(A) free field equivalent.

Fifty normal hearing adults participated in this study. Ten-second song clips for each of the five songs at the nine volume levels were convolved with the background noise conditions to create a total of 180 song clips. The participants were presented with randomized clips and their audibility of the songs was assessed. Results indicate that audibility varied among the five songs at the nine different volume levels in the four different background noise conditions. All of the songs were audible at volume levels

greater than or equal to 85 dB(A) in all background noise conditions. A song with a high peak SPL was not more audible at a quiet volume level compared to another song with a lower peak SPL. As the background noise volume level increased, the audibility of the songs decreased. As volume level of the song increased, the audibility of the songs increased. Therefore, a bystander 2’4” away from an individual listening to an iPod with standard iPod earbuds who indicates that the iPod song is audible does not necessarily indicate that the volume level is loud enough to damage a listeners hearing.

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CHAPTER 1

INTRODUCTION

An abundance of literature supports the fact that exposure to intense sound levels of occupational or recreational noise can cause a noise-induced hearing loss (NIHL) for the listener (Bradley, Fortnum, & Coles, 1987; Catalano & Levin, 1985; Carter, Waugh, Keen, Murray, & Bulteau 1982; Danhauer et al., 2009; Ferrari & Chan, 1991; Hughes et al., 1986; Niskar et al., 2001; Rabinowitz, 2000; Weiner, Kreisman, & Fligor, 2009). Approximately 26 million Americans between the ages of 20 to 69 years of age have NIHL due to occupational and recreational noise exposure (NIDCD, 2008). In more recent years, recreational noise exposure has been a topic of concern with many loud hobbies identified including fire arms, vehicles, power tools, children's toys, and listening to amplified music (Carter, Waugh, Keen, Murray, & Bulteau, 1982; Danhauer et al., 2009; Hughes et al., 1986; Rabinowitz, 2000; Weiner, Kreisman, & Fligor, 2009). Currently, particular attention has been drawn to recreational NIHL caused by amplified music (Bradley, Fortnum, & Coles, 1987; Chung, Des Roches, Meunier, & Eavey, 2005; Hughes et al., 1986; Weiner et al., 2009).

Amplified music is raising concern for increased risk of NIHL due to the increased popularity of new MP3 personal music players (Weiner, Kreisman, & Fligor, 2009). MP3 is the common term for an audio encoding format developed by the Moving Picture Experts Group (MPEG) labeled MPEG-1 Layer 3 (Garrigus, 1999). Many different manufacturers make MP3 players; however, the most popular of MP3 players is the Apple iPod with over 100 million sold (Weiner et al., 2009). Ethier (2008) estimated that about 275 million MP3 players will be sold by the year 2011. As the technology advances with new MP3 players, the devices are small enough to fit in the palm of one's hand with increasing memory capabilities enabling thousands of songs to be stored into one device (Danhauer et al., 2009; Garrigus, 1999). A main cause of alarm with MP3 players is their capability to reach extremely loud maximum output levels of greater than 100 dB(A) (Hodgetts, Rieger, & Szarko, 2007).

The combination of loud output sound levels and the duration of noise exposure are essential factors in determining the risk of NIHL (Bradley, Fortnum, & Coles, 1987; Catalano & Levin, 1985; Ferrari & Chan, 1991; Hughes et al., 1986). The small size and large memory capabilities of MP3 players enable users to listen to music for long periods of time at loud output sound levels (Hodgetts, Rieger, & Szarko, 2007). Furthermore, the greater amount of exposures to loud noise the greater the risk of NIHL due to a cumulative effect of the duration and intensity of the exposures (Chung, Des Roches, Meunier, & Eavey, 2005; Niskar et al., 2001). Noise-induced hearing loss is a great hazard to children and adolescent populations because the detrimental effects typically manifest gradually, which can go without notice until later in life (Chung et al., 2005; Niskar et al., 2001; Danhauer et al., 2009; Rabinowitz, 2000).

The effects of NIHL can be very damaging to the individual (Niskar et al., 2001). Noise-induced hearing loss can result in deficits in speech discrimination due to the high frequencies being affected first. With continued exposure to loud noise, NIHL can progress in severity of the loss as well as to advance into other frequencies (Niskar et al., 2001). A decrease in hearing sensitivity is not the only deficit that NIHL causes. Tinnitus in one or both ears, recruitment, hypersensitivity to sound, and distortion have been associated with individuals with NIHL (Fligor & Cox, 2004). The damaging affect of

NIHL can negatively influence the individual's education, social interactions, employment, and quality of life (Lusk, 2002; Niskar et al., 2001). Furthermore, children identified with a mild sensorineural hearing loss have been shown to score significantly lower on the Comprehensive Test of Basic Skills and demonstrated more behavioral problems and lower self-esteem compared to normal hearing children in the same grade (Folmer, Griest, & Martin, 2002).

Noise-induced hearing loss and the associated detrimental affects are preventable (Fligor & Cox, 2004; Lusk, 2002; Rabinowitz, 2000). Safety standards from the Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) serve to prevent workers from acquiring NIHL due to loud noise exposure at the workplace (NIOSH, 1998; OSHA, 1983). Both OSHA and NIOSH indicate that sound levels equal to or greater than 85 dB(A) on an 8-hour time weighted average are hazardous to hearing health and create risk for NIHL. According to standards, employees exposed to dangerous sound levels must participate in hearing conservation program in order to prevent NIHL (NIOSH, 1998; OSHA, 1983). Individuals that are exposed to hazardous levels of noise through recreational activities are not required to participate in any hearing conservation program (NIOSH, 1998; OSHA, 1983). Hearing conservation programs serve to raise awareness on the topic of NIHL so that individuals can better protect their hearing (Chung, Des Roches, Meunier, & Eavey, 2005; Danhauer et al., 2009; Ferrari & Chan, 1991; Folmer, Griest, & Martin, 2002; Lusk, 2002). Many beneficial hearing conservation programs have been identified, but have not been distributed to at risk populations effectively (Chung et al., 2005). Further research is needed on the recreational noise exposure levels that individuals are being exposed to, especially with the popular activity of listening to intense music through MP3 players (Danhauer et al., 2009). A better understanding of NIHL will assist in prevention of NIHL and provide helpful information to at risk populations.

CHAPTER 2

LITERATURE REVIEW

Noise-Induced Hearing Loss

It is well known that hearing loss can be caused by an individual being exposed to sound intensity levels and durations which harm the auditory system (Bradley, Fortnum, & Coles, 1987; Catalano & Levin, 1985; Carter, Waugh, Keen, Murray, & Bulteau 1982; Danhauer et al., 2009; Ferrari & Chan, 1991; Hughes et al., 1986; Niskar et al., 2001; Rabinowitz, 2000; Weiner, Kreisman, & Fligor, 2009). Rabinowitz (2000) reviewed facts about NIHL. Noise-induced hearing loss is classified as a sensorineural hearing loss, which typically becomes evident at the frequencies between 3000 and 6000 Hz first. Hearing loss can then progress with continued exposure to harmful sound. Exposure to sound is harmful when the intensity and duration are loud and long enough to damage the inner ear. Noise-induced hearing loss is an evident health problem as it is the most common cause of sensorineural hearing loss second to hearing loss due to aging (presbycusis). Rabinowitz (2000) estimated that about 10 million Americans have NIHL. While it is known that noise exposure can cause NIHL, individual susceptibility to NIHL is variable (Rabinowitz, 2000).

Niskar et al. (2001) researched the amount of American children who show symptoms of NIHL. Audiometric testing was completed on 5,249 children ranging in age from 6 to 19 years. Results of the study lead to the estimation that approximately 5.2 million children have NIHL in at least one ear. Audiometric results indicated that 14.6% of the children had hearing loss at the typical noise notch of NIHL between 3000 and 6000 Hz in both ears. The population of boy participants that revealed NIHL (14.8%) was significantly greater than girls (10.1%). These results indicate that children in the United States are at risk for NIHL (Niskar et al., 2001).

Henderson, Subramaniam, and Boettcher (1993) reviewed the various factors that can contribute to individual susceptibility to NIHL. Some inherent traits have been linked to individual susceptibility to NIHL including eye color, gender, age, and smoking. Individuals with blue eye color have been associated with greater susceptibility to NIHL than individuals with other eye colors. Men have also been connected to increased susceptibility to NIHL compared to women. Children and elderly individuals have shown greater susceptibility to NIHL compared to adults. Also, individuals who smoke cigarettes have been associated with more susceptibility compared to non-smoking individuals. While individual susceptibility varies, it is clear that sound intensity levels greater than 85 dB(A) begin to cause trauma to the auditory system (Henderson et al., 1993).

Anatomy of the Inner Ear

Trauma to the auditory system from noise exposure occurs in the cochlea in the inner ear (Bekesy, 1948; LePage & Murray, 1998; Lim, 1980; Smith, Moody, Stebbins, & Norat, 1987). Hudspeth (1985) reviews the vital structures and function of the cochlea. The components in the cochlea that are of concern for individuals with NIHL are the outer hair cells (OHCs) in the Organ of Corti. The OHCs are sensory receptors that play an important role in processing sound with sensitivity to selective frequencies. The OHCs have projections that rise out from the superior surface, called steriocilia, which are embedded in the tectorial membrane (Hudspeth, 1985). The steriocilia contain actin filaments, which enable motility properties and mechanical stiffness important for normal hearing (Flock, 1980).

Lim (1980) investigated the steriocilia of the OHCs in the cochleas of animals in order to review its characteristics. Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM) revealed that steriocilia of the OHCs are securely attached to the tectorial membrane as opposed to the loose attachment between the inner hair cells (IHCs) and the tectorial membrane. The health of the OHC seriocilia are vital for hearing sensitivity because cochleas traumatized by noise have shown to loose their stiffness (Lim, 1980).

