Noise Levels on a College Campus Across Various Locations, Events, and Transportation Services

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Abstract

Purpose: College students spend a significant amount of time attending school classes, extracurricular activities, and meetings, all involving varying levels of noise exposure. However, younger generations are not widely provided with education and support to prevent noise-related risks. This investigation measured noise levels at various campus locations and school events and analyzed the noise characteristics to document student noise exposure.

Methods: Fifteen locations were selected at the University of North Texas, taking into consideration where and when students spend significant amounts of time: ten on-campus locations across three different time periods, three different types of school events, and two modes of transportation. The noise was measured with a sound level meter at the center of each location. The noise was measured for two hours, and for the whole duration of each school event and transportation route. Noise dose and recommended exposure levels were computed.

Results: For the ten on-campus locations, noise levels significantly differed across morning and evening, with the average noise levels for evening being 4.4 dBA higher than in the morning. Significant differences in noise levels were found among the three location groups. In particular, a 137.5 dB LApk value was recorded at a sporting event. In addition, recommended exposure limits were exceeded at one school event.

Conclusion: Although the majority of noise levels measured across campus were below 85 dBA, cumulative noise exposure during a school event exceeded the recommended exposure levels. Therefore, educating and raising awareness among college students about potential noise exposure and NIHL is important.

Keywords: noise exposure; campus noise; noise-induced hearing loss

Introduction

Extended exposure to high noise levels can ultimately lead to permanent threshold shifts and noise-induced hearing loss (NIHL) (Melnick, 1991; Rabinowitz, 2000) because of damage to the cochlea and auditory nerve (Bohne & Harding, 2000). In order to prevent hearing damage due to acoustic injuries, adherence to two existing noise regulations is recommended: Occupational Safety and Health Administration (OSHA, 1983; 90 dBA for 8 hours in 5 dB steps) and National Institute for Occupational Safety and Health (NIOSH, 1998; 85 dBA for 8 hours in 3 dB steps). Traditionally, these regulations are applied to protect workers from acoustic injuries, and studies of occupational NIHL have focused on industrial noise. However, less attention is given to monitoring the noise exposure that individuals encounter in their daily lives. In particular, noise exposure can occur in unexpected places, such as school environments, and fewer studies have examined noise levels on college campuses. Because students can be continuously exposed to noise throughout their college years, determining the noise environment on campus will help establish protective guidelines.

Several previous studies have measured noise levels on college campuses, typically focusing on places where students traditionally gather, such as academic buildings, libraries, and cafeterias. For example, one study reported that average noise levels (Leq) at 15 different residential, academic, and recreational campus locations ranged from 46 to 72.08 dBA overall, with the following ranges observed across three measurement periods: 51.55 to 72.08 dBA during morning hours (9:30 am to 10:30 am), 46 to 62.15 dBA during lunch hours (12:30 pm to 1:30 pm), and 48.71 to 63.17 dBA during afternoon hours (4:30 pm to 5:30 pm) (Kumar et al., 2023). In another study, noise levels at nine campus locations were reported to range from 69 to 78 dBA during the morning (8 am to 9 am), 70.37 to 77.36 dBA during lunch hours (12 pm to 1 pm), and 71.99 to 79.41 dBA during evening hours (5 pm to 6 pm) (Özyonar et al., 2018). In a study of campus cafeteria noise levels, an average noise level of 73.3 dBA was recorded, with the primary noise sources including shifting chairs, tableware, and reflective surfaces (Choi et al., 2007). Rahimzadeh et al. (2024) also measured campus noise levels, reporting mean values ranging between 45.4 and 59.7 dBA across four different dormitories, and a mean value of 57.5 dBA in the library. Together, these previous studies indicate that students can be exposed to repeated low to moderate noise in multiple campus environments during their college years. However, these studies may not provide the full picture of potential noise exposure for college students, as the collegiate experience typically includes attendance at extracurricular campus events, potentially with a greater risk of noise exposure.

