Winter 11-1-2013

An Analysis of Sound Exposure in a University Instrumental Music Rehearsal Venue

Joe Farmer

Nelson Fumo
University of Texas at Tyler, nfumo@uttyler.edu

Michael Thrasher

NACWPI JOURNAL

OUR 62ND YEAR OF CONTINUOUS PUBLICATION

OFFICIAL PUBLICATION OF THE
NATIONAL ASSOCIATION OF
COLLEGE WIND AND PERCUSSION INSTRUCTORS

VOLUME 62 **WINTER 2013-2014** **NUMBER 2**

AN ANALYSIS OF SOUND EXPOSURE IN A UNIVERSITY INSTRUMENTAL MUSIC REHEARSAL VENUE

Joe Farmer, B.S., University of Texas at Tyler

Nelson Fumo, Ph.D., University of Texas at Tyler

Michael Thrasher, D.M.A., University of Texas at Tyler

Corresponding author contact information:
Michael Thrasher, D.M.A.
University of Texas at Tyler
School of Performing Arts
3900 University Blvd.
Tyler, TX 75799
E-mail: mthrasher@uttyler.edu
Telephone: (903) 566-7388
Fax: (903) 566-7483

INTRODUCTION

Exposure to high sound levels may lead to a variety of hearing abnormalities, including Noise Induced Hearing Loss (NIHL). Pre-professional university music majors may experience frequent exposure to elevated sound levels, and this may have implications on their future career prospects (Jansen, Helleman, Dreschler & de Laat, 2009). Studies suggest that college students (aged 18-25) who participate in instrumental music activities are particularly vulnerable to hearing damage and NIHL (Phillips, Henrich & Mace, 2010).

Additional research has focused on the relationship between musicians' activities and hearing loss. For example, a study by Kähäri, Axelsson, Hellström and Zachau (2001) reported that noise notches at 6,000 hertz were discovered in a selection of professional musicians, although the notches were not outside of normal limits. Another study (Parving, Ostri, Poulsen & Gyntelberg, 1983) administered audiometric pure tone examinations to a population of musicians from the Royal Danish Theatre. Findings revealed that when testing hearing acuity in one or both ears at levels below 20 dB, a total of 58% of the musicians had a hearing impairment. The study concluded that the impairment might be related to the frequent sound exposure inherent in symphonic music.

NIHL has become a medical issue for a large portion of the population, rating as the second most common form of sensorineural hearing deficit, and surpassed only by presbycusis (or age-related hearing loss) (Rabinowitz, 2012). Uncertainty concerning the risk factors and prevalence of NIHL and other hearing ailments among student musicians creates problems for researchers hoping to establish evaluative criteria for the safety of musical venues.

Current American standards regarding acceptable levels of sound exposure are defined by two agencies: the Occupational Safety and Health Administration (OSHA), and the National Institute of Occupational Safety and Health (NIOSH). OSHA standards for sound levels were last revised in October 1974, and remain as the maximum allowable noise levels in the workplace as enforced by law in the United States (U.S. Department of Labor, 2009). The standards are based on a permissible sound exposure of 90 dB for a duration of up to eight hours. Currently, the OSHA decibel exchange rate is set at 5 dB, where the exchange rate is defined as the amount of decibels at which the permissible sound level is reduced by 50%. For example, a 10 decibel exchange rate would allow that for every increase of 10 decibels, the allowable exposure time would be cut in half. NIOSH, on the other hand, recommends no more than 85 dB for up to eight hours, while utilizing a 3 dB

exchange rate (Center for Disease Control and Prevention, 2011). Figure 1 illustrates the relationship between dosage and decibel level as described by both agencies.

In 1981, OSHA required that all employers implement a hearing conservation program. The mandate limits workers to a time-weighted average noise level of 85 dB or lower over an 8 hour shift (United States Department of Labor, 2009). The program requires employers to track sound level readings, to educate employees on hearing loss, and to provide free annual hearing health screenings.

OSHA and NIOSH standards are applicable to most workplace and noise level applications. Although no music-specific sound level standards have been described, several studies use OSHA and NIOSH standards as the standard by which to assess the safety of music venues. For example, an investigation of 130 student music majors at the West Virginia University College of Creative Arts documented that all participants experienced daily noise doses that exceeded both OSHA and NIOSH standards (Callahan, et.al, 2011). In addition, Chesky (2010) found that students participating in a university wind band program experienced sound exposure levels that exceeded recommended safety standards.

