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

By

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THESIS APPROVAL PAGE

This is to certify that the thesis prepared by Kate Longenbach entitled "Effects of Pink 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.

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ABSTRACT

The Effects of Pink Background Noise, Song Selection, and iPod Volume Levels on the Audibility of Songs to Bystanders

Kate Longenbach

Recently, media attention has been focused toward the effects of personal mp3 players and their potentially damaging effects on hearing when listening at high levels. The current study aimed to determine whether the ability to overhear someone else's iPod from a distance away was indicative of dangerous listening levels, or levels greater than or equal to 85 dB(A).

An iPod Touch with standard earbuds was placed on a KEMAR mannequin in a sound treated test suite. The output from the iPod was recorded and measured from 2 feet four inches away to simulate a passer-by. Stimuli included five popular songs at nine volume settings on the iPod ranging between 0 and 100 percent volume. Recordings were mixed with four background noise conditions: quiet (31.6 dB(A) ambient noise, 45 dB(A), 60 dB(A), and 75 dB(A) of pink noise and played through an eight speaker array. Fifty participants (mean age of 23 years) with normal hearing were recruited to participate in the study. They were seated in the center of the sound treated booth and instructed to say "yes" when they were able to hear the music stimuli over the background noise.

The results suggested that when listening in a quiet setting, participants were likely to overhear someone else's iPod; however, the probability that the song had a long-term average output level than or equal to 85 dB(A) FFE was low. As background noise levels increase, the ability to overhear iPods decreases. Positive predictive value increased for the louder background noise conditions indicating that if a person is able to overhear someone else's iPod in noisy listening setting, it is more likely that the person is listening at a level greater than or equal to 85 dB(A). In the loudest background noise condition of 75 dB(A), the background noise completely masked all of the songs rendering them inaudible to the listeners, even songs with peak outputs greater than or equal to 85 dB(A). This study concluded that the ability to overhear someone else's iPod does not necessarily indicate they are listening at a dangerous volume level, and not overhearing someone's iPod does not necessarily indicate they are listening at a safe volume level.

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CHAPTER 1

INTRODUCTION

Hearing loss is the third most common medical condition present in older Americans (Yueh, Shapiro, MacLean, & Shakelle, 2003). Approximately 36 million Americans experience some degree of hearing loss according to National Institute on Deafness and Other Communication Disorders (NIDCD) estimates. While in many instances the cause of hearing loss cannot be prevented, a large percentage of Americans suffer from noise induced hearing loss (NIHL), a type of hearing loss that is nearly 100 percent avoidable (NIDCD, 2009).

According to the NIDCD, fifteen percent of Americans ages 20-69 have a hearing loss due to noise exposure (NIDCD, 2009). Noise may be one of the most prevalent occupational hazards and as many as 30 million Americans are exposed to dangerously loud levels of noise in the workplace (Rabinowitz, 2000). Aside from noise exposure in the workplace, many individuals also partake in noisy recreational and leisure activities that can cause potential damage to their hearing. Such activities include the use of power tools, recreational vehicles, and listening to amplified music (Rabinowitz, 2000).

While there are numerous sources of recreational noise, recent media attention has been focused toward the effects of personal listening devices. While such devices have been around for many years, their popularity have recently increased with the release of Apple's iPod in 2001 (Apple, 2007) and other MP3 devices. With the growing availability of iPods, pocket MP3 players, and MP3 integrated devices such as cell phones, Americans may be running a higher risk of potentially exposing themselves to harmful doses of noise on a daily basis.

CHAPTER 2

LITERATURE REVIEW

The Auditory System

The outer ear. The peripheral auditory system is located within the temporal bone of the skull (Gelfand, 2007). It is made up of three parts: the outer ear, middle ear, and inner ear (Gelfand, 2007). The outer ear is made up of the pinna or auricle, and the external auditory meatus (Alvord & Farmer, 1997). The pinna functions to funnel sound vibrations into the external auditory meatus toward the tympanic membrane and enhances the ability to localize sounds (Gelfand, 2007). The external auditory meatus is lined with skin and with the outermost two thirds being cartilaginous and the inner one third bone. It is approximately 2.3 centimeters in length and functions as a resonator, enhancing frequencies of 2000-5000 Hz by approximately 15 decibels (Alvord & Farmer, 1997; Gelfand, 2007).

The middle ear. The middle ear in an air filled cavity located between the tympanic membrane and the inner ear (Alvord & Farmer, 1997). The middle ear system consists of three small bones: the incus, which is embedded within the medial side of the tympanic membrane, the malleus, and the stapes which is fixated at the oval window (Gelfand, 1997). These bones are known as the ossicular chain. When sound is funneled though the external auditory meatus and strikes the tympanic membrane, the ossicular chain is set into motion. The chain functions as an impedance-matching mechanism, and it is the movement of the stapes footplate in the oval window which allows for the transmission of energy into the inner ear (Gelfand, 2007).

The inner ear. The inner ear is located in the petrous portion of the temporal bone which houses the cochlea as well as the balance organs (Gelfand, 2007). When the stapes footplate vibrates in the oval window, it sets up a traveling wave within the three fluid layers of the cochlea (Hudspeth, 1985). When the stapes moves and disturbs the inner ear fluid, one of the separating partitions, the basilar membrane, begins to move. It develops a traveling wave in a region that is dependent on the frequency of the stimulus. Low frequency sounds are stimulated near the apex of the cochlea, while high frequencies are stimulated near the base. The organ of Corti rests on the basilar membrane and contains approximately 16,000 hair cells. As the basilar membrane moves up and down with stimulation, so does the hair cells of the organ of Corti. The outer hair cells are embedded in the tectorial membrane, a shelf which runs along the organ of Corti. As the hair cells begin to move, a shear develops between the top surface of the outer hair cells and the lower surface of the tectorial membrane which causes the hair cells to bend (Hudspeth, 1985).

Displacement of the stereocilia causes a force on the linkages that connect each cell (Hudspeth, 1985). At the tip of each hair cell lie transduction channels and each channel has a gate that regulates the flow of ions into the cell. When the cell is in its resting state, each gate swings back and forth between its open and closed states. When a stimulus pushes the tips of the hair cells toward the kinocilium, or the tallest stereocilia, the linkages become stretched, the gates open and the cell becomes depolarized (Hudspeth, 1985). This causes a release of a neurotransmitter from the hair cell to the associated auditory neurons (Gelfand, 2007).

Noise- Induced Hearing Loss (NIHL)

Hearing loss caused by exposure to loud recreational or occupational noise is one of the most preventable causes of hearing loss (Rabinowitz, 2000). Noise-induced hearing loss (NIHL) is the second most common type of hearing loss following presbycusis. Noise induced hearing loss begins in the higher frequencies (between 3000-6000 Hz) and develops over time as a result of chronic noise exposure. By avoiding excessive noise exposure and through the use of hearing protective devices such as earplugs or muffs, such a hearing loss can be prevented. Another noise-related cause of hearing loss is acoustic trauma, which results from a brief exposure to a loud impulse noise (Rabinowitz, 2000).

Noise is described in terms of frequency or intensity, and the potential for hearing damage can be determined by the intensity and duration of a sound (Rabinowitz, 2000). Sound is measured in sound pressure level (SPL) in a logarithmic decibel (dB) scale. When referring to noise, the dB(A) scale is often used as it is weighted in the higher frequencies, those which are better perceived by the human ear. According to OSHA, noise can cause hearing damage at chronic exposures equal to an average SPL of 85 dB(A) or higher for an eight hour time period (Occupational Safety and Health Administration, 2010). In increase of SPL by 3 dB equals a doubling of intensity. Consequently, four hours of noise exposure at 88 dB(A) is equal to eight hours of exposure at 85 dB(A) (OSHA, 2010).

In order for a sound to be perceived, it must exert a shearing force of the stereocilia of the hair cells that line the basilar membrane in the cochlea (Rabinowitz, 2000). If in excess, it can cause damage to the cells or even cell death. Noise induced hearing loss is the results of extreme wear on these tiny structures of the inner ear (Rabinowitz, 2000).

An analysis by Niskar & colleagues (2001) aimed to estimate the prevalence of noise induced threshold shifts (NITS) among school-aged children through the use of data from the Third National Health and Nutrition Examination Survey (NHANES III). The survey was conducted from 1988-1994 and data were collected through household interviews followed by physical examinations. Audiometry and tympanometry were performed on 6-19 year olds. Noise-induced threshold shift (NITS) was identified with the following criteria for at least one ear: 1) Thresholds at .5 and 1 kHz were at 15 dB better; 2) the poorer threshold value at 3, 4, or 6 kHz was at least 15 dB poorer than at .5 or 1 kHz; 3) the threshold value at 8 kHz is at least 10 dB better than the poorest threshold at 3, 4, or 6 kHz (consistent with a noise-notch audiometric pattern).

Findings showed children age 12-19 years had a higher prevalence of NITS compared to children age 6-11 years. Among those with NITS, 14.6 percent had a noise notch in both ears. Fortunately, for the majority of children, only one frequency and one ear was affected by threshold shift (Niskar et al., 2001).

Recreational Noise Exposure

Two groups of rock-and-roll musicians were studied in order to determine whether or not exposure to exceedingly high levels of music during typical concerts produced a temporary threshold shift (TTS) in the musicians (Jerger & Jerger, 1970). Group A was made up of five adult males ages 17-23 and group B consisted of four younger adult males ages 14-15. Hearing thresholds were tested just prior to the concert and again within an hour of the concert's end. Findings indicated that in group A, four of the five participants sustained a TTS in the frequency region of 2-8 kHz. In group B (younger adult males), every member showed a TTS although the shifts were not as large as seen in group A (Jerger & Jerger, 1970).

Another study by Carter and colleagues (1982) investigated the correlation between the amount young people's recreational or occupational noise exposure and degree of noise induced hearing loss in those individuals. Participants included 944 young people aged 16-24 years. The participants were selected in three groups: students from the University of Sydney with recreational noise exposure only; office workers in the Commonwealth Public Service with no occupational noise exposure, but who were able to afford noisy recreations; and Stage I and Stage III trades apprentices who were exposed to both recreational and occupational noise. Subjects were interviewed and given an ear, nose and throat examination including audiometric testing. The interview consisted of questions regarding medical history, recreational activities, attendance of rock music events, and employment history. Study results provided limited evidence supporting noise induced hearing loss in young individuals as a result of listening to loud rock music. Results indicated that at 2000 Hz, hearing level was actually better for those attending more amplified music events. At 6000 and 800 Hz, hearing thresholds were poorer in those individuals with greater attendance, but this is difficult to sort out because occupational noise exposure tends to affect those frequencies before it affects 2000 Hz. This study did not strongly support the notion that hearing loss caused by amplified music is wide spread in people under age 21; however, if listening habits remain the same, there is suggested risk for noise-induced hearing loss by the mid twenties (Carter et al., 1982).

