Does the Intensity Level of an Instrument Influence a Musician's Preferred Listening Levels?

A Senior Honors Thesis

Presented in Partial Fulfillment of the Requirements for graduation *with distinction* in Speech and Hearing Science in the undergraduate colleges of
The Ohio State University

By

Brittany Komes

The Ohio State University
June 2010

Project Advisor: Dr. Lawrence Feth, Department of Speech and Hearing Science

Abstract

Noise induced hearing loss studies have shown that musicians are at a considerably greater risk of hearing loss because of their constant noise exposure with music, through band/orchestra rehearsals, private practices, and performances. The available literature on music and hearing discusses associations of the spatial relations of performers, as well as music technology of the MP3 players with intensity levels, but little information targets the intensity levels of the individual instrument.

The purpose of this study was to determine if specific musical instruments had a relationship with preferred listening levels of musicians. This study recruited 6 players of 4 different musical instruments: the woodwinds- saxophone and flute, and the brass-trumpet and tuba. The sound pressure level of his/her instrument was measured at maximum level of intensity the musician could play. Also, the research participants listened to an unfamiliar song at their preferred level of comfort and be asked to repeat the procedure and adjust the music to the maximum level they can tolerate. The results were recorded to verify a range of loudness that each participant found comfortable to listen to, and the collected listening data was compared with the intensity levels of the musical instruments that they play. I hypothesized that flutists would prefer to listen to maximum intensity levels because their instrument's sound source is closer to the ear and possibly more intense than the other three instruments.

The results were that there was no relationship between an instrument and preferred listening levels, however there seemed to be a positive linear relationship between an instrument's intensity level and a maximum listening level a musician was able to tolerate.

Dedication

This thesis is dedicated to my mother, Jenean, for her support and unconditional love.

Acknowledgments

I would like to acknowledge my defense committee members, Dr. Lawrence Feth, Dr. Christina Roup, and Professor Cantarino for sharing their time and knowledge. I would like to thank my advisor Dr. Lawrence Feth for helping me become more knowledgeable about bioacoustics and helping me through this whole research process. I would like to thank Dr. Evelyn Hoglund for her encouragement along the way. I also would like to recognize the college of Social and Behavioral Science as well as the college of Arts and Sciences for their generous contributions with research funding.

Table of Contents

Chapter 1: Introduction and Literature Review

Noise is everywhere; it appears with the spinning of a washing machine, in nature with the chirping of crickets, even with the shuffling of feet. Noise is a type of sound classified as unwanted, loud, or unexpected. "…Potentially harmful noise is not necessarily unpleasant or unwanted,(Bredenkamp, 2010)." Music is also another type of sound, and it can be classified as organized, desired, or pleasant. Repeated or continued exposure to high intensity sounds, such as noise and music, can cause damage to the inner ear. Noise exposure can cause temporary and permanent hearing loss, called noise-induced hearing loss (NIHL)(Bredenkamp, 2010). NIHL is caused by harmful, loud sounds that last a long time, and this sound can damage the sensitive structures in the inner ear (NIDCD, 2010). In the past, NIHL was generalized as long-term exposure to noisy industrial sounds, but music and its relationship to noise-induced hearing loss is a relatively new area of study that has been pushed to the forefront of Audiology research in the last few decades.

It is difficult to pinpoint the extent that music has contributed to hearing loss because noise exposure is a life-time accumulation (Fligor, 2007). Much of the data about noise exposure comes from a large population of subjects from work industries, and what is lacking is large population data for music exposure. The loud levels of music that is dangerous to our hearing depend on duration of exposure in a time and level-dependent manner (Fligor, 2007).

The time-and level-dependent manner refers to how differing intensity levels of noise affect human hearing over varying over a period of time (Neitzel, 2008). It is permissible to have a lower level of noise during a longer period of time without the risk of damaging hearing. There are standards and regulations for this exposure limit set forth by U.S. Occupational Safety and

Health Administration (OSHA) as well as US National Institute for Occupational Safety and Health (NIOSH). OSHA is an agency that sets the law of recommended standards for all U.S. industries, but NIOSH standards are also commonly used because of its stricter protection guidelines and the guideline consistency to meet the same standards of most scientific bodies internationally (Neitzel, 2008). Due to its more global standards, NIOSH is referenced in this research with the literature discussion (figure 1.1).