Smith, Moody, Stebbins, and Norat (1987) further investigated the effects of OHC damage on hearing sensitivity. Patas monkeys were injected with dihydrostreptomycin-sulfate (DHSM) to create OHC hearing loss. Loss of OHC function resulted in a loss of frequency selectivity and more than 50 dB loss in sensitivity. When the OHCs are damaged, the normal motion between the tectorial membrane and basilar membrane is disturbed. Damage to the OHCs results in irreversible hearing loss, which impairs speech understanding and localization abilities (Smith et al., 1987).

Personal Music Players

The investigation of personal music players and their influence on NIHL has been a topic of interest for many years (Carter, Waugh, Keen, Murray, & Bulteau, 1982; Catalano & Levin, 1985; Hughes et al., 1986). The technology of personal music players has advanced dramatically over the past 30 years, which keeps the topic thriving with new possibilities. Personal music devices increased in popularity in the 1980’s as stereo/cassette players, in the 1990's as Compact Disc (CD) players, and now in the 2000's as MP3 players.

Hughes et al. (1986) presented a review of the literature on leisure noise that has the potential to damage hearing. The most researched leisure noise was music. Individuals may be exposed to intense music at discotheques, concerts, and through the use of personal music players. The literature on amplified music indicate that sound levels can reach between 87 to 108 dB(A) at a discotheque and 101 to 105 dB(A) at a concert. Sound levels vary by individual preference when using a personal music player. When individuals aimed to listen to music through their personal music player as background noise the sound levels ranged between 60 to 83 dB(A) in the ear canal, and when the music was the main focus of attention the sound levels ranged between 66 to 102 dB(A) in the ear canal. Intense music from a personal music player has the potential to create NIHL (Hughes et al., 1986).

Carter, Waugh, Keen, Murray, and Bulteau (1982) sought to investigate whether exposure to intense music had caused hearing loss in young people ranging in age from 16 to 20 years. Participants (656 males and females) who had been exposed to noise through their occupation and/or recreation with normal otologic evaluations and no family history of hearing loss were given comprehensive audiologic evaluations. The results indicated that essentially the population of individuals 16 to 20 years of age had not incurred hearing loss due to loud music (Carter et al., 1982).

Catalano and Levin (1985) evaluated the risk of NIHL due to personal radio cassette players and headphones using a questionnaire and sound intensity testing of the three most popular brands of radio. The questionnaire was answered by 154 young college students ages 18 to 21 years. Over half of the participants (57.8%) were radio users. Based on the OSHA criteria for acceptable noise intensity and duration, 31.4% of radio users (41.2% of males and 29.2% of females) equaled to or surpassed the safe exposure criteria. These results indicated that personal radio cassette players used with headphones pose a risk for NIHL in young college adults (Catalano & Levin, 1985).

Bradley, Fortnum, and Coles (1987) investigated school children's hearing abilities and habits when listening to amplified music. A questionnaire about personal cassette players was completed by 1443 children ranging in age from 11 to 18 years. Sound levels were measured from personal cassette players of 11 randomly selected participants. Personal cassette players were owned by 37% of the participants. Of the participants who owned personal cassette players, 75% used them 1.4 hours per week, 50% used them 2.7 hours per week, and 25 % used them 4.4 hours per week. When the music was intended as background noise the mean equivalent free-field level was 65 dB(A) and as the listeners focus was 74 dB(A). These participants listening habits with personal cassette players did not pose a great risk for NIHL (Bradley et al., 1987).

Clark (1990) reviewed the literature on the risks of hearing loss due to listening to personal stereo systems. Wood and Lipscomb (1972) and Katz et al. (1982) reported maximum output levels through earphones from 110 to 128 dB(A). Kuras and Findlay (1974) reported the mean comfortable level chosen when listening to a song of individual choice through headphones averaged 88.1 dB(A). Rice, Breslin, and Roper (1987) reported that 25% of personal stereo system users listen at or above 90 dB(A) and 5% listen above 100 dB(A). Rice, Rossi, and Olina (1987) reported that 10% of personal stereo system users listened at or above 87 dB(A). The literature reported indicates that personal stereo systems can pose a risk to hearing health for some individuals (Clark, 1990).

Pugsley, Stuart, Kalinowski, and Armson (1993) investigated 30 normal hearing adults to assess hearing threshold changes after using a portable stereo system. Audiometric thresholds were obtained pre-experimental and post-experimental testing. Following a one-hour period of listening to continuous music at a comfortable listening level adjusted by each individual, none of the participants revealed decreased hearing sensitivity. Tinnitus was reported in 20% of the participants following the noise exposure. The results suggest that listening to one-hour of music at a comfortable level in a quiet room does not significantly reduce individuals hearing sensitivity (Pugsley et al., 1993).

Meyer-Bisch (1996) researched the hearing risk involved with exposure to amplified music by assessing 1364 subjects ranging in age from 13 to 45 years. A questionnaire was administered and audiometric thresholds were obtained. A personal music player was used at least two hours per week by 37.6% of males and 25.2% of females. Tinnitus and auditory fatigue were experienced in 35.2% of males and 32.1% of females who used their music player at least two hours per week. There was no audiometric difference between the participants who listened to music players compared to their control group except for participants who listened for greater than eight hours per week, who revealed about 2.6 dB threshold increase at 4000 and 6000 Hz. The risk for causing NIHL by listening to a personal music player appears to be reserved. According to this study individuals obtained the most hearing damage when attending a concert, followed by listening to personal music players, and the least hearing damage was acquired at discotheques (Meyer-Bisch, 1996).

Hellstrom, Axelsson, and Costa (1998) investigated whether exposure to loud music results in hearing threshold shifts in 21 normal hearing participants ranging in age from 13 to 30 years. The participants were first exposed to 105 dB SPL of 1/3 octave band pink noise with a 2000 Hz center frequency for ten minutes. Then 24 hours later, the subjects were exposed to music at a comfortably loud level. Pre-experimental and post-experimental audiologic thresholds were obtained for each noise exposure. All participants revealed a temporary threshold shift most pronounced at 2500 to 3000 Hz. The average level preferred by the individual when listening to music was 91.4 dB(A) for habitual personal music player listeners, 97.1 dB(A) for loud speaker listeners, and 91.9 dB(A) for infrequent music listeners. All participants reveal a temporary threshold shift most pronounced between 2000 and 5000 Hz following music exposure. The results indicate that there is a significant risk for acquiring NIHL from listening to personal music players (Hellstrom et al., 1998).

Fligor and Cox (2004) researched the output levels of six popular portable compact disc players and various headphones. The different style of headphones tested included vertical on headband, supra-aural on headband, supra-aural behind-the-headband, insert earphones, and circumaural. Output levels were measured using a Knowles Electronic Manikin for Acousitic Research (KEMAR). Maximum output levels ranged from 19 to 121 dB(A) free-field equivalent sound pressure levels. Output levels for the headphones varied between manufacturers and style; however, the smaller the headphone the higher the sound level. Based on NIOSH recommendations, an individual can safely listen to one hour of music through supra-aural headphones if the volume is set at high as 60% of the maximum output. When insert earphones are used the volume should be decreased for safer levels (Fligor & Cox, 2004).

Fligor (2007) reviewed various questions about hearing loss and MP3 players. The most common cause of hearing loss is both the process of aging and the cumulative effects of exposures to loud noise. The output sound level and duration of exposure are essential variables that influence the damaging effects of music. MP3 players have the potential to expose an individual to harmful levels and durations of noise. Safe level and time combinations have been evaluated. While a CD player could be listened to for 60 minutes at 60% of the maximum volume without posing a threat to hearing damage, it is suggested that when using an MP3 player and headphones a listener can have the volume set at 80% of the maximum volume for as long as 90 minutes. An estimate of about 5 to 15% of personal music player users listen to music at combinations of sound level and duration that could be harmful to their hearing (Fligor, 2007).

Hodgetts, Rieger, and Szarko (2007) researched how individuals preferred listening level on their personal music player might be influenced by environmental factors and headphone style. The participants included 38 normal hearing adults with an average age of 27.5 years. Each subject was put in nine different conditions of background noise and headphone style with instructions to adjust the sound level to where they thought it sounded “best”. In general, the participants chose higher sound levels when using the earbud headphone than with headphones that sit over the ear. The sound levels were the lowest when noise-reduction headphones were used. The participants chose higher sound levels with street background noise than multi-talker babble background noise; however, the levels were lowest in the quiet background noise condition. Overall, participants increased the sound level as background noise level increased and with smaller headphones (Hodgetts et al., 2007).

Peng and Huang (2007) investigated the effects of using personal music players on the hearing abilities of young adults. Participants included 120 college students ranging in age from 19-23 years. All participants indicated that they use a personal music player for at least one hour per day. Audiometric thresholds were obtained at the conventional frequencies of 500 to 8000 Hz as well as the extended high frequencies of 10,000 to 20,000 Hz. Results indicated that hearing thresholds at the frequencies of 3,000 to 8,000 Hz were higher in the participants who use personal music players compared to a control group. There was also a correlation between greater amount of exposure and a broader range of frequencies that were affected. The extended high frequencies indicated higher thresholds in participants with hearing loss compared to the control group, indicating that high frequency testing is an effective method for detecting hearing loss (Peng & Huang, 2007).

Weiner, Kreisman, and Fligor (2009) investigated whether a sound level is at a dangerous level if a bystander can hear the music from another person’s personal music player. The participants included 30 normal hearing adults who owned an MP3 player. The participants were instructed to adjust the volume of their MP3 player to the level they would like without looking at the device. An observer then made judgments whether the music was audible or not. The participants repeated the process in various background noise conditions, which included quiet, 45 dB(A), 60 dB(A), and 75 dB(A) of pink noise. Results indicated that as the listening level increased as the background level increased. Only 3% of participants chose listening levels above 85 dB(A) in the quiet condition, while 26% of participants chose listening levels above 85 dB(A) free-field equivalent in 75 dB(A) of pink noise in the background. However, as background noise increased, the audibility of the music to the observer decreased. In the quiet condition the music was audible to the observer even at safe levels of music. If a bystander can hear the music from another person's personal music device the level is not necessarily at a dangerous level. MP3 players are capable of presenting noise that is harmful to the auditory system, but the minority of participants took advantage of such high levels (Weiner et al., 2009).