Among recreational college activities, sporting events are popular with many students because they provide an affordable opportunity (i.e., free or low-cost admission) to socialize with peers. Previous reports of noise exposure during college football games for fans indicated average noise levels between 93 dBA and 95 dBA, with the noise levels of six fans, measured with a dosimeter, exceeding the OSHA action level (85 dBA) (Engard et al., 2010). Similar noise levels have also been observed in ice hockey games, with the average noise level (Leq) across two games measured between 81 and 97 dBA (Cranston et al., 2013). In another popular sport, basketball, a noise level of 84.64 dBA was reported (England & Larsen, 2014). Although the basketball games in the study did not exceed noise guidelines (NIOSH, 1998), participants showed temporary threshold shifts, based on pure-tone audiometry and otoacoustic emissions, after the games, indicating trauma to the hearing organ. According to Hoglin (2003), several noise factors, such as thundersticks and cheering sounds, have been reported to cause hearing damage (i.e., tinnitus) in a baseball game. Despite the fact that the noise exposure at certain sporting events may not exceed the established noise guidelines, students may participate in these events regularly over a series of weeks, months, and years, and it is worth noting that repeated moderate noise exposure could eventually lead to hearing changes. For example, in an animal study, hearing loss was observed in mice after repeated exposure to noise at a 90-dB sound pressure level (moderate noise exposure) for 1 hour per day over 5 days (Yamaguchi et al., 2024).

Previous studies have measured noise levels at different campus locations; however, few have analyzed noise levels across multiple school events, transportation methods, and campus locations in the same study to provide a more holistic view of noise exposure for college students. The primary goal of this study was to measure and analyze noise exposure levels across a wider array of campus environments (i.e., campus noise, different modes of transportation, and school events) experienced by college students attending a large public university. Therefore, this study aimed to extend existing research on noise exposure in college students in order to characterize potential risks and raise awareness of the potential for NIHL.

Methods

Noise measurements were conducted between October and December 2023 in 15 locations across the University of North Texas (UNT) (Figure 1), one of the largest universities in the United States, with 46,724 students enrolled in the fall semester of 2023. Because this study did not include human subjects, approval from the UNT Institutional Review Board (IRB) was not required.