When referring to NIOSH guidelines of noise exposure, the chart shows the maximum allowed daily hours and minutes for each intensity level (in decibels)(figure 1.1). The possibility of risk for hearing damage starts at 85 dBA, but there is more concern is at much higher levels of sound. Since natural sounds seem to be at lower levels, almost all high levels of sound are from man-made technology like sirens, rock concerts, or weaponry. These high levels can cause a possibility of NIHL, but this depends on the duration and consistency of the noise exposure. It seems possible that music can be a cause of NIHL, because people can have prolonged exposure to high levels of music (see instrument intensity figure 1.2). Experienced musicians are constantly around high music levels in band, orchestra, and ensemble rehearsals. Musicians are constantly with their instruments individually rehearsing. Even music technologies of the MP3 player have made music more accessible to daily listening. Because musicians spend a great deal of time around music to perfect their playing, issues of noise/music exposure are being addressed through scientific research to elicit the preventive measures that will help musicians from damaging their hearing.

Table 1-1. Combinations of noise exposure levels and durations that no worker exposure shall equal or exceed

Exposure level, *L* (dBA)	Duration, *T* Hours	Minutes	Seconds	Exposure level, *L* (dBA)	Duration, *T* Hours	Minutes	Seconds
80	25	24	—	106	—	3	45
81	20	10	—	107	—	2	59
82	16	—	—	108	—	2	22
83	12	42	—	109	—	1	53
84	10	5	—	110	—	1	29
85	8	—	—	111	—	1	11
86	6	21	—	112	—	—	56
87	5	2	—	113	—	—	45
88	4	—	—	114	—	—	35
89	3	10	—	115	—	—	28
90	2	31	—	116	—	—	22
91	2	—	—	117	—	—	18
92	1	35	—	118	—	—	14
93	1	16	—	119	—	—	11
94	1	—	—	120	—	—	9
95	—	47	37	121	—	—	7
96	—	37	48	122	—	—	6
97	—	30	—	123	—	—	4
98	—	23	49	124	—	—	3
99	—	18	59	125	—	—	3
100	—	15	—	126	—	—	2
101	—	11	54	127	—	—	1
102	—	9	27	128	—	—	1
103	—	7	30	129	—	—	1
104	—	5	57	130–140	—	—	<1
105	—	4	43	—	—	—	—

Figure 1.1 (National Institute for Occupational Standards and Safety, 1999)

Table 1-2. Unless otherwise specified (e.g., "near left ear"), all measurements were taken at 3 meters for a large number of musicians (inner two quartiles) using differing styles of playing and different instruments.

Musical instruments at 3 meters (at 0° azimuth)	***dBA***
Normal piano practice	60–90
Loud piano practice	70–105
Keyboards (electric)	60–110
Vocalist	70–85
Chamber music (classical)	70–92
Violin/viola (near left ear)	85–105
Violin/viola	80–90
Cello	80–104
Acoustic bass	70–94
Clarinet	68–82
Oboe	74–102
Saxophone	75–110
Flute (near right ear)	98–114
Flute	92–105
Piccolo (near right ear)	102–118
Piccolo	96–112[1]
French horn	92–104
Trombone	90–106
Trumpet	88–108
Tympani and bass drum	74–94
Percussion (at left ear near high hat)	68–94; peak 125 dB SPL
Amplified guitar (using in-ear monitoring)	100–106
Amplified guitar (using wedge loudspeaker monitoring)	105–112
Symphonic music	86–102
Amplified rock music	102–108
MP-3 player (volume 6/10)	94
MP-3 player (full-on volume)	105

[1]With a peak level of 126 dB SPL, piccolo players are banned from my office!
Note. From "How Loud Is that Musical Instrument?" by M Chasin, 2006, *Hearing Review*, *13*(3), p. 26. Used with permission.

Figure 1.2 (Chasin, 2009)

The Wind Ensemble Study

A study measured the varying levels of noise exposure in different sections of a wind-ensemble in university musicians (Walter, 2009). Over 200 participants in 3 different wind ensembles from a mid-size university in Southeastern U.S. were measured for 150 minutes to 200 minutes in their full band rehearsal consecutively for a week. A sound dose calculator from an excel program measured the average noise exposure every minute and converted the total number to a percentage. They based results to NIOSH standards, in which 100% would be the maximum noise exposure allowed in 1 day (see figure 1.1). From these findings, three groups of trombone players had the overall highest daily exposure with a daily average of 167%, 128%, and 186% from groups A,B, and C. The trumpet section had a daily mean of 148%, 209%, and 143%, and the three saxophone groups had daily averages of 106%, 168%, and 125%. The flutists had an average of 99%, 81%, and 73% (Walter, 2009).

