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Sound pressure levels measured at preferred listening levels of iPod users using Knowles Electronic Manikin for Acoustical Research

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SOUND PRESSURE LEVELS MEASURED AT PREFERRED LISTENING LEVELS OF iPOD USERS USING KNOWLES ELECTRONIC MANIKIN FOR ACOUSTICAL RESEARCH

by

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ABSTRACT

The present study (1) examined the sound pressure levels (SPLs) of iPod users and nonusers at preferred listening levels measured on Knowles Electronic Manikin for Acoustical Research (KEMAR), and (2) determined if those SPLs exceeded the OSHA standards for acceptable hearing levels. Forty subjects, divided into one of the four following groups participated in this study: (1) inexperienced males, (2) experienced males, (3) inexperienced females, or (4) experienced females. Each participant was asked to set the music stimuli to their preferred listening level while in the presence of background noise, simulating a real world listening environment. SPL values were then measured and averaged from 125 to 8000 Hz for both stimulus (music and white noise) and measurement (linear and A-weighted) scales using KEMAR and a program developed by National Instruments. The results revealed that SPL values were dependent on both stimulus (music or white noise) and measurement scale (linear or A-weighted); however, SPL values were not dependent on gender (male and female) or experience level (inexperienced and experienced). The results further revealed that, on average, SPLs in the ear canal produced by the iPod at a listener's preferred listening level did not exceed the OSHA standards for acceptable sound pressure levels. Nevertheless, listening to music at hazardous noise levels for extended periods of time may be detrimental to hearing sensitivity, thereby causing temporary and/or permanent hearing loss.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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CHAPTER I

INTRODUCTION

Research has shown that listening to music through personal listening devices at elevated levels may be destructive to individuals' hearing (Williams, 2005). With the technological advances in personal listening devices (i.e., devices are smaller and more appealing), listeners are using personal listening devices more frequently. For example, in 2001 the computer based software company, Apple™, introduced the iPod, a portable media player that stores between 500 and 10,000 songs. The iPod's small size, its ability to store a large number of songs, and the 20-hour battery life may allow individuals to unknowingly listen to hazardous noise levels for extended periods of time. Furthermore, the standard listening transducers for the iPod are the ear-bud headphones, which fit inside the concha of an individual's ear. These headphones differ from the supra-aural headphones because they sit further into the ear canal, thus possibly increasing the sound pressure level within the canal.

The Occupational Safety and Health Administration (OSHA) has developed standards, which factor in the amount of time and intensity level a stimulus can be safely heard. These standards state that any individual exposed to 90 dB(A) for a period of eight hours or 100 dB(A) for a period of two hours is at risk for hearing loss (Occupational Safety & Health Administration, 2006). Additionally, OSHA states that exposure to impulsive noise should not exceed 140 dB(A) peak sound pressure level (SPL).

To date, SPLs of iPod users preferred listening levels have not been compared to the OSHA standards. Therefore, the purpose of this study is to determine the SPLs in the ear canal produced by the iPod at a listener's preferred listening level. These preferred listening levels will be measured by asking a listener to set the iPod at his or her preferred listening level, placing the iPod on the Knowles Electronic Manikin for Acoustical Research (KEMAR), and making measurements using linear and A-weighted scales. These measurements will determine whether individuals preferred listening levels exceed the OSHA standards for acceptable hearing levels. The following research questions were addressed:

1. What are the SPLs of iPod users and nonusers at preferred listening levels measured using KEMAR?
2. Do these levels exceed OSHA standards for noise exposure?

CHAPTER II

REVIEW OF LITERATURE

In this review of literature, especially in the sections on "iPods," "Use Patterns of Personal Listening Devices," and "Effect of Personal Listening Devices on Hearing Sensitivity," I worked closely with my classmate and colleague, Lawrence E. Bridge. During the process of literature review and assembling our joint findings, we shared both our research and writing. Similarities between these sections of our dissertations should be noted and understood as intentional. Since our basic research subject matter was similar, we worked together closely on final texts to draw comparisons, and make fundamental distinctions.

iPods

Portable listening devices can be described as any portable device that runs on batteries and plays music over an extended period of time. Throughout the years, personal listening devices have become more and more advanced and have moved from the larger tape and compact disc players to smaller mp3 players. Today, the most popular portable listening device is Apple's iPod.

In 2001, Apple introduced a new portable listening device called the iPod (see Appendix A for pictorial representation of the iPods and its earbuds). The iPod is a portable media player, which can store between 250 and 10,000 songs and operates on a rechargeable battery that can last up to 20 hours (Serwer, 2005; Kahney, 2005).

The iPod's small size and ability to store a large number of songs makes it desirable to many individuals. It connects directly to any computer via a firewall cable, which allows listeners to transfer songs or videos directly to the device through a free jukebox application called Apple iTunes (Kahney, 2005). In addition to playing music and videos, the iPod also works as a notepad (i.e., similar to a palm pilot), calendar, address book database, game center, and can be used to transfer files the same way as a floppy disc (Darlin, 2006). The iPod has six easy controls, which include a menu (i.e., a screen that displays the main iPod menu to select functions), a play button, a select button (i.e., to allow for selecting a song), a skip forward button, a skip backward button, and a hold switch. The "hold" switch exists on top of the iPod, and when activated the iPod's buttons and scroll wheel become unresponsive, so the individual using the iPod cannot change anything on the device. Additionally, iPods typically come with earbud headphones that match the design of the device. As measured during this study, these earbud headphones have the ability to produce an output peak volume of 107.8 dB(A) using an A-weighted scale and 107.3 dB SPL using a linear scale.

Since the introduction of the iPod, the Apple Company has released five generations of devices. All generations vary in device size, hardware size, design, color, and price; however, all generations of iPods have generally the same capabilities. Because of the continuous updates in software, iPod sales have increased from 380,000 in 2001 to almost 22,500,000 in 2005, with sales continuing to increase (Apple, 2007). According to Apple's quarterly financial results in January 2007, total iPod sales reached

88,701,000 since their release in January of 2001. Apple also reported a United States earning of approximately $3.4 billion from iPod sales in 2006 (Apple, 2007).

Use Patterns of Personal Listening Devices

The following section describes research regarding listeners' use of personal listening devices. Specifically, patterns of personal cassette player (PCP) use, patient age, and leisurely activities are discussed. Generally, the results of the following studies by Wong, Van Hasselt, Tang, and Yiu (1990) and Ising, Babisch, and Hanee (1997) showed that individuals listen to PCPs at various listening levels, which range from soft to harmful. These results further indicated that PCP use may be dependent on the age of the user with younger individuals listening for longer periods of time. No shifts in hearing thresholds were noted; however, the authors stated that noise induced hearing loss is a progressive disorder that many times can only be detected after years of exposure.

First, Wong et al.(1990) examined typical use patterns of personal cassette players (PCPs) in young adults and the effects of PCP use on hearing thresholds. Four hundred and eighty seven individuals, aged 15 to 24 years, were interviewed to determine the duration and frequency of PCP usage, the place of use, the type of music played, and personal and environmental information. Results of the questionnaire concluded that 73% of PCP users and 81% of non-PCP users believed that PCPs could affect their hearing sensitivity. Results further indicated that the mean duration of PCP use was 2.8 years with an average listening time of 4.5 hours per week. No significant differences were found between education level, occupation, type of living environment, and PCP use.

In addition to the questionnaire, hearing thresholds were measured for 103 listeners. Among the 103 individuals, 78 were classified as a PCP user. A PCP user was classified as a listener that uses a PCP three or more days a week for at least six months. Results showed no significant difference in the hearing thresholds of PCP users and non-users. Furthermore, the mean SPLs obtained in the artificial ear at the listener's preferred listening level was 71.2 dB(A) (range = 58.6 – 115 dB[A]) and 69.5 dB(A) (range = 56 – 113 dB[A]) for rock and light music, respectively. The results indicate that the PCP users in this study were exposed to music at low levels for short periods of time, which were not harmful to the listeners' hearing. However, the researchers noted that the SPLs obtained in the present study were measured in a quiet environment, and that these levels would be more likely to be detrimental to hearing if measured in a noisy environment. The researchers also noted that noise induced hearing loss is a progressive disorder that can only be detected after years of exposure; therefore, the experimenters caution that listening to music at elevated levels for extended periods of time can be detrimental to a person's hearing.

In a similar experiment, Ising et al.(1997) investigated the music listening habits of 569 individuals between the ages of 10 and 17 years. The purpose of the study was to measure the music level at which individuals listen to when using PCPs and determine the average exposure time and intensity levels of PCPs and discotheques. Participants provided their own cassettes, placed them into a predetermined cassette player with earphones, and changed the volume to preferred listening level. The music was then measured for one minute using a dosimeter. The level of the music heard through PCPs was also measured through the free field in an anechoic room so that the sound pressure levels could be determined.

Results of the experiment conclude that 50% of the participants listened to PCPs for less than an hour per day, but chronic listeners listened between eight and ten hours per day. In addition, 10% of the participants between the ages of 12 and 16 years listened to PCPs at 110 dB (A); however, 17 year olds listened at a lower level. Researchers indicated that music levels greater than 90 dB (A) could lead to a steady increase in volume level due to temporary threshold shift. Researchers further indicated that listening to music at levels greater than 90 dB (A) for ten years can lead to approximately 40% of young people having a noise induced hearing loss.