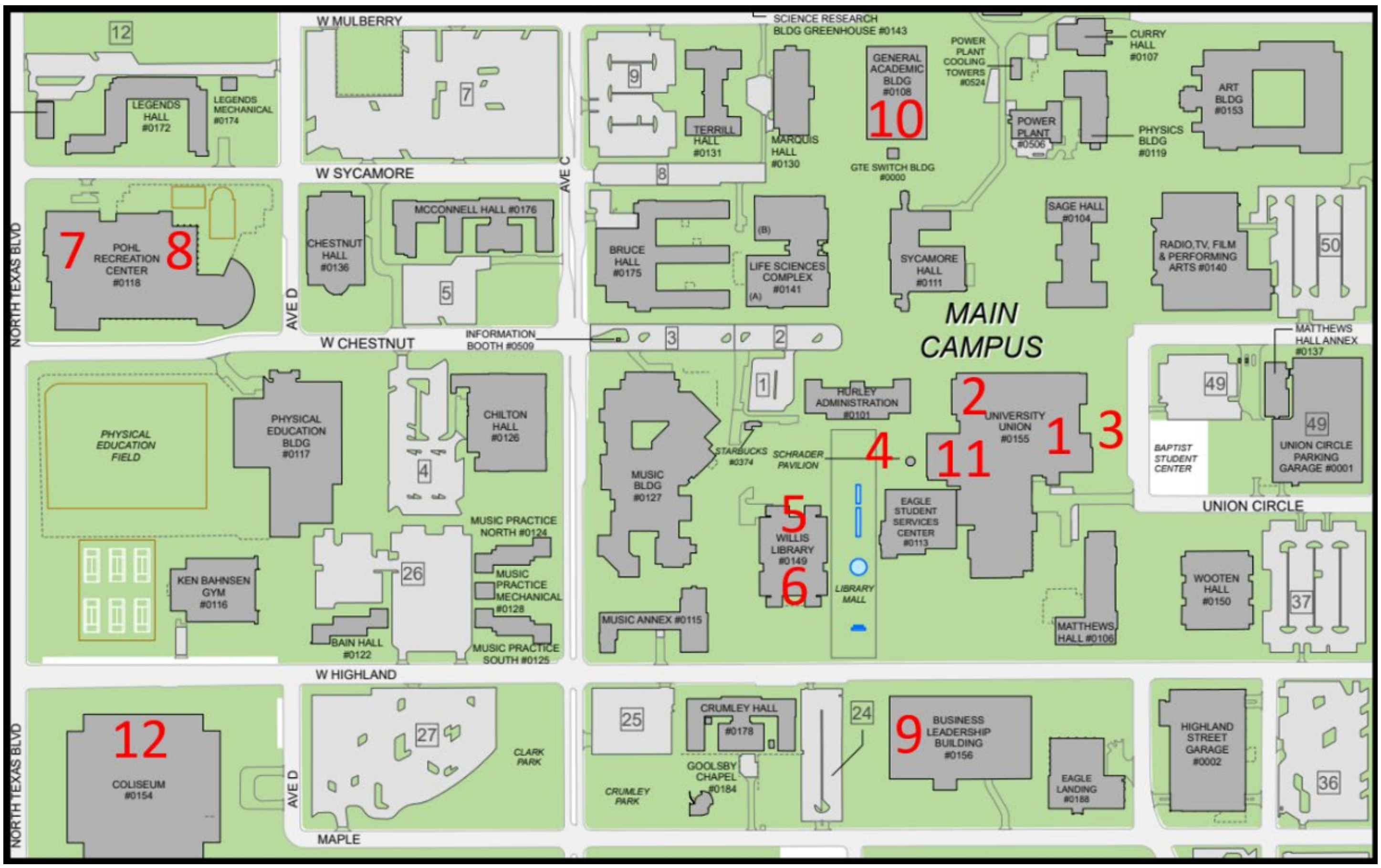

Figure 1 *Noise measurement locations at the University of North Texas. Each number represents a noise measurement location. Football stadium, bus, and train lines are not shown. This map was adapted from one provided by the UNT Division of Finance & Administration Facilities Department.*

Table 1
Noise Measurement Locations Include On-Campus (1–10), During School Events (11–13), and the Transportation Setting (14–15).

#	Location
1	Student Union 1 (Hallway)
2	Student Union 2 (Near the restaurants and tables)
3	Street 1 (In front of the Student Union)
4	Street 2 (Near the square)
5	Library 1 (1st floor)
6	Library 2 (2nd floor)
7	Gym 1 (Next to the exercise equipment)
8	Gym 2 (Near the treadmill)
9	Business Leadership Building (BLB) (1st floor where students study)
10	General Academic Building (GAB) (1st floor where students study)
11	Music events
12	Basketball stadium (Student Section)
13	Football stadium (Student Section)
14	Bus (7 lines)
15	Train (3 lines)

Noise Measurement Locations

Noise measurements were made for three location groupings: on-campus locations, school events, and transportation. A minimum of two measurements were conducted for each separate location (Table 1). For on-campus locations (i.e., 1–10 in Table 1), measurements were conducted during three different periods: morning (8 to 10 am), lunch (12 to 2 pm), and evening (3 to 5 pm). The periods were selected based on when there was a significant number of students in the school, usually spanning from the first to the last class time. The ten on-campus locations represent where students spend most of their time learning, studying, eating, meeting, or talking to other students. For the school events, which consisted of on-campus music and sporting events (i.e., 11–13 in Table 1), measurements were conducted from the beginning to the end of three different events. All school events were free of charge for students. Music event 1 (Latin Jazz Lab Band) was held at 9:00 pm. At this event, more than ten students majoring in music performed in a concert, playing instruments on stage. In Music Event 2 (student performance), students were recruited to perform on a first-come, first-served basis and also played instruments on stage. Music event 3 was held at 12 pm and was performed by student musicians. Sporting events consisted of home basketball and football games. Measurements were also made across two modes of campus transportation, buses and trains (i.e., 14–15 in Table 1), along the entire route for each mode. In total, measurements were taken for ten routes across the two modes of transportation. The UNT campus shuttle and connected bus provide transportation at UNT and in Denton, TX, and measurements were made across seven routes for these buses. For the train, noise measurements were made for routes on three lines, considering the students' residential areas: the regional line (train 1) between Denton and Carrollton, the green line between Carrollton and Dallas downtown (train 2), and the combined lines (regional line + green line, train 3).