The results of the study should cause a concern for musicians because these groups exposed daily to high levels of sound were supposed to represent a typical university band practicing in an acoustically-safe room. Their research examined whether results varied with different musicians, sitting in different locations in their instrument section. This study recorded that these subjects were far exceeding the recommended daily dosage of noise exposure. It's beneficial that this study considers the spatial differences of each instrument, sitting in a large band. Two flutists can be exposed to varying levels of noise if one may be in the back of a section, and the other in front. This study takes sound level measurements received by each musician, and averages them as an instrument section. The wind-ensemble researchers also recognize the periods of silence and time not playing in a song and between two songs during rehearsal. Music has variability. Because music is not a constant sound, it fluctuates in intensity with its dynamics. To assess these differences, measurements were consistently taken every minute during the Wind-Ensemble rehearsal and collectively calculated in the average.

Because this research was organized by instrument sections, it would be interesting to further develop the research to see which instrument section prefers to practice the most. This section could have more exposure to intense sound and be more at risk for hearing damage. Each musician's case history of noise exposure (outside of rehearsal) is an interesting investigation excluded from this particular experiment. This noise exposure may include hours of private rehearsal, listening to MP3 devices, and concert attendance. Strength of this study is the compensation of each individual person's location by randomly selecting a few individuals in each section, which answers the question of variable intensity levels of each section.

IPod and Preferred Listening Levels

An MP3 study that focused on the perception and attitudes of 76 urban and rural adolescents toward their MP3 players showed 24 of the students' preferred listening levels were at maximum volume on their MP3 player. The students reported that the cause of the high volume was to 1) block out interfering background noise- such as wind, talking, or traffic, and 2) enthusiasm of listening to their favorite band (Brug, Hosli, van der Ploeg, Raat, and Vogel (2008). This study did not take any measurement of music levels but based information from an interview. What can be learned from this study is to watch and understand the bias of preferred listening levels to music. Also it is important to be aware of the surroundings to eliminate competing background noise that could possibly have the subjects raise the volume to hear the song more clearly.

Music is becoming more main-stream with the use of modern day technology. To decide who is at risk from high levels of noise exposure from music is difficult to measure because it's an accumulation from years of exposure. Even the significance of risk does not mean it will affect all musicians, but more an emphasis on the possibility of future damage. Data needs to be collected that shows the relationship between musicians, and music intensity levels produced from musical instruments and music devices to lead into more research. With more research on music and hearing, information can be used to expand ideas and relationships associated with noise induced hearing loss from music and further our education with prevention.

The purpose of this thesis was to explore some of the relationships between musicians and their instrument's intensity levels. Questions that were explored were:

1) What are the maximum intensity levels of an instrument, and how does the instrument group compare to other different instrument groups in maximum intensity production?

2) How much variability in intensity is produced by different musicians of the same instrument?

3) How does an instrument's maximum intensity level influence a musician's preferred listening level to music?

4) How does an instrument's maximum intensity level influence the maximum levels a musician can tolerate music?

5) Is there an association between the maximum levels a musician can tolerate music and the number of hours in rehearsal?

To better understand the differences in structural composition of the instrument from which sound is produced, this research will also briefly review the literature on the instruments saxophone, flute, and trumpet. The tuba was eliminated from the thesis due to lack of volunteers that had problems and concerns with transporting such a large instrument.

Saxophone and its intensity

The player of the saxophone produces a source of energy: a flow of air that is above atmospheric pressure and the reed converts the steady airstream into acoustic power. Most of the energy is lost inside the bore with the internal walls of the saxophone, and the small fraction of air that remains is radiated sound. Blowing harder on the reed will add more pressure, and enter into the non-linear and clipping ranges which make the saxophone's sound louder because the higher harmonics falls within our hearing range. The effect of the bell on the end of the saxophone also plays an important role with resonating fundamental frequencies of low notes as well as the harmonics of higher notes, however blowing too hard will cause the reed to stay closed and not produce any sound (Wolfe, 1997) . The possible maximum intensity production of the instrument can be viewed at figure 1.2.

Flute and its intensity

The power of airflow in a flute is produced by the musician. The musician blows a stream of air into an embouchure hole, which has to match the correct speed of the frequency of the note being played. The force of air also produced at the correct angle at the embouchure hole to create a long sustaining note. A higher note would have a higher frequency. To create this, the musician would create more pressure in their stream of air and shorten the distance from their lips to the embouchure hole (Wolfe, 1997).

Trumpet and its intensity

Sound is produced on the trumpet by blowing into a metal mouthpiece with vibrating lips. Tightening and loosening the lips may produce different notes, but the various pitches are created from the compositional make-up with the many tubes. The varying loudness can be affected by mouthpiece, type of trumpet, blowing pressure, and where sound is measured. The sound from the trumpet is directional, and intensity measurements from in front of the horn and the ear have a considerable difference. Also, the sound is more damaging in the higher frequency range on a saxophone, which amplifies from the bell (Wolfe, 1997).