Student musicians devote many hours both to individual practice and group rehearsal. According to the 10,000-hour hypothesis (as set forth by Ericsson, Krampe, & Tesch-Römer, 1993), a student majoring in the art of music with the intention of mastering his/her instrument is likely to practice 10,000 hours over the course of 10 years, or the equivalent of almost 3 hours per day. In 2011, the National Association of Schools of Music affirmed that "music program policies, protocols, and operations must reflect attention to maintenance of health and injury prevention," and that (students enrolled in music unit programs and faculty and staff with employment status in the music unit must be provided basic information about the maintenance of health and safety within the contexts of practice, performance, teaching, and listening" (NASM 2011-12 Handbook Addendum, 2012). Consequently, efficient tracking and evaluation of the relative safety of venues for music instruction and performance has been defined as a key element in effective music pedagogy. The purpose of this study is to collect and analyze the sound load exposure of a population of university music students participating in instrumental music ensemble rehearsals.

METHODOLOGY

The subject venue is described as Fine Arts Center (FAC) 2007, located within the Cowan Fine Arts Center on the campus of the University of Texas at Tyler. This room serves as a rehearsal venue for a student jazz ensemble, a student jazz combo, and the university Wind Ensemble. The venue measures 29 feet by 45 feet (1,305 square feet), with a ceiling height of 12 feet. This results in a total room volume of 15,660 cubic feet. The venue is equipped with 39 sound absorption panels mounted on standard sheetrock walls. These panels range in size from 2 feet by 4 feet to 4 feet by 8 feet. Panels are constructed from dense foam material wrapped with fabric, and measure 3 inches deep in the center. In addition, sound absorbing pyramidal ceiling tiles are installed on the ceiling to further disseminate sound. These ceiling tiles are composed of fiberglass and form only a single three-dimensional protrusion per tile.

A total of three classes were recorded in this room: a student jazz ensemble, a student jazz combo, and the university Wind Ensemble. The Wind Ensemble and jazz combo met three times per week on Monday, Wednesday, and Friday from 12:30 to 1:45 and 3:00 to 4:15, respectively; while the jazz ensemble met twice a week on Tuesday and Thursday from 2:00 to 3:15. The Wind Ensemble met with a total count of 34 instrumentalists, the jazz combo met with a total of 8 instrumentalists, and the jazz ensemble with a total of 11 instrumentalists.

All measurements were taken using an ExTech 407764 Datalogging Sound Level Meter. The instrument was placed on a tripod and permanently set at a height of 6 feet from floor level. The tripod was set at the front of the room directly behind the instructor's podium. This point was chosen due to its location at which the majority of the instruments were focused. A research assistant engaged the instrument before each rehearsal session and disengaged the instrument immediately following the end of the rehearsal.

The sound level meter was calibrated and programmed so that the duration, time, and date of each recording was assigned to the respective sound levels. The instrument was programmed to record on slow response at 1-second intervals. This setting was chosen so that no peaks in the sound levels were lost. The frequency filter was set to A-weighting and the range of sound levels to be recorded was preset at 30dB to 130dB to represent the average sound level over the duration of the class. Data was collected every week and saved to an external memory storage device. The datalogger was then cleared and reset to collect the next sets of data.

The data collected from the datalogger each week was uploaded to a workbook and categorized based on the time and date at which it was recorded. The data was then uploaded to a separate workbook, where the sound levels were placed into a single column and labeled with their respective class name and date. For references purposes, a histogram was compiled for each class period's data collection. The histogram allowed for easy verification of the range of sound levels recorded in each session. A set of standard calculations was performed for all data sets for analysis purposes. These calculations included the time of the session in seconds, the maximum and minimum sound levels recorded, and an average dB value for the recording. This average dB value was not used for the final result of the study, due to the fact that it does not accurately represent the data in a way that could be analyzed for safety concerns. After all data points were loaded into the worksheet, the *Leq* definition for the exposure period (shift), Equation (1), was used as the primary data analysis tool. In Equation (1), T is the duration in hours of the particular sound level L_n in dBA.

$$L_{eq,shift} = 10\ log\ \left[\left(\frac{1}{T}\right)\times(T_1\times10^{0.1\ L_1} + T_2\times10^{0.1\ L_2}+\ldots+T_n\times10^{0.1L_n})\right] \quad (1)$$