In summary, PCP users were defined as those individuals who had listened to PCPs at least 3 days per week for a six-month time period. These studies further revealed that while some PCP users listened to PCPs at low levels for short durations, others listened at elevated levels (levels greater than 90 dB [A]) for longer time periods. Therefore, these listeners were at greater risks for temporary threshold shifts and noise-induced hearing loss.

Effect of Personal Listening Devices on Hearing Sensitivity

The following section describes potential risks associated with the use of personal listening devices. The results of the following experiments show mixed results as to whether personal listening devices cause potential risks to an individuals hearing sensitivity. On one hand, some experimenters have found that individuals using PCPs are at risk for decreased hearing sensitivity, noise-induced hearing loss, tinnitus, and temporary and permanent threshold shifts. Conversely, other experimenters have concluded that individuals are not at risk when using PCPs unless they are listening at elevated levels for extended periods of time.

First, Catalano and Levin (1985) distributed a questionnaire to 190 college students to determine the mean volume setting at which these individuals listen to music, as well as the number of hours they were exposed to portable radios each week. One hundred and fifty four students, aged 18-21 years, qualified and participated in the study. Next, the three most popular walkman radios from the questionnaire (i.e., Sony Walkman, Toshiba KT-VS1, and Sanyo M-G1) were used for sound intensity testing. The earphones were coupled to an artificial ear and the song *Flashdance* was played at each volume setting from 1 to 10. The researchers then established their own Auditory Risk Criteria (ARC) with a ten-year exposure to noise. This criterion was based on the American Academy of Ophthalmology and Otolaryngology and the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) noise recommendations.

Result of this study showed that the mean intensity level for males and females was 97.06 dB(A) (range = 77-110 dB[A]) and 94.67 dB(A) (range = 75-110 dB[A]), respectively. Additionally, mean exposure time for males was 13.97 hours per week (range = 4 – 75 hours per week), and mean exposure time for females was 8.04 hours per week (range 30 minutes per week – 75 hours per week).

In addition, results of the study indicated that approximately 31% of all radio users exceeded the ARC. Results further indicated that 57.8% of the participants were radio users. Of these, 41.2% of male users and 29.2% of females users were found to be at risk for noise-induced hearing loss. No significant difference in intensity level was found between males and females, but the length of exposure was found to be significantly different. Therefore, the difference between the 41.2% for males and 29.2% for females was attributed to exposure time.

Second, Rice, Breslin, and Roper (1987) measured unobstructed field levels (i.e., continuous A-weighted sound pressure levels [SPLs]) for 61 individuals using personal cassette players (PCPs) in a two-part experiment. Part one included 20 listeners who were asked to adjust the level of two predetermined songs to their preferred listening level using a Sony Walkman PCP in a laboratory setting. Then, 70 dB (A) of traffic noise was added, and the subjects were asked to reset their preferred listening level for each song in the laboratory. Part two included 41 individuals who were listening to their PCPs in typical daily listening environments. These individuals were asked if measurements could be made with their personal PCP at the listeners preferred level and at the listeners preferred level using the Sony Walkman PCP. Lastly, all participants were asked to complete a questionnaire detailing average hours per week they listened to their PCPs. A-weighted SPLs were measured in the following manner: (1) listeners were asked to set the PCPs at their preferred listening levels, (2) PCPs were placed on Knowles Electronic Manikin for Acoustical Research (KEMAR), and SPLs were measured, (3) transfer functions were applied as conversion factors from KEMAR to A-weighted SPLs.

Results of part one of this study showed no A-weighted SPL differences between the two songs when they were set at the listener's preferred listening levels. Results of part one further showed an increase of about 4 dB when listening in the presence of background noise compared to listening in a quiet environment. Results further showed no correlation between the amount of background noise and user listening level when listeners were evaluated in typical daily listening environments.

Lastly, data from all 61 listeners was pooled, and each listener's A-weighted SPL was compared to number of listening hours per week. The results showed that five percent of participants were exposed to levels that could be harmful to an individual's hearing [i.e. >90 dB (A)]. These results indicated that the presence of background noise may increase the SPL individuals set their PCPs, independent of the song used. These results further indicated that some listeners may be listening at levels that exceed the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) recommendations, which could be detrimental to hearing.

In a related study, Hellstrom and Axelson (1988) investigated the maximum output sound pressure levels (SPL) of three portable cassette players (the Sony WM-DD, Sony MDR-E282, and the Sony MDR-51) with headphones. White noise, one-third octave band filtered noise, modern pop music, and synthetic music were recorded to determine typical characteristics of portable cassette players (PCP). The SPLs were analyzed using a Knowles Electronics Manikin for Acoustic Research (KEMAR) and in real ears with mini-microphones. Fifteen normal hearing individuals, age 14 to 23 years, were asked to adjust the level of the music to the highest volume level they considered enjoyable. Probe tube measurements were taken to determine the SPLs in their ear canals for the different types of stimuli. Additionally, ten participants, aged 13 to 20 years, listened to music for one hour at their most comfortable listening level after which the researchers measured temporary threshold shifts (TTS). Furthermore, the experimenters also interviewed 154 individuals, aged 14 to 15, to determine listening habits.

Three interesting findings were discovered. Results of the experiment revealed that SPLs varied between the portable cassette players and headphones, with the maximum outputs ranging from 104 dB to 126 dB. First, when the subjects were told to listen at their highest comfortable volume level, mean SPLs corresponded to 112 dB SPL in free field. Additionally, when the individuals were told to take one of the earphones off, they wanted to decrease the volume level significantly. Second, when testing for temporary threshold shift, four individuals complained of tinnitus after listening to the music, and the mean threshold shift was 5 to 10 dB for frequencies between 1000 Hz and 8000 Hz. The threshold shift recovery time varied from 30 minutes to 30 hours. Third, results of the 154 interviews revealed that most individuals reported using personal listening devices during leisurely activities and holidays, and five percent listened for more that seven hours per week. In addition, the estimated equivalent SPL (i.e., how loud the experimenters expected the participants listen to their PCPs based on their interview answers) varied from 87 to 99 dB with a mean of 92 dB, and 64% of listeners experienced tinnitus after exposure to elevated music levels. The results indicated that different personal listening devices and different earphones have varying SPLs. Also, subjects listening at their highest comfortable level without pain are at risk for hearing impairment. The results further indicated that listening to music at a person's most comfortable level for an hour has the ability to cause a TTS and/or hearing impairment.

Turunen-Rise, Flottorp, and Tvete (1991) also investigated the effects of personal cassette players (PCPs) use on noise-induced hearing loss (NIHL). A-weighted equivalent and maximum SPLs for five types of PCPs (Sony Sports FM/AM Walkman VM-F63, Sony Professional Walkman, Sharps Graphic Equalizer AM/FM Stereo

Cassette Player JC-780, Philips Graphic Equalizer Stereo Cassette Player D 6535 and Unico Stereo Cassette Player) were measured on KEMAR in an anechoic room. Eleven tapes containing pop music, classical music, or light classical music, were played at the maximum gain setting (ten) for fifteen minutes on KEMAR, and the average output level was recorded. In addition, six individuals with normal hearing were tested while listening to music at the level eight gain setting. Temporary threshold shifts (TTS) were measured for each participant two minutes after listening to two of the pop music cassettes for a total of one hour. Recovery of the TTS was measured after 20, 40, and 120 minutes of listening to the music.

Results of this study showed that the PCPs A-weighted field equivalent sound pressure levels (SPL), as measured on KEMAR, ranged from 55 to 99 dB(A), depending on the gain setting. Likewise, different types of music also produced different A-weighted equivalent and maximum SPLs when evaluated on the same PCP at the same volume control setting. The pop music with percussion instruments was noted to produce the highest SPL and greatest temporary threshold shift. No significant SPL differences were measured between the semi-aural and supra-aural headphones on KEMAR. In addition, three individuals reported tinnitus after listening to the music at 95 dB(A). Based on these results, the researchers concluded that hearing loss is possible from listening to PCPs at extreme levels; however, most individuals were at low risk for hearing loss due to the fact that these individuals listen at low intensity levels for short periods of time. Furthermore, it should be noted that music containing percussion instruments may be more damaging to an individual's hearing than music without percussion instruments.

Airo, Pekkarinen, and Olkinuora (1996) performed a three-part noise exposure assessment on individuals using personal cassette players (PCP) with earphones. Fourteen individuals participated in the part one of the experiment. Probe tube measurements were taken on the participants in a quiet environment after listening to four music samples. Results of part one of the study revealed that the average listening level in quiet was 69 dB and ranged from 52 dB to 80 dB. Listening levels varied between the four music samples and were also judged to be higher with supra-aural earphones than with semi-aural earphones. Results further indicated that the average listening level in the presence of background noise was 82 dB and ranged from 61 dB to 104 dB (the mean background noise levels were 65 dB and 73 dB).

In part two of the experiment, probe microphone measurements were taken after listening to music samples in the presence of background noise on three of the original fourteen participants. Results concluded that the average listening time was 11 hours per week with an average listening level of 82 dB. The mean exposure level ranged from 55 dB to 101 dB.