The purpose of an investigation by Danenberg, Loos-Cosgrove, and LoVerde (1987) was to evaluate the effects of exposure to live rock music on the hearing of adolescents and adults attending a school dance. Participants included 20 junior and senior high school students aged 12-17 years. Seven members of the school faculty also participated in this study and ranged in age from 37-43 years. Air conduction thresholds were measured at 2000, 4000, and 6000 Hz and participants were tested just prior to the dance and after the dance. After the dance, a short survey was administered to determine if participants were experiencing tinnitus and if they had ever experienced temporary hearing loss accompanying a cold or following exposure to loud noise or music. A third threshold measurement was taken on six random participants who sustained a threshold shift three days following the dance. The concert lasted 2 ½ hours and measurements were taken on a Simpson 866 sound level meter at four locations in the room. Sound pressure levels were: 99 dB, 105.5 dB, 108 dB, and 112 dB for an average of 106.1 dB. Results indicated that nearly all participants sustained at least a 5 dB temporary threshold shift at one or more frequencies. Shifts varied as a function of frequency with greater average shifts occurring at 4000 and 6000 Hz (consistent with findings of noise-induced hearing loss). The largest temporary threshold shift (TTS) was seen at 4000 Hz and males experienced a slightly greater shift at 4000 and 6000 Hz than females. Of the 19 students, 15 reported tinnitus following exposure to rock music and 13 reported having some type of hearing difficulty accompanying a cold or following noise exposure. All adults reported tinnitus following the concert. Results from the second set of post exposure threshold testing were inconclusive. Only two students' thresholds completely recovered and two adults recovered only partially. This may be due to individual susceptibility and variation in recovery pattern. It is hypothesized that the extent of the recovery period may be more indicative of the effects of noise on the auditory system than the TTS itself. Finding may be limited for this particular study because all variables were not controlled for such as subjects' positions in the room and exiting the room throughout the concert (Danenberg, Loos-Cosgrove, LoVerde, 1987).

A study targeting users of recreational firearm users done to determine degree and prevalence of hearing loss in shooters and the relationship between their self-reported hearing difficulty and measured hearing thresholds (Stewart, Pankiw, Lehman, & Simpson, 2002). Participants included 232 shooters between the ages of 13 and 77. Hearing thresholds were measured at .5, 1, 2, 3, 4, and 6 kHz and hearing handicap was calculated using four different methods. The screening version Hearing Handicap Inventory for Adults (HHIA-S) was administered to individuals with hearing thresholds greater than 25 dB HL at any frequency. Results showed that hearing thresholds increased with age, especially in the participants above age 40 at test frequencies of 4000 and 6000 Hz. Results from the HHIA-S varied greatly among participants with high frequency hearing losses. Correlation between self-reported hearing handicap and pure tone calculations was highest for formulas that did not include 500 Hz (Stewart et al., 2002).

Rawool and Colligon-Wayne (2008) conducted a study in order to investigate college students' auditory life-styles and thoughts regarding noise exposure. A survey was administered to 238 college students. It was found that 44 percent of the participants use loud equipment or machinery without the use of hearing protection and 29 percent work in noisy environments. Seventy-five percent of participants were aware of the fact that loud noise can cause hearing damage, although 50 percent appeared to be exposing themselves to dangerously loud music. Forty-six percent of the participants reported that they do not use hearing protection during loud musical activities because they felt that it interferes with their ability to hear the music. Findings indicate a strong need for promoting healthier listening habits in college students (Rawool & Colligon- Wayne, 2008).

Chung and colleagues (2005) evaluated awareness of noise induced hearing in a young adult population. A 28 question survey was created and targeted toward young adults. The survey contained questions regarding demographics, general health and 16 questions specifically targeted toward hearing (hearing protection/preservation, loud recreational music, etc.). The survey was administered to every 30th visitor to the MTV website. Results indicated that hearing loss was defined as a very big problem in only eight percent of respondents. Sixty-one percent reported experiencing tinnitus and 43 percent reported a temporary hearing threshold shift after attending loud music venues. This study's results indicate that hearing loss is of low importance relative to other health problems faced by youths. This may be due to that fact that often the effects of hearing loss do not manifest themselves until later in life (Chung et al., 2005).

Serra and colleagues (2005) reviewed the effects of recreational noise exposure on the hearing thresholds of adolescents age fourteen to seventeen as well as psychosocial variables impacting hearing health. An annual audiologic evaluation was completed for each participant over a four year period. Thresholds were tested at octave frequencies from 250 Hz though 16,000 Hz. Five questionnaires were administered annually to gather information regarding recreational activities focusing on noise and attitudes related to noise in different environments. Sound levels were also measured at discos and real ear measurements were taken on a few subjects using personal stereo systems at their preferred volume setting. Findings indicated that mean hearing thresholds increased (became poorer) over the four years of the study for both genders. Participation in noisy activities also increased throughout the course of the study. Sound levels measured at discos well exceeded the 85 dB(A) 8 hour maximum daily exposure set forth by OSHA, while output from personal stereos ranged anywhere between 75-105 dB(A) (Serra et al., 2005).

A follow up of participants from the previously described study was performed by Biassoni and others (2005) in order to determine if the acquired hearing loss relates to the participants' recreational activities. The participants were classified into two subgroups based on hearing thresholds. Findings indicated that subgroup two had poorer hearing thresholds throughout the study as compared to subgroup one, especially in the higher frequencies. Subgroup two also had higher participation in noisy recreational activities than subgroup one during the last year of the study; however, participation in recreational activities increased over the course of the study for both subgroups. These findings indicate that while exposure to high levels of recreational noise can lead to hearing loss, this is dependent on the susceptibility of the individual (Biassoni et al., 2005).

Vogel and colleagues (2007) performed a systematic review of the literature regarding sociodemographic, psychosocial, and other correlates of hearing loss and risk factors in young people between the ages of 12 and twenty-five. Three databases were searched for articles associated with young people and hearing loss or hearing conservation and 33 articles were selected. Articles investigated sociodemographic correlates such as age, gender socioeconomic status, ethnicity, and country. Psychosocial correlates were also highlighted including rewards of maladaptive response, vulnerability and severity, response and self-efficacy, and cost of adaptive response. The primary focus of most studies was to determine prevalence of hearing loss among young people with a minor focus on possible correlates. Findings indicated that hearing loss prevention should be aimed toward young males of lower socioeconomic status, specifically toward changing listening habits associated with personal music players. There were no studies specifically investigating MP3 player use, however; correlates of other personal music devices were described. This review highlights the need for empirical research, specifically a longitudinal study to investigate the correlates of those who listen to loud music.

Occupational Noise Exposure

Theiry & Meyer-Bisch (1988) conducted a survey in order to determine the risk of hearing loss in industry where sound levels are close to exposure limits (85-90 dB(A)) and noises are partly impulsive. Testing was carried out in an auto-body workshop and sound levels were measured in each production sector. Audiograms were collected from 234 workers exposed to noise, and audiometric data from two reference populations were also used- one population “not exposed” to noise above 80 dB(A), and the other “exposed” to continuous industrial noise of 95 dB(A). Findings indicated equivalent continuous sound pressure levels at the work place averaging between 87-90 dB(A), with the sound being partly impulsive. Eleven percent of the workers exposed for the longest possible time period (18 years) had hearing thresholds greater than 25 dB at 1-3 kHz. For the non-exposed population of the same time period, corresponding risk was only three percent. For this study's population, risk of hearing handicap is higher than in similar studies done previously. This may be due in part to the impulsive nature of the noise in this workshop (Theiry & Meyer-Bisch, 1988).

In order to assess risk of development of noise induced hearing loss in professional musicians, sound level measurements as well as hearing threshold measurements were taken from musicians in the Chicago Symphony Orchestra (Royster, Royster, & Killion, 1991). Dosimetry readings were taken on stage for 44 musicians on two separate occasions and audiograms were completed for 59 musicians and compared to an age matched control group with no occupational noise exposure. Results showed L_{eq} values of 77-99 dBA with a mean of 89.3 dBA and 83-97 dBA with a mean of 90.5 dB(A) for the first and second dosimetry readings respectively. Audiometric test findings indicated 52.5 percent of the musicians had audiometric patterns consistent with noise induced permanent threshold shifts (NIPTS). The L_{eq} measurements were found to be predictive of threshold levels in the high frequencies (3-8 kHz) for musicians whose audiometric thresholds as well as sound level measurements were taken (Royster, Royster, & Killion, 1991).

Noise Standards

National Institute for Occupational Safety and Health (NIOSH). The National Institute for Occupational Safety and Health (NIOSH) has set forth a standard in order to protect workers from unsafe levels of occupational noise exposure. The NIOSH recommended exposure limit (REL) for occupational noise exposure is 85 decibels, A-weighted, as an 8-hour time-weighted average (See Table 1). Exposure to continuous, varying, intermittent, or impulsive is not to exceed 140 dB(A). With a lifetime exposure at the 85-dB(A) REL, there is an eight percent chance that an employee may develop a noise induced hearing loss.

Occupational Safety and Health Administration (OSHA). The Occupational Safety and Health Administration (OSHA) limits maximum noise exposure level to 90 dB(A) as an 8-hour, time-weighted average level (TWA) (Occupational Safety and Health Administration, 2010). Levels exceeding 90 dB(A) are permitted, but for shorter time durations. There is a five decibel correlation between duration and level of noise exposure (See Table 1).

Hearing Conservation Programs

If any employee's noise exposure exceeds the 85 dBA 8 hour TWA, a Hearing Loss Prevention Program (HLPP) must be implemented in the workplace (NIOSH, 2010; OSHA, 2010). When a new HLPP is initiated, an initial monitoring of the worksite or monitoring of noisy work tasks is to be conducted. This is to determine the noise exposure levels representative of all workers whose 8-hr TWA noise exposures may equal or exceed 85 dBA (NIOSH, 2010). All continuous, varying, intermittent, and impulsive sound levels from 80 to 140 dBA should be taken into account when determining noise measurements. Engineering controls, administrative controls, and work practices are to be used as much as possible to make certain that employees are not exposed to noise at or above the 85 dBA 8-hr time weighted average. For individuals whose exposure level does exceed the 85 dB A 8 hour TWA, appropriate hearing protection is to be provided at no cost to the employee (OSHA, 2010).

Workers are to have their hearing thresholds tested as a baseline within six months of start of employment and hearing must be tested or monitored annually (OSHA, 2010). Workers are required to avoid noise exposure levels of 85 dBA or greater for the 12 hours prior to testing. If a worker's annual test indicated a shift from the baseline thresholds of 10 dB or greater in either ear at 2000, 3000, 4000 Hz (a standard threshold shift or STS), the worker must be notified in writing and trained regarding use of hearing protection. According to OSHA, hearing protection is mandatory for those who have experienced an STS and for employees exposed to 90 dBA or higher. It is the responsibility of the employer to maintain accurate and up to date records for at least two years. Annual education regarding the effects of noise on hearing and the need for hearing protection must also be implemented into the hearing loss prevention program (OSHA, 2010).