Chapter 2: Methods

The main purpose of this study is to determine if there is a relationship between the intensity of a musical instrument and the musician's preferred listening levels.

Subjects

All six subjects were experienced musicians with normal hearing, tested in the Department of Speech and Hearing Science in Pressey Hall. The subjects were all young adults, from 20 to 25 years old. There were two female flutists; three male trumpet players; and 1 male saxophone player. Each subject was paid ten dollars for the hour long experiment. Four musical instruments were chosen to be the focus of this study: the tuba, the saxophone, the trumpet, and the flute. These four selected instruments are from two different instrument classifications, brass and woodwinds. These instruments range in intensity, and differ in structural composition. The tuba was eliminated due to difficulty with instrument transportation.

Materials

This study used four musical instruments- flute, saxophone, and trumpet that were provided by each musician. Experiment measurements were taken in the Anechoic Chamber, a room designed to insulate from exterior sources of noise as well as stop internal reflections of all sound waves. All measurements were taken with a Radio Shack Sound Level Meter. Questionnaire was specifically written for this research to gain insight to the subject's medical and musical history. Consent form, Demographic form, payment check, and payment receipt were all research forms provided by the Speech and Hearing Department.

Hearing screening was done in the university lab with an audiometer, and the iPod with ear buds was a personal device programmed with a testing song.

Testing Procedure

Each subject was given a consent form and a demographic form that identified their ethnicity for Ohio State University's record files. The subject then filled out a questionnaire that provided a case history of noise exposure, hearing problems, and musical experience. The subject was asked to bring his instrument into the anechoic chamber and to play from the lowest note to the highest note at maximum loudness. Each subject was told the timing he played each note was not important, that he should take his time with full breaths and play each note at maximum loudness . The maximum intensity measurement was recorded 3 inches from the outer ear of the subject with a Sound Level Meter.

An unknown song with an undistinguishable genre (an upbeat remix of the song Vuelvo al Sur by Astor Piazzola) was played on an iPod, with connected ear buds in the ears of each subject. Each subject was asked to adjust the volume control of the iPod to a preferred, comfortable listening level and to listen for two minutes. The ear bud was taken from the subject and placed into a Sound Level Meter coupler. The song was re-played keeping the adjusted volume, and the preferred intensity was recorded by mode. Because of the fluctuating nature of the song, the maximum and minimum dB levels of the preferred listening level were recorded for extra measurements, but not averaged in because of their seldom occurrence. The subject was asked to listen to the song a second time, but to adjust the volume to the maximum level he could tolerate listening to the music. After the subject listened for two minutes, the song was repeated into the adaptor with the adjusted volume, and a mode, minimum, maximum measurement was recorded of the maximum listening level. Each subject was guided into a laboratory room for a hearing screening where their hearing was evaluated (See appendix).

Chapter 3: Results

The results of the maximum playing level of the instrument vs. the musicians preferred listening are shown in figure 3.1. The added linear regression line from Sigma Plot program displays a line that is ‘best fit’ with all data points. The flat (constant) line does not show a strong linear relationship between the maximum playing level of the instrument and the preferred listening level of a musician to the selected song on an iPod.

Figure 3.2 shows the maximum level that the musician was able to tolerate listening to a selected iPod song and the amount of time he spent rehearsing his instrument in hours per week. The sporadic data points suggest that there is low association between variables, and the constant line ‘best fit’ between all data points implies no linear relationship. There is also no relationship between the type of instrument and the weekly rehearsal time.

The maximum intensity level that the musician played shows a positive relationship with the maximum listening level to the selected iPod song (figure 3.3). The positive association is shown by the ‘best fit’ linear regression line that inclines upwards. The higher intensity the musician played his instrument shows an association with the maximum level he was able to tolerate listening to the iPod song. This graph also shows that the each group of instruments shares similar intensity levels.