Hearing Conservation

Hearing conservation programs are mandatory for individuals in danger of occupational noise exposure (NIOSH, 1998; OSHA, 1983). Both NIOSH and OSHA indicate that dangerous levels of noise are equal to or greater than 85 dB(A) on an eight-hour time weighted average. Both NIOSH and OSHA indicate permissible noise exposure levels for various amounts of time per day (see Table 1). Hearing conservation programs are also available for individuals who are at risk for NIHL due to recreational noise exposure (Danhauer et al., 2009; Ferrari & Chan, 1991; Folmer, Griest, & Martin, 2002; Lusk, 2002).

Ferrari and Chan (1991) researched how warning signs and peer modeling techniques influence the behavior of individuals to lower the volume of their personal music devices. This two-part study began by setting warning signs up to discourage loud sound levels for personal music devices. The second part of the study involved two people modeling behavior of appreciating the risk of NIHL and turning down the volume of personal music players. Out of 7,811 people observed in a college building elevator for the first part of the study, 567 people had personal music players. Out of 4,069 people observed in the same elevators for the second part of the test, 433 people had personal music players. During the first part of the study, 85% of people wearing headphones had their music playing loud enough that an observer could hear it. Then, when warning signs were posted about hearing loss and personal music players, the percent dropped to 59% of people wearing headphones had their music playing loud enough that an observer could hear it. However, the average increased to 76% when the posters were removed. During the second part of the study, 85% of people wearing headphones had their music playing loud enough that an observer could hear it. Then, when two people modeled behavior that promoted turning the volume down, the average reduced to 46% of people wearing headphones had their music playing loud enough that an observer could hear it. When the model was gone, the mean increased to 77%; however, when the model was re-introduced the mean reduced again to 42%. Overall, the results indicated that both warning signs and peer modeling techniques for promoting hearing conservation were effective during implementation, and the peer modeling technique was most effective (Ferrari & Chan, 1991).

Folmer, Griest, and Martin (2002) reviewed hearing conservation education programs specifically designed to benefit children. A review of the literature indicated that 29 organizations provide beneficial and appropriate hearing conservation materials for children. Important recommendations that children should be encouraged to follow in order to protect their hearing include turning the volume down when exposed to loud sound sources and use ear plugs when necessary. Children should also be educated on the mechanisms of the auditory system, various types of hearing loss and what causes them, the effects of loud noise on the auditory system, and specific warning signs of NIHL.

These lessons learned in hearing conservation programs are important to children because literature indicates that children's understanding of hearing loss and noise improve significantly following completion of a hearing conservation program (Folmer et al., 2002).

Lusk (2002) reviewed literature to help inform individuals about how to prevent NIHL. An effective way to help prevent hearing loss is to decrease the sound level of noise that an individual is exposed to as well as decrease the duration of exposure to loud noise. It is difficult to predict exactly how noise exposure will affect an individual because individual susceptibility to NIHL is variable. Indicators that an individual may be at risk for NIHL include experiencing tinnitus and/or temporary hearing loss. Hearing conservation programs are important to help prevent NIHL as about 5.2 million children and young adults have been suggested to have NIHL with evidence of the typical NIHL noise notch at 4000 or 6000 Hz (Lusk, 2002).

Chung, Des Roches, Meunier, & Eavey (2005) utilized a web-based survey to evaluate young adults understanding of NIHL. The survey was completed by 9693 participants who ranged in age from 13 to 65 years. Only 8% of the participants indicated that hearing loss is a "very big problem." According to the participants, other health issues were more important such as sexually transmitted diseases, drug and alcohol use, depression, smoking, nutrition and weight, and acne. The participants who had some sort of hearing loss education were more likely to indicate that hearing loss is a problem. A surprisingly large amount of the participants (61%) reported that they had experienced some hearing loss and tinnitus following a concert. These results suggest that more young adults could benefit from a hearing conservation program (Chung et al., 2005).

Danhauer et al. (2009) surveyed college students to gain insight on college students' habits with iPod use and understanding of hearing loss. A questionnaire was completed by 609 college students. Results indicated that the majority of the college students were informed on hearing health; however, most students did not understand what signs can warn an individual of hearing loss and how to effectively prevent hearing loss. The majority (2/3) of the students were iPod users who may be at risk for NIHL if they do not recognize the signs and how to prevent it (Danhauer et al., 2009).

Hypotheses

This study seeks to further research on young adults with normal hearing who listen to personal music players. A common assumption people make is that if the music from an individual's personal music player is so loud that a bystander can hear it then it is loud enough to damage ones hearing (Weiner, Kreisman, & Fligor, 2009). According to Weiner et al. (2009), the assumption did not hold true in various listening environments. The present study further evaluates the idea that songs played through a personal music player can be loud enough to damage ones hearing if able to be overheard in various listening environments with young adults with normal hearing.

Dangerously loud volume levels.

H_0: All songs will be audible at volume levels greater than or equal to 85 dB(A) FFE.

H_A: Not all songs will be audible at volume levels greater than or equal to 85 dB(A) FFE.

Song selection.

H_0: Audibility will be equal for all songs regardless of peak SPLs (in dB(A)).

H_A: Audibility will not be equal for all songs regardless of peak SPLs (in dB(A)).

Background noise.

H_0: Audibility will be equal for all background noise levels.

H_A: Audibility will not be equal for all background noise levels.

Volume level.

H_0: Audibility will be equal for all volume levels.

H_A: Audibility will not be equal for all volume levels.

Predictions

The peak sound pressure level of the song chosen, the level of background noise, and the volume level will affect the participants' audibility of the song being played through an iPod. Specifically, it is predicted that audibility will increase as the songs' peak SPL (in dB(A)) increases; as the background noise level decreases; and as the volume level increases. Also, increases in the songs' peak SPL (in dB(A)) and volume level will increase the likelihood that the sound level of the listener is potentially hazardous to their hearing health.

Table 1

Permissible Noise Exposure Levels

Duration per day (in hours)	OSHA (in dB(A))	NIOSH (in dB(A))
8	90	85
6	92	86
4	95	88
3	97	89
2	100	91
1 ½	102	92
1	105	94
½	110	97
¼ or less	115	100

Note: Adapted from OSHA Standards – 29 CFR and NIOSH Publication No. 98-126.

CHAPTER 3

METHODS AND MATERIALS

Participants

Fifty normal hearing adults participated in this study. All participants were required to have clear otoscopic results, Jerger type A tympanogram shapes, and pure tone air conduction thresholds less than or equal to 15 dB HL at 0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 6.0, and 8.0 kHz bilaterally. All participants signed an informed consent form prior to testing. The researchers recruited the participants via phone and email. All testing was conducted at the Center for Amplification, Rehabilitation, and Listening (CARL) lab at TU. All participants were given a $10.00 iTunes gift card following completion of the research study.

Materials

Music stimuli.

The music stimuli used for the experimental testing included five songs, which were chosen from the top five selling songs on iTunes on June 14, 2009. The five songs included “Boom Boom” by The Blackeyed Peas, “I Gotta Feeling” by The Blackeyed Peas, “Love Game” by Lady GaGa, “You Know You Want Me” by Pit Bull, and “Fire Burning” by Sean Kingston.

Background noise conditions.

The music stimuli were presented in four background noise conditions. The background noise conditions included quiet, 45 dB(A) of speech babble, 60 dB(A) of restaurant noise, and 75 dB(A) of airplane noise. The quiet noise condition was measured at approximately 31.6 dB(A) of ambient noise inside the sound treated booth. The background noises were chosen to create environments that a participant may encounter in the real world.

iPod volume levels.

The music stimuli were presented at nine different volume levels of the iPod. The volume levels were 0, 12.5, 25, 37.5, 50, 62.5, 75, 87.5, and 100%. The volume levels represented every two clicks of the iPod volume levels.

Pre-Testing Procedures

A ten-second clip was taken from the chorus of each of the five songs. The song clips were equalized to their overall root-mean-squared (RMS) values using Adobe Audition. The Adobe Audition software was used to create a 0.1 second clip of a 440Hz tone. The 440Hz tone was inserted at the beginning and end of each song clip to signal to the participant when the song clip started and ended. The songs clips were imported into the iTunes program on a Dell PC, and then input into a standard iPod Touch with standard iPod earphones. The peak SPLs (in dB(A)) of the song clips were measured at nine volume levels of the iPod in 12.5% intervals (see Table 2). The measurements were performed in a sound-treated booth. The standard iPod earphones were placed on the Knowles Electronic Manikin for Acousitic Research (KEMAR) in a chair in the center of a sound treated booth. A 4006-TL – DPA omnidirectional microphone was used to record the stimuli at 2’4” away from KEMAR at 0 degrees azimuth to simulate a bystander. The microphone was coupled to a DigiDesign Digi002 Rack, which routes the sound to Protools 7.3 software on the Macbook laptop.

The peak SPL (in dB(A)) was measured for the 10-second clip of each of the five songs at the nine volume levels in quiet (31.6 dB(A) of ambient noise). The peak output levels in dB(A) for each song clip were measured using a IVIE IE-35 Real Time Audio Analyzer/Sound Level Meter with a type 1 microphone. The A-Weighted free-field equivalent (FFE) was calculated for each song using the Audioscan Verifit. The probe microphone was calibrated and placed into the researcher's ear canal. The iPod earbud was then placed in the ear with the probe tube, and using the speech-live setting each of the five songs at the nine volume levels were recorded on an excel spreadsheet. The values recorded on the excel spreadsheet were input into an FFE formula to calculate the A-weighted FFE of each song at the nine different volume level settings. The 10-second song clips were then calibrated using the IVIE IE-35 Real Time Audio Analyzer/Sound Level Meter located in the center of the sound treated booth and the Protools 7.3 software on the Macbook.