With increase prevalence of noise induced hearing loss among youth, experts recommend implementing hearing conservation education in schools as well. Folmer, Griest, and Martin (2002) reviewed existing hearing conservation programs designed for children and more specifically, compile a list of program and materials that are suitable for children while reviewing their components and assessing effectiveness. Hearing conservation education programs for youths were identified through literature and internet searches and the materials of each program were reviewed. Two lists were compiled and thoroughly described: 1) a list of 12 programs was identified as being suitable for children; and 2) 17 organizations that produce materials that could be used in the classroom. Findings from this extensive review indicated that the problem with hearing conservation education for children is lack of distribution of the information. By raising public awareness, informing teachers and administrators about existing programs, persuading teachers to integrate hearing conservation education into existing lesson plans, and seeking a mandates on federal, state, and local levels, this problem can be properly addressed. Hearing conservation should be regarded with as much importance as anti-smoking, anti-drug, teen pregnancy, and STD education programs that are currently implemented regularly in public schools (Folmer, Griest, & Martin, 2002).

Personal Listening Devices

Bradley & Fortnum (1987) conducted a study in order to gain insight into the effects of social noise exposure, namely, exposure patterns to amplified music from personal cassette players (PCPs). A questionnaire regarding ownership and use of PCPs and was sent and responses were obtained from 1443 school students between 11 and 18 years of age. Reports of hearing difficulty were much higher than expected and tinnitus was reported less than expected based on the National Study of Hearing (Davis, 1983). Hearing difficulty and tinnitus were noted most by those who listen to non PCP amplified music through headphones. For the second portion of the study, twenty-five students were asked to set the volume of a walkman with earphones to the level they would like. Music levels were measured using a KEMAR artificial head. Results showed listening levels for these individuals were far below the upper limit of acceptable occupational noise exposure without ear protection indicating that the participants were more conservative than initially anticipated (Bradley & Fortnum, 1987).

An increased use of personal stereo systems (PSS) in youth has raised concerns regarding the dangers of noise exposure (Clark, 1990). A survey by Clark indicated that 80-90 percent of fourth through sixth grade students use PSSs. A number of studies have been carried out to evaluate the risk of personal stereo use. Wood and Lipscomb (1972) reported SPLs of 124 dB(A) from headphones, while Katz (1982) found output levels as high as128 dBA. Both studies noted maximum sound pressure levels exceeding the OSHA 90 dB criterion for an eight hour workday. Kuras and Findlay (1974) asked young rock music fans to listen to their personal stereo system at their preferred levels. Most comfortable listening levels were obtained at 92.1 dB(A) for a selected piece and 88.1 dB(A) for their song of choice. In a review of this study by Davis (1985), an average listening level of 83.3 dB SPL was found when music was the central activity of interest. Catalano and Levin (1985) compared sound levels at all volume settings on three different PSSs and calculated daily dose for 154 college students. They compared their findings to OSHA standards and found that three cassette players varied in output from 60 dBA to 110-114 dB(A) for settings one and ten, respectively. Lee, Senders, Grantz, and Otto (1985) asked 16 volunteers to listen to rock music for a three hour period. Audiograms were generated before and after the listening. Six subjects were found to have temporary thresholds shifts of 10 dB at least one frequency while one user had a shift of 35 dB at 4000 Hz. Rice, Breslin and Roper (1987) described PSS use in terms of a free-field A weighted equivalent by applying a transfer function to levels obtained on an acoustic mannequin. Twenty five percent of surveyed users experienced levels of 90 dBA and 4 percent experienced levels of 100 dB(A). Rice Rossi and Olina (1987) looked at PSS use in school-aged children in Italy and England. They found 10 percent had exposure doses of at least 87 dB(A) and 20 percent reported feelings of fullness or ringing in their ears after listening. Use of PSSs can produce sound levels that are detrimental to the hearing mechanism, and when listened to at a loud volume for long periods of time, may cause noise-induced hearing loss (Clark, 1990).

A study was conducted to find prevalence of personal cassette player (PCP) use in youths in a Chinese community and to determine if there were any effects on hearing thresholds (Wong et al., 1990). Data was obtained from 487 youth ages 15-24 years. Participants were classified into two groups- users of PCPs and non-users of PCPs. Approximately one third of participants were selected for audiometric testing and hearing thresholds between users and non-users were compared. Additionally, participants were asked to listen to a pre-selected music track at their typical listening level. Sound level in the ear canal (Leq(A)) was then measured using a noise level meter connected to an artificial ear. Results indicated that 81 percent of participants were users of PCPs, and mean listening levels were 71.2 dB(A) and 69.5 dB(A) for light and rock music, respectively. Mean duration of use was 2.8 years and mean listening time was 4.5 hours per week. Regarding threshold testing, no significant differences were found between the users and non-users; however, the majority of both groups indicated that they felt listening to PCPs could have a negative effect on hearing ability (Wong et al, 1990).

Pugsley, Stuart and Kalinowski (1993) calculated test re-test differences (TRDs) in hearing thresholds for thirty young adults in order to determine if changes in hearing sensitivity were present following use of personal stereos. Audiometric thresholds were measured prior to and immediately following one hour of personal stereo use at the subject’s preferred listening level. Thresholds were compared to a matched control group exposed to one hour of quiet. Findings showed that none of the participants' TRDs exceeded critical difference values indicating no decrease in hearing thresholds following exposure (Pugsley, Stuart & Kalinowski, 1993).

Hellstrom, Axelsson, and Costa (1998) looked at the temporary threshold shift (TTS) produced by an average noise dose from personal cassette player (PCP). Twenty-one normal hearing participants were divided into three groups: frequent PCP users, those who listen through speakers, and infrequent listeners. Participants listened to 105 dB of pink noise for ten minutes through earphones and thresholds were measured before and after exposure. Twenty-four hours following exposure, participants were exposed to music. They were instructed to set the volume to a loud but comfortable level. A probe tube was placed in the canal of the ear with the best thresholds and the sound pressure level was measured every five seconds. Thresholds were again measured before and after music exposure. Findings showed very little differenced in pre and post thresholds in the frequent PCP user group and the group who listened through speakers. For pink noise exposure, maximum TTS was between 2.5-3 kHz in all three groups. For music, the largest TTS was seen between 3-.5-4 kHz. The largest TTS for music exposure was seen in the group that listened through speakers. Overall, listening resulted in relatively low TTSs suggesting that listening to PCPs for an hour at a loud level is unlikely to cause a noise induced hearing loss (Hellstrom, Axelsson, & Costa, 1998).

Danhauer et al. (2009) designed a survey for college students regarding their knowledge, experiences, attitudes and practices related to hearing health and iPod or personal stereo use. Online and paper surveys were given to college students from 40 United States universities and 609 responses were obtained. Survey results indicated that a majority of students are unaware of the signs of hearing loss and should be educated regarding the symptoms of hearing loss. Of those who owned personal listening devices, 2/3 of students owned iPods. Seventy-one percent of students reported listening at levels of 60 percent volume or louder, possibly exceeding safe listening levels. Over thirty-four percent of students reported frequently being in loud settings which could be detrimental to hearing if exposed for extended periods of time. While findings indicated that most students are using iPods in a way that is not harmful to their hearing, there are a small percentage of college students who are using personal listening devices in a potentially dangerous manner (Danhauer et al, 2009).

Personal Listening Devices in Background Noise

In a study by Catalano and Levin (1985), a model was developed to estimate life time exposure to recreational noise from use of portable radios with headphones. An estimate was then made regarding the proportion of listeners who may have a higher risk of developing a noise-induced hearing loss (NIHL) resulting from use of “Walkman”-type devices. A questionnaire was distributed to several classes at a college in New York City. Respondents consisted of 154 students between the ages of 18 and 21 years. The three most popular brands of “walkmen” were also chosen and their sound intensity levels were tested. A twenty second song clip was analyzed using a sound level meter and an artificial ear. Each “walkman” was tested separately and the process was repeated from volume settings one through twenty. Each student’s responses were evaluated for risk of developing a noise-induced hearing loss by comparing their reported dose to the auditory risk criteria (ARC) determined by OSHA. Each participant was put into one of four risk categories: 1) less than ARC; 2) equal or exceeding ARC by up to 100 percent;

3) exceed ARC by 100-200 percent; 4) exceed ARC by greater than 200 percent. Results indicated that approximately one third of all “Walkman” users exceeded the ARC and half of those who exceeded the criteria did so by more than 100 percent. While this does suggest potential hazard to the hearing mechanism, there is some question to the reliability of frequency of use and volume settings as these were reported by the participants. Therefore, there may be some degree of bias in these findings (Catalano & Levin, 1985).

Another study aimed to determine the volume levels of personal stereo devices by users in real-life settings and the durations at which individuals are listening (Williams, 2005). Personal stereo player levels were measured from random individuals passing by on the street at two locations: near the subway station and outside of a town hall. Participants were also given a short survey regarding hours of stereo use per day, years of use, hearing loss, tinnitus and noise exposure. Personal stereo levels were measured on a KEMAR mannequin with an artificial ear simulator. Findings showed no correlation between noise exposure and reported tinnitus. Males had greater noise exposure levels than females, although average participant exposure level was 79.8 dB (below the risk level of 85 dB). Findings from this study indicate that use of personal stereo devices alone does not increase the risk for a noise induced hearing loss (Williams, 2005).

A study was carried out in order to examine the relationship between the use of portable audio devices and hearing health of university students using objective and subjective measures (Ahmed et al., 2007). A questionnaire was administered to 150 students. Participants were all between the ages of 16 and 25, and 56 percent were male. The online survey consisted of 124 questions including such topics as demographics, transportation, work environment, personal and family hearing history, recreational activities, and portable audio device usage. Audiograms were recorded for 24 individuals participating in the second part of the study from 250-1400 kHz. The iPod output was measured using a Bruel & Kjaer head and torso simulator using standard earbuds. Thirty second stimuli were used to obtain output measurements using three different earbud styles. Participants listened in five different background noise levels – quiet, multi-taker babble at 50 dB SPL and 70 dB SPL, and traffic noise at 50 and 70 dB SPL. Speakers were positioned at 45 degree angles and testing was carried out in a sound treated room. Participants were asked to adjust the iPod to the volume of their liking.

Results indicated that 82 percent of participants owned some type of portable audio device with mp3 players being most popular. Most students used devices frequently (5-7 days per week) but listened at a mid level volume. Approximately thirteen percent believed they had a hearing loss which could be noise related. Objective results showed that output was lowest when the background noise condition was the lowest and increased with the level of background noise. While a majority of students used portable listening devices, it was generally found that most students were listening at safe levels (Ahmed et al., 2007).

Hodgetts and colleagues (2007) explored the effects of listening environment and type of earphone on individuals' preferred listening levels. Using a Creative MuVo N200 MP3 player, 38 participants were asked to listen to a song in three different listening environments: quiet, street noise, and multi-talker babble. Two earphone styles were used: an in the ear earbud, and an over the ear headphone with and without noise reduction. Participants were instructed to set the volume of the song to the level that sounds best to him or her, while a probe microphone in the ear canal measured output levels. Overall, participants had a higher preferred listening level when using in-the-ear earbuds while the lowest levels resulted when participants were using over the ear headphones. Participants had higher preferred listening levels in the two background noise conditions versus the quiet condition. Maximum output levels of the MP3 player with the different headphones were also tested on two of the authors. Maximum sound pressure levels were 110 dB(A) from the ear buds, 106.5 dB(A) from the over the ear headphones, and 100 dB(A) for over the ear headphones when noise reduction was activated (Hodgetts et al., 2007).

