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The effects of various modes of feedback on preferred iPod listening levels

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Abstract

The current study was conducted in an effort to promote safe listening habits of personal media player device users. Devices such as the iPod are known to have high output capacities well within the range of potentially hazardous sound levels, thus there is a concern that personal listening may pose a risk to hearing. Intuitive and real-time feedback representing the risk of hearing damage based on selected Preferred Listening Levels (PLLs) was provided to subjects they listened to an iPod. **Objective**: To provide listeners with tools to judge 'what is too loud' (and potentially damaging to hearing) so that they may use the knowledge to modify their listening habits to reduce their risk of noise-induced hearing loss. **Subjects**: Twenty, normal-hearing, young, female subjects participated in the study. **Measurements**: Ear canal sound level measurements were made of subjects' PLLs while listening to music in the presence of Visual, Vibro-tactile, and Auditory feedback and no feedback (used as a baseline). PLLs were separated into three sound intensity level categories; "safe" (<85dB SPL), "risky" (≥85dB SPL to <90dB SPL), and "unsafe" (≥90dB SPL), real-time feedback was administered according to the respective sound-level category. Subject's perceptions regarding influence, effectiveness and acceptability of feedback were also measured. **Results**: revealed lower PLLs for all feedback conditions relative to the no feedback condition, however only visual feedback resulted in significantly lower preferred listening levels ($p<0.05$). Visual feedback was shown to have the strongest influence on subjects' PLLs ($p=0.000$), and was perceived to be the most effective form of feedback to alert users to potentially hazardous sound levels ($p=0.007$). No form of feedback was significantly more acceptable to subjects (p=0.098). **Conclusions**: Results support the implementation of a Visual feedback system (into iPods) to alert users to hazardous PLLs to encourage safe listening habits. However due to general usage trends (iPods frequently being out of sight during use), the use of a multi-modal feedback system is suggested. Auditory and Vibro-tactile feedback could be easily detected even if an iPod is out of sight, could reduce PLLs or at a minimum alert users to attend to the Visual feedback.

Chapter I: Introduction

The increased portability and accessibility of personal music players has led to widespread use of these devices. Personal music players previously included portable cassette and compact disk (CD) players, however the majority of personal music players in use now are personal media players, often referred to as MP3 players. Personal media players, such as the Apple iPod, have become commonplace in daily activities such as housework, exercise, shopping, commuting, and while working. Personal media players have even been incorporated into many cell phones. In today's world it is difficult to go anywhere without seeing someone listening to some type of personal media player.

Despite their popularity, personal music/media players may pose some risk to consumers. It has been shown that many commercial personal music players have capacity to produced sound levels that are known to be hazardous to hearing (e.g. Fligor & Cox, 2004). Therefore use of these personal music devices may put users at risk, as they have the potential to cause permanent hearing damage. Additionally, the common activities and environments in which personal music players are typically used frequently contain excessive environmental noise. Add that to their capability to produce hazardous sound levels, resulting in dangerous combination. In the 2005-2006 the National Health and Nutrition Examination Survey (NHANES) (Shargorodsky, Curhan, Curhan, & Eavey, 2010), one out of five US adolescents 12 to 19 years old demonstrated hearing loss. Compared with results from the 1988-1994 NHANES, this constitutes a one-third increase in the prevalence of hearing loss (Niskar, Kieszak, Holmes, Esteban, Rubin, & Brody, 1998; Shargorodsky, et. al., 2010). Exposure to loud music via personal stereo devices may be a primary factor contributing to acquired hearing loss in adolescents.

The danger of this trend is increased risk for permanent hearing damage due to many interdependent factors involved with personal music player use. While many people tend to listen at safe sound levels regularly, factors such as the user selected volume level, the duration of use, and the listening environment, contribute to an individual's potential risk of permanent hearing damage during personal music player use. Some iPod users may be unaware of the potential damage caused by the hazardous sound levels based on their listening choices while listening with headphones, whereas others know of the potential damage and believe that they are selecting safe listening levels when they are not. The general public remains, for the most part, uneducated regarding what levels represent potential hazard to hearing and the accompanying negative consequences, such as temporary or permanent thresholds shifts and tinnitus, associated with the use of such devices (de Lourdes Quintanilla-Dieck, Artunduaga, & Eavey, 2009).

There have long been concerns regarding hearing and the use of personal music players. In the 1980's and early 1990's there were a number of research studies that examined the effects of the use of personal music players on hearing, and several studies determined that these effects were potentially hazardous to hearing (Catalano & Levin, 1985; Lee, Roberts, & Wald, 1985, Rice, Breslin, & Roper, 1987; Rice, Rosi, & Olina, 1987; Turunen-Rise, Flottorp, & Tvete, 1991). Mor recent research continues to support the potential risk (e.g., Fligor & Cox, 2004; Serra, Biassoni, & Richtert, 2005; Biassoni, Serra, & Richtert, 2005; Peng, Tao, & Huang, 2007). Conversely there have been other investigators who have challenged the idea that personal music players represent a hearing hazard, concluding that personal music players pose a low risk to hearing (e.g. Mostafapour, Lahargoue, & Gates, 1998; Williams, 2005; Torre, 2008; Epstein, Marozeau, & Cleveland, 2010). Regardless of the lack of consensus for risk, the statistics regarding hearing loss over the last twenty years are hard to ignore. Due to the coinciding trends, hearing loss and the increased prevalence of iPod and similar devices, many continue to speculate that increased exposure to loud music through the use personal music players may play a large role in the rise in hearing loss among the youth. Regardless of the magnitude of risk imposed by personal media devices, such as iPods, they may represent an excellent opportunity and means for providing education regarding hearing conservation. The widespread use of these devices, with their accompanying risk of noise-induced hearing loss, demand that the public and more specifically the individual users be educated about the safe use of these devices.

Chapter II: Review of Related Literature

Noise-Induced Hearing Loss

Hearing loss can be a direct result of exposure to noise. The term ‘noise-induced hearing loss’ (NIHL) is used to describe a permanent loss of hearing sensitivity due to noise exposure. NIHL can be the result of accumulated damage due to long term noise exposure, but it can also occur from a single exposure to excessive noise, or a combination of the two. A NIHL is comprised of a unique set of characteristics, including the permanent destruction of hair cells resulting in an audiometric high frequency sensory “notch”. This notch, often referred to as a ‘noise notch’, produces a specific pattern of reduced hearing sensitivity at 3000 Hz, 4000 Hz, or 6000 Hz with 10-15dB HL better hearing thresholds at adjacent frequencies (McBride & Williams, 2001). Hearing recovery at 8000 Hz, compared to the 3000-6000 Hz range, is helpful to distinguish NIHL from presbycusis or age-related hearing loss (Coles, Lutman, & Buffin, 2000).

Effects of Exposure to Hazardous Sound Levels

The hearing damage that occurs as a result of noise exposure is often gradual, but permanent, and can range greatly in severity and perceptual consequences. Several physiological changes can take place with hearing damage such as cochlear hair cell death, degeneration of spiral ganglion cells and the cell bodies afferent nerve fibers, and even changes within the central auditory nervous system (Clark, 1991; Kujawa & Liberman, 2006). These physiological changes can result in a loss of hearing sensitivity, tinnitus, poorer overall speech discrimination, especially in noise, all of which can have significant impacts on communication, a key component of human interaction. Additionally Kujawa and Liberman (2006; 2009) have shown that noise exposed ears are more vulnerable to age-related hearing loss, with early noise exposure leading to increased vulnerability compared to ears exposed to noise at later ages.

Individual Susceptibility

Many people regularly expose themselves to hazardous noise, knowingly or unknowingly putting themselves at risk for hearing loss, however the effects of exposure can vary from person to person. There are several factors that contribute to individual risk for hearing loss due to noise exposure including, ear canal resonance (Henoch & Chesky, 1999), frequency and duration of noise exposure, individual susceptibility to noise, and previous noise exposure at a young age (Kujawa & Liberman, 2006). Other factors contributing to the problem include poor awareness of several aspects regarding hearing including an understanding of risk criteria for hearing damage, the consequences of hearing loss, and necessary precautions to prevent NIHL. Recent surveys have shown a lack of concern for hearing among young adults, which has indicated a need for increased awareness and better education, and the need for hearing protection (de Lourdes Quintanilla-Dieck, et. al., 2009; Vogel et. al., 2008).

While most people are aware that exposure to very loud sounds can cause hearing related problems. People have experienced symptoms such as a decrease in hearing and even a high-pitched ringing sensation, tinnitus, following exposure to loud music, such as attending a loud concert. According to a recent survey (de Lourdes Quintanilla-Dieck, et. al., 2009) 38% of participants reported having experienced hearing-related problems following personal media player use, a significant increase from the prior survey investigated in the research.

While many only experience these hearing problems temporarily, therefore encouraging the belief that no permanent damage was done, recent research has shown otherwise (Kujawa & Liberman, 2009). According to Kujawa and Liberman (2009) parts of the ear do recover post-acoustic trauma however other areas show permanent damage post-exposure but the damage is not evident on physiological and/or behavioral test measures (pure tone audiometry, Otoacoustic emissions, or auditory brainstem responses testing) and the damage can continue for weeks to months after the initial exposure.

To summarize, the initial event of the noise exposure that incurs damage to the ear long precedes the ultimate consequences of the post-exposure damage. This concept is relatively new and seems to contradict the perception of the damage due to noise exposure. The conventional wisdom is that if the negative hearing consequences (i.e. tinnitus and temporary threshold shifts) following noise exposure dissipate shortly after exposure there was only temporary damage. This is not in fact the case with noise exposure, in reality, following an event of noise exposure permanent damage to the ear has occurred despite the fact that post-event hearing problems subside. This information is very important for prevention of noise induced hearing loss however it is for the most part unknown to the general public, demonstrative of the need for education in order to change the perception of noise exposure.

Permissible Noise Levels

The potential damage to hearing due to high level or excessive noise is not a new phenomenon. Accounts of terms to describe a hearing loss due to noise damage have existed as early as the 1700's. Ramazzini (1713, as cited in Public Health Service; Centers for Disease Control; National Institute for Occupational Saftey and Health, 1988) described a so-called '*blacksmiths' deafness*', due to hearing loss resulting from hammering metals. And in the 1800's the term 'boilermakers' deafness' was coined in Britain by Thomas Barr in order to describe a noise induced hearing loss (Bunch, 1948 as cited in Public Health Service; Centers for Disease Control; National Institute for Occupational Saftey and Health, 1988).

Steps have been taken in an effort to help prevent NIHL. In 1969 the federal government enacted the first standards for noise exposure in the Walsh-Healey Public Contracts Act Safety and Health Standards for Federal Supply Contracts (34 FR 7946-9, 1969) however the standards only applied to government funded projects. Shortly after the Occupational Safety and Health Act of 1970 established the Occupational Safety and Health Administration (OSHA) in order to protect workers from occupational hazardous, including noise exposure (36 FR 10518, 1971). The legislation set forth certain standards for levels of permissible noise for designated exposure times employers were required to comply within the work place.

