Brigham Young University E.A.R.S – Educational Acoustics Research Study

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ABSTRACT

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For years, the effects of sound pressure level measurements upon human hearing and psychology have been studied, and only in recent years scientists have seen a link between these measurements and headphones connected to portable listening devices. The Brigham Young University Educational Acoustics Research Study (E.A.R.S) is an interactive demonstration devoted to acquiring samples of the student body that connect findings between the use of headphones with portable listening devices, such as mp3 players, and educating individuals in the process. This report will highlight the reasoning for conducting the study, describe the proper background in acoustics needed to understand the material, and analyze the results from the study, while concluding observations. The study will evaluate the overall sound pressure level due to a one second L_{eq}, safe listening time according to non-occupational noise criterion, and demographics that define the individual, such as age, gender, listening preference, and mp3 player. Also, the study will ask the individual about their listening habits and if they will change based around the feedback received from the E.A.R.S. This study will ultimately benefit science with information to understand connections between listening habits and safe practices of listener protection.

Keywords: sound pressure level, headphones, mp3 player, listening habits, safe listening time

ACKNOWLEDGEMENTS

I was supported by the Brigham Young University Department of Physics and Astronomy. I like to thank Dr. Traci Neilsen for conducting the research opportunities via her Physics 167 Acoustics class. Jay Erying for an outstanding use of time and commitment in compiling the structure of the LabVIEW code for E.A.R.S. Brad Moser for his contribution of the origination of the E.A.R.S concept and initial implementation. I would also like to thank my advisor, Dr. Kent Gee for the extensive help that they contributed to the guidance with this senior capstone. Finally, I would like to thank my peers and reviewers for their many insights.

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Chapter 1

Introduction

1.1 Background in Acoustics

Noise-induced hearing loss is a silent destroyer among a vast technological community connected with portable media. This hearing loss has been subjected to one's exposure in non-occupation noise, especially in youth. When exposed to harmful noise—sounds that are too loud or loud sounds that last a long time—sensitive structures in our inner ear can be damaged, causing noise-induced hearing loss (NIHL). Prolonged exposure can cause vast hearing related problems as well, such as temporary threshold shift, permanent threshold shift, tinnitus, and presbycusis, and age-related hearing loss. Tools have been developed to assist individuals to become aware of this growing problem, and through proper education in protection and monitoring one can avoid this dilemma.

The Brigham Young University Acoustics Research Group E.A.R.S. project will provide the community with a better understanding of their exposed acoustical environment. The E.A.R.S. project is an acronym for, "Educational Acoustics Research Study." The intent of the project is to bring scientific data collected from an apparatus that is designed to listen to sampled music from the subject's mp3 listening device or other means of portable music, as well as educate the subject about basic acoustics, sound levels, and sound exposure.

The E.A.R.S. is a step into right direction as a tool to assist in noise-induced hearing loss prevention. The project bases itself around many principles of acoustics, which include sound pressure level, L_{eq}, and a safe listening time developed from sound exposure.

1.1.1 Sound pressure level

Acoustics is the study of all energy in the form of mechanical waves in either the form of generation, transmission, and reception. Sound, which is typically regarded as the product of the physics of acoustics, is the mechanical wave that is emphasized in this study. All sound has two properties associated with its identity: mass and a restoring force, and can either be random or time-harmonic. To simplify, the assumption will be made that time-harmonic sound is observed. Thus, the simplest examination of a sound wave would be the propagation of sound via the vocal chamber of a human. The voice has a mass that can be explained as a density of air times a unit of volume occupying space and it has a restoring force, which creates an oscillation as it encounters the stiffness of the air, i.e. air friction (drag).

The oscillation that occurs is a sound wave, as it creates a disturbance in the pressure in the air. The disturbance is very small ($p_{acoustic} << ATM$), relative to the atmospheric pressure in the air, given that the process is adiabatic in nature, meaning it does depend upon temperature, initial pressure, and volume. However small the disturbance may be in the pressure of the medium in which the sound is propagating, the oscillation is observed with amplitude that measured in acoustic pressure, i.e. $p_{accoustic}$. The acoustic pressure is measured in Pascal (Pa) and is notably defined to have a reference acoustic pressure of 20 μPa (20×10^{-6} Pa), called p_{ref}.

Sound pressure level is a comparison of the root-mean square acoustic pressure, p_{rms}, relative to the reference acoustic pressure (*Blackstock*, 2000). The measurement was developed by Bell Laboratories as a way to express a wide range of pressures on a logarithmic scale with ease and a consistent way for humans to express relative loudness as a ratio between two sounds. The logarithmic scale is of base 10, and is expressed in the unit of decibel, or dB. Thus, full equation is expressed as

$$Sound\ Pressure\ Level = SPL = 20\log_{10}\left(\frac{p_{rms}}{p_{ref}}\right),\ where\ p_{rms} = \sqrt{\frac{1}{T}\int_0^T p_{acoustic}^2 dt}\ and\ T\ is\ the\ Period \tag{1.1}$$

Therefore, sound pressure level has a range from 1 dB (p_{ref}/p_{ref}) where it is interpreted to be the faintest sound detected among humans measured empirically, to 140 dB and excess. Typically, the threshold of hearing is considered as 1 dB and the threshold of loudness is regarded as 120 dB, at which hearing loss is imminent. 140 dB is known as the threshold of pain, at which levels can become potentially lethal without industrial proper protection. All of these levels are measured relative to 20 μPa.

This measurement is important to self-awareness of noise-induced hearing loss. Also, certain conditions of these frequency-based waveforms acoustics pressures are important. The weight that is assigned to a sound pressure level can have a significant effect on the levels in which criterion can be expressed. The weight is assigned based on the frequency range in which the content measured occurs, in order to better scale the value to a listening environment. The E.A.R.S. demo uses an A-weighting and is expressed in dBA, which caters to more of the frequencies that are within human speech and noise. The A-weight equation (*Kinsler et al., 2000*) as a function of frequency, where A(f) is the weight function is added to the sound pressure level, can be expressed as,

$$R_A(f) = \frac{12200^2 \cdot f^4}{(f^2+20.6^2)\sqrt{(f^2+107.7^2)(f^2+737.9^2)}\ (f^2+12200^2)}$$

$$A(f) = 2.0 + 20\log_{10}(R_A(f))$$

(1.2 & 1.3)

This weighting is also the standard in which sound exposure levels are measured.

1.1.2 L_{eq}

The L_{eq}, or Equivalent continuous sound level is a steady-state sound that has the same A-weighted level as that of a time-varying sound averaged in energy over the specific time interval (*Kinsler et al., 2000*). In other words, the L_{eq} is a sound pressure level measurement that accounts for time-varying signals, in which can be examined for a specific allotted time. This allows for a more accurate sum of the acoustic pressures in which one can observe events over certain periods of time. Most L_{eq} are measured in one-second intervals and others can vary in time as much as 8 hours to 24 hours as standards. The L_{eq} can be expressed as,

$$L_{eq} = 10\log_{10}\left(\frac{1}{t_1 - t_2}\int_{t_1}^{t_2}\frac{p^2_{acoustic}}{p^2_{ref}}dt\right),\ where\ t_1,\ t_2,\ and\ dt\ are\ measured\ in\ the\ same\ units$$

(1.4)

Also, another important principle is the addition of coherent sources of sound to equate an overall L_{eq} between two different signals, such as the ones in the E.A.R.S. Coherence means that the sound pressures are of the same constant phase. Thus, because the measurement of L_{eq} is based on a logarithmic scale the levels cannot be summed and then averaged as if they were linear, but rather the acoustic pressures must be examined. L_p, the addition of coherent sources as a level can be described mathematically as

$$L_p = 10\log_{10}\left(\sum_{n=1}^{N} 10^{\frac{L_{p,n}}{10}}\right),\ \textit{where N is the number of signal levels summed} \tag{1.5}$$

This means that the overall L_{eq} between two signals is the addition of the dissected acoustic pressures summed over the total number of signal levels and then put back into a logarithmic scale. Once the overall L_{eq} is obtained, one can study the effects of the sound exposure and then calculate a safe listening time where noise is present.