A study by Weiner, Kreisman, & Fligor (2009) aimed to determine if the ability to overhear music from another person's MP3 player headphones indicates that the output level is damaging to the listener's hearing. Thirty participants with normal hearing were seated in a sound treated room surrounded by four speakers at 45, 135, 225, and 315 degrees azimuth. A probe microphone was placed in the participants' ear canal to measure the output level from the MP3 player. Participants were asked to select a random song on their MP3 player and set the volume to zero. The screen was then covered and participants were asked to "adjust the volume to where you like it." Output levels were taken and observer judgments were made four times in thirty second intervals in four levels of randomized background noise: Quiet (ambient noise of 34 dB(A)), 45 dBA of pink noise, 60 dB(A) of pink noise, and 75 dB(A) of pink noise. Results showed an average increase of 13 dB when listening in background noise and 26 percent of participants listened at levels above 85 dB(A) FFE in the highest background noise condition. A significant correlation was found between audibility and set listening levels in background noise suggesting that if music can be overheard in noisy environmental settings, it is more likely that the music is set at a high intensity level. The sensitivity and specificity of "If I can hear it, that means it's too loud" was assessed and it was found that in the quiet condition, sensitivity was 100 percent; however, as background noise increased, sensitivity decreased and the number of false negatives increased. In general, this study found that if you can overhear a person's MP3 player, it does not necessarily mean they are listening at an unsafe level (Weiner, Kreisman, & Fligor, 2009).

Hypotheses

Dangerous listening levels. Considering the previous research, the purpose of this investigation is to determine whether or not overhearing another person's iPod indicates that they are listening at an unsafe volume level (a long-term average level above 85 dB(A) FFE).

H_o: All song clips with long-term average amplitudes greater than or equal to 85 dB(A) FFE will be audible to participants.

H_a: All song clips with long-term average amplitudes greater than or equal to 85 dB(A) FFE will not be audible to participants.

Volume setting. The factor volume setting compares audibility of each volume setting on the iPod. In order to accept the null hypothesis, all volume levels need to have equal audibility. If the audibility level for each song is not equal, the null is rejected in favor of the alternate hypothesis.

H_o: Participants will hear the music equally at all volume settings.

H_a: Participants will not hear the music equally at all volume settings.

Background noise. The factor background noise compares audibility in each level of background noise. In order to accept the null hypothesis, hearing in all background noise conditions will be equal. If audibility in all background noise conditions is not equal, the null is rejected in favor of the alternate hypothesis.

H_o: Audibility in all background noise conditions will be equal.

H_a: Audibility in all background noise conditions will not be equal.

Music stimuli. The factor music stimuli compares audibility for each different song selection. In order to reject the null hypothesis, all music stimuli need to have equal audibility. If the music stimuli are not equally audible, the null is rejected in favor of the alternate hypothesis.

H_o: All songs will have equal audibility.

H_a: All songs will not have equal audibility.

Predicted Findings

As volume level increases, it is expected that participants will be able to hear the songs more easily. Conversely, as background noise increases, it is expected that audibility of the songs will decrease. The peak output level in SPL of each song is different, even though each song clip has been equalized for overall RMS amplitude. If the difference in peak output level between songs is large enough (one song peaks louder than another), the song with the higher peak output SPL will be more audible.

Table 1.

Permissible Occupational Noise Exposure Levels in dB(A)

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

Note: Descriptive note. Adapted from Occupational Safety and Health Administration Standard 1910.95(b)(2) and National Institute of Occupational Safety and Health Publication No. 98-126.

CHAPTER 3

METHODS AND MATERIALS

Participants

Fifty adults, 20 males and 30 females, between the ages of 20-28 years (M= 23.5 years, median= 23 years, mode= 23 years) were recruited to participate in this study. Participants were recruited by the principal investigators through e-mail and by phone. The study was conducted in the Center for Amplification, Rehabilitation, and Listening at Towson University. Participants received a ten dollar iTunes gift cards in compensation for their time.

Materials

Five top selling songs from iTunes for the week of June 14, 2009 were selected as the music stimuli. The songs included “Boom Boom Pow” by the Black Eyed Peas, “Fire Burning” by Sean Kingston, “I Gotta Feeling” by the Black Eyed Peas, “I Know You Want Me” by Pitbull, and “Love Game” by Lady Gaga. A ten second clip was sampled from the chorus of each song. The song clips were be equalized for overall RMS amplitudes using Adobe Audition 1.5 and were be imported into iTunes on a Dell PC. The equalized song clips were then imported onto an iPod Touch with standard iPod earbuds.

All measurements were carried out in a double walled sound treated test suite. A KEMAR mannequin was placed in a chair in the center of the test suite. A DPA 4006-TL omnidirectional microphone was placed 2 feet 4 inches at 0-degrees azimuth from

KEMAR's head in order to simulate approximate distance of an individual passing by someone listening to the iPod. The microphone was coupled to a DigiDesign Digi002 rack, which served as the external interface/router for the ProTools 7.3 software on the Macbook laptop. The earbuds of the iPod were placed in the ears of the KEMAR mannequin in order to record the audibility of each song clip. All samples were recorded in a quiet condition (ambient background noise of 31.6 dBA). The audibility of each ten second song clip was recorded at nine different volume settings on the iPod (0, 12.5, 25, 37.5, 50, 62.5,75, 87.5, and 100 percent). The iPod volume icon has 16 dashes which range from zero dashes (0 percent volume) to 16 dashes at 100 percent volume. For the study, song clips were recorded at every second dash on the volume icon, or every 12.5 percent of maximum volume. The peak output levels in dB(A) for each song clip were measured via an IVIE IE-35 real-time audio analyzer/sound level meter, with a Type-I microphone. After the song clips were recorded in quiet using ProTools 7.3, the recording files were transferred into the Adobe Audition 1.5 software program on a Dell PC.

Using Adobe Audition 1.5 software, a 0.1 second 440 Hz tone was added at the beginning and ending of each ten second song clip to signal when each clip starts and stops as some of the clips were inaudible (e.g. segments recorded at 0 percent volume). The recordings were then transferred back to the MacBook. Using ProTools 7.3, the recordings in quiet were duplicated three times for a total of four copies. Each set of recordings was mixed with a different background noise condition. The conditions included quiet, or ambient noise of 31.6 dB(A), and 45 dB(A), 60 dB(A), and 75 dB(A) of pink noise. The pink noise was correlated and was generated through ProTools 7.3.

The recordings and pink noise were routed through the DigiDesigns Digi002 rack to eight KRK Rokit Power 5 speakers. The speakers were arranged in an array two feet 4 inches from the center of the participant's head at 0, 45, 90, 135, 180, 225, 270, 315 degrees azimuth. The song clip recordings were routed through the speaker at 0 degrees (directly in front of the participant) to simulate the sound coming from the iPod of a passer-by. The pink noise was routed through the seven additional speakers. Pink noise was calibrated through ProTools 7.3 to background levels of 45 dB(A), 60 dB(A) and 75 dB(A) using the IVIE IE-35 real-time audio analyzer/sound level meter placed in the center of the room, 2 feet 4 inches from the speakers on all sides, again simulating the passerby in diffuse background noise.

Through the ProTools 7.3 software, the noise recordings were convolved with the five different songs clips at each of the nine possible volume levels for a total of 180 different song, volume, and noise combinations. A random presentation list was generated for each participant using the website random.org. For each participant, each of the 180 clips were selected individually from the ProTools 7.3 file and played through the speakers.

Long-term average amplitude in dB(A) for each song clip at each volume level was measured at the level of the principal investigator's eardrum using an AudioScan Verefit system. A probe tube was placed in the principal investigator's ear canal and a continuous sound level measurement was recorded for each ten- second song clip. Long-term average amplitudes dBA of each clip were equated to free-field equivalent (FFE) levels using a correction factor in order compare the data to damage-risk criteria.

Procedures

An audiologic screening was conducted on each of the participants to confirm normal hearing and normal middle ear function before participation in the study. An otoscopic examination was performed, followed by a bilateral tympanometry screening using a Madsen Otoflex 100 immittance bridge. Pure tone air conduction testing was performed bilaterally using a pulsed 15 dB HL pure tone stimuli presented through a Grason-Stadler GSI 61 audiometer with EAR-TONE ER insert earphones. Thresholds were screened from 250 Hz through 8000 Hz including interoctaves. Following completion of the audiologic screening, the earphones were removed and the participant was seated in the center of the sound treated test suite.

Written instructions will be provided to the participant stating “You will be listening to ten-second segments of noise and/or music. If at any time during the ten second segment, you hear the music, say “yes.” The next sound clip will begin shortly thereafter. During some clips, you may not hear the music at all.” After the participant indicated that he or she understood the instructions, the background noise levels were presented to the participant in order to familiarize the participant with the listening environment. Participant responses to each song clip were recorded on a paper data sheet and later entered into an excel spreadsheet.

Results were analyzed using descriptive statistics. Positive predictive value (PPV), negative predictive value (NPV), sensitivity, and specificity were calculated by song and condition in order to determine whether audibility of the music over the background noise was indicative of dangerously loud listening levels. A receiver operating characteristic (ROC) curve was constructed to determine the optimal listening condition in which overhearing the music is indicative of dangerous listening levels.

Figure 1. Screenshot of top selling iTunes songs for the week of June 14, 2009.

CHAPTER 4

RESULTS

Peak sound pressure level in dB(A) at the recording microphone for each song clip at each of the nine volume percent levels on the iPod are displayed in Table 2. All clips were recorded in quiet (31.6 dB(A) of ambient noise in the sound booth). "Love Game" had the highest peak SPL at the recording microphone and peaked at 59.2 dB(A) at 100 percent volume level. "I Gotta Feeling" had the lowest peak SPL measured at the recording microphone and peaked at 56.3 dB SPL. At 0 percent volume on the iPod, none of the songs peaked above the ambient noise level of the sound treated booth and all peaks were recorded at 31.6 dB(A) for each song clip. For volume settings of 0, 12.5, 25, and 37.5 percent, peak SPLs at the recording microphone remained within 1 dB of the ambient background noise indicating very little change in peak sound pressure levels.

Long-term average amplitudes in dB(A) for each song clip at each volume level were measured in the ear canal of the principal investigator while listening with standard iPod earbuds. Values were then equated to free-field equivalent (FFE) values in dB(A) for comparison with established damage risk criteria set forth by OSHA. Findings are displayed in Table 3. "I Gotta Feeling" had the highest output when presented at 100 percent volume level with a long-term average amplitude of 95.8 dB(A) FFE. "Love Game" had the lowest long-term average amplitude when presented at 100 percent volume level at 91.6 dB(A) FFE. When presented at 100 percent volume level on the iPod, all of the song clips had long-term average amplitudes greater than 85 dB(A) FFE indicating potential risk for auditory damage. At 87.5 percent volume, 4 out of the 5 song clips had long-term average amplitudes greater than or equal to 85 dB(A). At 75 percent volume level and below, none of the song clips had average outputs greater than or equal to 85 dB(A) FFE. Recordings from the ear canal at 0 percent volume showed that long-term average amplitude levels were within 1 dB(A) of ambient noise in the room for all songs, indicating very little change in sound pressure level.