Additionally, fifty individuals using PCPs on the street were asked to participate in part three of the experiment. These individuals were asked not to change their volume setting so that measurements could be taken through an acoustic coupler, SPL meter and a calibrated DAT recorder. Additionally, subjects were questioned about PCP exposure time and typical listening situations. Results indicated that individuals listen to music significantly louder in the presence of background noise and may be at risk for hearing impairment at levels that exceed 85 dB SPL.

In a similar study, Fligor and Cox (2004) investigated the output levels from six different portable compact disc players to see if the levels caused noise induced hearing loss in listeners. In addition, the researchers measured different styles of headphones to see if the headphone style influenced the output level of the compact disc player. A Knowles Electronics Manikin for Acoustical Research was used to measure output levels recorded from headphones at different volume settings. White noise and eight different types of music were used to measure the output levels of the devices. White noise was used to measure the output levels due to it providing equal energy across the entire frequency spectrum and did not fluctuate like the different genres of music. The white noise and music were played through a CD player with the standard headphone and measured at volume control settings 5 – 10. Next, each CD player was measured at the maximum level (10) with each additional headphone to determine the difference in maximum output.

Results of the experiment revealed output levels varied among manufacturer and type of headphone used, with the smallest headphone producing the highest output level. The peak sound pressure level was the lowest for classical music (109 dB SPL) and the highest for rock music (139 dB SPL). The results indicate that different types of CD players and headphones produce varying output sound pressure levels. Results further indicate that the maximum output levels produced may create a significant risk for hearing impairment.

Pugsley, Stuart, Kalinowski, and Armson (1993) investigated the effect of portable stereo system (PSS) use on hearing sensitivity. Thirty individuals with normal hearing sensitivity, normal middle ear function, and no noise exposure of PSS use for one day served as the participants for this study. Immediately after testing, each participant listened to the PSS for one hour at their preferred listening level in a quiet room. The results revealed that, on average, one hour of PSS use at preferred listening levels does not contribute to decreases in hearing sensitivity. The researchers, however, cautioned that although hearing sensitivity was not affected by PSS use in the current study, the following factors could decrease hearing sensitivity in PSS users: the presence of background noise, the style of earphones, the type of PSS device, the type of music stimulus presented, exposure time, and the preferred listening level. These results indicate that one hour of PSS use at the individuals preferred listening level does not cause a significant decrease in an individuals hearing sensitivity.

Lastly, Williams (2005) recently performed a study on the normal everyday listening levels by individuals using personal stereo players (PSP) and the approximate time that these individuals use PSPs. Fifty-five persons aged 15 to 48 years, who were using PSPs at the time, were approached at random on the street and asked to participate in the experiment. Individuals were approached at two different locations that were chosen to represent typical background noise levels. When the individuals agreed to participate, the volume setting of their PSP at that time was measured on a Knowles Manikin for Acoustic Research (KEMAR) fitted with a Zwislocki artificial ear simulator. The participants were then asked to fill out a questionnaire concerning the amount of hours per day of PSP use, years of PSP use, incidence of tinnitus, history of hearing loss, conversational difficulty in background noise, and their occupation.

Results of the experiment revealed that the average sound pressure levels ranged from 73.7 dB to 110.2 dB. Also, personal PSP listening times ranged from 40 minutes to

13 hours per day with the number of years of PSP usage ranging from one month to around 15 years. Results further revealed that males listened to PSPs at a significantly higher level than females (80.6 dB compared to 75.3 dB). There were no significant correlations between hearing loss or tinnitus caused by PSPs. The results indicate that males listen to PSPs at higher intensity levels, but there is not a significant risk to hearing sensitivity from PSP use alone.

In summary, the risk of occurrence of hearing loss while using personal listening devices is dependent on several factors including the type of listening device, style of earphones, type of music stimulus presented, exposure time, preferred listening level, and presence of background noise. In other words, some experiments found that individuals using personal listening devices are possibly at risk for reduced hearing sensitivity while other experiments have determined that individuals are not at risk unless they are listening at elevated levels for extended time periods.

Hearing Conservation in the United States

A significant amount of listeners are losing their hearing due to a combination of noise exposure and lack of knowledge and/or concern for this topic. Therefore, standards and regulations have been developed to identify the effects of high noise levels and methods for controlling these effects (Suter, 2000). In the United States, the initiation of federal regulations for noise control followed a sequence of consensus statements, handed out by organizations such as the American Standards Association (precursor to ANSI) and the National Research Council Committee on Hearing and Bioacoustics (CHABA). Even though these organizations showed a proficient level of knowledge, there continued to be a need for uniformity (Suter, 2000).

Development of Occupational Safety and Health Administration

In 1970, the United States Congress passed the Occupational Safety and Health Act (Public Law 91-596), which mandated employers protect their workers from various chemical and physical dangers, including noise (Suter, 2000). This Occupational Safety and Health Act founded both the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH). OSHA, located in the Department of Labor, is accountable for establishing, distributing, and enforcing workplace safety and health regulations (NIOSH, 2006). Likewise, NIOSH, located in the Department of Health and Human Services, was assigned the responsibilities of conducting research, criteria development, and educational seminars (NIOSH, 2006).

In 1971, a regulatory limit on the amount of noise in the environment was established for all industries engaging in interstate commerce. This limit is called the permissible exposure limit (PEL). The regulations set the PEL at 90dB(A) with a 5-dB exchange rate, the relationship between noise level and duration. In other words, 90 dB (A) is the legal exposure limit recommended for an 8-hour timeframe. Furthermore, as intensity increases, duration to noise should decrease. Specifically, for every 5-dB increase in intensity, exposure to noise should decrease by half. The regulation also implements the reduction of noise levels to the PEL by engineering or administrative controls when practical, the wearing of hearing protection devices (HPDs) if noise is above the PEL, and the administration of a continuing, effective hearing conservation program for personnel exposed to noise above the PEL (see Table 1 for PEL standards; Suter, 2000).

Table 1. Total time of allowed exposure for specific noise levels.

A – Weighted Sound Level (dB)	**Reference Duration (hour)**	**A – Weighted Sound Level (dB)**	**Reference Duration (hour)**
80	32.0	**105**	1.0
81	27.9	**106**	0.87
82	24.3	**107**	0.76
83	21.1	**108**	0.66
84	18.4	**109**	0.57
85	16.0	**110**	0.5
86	13.9	**111**	0.44
87	12.1	**112**	0.38
88	10.6	**113**	0.33
89	9.2	**114**	0.29
90	8.0	**115**	0.25
91	7.0	**116**	0.22
92	6.1	**117**	0.19
93	5.3	**118**	0.16
94	4.6	**119**	0.14
95	4.0	**120**	0.125
96	3.5	**121**	0.11
97	3.0	**122**	0.095
98	2.6	**123**	0.082
99	2.3	**124**	0.072
100	2.0	**125**	0.063
101	1.7	**126**	0.054
102	1.5	**127**	0.047
103	1.3	**128**	0/041
104	1.1	**129**	0.036
		130	0.031

In 1981 OSHA revised the noise regulation, making specific requirements for noise measurement, audiometric testing, the use and care of HPDs, employee training and education, and recordkeeping (Suter, 2000). In 1983, OSHA again revised Section C of the standard, which detailed the guidelines for hearing conservation programs. The revised Section C from 1983 and Sections A and B of 1981 are the federal guidelines that are used for noise exposure today (see Appendix B for summary of current OSHA guidelines for noise exposure). Furthermore, the Occupational Safety and Health Act of

1970 also allowed state agencies to issue and enforce their own regulations, as long as these regulations were at a minimum as protective as those made known by the federal OSHA (Suter, 2000). Suter (2000) comments that about half of the states have chosen to do this while the rest choose to utilize federal enforcement guidelines.

In the United States, the OSHA guidelines are enforced through the use of OSHA inspectors. The inspectors visit facilities to determine if the facility is functioning under all sections of the OSHA guideline. If the facility is not found to be in compliance with the guideline, the inspector can issue citations for noncompliance (Suter, 2000).

In summary, OSHA and NIOSH are organizations whose purpose is to guarantee the safety and health, including hearing health, of people in the workforce by setting and enforcing standards and providing training through education. It is their duty to make certain that employees and employers protect themselves by following implemented guidelines that restrict or reduce the probability of being subjected to self-inflicted and/or environmental harm.

Knowles Electronic Manikin for Acoustical Research

According to Gunner Rasmussen's Acoustic Systems (GRAS), the exclusive manufacture of Knowles Electronic Manikin for Acoustic Research (KEMAR), KEMAR is an acoustic research instrument/manikin that allows for reproducible measurements for establishing the performance of hearing aids and other electroacoustic devices. Dillon (2001) defines KEMAR as a manikin comprised of a head and torso, with an ear simulator built inside each ear. Each dimension of KEMAR was designed to portray an average human adult (Burkhard & Sachs, 1978).

Primary measurements that were considered in constructing the head and face dimensions of KEMAR were taken from a 1950 United States Air Force survey of 4000 males (mean age = 28 years) and 852 females (mean age = 20 years) with all measurements being within 4% of the median (Mueller, 2006). KEMAR was originally referred to as IRPI because the initial research conducted on KEMAR took place at Industrial Research Products, Incorporated, which was owned and directed by Hugh S. Knowles. In 1952, this corporation was bought by Knowles Electronics, who named the manikin KEMAR (Mueller, 2006). Currently, KEMAR is part of the research team at GRAS, a company that manufactures acoustic products such as pre-amplifiers, microphones, and signal conditioning devices (Mueller, 2006). As the name implies, research is one of the primary uses of KEMAR.