1.1.3 Safe Listening Time

Sound exposure is the quantity in which a person is exposed to sound at any sound pressure level. More effectively, examination of the sound exposure time is the amount of time one person can listen to the sound exposure at any given time. However, the most effective method of determining factors for noise-induced hearing loss is the sound exposure level, SEL, which combine the sound exposure and sound exposure time. The SEL is a level on a logarithmic scale that expresses a total sound energy of the whole averaging period with reference duration of one second rather than t_2 to t_1. This calculation assists in providing industries whose exposure is over an extended period of time, which when calculated, tells the person the allotted sound exposure time one can endure. The SEL can be expressed mathematically as,

$$SEL = 10\log_{10}\left(\frac{1}{T_0}\int_{-\infty}^{+\infty}\frac{p_{acoustic}^2}{p_{ref}^2}\right),\ \textit{where } T_0 \textit{ is the refernce time of 1 second} \tag{1.6}$$

The Occupational Safety and Health Administration (OSHA) determined these values of SEL in 1970 to come up with a standard for Americans to prescribe the allotted time one can be exposed to a certain level. This administration has seen links between exposures of prolonged time (measured in years) to noise-induced hearing loss. In Figure 1.3.1, an audiogram shows the hearing level expressed in dB of a person exposed to occupational noise over a span of various frequencies, showing the harms of noise-induced hearing loss.

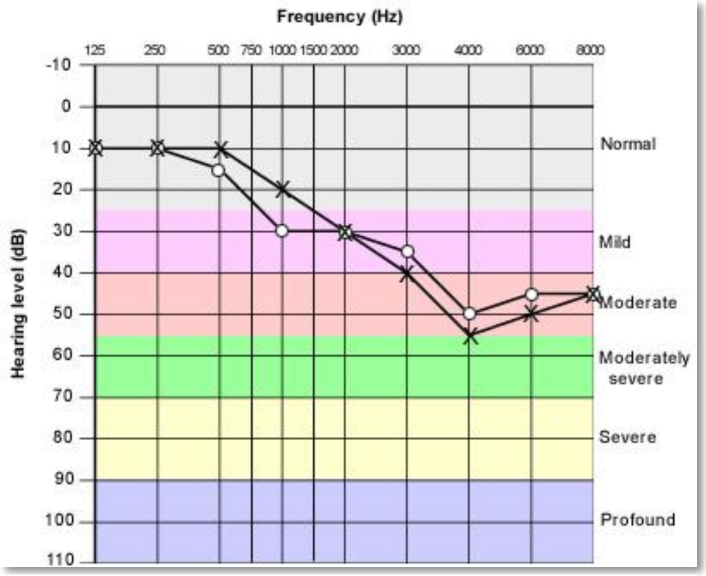


Figure 1.3.1 – This audiogram shows NIHL in a 55-year old male factory worker who complained of onset tinnitus. Notice the high frequencies have been affected in a moderate to moderate-severe manner. (*Nisker*, 1956)

OSHA has provided certain guidelines for non-occupational noise and judging the daily noise exposure levels when estimating the possible dangers to hearing. Table 1.3.1 explains the calculations for the limitations and the prescribed time for each level (*Kinsler et al, 2000*).

Limiting Daily Exposure Time	Sound Level Slow Response (in dBA)
Less than 2 min	115
Less than 4 min	110
Less than 8 min	105
15 min	100
30 min	95
1 hr.	90
2 hr.	85
4 hr.	80
8 hr.	75
16 hr.	70

Table 1.3.1 –Daily noise exposure levels for non-occupational noise (Kinsler, 2000)

1.2 Context

The E.A.R.S project is not the first study that has been conducted to study the effects of noise-induced hearing loss with those using portable listening devices. First, the E.A.R.S. concept, which uses a mannequin head to imitate the acoustics shadow of the human head with two symmetrical placed ears, has been developed in the professional environment as ear simulators. In fact, the Knowles Electronic Manikin for Acoustic Research (KEMAR) is a professional mannequin mounted with such technology meant to record and analyze data for acoustics exposed to the ears. The KEMAR will be later explained in the calibration section.

Technology has vastly increased the risk of noise-induced hearing loss as the availability of portable listening devices has increased. In recent studies, it was found that 76.7% of university students at the University of Toronto at Mississauga, and 61% of high school students, and 23% of adults polled in the United States had either had a iPod or other mp3 listening device(*Ahmed et al, 2007*). Therefore, as the availability has gone up, it is very plausible that the influences of noise-induced hearing loss are on the rise. Also, research has been done to see what the maximum outputted sound pressure levels of sampled mp3 players can achieve.

Research in 2008 evaluated nine of the most popular digital audio players, of which at the maximum volume settings, outputted a range of 101 to 107 dBA(*Keith et al, 2008*). That same study also evaluated that after different adjustments, such as the device output voltage, earphone sensitivity, and earphone fit could vary in 10 to 16 dBA, and up to levels of 125 dBA (*Keith et al, 2008*). In comparison, results obtained 7 years prior to the study conducted in 2008, it was found that the 7 most popular digital audio players was around an average of 104 dBA (*Keith et al, 2001*). It was concluded, that factors of longer battery life, more storage capacities, and easier portability allotted for the increase of about 5 dBA(*Hodgetts et al, 2009*).

After looking at these factors, it is clear that there is a rise in increased sound pressure levels of digital audio devices. The connection between these levels and noise-induced hearing loss has also been linked.

> "There is some research suggesting that teenagers and young adults demonstrate symptoms of noise-induced hearing loss. Specifically, 15.5% of adolescents aged 12-19 had threshold shifts displaying a notch pattern commonly associated with noise exposure in one or both years…the majority of young adults have experienced tinnitus (i.e. phantom rushing, buzzing, ringing in the ears) and hearing impairment after loud music exposure. (*Axelsson et al, 1994*)"

These findings helped me understand the importance of the need to educate individuals about the personal hearing and level monitoring.

1.3 **Motivation**

I have always wanted to examine the connection between noise-induced hearing loss and L_{eq}'s. However, I can't exactly study those effects with the E.A.R.S., because it does not examine the prolonged effects of the listening device. Thus, I found the project started as a senior RET physics capstone project by Brad Moser, extremely appealing because its use of the fundamentals of acoustics and personal awareness to hearing protection.

By completing this project, I intend to see connections in a change in listening habits with the self-discovery of sound exposures due to extreme acoustic pressures to the ears. I also intend to educate the individual to monitor their hearing through the safe listening time that is displayed to them, and the protection that they will supply to their ears.

Chapter 2

Methods of Educational Acoustics Research Study

2.1 Construction of E.A.R.S.

The original concept of the E.A.R.S. project was the concept of Brad Moser in association with his advisors of Kent Gee and Brian Anderson. The concept includes a mannequin head with microphones in the ears connected to a computer that runs an interactive program to allow the user to analyze the sound that is coming into their ears. The project was designed to educate the user about noise-induced hearing loss and sound pressure levels that one might be exposed to.