Instrumentation

Noise level measurements were conducted with a sound level meter (Model 831, Larson Davis) containing a 1/2-inch random incidence microphone (Model 377C20) and pre-amplifier (PRM831), capable of measuring up to 146 dB SPL, with a frequency range of 3.15 Hz to 16,000 Hz. A windshield ball covered the microphone. The sound level meter was set to the slow response time mode (time constant: 1000 ms; OSHA, 1910.95) and recorded noise levels using A-weighting in 1 octave frequency bands. Before each measurement day, the sound level meter was calibrated (Larson Davis CAL 200, 114 dB at 1000 Hz) and set for a two-hour sampling period at a sampling rate of 48 ksps. All measurements automatically stopped after two hours, except for school events and transportation. In the case of school events and transportation, the noise measurements were initiated and ended by the experimenter for the duration of each event and location. For the on-campus locations, the sound level meter was positioned on a tripod in the center of each location. For the music performances, the sound level meter was placed in the student seating area, with the microphone positioned to face the stage. For the sporting events, the sound level meter was located in the designated student seating area for both the football and basketball games, with the microphone facing the football field or the floor of the basketball arena. For transportation, the sound level meter was located in the center of the bus and train for the entirety of the route. To prevent artificial noise from the experimenter and onlookers, the equipment was marked with a sticker, "Do not touch, and do not talk," and was continuously monitored by the experimenter.

Data Processing and Analyses

A software program (G4 LD utility) analyzed the data transferred from the sound level meter. The analysis was conducted in two units: dBA (A-weighted decibels), reflecting the sensitivity of the human ear to mid and high frequencies while de-emphasizing low frequencies, and dBZ (Z-weighted decibels), which is a flat frequency weighting. Three sound level metrics were analyzed for 2-hour measurement periods: LAeq (average sound level with A-weighting over the given period), LASmax (maximum sound level with A-weighting and slow time over the given period), and LASmin (minimum sound level with A-weighting and slow time over the given period). All levels reported in this study represent A-weighted equivalent continuous sound levels (LAeq), expressed in dBA. Z-weighted measurements were analyzed using identical metrics as the A-weighted measurements. In addition, Z-weighted measurements were also analyzed using 1-octave bands ranging from 31.5 Hz to 16,000 Hz, based on the noise frequency spectrum (Figure 2 [campus location], Figure 3 [school events], and Figure 4 [transportation]). This approach allowed us to identify and compare dominant frequency bands across locations. Descriptive statistics of the noise levels were calculated for each location, including mean, median, interquartile range (IQR), skewness, and kurtosis for each location.