The speech babble background noise was a 10-second clip copied from track 24 of the QuickSIN Speech-in-Noise version 1.3 CD (Etymotic Research Inc., 2006). The speech babble clip was then imported into the Protools 7.3 software on the Macbook. The restaurant background noise was a 10-second clip copied from a recording of a restaurant and imported into the Protools 7.3 software on the Macbook. The airplane background noise was a 10-second clip copied from a recording from the inside of an airplane and imported into the Protools 7.3 software on the Macbook. The background noise was presented using eight Rokit Powered 5 speakers located at 45, 90, 135, 180, 225, 270, and 315 degrees azimuth. The music was presented using the Rokit Powered 5 speaker located at 0 degrees azimuth. The speakers were calibrated for the background noise conditions and the music stimuli using the IVIE IE-35 Real Time Audio Analyzer/Sound Level Meter with a type 1 microphone placed in the center of the sound treated booth.

The 10-second song clips for each of the five songs at the nine different volume levels were convolved with the four different background noise conditions in the Protools 7.3 software on the Macbook, to create a total of 180 song clips.

Testing Procedures

A hearing screening was conducted on all participants prior to experimental testing to indicate that the participants had normal hearing. First, an otoscopic examination was performed bilaterally with a Welch-Allyn otoscope. Second, tympanometry was performed bilaterally using a Madsen Otoflex 100 immittance bridge that was calibrated according to the American National Standards Institute (ANSI) standards. Third, pure tone air conduction testing was performed bilaterally in a sound-treated booth using the GSI 61 clinical audiometer that was calibrated to ANSI standards. The air conduction testing was performed using a pulsed 15 dB HL pure tone stimuli presented through E-A-RTONE 3A insert earphones at 0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 6.0 and 8.0 kHz bilaterally. The participants were instructed to listen carefully for a “beep” sound and say “yes” if they heard it.

Following the completion of the hearing screening, participants began experimental testing. The participants were seated in the center of a sound treated booth with eight Rokit Powered 5 speakers surrounding them at 0, 45, 90, 135, 180, 225, 270, and 315 degrees azimuth. The order of presentation was randomized for all conditions and for all participants using the research randomizer website (Urbaniak & Plous, 2010). The music was presented via the Protools 7.3 software on the Macbook through the Rokit Powered 5 speaker located at 0 degrees azimuth. The background noises were presented via the Protools 7.3 software on the Macbook through the Rokit Powered 5 speakers located at 45, 90, 135, 180, 225, 270, and 315 degrees azimuth. Each participant was instructed to listen to the 10-second music segment. A beep indicator would play at the start and end of the music segment. The participant was told to say the word “yes” as soon as they were able to hear that a song was playing, and say the word “no” at the end of the song segment if they did not hear a song. The participant did not need to be able to identify what song was playing because audibility of a song was based on detecting that a song was playing. The participant was informed of the four different background noise conditions, and was presented the background noise conditions before testing in order to familiarize the participant with the different noises and volume levels. Both verbal and written instructions were provided. After presenting the instructions, the participant was asked if he/she had any questions to ensure that the instructions were understood.

CHAPTER 4

RESULTS

The five songs used for this research study were analyzed by their peak SPL in dB(A) measured at a distance of 2’4” from the source at the nine different volume settings (see Table 2). As the volume level increased, the peak SPL in dB(A) increased in all of the songs. At volume levels from 0 – 37.5% all songs were at or near the ambient noise level of 31.6 dB(A). At 50% volume level the song “Fire Burning” had the lowest peak SPL at 32.7 dB(A) and “Boom Boom” had the highest peak SPL at 38.1 dB(A). At 62.5% volume level the songs “I Gotta Feeling” and “I Know You Want Me” had the lowest peak SPL at 36.2 dB(A) and “Boom Boom” had the highest peak SPL at 38 dB(A). At 75% volume level the song “I Know You Want Me” had the lowest peak SPL at 41.6 dB(A) and “Boom Boom” had the highest peak SPL at 45.3 dB(A). At 87.5% volume level the song “I Know You Want Me” had the lowest peak SPL at 49.2 dB(A) and “Love Game” had the highest peak SPL at 52.6 dB(A). At 100% volume level the song “I Gotta Feeling” had the lowest peak SPL at 56.2 dB(A) and “Love Game” had the highest peak SPL at 59.2 dB(A).

The five songs used for this research study were also analyzed by their A-weighted free-field equivalent (FFE) at the nine different volume settings (see Table 3). The A-weighted FFE was calculated for each of the five songs at the nine different volume levels in order to indicate if a song was at a dangerously loud level according to OSHA and NIOSH safety standards (NIOSH, 1998; OSHA, 1983). The FFE in dB(A) reached dangerous noise levels of greater than or equal to 85 dB(A) according to NIOSH standards at the 87.5 and 100% volume levels in all of the songs. As the volume level increased, the FFE in dB(A) increased in all of the songs. At the 0% volume level the songs ranged from 35.9 dB(A) FFE for the song “I Gotta Feeling” and 36.8 dB(A) FFE for the song “Boom Boom”. At the 12.5% volume level the songs ranged from 42.7 dB(A) FFE for the song “Love Game” and 49.3 dB(A) FFE for the song “Boom Boom”. At the 25% volume level the songs ranged from 48.5 dB(A) FFE for the song “Love Game” and 55.7 dB(A) FFE for the song “Boom Boom”. At the 37.5% volume level the songs ranged from 55.5 dB(A) FFE for the song “Love Game” and 63.7 dB(A) FFE for the song “Boom Boom”. At the 50% volume level the songs range from 61.9 dB(A) FFE for the song “Love Game” and 70.2 dB(A) FFE for the song “Boom Boom”. At the 62.5% volume level the songs ranged from 70.0 dB(A) FFE for the song “Love Game” and 77.9 dB(A) FFE for the song “Boom Boom”. At the 75% volume level the songs ranged from 76.7 dB(A) FFE for the song “Love Game” and 84.3 dB(A) FFE for the song “Boom Boom”. At the 87.5% volume level the songs ranged from 84.7 dB(A) FFE for the song “Love Game” and 88.8 dB(A) FFE for the song “I Gotta Feeling”. At the 100% volume level the songs range from 91.6 dB(A) FFE for the song “Love Game” and 95.8 dB(A) FFE for the song “I Gotta Feeling”.

A spectral analysis was performed for the 45 dB(A) background noise, 60 dB(A) background noise, and 75 dB(A) background noise. The spectral analysis for the 45 dB(A) background noise of speech babble displays energy from 0 to 22000 Hz with the most energy in the low frequencies sloping as frequency increases (see Figure 1). The spectral analysis for the 60 dB(A) background noise of restaurant noise displays energy from 0 to 22000 Hz with the most energy in the low frequencies gradually sloping as frequency increases (see Figure 2). The spectral analysis for the 75 dB(A) background noise of airplane noise displays energy from 0 to 22000 Hz with the most energy in the low frequencies sloping until a precipitous decrease in energy at 12000 Hz (see Figure 3).

The participants included 20 males and 30 females ranging from 20 to 28 years of age (*M* = 23.5 years, *SD* = 1.67). All of the participants underwent the pre-testing procedures and the testing procedures. During testing the participants' audibility responses were recorded on a datasheet, and then transferred to an excel spreadsheet for analysis. A song was considered audible if at least 50% of the participants responded that the song was audible in each test condition. The participants' responses to the audibility of the songs at the different volume levels in the quiet background noise condition are displayed in Table 4. The song "Boom Boom" was audible from 37.5 to 100% volume levels in the quiet background noise condition. The song "Fire Burning" was audible from 25 to 100% volume levels in the quiet background noise condition. The song "I Gotta Feeling" was audible from 50 to 100% volume levels in the quiet background noise condition. The song "I Know You Want Me" was audible from 37.5 to 100% volume levels in the quiet background noise condition. The song "Love Game" was audible from 37.5 to 100% volume levels in the quiet background noise condition.

The participants' responses to the audibility of the songs at the different volume levels in the 45 dB(A) background noise condition are displayed in Table 5. The song "Boom Boom" was audible from 50 to 100% volume levels in the 45 dB(A) background noise condition. The song "Fire Burning" was audible from 25 to 100% volume levels in the 45 dB(A) background noise condition. The song "I Gotta Feeling" was audible from 50 to 100% volume levels in the 45 dB(A) background noise condition. The song "I Know You Want Me" was audible from 37.5 to 100% volume levels in the 45 dB(A) background noise condition. The song “Love Game” was audible from 37.5 to 100% volume levels in the 45 dB(A) background noise condition.

The participants’ responses to the audibility of the songs at the different volume levels in the 60 dB(A) background noise condition are displayed in Table 6. The song “Boom Boom” was audible from 62.5 to 100% volume levels in the 65 dB(A) background noise condition. The song “Fire Burning” was audible from 62.5 to 100% volume levels in the 60 dB(A) background noise condition. The song “I Gotta Feeling” was audible from 62.5 to 100% volume levels in the 60 dB(A) background noise condition. The song “I Know You Want Me” was audible from 62.5 to 100% volume levels in the 60 dB(A) background noise condition. The song “Love Game” was audible from 62.5 to 100% volume levels in the 60 dB(A) background noise condition.

The participants’ responses to the audibility of the songs at the different volume levels in the 75 dB(A) background noise condition are displayed in Table 7. The song “Boom Boom” was audible from 75 to 100% volume levels in the 75 dB(A) background noise condition. The song “Fire Burning” was audible from 62.5 to 100% volume levels in the 75 dB(A) background nose condition. The song “I Gotta Feeling” was audible from 75 to 100% volume levels in the 75 dB(A) background noise condition. The song “I Know You Want Me” was audible from 75 to 100% volume levels in the 75 dB(A) background noise condition. The song “Love Game” was audible from 75 to 100% volume levels in the 75 dB(A) background noise condition.