The technical details of this construction will be briefly explained; however, due to the fact the construction of the project was evaluated with association of another capstone, the details are simply informative. The mannequin head was ordered from a supplier and then sculpted to fit two anatomically correct silicone ears, in which a set of Audio-Technica 3.5 mm ¼" microphones. These microphones are passive and require a direct DC supply of 1.5 volts to power to each microphone. A voltage divider is placed inline between the microphones and the computer. The setup of these details can be seen in Figure 2.1.1.

Figure 2.1.1 – The construction of the E.A.R.S. mannequin with microphone ear and voltage divider featured.

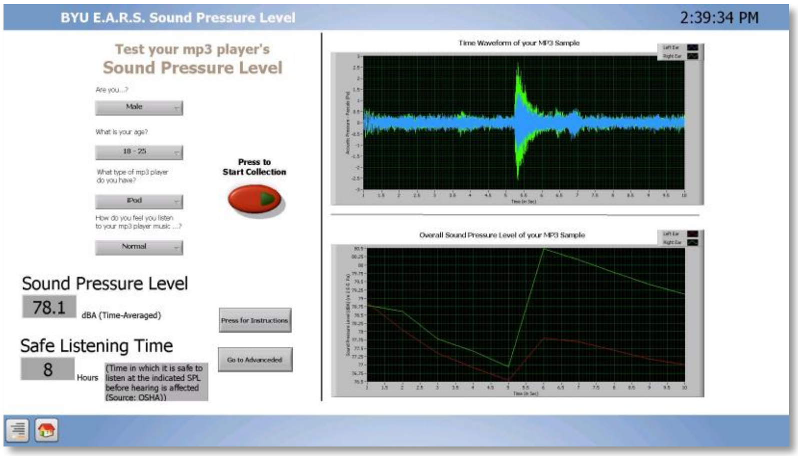
The remaining component of the construction simply is the LabVIEW program that brings the analysis together.

2.2 Programming E.A.R.S in LabVIEW™

The original concept developed by Brad Moser compiled the initial ideas of the flow of the content in the program. The program features an introductory screen ("Home"), an intermediate screen explaining instructions for operation, the E.A.R.S. survey and collection, and finally an advanced screen. The advanced screen is designed for more than just the common user (one who might have training in acoustics) to see different signal analysis of the inputted signal. The introductory screen introduces the user to the study. The screen contains a slideshow of the Brigham Young University Acoustics

Research Group photos while introducing the user to concepts that assess and inform. The Home screen features an interactive window popup informing the user of different topics such as NIHL, L_{eq}, ear canals, and even an interactive applet designed to show the user what sounds are expected to be at a certain sound pressure level.

Advancing from the Home screen leads the user to the instructions page. The instructions inform the user of the proper techniques used in acquiring proper and adequate data for analysis. The E.A.R.S. survey and collection screen is then introduced. The screen displayed for the E.A.R.S. collection is represented by Figure 2.2.1. First the screen asks the user some key demographics, allowing the user to input data to be analyzed later as potential factors that influence level readings (see Chapter 3). The demographics asked in the survey are stored as a text file and accessed remotely. The user then presses the "Start Collection" button on the screen, which initializes 10 seconds of data recorded from the mannequin's ears through the microphones into the computer's Line In of the on-board sound card. The data is then separated by channel and processed through the calculation for a 1 second L_{eq} A-weighted level and then the two signals are then added through the addition of two coherent acoustic pressures and compiled as a level. The outputted level is the sound pressure level displayed to the user. Also, from that derivation, the safe



Are you...? Male

What is your age? 18 - 25

What type of mp3 player do you have? iPod

How do you feel you listen to your mp3 player music ...? Normal

Sound Pressure Level 78.1 dBA (Time-Averaged)

Safe Listening Time 8 Hours (Time in which it is safe to listen at the indicated SPL before hearing is affected (Source: OSHA))

Figure 2.2.1 – A screen capture from the BYU E.A.R.S. Data Collection and Survey Screen.

listening time is determined using Table 1.3.1. The displayed graphs are the graphical representation of the time-waveform of the acoustic pressures for 10 seconds and the 1-second L_{eq}'s for each channel/ear of the 10 seconds.

The last screen of the E.A.R.S program is the advanced screen. The screen features both time-waveform and frequency-based analysis of a collected 10-second signal of both channels/ears. The first two graphs are a repeat of the same graphs seen in the collection screen, and the last two feature a power spectrum and 1/3 octave-band analysis. The power spectrum is for the advanced user to detect the key frequencies that make up its content, such as fundamentals, harmonics, and overtones, as well as resonances. The 1/3 octave-band analysis would assist the user in understand which bands of frequencies to attenuate or amplify in their portable listening device to acquire a certain response in their listening. All this analysis is central to the study, but without calibration and references, the data would be invaluable.

2.3 Calibration

Calibration is the process by which the references of the E.A.R.S can be set and understood to be true. The goal was to calibrate the values to a ± 1 dBA. The goal was also to obtain, through calibration, a sample sine wave through the KEMAR, record the amplitude of the pressures, and then match them with the E.A.R.S. However, this seemed to be more impractical then helpful. The dilemma with the KEMAR was the whenever the pressures were matched in amplitude it would increase the noise floor of the E.A.R.S. and effect the overall sample. Thus, a new calibration method was selected.

The calibration method selected was using a GRAS 1 kHz Calibrator which outputted a 1 kHz sine tone at 114 dBA. It would match the level from the outputted tone from calibrator in the E.A.R.S. The calibrator needed a way to effectively send its tone into the E.A.R.S because of its vertical shape, and its function was only meant for a microphone. Thus, a 1/8” X 1/16” surgical latex tube was mounted in the calibrator inserted in the opening of one of the mannequin’s ears, as shown in Figure 2.3.1. However, before any true measurements were to take place, one must first measure if the effectiveness of the calibrator might have been affected by the extension in the surgical tube.

Figure 2.3.1 – a GRAS 114 dBA 1 kHz Calibrator fixed in the ear of the E.A.R.S. mannequin.

The effectiveness was measured by setting the microphone’s sensitivity of a ¼” condenser microphone using a calibrator computer program with the tone being produced by the GRAS 114 dBA 1 kHz Calibrator. The ¼” condenser microphone’s sensitivity was measured to have an initial value of 3.33 mV/Pa. The surgical tube was then applied with the same length that would be fastened to the calibrator to the microphone to and the calibrator program measured a value of 3.37 mV/Pa for its sensitivity. This process can be seen in Figure 2.3.2. The effectiveness would then be evaluated according to the Equation 2.3.1, below.

$$Effectiveness\ (in\ dB) = 20\log_{10}\left(\frac{S_{new}}{S_{ref}}\right),\ where\ S_{ref}\ is\ the\ referenced\ microphone\ sensitivity \tag{2.3.1}$$

The effect of the surgical tubing to the microphone was only a difference of 0.1dB.


Figure 2.3.2 – ¼” Condenser Microphone connected to the GRAS calibrator measuring its sensitivity via the surgical tube.