United States governmental agencies, including the Occupational Safety and Health Administration (OSHA), the Center for Disease Control's (CDC) National Institute for Occupational Safety and Health (NIOSH), have set forth standards for limiting noise exposure in order to minimize risk. Though OSHA and NIOSH's recommendations are very similar, OSHA standards permit higher levels of exposure for longer periods of time compared to NIOSH's more conservative recommendations. The permissible exposure level (PEL) in the work place per OSHA is a time-weighted average (TWA) of 90dBA for an eight-hour period (OSHA, 1983). The same standard also states that exposure time should be cut by half each time the sound intensity level increases by 5 dB, this is known as an exchange rate (OSHA, 1983). This means that if the noise level of a work environment is 95 dBA (TWA) the maximum amount of time that should be spent in that environment is four hours, and for 100 dBA sound levels the exposure time should be reduced to only two hours. For an 85 dBA sound level OSHA permits an exposure time of sixteen-hours, whereas NIOSH recommends limiting exposure time to only eight-hours. This is because NIOSH recommends an 85 dBA level for eight-hours with a 3 dB time-intensity tradeoff (NIOSH, 1998). According to NIOSH's recommended exposure limit (REL), workers should only spend 15 minutes in an environment where they are exposed to 100 dBA noise levels, OSHA permits an exposure time eight times that with a maximum exposure time of two-hours for 100dBA levels.

There has been criticism of OSHA's standards in that they are too lenient for the purposes of preventing NIHL, and many organizations including the Department of Defense, the US Armed Forces (Army, Air Force and Navy) and The American Conference of Government Industrial Hygienists (ACGIH) have employed the 85 dBA exposure level as their own standard (ACGIH, 2000; Department of Defense, 1996). In addition, according to the World Health Organization (WHO) many other countries including but not limited to Finland, France, Germany, Hungary, Italy, the Netherlands, New Zealand, Norway, Poland, Spain, Sweden, the United Kingdom, all utilize an eight-hour average, A-weighted sound pressure level of 85dB with a 3dB exchange rate in order to minimize risk of occupational NIHL (Johnson, Papadopoulous, Watfa, & Takala, 2001).

Leisure Noise

Historically occupational noise exposure has been the primary cause of NIHL and OSHA safety standards have done a great deal to reduce NIHL. However those standards only apply in the work place. Unfortunately occupational noise is not the only source of noise exposure. So-called 'leisure noise', or 'recreational noise' exposure is becoming increasingly problematic. Numerous environments and activities that people regularly enjoy that have the potential to cause NIHL. For example, several hobbies such as skeet-shooting, hunting, riding motorcycles, playing in a band, metal and woodworking hobbies can all involve potentially hazardous sound levels (Fligor & Cox, 2004). Additionally there are several events and environments that can potentially expose attendees to dangerous sound levels such as, sporting events, concerts, bars/clubs, auto races, and mass transit. Unfortunately OSHA standards for permissible noise levels only pertain to the workplace environment; to date, the public is in need of protection from noise damage due to leisure noise.

Music Induced Hearing Loss

The hearing damage that can occur as a result of exposure to leisure noise, such as loud music at concerts, parties, clubs, and during personal music player use, is a growing public health concern. So much so that the hearing science and the public health world have introduced a new term, music-induced hearing loss (MIHL). The term music-induced hearing loss refers to an unconsciously, self-inflected, noise-induced hearing loss (NIHL) that results from excessive exposure to loud music (de Lourdes Quintanilla-Dieck, et. al., 2009). Although MIHL can occur as a result of exposure to various sources of loud music, the hearing damage specifically associated with personal music/media player use will be the primary focus of the current study.

Prevalence

Nearly 26 million American adults (aged 22-69) suffer from hearing loss that was likely due to noise exposure (U.S. Department of Health & Human Services; National Institutes of Health; National Institute on Deafness and Other Communication Disorders, 2008) There is mounting evidence to indicate an alarming shift in the prevalence of hearing loss in younger populations. There the two most recent National Health and Nutritional Examination Survey (NHANES) have provided shocking figures regarding the prevalence of hearing loss; NHANES III was conducted from 1988-1994, and the most recent was conducted from 2005-2006. According to the 2005-2006 NHANES the prevalence of hearing loss has increased by one-third among children ages 12-19 years in the United States, 16.4% presenting with NIHL (Shargorodsky et. al., 2010). The prevalence of hearing loss has changed dramatically, it is risen to 19.5% up from 14.9% in 1988-1994, representing a 31% increase in hearing loss (Shargorodsky, et al, 2010; Niskar, et. al., 1998). In addition to the overall increase in prevelance of hearing loss among America's youth, there was also a rise in severity of hearing loss. The prevelance of mild, or worse, hearing loss increased by 77%; 3.5% in NHANES 1988-1994, 5.3% in NHANES 2005-2006 (Shargorodsky, et al, 2010). Also, according to Henderson, Testa & Hartnick (2011) the latest NHANES survey (2005-2006) indicated that 34.8% of subjects reported some type of noise expoxure with in the previous 24-hours (including personal listening with headphones), which was up from only 19.8% in the previous NHANES study (1988-1994). Additionally, the prevelance of noise induced threshold shifts (NITSs) also increased between the two surveys. According to

NHANES 1988-1994, 15.9% of children suffered from noise induced threshold shifts (NITSs), that figure rose to 16.8% in the latest NHANES survey (Henderson, et. al., 2011).

The increased prevalence of hearing loss has forced many people to consider the role the personal music player in regards to hearing risk. Personal music players have been in use for several years but recent technological improvements have made it possible for these devices to deliver undistorted, high quality sound, even at high volume levels. When NHANES 1988-1994 was conducted, portable personal music player such as the Walkman cassette player and later the Discman compact disk player were in use. However when the most recent NHANES 2005-2006 was completed a much more sophisticated and portable personal music player had gained popularity, the personal media player.

Personal Media Players

The increased portability, and accessibility of personal media players, such as the iPod, has lead to widespread use of these devices. According to a recent survey conducted in 2007, the vast majority of respondents (75%) owned some sort of personal media device and 24% of subjects reported listening to the device more than 15 hours a week (de Lourdes Quintanilla-Dieck, Artunduaga, & Eavey, 2009). Personal media players offer several advantages over their predecessors. Compared to personal compact disk and cassette players the fully digital personal music player has many benefits including improved battery life, increased capabilities and superior portability. Overall, the newer personal media players tend to be lighter and there is no need to carry multiple cassettes or CDs along with you for prolonged listening and musical variety, personal media players have the capacity to store hundreds-to-thousands of songs right at users' fingertips.

Personal media players were a great technological advancement however there are some aspects of these devices that are very different from previous devices, and these changes have added to the potential risk for hearing damage. The increased access to an extensive supply and variety of music all in one place is very convenient, but it can also serve to increase listening duration. Before devices were able to store digital music files users could only listen to music uninterrupted for a limited amount of time as CDs and cassettes had limited storage space and therefore inherently put limits on uninterrupted music listening. Additionally, trends in headphone styles were also seen with personal media player use during the two surveys. Most personal cassette players and CD players were most often coupled to either supra-aural or circumaural headphones, however the latest trend for personal media players is an in-the-ear ('ear bud') headphone style. The change in headphone style to an in-the-ear style provides an opportunity for increased sound output of personal media devices.

There have been several studies investigating the maximum output levels of personal music players with stereo headphones, and results have shown that these devices are capable of producing sound levels from 91 dBA to 128 dBA (Wood & Lipscom, 1972; Katz, Gerstman, Sanderson, & Buchanan, 1982; Fligor & Cox, 2004). Fligor and Cox (2004) investigated the output levels of comercially available devices finding that output levels were between 91dBA-121dBA, peak sound pressure levels exceeded 130dB SPL for some devices, and the in-the-ear, or earbud, style headphones were capebale of producing output levels 7-9dB greater than earphones worn outside of the ear. According to the American Speech-Language and Hearing Association (ASHA) a 75% volume setting on an Apple iPod corresponds to approximately 109dBA (specifically, 107-111dBA), at full capacity the iPod was capable of producing levels as high as 125dBA (ASHA, 2006).

Knowing that many personal music and media players have capacity to produce sound levels that are known to be hazardous to hearing, it can be assumed that their use has the potential to cause permanent hearing damage. Combining their high-output along with the common activities and environments that iPods are typically used further increases the associated danger. While many people tend to listen at safe sound levels under a regular basis many factors such as the user selected volume level, the duration of use, and the listening environment, contribute to an individual's potential risk of permanent hearing damage during use.

The Effects of Listening Environments

There has been research demonstrating that people tend to listen at increased volume levels in the presence of background noise (Hodgetts, Rieger, & Szarko, 2007; Vogel, Burg, Hosli, Van Der Ploeg, & Raat, 2008; Fligor & Ives, 2006) thus increasing the potential risk to hearing. Many people report they knownily increase the volume of their music in order to override enviromental noise. According to a recent survey (de Lourdes Quintanilla-Dieck, Artunduaga, & Eavey, 2009) nearly 50% of participants indicated their prefered listening level was greater than 75% capacity, and 89% of respondents report increasing the volume level in the presence of loud enviromental sounds such as traffic. Other surveys have found similar findings. Vogel, et. al. (2008) interviewed adolecents in order to determine opinons and behaviors surrounding personal music players and exposure to loud music. According to their research many students expressed motives for listening to their music at high volume levels, the most frequent reason was to reduce background noise.

Hodgets et. al. (2007) investigated preferred listening levels in different listening environments using university faculty/staff members. Their findings indicated that listening levels were affected by the headphone style and environment while listening- chosen listening levels increased as environmental background noise increased (Hodgetts, Rieger, & Szarko, 2007). Fligor and Ives (2006) reported similar findings in doctoral students from their research that measured preferred listeing levels in quiet enviroments, where most subjects chose safe volume levels, and in 80dBA background noise (simulating an airplane cabin noise enviroment). In the noisy enviroment the majority of subjects wearing non-isolating earphones chose listening levels in excess of 85dBA; confirming that the level of background noise can impact preferred listening levels. Additionally Gordon-Hickey and Moore (2007) recently found that the acceptable noise level (ANL), defined as the maximum level of background noise one will accept while listening to speech, was considerably higher for music compared with other types of noise.

Listening Habits

The level of background noise is not the only determinent of risk, listeing duration is also a highly infulential factor. A recent survey conducted on a college campus indicated that the majority of students listened to personal media devices, with headphones, for at least 3 hours each day (Shah, Gopal, Reis, & Novak, 2009). The results of Shah et. al. (2009) are very similar to other reports of average listening habits. According to de Lourdes Quintanilla-Dieck, Artunduaga, & Eavey (2009) a recent survey reported many participants admited to listeing to their personal music devices for more than 15 hours per week, while Williams (2005) reported an average listening time of 2.38 hours per day. Torre (2008) examined the listening habits, including the volume settings and output of devices, average listening durations, common listening environments, of students at San Diego State University. Reported average listening times in the study were approximately 1 to 3 hours per day (Torre, 2008). Many of the students surveyed (41%) reported listening at loud or very loud volumes regularly, corresponding to approximate sound levels of 87.7dB SPL and 97.8dB SPL respectively (Torre, 2008).

The study conducted at San Diego State University also found gender to be potential contributors to individual risk. Torre (2008) found a significant gender effect, with men being more likely to listen at louder volumes for longer durations compared to the habits of females in the study. Others (Williams, 2005; Fligor & Ives, 2006; Ahmed, et al., 2007) have also found gender difference associated with preferred music listening levels, with females tending to select lower preferred listening levels compared to males.