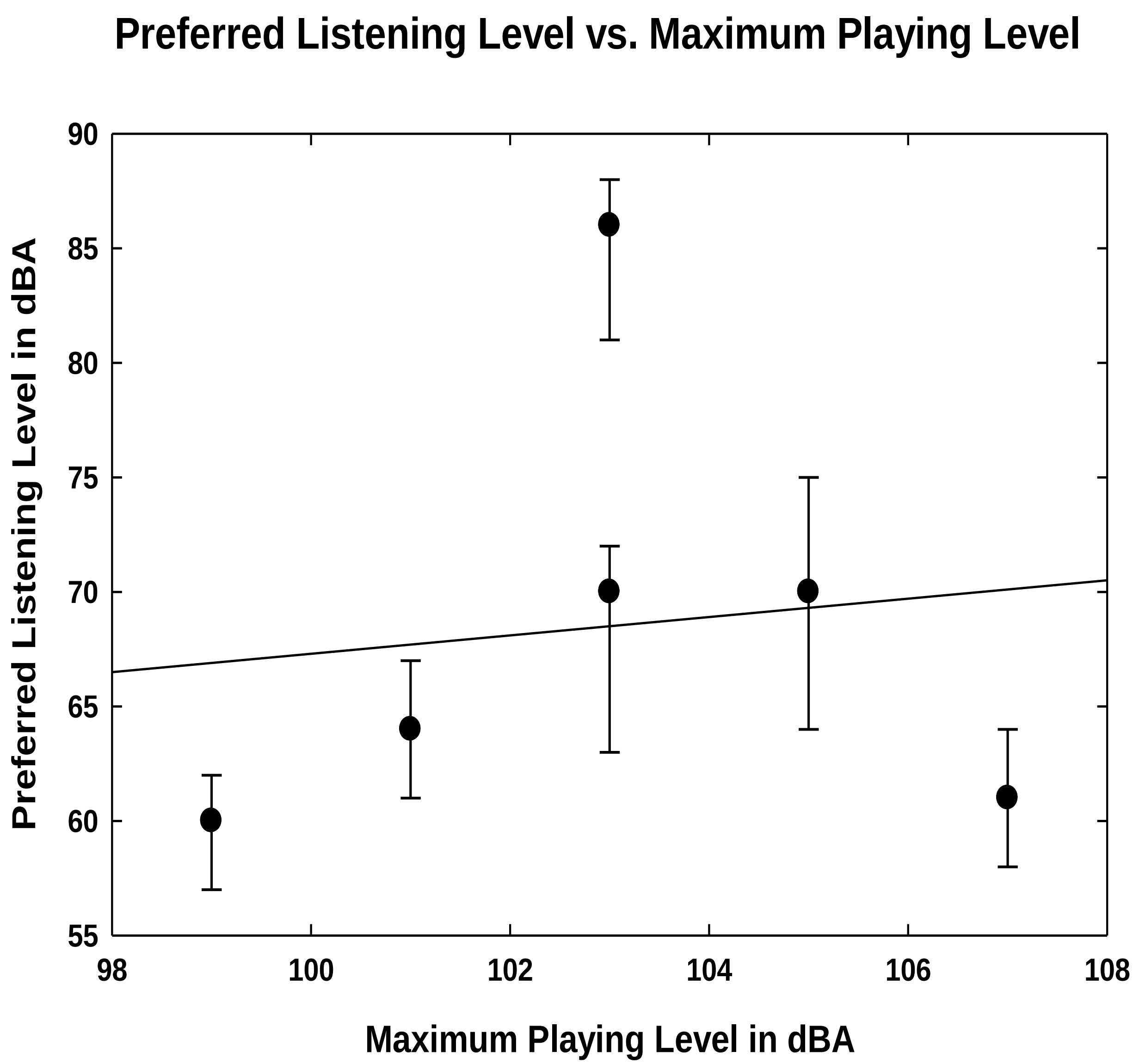

Figure 3.1 Musician's maximum playing level of his instrument vs. the preferred level he chose to listen to a song on an iPod. The black circles represent mode measurements from both axis, and the bars protruding from top and bottom of the circles are maximum and minimum Y-values that the song fluctuated. The line across the data is a linear regression line from Sigma Plot.