The next part of the calibration made sure that the microphone sensitivities were measured correctly for ear of the mannequin in order for the E.A.R.S program to properly transform the voltage of the ear into Pascals. This was done by obtaining the original reference pressure that was outputted to the microphone, multiplying it by the original sensitivity that was set by the E.A.R.S, and dividing that quantity by the intended pressure that is needed for a 114 dB sound pressure level. It can be expressed in Equation 2.3.2,

$$S_{new} = \frac{S_{old} \cdot P_{old}}{P_{114\ dBA}}, \ where\ P_{114\ dBA}\ is\ defined\ as\ 14.17\ Pa \tag{2.3.2}$$

The S_{new} calculated from this calculation came out to 3.13 mV/Pa for the left ear (Channel 0) and 3.19 mV/Pa for the right ear (Channel 1). Thus, the E.A.R.S. ears were set to those sensitivities and through the process of calibrating as shown in Figure 2.3.1, the amplitude of the pressure of the 1 kHz sine wave was matched and the 114 dBA sound pressure level was set.

Lastly, it was noted when everything was calibrated that the noise floor was very high, around the magnitude of 94 dBA. The noise floor measured by a Sound Level Meter is around 67 dBA-74 dBA. It was found that there was a fair amount of electrical noise being introduced into the calculation. A notch filter was then introduced after looking at the power spectrum of the two signals, and filters were placed at the 120, 240, and 360 Hz to attenuate the noise. The noise was reduced to a sound pressure at 74 dBA.

2.4 The Study

The study includes a diagnostics portion and a survey portion. The diagnostics portion is the actual data sampled from each participant where it would include their gender, age, mp3 player, sound pressure level, loudest sound pressure level outputted by the headphones, and a safe listening time. This section also includes the music genre of the sample. The survey portion includes questions designed around the perception and interpretation of the experiment. Questions varied from: Were you surprised at how loud you listen to your music? Do you believe that that knowledge that you gained by participating in this study will have an impact on your listening habits, and why? And how many hours a day on average do you listen to your mp3 player? These questions were designed to verify if the data would support some relative conclusions. The sample E.A.R.S. Study Survey can be found on page 23.

The study looked at key information such as the overall SPL of all participants and overall outputted SPL by their portable listening devices of all participants. The study then examined demographics, such as age and gender. The safe listening time was broken down into the overall sample and gender. Lastly, the SPL was sampled for specific portable listening devices as well as certain music genres.

Chapter 3
Data Analysis

3.1 Experiment Results

The study was conducted between the dates of December 3rd, 2012 and December 5th, 2012. The participants sampled consisted of the Dr. Neilsen's Physics 167 class at Brigham Young University, and associated friends of classmates. The total number of participants was 87. The number of females sampled in the study was 48, as compared to 39 men. The majority of those sampled were between the ages of 18-25, with 3 participants in the category of 25-30 year olds.

In Figure 3.1.1, the overall sound pressure level of those sampled in the study can be observed. This histogram shows the percent of those that exceeded a certain SPL. The most common SPL is 81 dBA at 13%, and highest SPL is 112 dBA and the lowest is 75 dBA.

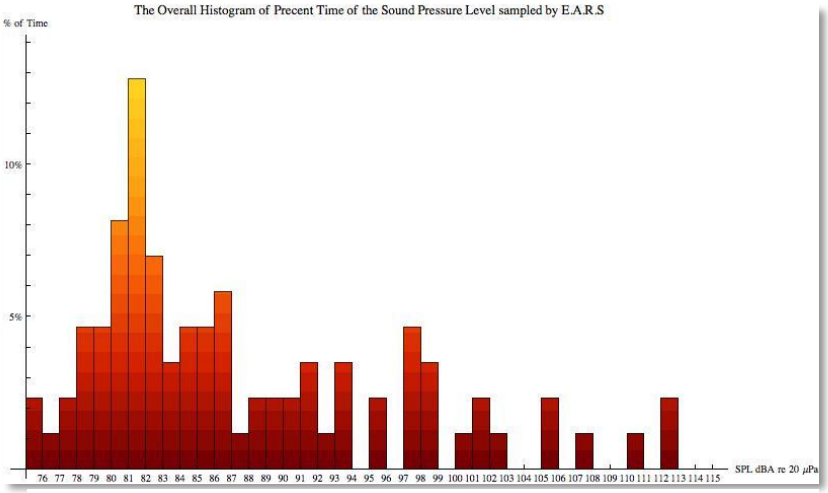


Figure 3.1.1

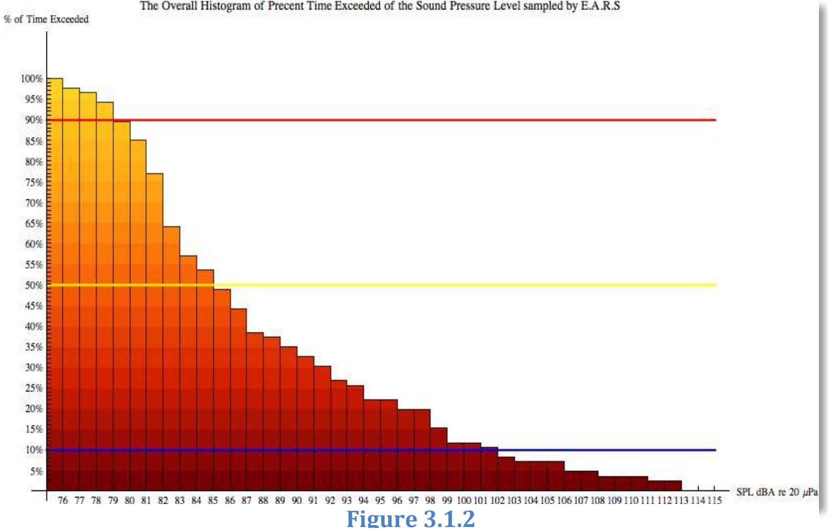
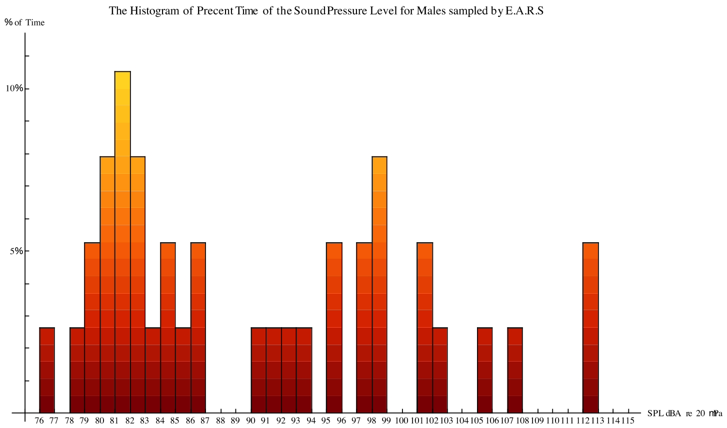
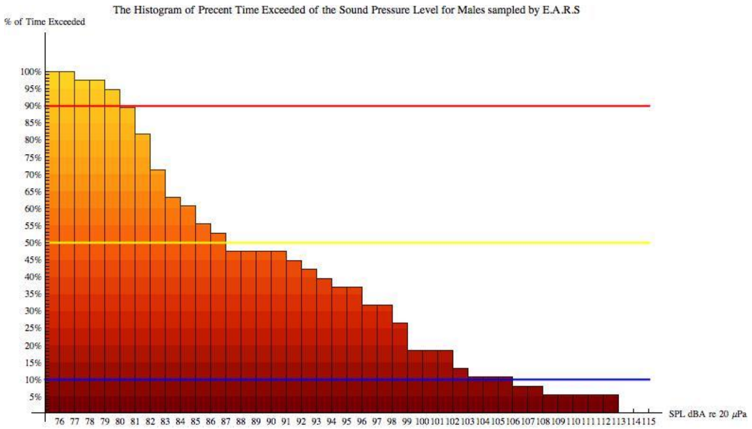


Figure 3.1.2

In Figure 3.1.2, the histogram displays the amount of time exceeded in percentages by sound pressure levels of all of the participants. Each of the lines indicated on the figure, represent 90% (Red), 50% (Yellow), and 10% (Blue) of the time exceeded.