Minimizing Risk

Considering personal listening devices represent a potential risk for noise-induced hearing loss, or music-induced hearing loss, it would be only fitting that certain precautions and recommendations were in place to help reduce this risk, right? It has been suggested that manufactures should be required to set a limit on the maximum output of personal listening devices (Biassoni et al, 2005). Although this would be very effective for minimizing risk, it would likely not be popular with users. Vogel et. al. (2008) reported adolescents' opinions regarding sound output limits on personal listening devices, however many subjects reported that they would not purchase a sound-limited device or would disable the sound-limiter (if it was an optional feature). Nearly all of the adolescents surveyed reported that they would like to decide for themselves how to use personal listening devices instead (Vogel et. al., 2008).

Another interesting finding of Vogel et al (2008) was the poor judgment of dangerous sound levels, subjects "showed no true understanding of how to determine which volume was too loud". This lack of understanding may explain the tendency of adolescents surveyed to underestimate their own vulnerability to hearing loss (Vogel et al, 2008). In contrast to the opinions of adolescents in Vogel et al (2008), a survey of adults conducted by Shah et al (2009) reported that 85% of adults were concerned about NIHL. According to the same survey, 77% of subjects indicated they were willing to listen to their devices at lower volume levels in order to protect their hearing (Shah et al, 2009). Despite the age-related difference of opinions regarding personal listening, there is one commonality- a need for education. Specifically, listeners need a way to better judge what volume setting on their device constitutes a "dangerous" sound level.

Applying Occupational Standards to Personal Listening

Another possible, and readily available, solution to minimize the risk for hearing damage is to apply the occupational noise safety guidelines to personal listening in order to determine safe listening durations for respective volume settings. This method would also provide listeners with a way to determine 'how loud is too loud?'. Others have attempted to apply these standards by generating theoretical noise doses based on the listening habits of iPod users. Recently Portnuff and Fligor (2006) used NIOSH's risk criteria for noise to estimate noise dose for iPod listening. They reported that an iPod set at a 70% volume level is safe to listen to for approximately 4.6 hours when listening with stock iPod earbuds (Portnuff & Fligor, 2006). Portnuff and Fligor (2006) also reported that when the volume is set at full capacity, 100% noise dose is reached after only five minutes of listening. It is not entirely unlikely that listeners choose to listen to their iPod at full capacity, however it is doubtful that the listening duration at that level is five minutes or less, therefore there is risk of hearing damage.

For the purposes of the present study the term iPod will be used as an umbrella term for personal media players.

Statement of the Problem

There are several measures that can be taken to reduce the risk of hearing damage in order to help prevent MIHL and the majority of which are simple strategies to modify behavior. The present study was conducted in an effort to promote safe listening habits of iPod users by giving them the means to judge 'how loud is too loud?'. This was accomplished by providing intuitive, and real time feedback regarding the risk for potential hearing damage based on volume selection. The research was inspired by a previously conducted study (Knox, 2009), which investigated a potential method for modifying listening behaviors. Specifically, a method by which the preferred listening levels (PLLs) of personal media device users may be positively influenced in order to reduce exposure to potentially hazardous sound levels.

Previous Research

Knox (2009) investigated the effects of visual feedback on preferred iPod listening levels, the research served as the basis for the current study. The results of Knox (2009) indicated that the presence of visual feedback significantly influenced PLLs, resulting in lower PLLs when the visual feedback was present compared to when no feedback was available. Though the results of Knox (2009) were significant, there were some limitations of the research. The primary weakness was the nature of the feedback used; while visual feedback was intuitive and effective, it may be considered impractical. The current study aimed to address the practicality surrounding the nature of the feedback, and certain subject limitations.

A power analysis of the Knox (2009) study found a large effect size (Cohen's d=1). Standard power analysis (Cohen, 1998), based on the previously identified a large the effect size indicated that total sample size of 13 subjects would be sufficient to detect a significant difference of the preferred listening levels in the different feedback conditions.

Objective

The present study was conducted in an effort to promote safe listening habits during iPod use by using various feedback modalities that were simple to interpret. Knox (2009) employed a visual form of feedback to indicate the "safeness" of the selected listening level. While the visual feedback proved effective, there is an obvious, but inherent problem with visual feedback- listeners are not always able to see the screen of their iPod® during use. A Visual Feedback system can only be effective if it is utilized properly. Considering general usage trends it is highly likely that iPods may be kept out of view while listening ultimately rendering visual alerts essentially useless. For that reason it is very obvious that visual feedback cannot always be an effective means for alerting users to potentially hazardous sound levels. To address this potential weakness the current study included two additional forms of feedback, auditory and vibro-tactile in addition to the visual feedback. These three modes of feedback, visual, auditory and vibro-tactile, provided the listener with a level of sound intensity and potential risk for hearing based on the current listening level selection. The criteria used to alert users to potentially risky listening levels was loosely based on NIOSH's damage-risk criteria. Each feedback modality was individually assessed in a laboratory in the presence of controlled background noise, as to simulate a possible real life noisy listening environment. The primary goal was to determine the efficacy of each mode of feedback. That is, does the presence of an indicator regarding the sound intensity level influence listeners' volume selection?

The present study will examine the effectiveness of the feedback modalities for reducing preferred listening levels (PLLs). The study will also compare the efficacy of the feedback modalities within themselves. If all modes of feedback are effective, are they equally effective? Individual perceptions regarding feedback acceptability, strength of influence, and strength of preference will also be assessed.

Research Questions

The following questions were addressed in the current study:

1. Does the presence of real-time feedback affect preferred listening levels (PLLs)?
    a. Which mode(s) significantly reduce PLLs?
2. How much do users believe each feedback modality influenced their PLL decisions?

3. Which mode of feedback do users perceive to be the most effective for alerting (them) to potentially hazardous sound levels?
4. Which mode of feedback was most acceptable to listeners (specifically, which would subjects chose for use in their own iPod)?

Hypotheses

The following null hypotheses were put forth for testing the above research questions.

Effects of real-time feedback on preferred listening levels:

H_0: The presence of real-time feedback does not affect preferred listening levels.

H_1: The presence of real-time feedback does affect preferred listening levels.

It was expected that iPod users' PLLs would be reduced if provided with feedback regarding potentially dangerous sound levels, compared to when no feedback was available.

H_0: The effects of real-time feedback on preferred listening levels are not significantly different.

H_1: The effects of real-time feedback on preferred listening levels are significantly different; specifically the effects of real-time Auditory feedback are greater than the effects of Visual and Vibro-tactile real-time feedback.

Though it was hypothesized that all feedback modalities would result in reduced PLLs (compared to when no feedback was present), however Auditory Feedback was expected to have the greatest effect on PLLs resulting in the lowest PLLs across all feedback conditions.

This hypothesis was formed due the disruptive nature of the Auditory Feedback. It was thought that the Auditory feedback modality would affect PLLs the most, resulting in the lowest PLLs, as its presence directly interfered with users' listening experience. The assumption being that it would be more difficult for listeners to ignore the distortion caused bye the presence of the Auditory feedback, which would contribute to a less enjoyable listening experience, therefore users would be likely to select lower volume levels in order to minimize the effects of the Auditory feedback, or avoid it entirely.

Strength of Influence

H_0: The influence of individual feedback modalities (on preferred listening levels) is not significantly different.

H_1: The influence of individual feedback modalities (on preferred listening levels) is significantly different; specifically, Auditory feedback has a stronger influence on preferred listening level decisions.

It was hypothesized that the Auditory Feedback would be perceived to have the strongest influence on subjects PLLs because it directly interferes with users' listening experience. It was presumed that the nature of the interference posed by Auditory feedback would strongly influence users to adjust their listening levels so that the feedback would not cause listening disruptions.

Perceptions of Effectiveness and Acceptability of Feedback Modality:

H_0: There is no significant difference between the effectiveness of feedback modalities for alerting listeners to potentially hazardous listening levels.

H_1: There is a significant difference between the effectiveness of feedback modalities for alerting listeners to potentially hazardous listening levels, specifically Auditory feedback is perceived by listeners to be more effective than Visual and/or Vibro-tactile feedback.

H_0: There is no significant difference in the acceptability of feedback modalities.

H_1: There is a significant difference in the acceptability of feedback modalities specifically; Auditory feedback is not an acceptable form of feedback.

The expectation that the Auditory feedback would be perceived as the most effective for alerting listeners to hazardous sound levels was, again, based on the disruptive nature of the feedback modality itself. Although the Visual and Vibro-tactile feedback modalities relay the same information regarding potential listening hazard, the feedback modalities do not directly disrupt, or detract from, the listening experience as the Auditory feedback does. For the same reasons, it was presumed that the Auditory feedback would not be perceived as an acceptable form of feedback, whereas the Visual and Vibro-tactile feedback modalities were expected to be equally acceptable.

Chapter III: Methodology

Research Design

The present study was designed to investigate Preferred Listening Levels (PLLs) of iPod users in the presence of feedback of the sound level of the music, compared to the PLLs measured in the absence of feedback. The study was conducted as a within-subject, repeated measures, experimental research design, with the independent variable existing as the feedback condition and the dependent variable being the resulting PLL. There were a total of four conditions -- three "feedback conditions" (visual, vibro-tactile, and auditory) -- and a "no feedback" condition to serve as the baseline for the experiment.

Counterbalancing was also used to eliminate any effects of order. Specifically, the sequence of the experimental conditions subjects participated in during each session was pre-determined at random. Subjects were all assigned a participant number in Microsoft Excel, and a random number generator was used to randomly determine the order of each subjects' conditions. There were six different condition sequences of which subjects were randomly assigned. During the first of three sessions, subjects were exposed to two conditions, the control "no feedback" condition and one pre-determined experimental "feedback" condition. Subjects were tested on the remaining experimental "feedback" conditions over the next two sessions, again as predetermined and randomized.

Subjects

Twenty-four subjects volunteered for the study, a total of twenty subjects completed the study. All subjects were female, between 19 to 22 years old (mean age: 20.6 years). Just as was done in the previous research conducted by Knox (2009), female subjects were used exclusively in this study due to previously identified gender differences associated to PLLs. According to previous research (Williams, 2005; Fligor & Ives, 2006; Torre 2008) female listeners tend to select lower preferred listening levels than male listeners. Students enrolled in the Communication Sciences and Disorders major were not permitted to participate in the current study, as this was a weakness identified in the pilot study (Knox, 2009). Specifically students enrolled in the CSD major were more likely to have a greater than average knowledge of hearing-related information, potentially biasing the subjects' listening decisions during the study. In addition to the aforementioned requirements, subjects were also required to have normal hearing and an unremarkable otologic history evidenced by a case history questionnaire, otoscopy, middle ear assessment, and pure tone audiometry, in order to be a research subject. For the purposes of this study, normal hearing was defined as pure tone thresholds no worse than 25dB HL at octave frequencies from 250Hz to 8000Hz bilaterally.