Due to the fact that each class period had a slightly different duration, the definition of *Lex,8*, Equation (2), was used in order to have a parameter for comparison. In Equation (2), T is the shift duration in hours, and *Lex,8* takes each *Leq,shift* result and converted it to its equivalent 8-hour counterpart.

$$L_{ex,8} = L_{eq,shift} + 10\ log\ \left(\frac{T}{8}\right) \quad (2)$$

Using the information collected from both the *Leq,shift* and *Lex,8* it was possible to also calculate the sound dosage for each particular setting in accordance with Equation (3).

$$Dose = 100\times\left(\frac{T}{8}\right)\times10^{\frac{(L_{eq,shift}-85)}{10}} \quad (3)$$

The sound dosage is a calculation of how much exposure has been processed before the setting approaches dangerous levels, where T is the total recording time in hours for calculating *Leq,shift*. As discussed in the background of this report, it is important to consider both OSHA and NIOSH standards when studying the proximity to dangerous sound level exposure. With this in mind, the dosage equation was altered in a fashion that would produce a result for both agencies according to their unique 8-hour dosage indications.

RESULTS

The results of the study were based on data retrieved from the datalogger over a period of eight weeks, spanning September 19 to November 24, 2012. During this time, a total of 33 recordings were collected, each with an average duration of 1.28 hours (1 hour and 17 minutes). The lowest decibel values recorded fell below the minimum value of the range set for the meter (30dB), while the loudest recorded noise levels reached 130 dB, which was the highest value of the range set for the meter. Results were obtained for each individual class assuming that students were only involved in one of the three recorded classes. However, during a student's academic career it is common to be involved in multiple rehearsal activities over the course of a single day. With this in mind, it is important to not only evaluate each class as a single entity, but also to combine class recordings which fall on the same day. For this particular study, only two of the three classes fell on the same day, MUEN 1131 (Jazz Combo) and MUEN 1140 (Wind Ensemble), with results given in the Combo Class column on Tables 1 to 3.

Table 1 presents the average duration of each class, standard deviation, and minimum and maximum class times for each course. The information is kept in seconds, because that is the resolution of the data collection; for every second there is one sample of the decibel level. The data can also be seen in hours on the right column to give a better idea of the actual length of the class. The class times had a significant range of durations. The longest recorded class time lasted 3.89 hours while the shortest was only 0.23 hours. Although the average class time for all recordings comes to 1.28 hours, it is important to understand that this number cannot be thought of as an accurate representation for the remarkably high and low class times. For the purpose of data analysis, however, the average recording time fit the expected class time within 2 minutes.

The next results to be shown are the *Leq,shift* and *Lex,8* values for each recorded class. Table 2 lists the average, standard deviation, and minimum and maximum data for every recording session. Similarly, Table 3 illustrates the equivalent dosages experienced during the class times listed. This data serves as a guide for determining how close the sound level was to approaching dangerous dosages. For each respective standard (NIOSH and OSHA), the percentage represents the proximity of exposure to harmful levels (0% being no exposure and 100% representing the maximum allowed exposure).

DISCUSSION

In order to define whether or not a class is being exposed to a dangerous sound dosage, it is helpful to refer to the dosage (%) value in the related tables. Out of a total of 33 recording sets, none exceeded the mandatory OSHA values for safety regulations, and only one exceeded the recommended NIOSH values. This information suggests that the room in which the recordings took place is safe for the amount of sound being produced according to the legal OSHA workplace values; however, due to the proximity of some recording sets to the maximum allowable dosage level, it would be common in most manufacturing industries to implement a hearing conservation program as mentioned in the background of this report. The dosages measured by NIOSH standards consistently fell within the safe range with the exception of one session. This indicates that a corrective action may be needed to address these situations.

A major inconsistency in the data can be rationalized when considering the general nature of a music group. Because each piece of music is unique and has different dynamics than the piece before, there will be a wide range of volume differences with each recording set. In addition to these unique styles of music, the professor can also play a major role in controlling the overall volume of the rehearsal. Due to the fact that each professor possesses his or her own style of how a piece should sound, class volumes can easily differ from session to session. Because of this inconsistent behavior from the different pieces of music, as well as different professors, it is important to utilize a data analysis method which takes all data sets into account and weights them according to their $L_{eq,shift}$. It can be seen that on average the dosage for each class period fell below 30%, with the next highest dosage measuring 62.9% of NIOSH allowances for MUEN 1135. This trend shows that the maximum NIOSH dosage of 306% recorded in MUEN 1140 cannot be thought of as an outlier, but rather as an uncommon situation when compared with the other results. The high value results from the decibel's logarithmic behavior. The recording set for this particular data has several seconds of high values which indicates that the performer should take a rest. However, this is the only data set that indicates any inherent danger.