Since its origination in 1972, numerous research audiologists and hearing aid manufacturers have used KEMAR for the purposes of examining the characteristics of hearing aids under more lifelike conditions (i.e., on a head and torso). Specifically, KEMAR was developed to provide more realistic test conditions and experimental flexibility (Burkhard & Sachs, 1978). Furthermore, KEMAR serves as an evaluation tool for wearer simulation of all types of hearing aid fittings (Burkhard & Sachs, 1978).

In summary, KEMAR is a means of research in the discipline of hearing. It is a manikin assembled on the foundation of an average adult individual, which allows for accurate predictions of hearing aid performance. KEMAR, known to provide precise repeatable measurements, is further being studied to determine other significant uses.

CHAPTER III

METHODS AND PROCEDURES

Participants

Forty adults (20 men and 20 women) with normal hearing sensitivity participated in this study. Participants were recruited from undergraduate and graduate classes in the Department of Speech at Louisiana Tech University (Ruston, LA). The inclusion criteria for both groups included: (1) normal hearing sensitivity (defined as 20 dB HL at all octave frequencies from 250 – 8000 Hz) and (2) age 18 to 25 years (M = 21.28 years, SD = 1.50 years). Furthermore, the participants were divided into the following two groups: inexperienced iPod users and experienced iPod users. Experienced iPod users were defined as listeners who listened to an iPod or other personal listening devices (PLD) at least three days per week for at least six months. Table 2 displays the amount of time experienced versus inexperienced iPod users listened to their devices in months, days per week, and hours per day.

Table 2. Mean time (and standard deviations) of iPod use in hours, days, and months.

Listening Length	Inexperienced Users	Experienced Users
In months	.68 months (1.99)	14.85 months (13.60)
Days per week	.85 days (1.27)	5.25 days (1.62)
Hours per day	.60 days (.77)	1.78 hours (.85)

Qualification Procedures

Upon arrival, each participant was given an overview of the experiment and signed an informed consent form prior to testing (see Appendix C for informed consent). In addition, the following demographic information was collected for each participant: age, gender, if the participant owned an iPod or other PLD, number of hours of daily usage, number of days per week of usage, personal preference for the song used for testing, and history of otologic pathology (see Appendix D for demographic sheet).

Otoscopy was completed bilaterally on each participant with a Welch Allen otoscope in order to view the ear canal and tympanic membrane. If otoscopy revealed an ear that was not healthy or if there was occluding cerumen, the individual was excluded from the study and appropriate recommendations were made. Following the otoscopic examination, tympanometry was completed bilaterally using a Grason Stadler (GSI) Tympstar Middle-Ear Analyzer (serial #AL051305). Tympanometry was administered to ensure that each patient had normal middle ear function bilaterally. The criterion for normal tympanometry was as follows: ear canal volume between 0.5-2.0 cc, static compliance between 0.3-1.7 cc, and ambient air pressure between +/-100 daPa.

Pure-tone auditory thresholds were then screened with a clinical audiometer (GSI 61, serial #AA063067) and supraaural headphones (TDH-50P) in a sound-treated booth (IAC-30; dimensions: 9′4″ by 9′8″) with acceptable ambient noise levels (ANSI, S3. 1-1991). The audiometer was calibrated to the American National Standards Institute (ANSI, S3. 6-1996) standards. Normal hearing was defined as thresholds of 20 dB HL at octave frequencies from 250 to 8000 Hz for each ear. If any threshold exceeded 20 dB HL, the participant was excluded from the study and recommended to the Louisiana Tech Speech and Hearing Center for a complete audiological evaluation.

Each participant then walked with the tester to the audiological booth, which was housed in Woodard Hall (Louisiana Tech University, Ruston, Louisiana). During this walk, each participant was asked to listen to the song *I Still Remember* by the Bloc Party through a 60 GB Apple iPod (serial #:JQ447CWVRSR). This song was chosen for the following reasons: (1) it contained an upbeat melody; (2) it simulated a real world stimulus, and (3) music is what is commonly listened to on iPods. Each participant was asked to adjust the level of the song to his or her preferred listening level while walking to Woodard Hall (Note: The entire song was listened to while the participant was outside between Robinson and Woodard Halls). The purpose of the walk was to allow the participant to adjust the iPod volume, in a real world situation, to their preferred listening level. Once the preferred volume level was reached, it was locked onto the iPod by activating the "hold" feature to ensure that the volume level could not be manipulated during the experimental testing.

Sound Pressure Level Measurements using KEMAR

In a subsequent study, listeners were asked to adjust an iPod to their preferred listening level while outside. The hold feature was then activated at the listener's preferred listening level. For the present study, the iPod was taken from the listener and placed on KEMAR's right ear at the participant's preferred listening level. Then, sound pressure levels (SPLs) for both the song *(I Still Remember)* and white noise were measured using a sound level meter (SLM) software developed by National Instruments.

It should be noted that the software was developed so that SPL measurements could be recorded and extracted from KEMAR.

First, SLM settings were adjusted for the software (see Appendix E for SLM software settings for measurements using KEMAR). Then, with the iPod in KEMAR's right ear at the listener's locked preferred listening level, the following four measurements were taken: a linear measurement with the song as the stimulus; an A-weighted measurement with the song as the stimulus; a linear measurement with white noise as the stimulus; and an A-weighted measurement with white noise as the stimulus. It should be noted that measurements for the song were averaged over 255 seconds (i.e., the length of the song), and measurements for the white noise were averaged over 60 seconds. In addition, prior to testing, a spectral analysis was conducted to confirm that the route mean square (RMS) level of the song and that of the white noise were similar. All sound level measurements consisted of 30 data points measured in 1/3-octave steps over a frequency range of 20 to 20,000 Hz. Data for output levels were extracted from KEMAR, transferred to a SLM program, coded by the participant's name, and downloaded to a Dell Otiplex GX280 computer for subsequent data analysis.

CHAPTER IV

RESULTS

Sound Level Measures

One purpose of the present study was to obtain probe microphone measurements at listeners' preferred listening levels using KEMAR and a recording software developed by National Instruments (Note: The purpose of this software was to record SPLs from KEMAR's ears in 1/3 octave bands across the frequency range of 20 to 20,000 Hz.). Each participant's SPL values were downloaded into an excel document for subsequent data analysis. Specifically, SPL values were averaged across participants at each frequency to determine the mean curve for each gender (male and female), experience level (inexperienced iPod user and experienced iPod user), stimulus (music and noise), and measurement scale (linear or A-weighted). Figures 1-4 show SPL values from 20 to 20,000 Hz for male versus female participants for the four different stimuli / measurement scales (i.e., music measured using a linear scale; music measured using an A-weighted scale; white noise measured using a linear scale, and white noise measured using an A-weighted scale).

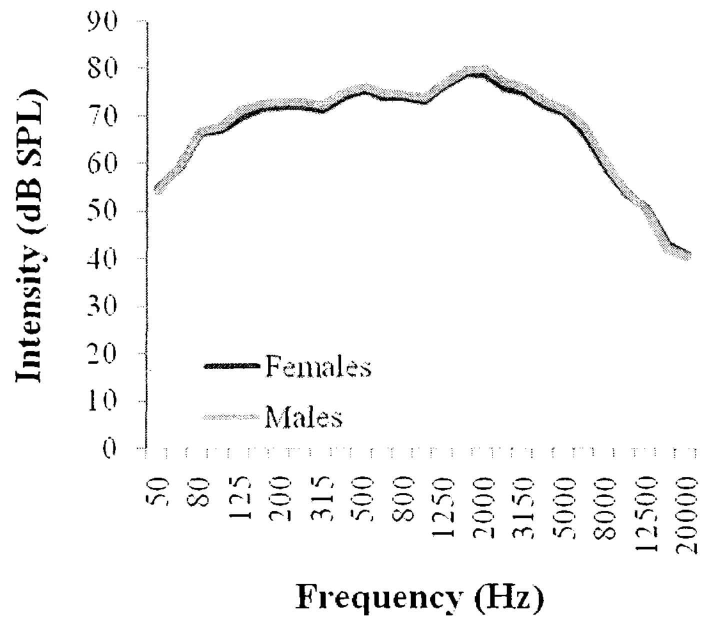


Figure 1: SPL as a function of frequency measured on KEMAR using the music stimulus and linear measurment scale for male and female participants.

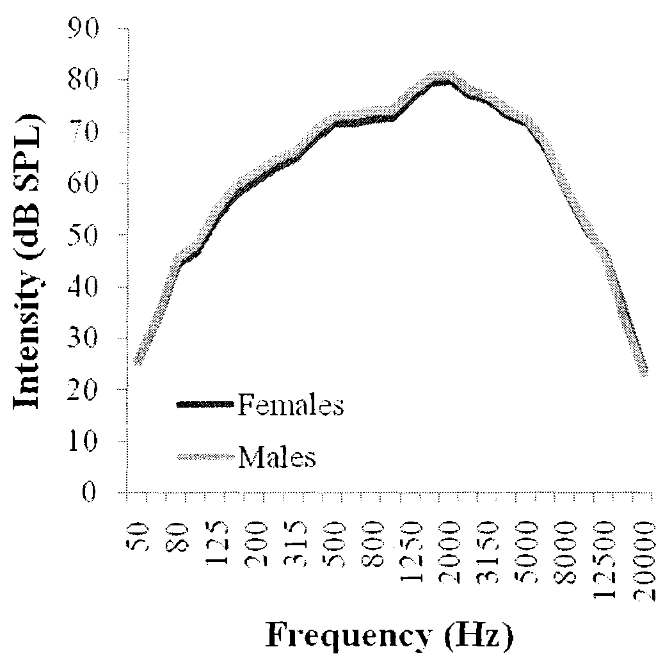


Figure 2: SPL as a function of frequency measured on KEMAR using the music stimulus and A-weighted measurement scale for male and female participants.