Table 4 displays participant responses to each of the five song clips and each of the nine volume settings on the iPod for four different background conditions. Song clips included “Boom Boom Pow,” “I Gotta Feeling” by Black Eyed Peas, “Love Game” by Lady Gaga, “I Know You Want Me” by Pitbull, and “Fire Burning” by Sean Kingston. Numbers represent the number of participants who indicated the song clip was audible over the background noise.

In the quiet background condition (31.6 dB(A) ambient noise), all songs were inaudible at the 0 and 12.5 percent volume on the iPod, the lowest volume settings. At 25 percent volume, only three of the songs were audible during greater than or equal to 50 percent of trials. At 37.5 percent volume and greater, all songs were audible to participants greater than or equal to 50 percent of trials. In the 45 dB(A) pink noise background condition, all songs were inaudible at volume levels of 0 through 37.5 percent. At 50 percent volume, only one song was audible to participants (“I Know You Want Me”). At volume settings of 62.5 percent and louder, all songs were audible to participants greater than or equal to 50 percent of trials.

In the 60 dB(A) pink noise background condition, all songs were inaudible from 0 percent to 62.5 percent. At 75 percent volume on the iPod, only one song was audible to the participant ("I Know You Want Me"). At volume settings of 87.5 and 100 percent, all songs were audible to participants greater than or equal to 50 percent of trials. In the 75 dB(A) background noise condition, none of the songs were audible to participants greater than or equal to 50 percent of the time regardless of volume setting on the iPod.

In order to determine if overhearing another person's iPod is useful in predicting whether he or she is listening at a dangerously loud level (a level equal to or above the 85 dB(A) FFE noise criteria), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were considered. Sensitivity measures the proportion of actual positives that are correctly identified (Parikh, Mathai, Parikh, Sekhar, & Thomas, 2008). For the purpose of this study, sensitivity is the percentage of people who heard the song clip (said "yes") when the song clip was actually playing at a long-term average amplitude level of 85 dB(A) FFE or louder. Specificity looks at the proportion of negatives that are correctly identified. In this study, this would be the percentage of people who did not hear the song clip playing (said "no") when the song clip was playing at a long-term average amplitude level below 85 dB(A) FFE. Positive predictive value (PPV) uses both sensitivity and specificity and reflects the likelihood of a "disease" (a song clip playing with a long-term average amplitude level above 85 dB(A) FFE) when it is identified as such (when the participant says "yes"). Positive predictive value measures performance of a diagnostic method and relies on the prevalence of the "disease." Negative predictive value (NPV) shows the proportion of participants with a negative result who were correctly "diagnosed" (proportion of participants who said "no" when the song clip was playing at a long-term average amplitude level below 85 dB(A) FFE) (Parikh et al., 2008). For this study, PPV for the song clips being overheard by the observer show the probability that being able to overhear someone else's iPod is indicative of dangerously loud listening levels (long-term average amplitude levels greater than or equal to 85 dB(A) FFE.

Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for all songs combined in each background noise condition are displayed in Table 5. Sensitivity for songs played in quiet, 45 dB(A) and 60 dB(A) of pink noise ranged from 91 to 99 percent. This indicates that songs with volume levels greater than or equal to 85 dB(A) were audible to the participants 91-99 percent of the time. In the 75 dB(A) pink noise condition, sensitivity was only 10 percent. This indicates that songs playing at long-term average amplitude levels greater than or equal to 85 dB(A) FFE were only audible to the participants ten percent of the time. Specificity was greatest in the 75 dB(A) condition indicating that songs playing at levels less than 85 dB(A) FFE were inaudible 92 percent of the time. Specificity was most poor in the quiet background condition showing that when the songs were playing at a level less than 85 dB(A), they were inaudible to the participant only 33 percent of the time indicating a high number of false positives.

Positive predictive value (PPV) ranged from 28 percent to 62 percent across background conditions. The PPV was most poor in the 75 dB(A) pink noise condition at only 28 percent, and was best in the 60 dB(A) condition at 62 percent. In other words, even in the best condition, responses were only accurate 62 percent of the time. In general, PPV increased as background noise increased (except for the 75 dB(A) condition), however; PPV still remained poor. These results indicate that this task is not a very accurate screening measure.

Negative predictive values (NPV) ranged from 97 percent to 99 percent for quiet, 45 dB(A) and 60 dB(A) pink noise conditions. These scores indicate that when participants said they did not hear the clip in quiet, soft, or moderate pink noise background conditions, it was highly unlikely that the song clip was greater than or equal to 85 dB(A).

Sensitivity, specificity, PPV, and NPV in the quiet (31.6 dB(A) ambient noise) background condition are listed by song in Table 6. Sensitivity for all songs ranged from 96 to 100 percent, which suggests that when each of the five song clips were played at long-term average amplitude levels greater than or equal to 85 dB(A), they were audible to participants 96 to 100 percent of the time. Sensitivity was highest (100 percent) for “Boom Boom Pow,” “Fire Burning,” and “Love Game.” Sensitivity was lowest for “I Know You Want Me,” at 96 percent. Specificity measures ranged from 27 percent to 63 percent across song clips. Specificity was greatest for “I Gotta Feeling” (63 percent) due to the fact that there were fewer false positives for this song. Specificity was most poor for “Fire Burning.” Specifically, when this particular song clip was played at a level less than 85 dB(A), the clips were inaudible to the participant only 27 percent of the time. These poor specificity measures indicate a high number of false positives for all songs in the quiet background condition even though the long-term average amplitude levels were less than 85 dB(A) FFE.

Positive predictive value (PPV) ranged from 15 percent to 43 percent across the five song clips played in quiet. The PPV was most poor for “Love Game” (only 15 percent), and was best for “I Gotta Feeling” and “I Know You Want Me” (both 43 percent). This means that even with the best song being played, responses were only accurate 43 percent of the time. This indicates that this screening measure is not a very accurate in a quiet background condition for any of five songs. Negative predictive values (NPV) ranged from 96 percent to 100 percent across the five song clips when played in the quiet background condition. These high NPV scores indicate that when participants said they did not hear the song clip, it was highly unlikely that the song clip was played at a level greater than or equal to 85 dB(A) FFE.

Sensitivity, specificity, PPV, and NPV in the 45 dB(A) pink noise background condition are listed by song in Table 7. Sensitivity for all songs ranged from 96 to 98 percent. These high sensitivity scores indicate that when each of the five song clips were played at long-term average levels greater than or equal to 85 dB(A) FFE, they were audible to participants 96 to 99 percent of the time. Sensitivity was highest (99 percent) for “I Gotta Feeling.” Sensitivity was lowest for “Boom Boom Pow,” “I Know You Want Me,” and “Love Game,” all of which had scores of 96 percent. Specificity measures ranged from 31 percent to 70 percent across song clips. Specificity was greatest for “I Gotta Feeling” indicating that when that particular song was played at levels less than 85 dB(A) FFE, it was inaudible 70 percent of the time. This finding is consistent with specificity in the quiet background noise condition where “I Gotta Feeling” was also found to have the highest specificity score. Specificity was most poor for “I Know You Want Me” showing that when this particular song clip was played at a long-term average amplitude level less than 85 dB(A) FFE, the clips were inaudible to the participant only 31 percent of the time. These scores indicate a high number of false positives for across all songs presented in the 45 dB(A) background condition, meaning participants heard the song clips at levels less than 85 dB(A) FFE.

Positive predictive value (PPV) ranged from 37 percent to 49 percent across the five song clips played in 45 dB(A) of pink background noise. The PPV was lowest for "Love Game" (only 37 percent), and was best for "I Gotta Feeling" (49 percent). This means that even with the best song clip ("I Gotta Feeling") being played, participants only correctly identified songs with long-term average amplitudes greater than or equal to 85 dB(A) FFE accurately about half of the time. This indicates that this screening measure is not a very accurate in a 45 dB(A) pink noise background condition for any of five song clips because results were wrong approximately half of the time. Negative predictive values (NPV) ranged from 96 percent to 100 percent across the five song clips when played in the 45 dB(A) pink noise background condition. These high NPV scores indicate that when participants said they did not hear the song clip, it was highly unlikely that the song clip was playing at an average level greater than or equal to 85 dB(A) FFE.

Sensitivity, specificity, PPV, and NPV for each of the five song clips in the 60 dB(A) pink noise background condition are displayed in Table 8. Sensitivity measures range from 75 percent to 98 percent. "Fire Burning" had the highest sensitivity score while "I Gotta Feeling" had the lowest sensitivity score. These scores indicate that when songs were playing at long-term average amplitude levels greater than or equal to 85 dB(A) FFE, they were audible to the participants between 75 and 98 percent of the time depending on the song. Specificity was greatest for "I Gotta Feeling" indicating that when that particular song was played at levels less than 85 dB(A) FFE it was inaudible 87 percent of the time. This finding is consistent with the 45 dB(A) pink noise background condition and the quiet background condition which both indicated "I Gotta Feeling" had the best specificity. "Love Game" had the lowest specificity score, 75 percent, indicating that when this particular song was played at a level less than 85 dB(A) FFE, it was inaudible to the participant 75 percent of the time. Specificity scores were higher in the 60 dB(A) pink noise background condition compared to the quiet condition and the 45 dB(A) pink background noise condition meaning that participants were less likely to overhear song clips when they were playing at levels less than 85 dB(A) FFE.

Positive predictive value (PPV) ranged from 32 percent to 65 percent across the five song clips played in 60 dB(A) of pink background noise. The PPV was most poor for "Love Game" (consistent with findings in 45 dB(A) pink noise background condition) and was best for "Boom Boom Pow." This means that when the ideal song clip ("Boom Boom Pow") was played, participants correctly identified songs playing at long-term average amplitude levels greater than or equal to 85 dB(A) accurately 65 percent of the time. Positive predictive value was highest overall in the 60 dB(A) background condition indicating that overhearing song clips in 60 dB(A) of pink noise is the best indicator that a song is peaking at a dangerously loud level (a long-term average amplitude level greater than or equal to 85 dB(A) FFE.

Negative predictive values (NPV) ranged from 92 percent to 99 percent across the five song clips when played in the 60 dB(A) pink noise background condition. These high NPV scores indicate that when participants said they did not hear the song clip, it was highly unlikely that the song clip was playing at a level greater than or equal to 85 dB(A) FFE.

Sensitivity, specificity, PPV, and NPV for each of the five song clips in the 75 dB(A) pink noise background condition are displayed in Table 9. Sensitivity measures ranged from 2 percent to 20 percent. "I Know You Want Me" had the highest sensitivity score while "Love Game" had the lowest sensitivity score. These scores indicate that when songs were playing at long-term average amplitude levels greater than or equal to 85 dB(A) FFE, they were only audible to the participants 2 to 10 percent of the time depending on the song. Sensitivity was poorest in the 75 dB(A) pink noise background condition. Specificity scores ranged from 91 to 93 percent. Specificity was greatest for "I Know You Want Me" indicating that when that particular song was played at levels less than 85 dB(A) FFE the clips were inaudible 93 percent of trials.