Aside from the high values previously discussed, the rehearsal room remains in a safe range of values for both NIOSH and OSHA regulations. With the majority of the recording sessions not exceeding 50% of the maximum allowable dosage on a regular basis, the data indicates that the teachers and students have an accurate perception of what dosages are safe and what type of behavior can potentially harm their hearing abilities.

Although the study deems the room a safe environment for rehearsal, a single research investigation can never predict the needs and tolerances of each individual's hearing abilities. The results included in this paper are only based on standards set forth by two major agencies, which are believed to be true for the majority of the population. For matters regarding safety and possible danger to vital senses, each participant should cater to his or her unique characteristics and needs.

CONCLUSION

Students majoring in music devote many hours to practice, causing them to be exposed to sound levels that could lead to a variety of medical conditions. In this sense, the overall purpose of this study was to determine the hearing safety of students practicing in the rehearsal room identified as Fine Arts Center (FAC) 2007 at the University of Texas at Tyler. Results from this study suggest that the risk of approaching dangerous dosages of noise is a valid concern with at least one instance of a non-conformity during this eight week period. In most cases, the dosage achieved was between 5% and 30% that of the maximum allowance set forth by the OSHA and NIOSH standards, with a few sessions reaching 60%, and one session exceeding 100%. The safety of a specific venue may be compromised by allowing students or teachers to remain active in the venue for excessive periods of time in a single day. This factor should influence decisions concerning scheduling of rehearsals involving the same individuals. Utilizing the protocol described in this study may potentially assist musicians and engineers to better manage possible risks to hearing health.

REFERENCES

Calculating Lex,8: Guideline: amendments to noise requirements in the regulation for industrial establishments & oil and gas-offshore. (2011). Ministry of Labour / Ministère du Travail. Retrieved from http://www.labour.gov.on.ca/english/hs/pubs/noise/gl_noise_appb.php. [Last Accessed April 22, 2013].

Callahan, A.J., Lass, N.J., Foster, L.B., Poe, J.E., Steinburg, E.L., & Duffe, K.A. (2011). Collegiate musicians' noise exposure and attitudes on hearing protection. Hearing Review. Retrieved from http://www.hearingreview.com/issues/articles/2011-06 _04.asp.

Chesky, K. (2010). Measurement and prediction of sound exposure levels by university wind bands. *Medical Problems of Performing Artists*, 25(1), 29-34.

Ericsson, K.A., Krampe, R.T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*(3), 363.

Formulae for Leq, Lex, Noise Dose & Time. (n.d.). Basic Noise Calculations. Retrieved from www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/basic_ noise_ calculations.pdf [Last Accessed April 22, 2013].

Jansen E.J.M., Helleman, H.W., Dreschler, W.A., & de Laat J.A. (2009). Noise induced hearing loss and other hearing complaints among musicians of symphony orchestras. *International Archives of Occupational and Environmental Health*, *82*(2), 153-164.

Kähän K.R., Axelsson A., Hellström P.A., & Zachau, G. (2001). Hearing assessment of classical orchestral musicians. *Scandinavian Audiology*, *30*(1), 13-23.

NIOSH. (2011). Workplace Safety and Health. In *Noise and Hearing Loss Prevention*. Retrieved from http://www.cdc.gov/niosh/topics/noise/stats.html [Last Accessed October 20, 2012].

Niquette, P.A. (n.d.). Noise exposure: explanation of OSHA and NIOSH safe- exposure limits and the importance of noise dosimetry. Retrieved from http://www.etymotic.com/pdf/er _noise_ exposure_ whitepaper.pdf [Last Accessed September 30, 2012].

Occupational Safety and Health Administration. (2009). Occupational noise exposure. Retrieved from http://www.osha.gov/SLTC/noisehearingconservation/ [Last Accessed October 30, 2012].

Parving, A., Ostri, B., Poulsen, J., & Gyntelberg F. (1983). Epidemiology of hearing impairment in male adult subjects at 49-69 years of age. *Scandinavian Audiology*, *12*(3), 191-196.

Phillips, S.L., Henrich, V.C., & Mace, S.T. (2010). Prevalence of noise-induced hearing loss in student musicians. *International Journal of Audiology*, *49*(4), 309-316.