The participants’ responses to the audibility of the songs were analyzed according to sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) in the four different background noise conditions (see Table 8). The sensitivity for all background noise conditions range from 0.93 to 0.99, which indicates that songs across all volume levels were audible to the participants 93 to 99% of the time in which the song should have been audible. The specificity for all background noise conditions range from 0.88 to 0.99, which indicates that songs across all volume levels were inaudible to participants 88 to 99% of the time when the song should have been inaudible. The PPV for all background noise conditions range from 0.83 to 0.94, which indicates that 83 to 94% of participant responses that songs were audible were correct responses across all volume levels. The NPV for all background noise conditions range from 0.86 to 1.00, which indicates that 86 to 100% of participant responses that indicated songs were inaudible were correct responses across all volume levels.

The participants' responses to the audibility of the songs at a dangerously loud noise level (greater than or equal to 85 dB(A) FFE) were analyzed according to sensitivity, specificity, PPV, and NPV in the four background noise conditions (see Table 9). Figure 4 displays the sensitivity compared to the false positive rate for the four background noise conditions with a receiver operating characteristic (ROC) curve. The sensitivity and NPV were 1.00 in all background noise conditions. The sensitivities of 1.00 indicate that all songs at volume levels of greater than or equal to 85 dB(A) FFE were audible to the participant 100% of the time. The NPVs of 1.00 indicate that 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. As background noise increased, the specificity and PPV increased. The specificities range from 0.41 to 0.77, which indicates that songs were inaudible to participants 41% of the time when the song was at a volume level less than 85 dB(A) FFE in the quiet background noise condition, and increased to 77% of the time in which the song was less than 85 dB(A) FFE in the 75 dB(A) background noise condition. The PPV range from 0.33 to 0.56, which indicates that 33% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses in the quiet background noise condition, and increased to 56% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses in the 75 dB(A) background noise condition.

The participants' responses to the audibility of each song at a dangerously loud noise level (greater than or equal to 85 dB(A) FFE) were analyzed according to sensitivity, specificity, PPV, and NPV in the quiet background noise condition (see Table 10). The sensitivity and NPV were 1.00 for the songs "Boom Boom," "Fire Burning," "I Gotta Feeling," and "Love Game". The sensitivity and NPV was 0.99 for the song "I Know You Want Me". The sensitivity of 0.99 and 1.00 indicate that all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participants 99 to 100% of the time. The NPV of 0.99 and 1.00 indicate that 99 to 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificity ranged from 0.34 to 0.55, which indicates that songs were inaudible to participants 34 to 55% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPV range from 0.30 to 0.40, which indicates that 30 to 40% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses.

The participants' responses to the audibility of each song at a dangerously loud noise level (greater than or equal to 85 dB(A) FFE) were analyzed according to sensitivity, specificity, PPV, and NPV in the 45 dB(A) background noise condition (see

Table 11). The sensitivity and NPV were 1.00 for all songs. The sensitivity of 1.00 indicates that all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participant 100% of the time. The NPV of 1.00 indicates that 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificity range from 0.34 to 0.55, which indicates that songs were inaudible to participants 34 to 55% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPV range from 0.30 to 0.40, which indicates that 30 to 40% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses.

The participants' responses to the audibility of each song at a dangerously loud noise level (greater than or equal to 85 dB(A) FFE) were analyzed according to sensitivity, specificity, PPV, and NPV in the 60 dB(A) background noise condition (see Table 12). The sensitivity and NPV were 1.00 for all songs, except the song "I Know You Want Me" had a sensitivity of 0.99. The sensitivity of 0.99 and 1.00 indicate that all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participant 99 to 100% of the time. The NPV of 1.00 indicates that 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificity range from 0.60 to 0.67, which indicates that songs were inaudible to participants 60 to 67% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPV range from 0.42 to 0.48, which indicates that 42 to 48% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses.

The participants' responses to the audibility of each song at a dangerously loud noise level (greater than or equal to 85 dB(A) FFE) were analyzed according to sensitivity, specificity, PPV, and NPV in the 75 dB(A) background noise condition (see Table 13). The sensitivity and NPV were 1.00 for all songs, except the song "Love Game" had a sensitivity of 0.99. The sensitivity of 0.99 and 1.00 indicate that all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participant 99 to 100% of the time. The NPV of 1.00 indicates that 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificity range from 0.72 to 0.81, which indicates that songs were inaudible to participants 72 to 81% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPV range from 0.51 to 0.60, which indicates that 51 to 60% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses.

Table 2

Peak SPL (in dB(A)) of Music Stimuli at Nine iPod Volume Settings

iPod Volume Level (%)	"Boom Boom" by The Blackeyed Peas	"I Gotta Feeling" by The Blackeyed Peas	"Love Game" by Lady GaGa	"I Know You Want Me" by Pitbull	"Fire Burning" by Sean Kingston
0	31.6	31.6	31.6	31.6	31.6
12.5	31.6	31.7	31.7	31.8	32.0
25	31.6	31.9	31.7	32.0	31.7
37.5	31.7	32.7	31.9	32.8	32.0
50	38.1	35.0	33.2	33.0	32.7
62.5	38.0	36.2	37.9	36.2	36.6
75	45.3	42.1	44.2	41.6	42.6
87.5	51.8	49.9	52.6	49.2	49.6
100	58.7	56.2	59.2	56.5	56.3

Note: Peak SPL was recorded 2 feet four inches from the mannequin at 0 degrees azimuth.

Table 3

A-Weighted FFE of Long-Term Average Amplitude Levels of Music Stimuli at Nine iPod Volume Settings

iPod Volume Level (%)	"Boom Boom" by The Blackeyed Peas	"I Gotta Feeling" by The Blackeyed Peas	"Love Game" by Lady GaGa	"I Know You Want Me" by Pitbull	"Fire Burning" by Sean Kingston
0	36.8	35.9	36.0	36.7	36.1
12.5	49.3	45.3	42.7	43.8	44.4
25	55.7	51.8	48.5	50.0	50.8
37.5	63.4	59.1	55.5	57.3	57.8
50	70.2	65.5	61.9	63.9	64.8
62.5	77.9	73.5	70.0	72.1	72.8
75	84.3	80.8	76.7	78.6	79.8
87.5	88.3	88.8	84.7	86.6	87.8
100	94.5	95.8	91.6	93.4	93.9

Note: All numbers are expressed in dB(A). Peak pressure levels were measured in the principle investigator's ear with standard iPod earbuds using an Audioscan Verefit system.

Table 4

Number of Responses that the Songs were Audible at Nine Volume Levels in the Quiet Background Noise Condition

	Volume Level								
Song	0%	12.5%	25%	37.5%	50%	62.5%	75%	87.5%	100%
"Boom Boom"	1	2	5	44*	50*	50*	50*	50*	50*
"Fire Burning"	4	2	27*	48*	50*	50*	50*	50*	50*
"I Gotta Feeling"	1	2	2	2	50*	50*	50*	50*	50*
"I Know You Want Me"	1	1	21	50*	50*	50*	50*	50*	49*
"Love Game"	2	1	17	50*	50*	49*	50*	50*	50*
Total	9	8	72	194*	250*	249*	250*	250*	249*

Note: Audibility is labeled with a star symbol (*) if the song was audible for at least 50% of responses. There were 50 possible responses for each song at each volume level.

Table 5

Number of Responses that the Songs were Audible at Nine Volume Levels in the 45 dB(A) of Speech Babble Background Noise Condition

	Volume Level								
Song	0%	12.5%	25%	37.5%	50%	62.5%	75%	87.5%	100%
"Boom Boom"	2	1	0	16	48*	50*	50*	50*	50*
"Fire Burning"	0	14	44*	50*	50*	50*	50*	50*	50*
"I Gotta Feeling"	3	3	1	16	49*	50*	50*	50*	50*
"I Know You Want Me"	0	0	2	36*	50*	50*	50*	50*	50*
"Love Game"	0	2	3	31*	49*	49*	50*	50*	50*
Total	5	20	50	149*	246*	249*	250*	250*	250*

Note: Audibility is labeled with a star symbol (*) if the song was audible for at least 50% of responses. There were 50 possible responses for each song at each volume level.

Table 6

Number of Responses that the Songs were Audible at Nine Volume Levels in the 60 dB(A) of Restaurant Background Noise Condition

	Volume Level								
Song	0%	12.5%	25%	37.5%	50%	62.5%	75%	87.5%	100%
“Boom Boom”	1	2	3	6	11	41*	50*	50*	50*
“Fire Burning”	3	3	5	7	22	49*	50*	50*	50*
“I Gotta Feeling”	3	0	3	3	18	38*	50*	50*	50*
“I Know You Want Me”	2	2	4	4	21	45*	50*	50*	49*
“Love Game”	4	3	3	3	12	43*	50*	50*	50*
Total	13	10	18	23	84	216*	250*	250*	249*

Note: Audibility is labeled with a star symbol (*) if the song was audible for at least 50% of responses. There were 50 possible responses for each song at each volume level.

Table 7

Number of Responses that the Songs were Audible at Nine Volume Levels in the 75 dB(A) of Airplane Background Noise Condition

	Volume Level								
Song	0%	12.5%	25%	37.5%	50%	62.5%	75%	87.5%	100%
"Boom Boom"	0	1	1	0	4	23	47*	50*	50*
"Fire Burning"	0	1	0	2	2	43*	50*	50*	50*
"I Gotta Feeling"	0	1	3	0	2	11	49*	50*	50*
"I Know You Want Me"	1	0	1	1	1	21	50*	50*	50*
"Love Game"	3	1	3	0	0	24	50*	49*	50*
Total	4	4	8	3	9	122	246*	249*	250*

Note: Audibility is labeled with a star symbol (*) if the song was audible for at least 50% of responses. There were 50 possible responses for each song at each volume level.

Table 8

Sensitivity, Specificity, PPV, and NPV of Audibility in the Four Background Noise Conditions

Condition	Sensitivity	Specificity	PPV	NPV
Quiet	0.96	0.88	0.94	0.92
45 dB(A) speech babble	0.93	0.90	0.95	0.86
60 dB(A) restaurant noise	0.97	0.88	0.87	0.97
75 dB(A) airplane noise	0.99	0.90	0.83	1.00

Note: The quiet condition was 31.6 dB(A) of ambient noise.