Subject Selection

Initial subject selection was based on a Music Preference Survey, which can be found in Appendix B. Individuals interested in participating in the study were given a survey regarding their music preferences. Seven songs where chosen from the 2012 Grammy Nominees CD, as that CD was representative of current popular music across several different musical genres (alternative, country, pop, rock and alternative). Potential subjects were asked to rate their preference for each the seven songs included in the survey. The seven songs were as follows;

1. "Rolling in the Deep" by Adele

2. “Grenade” by Bruno Mars
3. “Moves Like Jagger” by Maroon 5
4. “You and I” by Lady Gaga
5. “Pumped Up Kicks” by Foster the People
6. “Mean” by Taylor Swift
7. “Super Bass” by Nicki Minaj

A visual analog scale (11 centimeters long) representative of ‘really dislike’ on the far left and ‘really like’ on the far right was used to indicate song preference. The directions instructed potential participants to make a tick mark along the scale to indicate their preference for each song. At least one song choice had to be rated as a “like” to be considered for inclusion. A “like” was defined as a mark along the right half of the visual analog scale. The assumption being that subjects are more likely to select a listening level consistent with their regularly preferred listening level if they listen to songs they enjoyed. Naturally, the preferred listening level for music that a listener truly dislikes is “off.”

Procedure

Subjects that were deemed potentially eligible to participate in the study by the subject selection survey attended an initial research session. At the first session, potential subjects completed a pre-participation evaluation to determine if they were qualified to further participate in the study. This required the completion of an informed consent form (Appendix A), consenting to participate in research, a questionnaire regarding otologic case history (Appendix C), and an audiologic evaluation.

Pre-trial Assessments

Potential research subjects were asked to fill out a short questionnaire (Appendix C) that included questions regarding their ear and hearing health and history including tinnitus, recent noise exposure, prior ear infections, prior ear surgeries, and prior hearing loss. Additionally the questionnaire included a question regarding the presence of any current hearing difficulties or congestion such as a head cold or a 'clogged feeling in the ears', as to indicate the possibility of a temporarily compromised middle ear system. The presence, or absence of a middle ear problem was then confirmed by otoscopy and tympanometry, which were performed after the questionnaire.

Otoscopy was completed using a Welch Allyn diagnostic otoscope prior to any and all measurements made during research sessions. The external ear canal was visually inspected to ensure that excessive cerumen was not present, as it could interfere with sound level measurements, and that the overall appearance of the canal and tympanic membrane was unremarkable. Following otoscopy tympanometry was performed using a Grason Stadler Instruments TympScreener (GSI-37; SN: 20020129; Cal. 9/8/11). Tympanometry measures were required to be considered within normal limits. Specifically, for the purposes of this study, normal tympanometry results were evidenced by static compliance between 0.4mL and 1.0mL and normal middle ear pressure between +50daPa and -50daPa. Hearing sensitivity was measured bilaterally at octave frequencies between 250Hz and 8kHz using a modified Hughson-Westlake technique in a double-walled sound treated booth using a calibrated (ANSI S 3.21, 2004) Beltone AudioScout portable audiometer. Once subjects completed the collective pre-trial assessments they were able to participate in the sound level measurements of the study.

Music

The seven songs used in this study were individually manipulated using Cool Edit Pro computer software. Manipulation of the digital music files was necessary for several reasons. First, each song file was edited as to only include the chorus (and bridge, if present) of the song so as to create a more stable music sample (such as a soft introduction). This modification was recommended by the previous researcher as Knox (2009) observed a subject tendency to select PLL within the first 10 seconds of the song, often long before the music selection reached the more stable chorus section. Next, the overall root-mean-square (RMS) amplitude of each music sample was normalized resulting in same overall RMS.

In addition to the seven music files an eighth sound file was digitially created. A 10-second, 1000Hz calibration tone was created in Cool Edit Pro and saved as an MP3 file. The sound intensity of the calibration tone was manipulated so that it was equal to the same overall RMS level of the music samples. The 1000Hz calibration tone was created to represent the overall RMS level of the music sample once subjects had selected their preferred listening level. Subjects selected their PLL while listening to the music sample they had selected, after which the RMS level in the ear canal was determined for the calibration tone and this became the metric used in the subsequent analysis.

Once the normalization process was completed the eight digital music files were saved as MP3 files and were downloaded into iTunes software where they were eventually uploaded to an Apple iPod Classic. The iPod was then coupled to a transducer (standard Apple iPod earbud earphones).

Instrumentation

All data collection took place in the sound booth with the following equipment; an Etymotic Research ER-7C probe microphone system, a National Instruments SCXI-1303 Signal Conditioning module housed in a SCXI-1000 Chassis, a Dell Optiplex GX280 computer, an Apple iPod Classic and a custom-made vibration device and a custom-made auditory signal regulating device. During sound level measurements the probe microphone was located in the subjects' ear canal, while the pre-amplifier coupled to the probe microphone was suspended from subjects' ears. The microphone system recorded ear canal sound levels and transferred data to the computer via the signal conditioning module. Data was processed using LabVIEW 8.2 software, which also provided sound level information visible to the researcher. The LabVIEW software was also used to provide subjects with the appropriate feedback during each research condition.

Two LabVIEW programs were created in order to deliver the various modes of feedback - they differed on whether they presented auditory or vibro-tactile feedback. One program was designed to display sound level information, visual feedback or deliver auditory feedback. The second program was also able to display sound level information, visual feedback, or vibro-tactile feedback depending on the selected screen tab. Specifically, three tabs were present on the researcher's screen in both programs; the first tab displayed sound level information, the second tab was used to provide visual feedback while the third tab was used either to provide vibro-tactile feedback or auditory feedback. See Figure 1 for a screenshot of the LabView software in use, the three tabs are circled in red.

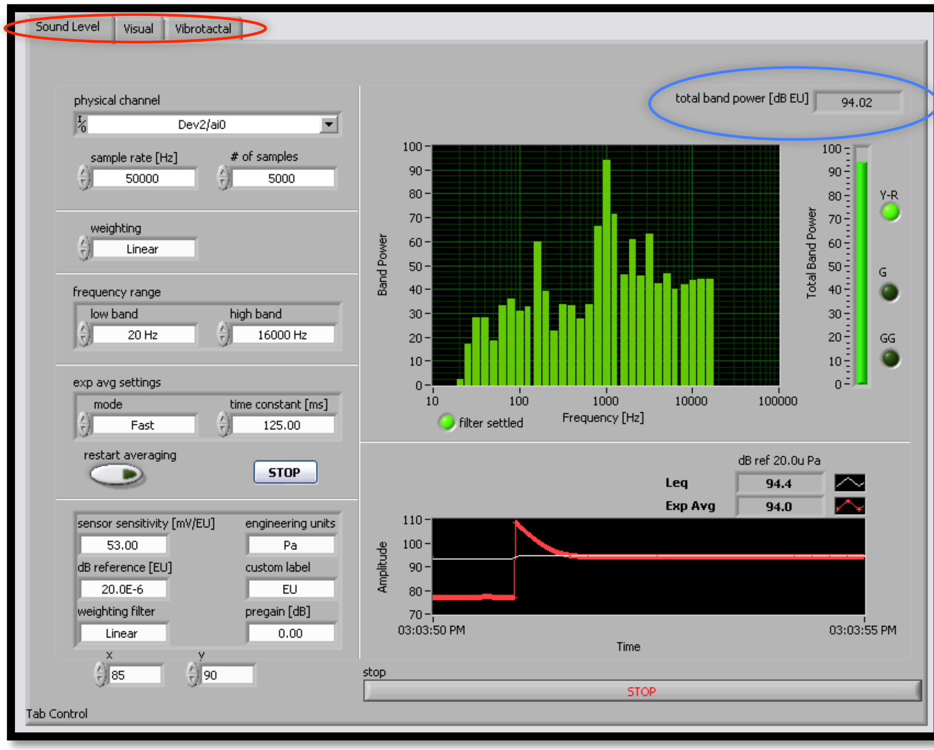


Figure 1. A screenshot of the custom Sound Level Meter based on LabView platform. The display tabs for feedback and sound level information can be seen within the red circled area. The blue circle displays the average RMS sound level information.

	Visual FB	Auditory FB	Vibrotactile FB
Safe (< 85 dB SPL)		No interference	No interference
Risky (85-90 dB SPL)		Minor interference in the music (audio cut out)	Minor interference (few vibration pulses)
Unsafe (>90 dB SPL)		Intense interference in the music (audio cut out)	Intense interference (more frequent vibration pulses)

Table 1. Summary of modality specific feedback based on listening levels.. It describes the modes of feedback (visual, auditory, and vibro-tactile), the SPL at which feedback was administered, and describes the feedback for a given criteria. Visual feedback consisted of a large colored sphere on a computer screen visible to subjects. The sphere was green for sound levels below 85dB SPL, yellow for sound levels 85-89.9 dB SPL, and red for levels greater than 90 dB SPL.Minor interference in the auditory feedback mode was characterized by the music cutting in and out twice per second, each time for approximately 1.5 milliseconds, and intense interference was characterized by the music cutting-in and out five times per second, in 1 millisecond intervals. In the vibro-tactile feedback condition, intense interference was characterized by several intense vibrations rapidly delivered and the minor interference pattern was characterized by relatively weak vibrations delivered slowly.

During the Visual Feedback condition a secondary computer screen was visible to subjects to provide the visual feedback, this information was also displayed via the LabVIEW software. See Table 1 for a summarized view of the descriptions and presentations levels for the feedback modalities. In the Vibro-tactile Feedback condition LabVIEW data was sent from the computer to the SCXI signal conditioner to the vibration device that was positioned on the back of the subjects' hand, held in place with a Velcro strap, to provide the vibro-tactile feedback. In order to provide auditory feedback LabVIEW data was sent from the computer to the SCXI signal conditioner to the auditory signal regulating device coupled to the iPod via one port and the earphones via the second port. (See Figure 2 for a block diagram display of the instrumentation setup. See Figures 3, 4, and 5 for photos of the feedback systems in use. See Appendix F for additional photos of instrumentation.)

Both programs created in LabVIEW analyzed the incoming data to determine the sound intensity level as it was recorded in the ear canal in real time. The resulting RMS level was displayed on the sound level tab on the researcher's monitor. See Figure 1 for an example of the researcher's view of the LabView software, the resulting RMS level is circled in blue.

The software was programed to analyze the incoming signal and instantaneously categorize the sound measurement according to the intensity level. Sound levels equal to or greater than 85dB SPL indicated a need for feedback while no feedback was indicated for levels less than 85dB SPL. Incoming signals that triggered feedback were also analyzed in terms of their sound levels so that they could further be divided into two categories. This was accomplished using two sound intensity threshold levels: 85dB SPL and 90dB SPL. That is sound levels between at or above 85dB SPL but below 90 dB SPL activated the first level of feedback and sounds at or exceeding 90dB SPL activated the second level of feedback. This ultimately resulted in a total of three categories of sound levels reflective of individual risk to hearing as determined by their volume selection at that moment. For the purposes of this study, the sound level categories were labeled as followed; "safe" (<85dB SPL), "risky" (≥85dB SPL to <90dB SPL), and "unsafe" (≥90dB SPL). (See Table 1 for a summary of the individual feedback modalities along with the respective presentation levels.) These sound level categories were chosen to be roughly equivalent to OSHA and NIOSH's permissible 8-hour exposure levels (OSHA, 1983; NIOSH, 1998).

All feedback was administered according to the real-time sound level measurements from subjects' ear canals. When the LabView software measured a sound level to be in the potentially hazardous or "risky" category, the first level of feedback was delivered. When the sound intensity in the ear canal exceeded 90dB SPL, the second level of feedback, "unsafe" was administered.