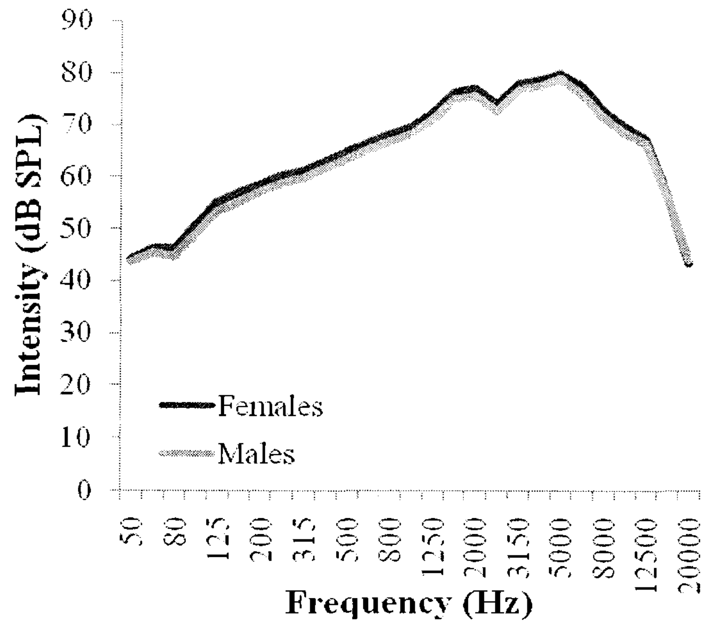


Figure 3: SPL as a function of frequency measured on KEMAR using the white noise stimulus and linear measurement scale for male and female participants.

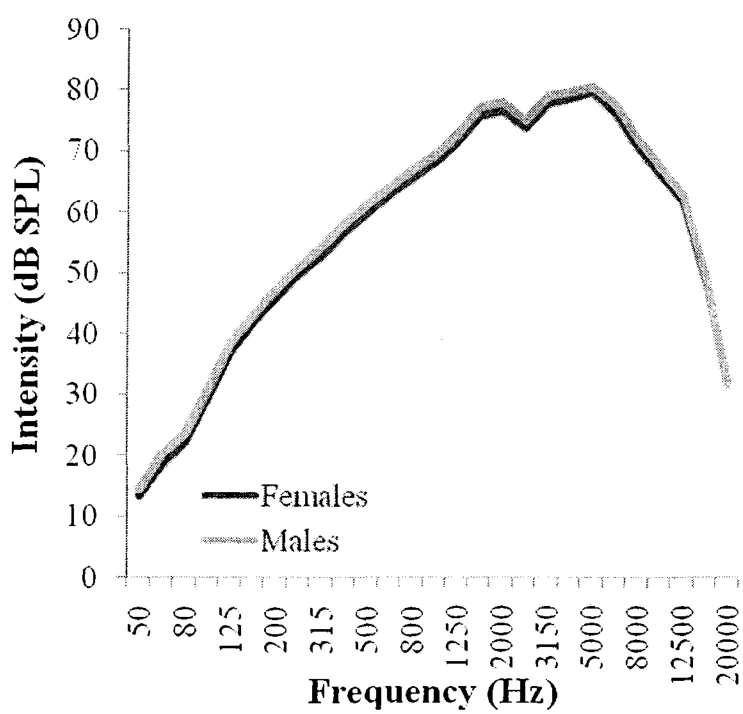


Figure 4: SPL as a function of frequency measured on KEMAR using the white noise stimulus and A-weighted measurement scale for male and female participants.

Likewise, Figures 5 – 8 show SPL values from 20 to 20,000 Hz for inexperienced versus experienced participants for the four different stimuli / measurement scales (i.e., music measured using a linear scale; music measured using an A-weighted scale; white noise measured using a linear scale, and white noise measured using a A-weighted scale). It should be noted that an experienced iPod user was defined as a listener that listened to an iPod for at least three days per week for six consecutive months.

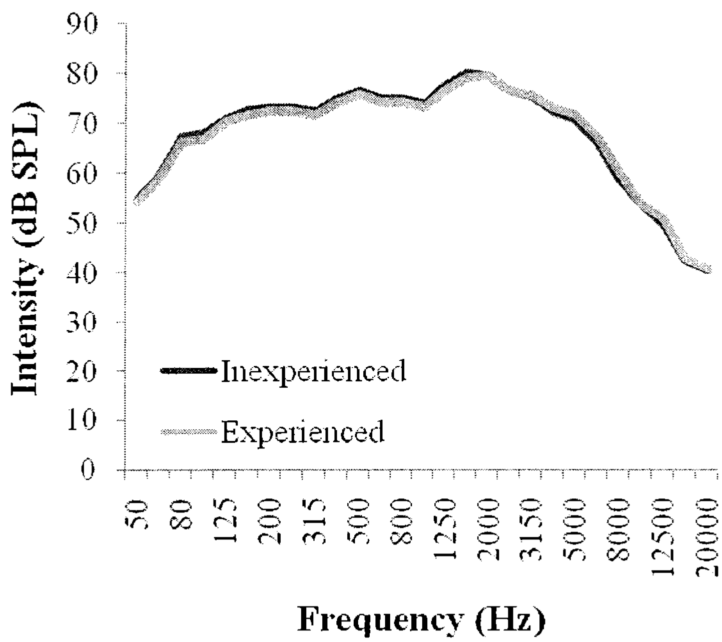


Figure 5: SPL as a function of frequency measured on KEMAR using the music stimulus and linear measurement scale for inexperienced and experienced participants.

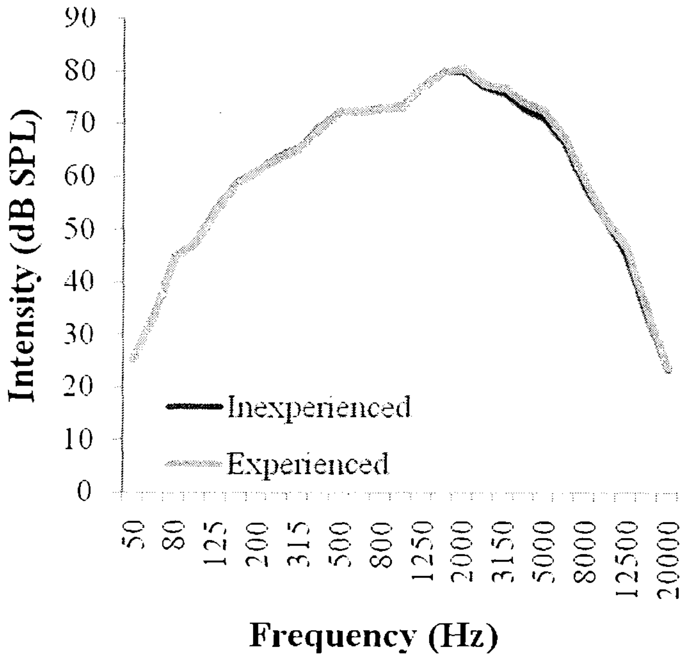


Figure 6: SPL as a function of frequency measured on KEMAR using the music stimulus and A-weighted measurement scale for inexperienced and experienced participants.

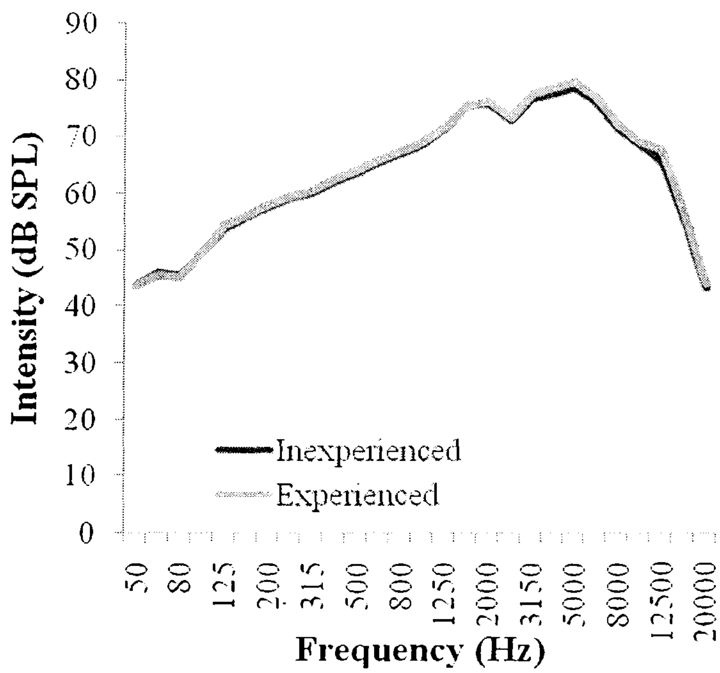


Figure 7: SPL as a function of frequency measured on KEMAR using the white noise stimulus and linear measurement scale for inexperienced and experienced participants.