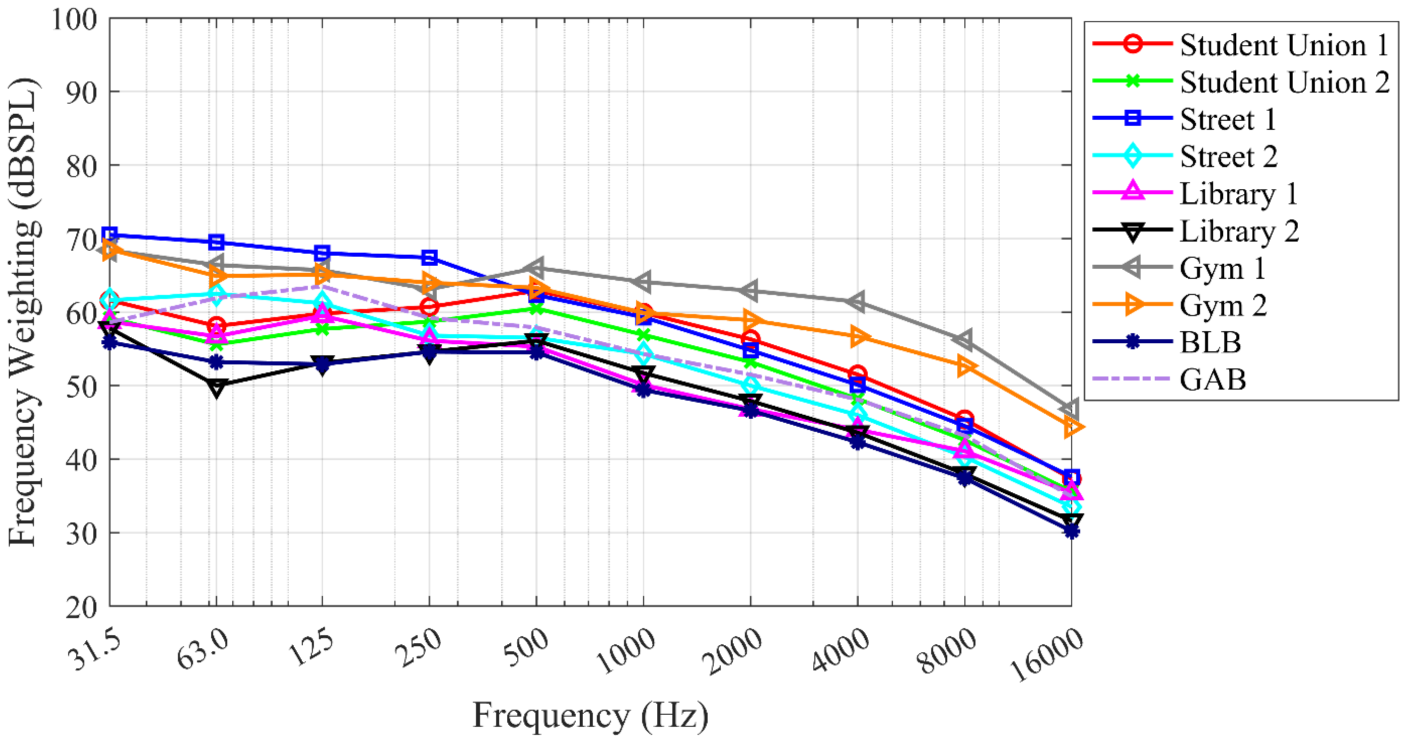

Figure 2: *Average noise levels at campus locations from 31.5 Hz to 16,000 Hz in 1-Octave Bands based on Z-weighting (dB SPL).*