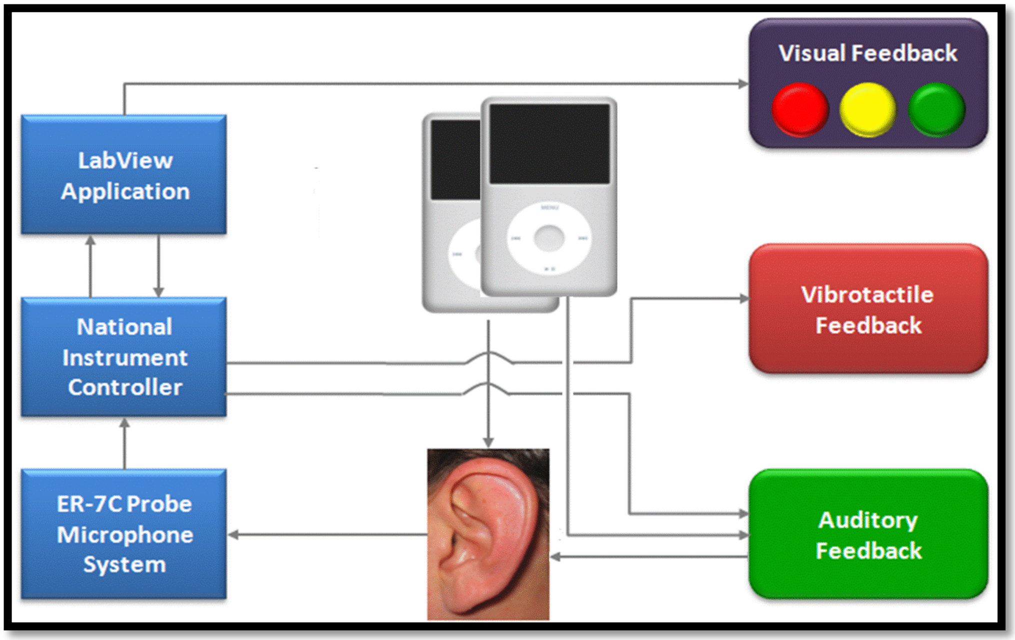


Figure 2. *Block diagram of the instrumentation set up*

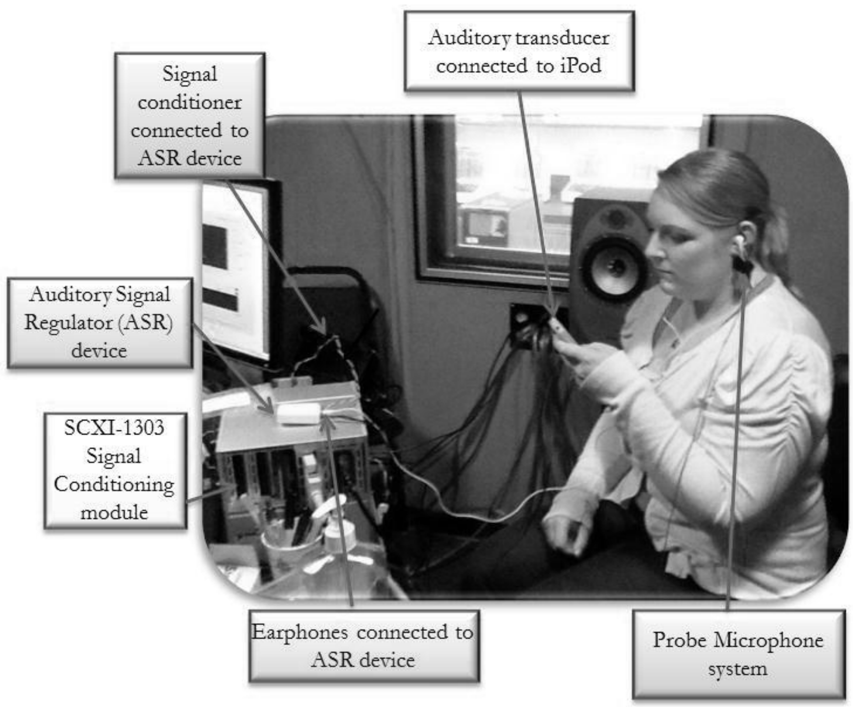


Figure 3. *Hardware set up for Auditory Feedback*

Figure 4. Vibro-tactile Feedback System.
Subject using the Vibro-tactile Feedback system; device attached to the back of the same hand used for adjusting the iPod

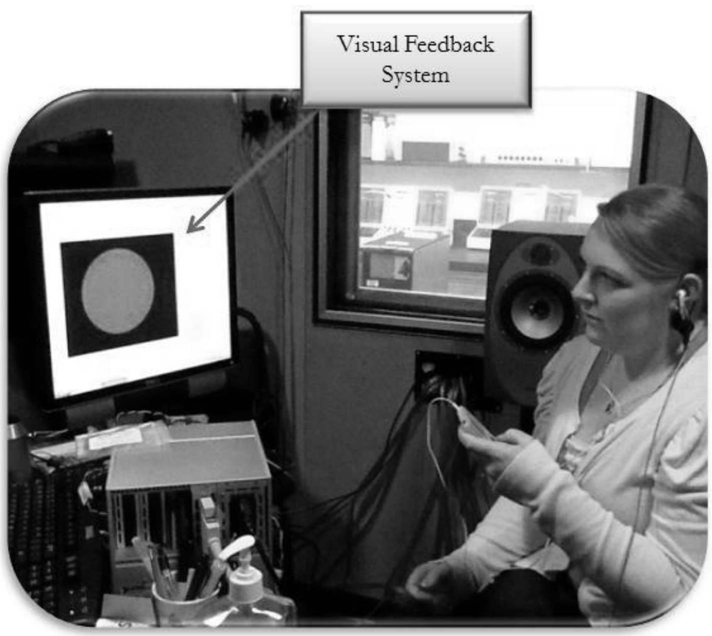


Figure 5. Visual Feedback system.
Subject using the Visual Feedback system; a computer screen with the color-changing sphere positioned in front of subjects

Background Noise

Artificial background noise was presented in the soundfield during all measurement sessions in order to simulate a real-life listening environment. The background noise, 6-talker speech babble, was presented through a Tannoy System 600 loudspeaker in the test booth from a Harman Kardon CD player located outside the testing booth. The speaker was set up inside the booth so that it was positioned approximately 20 inches from the where the subjects' head would be located during measurement sessions, located at 180 degrees azimuth. Prior to data collection, the artificial background noise was calibrated to a level of 80 dB SPL at the approximate location of where subjects' head were to be during measurement sessions. The level of the background noise was chosen to be 80dB SPL to create a realistic listening environment, as determined by the environmental noise levels that were measured in public areas by Williams (2005) while researching listening levels of personal music players in those public areas. Additionally, previous studies examining listening levels in noisy environments (Knox, 2009; Fligor, 2007) also used 80dB SPL to simulate real-world background noise.

Calibration

The background noise was calibrated at the approximate level of the subjects' head and ear canal using a portable Quest Electronics 215 sound level meter to verify the background noise was delivered at an average level of 80 dB SPL. The probe-tube microphone measurement system was calibrated prior to data collection, and the accuracy was assessed prior to each measurement session. Calibration of the probe-microphone measurement system was completed using the built-in calibration device of the pre-amplifier of the ER-7C probe microphone system. The probe tube microphone was placed inside the built-in calibrator as it produced a 94 dB SPL, 1kHz, pure tone. The sensor sensitivity setting for the analysis of the recorded signal was then adjusted on the LabView software program, where data analysis occurred, until the measured sound level matched the level of the calibrator output in order to ensure accuracy of the measurement system.

Data Collection

Each subject participated in a total of three separate measurement sessions, each lasting approximately 10-25 minutes. A time gap of at least 24 hours was required between sessions in order to reduce direct influence of a condition on future measurements.

During the first session subjects participated in two research conditions; the control and one feedback condition. The subsequent measurement sessions only consisted of only one feedback condition in each session. Preferred listening levels (PLLs) were obtained in each condition while subjects listened to an iPod playing the song for which they had awarded the highest rating on the Subject Selection Survey; their single song choice was used for all conditions.

Subjects were provided written instructions for the specific feedback condition depending on the predetermined sequence of conditions for that subject; auditory feedback, visual feedback, or vibro-tactile feedback. In the No Feedback condition the directions for whichever Feedback condition the subject would be exposed to directly following the No Feedback condition. Subjects were permitted to keep the directions throughout the measurement session. Once subjects acknowledged they had read the directions, and the researcher answered any questions, the sound level measurement process began.

A silicone probe tube, attached to the probe-microphone system, was inserted into the subjects' left ear canal. The research space was configured in such a way that only subjects' left side was easily accessible. In order to ensure proper insertion depth for measurement, the probe tube was inserted into the ear canal so that the designated marker (located 25mm from the inserted tip) was in line with subjects' intertragal notch. Once the probe-tube was properly placed, subjects were asked to place the insert earphones into their ears, while ensuring that the probe tube was not dislodged from the left ear canal. The experimenter verified that the insert earphones and probe tube were properly positioned before moving to the next step.

Following placement of the probe tube and earphones subjects were handed the iPod and the background noise was turned on. The researcher set the volume level of the iPod to 50%, in the middle, prior to giving subjects the iPod. Subjects were instructed to press play once the background noise started, adjust the volume of the iPod to select their preferred listening level (PLL), then raise their hand to signal when their volume selection was complete. While there was no explicit time limit given for subjects to choose their PLL there was however an implicit time limit of the duration of the music clip for making a decision. There were no instances for which a subject was not able to determine their PLL within the duration of the music clip.

After subjects signaled their final selections, the researcher obtained the PLL via probe microphone measurements of the sound level of the calibration tone at the volume level that had been selected by the subject. The recorded sound level, displayed in the Sound Level tab in LabVIEW, represented the overall RMS sound intensity subjects would be exposed to if they listened to the music sample in its entirety at the corresponding volume they selected.

The first condition, known as the "no-feedback" condition, served as the control. Once sound intensities were measured in the No Feedback condition, subjects participated in one experimental feedback condition. The measurement procedure was the same as that used as in the control condition measurement. The subsequent sessions were conducted in the same manner with the exception that prior to the sound level measurements subjects were only required to participate in the pre-trial survey, and only one feedback condition of which they had not yet participated.

Follow-up Survey Questions

At the end of the final session subjects were asked to complete a Post-Trial Survey (Appendix D). Subjects were asked if at any point their volume selections elicited feedback in any of the conditions. Three dependent variables were obtained from these post-trial surveys: strength of preference influence, perceived effectiveness, and perceived acceptability. Strength of influence was assessed by having subjects indicate the amount of influence of each feedback modality had on their selected listening level along an 11-centimeter visual analog scale from no influence to strong influence on an 11-centemiter visual analog scale (items 1b, 2b, and 3b on post-trial survey). Markings were measured by distance (in centimeters), the farther the marking was along the scale the stronger the influence; the left of the scale represented no influence while the right end of the scale was representative of strong influence. The distance measurement of the feedback modality indicating the strongest influence was recorded as the strength of influence measurement. Perceived effectiveness was measured by having subjects indicate which mode of feedback they believed to be the most effective for alerting them to potentially hazardous listening levels (item 4 on post-trial survey). Perceived acceptability was measured by asking subjects, “If this were your iPod and your music, which mode of feedback (visual, auditory, or vibro-tactile) do you think you would find most acceptable to alert you to potentially hazardous listening levels? That is, if you had the option of any one of these modes of feedback on your own iPod, which would you choose?” (item 5 on post trial survey). Enough space was provided for subjects to include an explanation of their choice if desired for the questions (items 4 and 5 on the post trial survey).