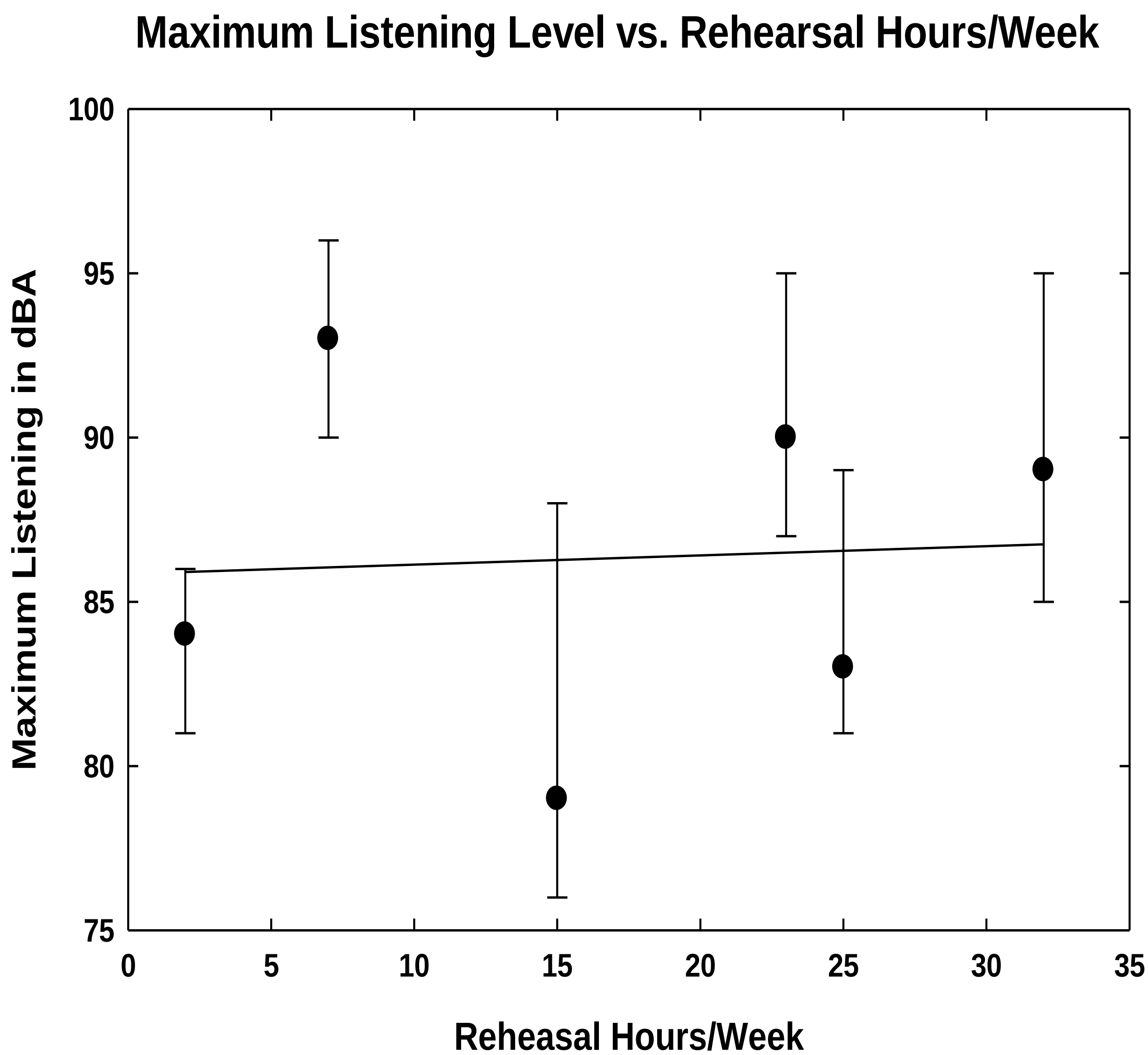

Figure 3.2 Musician's weekly rehearsal time measured in hours in relation to the maximum level he was able to listen to a song on an iPod. In the event that the musician plays two instrument's the rehearsal time is measure by the collective hours of individual or group practice of the one single tested musical instrument. The black circles represent mode measurements, and the bars protruding from top and bottom of the circles are maximum and minimum values that the song fluctuated. The line across all data points is a linear regression line from Sigma Plot.