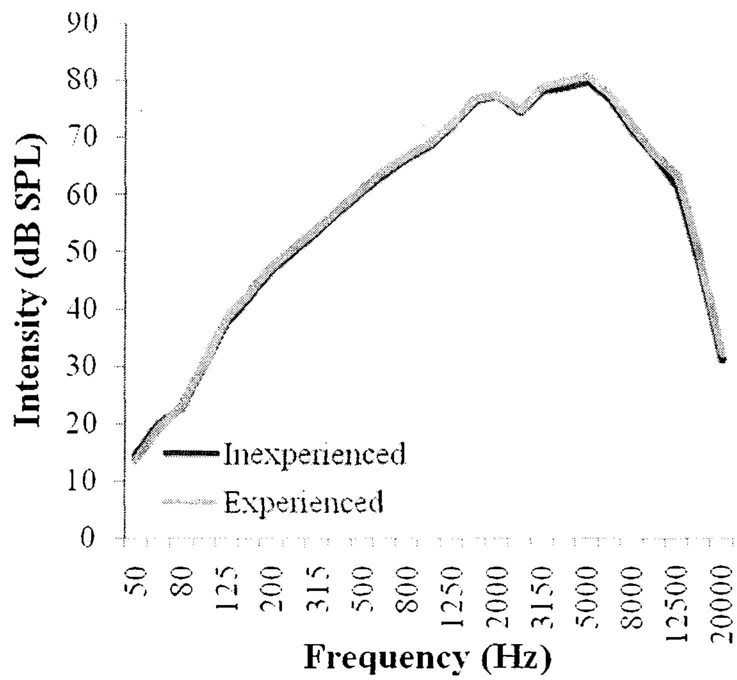


Figure 8: SPL as a function of frequency measured on KEMAR using the white noise stimulus and A-weighted measurement scale for inexperienced and experienced participants.

For data analysis purposes, each participant's SPL values were averaged from 125 to 8000 Hz for each stimulus (music and white noise) and measurement scale (linear and a-weighted). A four-way repeated measures analysis of variance (ANOVA) was performed to evaluate the effects of gender, experience level, stimulus, and measurement scale on SPL value measured using KEMAR. The dependent variable was SPL value. The within-subject factors were stimulus with two levels (music and white noise) and measurement scale with two levels (linear and A-weighted). The between-subject factors were gender with two levels (males and females) and experience level with two levels (inexperienced and experienced). The analysis revealed a significant main effect for the stimuli ($F[1,36] = 267.79$, $p < 0.001$) and measurement scale ($F[1,36] = 214.92$, $p < 0.001$). There were no significant main effects for gender ($F[1,36] = 0.20$, $p = 0.66$), experience level ($F[1,36] = 0.01$, $p = 0.94$) or for any of the following interactions: stimuli by gender ($F[1,36] = 0.214$, $p = 0.647$), stimuli by experience ($F[1,36] = 0.80$, $p = 0.376$), measurement scale by gender ($F[1,36] = 0.007$, $p = 0.933$), measurement scale by experience level ($F[1,36] = 0.542$, $p = 0.466$), stimuli by measurement scale ($F[1,36] = 0.386$, $p = 0.538$), stimuli by gender by experience level ($F[1,36] = 1.612$, $p = 0.212$), stimuli by measurement scale by gender ($F[1,36] = 0.004$, $p = 0.950$), measurement scale by gender by experience level ($F[1,36] = 0.206$, $p = 0.652$), stimuli by measurement scale by experience level ($F[1,36] = 0.30$, $p = 0.587$), stimuli by gender by expereince level by measurement scale ($F[1,36] = 0.43$, $p = 0.519$). These results indicate that SPL values were dependent on the following (1) the stimulus used (i.e., music [$M = 71.55$] or white noise [$M = 66.75$]) and (2) the measurement scale used (i.e., linear [$M = 70.78$] or a-weighted [$M = 67.52$]). These results further indicate that SPL values were not dependent on the following (1) the subject's gender (female [$M = 68.49$] or male [$M = 69.81$]) or (2) the subject's experience level (inexperienced [$M = 69.03$] or experienced [$M = 69.27$]).

Comparison to OSHA Standards

Another purpose of the present study was to compare SPLs at the listeners preferred listening level to OSHA standards for acceptable hearing levels. It should be noted that 90 dB(A) is the legal exposure limit suggested for an 8-hour time period (Suter, 2000). Therefore, 90 dB(A) was the control value for this particular study.

Two independent t-tests were used to assess whether the means for the two stimuli (music or noise) were significantly different from 90 dB(A). It should be noted that for comparison to OSHA standards, only the A-weighted measurements were compared to the control value. This is because OSHA uses the A-weighted measurement as a reference when conducting noise measurements. The results showed that the measured levels were significantly lower than the OSHA standard of 90 dB(A). Specifically, the average music and white noise stimuli were 14.0 dB and 16.9 dB softer than the OSHA standard, respecitvely. These results indicate that, on average, the SPLs in the ear canal produced by the iPod at a listener's preferred listening level did not exceed the OSHA standards for acceptable hearing levels.

Secondary Data Analysis

Although the analysis conducted using average group data (i.e., SPLs averaged for 1/3 octave bands from 20 to 20,000 Hz) showed iPod users listened well below 90 dB(A), examination of individual subject data suggested that eight listeners (three experienced and five inexperienced) peak SPL exceeded 90 dB(A). Therefore, four independent t-tests were performed for the eight listeners whose peak values were at or greater than 90 dB(A) (see Table 3 for peak data analysis results); a Bonferroni adjustment was applied for multiple comparisons. The results indicated that none of the peak values were significantly different than 90 dB(A). In other words, none of the eight listeners were listening at averaged levels at or significantly higher than 90 dB(A).

Table 3. Peak SPL values for the music and noise stimuli measured linearly and using the A-weighted scales for the eight listeners whose average values exceeded 90dB(A).

Measures	Mean (SD)	T - value	dF	Significance
Music Linear Peak	93.68 (4.15)	2.51	7	0.16
Music A-weighted Peak	93.25 (5.52)	1.67	7	0.28
Noise Linear Peak	92.30 (5.18)	1.26	7	0.25
Noise A-weighted Peak	93.06 (5.14)	1.69	7	0.41

CHAPTER V

DISCUSSION

The purpose of the present study was twofold: 1) to obtain probe microphone measurements at listeners' preferred listening levels using Knowles Electronic Manikin for Acoustical Research (KEMAR) and a recording software developed by National Instruments and 2) to compare sound pressure levels (SPLs) at the listeners preferred listening level to the Occupational Safety and Health Administration (OSHA) standards for acceptable hearing levels. A total of 40 subjects (10 inexperienced males, 10 experienced males, 10 inexperienced females, and 10 experienced females) participated in the study. Each participant's SPL values were averaged from 125 to 8000 Hz for both stimuli (music and white noise) and measurement scales (linear and A-weighted). It should be noted that experienced users were defined as listeners who listened to an iPod or other personal listening device at least three times weekly for at least six months.

The results obtained revealed a significant main effect for stimulus (music or white noise) and measurement scale (linear or A-weighted). In other words, SPL values were dependent on both stimulus and measurement scale. These results were expected due to the following reasons. First, white noise provides equal energy across the entire frequency spectrum while music fluctuates across the frequency spectrum. Second, expected differences were seen between the two measurement scales because the linear scale weights all frequencies by the same degree (i.e., 500 Hz has the same degree of relevance as 1000 or 2000 Hz) whereas the A-weighted scale is adjusted to conform to the frequency response of the human ear. In other words, the linear scale does not weight the frequencies in the same way as the human ear judges loudness while the A-weighted scale includes only those frequency components to which human ears are most sensitive (i.e., deemphasizing the lower frequencies and placing more emphasis on the mid to high frequencies).

Furthermore, the results showed that SPL values were not dependent on gender (male and female) or experience level (inexperienced and experienced). In other words, SPL values were not different for males versus females or experienced versus inexperienced users. These results were somewhat expected based on previous research; however, previous research comparing male and female listening levels is inconclusive. While some research states that males listen to personal listening devices at significantly higher intensity levels than females (Williams, 2005), other research states that males and females listen to PLDs at approximately the same intensity levels (Catalano and Levin, 1985). Furthermore, results obtained from the present study support the theory that males and females listen at approximately the same intensity levels when asked to choose their preferred listening level.

Additionally, the preferred listening levels of experienced and inexperienced users were not expected to be different based on previous research that showed comparable mean SPLs between PCP users (M = 71.2 dB[A]) and non-PCP users (M = 69.5 dB[A]) (Wong et al., 1990). Furthermore, research also states that sound pressure levels (SPLs) at preferred listening levels may be related to age (Ising et al., 1997). Ising and colleagues (1997) investigated the music listening habits of individuals between the ages of 10 and 17 years and found that a percentage of younger individuals listened to PCPs at 110 dB(A). In addition, it was noted that 17 year olds listened at lower levels. Consequently, younger individuals have been known to listen to music at louder levels and for longer durations. However, in the present study, preferred listening levels were measured in college-aged students between the ages of 18-25 years, and the results showed no difference in preferred listening levels for experienced and inexperienced users. Based on previous research it should, however, be noted that differences may be seen between experienced and inexperienced listeners for younger generations.