The remaining figures and results will be analyzed in the Section 3.2, but the next three pages will display accompanying figures representing the data collected.


The Histogram of Precent Time of the Sound Pressure Level for Males sampled by E.A.R.S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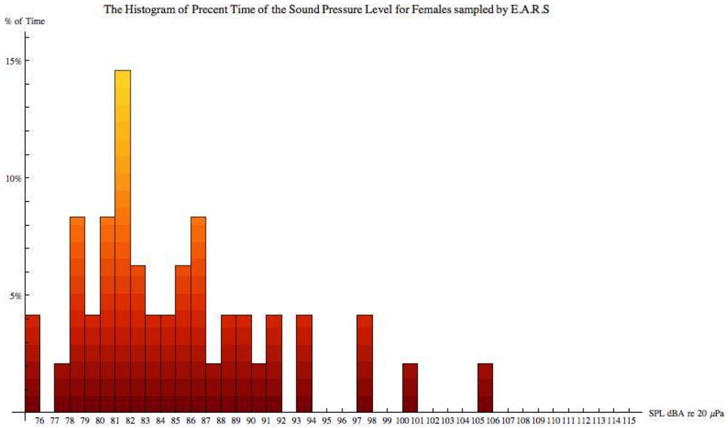
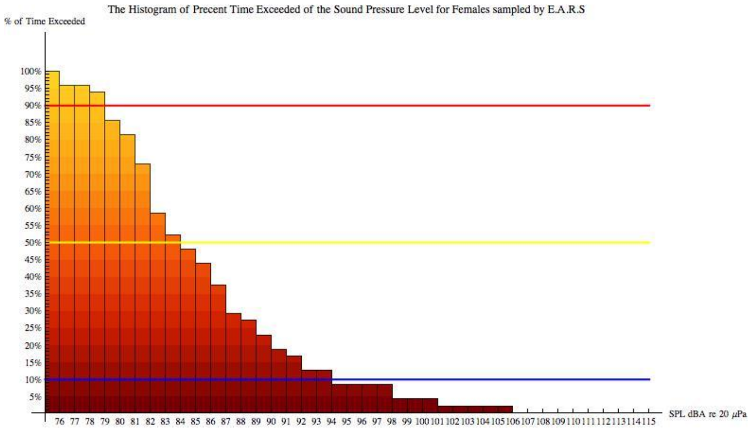

The Histogram of Precent Time of the Sound Pressure Level for Females sampled by E.A.R.S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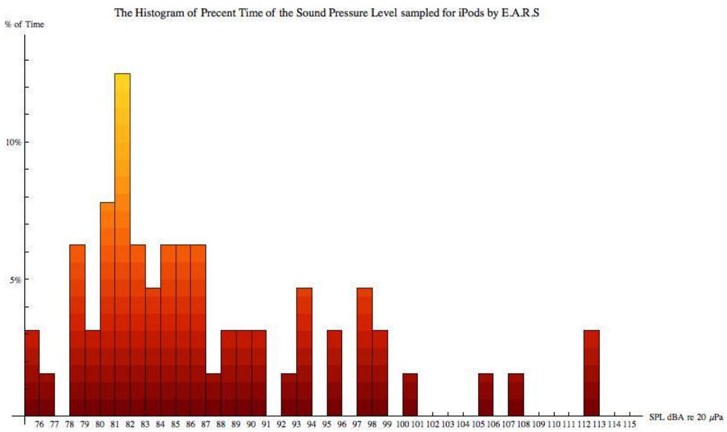
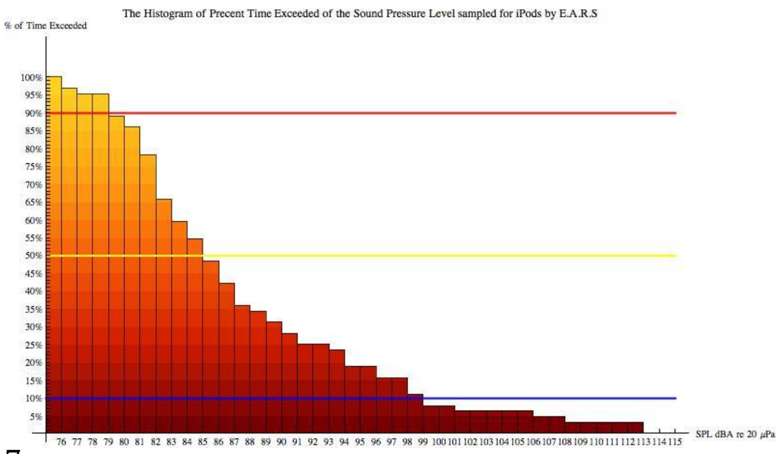

The Histogram of Precent Time of the Sound Pressure Level sampled for iPods by E.A.R.S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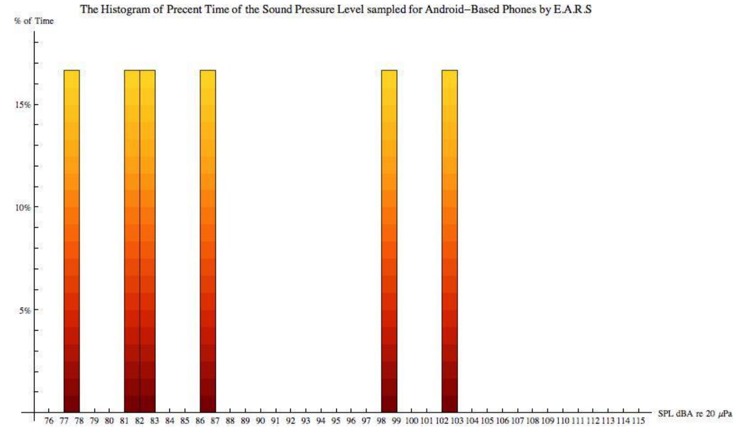
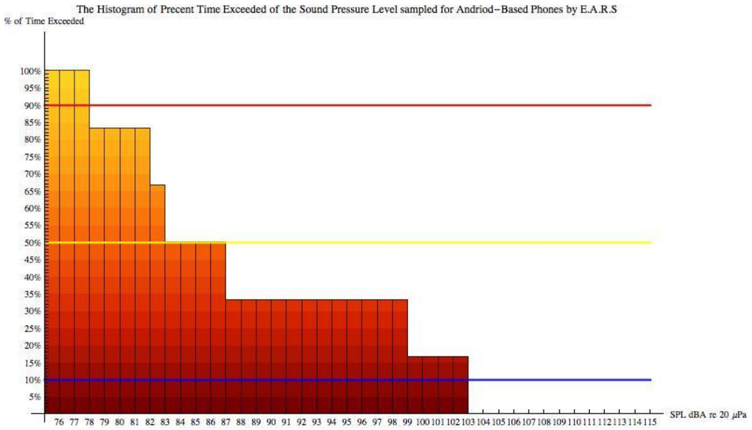