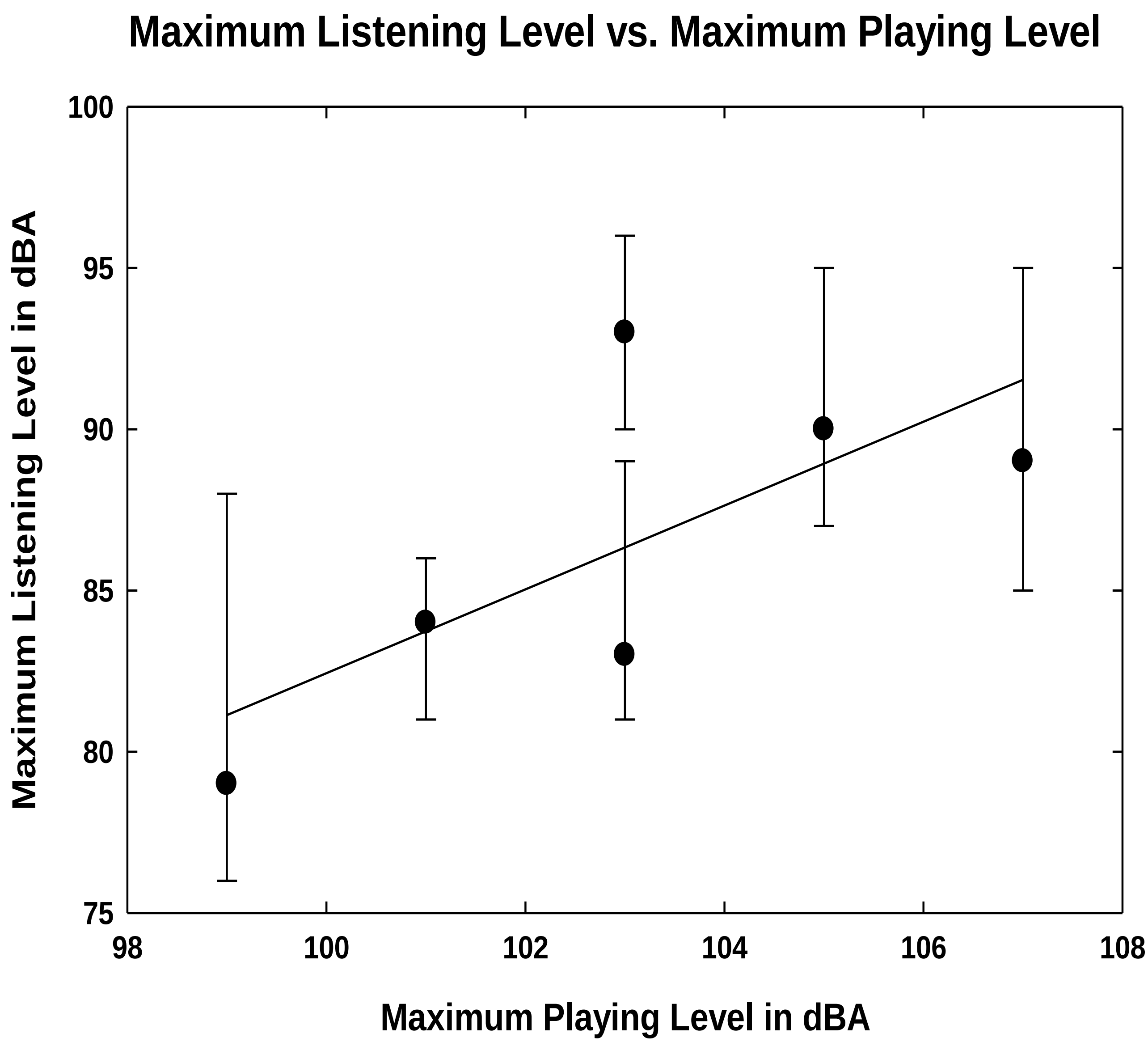

Figure 3.3 Musician's maximum playing level of his instrument vs. the maximum level he could tolerate a song on an iPod. The black circles represent mode measurements from both axis, and the bars protruding from top and bottom of the circles are maximum and minimum Y-values that the song fluctuated. The diagonal line is a linear regression line from Sigma Plot.

Chapter 4: Discussion/Conclusion

The intensity level that a musician played his instrument did not show a relationship with a musician's preferred listening levels (figure 3.1) The data points were in a non-linear formation, a trend toward an upside down 'u-shape' pattern. The graph seems to show this parabolic digression, but due to the lack of subjects in data points, there may be an outlier on either end which would cause it to become a linear digression. Such as that there is no easy explanation for a parabolic digression, it is safe to say that the lack of sufficient data is the cause for this phenomenon. The advantage of more subjects in future research can better confirm a possible association. If more saxophone players with high intensity levels showed higher levels of preferred listening, this figure can easily trend toward a possible positive relationship. Unfortunately, only testing 1 available saxophone player could have skewed this graph if he were in fact an outlier.

The intensity level that a musician played his instrument did not show a relationship with the hours he put into weekly rehearsing (fig. 3.2). It is a very interesting to see this particular lack of relationship because the hours of rehearsal time did not influence the tolerance to maximum intensity levels of the iPod. Rehearsal time exposes a musician to loud if not dangerous levels of sound. It could be assumed that a musician could tolerate higher levels of sound being acclimated to their noisy environment but this assumption is false as shown by figure 3.2. It is useful to examine that rehearsal does not influence maximum hearing levels, because it leads into the next question of "what does?" with figure 3.3.

There is a positive linear relationship with the maximum intensity level of the instrument and the musician's maximum listening level (figure 3.3). This can be influenced by a variety of factors. Maybe the subjects had higher thresholds and so they chose louder instruments? Maybe the intensity level of the louder instruments preferred the song choice and therefore was able to listen to the volume at a higher level? These research findings show a relationship that can be possible to further in developing this concept and expanding these ideas.