Table 9

Sensitivity, Specificity, PPV, and NPV of Audibility at a Dangerously Loud Level (greater than or equal to 85 dB(A) FFE) in the Four Background Noise Conditions

Condition	Sensitivity	Specificity	PPV	NPV
Quiet	1.00	0.41	0.33	1.00
45 dB(A) speech babble	1.00	0.45	0.34	1.00
60 dB(A) restaurant noise	1.00	0.65	0.45	1.00
75 dB(A) airplane noise	1.00	0.77	0.56	1.00

Note: The quiet condition was 31.6 dB(A) of ambient noise.

Table 10

Sensitivity, Specificity, PPV, and NPV of Audibility at a Dangerously Loud Level in the Quiet Background Noise Condition for Five Songs

Song	Sensitivity	Specificity	PPV	NPV
"Boom Boom"	1.00	0.42	0.33	1.00
"Fire Burning"	1.00	0.34	0.30	1.00
"I Gotta Feeling"	1.00	0.55	0.40	1.00
"I Know You Want Me"	0.99	0.36	0.31	0.99
"Love Game"	1.00	0.37	0.31	1.00

Note: The quiet background noise condition is 31.6 dB(A) of ambient noise. A dangerously loud level was considered greater than or equal to 85 dB(A) FFE.

Table 11

Sensitivity, Specificity, PPV, and NPV of Audibility at a Dangerously Loud Level in the 45 dB(A) Speech Babble Background Noise Condition for Five Songs

Song	Sensitivity	Specificity	PPV	NPV
"Boom Boom"	1.00	0.52	0.37	1.00
"Fire Burning"	1.00	0.26	0.28	1.00
"I Gotta Feeling"	1.00	0.51	0.37	1.00
"I Know You Want Me"	1.00	0.46	0.35	1.00
"Love Game"	1.00	0.47	0.35	1.00

Note: A dangerously loud level was considered greater than or equal to 85 dB(A) FFE.

Table 12

Sensitivity, Specificity, PPV, and NPV of Audibility at a Dangerously Loud Level in the 60 dB(A) Restaurant Background Noise Condition for Five Songs

Song	Sensitivity	Specificity	PPV	NPV
“Boom Boom”	1.00	0.67	0.48	1.00
“Fire Burning”	1.00	0.60	0.42	1.00
“I Gotta Feeling”	1.00	0.67	0.47	1.00
“I Know You Want Me”	0.99	0.63	0.44	1.00
“Love Game”	1.00	0.66	0.46	1.00

Note: A dangerously loud level was considered greater than or equal to 85 dB(A) FFE.

Table 13

Sensitivity, Specificity, PPV, and NPV of Audibility at a Dangerously Loud Level in the 75 dB(A) Airplane Background Noise for Five Songs

Song	Sensitivity	Specificity	PPV	NPV
"Boom Boom"	1.00	0.78	0.57	1.00
"Fire Burning"	1.00	0.72	0.51	1.00
"I Gotta Feeling"	1.00	0.81	0.60	1.00
"I Know You Want Me"	1.00	0.79	0.57	1.00
"Love Game"	0.99	0.77	0.55	1.00

Note: A dangerously loud level was considered greater than or equal to 85 dB(A) FFE.