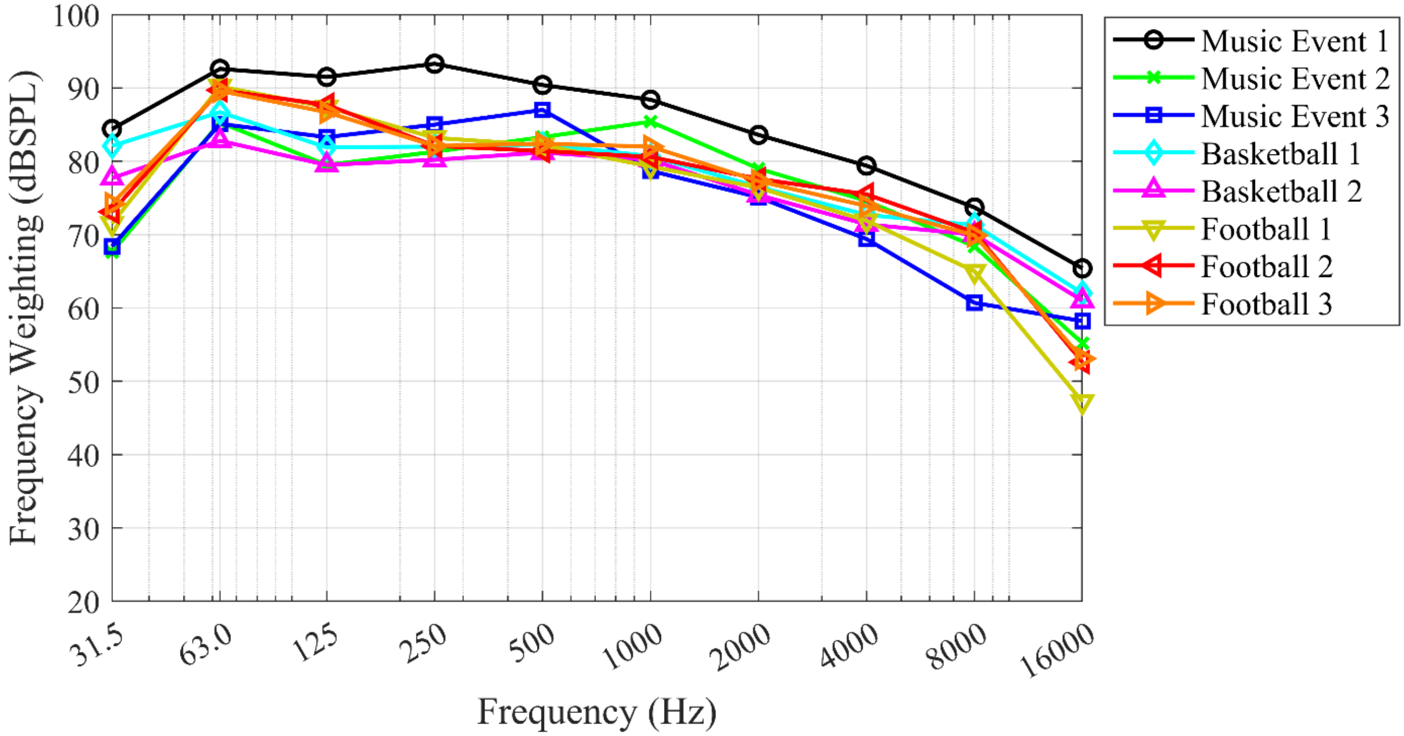

Figure 3. *Noise levels of school events: music (n=3), basketball (n=2), and football (n=3), from 31.5 Hz to 16,000 Hz in 1-Octave Bands based on Z-weighting (dB SPL).*