Chapter IV: Results

Data analysis was performed on the measurements obtained from twenty subjects that participated in the study. Measurements of subjects' preferred listening levels (PLLs) in each feedback condition, subjects' individual ratings of influence for each feedback modality (strength of influence), and subjects perceptions of feedback efficacy and acceptability (perceived effectiveness and perceived acceptability), were used to address the research questions being investigated in the present study. An alpha level of .05 was used as the criteria for significance for all statistical measures used, resulting in a 95% confidence interval.

Preferred Listening Levels

The preferred listening levels (PLLs) ranged from 79.08 to 100.83 dB SPL with an average PLL of 85.12 dB SPL (SD= 6.15) in the No Feedback condition. Mean PLLs of the feedback conditions were 83.05 dB SPL (range = 75.70 - 97.73; SD=6.10) for Visual, 83.32 dB SPL (range = 76.54 - 96.18; SD=6.03) for Vibro-tactile, and 83.61 dB SPL (range = 78.61 – 92.74; SD=4.49) for the Auditory Feedback condition (see Figure 6).

A repeated-measures analysis of covariance (ANCOVA) was performed with feedback modality (four levels) as within-subject factors and strength of influence as a covariate. Statistical analysis of preferred listening levels (PLLs) was performed using a single covariate, strength of influence, only due to poor internal consistency among subjects. Results indicated no significant main effect of feedback type [f (3,54)=0.355, p=0.785] or interaction of feedback type and strength of influence [f (3,54)=0.881, p=0.457].

A series of paired comparison post-hoc tests were performed with Bonferroni correction to identify any pairwise difference between feedback conditions. Post-hoc testing revealed significantly different PLLs in the no feedback condition compared to the condition where visual feedback was present. There were no significant differences between the no feedback, vibro-tactile feedback and auditory feedback conditions. Although PLLs were lower for all feedback conditions relative to the no feedback condition, only visual feedback resulted in significantly lower preferred listening levels compared with the no feedback condition ($p<0.05$).

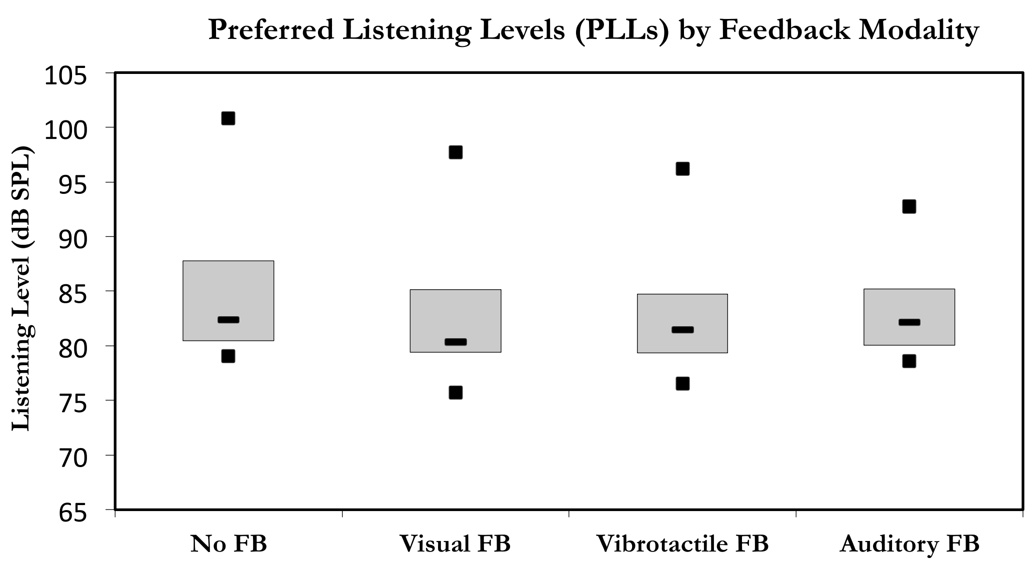


Figure 6. Box plots of preferred listening levels (PLLs) for the four feedback conditions. The boxes are marked by median, 25th and 75th percentiles. Filled squares indicate maximum and minimum levels

Lowest Individual Preferred Listening Levels by Feedback Modality

Each subjects' preferred listening level (PLL) was assessed across the three feedback conditions in order to determine the feedback modality that resulted in the lowest PLL for each subject. Individual PLLs were lowest in the Vibro-tactile condition for 40% of subjects

(6/20). Lowest individual PLLs were recorded during the visual feedback condition for eight subjects, 60% of subjects, and for six subjects (40%) their lowest individual PLL was recorded in the Auditory condition

Strength of Influence

Each subject was asked to indicate the amount of influence they believed each feedback modality had on their preferred listening level (PLLs) by marking an 11-centemiter visual analog scale; indicating no influence on the left, and strong influence on the right of the scale (items 1b, 2b, and 3b on the post trial survey). Subjects' ratings of influence for each feedback modality corresponded to the distance (as measured in centimeters) of subjects' markings measured along the visual analog scale. The highest rating was identified for each subject to determine 'Strength of Influence'. The 'Strength of Influence' measurement inherently contained a quantitative (the rating value) and qualitative component (the feedback modality in which the highest rating value was identified). The Strength of Influence rating value was used as a covariate for data analysis.

Of the twenty subjects, four subjects (20%) indicated that all three feedback modalities had equal influence on their respective PLLs. (See Figure 6 for a graph representing subjects' ratings of feedback influence for each feedback modality.) Of the remaining sixteen subjects, 75% (12/16) indicated visual feedback had the strongest influence on their listening levels with an average strength of 6.7 (range 1 to 11.9; SD=4.01). Auditory and Vibro-tactile feedbacks were each rated to have the strongest influence on PLLs by 12.5% of subjects (2/16) with average strength ratings of 3.53 (range=1 to 10.5;

SD=2.99) and 3.76 (range= 1 to 10.5; SD= 3.49) respectively. See Figure 7 for Strength of Influence distribution by feedback modality.

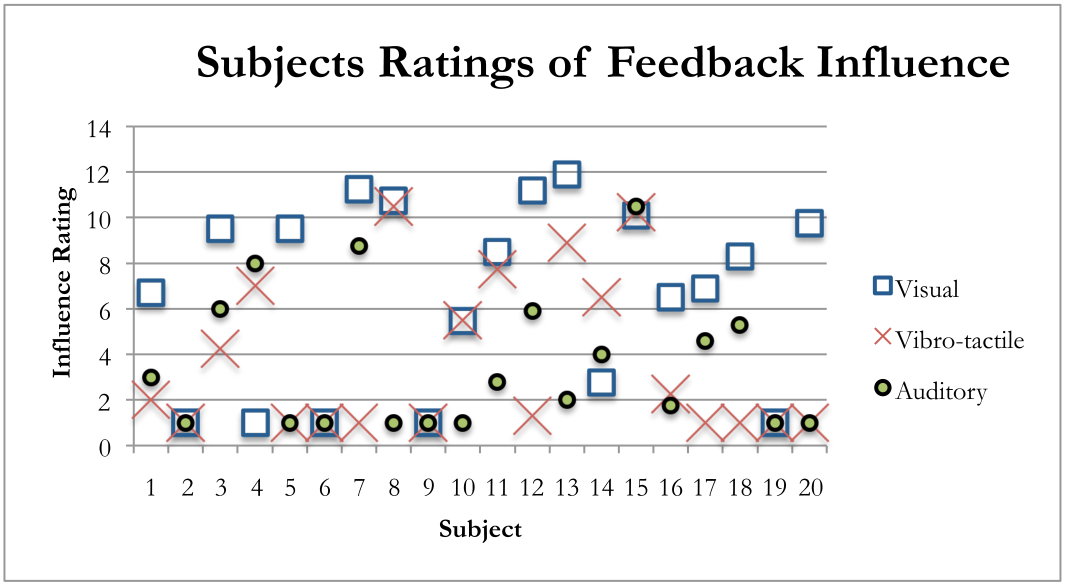


Figure 7. Subjects' perceptions of influence for each feedback modality.
Subjects 2, 6, 9, &19 indicated equal influence for all feedback modalities

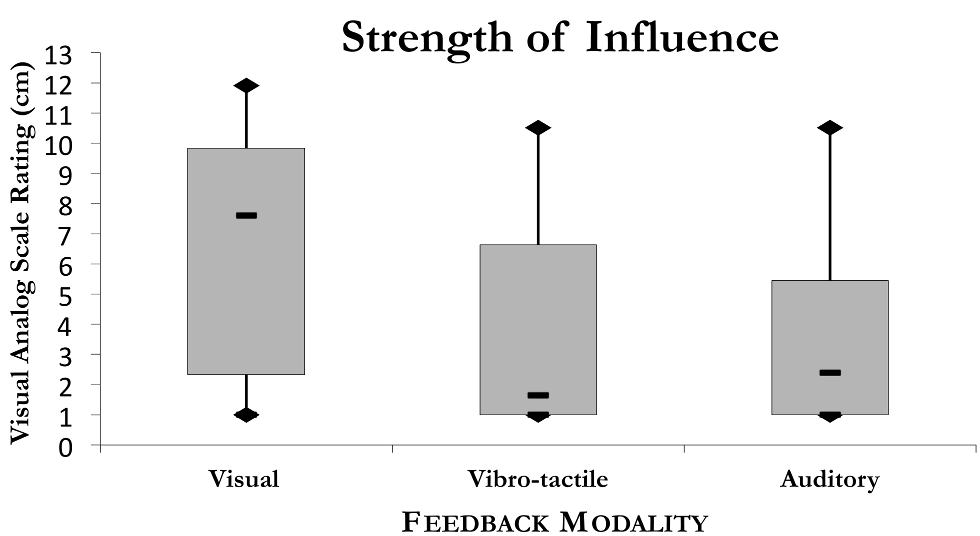


Figure 8. Boxplots of Strength of Influence by Feedback Modality.
The boxes are marked by median, 25th and 75th percentiles. Filled diamonds indicate maximum and minimum ratings

Strength of Influence was assessed using a chi-squared goodness of fit test. The results were significant, subjects perceived visual feedback to have the strongest influence on their PLLs compared with the other feedback modalities [X^2 (2, n=16) =18.75, p=0.000]. A large effect size (W=0.625) was found (Cohen, 1998).

Perceptions of Effectiveness and Acceptability

Sixty percent of subjects (12/20) indicated visual feedback to be the most effective form of feedback when asked which of the three feedback modes they believed was most effective for alerting them to potentially hazardous listening levels. Vibro-tactile feedback was chosen to be the most effective form of feedback by 25% of subjects (5/20), while only 15% of subjects (3/20) selected auditory feedback. Of the four subjects that had indicated an equal strength of influence for all feedback modes on previous questions (items 1b, 2b, and 3b on the post trial survey), three of those subjects selected the visual feedback to be the most effective form of feedback (item 4 on the post trial survey). One subject from that group of four chose auditory feedback as the most effective form of feedback.