Figure 1

Spectral Analysis of Speech Babble Noise

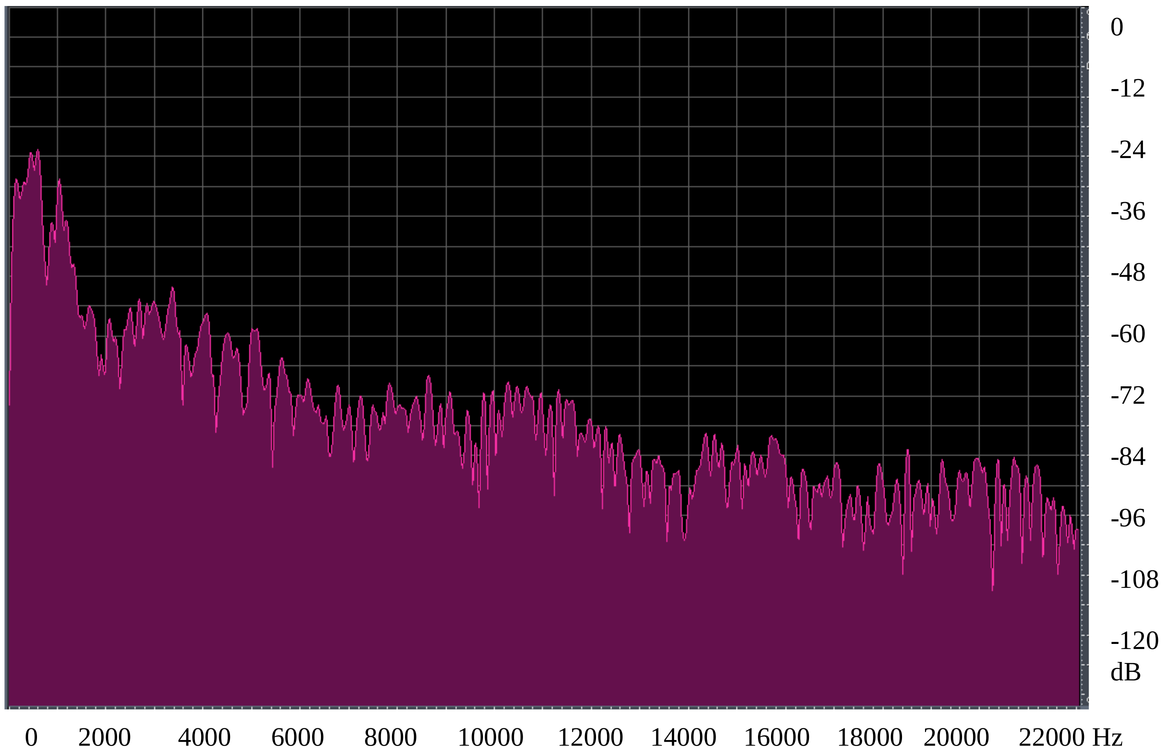


Figure 2

Spectral Analysis of Restaurant Noise

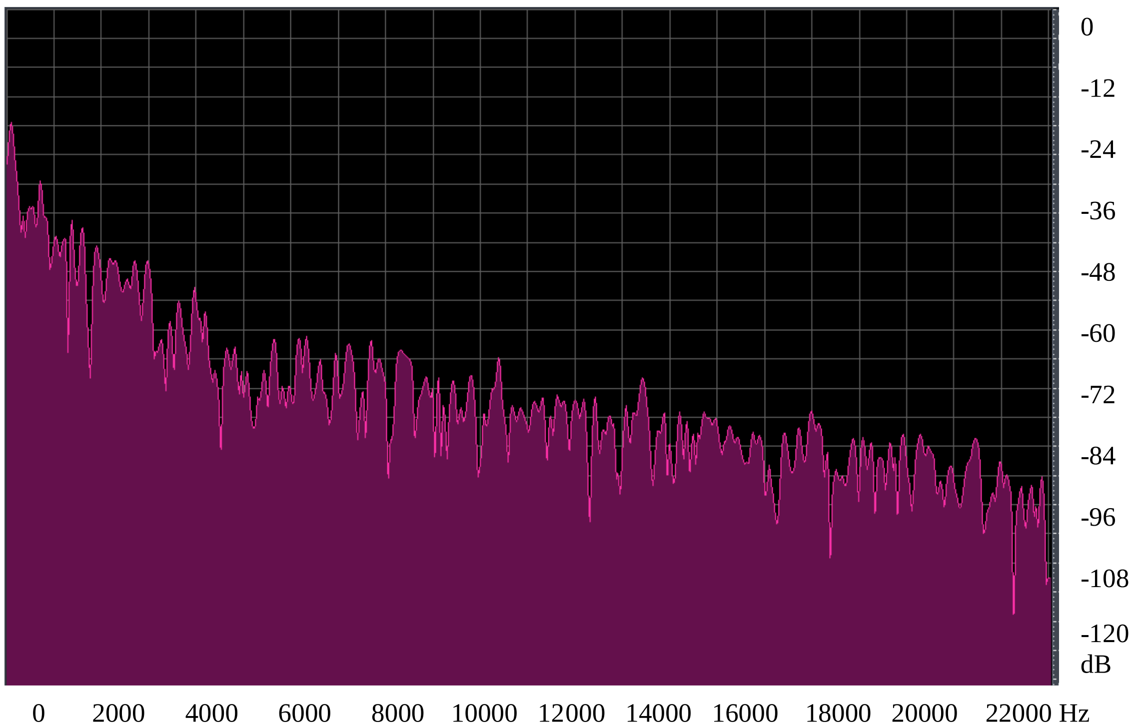


Figure 3

Spectral Analysis of Airplane Noise

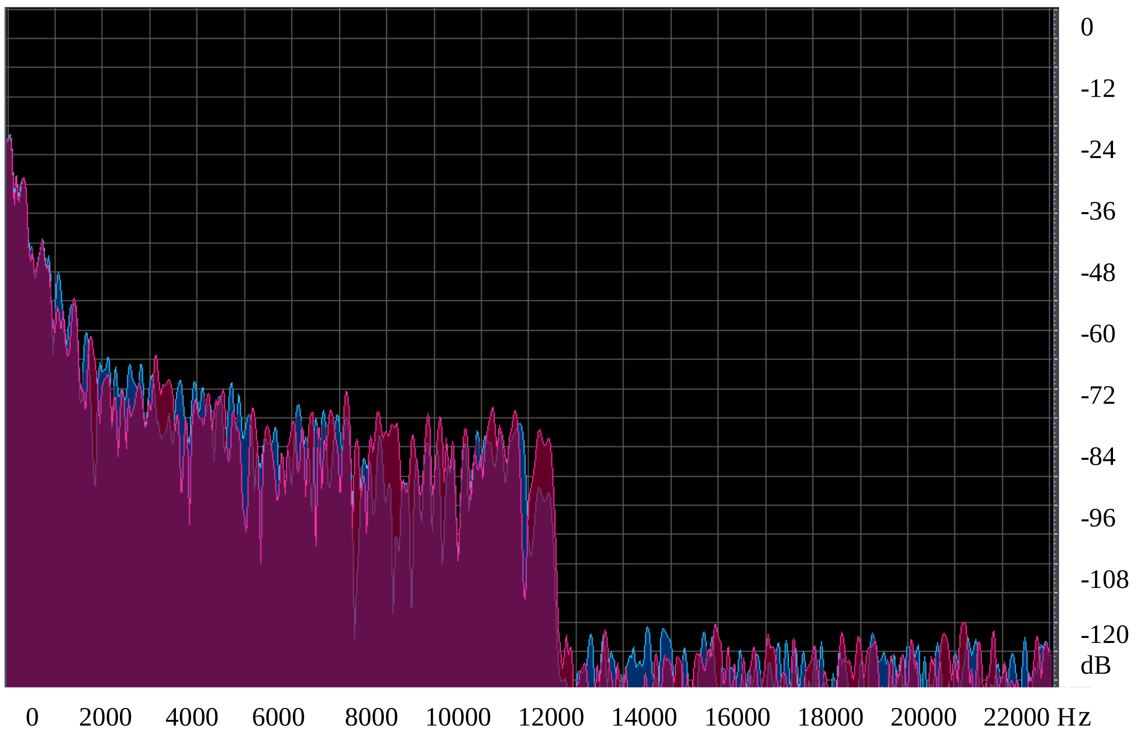
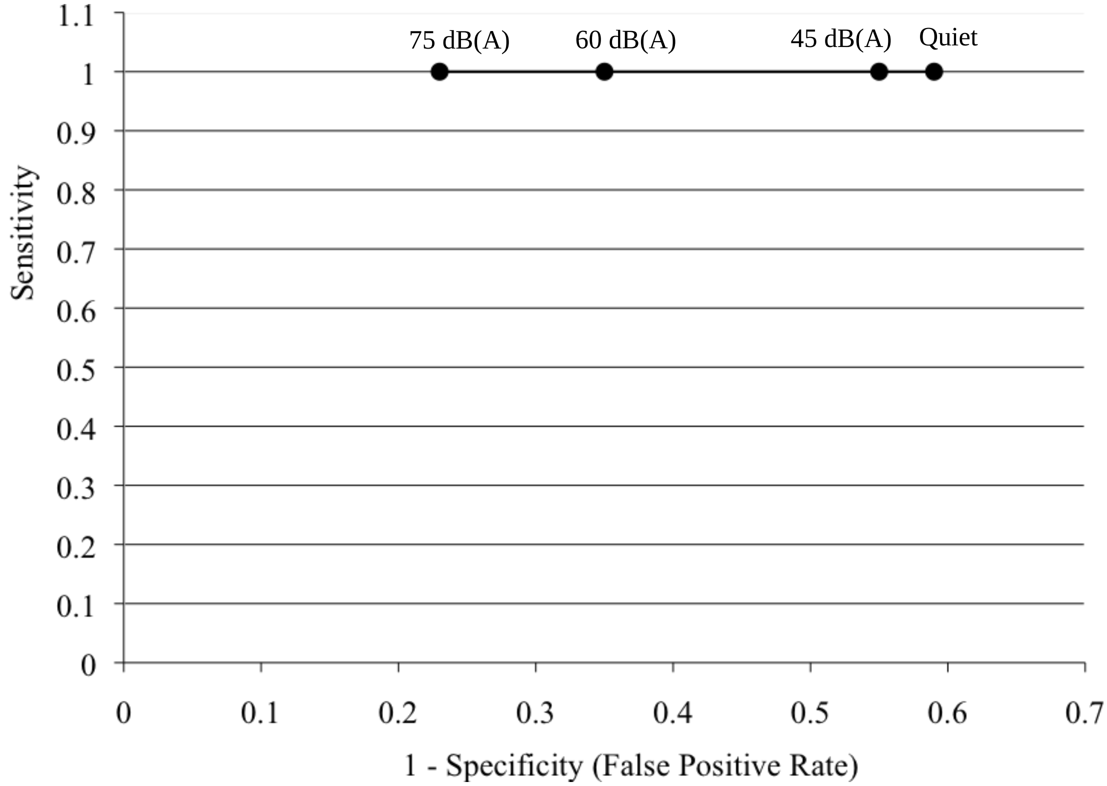


Figure 4

ROC Curve



CHAPTER 5

DISCUSSION

This research study investigated the effects of real world background noise, song selection, and volume level on the audibility of songs by bystanders. The real world background noises included quiet (31.6 dB(A) of ambient noise), 45 dB(A) of speech babble, 60 dB(A) of restaurant noise, and 75 dB(A) of airplane noise. The five songs included “Boom Boom” by The Blackeyed Peas, “I Gotta Feeling” by The Blackeyed Peas, “Love Game” by Lady GaGa, “You Know You Want Me” by Pit Bull, and “Fire Burning” by Sean Kingston. The volume levels on an iPod touch included 0, 12.5, 25, 37.5, 50, 62.5, 75, 87.5, and 100%. The purpose of the research study was to determine if audibility of a song by a bystander in the different background noise conditions indicated that the volume level was set at a dangerously loud level of greater than or equal to 85 dB(A) FFE. The FFE was calculated for the five songs at the nine volume levels recorded in the ear canal in order to compare the results to established damage-risk criteria. The A-weighted FFE measurements for all of the songs show that the 87.5 and 100% volume levels are the only volume levels that are considered dangerously loud. A song was considered dangerously loud at 85 dB(A) FFE according to OSHA and NIOSH safety standards that indicate noise is hazardous to hearing health and creates risk for NIHL at a level equal to or greater than 85 dB(A) on an eight-hour time weighted average.

Dangerously Loud Volume Levels

The null hypothesis that all songs will be audible at volume levels greater than or equal to 85 dB(A) FFE was accepted. All of the five songs were considered dangerously loud (greater than or equal to 85 dB(A) FFE) at 87.5 and 100% volume levels. All of the songs were audible at volume levels greater than or equal to 85 dB(A) FFE in all background noise conditions. The participants' audibility responses at dangerously loud volume levels resulted in a sensitivity and NPV of 1.00, which indicates that all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participant 100% of the time and 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificity and PPV of the audibility responses at dangerously loud volume levels increased as the background noise volume level increased. In the quiet background noise condition audibility of the songs at a dangerously loud level had a specificity of 0.41 and a PPV of 0.33, which indicates that songs were inaudible to participants 41% of the time when the song was at a volume level less than 85 dB(A) FFE and 33% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. In the 45 dB(A) background noise condition audibility of the songs at a dangerously loud level had a specificity of 0.45 and a PPV of 0.34, which indicates that songs were inaudible to participants 45% of the time when the song was at a volume level less than 85 dB(A) FFE and 34% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. In the 60 dB(A) background noise condition audibility of the songs at a dangerously loud level had a specificity of 0.65 and a PPV of 0.45, which indicates that songs were inaudible to participants 65% of the time when the song was at a volume level less than 85 dB(A) FFE and 45% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. In the 75 dB(A) background noise condition audibility of the songs at a dangerously loud level had a specificity of 0.77 and a PPV of 0.56, which indicates that songs were inaudible to participants 77% of the time when the song was at a volume level less than 85 dB(A) FFE and 56% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. Results indicate that audibility of a song coming from another person’s iPod is not a good indicator that the volume level of the song is at a dangerously loud level of greater than or equal to 85 dB(A) FFE. As the volume level of background noise increases, it is more likely that audibility of a song coming from another person’s iPod is at a dangerously loud level compared to quieter levels of background noise.

Analysis of the audibility responses at dangerously loud volume levels for the five songs individually resulted in similar sensitivity, specificity, PPV, and NPV values compared to the results of the audibility responses at dangerously loud volume levels for all of the songs combined. In the quiet background noise condition, sensitivities and NPVs indicate that all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participant 99 to 100% of the time and 99 to 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) were correct responses. The specificities indicate that songs were inaudible to participants 34 to 55% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPVs indicate that 30 to 40% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. The specificities and PPVs for the songs from lowest to highest were “Fire Burning,” “I Know You Want Me,” “Love Game,” “Boom Boom,” and “I Gotta Feeling” in the quiet background noise condition.

In the 45 dB(A) background noise condition, sensitivities and NPVs indicate all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participants 100% of the time and 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificities indicate that songs were inaudible to participants 26 to 52% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPVs indicate that 28 to 37% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. The specificities and PPVs for the songs from lowest to highest were "Fire Burning," "I Know You Want Me," "Love Game," "I Gotta Feeling," and "Boom Boom" in the 45 dB(A) background noise condition.

In the 60 dB(A) background noise condition, sensitivities and NPVs indicate all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participants 99 to 100% of the time and 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificities indicate that songs were inaudible to participants 60 to 67% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPVs indicate that 42 to 48% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. The specificities and PPVs for the songs from lowest to highest were "Fire Burning," "I Know You Want Me," "Love Game," "I Gotta Feeling," and "Boom Boom" in the 60 dB(A) background noise condition.

In the 75 dB(A) background noise condition, sensitivities and NPVs indicate all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to the participants 99 to 100% of the time and 100% of participant responses that songs were inaudible at volume levels less than 85 dB(A) FFE were correct responses. The specificities indicate that songs were inaudible to participants 72 to 81% of the time when the song was at a volume level less than 85 dB(A) FFE. The PPVs indicate that 51 to 60% of participant responses that songs were audible at volume levels greater than or equal to 85 dB(A) FFE were correct responses. The specificities and PPVs for the songs from lowest to highest were “Fire Burning,” “Love Game,” “Boom Boom,” “I Know You Want Me,” and “I Gotta Feeling” in the 75 dB(A) background noise condition.