Comparison to OSHA Standards

The second purpose of the present study was to compare SPL data to the OSHA standards for noise exposure. Data for this portion of the study were interpreted and compared using the A-weighted noise scale only. This was done because the A-weighted scale is the standard scale used by OSHA to measure SPLs in noisy environments.

Overall data analysis (i.e., averaged across all listeners) showed that when individuals were listening at their preferred listening level, the overall SPL was lower than the OSHA standard of 90 dB(A). Particularly, average music stimuli were 14.0 dB softer than the OSHA standard while average white noise stimuli were 16.9 dB softer than the OSHA standard. These results indicate that SPLs produced by the iPod at a listener's preferred listening level did not exceed the OSHA standards for acceptable hearing levels. These results were unexpected based on previous research. While the research remains controversial on whether individuals listen at levels that may be harmful to hearing acuity (Fligor et al., 2004, Williams, 2005, Rice et al., 1987), research consistently states that SPLs may exceed OSHA standards (and be detrimental to hearing) when listening in the presence of background noise. More specifically, some research states that some individuals were at risk for reduced hearing sensitivity when using personal listening devices while other studies determined that these individuals were not at risk unless they listened at elevated levels for extended time periods or listened in the presence of background noise. For instance, Rice et al. (1987) noted that individuals showed an increase in preferred listening level when listening in the presence of background noise as compared to listening in a quiet environment, implicating that the presence of background noise may increase the SPL individuals set their PCPs. The researchers also indicated that some listeners may be listening at levels that exceed OSHA standards, which could be detrimental to hearing. A similar study by Airo et al. (1996) concluded that individuals listen to music significantly louder in the presence of background noise and may be at risk for hearing impairment at levels that exceed 85 dB SPL. Thirdly, Pugsley et al. (1993) cautioned that factors such as 1) the type of portable stereo system [PSS] device, 2) the type of music presented, 3) the style of earphones, 4) the presence of background noise, and 5) exposure time may all contribute to decreased hearing sensitivity in PSS users.

Furthermore, individual data analysis showed that eight listeners' peak SPL were above the OSHA acceptable limit of 90 dB(A). These peak SPL values were further analyzed. The results indicated that none of the average peak values were significantly louder than 90 dB(A). In other words, none of the eight listeners were listening at peak levels that were significantly louder than 90 dB(A) (see Table 3 for average peak SPLs for these eight listeners). It should be noted, however, that the researchers understand that the individuals who listened at levels that exceeded 90 dB(A) may be at risk for hearing impairment, depending on how long and often they listened at these levels.

In summary, there were two purposes for the present study: 1) to determine the SPLs of iPod users and nonusers at preferred listening levels measured using KEMAR and 2) to determine if those SPLs exceeded the OSHA standards for acceptable hearing levels. A total of 40 subjects participated in the study and were categorized according to the following four groups: 1) inexperienced males, 2) experienced males, 3) inexperienced females, and 4) experienced females. Experienced listeners were those individuals who were identified as listening to an iPod or other personal listening device at least three times per week for at least six months. SPL values were measured and averaged from 125 to 8000 Hz for both stimulus (music and white noise) and measurement (linear and A-weighted) scales using KEMAR and a recording software developed by National Instruments. The results revealed that SPL values were dependent on both stimulus (music or white noise) and measurement scale (linear or A-weighted); however, SPL values were not dependent on gender (male and female) or experience level (inexperienced and experienced). The results further revealed that, on average, SPLs in the ear canal produced by the iPod at a listener's preferred listening level did not exceed the OSHA standards for acceptable sound pressure levels. Nevertheless, listening to music at hazardous noise levels for extended periods of time may be detrimental to hearing sensitivity, thereby causing temporary and/or permanent hearing loss.

REFERENCES

Airo, Pekkarinen, J., & Olkinuora P. (1996) Listening to music with earphones: An assessment of noise exposure. *Acustica, 82*, 885-894.

Apple. Apple reports first quarter results. 17 January 2007. Retrieved February 12, 2007.

Burkhard, M.D., & Sachs, R.M. (1978). Anthropometric manikin for acoustic research. In M.D. Burkhard (Ed.), *Manikin Measurements* (pp. 3-11). Illinois: Industrial Research Products, Inc.

Catalano, P. J., & Levin, S. M. (1985). Noise-induced hearing loss and portable radios with headphones. *International Journal of Pediatric Otolaryngology, 9*, 59-67.

Darlin, Damon. The iPod ecosystem. *New York Times.* 3 February 2006. Retrieved on 21 March 2007.

Dillon, H. (2001). *Hearing Aids*. New York: Thieme.

Fligor, B. J., & Cox, C. (2004). Output levels of commercially available portable compact disc players and the potential risk to hearing. *Ear & Hearing, 25* (6), 513-527.

Hellstrom, P. A., & Axelsson, A. (1988). Sound levels, hearing habits and hazards of using portable cassette players. *Journal of Sound and Vibration, 127* (3), 521-528.

Ising, H., Babisch, W., & Hanee, J. (1997). Loud music and hearing risk. *Journal of Audiological Medicine, 6* (3), 123-133.

Kahney, Leander. Straight dope on the birth of iPods. *Wired News.* 17 October 2005. Retrieved March 22, 2007.

Mueller, G. (2006). Where in the world is KEMAR?. *The Hearing Journal*, 59 (4), 10.

National Institute for Occupational Safety and Health. Retrieved November 5, 2006, from http://www.cdc.gov/niosh/about.html.

Occupational Safety and Health Administration. Retrieved November 6, 2006 from http://www.osha.gov.html.

Pugsley, S., Stuart, A., Kalinowski, J., & Armson, J. (1993). Changes in hearing sensitivity following portable stereo system use. *American Journal of Audiology, 2* (3), 64-67.

Rice, C. G., Breslin, M., & Roper, R. G. (1987). Sound levels from personal cassette players. *British Journal of Audiology, (21)*, 273-278.

Serwer, Andy. It's iPod's revolution: We just live in it. *Fortune.* 27 June 2005. Retrieved March 21, 2007.

Suter, A. H. (2000). Standards and regulations. E.H. Berger, L.H. Royster, D.P. Driscoll, and M. Layne (Eds). The Noise Manual (pp 639-665). USA : American Industrial Hygiene Association.

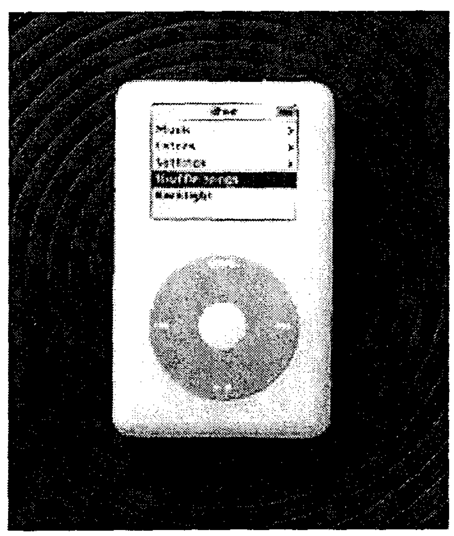
Turunen-Rise, I., Flottorp G., & Tvete, O. (1991). Personal cassette players ("walkman"). Do they cause noise-induced hearing loss? *Scandinavian Audiology (20),* 239-244.

Williams, W. (2005). Noise exposure levels from personal stereo use. *International Journal of Audiology, 44*, 231-236.

Wong, T. W., Van Hasselt, C. A., Tang, L. S., & Yiu, P.C. (1990). The use of personal cassette players among youths and its effects on hearing. *Public Health, (104)*, 327-330.

APPENDIX A

VISUAL REPRESENTATION OF iPOD AND EARPHONES



APPENDIX B

OSHA REGULATIONS, INTERPRETATIONS, AND RECOMMENDATIONS

Issue	**Description and Definition**	**OSHA Recommendation (29 CFR 1910.95)**
Action Level (AL)	The time-weighted average (TWA) exposure which requires program inclusion, hearing tests, training, and optional hearing protection.	AL = 85 dBA TWA. AL is exceeded when TWA > or = 85 dBA, integrating all sounds from 80- 130 dBA.
Permissible Exposure Limit (PEL)	The TWA, which when exceeded, requires feasible engineering and (MSHA)/ or (OSHA) administrative controls, and mandatory hearing protection.	PEL = 90 dBA TWA. PEL is exceeded when TWA > 90 dBA, integrating all sounds from 90-140 dBA, as inferred from Table G-16 of 1910.95 (b).
Exchange Rate	The rate at which exposure accumulates; the change in dB TWA for halving/doubling of allowable exposure time.	5 dB.
Ceiling Level	The limiting sound level above which employees cannot be exposed.	No exposures > 115 dBA; there is evidence that this ceiling level is not being enforced.
Impulse Noise	Noise with sharp rise and rapid decay in level, ≤ 1 sec. in duration, and if repeated, occurring at intervals > 1.	To be integrated with measurements of all other noise, but should not exceed 140-dB peak SPL.
Monitoring	Assessment of noise exposure.	Once to determine risk and HCP inclusion; from there as conditions change resulting in potential for more exposure.
Noise Control	Investigation and implementation of feasible engineering and administrative control measures.	Feasible controls required where TWA > 90 dBA; subsequent compliance policy (which may be changed/revoked by OSHA at any time) permits proven effective HCP in lieu of engineering where TWA < 100 dBA.
Hearing Protection	Exposure requirements and conditions for use of hearing protection devices (HPDs).	Optional for ≥ 85 dBA TWA; mandatory for > 90 dBA TWA, and for ≥ 85 dBA TWA for workers with STS. Protect to 90 or to 85 with STS. Choices must include a "variety" which is interpreted as at least 1 type of plug and 1 type of muff.
Evaluation of Hearing Protector Effectiveness	Method of assessing adequacy of HPDs.	Use manufacturer's labeled NRRs to assess adequacy, but subsequent compliance policy stipulates 50% derating of NRRs to compare relative effectiveness of HPDs and engineering controls.