Subjects' selection of the feedback mode they believed was most effective for alerting them to potentially hazardous listening levels was assessed using a chi-squared goodness of fit test. The results were significant X^2 (2, n=20) =10.050, p=0.007, visual feedback was perceived to be significantly more effective for altering users to potentially hazardous listening levels compared with the other feedback modalities. A medium-large effect size (W=0.409) was found (Cohen, 1998).

Just over half of the subjects (11/20) in the study were found to be consistent in regards to their preferences, that is the mode of feedback they indicated to be most effective (item 4 on the post trial survey) was the same mode of feedback of which they had indicated to have the greatest influence (items 1b, 2b, and 3b on the post trial survey).

Perceived Acceptability

The last question of the survey asked subjects to indicate the mode of feedback they found most acceptable for alerting them to hazardous sound levels, and would chose to use along with their own iPod. Vibro-tactile feedback was chosen to be the most acceptable form of feedback by 45% (9/20) of subjects, while 40% (8/20) considered visual feedback to be the most acceptable. Only 15% (3/20) of subjects indicated they would chose to have auditory feedback in their own iPod. Comparison of individual subjects' choice of effectiveness and acceptability; 25% of subjects (5/20) indicated that the mode of feedback they believed was the most effective was not the same as the feedback mode they chose to have in their own iPod.

Subjects' selection of the feedback mode they believed was the most acceptable form of feedback, of which they would chose to use with their own iPod, was assessed using a chi-squared goodness of fit test. The results were not significant X^2 (2, n=20) =4.650, p=0.098, no feedback mode was significantly more acceptable than any other feedback modality. A small effect size (W=0.278) was found (Cohen, 1998).

	Feedback Modality		
	Visual	Auditory	Vibro-tactile
Strength of Influence*	12 (75%)	2 (12.5%)	2 (12.5%)
Perceived Effectiveness	12 (60%)	3 (15%)	5 (25%)
Perceived Acceptability	8 (40%)	3 (15%)	9 (45%)

Table 2. Distribution of Subject Perceptions of Feedback (n=20)*
** n=16, 4 subjects indicated all feedback modalities were perceived to have equal influence*

Chapter V: Discussion

The main purpose of the present study was to investigate the effects of real-time feedback on iPod listeners' volume habitual preferences, the expectation being that the presence of feedback would significantly reduce the listening levels chosen by users. Thus reducing the risk of MIHL/NIHL due to iPod use. This research was conducted based on the knowledge of the capabilities of these devices as they are able to produce sound levels that pose risk to hearing, with output levels as high as 121dBA (Fligor & Cox, 2004). While the output capacities of most devices are out of users' control, users' personal volume level selections and listening durations are well with in their control. Currently, adequate tools for users to assess dangerous listening levels and to make informed decisions regarding listening habits are not available with these devices. It was hypothesized in this study that if users were provided tools to assess their listening (i.e., real-time Visual, Auditory, or Vibro-tactile Feedback) that they would chose lower listening levels, ultimately adjusting their listening habits to minimize their risk of hearing damage. Knox (2009) established that Visual feedback significantly influenced preferred listening levels (PLLs); however, the current study also investigated visual feedback and auditory and vibro-tactile feedback based on the thought that auditory and vibro-tactile feedback may offer a more practical alternative for alerting users to potentially hazardous sound levels.

Results Summary

The primary hypothesis of the present study stated that the presence of feedback, regardless of the modality, would have a significant affect upon subjects' PLLs. Observationally, the average preferred listening levels (PLL) across the four conditions indicated that the presence of feedback did result in lower PLLs, however data analysis revealed that only the Visual modality resulted in a statistically significant difference. ($p=0.023$, based on paired comparison post-hoc testing with a Bonferroni correction). The lack of significant findings was initially discouraging however upon further exploration of the results however it was determined that over 50% of the research subjects (11/20) were already listening at "safe" volume levels as indicated by the PLLs recorded in the no feedback condition. Therefore rendering feedback of any kind unnecessary. This result was unexpected based on listening trends reported by previous studies, which were discussed in Chapter I.

Although the majority of subjects' preferred listening levels (PLLs) did not necessarily put them at risk for MIHL, subjects did seem to display a healthy curiosity during the feedback conditions. Based on baseline measurements only nine total subjects would have been exposed to feedback according to their respective PLLs measured in the No Feedback condition. According to the baseline measurements five subjects' PLLs were found to be in the "risky" listening category (85dB SPL – 89 dB SPL), and only four subjects' PLLs were categorized as "unsafe" (≥90dB SPL) during baseline measurements. However, despite these baseline measurements, each subject adjusted the volume level enough to evoke the feedback, in each feedback condition. It is believed that subjects manipulated their volume selections that way in order to 'test out' how loud was 'too loud'.

Auditory Feedback

The hypotheses specifically applicable to the Auditory Feedback modality proved to be incorrect. It was hypothesized that the Auditory Feedback modality would be the most effective form of feedback for lowering PLLs and it would be perceived to have the greatest influence on users' listening decisions. This was expected based on the concept that listeners would not tolerate the auditory distortions imposed by the feedback and would adjust the volume level accordingly in order to avoid listening distorted music. Compared to the other forms of feedback it was thought that the auditory feedback would be more difficult to ignore because it directly interfered with subjects' listening experience. Whereas the visual and vibro-tactile feedback modalities did not necessarily interfere with listening experience and therefore could be more easily ignored if desired. For the same reason, it was also hypothesized that the auditory feedback would be perceived as an annoyance to listeners, and hence not be chosen as an acceptable mode of feedback. Results indicated that Auditory Feedback did not significantly affect PLLs and was not rejected by listeners despite its disruptive nature. In fact, 15% of subjects indicated that the Auditory Feedback was the most acceptable form of feedback and would choose it for use in their own device. Based on the results of the study the hypotheses regarding Auditory feedback should be rejected.

Internal Consistency

The fourth question of the exit survey asked subjects to choose the feedback modality they believed was the most effective for alerting them to potentially hazardous listening levels (perceived effectiveness). This question was asked for two reasons. First to determine qualitatively the feedback modality subjects perceived to be the most effective for alerting to potentially hazardous levels during iPod listening. Secondly, the question was posed as a check on internal subject consistency; did subjects' perceptions regarding efficacy, the feedback modality they selected to be the most effective, coincide with the influence rating they previously provided for that feedback modality ('strength of preference')? Just over half of subjects showed internal consistency in regards to their perceptions of feedback, that is they selected the same mode of feedback of which they had previously indicated, quantitatively, to have the strongest influence on their listening decisions (the 'strength of preference' measure).

Limitations of the Current Study

Like most all studies the current research project had some limitations. First, it is highly likely that reactive effects, specifically the Hawthorne effect, influenced the results. Most subjects did not turn up their volume control dial to hazardous listening levels. This could be as a result of being in an experiment where they are instructed to select a listening level. May be they were being influenced because the researcher was "watching" their listening level. Second, the subject population itself also limits the generalizability of the present study. Specifically, the study consisted of a convenience sample, all subjects included were college students that volunteered for the study, it was not a random subject population. Third, the present study only included a limited selection of music, which may have also influenced PLLs. The selection of the music sample may not have been each subject's preferred song to listen at a loud level. For example, some genres are most enjoyed at a comfortable listening level. In such a case, the subject may not have preferred to increase the volume to hazardous levels. Lastly the present study did not examine the effects of training or education. It is possible that feedback effects could have been different if subjects were provided with more information about hearing loss and the negative consequences that can result due to exposure to hazardous levels of sound prior to being exposed to the feedback modalities in the study.

Conclusions

Overall these results suggest that if sound level detectors and systems capable of generating Visual feedback when listening levels reached potentially dangerous levels were incorporated in to personal music systems, users would select lowering listening levels, therefore essentially reducing their risk of MIHL. The results from this study indicate that overall the Visual feedback system was the ideal method for alert users to potentially hazardous listening levels. The presence of Visual Feedback resulted in significantly lower PLLs compared to PLLs selected in the presence of Auditory, Vibro-tactile, or No Feedback. Additionally, subjects' perceptions of the Visual feedback were positive; subjects perceived the Visual feedback to be both influential and effective. Though the results affirmed the efficacy of the Visual feedback system, the original predicament regarding Visual feedback still exists. In general iPods are frequently kept out of sight while they are in use. Therefore, a Visual Feedback system would be rendered useless if users are not continuously viewing their iPods while listening.

While the Auditory and Vibro-tactile feedback did not significantly influence PLLs as expected, on average they did however result in lower listening levels. In addition, both Auditory and Vibro-tactile feedback could be easily detected while listening regardless of the location of the iPod, thus giving providing an advantage over a Visual feedback system. Based on the advantageous nature of the Auditory and Vibro-tactile feedback over Visual feedback and the observations of the current study it would not be implausible to expect that the presence of Auditory or Vibro-tactile feedback could influence PLLs to some degree. Or at the very minimum provide the means to alert listeners to direct their attention to the iPod screen in order to utilize the, user preferred and effective, Visual feedback system. For this reason, the researcher suggests that a multi-modal feedback system would be a beneficial compromise for effectively alerting users to potentially hazardous sound levels. That is pairing the Visual Feedback system with the Vibro-tactile and Auditory Feedback systems. An obvious solution especially considering that we ourselves are multimodal beings.

Based on the results, and opinions generated by the current study, a combined Auditory, Visual and Vibro-tactile feedback would represent the best compromise for listeners in order to promote safe personal listening in the real world. Visual feedback significantly influences PLLs while Auditory and Vibro-tactile feedback were both acceptable to listeners and unlike Visual feedback could easily be detected at any time while listening. If a multi-modal feedback system were incorporated into iPod devices it would provide users with the knowledge and tools to make informed decisions regarding their listening habits. Users would have the means to determine what listening levels are considered 'too loud' and are potentially hazardous to hearing, ideally choosing to modify their listening behavior in order to reduce their individual risk for hearing damage.

Recommendations

The results of this study provide important information about the influence of feedback on listening habits, and the mode of feedback that is most acceptable to users. This information supports the implementation of sound level monitors (and feedback indicators) by the portable media player industry in order reduce the consumers' risk of hearing damage, or music-induced hearing loss (MIHL). Specifically, when real-time information regarding individual risk for hearing damage is available to listeners it will encourage users to select lower, safer, listening levels, essentially reducing individual risk for MIHL.

The envisioned applications of the methods investigated in this study are as follows. Sound-level monitors would be incorporated into personal media devices along with a multi-modal feedback system in order to create a 'Safe Listening' feature. The sound-level monitor would activate all three feedback modalities simultaneous when volume selections reached hazardous levels. The first time the feedback system is triggered a message would pop up on the device screen. The message would explain what the user had just experienced, specifically informing users of the meaning of the presence of feedback. The message would also direct users to the user manual for additional information including further information on hearing, hearing loss, and safe listening habits. Once the user dismisses the initial message, a second warning would appear to inform users that the 'Safe Listening' feature was an optional feature aimed at reducing the risk of hearing damage caused by listening to loud music. The second message would further explain that users had the option to individually deactivate the feedback systems. For example, a user could choose to deactivate the Auditory feedback system while the Visual and Vibro-tactile feedback systems remained activated. Regardless of users decisions to activate or deactivate the feedback features, the incorporation of this type of feedback system would serve as an opportunity to easily provide education regarding safe listening to the public on a large scale.