Positive predictive value (PPV) ranged from 3 to 45 percent in the 75 dB(A) pink noise background condition. The PPV was greatest for "I Know You Want Me" and most poor for "Love Game." Overall, PPV was lowest in the 75 dB(A) pink noise background condition compared to the other three background conditions, regardless of song. This indicates that when songs were played at levels greater than or equal to 85 dB(A) FFE in this condition, they were only overheard by participants a small percentage of the time.

Negative predictive values (NPV) ranged from 77 percent to 80 percent across the five song clips when played in the 75 dB(A) pink noise background condition. These NPV scores indicated that when participants said they did not overhear the song clip, it was unlikely that the song clip was playing at a long-term average amplitude level greater than or equal to 85 dB(A) FFE.

In order to determine the accuracy of a screening measure, a receiver operating characteristic (ROC curve) is constructed. The ROC curve provides a way to examine the accuracy of a diagnostic test (in our study, overhearing a song clip indicating a dangerously loud listening level) and establish a threshold or cut-off for distinguishing between a positive or negative result (Rao, 2003).

Diagnostic tests typically involve a tradeoff between sensitivity and specificity (Rao, 2003). For example, if a threshold is set too low, results may show high sensitivity but low specificity. This yields many false positives (people overhearing songs with average amplitudes less than 85 dB(A) FFE criteria and therefore not a dangerous level). If a threshold is set too high, results may show high specificity but poor sensitivity. Rao (2003) reported that the best threshold or cutoff values have high sensitivity and low 1-specificity values. When plotted on the ROC curve, this point will be located closest to the upper left corner of the graph. After all points are plotted, the area under the curve is examined. The larger the area, the more accurate the measurement tool is. A perfect measurement tool (100 percent sensitivity and specificity) would be located at the (0,1) intersection on the graph and have an area of 1.0 (Rao, 2003).

An ROC curve for participant responses in each level of background noise in displayed in Figure 2. The figure shows that the 60 dB(A) pink noise background condition was the best cutoff. It has the highest sensitivity specificity tradeoff with sensitivity being 91 percent and 1-specificity being 16 percent. This indicates that predictability was highest in the 60 dB(A) pink noise condition (overhearing music from someone's iPod in a 60 dB(A) pink noise background condition is the best predictor they the individual is listening at a level greater than or equal to 85 dB(A)). While the quiet condition has a high sensitivity value (99 percent), the specificity value was low (43 percent) indicating that when songs were played at levels less than 85 dB(A), they were inaudible during fewer than half of the trials.

The thresholds or cutoffs increased as background noise levels increased from quiet (31.6 dB(A) of ambient noise, to 45 dB(A) and 60 dB(A) of pink noise; however, when background noise increased to 75 dB(A), the cutoff decreased significantly. Sensitivity was only 10 percent in this condition, while specificity was 92 percent. This indicated that the proportion of actual positives (song clips with long-term average amplitude levels greater than or equal to 85 dB(A) FFE) were only correctly identified (overheard by participants) ten percent of the time.

Linear spectrum analyses of the pink noise stimuli and for one song clip ("Boom Boom Pow" was selected at random) were performed in order to determine a probable cause for the lack of audibility of songs presented in the 75 dB(A) pink noise background condition. An image of the pink noise spectrum analysis is shown in Figure 3 and an image of the song spectrum is shown in Figure four. Both spectrums have a relative dB scale on the y axis and frequency along the x axis.

The linear spectrum analysis for the pink noise shows little change in amplitude through 10,000 Hz. In other words, amplitude remains the same through the low, mid, and high frequencies. At ultra high frequencies (those above 10,000 Hz), the amplitude begins to decrease. By 20,000 Hz, the amplitude decreased by approximately 30 decibels compared to the lower frequencies. When the pink noise was presented at a set volume level, all frequencies through 10,000 Hz were represented at a nearly equal level while the higher frequencies were represented at a lower level. If examined over a longer period of time, peaks would even out and the spectrum would appear like a flat slope.

The linear spectrum analysis for “Boom Boom Pow” shows amplitude differences across frequencies. The largest amplitudes are located between 500 and 4000 Hz and energy decreases above 4000 Hz. The relative decibel scale shows that amplitude is approximately 30 dB lower in the highest frequencies compared to the mid and low frequencies.

Table 2.

Peak Sound Pressure Level (in dBA) of Five Songs at Nine iPod Volume Settings (in Percent)

	Song Title				
iPod Volume Setting	"Boom Boom Pow"	"I Gotta Feeling"	"Love Game"	"I Know You Want Me"	"Fire Burning"
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	56.2	49.2	49.6
100%	58.7	56.2	59.2	56.5	56.3

Note: Peak sound pressure level (SPL) recordings in dB A for five song clips ("Boom Boom Pow" by Black Eyed Peas, "I Gotta Feeling" by Black Eyed Peas, "Love Game" by Lady Gaga, "I Know You Want Me" by Pitbull, and "Fire Burning" by Sean Kingston) playing through standard iPod earbuds on a KEMAR mannequin recorded in quiet (31.6 dB(A) of ambient noise). Peak SPL was recorded 2 feet four inches from the mannequin at 0 degrees azimuth.

Table 3.

Free-Field Equivalent of Long-Term Average Amplitude Levels in dB(A)Measured in the Ear Canal at Nine iPod Volume Settings

	Song Title				
Volume on iPod (in %)	Boom Boom Pow	I Gotta Feeling	Love Game	I Know You Want Me	Fire Burning
0	36.8	35.9	36.0	36.6	36.1
12.5	49.3	45.3	42.7	43.8	44.5
25	55.7	51.8	48.5	50.0	50.8
37.5	63.4	59.1	55.5	57.3	57.9
50	70.2	65.5	62.0	63.9	64.8
62.5	77.9	73.5	70.0	72.0	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*	94.0*

Note: Free Field Equivalent (FFE) in dBA of long-term average amplitude levels measured in the ear canals at nine iPod volume settings for five song clips. Peak pressure levels were measured with standard iPod earbuds placed in the principle investigator’s ears using an Audioscan Verefit system. Asterisk (*) denotes long-term average amplitude levels exceeding 85 dB(A) FFE (potentially dangerous listening levels).

Table 4.

Audibility of Song Clips Played on iPod at Nine Volume Settings in Four Background Noise Conditions

		Volume Level in Percent on iPod								
Background Condition	Song Title	0	12.5	25	37.5	50	62.5	75	87.5	100
Quiet	Boom Boom	0	4	16	48*	49*	48*	49*	50*	50*
	Fire Burning	14	10	42*	47*	47*	47*	50*	50*	50*
	I Gotta Feeling	7	11	9	47*	49*	48*	49*	50*	49*
	I Know You…	5	13	30*	49*	46*	49*	50*	48*	48*
	Love Game	8	12	26*	47*	48*	48*	49*	50*	50*
45 dB(A)	Boom Boom	6	8	6	8	5	48*	47*	48*	48*
	Fire Burning	5	4	4	9	23	47*	48*	50*	48*
	I Gotta Feeling	8	7	3	7	5	26*	48*	49*	50*
	I Know You…	5	5	4	3	43*	49*	50*	45*	49*
	Love Game	3	3	6	3	10	48*	50*	49*	48*
60 dB(A)	Boom Boom	9	5	6	5	10	6	8	40*	50*
	Fire Burning	5	4	5	7	8	13	17	49*	49*
	I Gotta Feeling	8	9	3	4	9	10	3	27*	48*
	I Know You…	5	7	6	7	10	6	36*	47*	49*
	Love Game	6	6	7	7	10	4	11	49*	48*
75 dB(A)	Boom Boom	2	3	5	5	0	4	2	5	4
	Fire Burning	6	6	4	2	5	8	2	5	9
	I Gotta Feeling	8	2	6	3	3	3	7	2	2
	I Know You…	3	3	5	4	5	0	4	3	17
	Love Game	3	4	1	8	5	1	6	4	1

Note: Audibility judgments for five song clips ("Boom Boom Pow" by Black Eyed Peas, "I Gotta Feeling" by Black Eyed Peas, "Love Game" by Lady Gaga, "I Know You Want Me" by Pitbull, and "Fire Burning" by Sean Kingston) played at nine volume settings on the iPod (0%-100% volume) in four background noise conditions (Quiet (31.6 dB(A) ambient noise, 45 dB(A), 60 dB(A), and 75 dB(A) pink noise). The numbers represents "yes" responses out of 50 total participants. Asterisk (*) denotes song clip was audible $\geq$ 50% of participants.

Table 5.

Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) Combined by Condition

Condition	Sensitivity	Specificity	PPV	NPV
Quiet	0.99	0.33	0.30	0.99
45 dB(A)	0.97	0.63	0.43	0.99
60 dB(A)*	0.91	0.84	0.62	0.97
75 dB(A)	0.10	0.92	0.28	0.78

Note: Sensitivity, specificity, positive predictive value, and negative predictive value by background noise condition with songs combined using 85 dB(A) FFE cut-off value. Asterisk (*) denotes condition where best predictability was found.

Table 6.

Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) in Quiet Condition

Song Title	Sensitivity	Specificity	PPV	NPV
Boom Boom Pow	1.00	0.39	0.32	1.00
Fire Burning	1.00	0.27	0.28	1.00
I Gotta Feeling	0.99	0.63	0.43	1.00
I Know You Want Me	0.96	0.31	0.43	0.96
Love Game	1.00	0.28	0.15	1.00

Note: Sensitivity, specificity, positive predictive value, and negative predictive value based on participant responses in quiet background noise condition (31.6 dB(A) ambient noise) using 85 dB(A) FFE cut-off value.

Table 7.

Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) in 45 dB(A) Pink Noise Condition

Song Title	Sensitivity	Specificity	PPV	NPV
Boom Boom Pow	0.96	0.63	0.43	0.98
Fire Burning	0.98	0.60	0.41	0.99
I Gotta Feeling	0.99	0.70	0.49	1
I Know You Want Me	0.96	0.31	0.43	0.96
Love Game	0.96	0.57	0.37	0.97

Note: Sensitivity, specificity, positive predictive value, and negative predictive value based on participant responses in 45 dB(A) pink noise background condition using 85 dB(A) cut-off value.

Table 8.

Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) in 60 dB(A) Pink Noise Condition

Song Title	Sensitivity	Specificity	PPV	NPV
Boom Boom Pow	0.90	0.86	0.65	0.97
Fire Burning	0.98	0.83	0.62	0.99
I Gotta Feeling	0.75	0.87	0.62	0.92
I Know You Want Me	0.96	0.86	0.55	0.92
Love Game	0.96	0.75	0.32	0.99

Note: Sensitivity, specificity, positive predictive value, and negative predictive value based on participant responses in 60 dB(A) pink noise background condition using 85 dB(A) cut-off value.

Table 9.

Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) in 75 dB(A) Pink Noise Condition

Song Title	Sensitivity	Specificity	PPV	NPV
Boom Boom Pow	0.09	0.91	0.30	0.78
Fire Burning	0.14	0.91	0.30	0.79
I Gotta Feeling	0.04	0.91	0.11	0.77
I Know You Want Me	0.20	0.93	0.45	0.80
Love Game	0.02	0.92	0.03	0.80

Note: Sensitivity, specificity, positive predictive value, and negative predictive value based on participant responses in 75 dB(A) pink noise background condition using 85 dBA cut-off value.

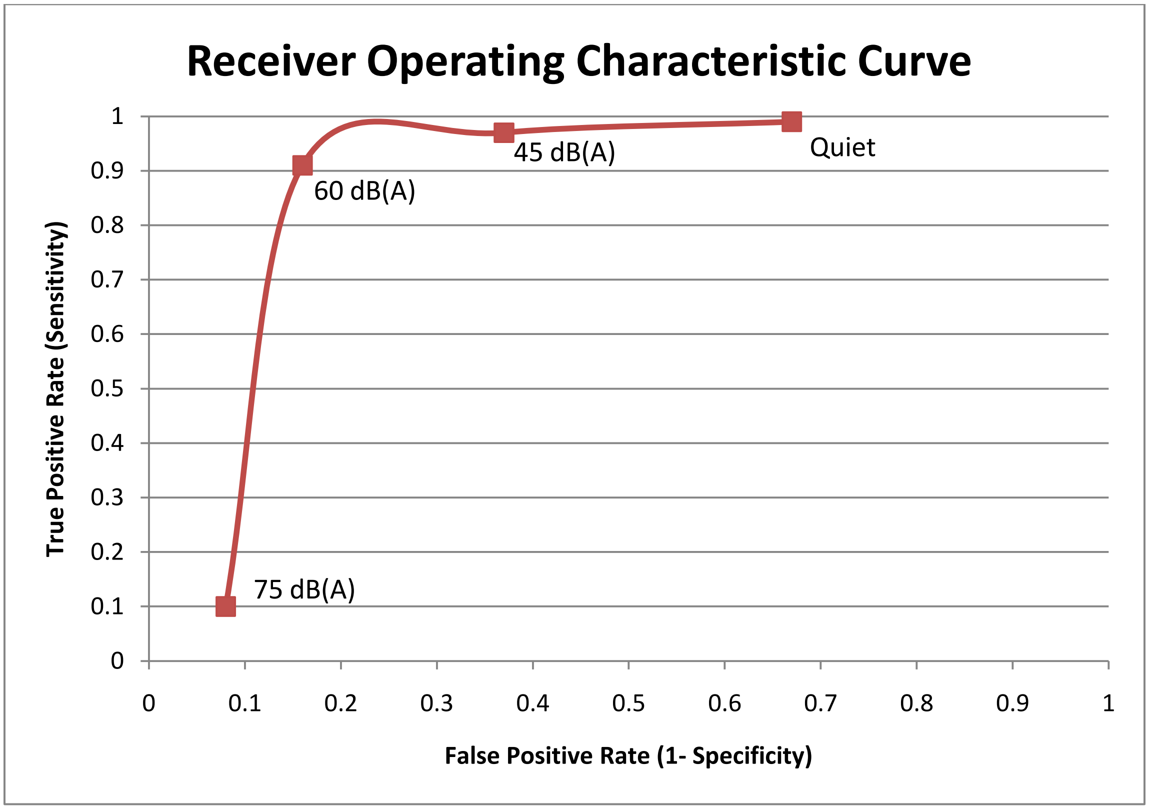

Figure 2. Receiver Operating Characteristic (ROC) curve for audibility of iPod playing at long-term average amplitude levels above 85 dB(A) FFE in four different background noise conditions: Quiet (31.6 dB(A) of ambient noise), 45 dB(A), 60 dB(A), and 75 dB(A) of pink noise.

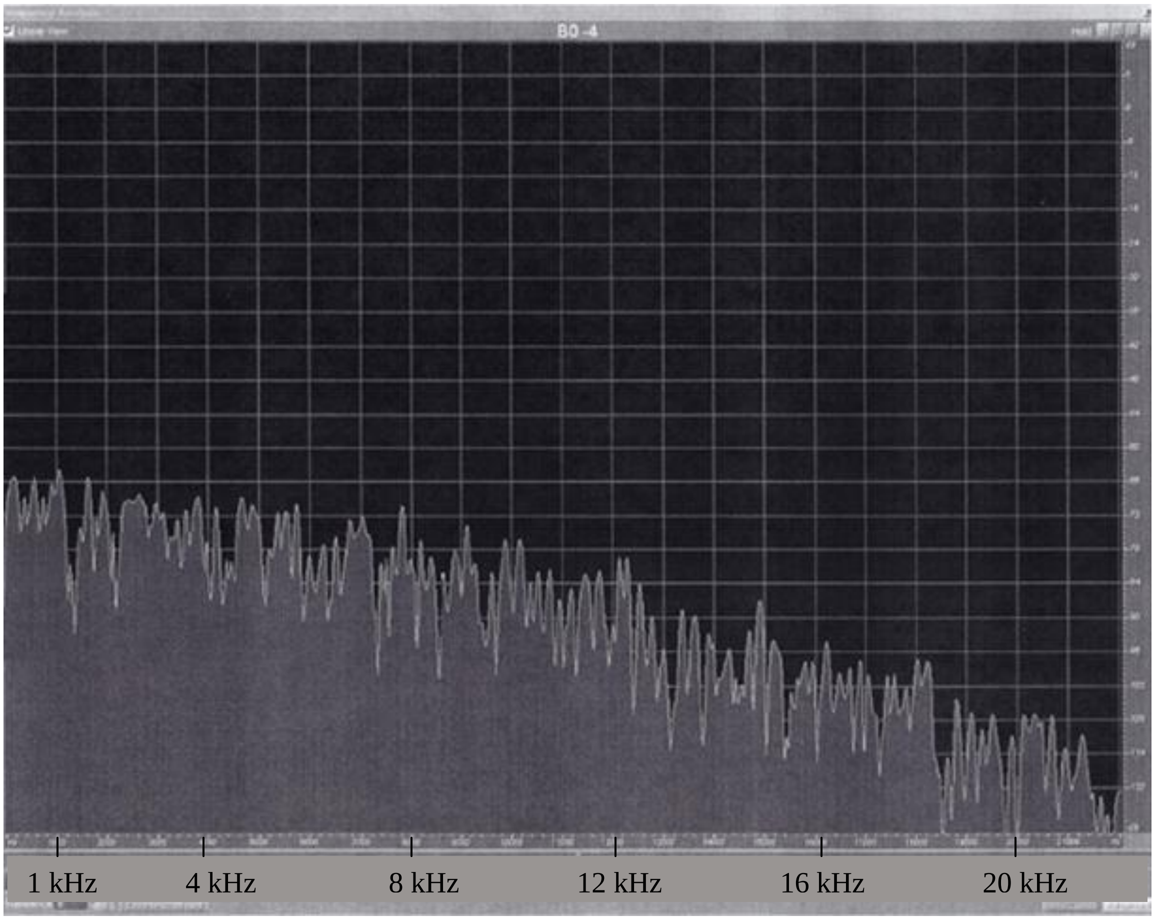

Figure 3. Linear spectrum analysis of correlated pink noise generated and analyzed through Adobe Audition 1.5. A relative decibel scale is displayed on the y axis in 6 dB increments and frequencies from 500 through 21,000 Hz are displayed on the x axis.

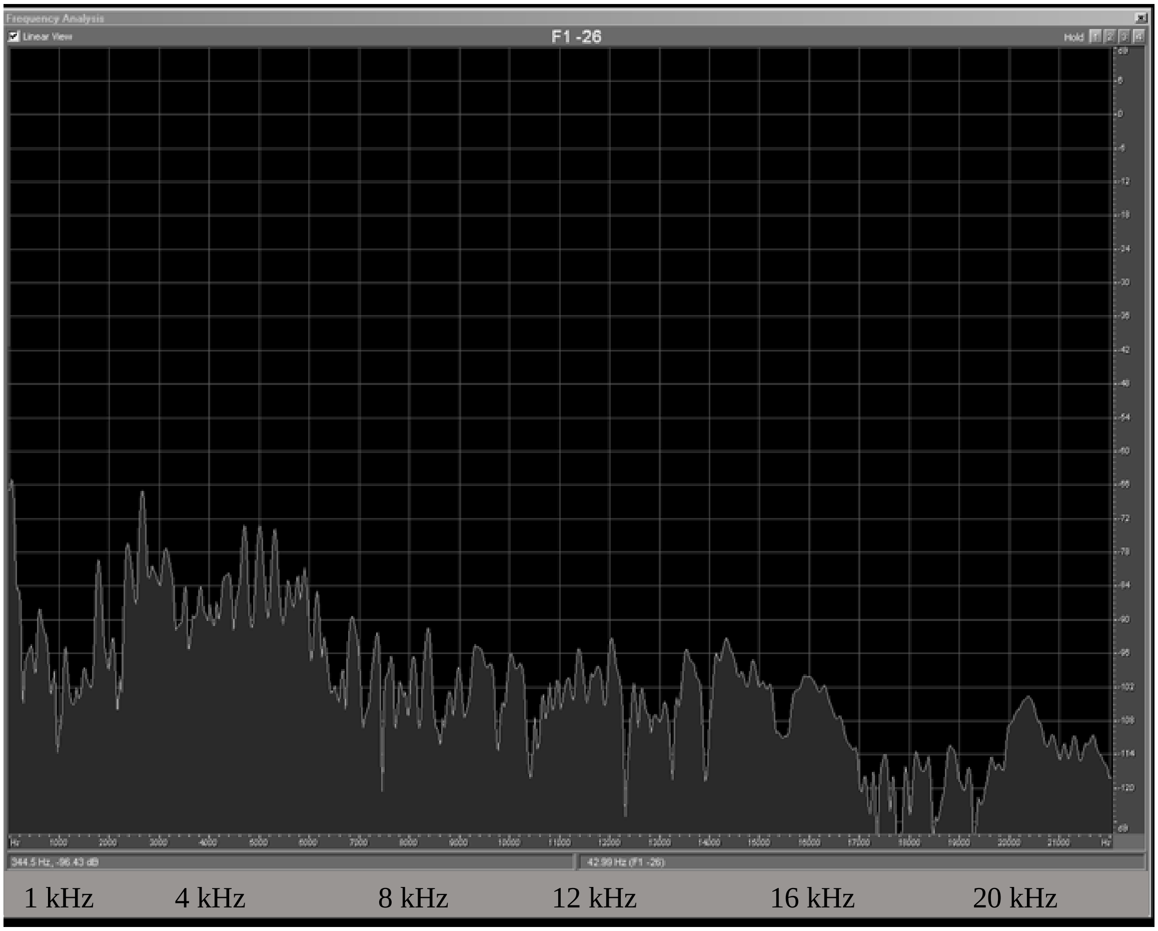

Figure 4. Linear spectrum analysis for music stimuli ("Boom Boom Pow") analyzed through Adobe Audition 1.5. A relative decibel scale is displayed on the y axis in 6 dB increments and frequencies from 500 through 21,000 Hz are displayed on the x axis.