The Histogram of Precent Time of the Sound Pressure Level sampled for Android–Based Phones by E.A.R.S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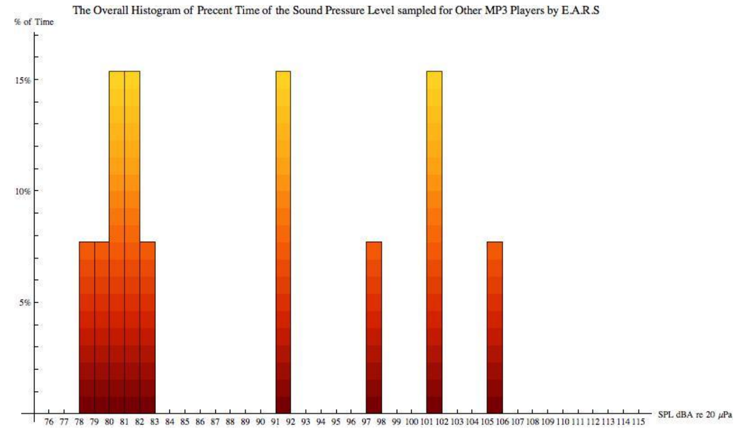
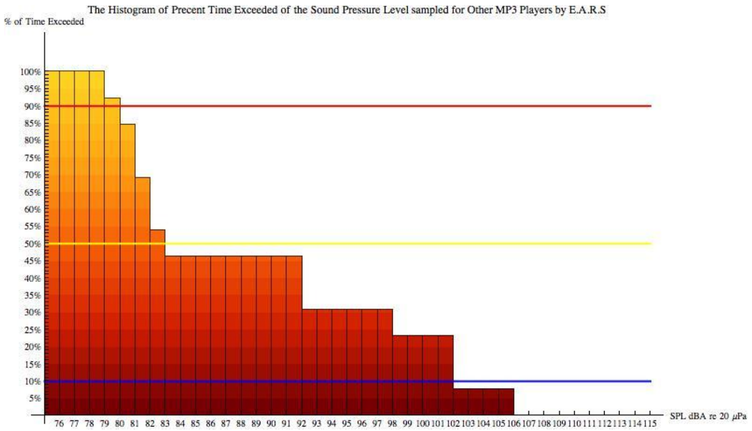
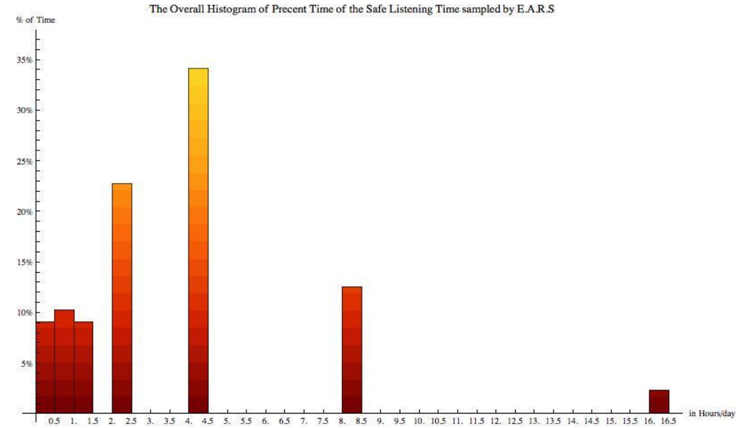
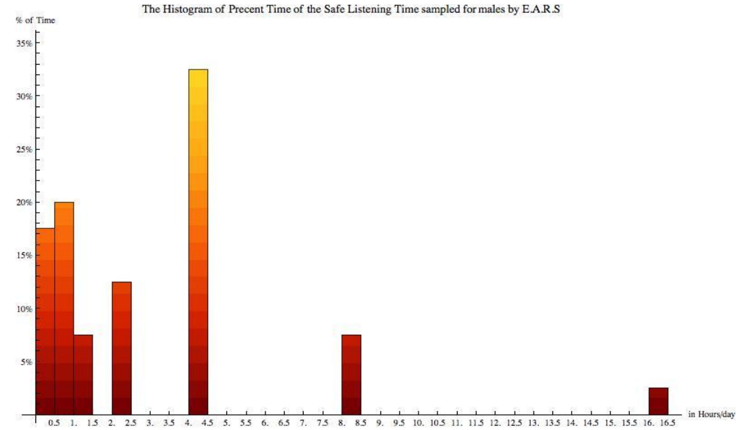
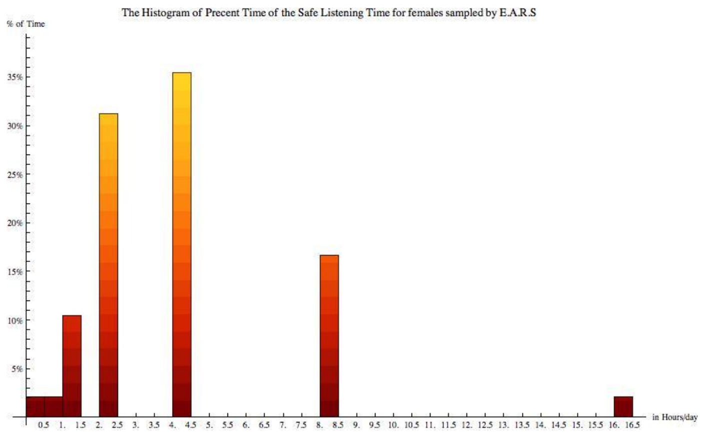

The Overall Histogram of Precent Time of the Sound Pressure Level sampled for Other MP3 Players by E.A.R.S

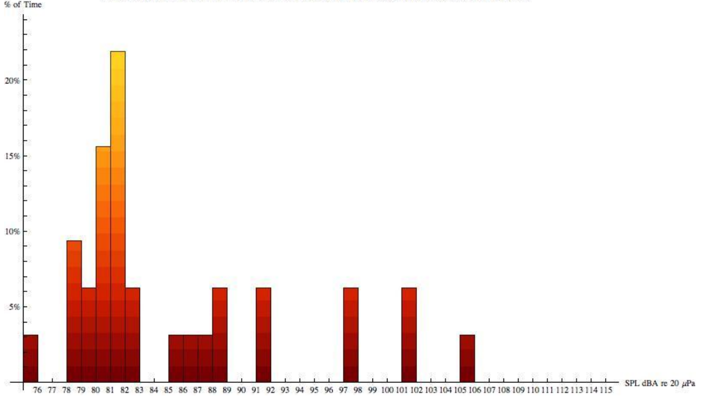

The Histogram of Precent Time Exceeded of the Sound Pressure Level sampled for Other MP3 Players by E.A.R.S


The Overall Histogram of Precent Time of the Safe Listening Time sampled by E.A.R.S

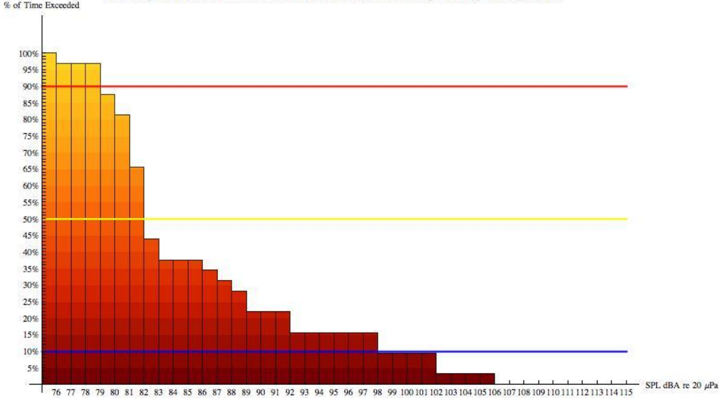

The Histogram of Precent Time of the Safe Listening Time sampled for males by E.A.R.S