Future Studies

As previously discussed the present study did have certain limitations, and there is a great need for further research in this area. Specifically, studies investigating the effects of training and education on preferred listening levels. Education regarding hearing loss and hearing conservation were not addressed in the present study. It may also be a worthwhile endeavor to investigate the effects of a combined or multi-modal feedback system on preferred iPod listening levels, compared to the effects of individual feedback modalities examined in this study. Additional studies with larger and random subject populations to include male subjects and eventually both genders are also needed in this area.

Appendix A. Informed Consent Form

Consent to Participate in Research

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by Justine Angilletta, a doctoral audiology student from James Madison University. The purpose of this study is to explore the effects of providing various types of feedback information regarding the safety of the sound levels chosen while listening to music through an iPod. This study will contribute to the student's completion of her doctoral (Au.D.) dissertation.

Research Procedures

Should you decide to participate in this research study, you will be asked to sign this consent form once all your questions have been answered to your satisfaction. In this study you will then be asked to listen to music, in the presence of background noise, through an iPod at a level of your choosing. Visual, Auditory, and/or Vibrotactile feedback regarding the safety of the sound level will be provided during a portion of the measurement components. Sound level measurements will then be taken at the level of your ear canal.
This procedure will be repeated multiple times using different feedback modes.

Time Required

Participation in this study will require approximately 1 hour of your time. This will be divided into four sessions, each lasting approximately 15 minutes.

Risks

The investigator does not perceive more than minimal risks from your involvement in this study.

Benefits

While there are no direct benefits of participation in this study, your participation will be used to advance research in methods to reduce risk of noise-induced hearing loss for portable music player (iPod) users.

Confidentiality

The results of this research will be presented at a regional conference in Audiology. The results of this project will be coded in such a way that the respondent's identity will not be attached to the final form of this study. The researcher retains the right to use and publish non-identifiable data. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researcher. Upon completion of the study, all information that matches up individual respondents with their answers will be destroyed.

Participation & Withdrawal

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

Questions about the Study

If you have questions or concerns during the time of your participation in this study, or after its completion or you would like to receive a copy of the final aggregate results of this study, please contact:

Justine Angilletta
CSD Department
James Madison University
angilljx@dukes.jmu.edu

Questions about Your Rights as a Research Subject

Dr. David Cockley
Chair, Institutional Review Board
James Madison University
(540) 568-2834
cocklede@jmu.edu

Giving of Consent

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

____
Name of Participant (Printed)

______________________________________ ______________
Name of Participant (Signed) Date

______________________________________ ______________
Name of Researcher (Signed) Date

Appendix B. Subject Selection Survey

IPOD SUBJECT SELECTION SURVEY

Name: ________________________________ **Major**: ____________________

Email:_________________________@dukes.jmu.edu **DOB**: _____________

I am interested in participating in the iPod study, and agree to be contacted if chosen as a subject.

____
Signature

Please mark your preference for the following music selections:

Selection #1 *(Rolling in the Deep by Adele)*

Really Dislike---Really Like
Neutral

Selection #2 *(Grenade by Bruno Mars)*

Really Dislike---Really Like
Neutral

Selection #3 *(Moves Like Jagger by Maroon 5)*

Really Dislike---Really Like
Neutral

Selection #4 *(You and I by Lady Gaga)*

Really Dislike---Really Like
Neutral

Selection #5 *(Pumped up Kicks by Foster the People)*

Really Dislike---Really Like
Neutral

Selection #6 *(Mean by Taylor Swift)*

Really Dislike---Really Like
Neutral

Selection #7 *(Super Bass by Nicki Minaj)*

Really Dislike---Really Like
Neutral

Appendix C: Pre-trial Assessment Survey

PRE-TRIAL SURVEY

Do you regularly experience ringing in your ears (tinnitus)? YES NO

If yes, how often? ______________________________

Have you ever had ear surgery, infection, or hearing loss? YES NO

If yes, please explain: ______________________________

Have you been exposed to any loud noise in the last 48 hours? YES NO

If yes, please explain: ______________________________

Do you currently have a head cold, a clogged feeling in your ears, or difficulty hearing? YES NO

If yes, please explain: ______________________________

For Researcher Use Only

Otoscopy:	Normal	Abnormal		**Tymp-screening**:		Normal		Abnormal
	Selection:	1	2	3	4	5	6	7

ID: ______________________

Appendix D: Post-trial Exit Survey

EXIT SURVEY

Your iPod listening levels were measured in 4 different conditions:

- Visual feedback (colored dot)
- Auditory feedback (music cutting in and out)
- Vibrotactile feedback (iPod vibrations)
- No feedback

Please answer the following questions about your participation in the study;

1. Did you ever hear the music cut in and out? **NO** **YES** … *if yes, please proceed to question 1a.*

1a. Do you believe the music cutting in and out influenced your volume level selection?
YES …*please proceed to question 1b* **NO**

1b. Mark along the line how much you believe the presence of feedback influenced your volume selection?

No Influence---Strong Influence

2. Did you ever feel the iPod vibrate? **NO** **YES** … *if yes, please proceed to question 2a.*

2a. Do you believe the iPod vibrations influenced your volume selection?
YES …*please proceed to question 2b* **NO**

2b. Mark along the line how much you believe the presence of feedback influenced your volume selection?

No Influence---Strong Influence

3. Did you ever see the colored dot change? **NO** **YES** … *if yes, please proceed to question 3a.*

3a. Do you believe the colored dot influenced your volume selection?
YES …*please proceed to question 3b* **NO**

3b. Mark along the line how much you believe the presence of feedback influenced your volume selection?

No Influence---Strong Influence

4. Which form of feedback do you believe had the greatest influence on your iPod listening level selection? (That is, which was most effective at alerting you to potentially-hazardous levels?) *If you don't believe any form of feedback influenced your iPod listening level selection please explain why.*

5. If this were your iPod and your music, which mode of feedback do you think you would find most acceptable to alert you to potentially hazardous listening levels? (That is, if you had the option of any one of these modes of feedback on your own iPod, which would you choose?)

Appendix E: Individual Feedback Modality Instructions

iPod Study Instructions (Visual)

Step 1: A small microphone will be placed in your ear canal.
This may tickle your ear but should not hurt. IPod earbuds will then be placed in your ears, on top of the microphone.
Please do not attempt to adjust the earbuds or microphone in your ears.
Be sure to inform the researcher if the earbud is uncomfortable or not seated properly at any time.

Step 2: Simulated background noise will be presented though a loudspeaker.
Once the background noise is turned on, push "Play" on the iPod.

Step 3: Adjust the iPod volume by turning the volume wheel, until the volume is where you would choose to listen in a normal everyday listening situation. You may take as long to adjust the volume as you would like.

When you have found your preferred listening level for the song, signal the researcher by raising your hand.

NOTE: You may or may not see colored dots on the screen in front of you, the color of the dot reflects the level of the sound in your ear.

The dot is colored coded as follows:

GREEN = Safe
You can safely listen at this level for a long time

YELLOW= Risky or approaching unsafe
Limit your listening time at this level

RED= Unsafe
Prolonged listening at this level could cause damage to your ears

iPod Study Instructions (Vibro-tactile)

Step 1: A small microphone will be placed in your ear canal.
This may tickle your ear but should not hurt. Ipod earbuds will then be placed in your ears, on top of the microphone.
Please do not attempt to adjust the earbuds or microphone in your ears.
Be sure to inform the researcher if the earbud is uncomfortable or not seated properly at any time.

Step 2: Simulated background noise will be presented though a loudspeaker.
Once the background noise is turned on, push "Play" on the iPod.

Step 3: Adjust the iPod volume by turning the volume wheel, until the volume is where you would choose to listen in a normal everyday listening situation. You may take as long to adjust the volume as you would like.

When you have found your preferred listening level for the song, signal the researcher by raising your hand.

NOTE: You may or may not feel the iPod vibrate. When the iPod vibrates it reflects the level of the sound in your ear.

The different vibration patterns indicate:

NONE — **=Safe**
You can safely listen at this level for a long time

SLOW PULES — **=Risky or approaching unsafe**
Limit your listening time at this level

QUICK PULSES — **=Unsafe**
Prolonged listening at this level could cause damage to your ears

iPod Study Instructions (Auditory)

Step 1: A small microphone will be placed in your ear canal.
This may tickle your ear but should not hurt. iPod earbuds will then be placed in your ears, on top of the microphone.
Please do not attempt to adjust the earbuds or microphone in your ears.
Be sure to inform the researcher if the earbud is uncomfortable or not seated properly at any time.

Step 2: Simulated background noise will be presented though a loudspeaker.
Once the background noise is turned on, push “Play” on the iPod.

Step 3: Adjust the iPod volume by turning the volume wheel, until the volume is where you would choose to listen in a normal everyday listening situation. You may take as long to adjust the volume as you would like.

When you have found your preferred listening level for the song, signal the researcher by raising your hand.

NOTE: You may or may not hear the music playing on the iPod fade in and out. When the music fades in and out it reflects the level of the sound in your ear.

The different fading patterns indicate:

NONE — **=Safe**
You can safely listen at this level for a long time

3 SLOW PULES — **=Risky or approaching unsafe**

Limit your listening time at this level

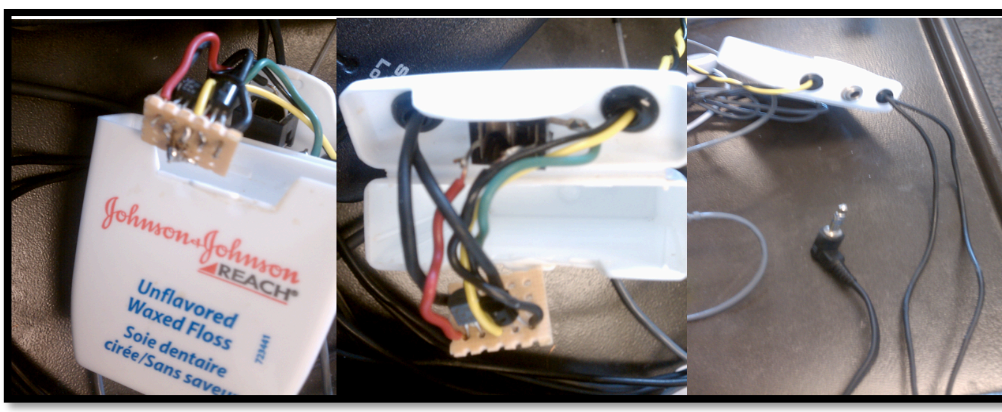
5 QUICK PULSES — **=Unsafe**

Prolonged listening at this level could cause damage to your ears

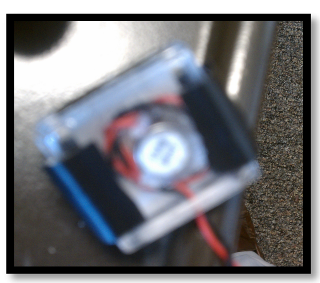
Appendix F: Additional Photos of Instrumentation

National Instruments Signal Conditioning Module housed in a SCXI-1000 Chassis

Custom made Auditory Signal Regulating Device



Custom made Vibration Device



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