The weaknesses that need to be addressed in this study are the intensity measurements and lack of subjects. Although mode measurements of listening levels were the best choice with the Sound Level meter from Radio Shack, a more accurate and precise recording could have been measured with a different device. Originally KEMAR (Knowles Electronic Manikin for Acoustic Research) was intended to be used for this purpose which would have averaged in the recorded intensity level during the span of the song, but due to unexpected errors in the Sound Level Meter, the method and project equipment was changed to a Radio Shack Sound Level Meter. Another weakness is that this study demands more subjects. This study should be continued and updated with additional subjects, but unfortunately there was low participation even with the paying incentive. From the responses to the flyer, no tuba players were willing to bring in their instrument due to its large size and heaviness. The location of the building made it difficult for tuba players to bring their instrument by university bus.

Future research

This study has explored the intensity of an instrument and a musician's preferred listening levels. Further research could be made with adjustments to this study in instrument choice. An interesting comparison would be the unilateral affects of stringed instruments and the musician's preference listening level of each ear. Also furthering the idea of hearing threshold, the maximum listening level can be tested with a variety of different musicians, and/or even comparing results with tested non-musicians. Also expanding the project of maximum intensity vs. maximum listening level, the change of music genre could be an interesting variable that could result in various preferences. If the musician picked out his most preferred song, maybe his preferred listening level would harbor different results.

Chapter 5: References

Brug, J., Hosli, E., van der Ploeg, C., Raat, H., & Vogel, I. (March 2008). MP3 Players and Hearing Loss: Adolescents' Perceptions of Loud Music and Hearing Conservation. *Journal of Pediatrics, 152*. Retrieved from http://www.mdconsult.com/

Bredenkamp, J (2010) Noise-Induced Hearing Loss and Prevention. Retrieved

Chasin, Marshall (2004). Ask the Expert. *Noise Exposure*. Retrieved (May 2010) from http://www.audiologyonline.com/askexpert/display_question.asp?question_id=211

Chasin, Marshall (2009). *Hearing Loss in Musicians: Prevention and Management.* San Diego, CA: *Plural Publishing Inc.*

Fligor, B. (October 2007). Hearing Loss and iPods: What happens when you turn them up to 11*? The Hearing Journal, 60.* Retrieved (May 2010) from http://journals.lww.com/thehearingjournal/Fulltext/2007/10000/Hearing_loss_and_iPods__What_happens_when_you_turn.3.aspx

National Institute for Occupational Safety and Health. (June 1998). [Graph illustrating the combinations of noise exposure levels and durations that no worker exposure shall equal or exceed]. Retrieved from (April 2010) http://www.cdc.gov/niosh/docs/98-126/chap1.html#11

National Institute on Deafness and Other Communication Disorders (2009). *Noise Induced Hearing Loss.* Retrieved (April 2010) from http://www.nidcd.nih.gov/health/hearing/noise.htm

Neitzel, R. M.S., CIH (2008). Ask the Expert. *NIOSH and OSHA Permissible Noise Exposure Limits*. Based on *Construction Noise: How Bad Is It and What Can Be Done About It?* Retrieved (May 2010) from http://www.audiologyonline.com/askexpert/display_question.asp?question_id=573

Walter, Jennifer Stewart (June 2009). Sound Exposure Levels Experienced by University Wind Band Members. *Medical Problems of Performing Artists, volume 24 issue 2*. Retrieved (April 2010) from http://www.sciandmed.com/mppa/journalviewer.aspx?issue=1180&article=1785

Wolfe, Joe (1997). *Music Acoustics UNSW.* Retrieved from (January 2010)
http://www.phys.unsw.edu.au/music/

Appendix A

Ohio State University Psychoacoustics Laboratory
Research Lab 6, Pressey Hall, 1070 Carmack Rd.
Columbus, Ohio 43210

THE OHIO STATE UNIVERSITY

Initials: ____________ Date: ________ DOB: ________

Tested by: ____________ Age: ________ Lab: 8 | 1 | 2 | 4 | ______

AUDIOGRAM

Frequency in Hertz (HZ)

750 1500 3000 6000

250 500 1000 2000 4000 8000

Hearing Level (dB re: ANSI, 1996)

-10 0 10 20 30 40 50 60 70 80 90 100 110 120

Audiogram Key

		RE	LE	Both
AC	Unmasked	O	X	
	Masked	Δ	□	
BC	Unmasked	<	>	
	Masked	[	]	
Soundfield				S

Comments: ____________

Pure Tone Average

RE	LE

Speech Reception Threshold

	RE	LE	SF
HL			

Test used: ________

Speech Discrimination

	RE %	LE %	SF %
HL			

Test used: ________

Tympanometry: Normal Abnormal Remarks: ____________

Otoscopy: Remarks: ____________

DPOAEs: Normal Abnormal Remarks: ____________

(Attach printout of report)

Audiogram used for hearing screening