The Histogram of Precent Time of the Safe Listening Time for females sampled by E.A.R.S

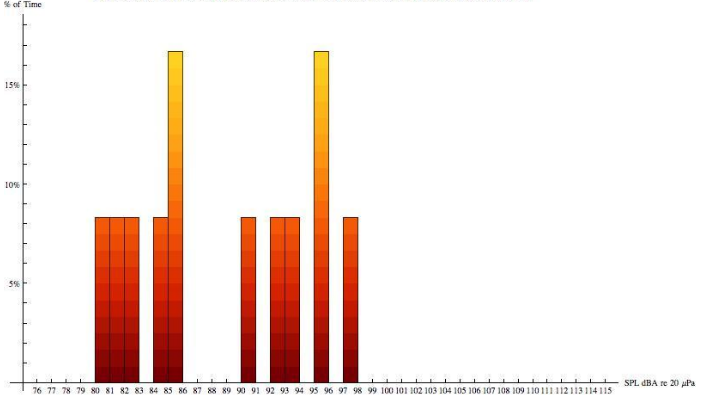
The Histogram of Precent Time of the Sound Pressure Level sampled for Pop Music by E.A.R.S



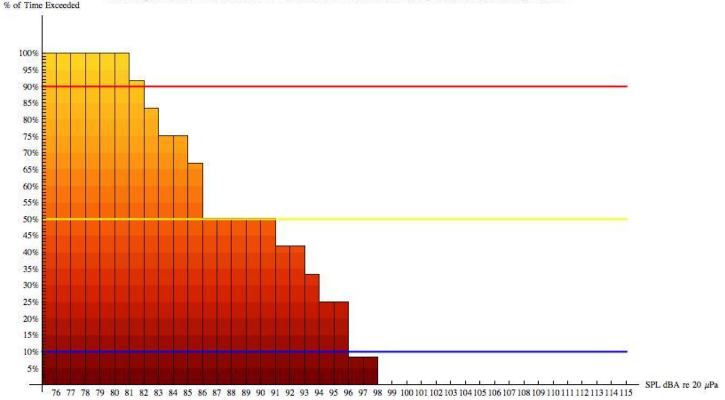
The Histogram of Precent Time Exceeded of the Sound Pressure Level sampled for Pop Music by E.A.R.S



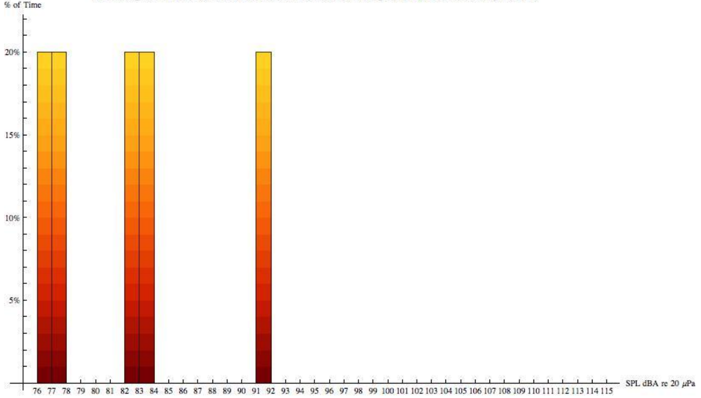
The Histogram of Precent Time of the Sound Pressure Level sampled for Rock Music by E.A.R.S



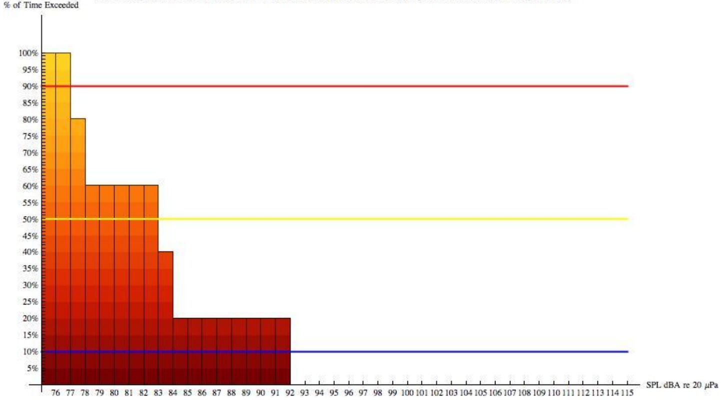
The Histogram of Precent Time Exceeded of the Sound Pressure Level sampled for Rock Music by E.A.R.S



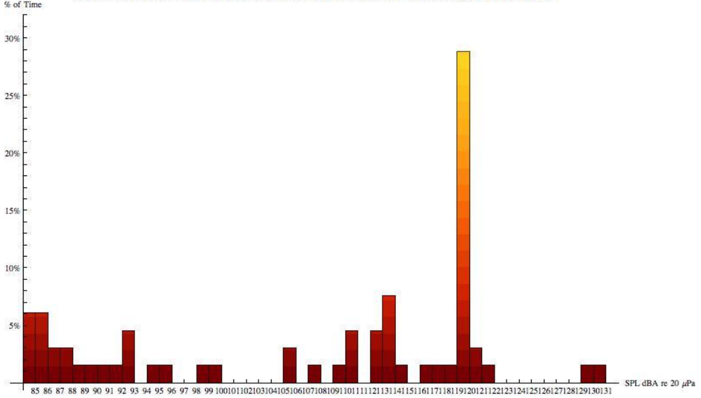
The Histogram of Precent Time of the Sound Pressure Level sampled for Classical Music by E.A.R.S



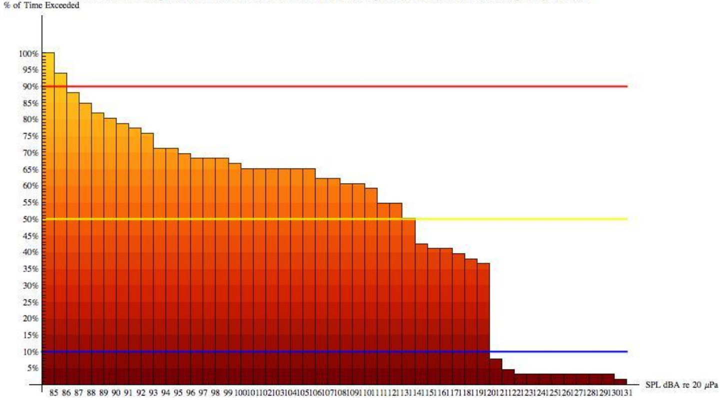
The Histogram of Precent Time Exceeded of the Sound Pressure Level sampled for Classical Music by E.A.R.S



The Overall Histogram of Precent Time of the loudest outputted Sound Pressure Level sampled by E.A.R.S



The Overall Histogram of Precent Time Exceeded of the loudest outputted Sound Pressure Level sampled by E.A.R.S



3.2 Data Analysis

The data collection taken from the study proved to have strong results. The overall results for all 87 participants for sound pressure level stated that 50% of the time, 87 dBA was achieved. Males show a significant difference between females in sound pressure levels, where 50% of the time 87 dBA was achieved in comparison to only 84 dBA in females. The results suggest that men listen at louder levels of music in their mp3 players more than females by 3 dBA. Interestingly enough, the results show that the most common preferred listening level between both genders was 81 dBA. Studying the safe listening time, results show that the majority for both genders can listen to 4 hours of a level of 80-85 dBA.