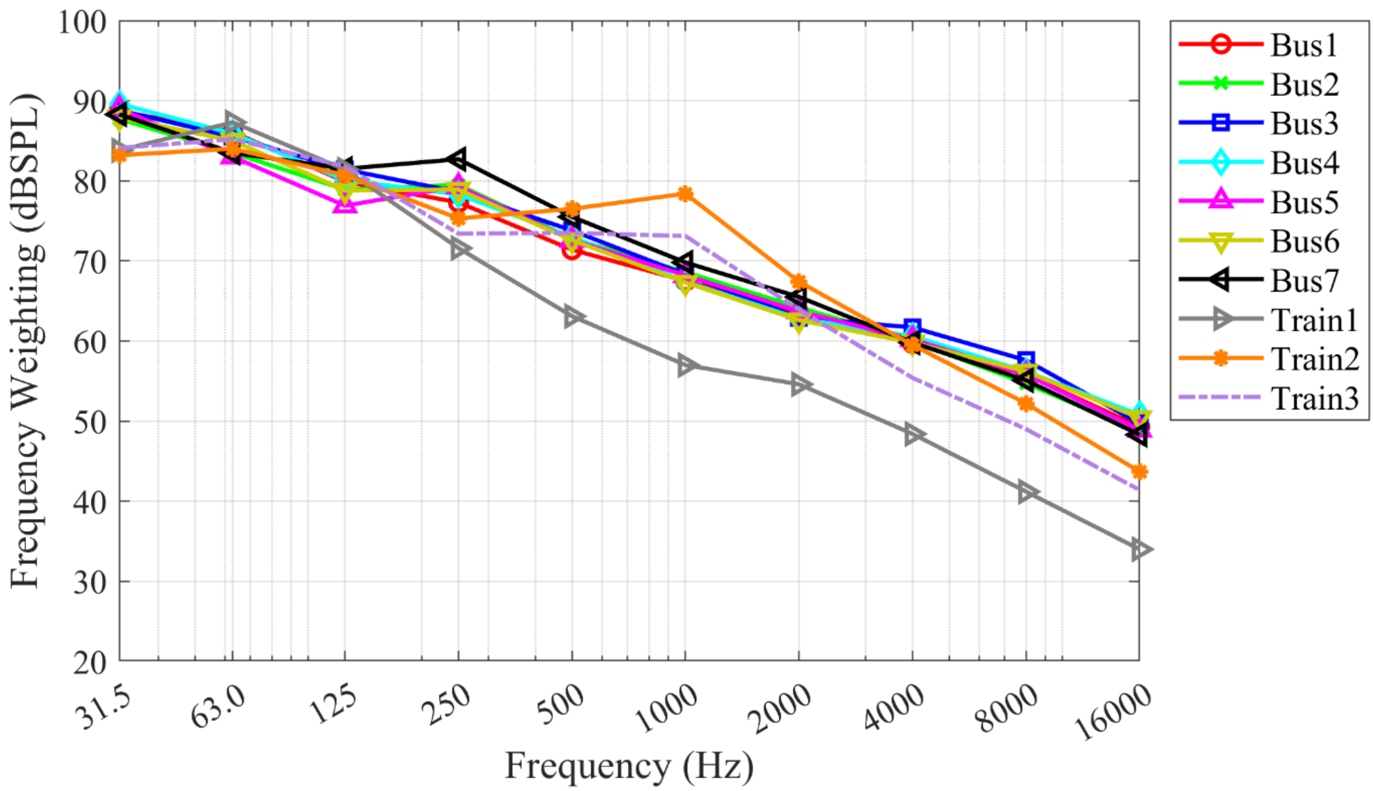

Figure 4. *Average noise level of transportation locations: bus and train, from 31.5 Hz to 16,000 Hz in 1-Octave Bands based on Z-weighting (dB SPL).*

The noise dose was calculated based on the following methods: NIOSH, using a 3-dB exchange rate aligned with the Recommended Exposure Level (REL), where T represents the allowable exposure time.

$$T = \frac{8\ hours}{2^{(Level\ -85\ dBA)/3\ dB}}$$

To assess the noise exposure in terms of percent of REL, the Dose (%) was used as follows:

$$Dose\% = 100 \times \frac{Duration\ of\ Exposure\ (hours)}{T}$$

For the on-campus location data, a nonparametric Friedman test was performed to determine whether average noise levels (dBA) differed by time of day and location. Post-hoc comparisons and consistency analyses were conducted using Wilcoxon signed-rank tests. Kruskal-Wallis H tests were used to determine if average noise levels (dBA) differed within the events and transportation locations. A Kruskal-Wallis H test was also used to compare average noise levels (dBA) and noise spectra across the three location groups (campus locations, school events, and transportation), and post-hoc comparisons were conducted using Mann-Whitney U tests.

Results

Noise Levels at Ten Campus Locations

A summary of the noise measurements for the ten on-campus locations for the morning, lunch, and evening time periods is found in Table 2.

Table 2. *Noise levels over two hours at 10 campus locations (LAeq, dBA). Identical rounded mean values (63.2 dBA) reflect the actual averages of 63.16 dBA (lunch) and 63.18 dBA (dinner).*