CHAPTER 5

DISCUSSION

The purpose of this study was to determine whether the ability to overhear another individual's iPod is indicative of a dangerously loud listening level that could potentially be harmful to hearing. The answer to the question "If I can overhear someone's iPod, does that mean they are listening at a dangerously loud level?" may not be a particularly clear cut one. There are numerous factors that influence audibility of an iPod including volume setting on the device, song choice, and level of background noise. Each of these factors must be taken into consideration.

Dangerous Listening Levels

The first null hypothesis for the current study stated that all song clips with long-term average amplitude greater than or equal to 85 dB(A) FFE would be audible to participants. Considering the findings, the null hypothesis could not be rejected in favor of the alternate hypothesis for the quiet background condition, 45 dB(A) pink noise background condition, and 60 dB(A) pink noise background conditions. The null was rejected in favor of the alternative hypothesis for the 75 dB(A) pink noise background condition.

When participants were listening for music clips in quiet, and in soft and moderate levels of pink background noise, clips playing at long-term average amplitude levels greater than or equal to 85 dB(A) FFE were audible more than half of the time to all participants. In a previous study by Weiner, Kreisman and Fligor (2009), when an observer was listening for music clips from an iPod in a quiet background condition and 45 dB(A) pink noise background condition, the majority of trials playing at or above the 85 dB(A) FFE level were also audible. The previous study found that in the 60 dB(A) pink background noise condition, a few trials where songs were playing at levels above 85 dB(A) FFE were inaudible to the observer. Findings from the current study also showed that during a few of the trials in the 60 dB(A) pink noise condition, not all participants could overheard songs with long-term average amplitudes greater than or equal to 85 dB(A) FFE; however, the majority were audible.

Results from the current study revealed that when participants were listening for music in 75 dB(A) of pink background noise, none of the song clips were audible greater than or equal to half of trials. After examining the linear spectrum analyses of the pink noise and the music stimuli, it was determined that the song clips were completely masked by the noise. None of the song clips had peak outputs in SPL around or above the energy in the background noise when the noise was presented at 75 dB(A) and the signal to noise ratio was very poor.

Weiner, Kreisman and Fligor (2009) found that when an observer was listening for music stimuli in a 75 dB(A) pink noise background condition, some trials with long-term average amplitudes greater than 85 dB(A) FFE were audible to the observer. The audibility of certain clips was likely due to the fact that music stimuli levels were selected by participants long-term average amplitudes in dB(A) FFE for some songs in the previous study exceeded levels of 100 dB(A) FFE. The loudest song clips from the current study had maximum long-term average amplitudes of 95.8 dB(A) FFE resulting output differences of 5 dB or greater when compared to the previous study.

Volume Setting

The factor volume setting compared the audibility of each volume setting on the iPod. The null hypothesis for volume setting stated that participants would hear the music equally at all volume settings. Based on findings, the null hypothesis was rejected in favor of the alternate hypothesis. In other words, participants did not hear the music equally at all volume settings on the iPod.

When songs were presented at iPod volume percentages in quiet, songs were inaudible at 0 and 12.5 percent levels. At 25 percent volume level, only 3 out of 5 songs were audible in greater than or equal to 50 percent of trials. This indicated that songs are not equally audible across volume settings. When peak sound pressure level was measured for each song at each volume level, peak outputs varied from 31.6 dB(A) (essentially no change) at 0 percent volume level to 59.2 dB(A) at 100 percent volume level for one song playing at the highest volume percentage. This indicates that the higher the volume level, the more likely it is that a passerby will overhear the listener's iPod.

These findings are in agreement with previous findings from a study by Weiner, Kreisman, & Fligor (2009). Results showed that during all trials that were inaudible to the observer, music was playing at long-term average amplitude levels less than 85 dB(A) FFE. During trials where music was playing at levels greater than or equal to 85 dB(A) FFE, song clips were audible to the observer while during other trials songs were not audible. Findings from the current study show that all songs at volume levels greater than or equal to 85 dB(A) FFE were audible to participants greater than or equal to 50 percent of the time. Song clips played at lower volume levels were audible or inaudible depending on the background noise condition in which they were presented. Regardless, previous and current findings support the hypothesis that audibility is not equal at all volume settings.

Background Noise

The factor background noise compared audibility in each level of background noise. The null hypothesis for background noise stated that audibility would be equal in all background noise conditions. Based on the results of this study, the null hypothesis was rejected in favor of the alternate hypothesis. Findings suggested that audibility was not equal in all background noise conditions.

When participant responses to song clips played in the four background conditions, it is clear that the music is more audible in certain background conditions and less audible in others. In the quiet background condition (ambient room noise of 31.6 dB(A)), participants overheard the song clips at low volume settings on the iPod (between 25 and 37.5 percent). These are levels well below the 85 dB(A) FFE dangerous listening level. As background noise increased to 45 dB(A) and 60 dB(A) of pink noise, the ability to overhear the songs decreased. In the loudest background condition of 75 dB(A), songs were inaudible regardless of the volume level at which they were presented.

When listening in quiet, it is highly likely to overhear a person's iPod, even if they are not listening at a dangerously loud level. Sensitivity measured in this condition was high; however, specificity was very poor due to the high number of false positives in the quiet background condition. In other words, it is common to overhear the music in this condition even if the long-term average amplitude level of the song is below 85 dB(A) FFE. This was reflected by the low positive predictive value (PPV) for this condition, which was only 30 percent.

As background noise level increased, the PPV also increased; however, not greatly. In the current study, when music clips were presented 45 dB(A) pink noise background condition, positive predictive value (PPV) did increase in comparison to the quiet condition; however, it was still only 43 percent. Positive predictive value (PPV) was highest in the 60 dB(A) pink noise background condition. The PPV was 63 percent in this condition indicating that the test was accurate for overhearing songs with long-term average amplitude levels greater than or equal to 85 dB(A) approximately 2/3 of the time. This finding suggests that if you overhear someone's iPod in a 60 dB(A) pink noise background condition, there is a higher probability that the person is listening at a dangerous level compared to overhearing the iPod in the two quieter background conditions.

When listening for songs in the 75 dB(A) pink noise background condition, all song clips, regardless of presentation level, were inaudible to the participants. As stated previously, it was concluded that the song clips were completely masked by the noise as none of the song clips had SPLs that peaked around or above the energy in the background noise when the noise was presented at 75 dB(A). Therefore, using this screening tool in the 75 dB(A) pink noise condition was practically useless, because even songs with long-term average amplitude levels greater than or equal to 85 dB(A) FFE were inaudible to the participants.

These findings are consistent with findings from Weiner, Kreisman, and Fligor (2009). They determined that as background noise increased, audibility of music to the observer decreased. Positive predictive value (PPV) increased slightly and number of false positives decreased as background noise increased. They found PPV was greatest in the 75 dB(A) pink noise background condition. In the current study, findings showed that PPV increased as background level increased, but once the level reached 75 dB(A), PPV dropped substantially. This may have been due to the masking effects of the noise as pink noise exceeded even the highest peak sound pressure level by 15 dB(A). In addition, free-field equivalent (FFE) in dB(A) of music stimuli from the previous study exceeded that of the loudest song clips from the current study by 5 dB(A) FFE or more.

The results supporting that audibility is not equal across background conditions are agreement with findings from Ahmed, et al. (2007). Findings from that investigation suggested that listening levels increased as level of background noise increased. This suggests that audibility decreases when background noise increases.

Music Stimuli

The factor music stimuli compared audibility for each different song selection. The null hypothesis for music stimuli stated that audibility would be equal for all songs. According to results from this study, the null hypothesis was rejected in favor of the alternate hypothesis. The alternate hypothesis predicted that all songs would not be equally audible.

After examining participant responses, it was determined that audibility varies slightly between songs. Even though songs were equalized for overall RMS amplitudes, there were still slight differences in their peak sound pressure levels. This caused some of the songs to be more audible than others in certain conditions. For example, “I Know You Want Me” was audible to participants at lower volume settings than the others songs in the 45 dB(A) and 60 dB(A) background conditions. In quiet, “Fire Burning,” “I Know You Want Me,” and “Love Game” were all audible at 25 percent volume, while “Boom Boom Pow” and “I Gotta Feeling” were inaudible at the same level.

Study findings regarding music stimuli are supported in previous work by Thiery & Meyer-Bisch (1988). The previous study measured equivalent A-weighted sound pressure levels in an automobile workshop. They found that due to the overlaying impulse noises, differences in peak output levels and mean continuous output varied by as much as 27 dB(A). Similarly, the variance in peak sound pressure level between songs and song styles may contribute to the difference in audibility between songs, even though their continuous mean output is similar at equal volume settings. In other words, songs with higher peak levels may be more audible than songs with lower peak levels.

Study Limitations

There were a number of limitations to this study. One limiting factor may have been that the study was carried out in a sound treated test suite. Pink noise was used as the background noise, which created a very atypical listening situation. While participants were instructed to say “yes” only when they heard the song clip over the noise, the synthetic listening environment may have contributed to the high number of false positives in some of the conditions. The study only used ten second samples of each song (a sample of the chorus) in order to save time and to reduce participant listening fatigue. There is a possibility that the selected ten-second clips did not capture the loudest peak SPL from the entire song which could have potentially impacted results.

Future Directions

While in some ways, the current study confirmed the findings of the previous Weiner, Kreisman, and Fligor (2009) study, it is still unknown if these findings are applicable in real world situations. In a preliminary study by Ecos (2011), the ability to overhear iPods in “real world” noise settings including speech noise, restaurant noise, and airplane noise, was examined. Findings from this study may have more applicability to real life listening settings. It may also be of benefit to look at this study using different age populations. The study could be carried out with children and elderly adults to see if they are any age differences. While the current study used popular songs from iTunes as the music stimuli, it may be of interest to look at the audibility of songs from different genres of music. The songs from the current study were selected because they were well known, but were generally the same types of songs. In addition, the current study used an iPod Touch with standard iPod earbuds to assess audibility. In the future, it may be beneficial to look at different types of mp3 players and different styles of headphones to examine any differences in outputs.

Conclusion

The current study aimed to determine whether the ability to overhear someone else’s iPod was indicative of dangerous listening levels, or long-term average amplitude levels greater than or equal to 85 dB(A). The investigation determined that in a quiet listening setting, it is highly likely to overhear someone else’s iPod, however, the chance that the person is listening at a dangerous level is only 30 percent which is low. As background noise levels increase, the ability to overhear iPods generally decreases. Positive predictive value was higher in the louder conditions indicating that if a person is able to overhear someone else's iPod in noisy listening setting, it is more likely that the person is listening at a long-term average amplitude level greater than or equal to 85 dB(A) FFE. In the loudest background noise condition of 75 dB(A), the noise completely masked all of the songs rendering them inaudible to the listeners- even songs that were presented at levels greater than or equal to 85 dB(A) FFE. Overall, this study concluded that the ability to overhear someone else's iPod does not necessarily indicate they are listening at a dangerously volume level, and not overhearing someone's iPod does not necessarily indicate they are listening at a safe volume level.

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