Weiner, Kreisman, and Fligor (2009) conducted a similar research study, which assessed audibility of an iPod as a bystander in quiet, 45, 60, and 75 dB(A) of pink background noise. Similar results indicate that the specificity and PPV for audibility of a song being played in a bystander’s iPod at a volume level greater than or equal to 85 dB(A) FFE increases as background noise level increases. Specificity increased from 0.09 to 0.55 as the background noise increased. Positive predictive value increased from 0.09 to 0.42. Results that differed from the present research study are that sensitivity decreases at background noise level increases. The differing results may be due to the different background noise used. The sensitivity decreased from 1.00 to 0.67 as background noise increased from quiet to 75 dB(A) of pink noise.

Overall, results from the present study show that all songs were considered audible 100% of the time when the volume level was greater than or equal to 85 dB(A) FFE. The criterion for a song to be audible was if at least 50% of participants responded that the song was audible. Weiner, Kreisman, and Fligor (2009) found slightly different results compared to the present study. Songs from an iPod were audible to a bystander 75% of the time when the volume level was 87 dB(A) and 50% of the time when the volume level was 73.5 dB(A) with 75 dB(A) of pink background noise. There was no correlation between audibility of a song by the bystander and an iPod volume level greater than or equal to 85 dB(A) FFE in quiet background noise; however, there was a correlation between audibility of a song by the bystander and an iPod volume level greater than or equal to 85 dB(A) FFE in 45, 60, and 75 dB(A) of pink background noise. These results suggest that audibility of someone else's iPod may indicate that the iPod volume level is safe or dangerous. Similarly, the present study indicates that both volume levels at a safe and dangerously loud level were audible to a bystander in quiet, 45, 60, and 75 dB(A) of background noise. Results of both the previous research study and this research study indicate that overhearing another person's iPod is not a good indicator that the volume level of the iPod is at a dangerously loud level.

Song Selection

The null hypothesis that audibility would be equal for all songs regardless of peak SPLs (in dB(A) FFE) was rejected and the alternate hypothesis that audibility would not be equal for all songs regardless of peak SPLs (in dB(A) FFE) was accepted. Participants' audibility responses varied among the five songs at the nine different volume levels in the four different background noise conditions. The participants' audibility responses indicated sensitivity, specificity, PPV, and NPV ranging from 0.83 to 1.0. The minimum audible volume levels for the songs in the four different background noise conditions do not correlate with the highest peak SPL. The results of the audibility of the songs based on the peak SPL were not expected. It was predicted that as peak SPL increased, audibility of the song would increase. Therefore, the songs with the highest peak SPL would be heard at quieter volume levels. However, results of this research study indicate that a song with a high peak SPL was not more audible at a quiet volume level compared to another song with a lower peak SPL.

Background Noise

The null hypothesis that audibility would be equal for all background noise levels was rejected and the alternate hypothesis that audibility would not be equal for all background noise levels was accepted. As the background noise volume level increased, the audibility of the songs decreased. In the quiet background noise condition a total of 1,467 true positive responses indicated that the songs were audible. In the 45 dB(A) background noise condition a total of 1,406 true positive indicated that the songs were audible. In the 60 dB(A) background noise condition a total of 965 true positive responses indicated that the songs were audible. In the 75 dB(A) background noise condition a total of 788 true positive responses indicated that the songs were audible. A decrease in audibility as background noise increased was expected because the louder background noise would overpower some of the songs at lower volume levels. It was predicted that audibility would increase as background noise level decreased. Weiner, Kreisman, and Fligor (2009) found similar results of audibility of iPod songs in quiet, 45, 60, and 75 dB(A) of pink background noise. As background noise level increased, the audibility of the song to an observer decreased.

Volume Level

The null hypothesis that audibility would be equal for all volume levels was rejected and the alternate hypothesis that audibility would not be equal for all volume levels was accepted. As volume level of the song increased, the audibility of the songs increased. In the quiet background noise condition the song “Fire Burning” was audible from 25 to 100% volume levels, “Boom Boom,” “I Know You Want Me,” and “Love Game” were audible from 37.5 to 100% volume levels, and “I Gotta Feeling” was audible from 50 to 100% volume levels. In the 45 dB(A) background noise condition the song "Fire Burning" was audible from 25 to 100% volume levels, "I Know You Want Me" and "Love Game" were audible from 37.5 to 100% volume levels, and "Boom Boom" and "I Gotta Feeling" were audible from 50 to 100% volume levels. In the 60 dB(A) background noise condition all of the songs were audible from 62.5 to 100% volume levels. In the 75 dB(A) background noise condition the song "Fire Burning" was audible from 62.5 to 100% volume levels and "Boom Boom," "I Gotta Feeling," "I Know You Want Me," and "Love Game" were audible from 75 to 100% volume levels. The audibility responses to the songs increased as the volume level increased. The increase in audibility as volume level increased was expected. It was predicted that audibility would increase as volume level increased. Weiner, Kreisman, and Fligor (2009) found that an observer's audibility of another person's iPod increased as volume level increased.

Limitations

This research study was not without limitations. It is important to note that the participants were asked to listen for a song as if they were bystanders overhearing someone else's iPod. The participants may have been indicating that some very quiet songs were audible; however, in a real world situation a bystander may not be particularly listening to see if another person's iPod song could be overheard and not notice a quiet song playing. Therefore, attention is a factor to consider when generalizing results to real world situations. It can be assumed that most people do not notice someone else's iPod unless the song is loud enough that it catches their attention. Participant attention during testing should also be considered. It took about one hour to test each participant, and participants may have lost attention to the task at some points during experimental testing. It is also important to note that the age range of the participants very small. This research study focused only young adults ranging from 20 to 28 years of age. The group of participants also included more females than males. Another limitation to this research study is that the songs used did not represent a variety of music genres. Furthermore, the research study did not explore the effects of using other MP3 players or headphone styles besides the iPod touch and standard iPod earphones.

Future Research

The limitations noted for this study as well as limited comparable research available indicate some areas for future research. Further research on this topic may be conducted on male and female participants of other age groups (younger or older) to see if age music affects audibility of a bystander's personal music player. Multiple genres of music may be used for the music stimuli to see if the genre of music affects audibility of a bystander's personal music player. Different types of headphone styles, including in the ear and over the ear styles, should be researched to see if headphone style affects audibility of a bystander's personal music player. Different types of MP3 players should be researched to see if the type of MP3 player affects audibility of a bystander's personal music player. Further researcher may also include songs that are longer than a 10 second clip to see if listening to the song clips longer affects audibility of a bystander's personal music player. For more precise volume level information, further research may also include all of the volume levels available in the MP3 player. Investigating the audibility of songs in more intense levels of different types of real world background noise may provide additional information compared to the results of the present study. Real world background noises that are louder than 75 dB(A) may include lawn mower noise, construction site noise, or factory noise.

Conclusion

This research study investigated the effects of real world background noise, song selection, and volume level on audibility of a song as a bystander 2'4" away from someone listening to an iPod touch with standard iPod earbuds. Results of this research study revealed that audibility was not always an indicator that the song was at a dangerously loud volume level. The peak SPL of the song did not have an effect on audibility. Results also indicate that as background noise increases, audibility decreases. Results indicate that as volume level increases, audibility increases. Participants were able to hear music at volume levels less than 85 dB(A) FFE in quiet, 45 dB(A) of speech babble, 60 dB(A) of restaurant noise, and 75 dB(A) of airplane background noise. Therefore, if a bystander 2'4" away from an individual listening to an iPod with standard iPod earbuds overhears the iPod song, it does not necessarily indicate that the volume level is loud enough to damage a listeners hearing.

Research on the damaging capabilities of personal music players on listeners' ears is important because the effects can be severe and are preventable. The damaging effects of noise on ears include sensorineural hearing loss, tinnitus, recruitment, hypersensitivity to sound, and distortion (Niskar et al., 2007; Rabinowitz, 2000). Noise-induced hearing loss is the most common cause of sensorineural hearing loss second to hearing loss due to aging (Rabinowitz, 2000). Information about the damaging effect of music on listeners' ears and how to prevent these effects can be effectively presented through hearing conservation programs (Niskar et al., 2007). Particular interest in the investigation of iPods in this study is warranted because MP3 players have the potential to expose listeners' to dangerous volume levels of noise and about 5 to 15% of people are suggested to be listening to MP3 players at dangerously loud volume levels (Fligor, 2007).

The general assumption seems to be that overhearing someone else's personal music player indicates that the volume level is at a dangerously loud volume level. Ferrari and Chan (1991) used observers' audibility of another person's personal music player as criteria for indicating a person was listening at a dangerously loud volume level. The results of this research study do not support the suggestion that overhearing someone else's personal music player indicates that the volume level is at a dangerously loud volume level. Further research is needed on the ear health hazards of listening to personal music players to help audiologists provide accurate information for patients and participants in hearing conservation programs about the effects and prevention of NIHL.

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CURRICULUM VITA

NAME: Melina Ecos

PERMANENT ADDRESS: 14066 Saddle River Drive
North Potomac, MD 20878

PROGRAM OF STUDY: Audiology

DEGREE AND DATE TO BE CONFERRED: Doctor of Audiology, 2012

Secondary education: Thomas S. Wootton High School,
Rockville Maryland, 2004

Collegiate institutions attended	Dates	Degree	Date of Degree
Towson University	2004-2008	B.S.	May 2008

Major: Speech-Language Pathology, Audiology, and Deaf Studies

Towson University	2008-Present	Au.D.	May 2012 (expected)

Major: Doctor of Audiology

Professional Presentations:

Ecos, M., & Kreisman, B. (2008, April). Spatial Resolution: Effects of Stimuli Angles on CRM Scores. Poster session presented at the meeting of The American Academy of Audiology, Charlotte, NC.

Clinical Internships:

Johns Hopkins Bayview Medical Center	4940 Eastern Avenue Baltimore, Maryland 21224
The Lincoln Intermediate Unit 12	65 Billerbeck Street New Oxford, PA 17350
ENTAA Care	203 Hospital Drive #200 Glen Burnie, MD 21061

Clinical Externships:

Greater Baltimore Medical Center	205 Broad Street 4th Floor Philadelphia, PA 19107