The portable listening device that was most used was an iPod mp3 player with 65 participants, followed by 9 for Android, and 13 for other portable listening devices. The results for 50% of the time exceeded for the iPod were 85 dBA. In comparison, the Android-based mp3 player exceeded 83 dBA 50% of the time, and 82 dBA 50% of the time for other mp3 players. These findings suggest that the loudest mp3 player combined with headphones of those sampled is the iPod, and the softest sampled are other mp3 players. As a side note, the iPod mp3 player comes with the same headphones across their players, which could attribute to the results showing that they are the loudest.

The findings among different music genres sampled show interesting results as well. The loudest music genre sampled among those sampled in the study was Rock music that showed results of 86 dBA and higher was exceeded 50% of the time. Both music genres sampled in the study that exceeded 82 dBA 50% of the time were classical and pop music. The overwhelming majority of participants listen to popular music (32 participants), and yet those that listen to classical music (5 participants) listen at the same level of sound pressure.

The most surprising statistic of the study was the loudest outputted sound level of the combined mp3 system, headphones and mp3 player. The loudest level obtained by an mp3 system was 129 dBA, and 50% of the time 113 dBA and louder was achieved. These results show that if one listens to the 113 dBA of music (50% of the mp3 players have this capability) then 4 minutes or less of the music could be heard before OSHA stated that noise-induced hearing loss would ensue.

Chapter 4

Conclusion

The Brigham Young University Educational Acoustics Research Study (E.A.R.S) capstone project succeeded in drawing conclusions with sound pressure levels and their effects of noise-induced hearing loss. It was proven that most mp3 players have the significant capability to exceed the recommendation by OSHA of 85 dBA per day use of non-occupational noise. It was also shown that over half of the students that were sampled exceeded the limits of the 85 dBA recommendation.

The study did not have the capability to link noise-induced hearing loss to any the levels that were sampled, due to the limitation in time. However, one improvement for the future would be to ask those sampled if their listening habits have changed because of the study. Initially, the question was asked, and the majority stated that they will change their habits, but the answers were given at the same time as the experiment. The finding simply proves that if students continue to listen at these levels, then noise-induced hearing loss may occur. The significance of the project was to promote awareness and educate the individual of noise-induced hearing loss, and that was achieved.

Name: ___________________________

BYU E.A.R.S
BYU Educational Acoustic Research Study

Demographics

(Please record this information from the E.A.R.S. demo)

Gender: ____________
Age: _______

What mp3 device do you listen to your music? ___________________________

What sound levels do you normally listen at? (i.e., Soft, Normal, Loud) ________________

Sound Pressure Level (SPL – in dBA (re 20 μPa)): ________

Loudest Sound Pressure Level obtained from headphones: ________

Safe Listening Time (in hours/day): ________

Music Genre of sample: _____________

Survey

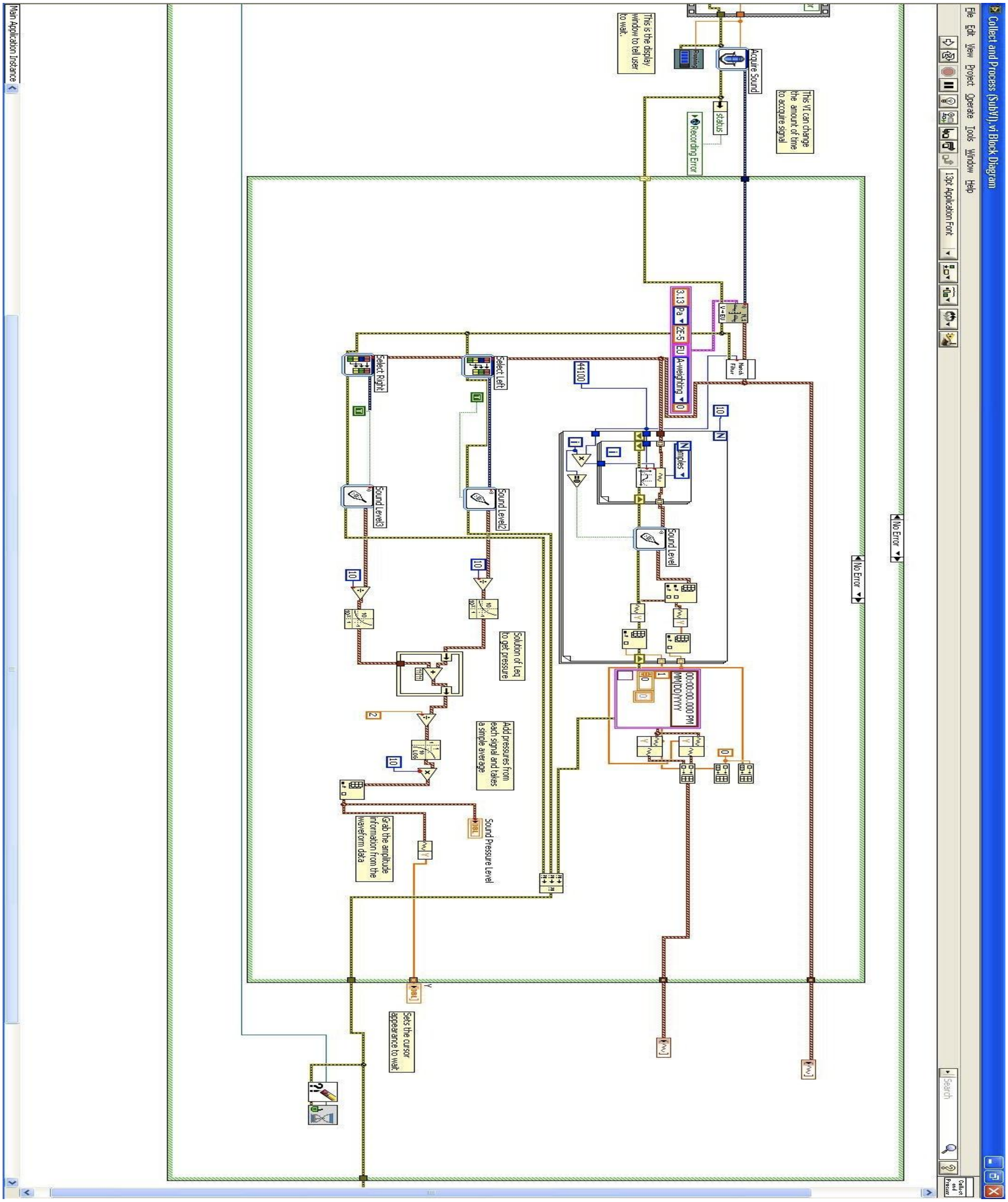
Were you surprised at how loud you listen to your music? (if yes, what did you learn in the process?)

Did you exceed the recommended safe listening time (>85 dBA or 2 Hours/Day) at which permanent sound damage occurs? (if yes, by how much do you exceed that time?)

How many hours a day on average do you listen to your mp3 player?

Do you believe that that knowledge that you gained by participating in this study will have an impact on your listening habits, and why?

Sample of E.A.R.S. LabVIEW™ Code



This is the display window to tell user to wait.

This VI can change the amount of time to acquire signal

Solution of Leq to get pressure

Add pressures from each signal and takes a simple average

Grab the amplitude information from the waveform data

Sets the cursor appearance to wait.

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