Rabinowitz, P.M. (2000). Noise-induced hearing loss. *American Family Physician*, *61*(9), 2759- 2760.

The United States Department of Labor (n.d.). Noise exposure computation. Retrieved from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p _id=9736 [Last Accessed October 1, 2012].

U.S. Department of Labor (2009). Reflections on OSHA's History. Retrieved from http://www.osha.gov/history/OSHA_HISTORY_3360s.pdf[Last Accessed September 30, 2012].

Figure 1. Permissible Noise Dosage as a Function of Sound Level.

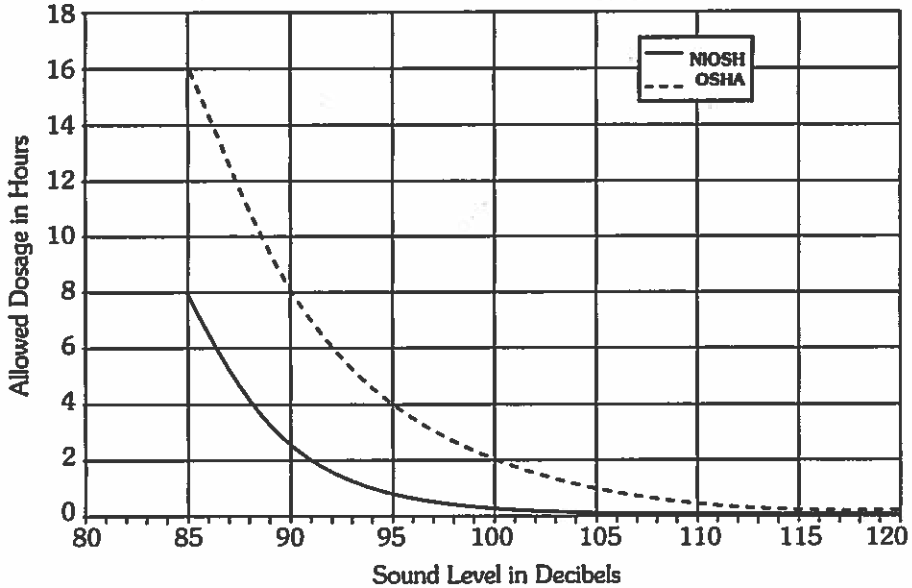

Table 1. Class Duration

	Jazz Combo		Jazz Ensemble		Wind Ensemble		Combo Class	
	(MUEN 1131)		(MUEN 1135)		(MUEN 1140)		(MUEN 1131) + (MUEN 1140)	
	Seconds	Hours	Seconds	Hours	Seconds	Hours	Seconds	Hours
AVG:	3878	1.08	3453	0.96	6526	1.18	9142	2.54
STDEV:	1427	0.40	2281	0.63	3795	1.05	4821	1.34
MIN:	1690	0.47	831	0.23	1771	0.49	2851	0.79
MAX	5601	1.56	6904	1.92	13986	3.89	14631	4.06

Table 2. Level Results

	MUEN 1131		MUEN 1135		MUEN 1140		Combo Class	
	Leq,shift (dB)	Lex,8 (dB)	Leq,shift (dB)	Lex,8 (dB)	Leq,shift (dB)	Lex,8 (dB)	Leq,shift (dB)	Lex,8 (dB)
AVG:	84.9	75.9	88.3	77.9	83.2	75.2	83.9	78.2
STDEV:	3.3	3.4	1.5	4.6	4.2	8.2	2.8	3.2
MIN:	79.6	72.4	85.5	71.0	76.7	48.5	79.5	74.4
MAX	89.7	81.5	90.7	83.0	97.4	89.9	87.0	82.9

Table 3. Dosage Results

	MUEN 1131		MUEN 1135		MUEN 1140		Combo Class	
	NIOSH Dosage (%)	OSHA Dosage (%)	NIOSH Dosage (%)	OSHA Dosage (%)	NIOSH Dosage (%)	OSHA Dosage (%)	NIOSH Dosage (%)	OSHA Dosage (%)
AVG:	16.3	5.1	29.0	9.2	31.7	10.0	26.3	8.3
STDEV:	14.7	4.6	22.1	7.0	71.5	22.6	19.7	6.2
MIN:	5.5	1.7	3.9	1.2	0.0	0.0	8.7	2.8
MAX	44.9	14.2	62.9	19.9	306.0	96.8	61.1	19.3