Issue	Description and Definition	OSHA Recommendation (29 CFR 1910.95)
Audiometric Technician	The person who conducts audiometric testing and routine review under guidance of a professional supervisor.	Must be responsible to supervisor (see above). CAOHC certified, or has demonstrated competence to supervisor. When microprocessor audiometers used, certification not required.
Audiometry	Initial and ongoing hearing tests used to assess the efficacy of hearing conservation measures.	Required annually for all workers exposed ≥ 85 dBA TWA. Baseline test within 6 months of exposure; 12 months if using mobile testing service, with HPDs in the interim.
Quiet Period Prior to Baseline Audiogram	Period of nonexposure to workplace noise required prior to baseline audiogram.	14 hrs.; use of HPDs acceptable as alternative.
Background Noise	Permissible noise in audiometric test chamber during testing.	Levels specified as 40 dB @ 500 and 1000Hz, 47 dB @ 2000 Hz, 57 dB @ 4000 Hz, and 62 dB @ 8000 Hz.
Audiogram Review and Employee Notification	Required actions following audiograms.	Not specified unless STS is detected; see STS follow-up.
STS (OSHA/MSHA – Standard Threshold Shift; NIOSH – Significant Threshold Shift)	A change in hearing compared to an earlier (baseline) hearing test that requires follow up action.	≥ 10-dB average shift from baseline hearing levels at 2000, 3000 and 4000 Hz in either ear.
STS Retests	Follow-up audiogram that is permitted or required when initial STS is detected.	May obtain retest within 30 days and substitute for annual audiogram.
STS Follow-up	Required actions when an STS is detected.	Notify worker within 21 days: unless STS is not work-related, must fit or re-fit employee with HPDs and select higher attenuation if necessary, refer for audio/otological exam if more testing needed or problem due to HPDs, and inform employee of need for exam if problem unrelated to HPD usage is suspected.
Baseline Revision	Procedures for revising the baseline audiogram to reflect changes in hearing.	Annual audio substituted for baseline when STS is persistent or thresholds show significant improvement.
Presbycusis or Age Correction	Adjustments for hearing levels for anticipated effects of age.	Allowed.
Recordable or Reportable Hearing Loss	Amount of hearing loss triggering reporting requirements on workplace injury/illness logs.	By OSHA directive, ≥ 25-dB average shift from original baseline at 2000, 3000, and 4000 Hz, in either ear, w/age correction; rule change pending.

Issue	Description and Definition	OSHA Recommendation (29 CFR 1910.95)
Warning Signs and Postings	Requirements to post signs for noisy areas or to post regulations	Hearing conservation amendment shall be posted in workplace.
Record Retention	Specification on retention of data, and transfer requirements if employer goes out of business.	Noise surveys for at least 2 yrs., hearing tests for duration of employment, with requirement to transfer records to successor if employer goes out of business.

APPENDIX C

INFORMED CONSENT FORM

HUMAN SUBJECTS PERMISSION FORM

The following is a brief summary of the project in which you have been asked to participate. Please read this information before signing below:

TITLE: Sound pressure levels within the ear canal of iPod users.

PURPOSE OF STUDY/PROJECT: The purpose of this experiment is to determine sound pressure levels (SPL) in the ear canals of iPod users when the volume is set to the individual's preferred listening level.

PROCEDURES: Each participant will be asked to listen to a song through a 60 GB Apple iPod. The participant will be instructed to set the volume level to their preferred listening level. After completion of the song, the volume level will be locked into place. Monaural probe microphone measurements (Audioscan RM500SL) will be conducted for the two types of stimuli ("I Still Remember" and white noise) on each participant to determine typical sound pressure levels. Data for output levels recorded at the tympanic membrane will be stored in the probe microphone system and downloaded to a personal computer for subsequent data analysis.

INSTRUMENTS: The subject's identity will not be used in any form in the analysis or representation of the data. Only numerical data such as sound pressure levels in the ear canal will be used in the presentation of the results.

RISKS/ALTERNATIVE TREATMENTS: There are no known risks to subjects. All procedures will be conducted at listeners preferred listening levels.

BENEFITS/COMPENSATION: Each participant will receive a free hearing screening provided by Louisiana Tech Speech and Hearing Center.

I, ______________________________, attest with my signature that I have read and understood the above description of the study, "Sound pressure levels within the ear canal of iPod users," and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University and/or Louisiana Tech Speech and Hearing Center. Furthermore, I understand that I may withdraw from the study at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results will be confidential, accessible only to the project director, principal experimenters, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

______________________________ ____________________

Signature of Participant Date

CONTACT INFORMATION: The principal experimenter listed below may be reached to answer questions about the research, subject's rights, or related matters.

Matthew Bryan, Au.D., CCC-A — Department of Speech (318) 257-3102
Melinda Freyaldenhoven, Ph.D., CCC-A — Department of Speech (318) 257-2146

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:

Dr. Les Guice	(318)257-4647	Dr. Mary Livingston	(318)257-2292
Nancy Fuller	(318)257-5075		

APPENDIX D

DEMOGRAPHIC SHEET

Participant Questionnaire Date: ___________

Name: ________________________ Subject #: _____________________

Gender: M / F Birthday/Age: _________________

Phone Number: ________________ Email: ________________________

Do you currently own an iPod? YES / NO

If yes, how long (in years) have you owned your iPod: _________________

If no, do you use any other kind of personal listening device, such as a portable CD player or an mp3 player (please specify the kind of device)?

___________________________/ Time (in years) of ownership: ________________

How many days per week do you listen to your personal listening device (circle one)?

a. one	f. five
b. two	g. six
c. three	h. seven
e. four	i. other: ______________

How many hours per day do you listen to your personal listening device – list one: ____

A. less than 1 hour	B. 1 – 2 hours	C. 2 – 3 hours
D. 3-4 hours	E. 4-5 hours	F. 5-6 hours
G. 6-7 hours	H. 7-8 hours	I. 8-9 hours
J. 9-10 hours	K. more than 10 hours	

How many consecutive months have you listened to your personal listening device – list one: _____

A. less than 1 month	B. 1 month	C. 2 months
D. 3 months	E. 4 months	F. 5 months
G. 6 months	H. 7 months	I. 8 months
J. 9 months	K. 10 months	L. 11 months
M. 12 months	N. More than 12 months (how long in years ____)	

On a scale from 1 - 5, with five (5) being very high preference for the song and one (1) being extreme dislike, rate your preference of the song you listened to (circle your rating):

Extreme Dislike	Dislike	Neutral	Prefer	High Preference
1	2	3	4	5

Have you ever been diagnosed with a hearing loss? Yes / No

Do you have any reason to suspect you have a hearing loss? Yes / No

If so, why? ____

Have you ever experienced ringing in your ears?

If so, how often:_______________and when:__________________________

APPENDIX E

SOUND LEVEL METER SOFTWARE SETTINGS FOR MEASUREMENTS USING KEMAR

SOUND LEVEL METER SOFTWARE SETTINGS FOR MEASUREMENTS USING KEMAR

1) Take iPod from participant and place earbud on the right ear of KEMAR.
2) Click Short cut to channel SLM.
3) Under "physical channel" select browse.
    a. Select ai0/ai1.
4) Change averaging type from exponential to linear. The following settings should be changed:
    a. Intermediate Integration time = 100ms
    b. Total integration time = 255s for music and 60s for white noise.
    c. Sensor sensitivity = 10.5 for ai0 and ai1.
    d. Weighting filter = linear
    e. Octave bandwidth = 1/3 octave.
5) Select Weighting as either "linear" or "a-weighting" depending on measurement being taken.
6) Other settings on the SLM program that does not need changing are:
    a. Frequency Range [Hz]
        i. Low Frequency = 20.00
        ii. High Frequency = 20000.00
    b. Sample Rate = 50000
    c. Sensor Information
        i. dB Reference [EU] = 20.0E-6
        ii. Weighting filter = linear
        iii. Engineering units = Pa
        iv. Custom label = EU
        v. Pregain [dB] = 0.00
7) Select the box that says "write octave data to file?"
8) it play on the iPod.
9) Click S*tart Acquisition.*
10) When the song is over, hit stop/pause on the iPod.
11) Click S*top and Close* on the software.
12) Change the file name from Session D to the participants name and click ok.
13) The file will go into the folder on the desktop named "measures from KEMAR."