	Morning (8:00-10:00 am)			Lunch (12:00-2:00 pm)			Evening (3:00-5:00 pm)			
	LAeq	LAS max	LAS min	LAeq	LAS max	LAS min	LAeq	LAS max	LAS min	Average (LAeq)
Student union 1	57.8	78.7	43.7	67.8	83.7	58.2	68.3	93.4	60.0	64.6
Student union 2	57.0	81.5	43.7	65.4	87.9	53.4	63.1	85.0	50.9	61.8
Street 1	64.8	94.0	52.0	64.7	87.6	54.7	65.3	87.0	54.3	64.9
Street 2	61.3	89.0	51.1	57.1	81.7	49.2	58.6	78.4	52.1	59.0
Library 1	52.0	76.4	40.5	64.0	85.9	48.6	57.6	83.7	45.6	57.9
Library 2	48.1	76.1	40.2	58.1	76.4	40.6	64.9	82.7	47.6	57.0
Gym 1	69.7	91.0	57.4	68.3	89.8	58.1	71.6	94.7	61.2	69.9
Gym 2	65.4	78.2	56.5	66.7	78.9	60.0	66.7	82.3	58.0	66.3
BLB	52.4	85.4	41.9	58.8	85.0	43.9	55.4	83.0	42.4	55.5
GAB	59.2	82.1	53.5	60.7	80.4	54.2	60.3	79.3	52.9	60.1
Average	58.8	83.2	48.1	63.2	83.7	52.1	63.2	85.0	52.5	61.7

BLB = Business Leadership Building; GAB=General Academic Building.

Overall, the highest noise levels were observed in the evening (63.2 dBA), whereas the lowest levels occurred in the morning (58.8 dBA). For the on-campus location data, to determine whether average noise levels (dBA; dependent variable) differed across the three time periods (morning, lunch, and evening), the nonparametric Friedman test was performed with location as the blocking variable and time period as the grouping variable. Noise levels significantly differed across morning, lunch, and evening time periods [$\chi 2(2, N=10) = 6.0$, $p = 0.05$]. Post-hoc pairwise comparisons using the Wilcoxon signed-rank test revealed that noise levels were significantly higher in the evening compared to the morning across locations ($p = 0.02$), but no differences in noise levels between the morning and lunch time periods ($p = 0.06$), or lunch and evening time periods existed ($p = 0.86$). The highest average noise level (69.9 dBA) was observed in the gym 1. The primary noise sources in the gym were observed by the experimenter to be the sound of equipment being used, especially the sound of equipment being dropped (such as dumbbells and bars), the operation of the treadmills, and the playing of music from a speaker.

For the on-campus noise locations (Figure 2), based on Z-weighted measurement in octave bands from 31.5 Hz to 16,000 Hz, the low frequency range between 31.5 Hz and 500 Hz is generally flat and gradually decreases above 1000 Hz. None of the campus locations exceeded the REL limit according to the noise dose calculations.

Noise Levels at Event Locations

A summary of noise levels for school events is provided in Table 3. Each event was measured from the beginning to the end of the event (three music events, two basketball events, three football events). The average times for the events were as follows: music (1 hour 41 minutes 28 seconds), basketball (2 hours 7 minutes 42 seconds), and football (3 hours 20 minutes 18 seconds). Music Event 1 had the highest recorded noise level (93 dBA), while Basketball 1 and 2 had an average noise level of 84.6 dBA, and Football 1, 2, and 3 had an average level of 85.5 dBA. During the football games, the levels of the marching band and cheering sounds were temporarily observed to exceed 100 dBA, and, of note, the sound of fireworks was recorded at 137.5 dB LApk. A Kruskal-Wallis test was performed to determine if the average noise level (dBA; dependent variable) differed across the three types of events, and results showed no significant difference in noise levels across the music, basketball, or football events [$H(2) = 5.56$, $p = 0.06$]. One school event, Music Event 1, exceeded the REL according to the noise dose calculation (184.5%). All other events met the REL guideline.

For school events (Figure 3), based on Z-weighted measurement in octave bands from 31.5 Hz to 16,000 Hz, Music event 1 recorded the largest values across all frequencies. All events generally showed a similar pattern, with high noise levels recorded between 63 Hz and 500 Hz, decreasing above 1000 Hz.

Table 3. *Noise levels during campus events (LAeq, dBA).*

	ID	Duration	LAeq	LASmax	LASmin	Dose (%)
Music event	1	02:19:23	93.0	105.4	53.8	184.5%
	2	01:48:35	87.9	106.4	56.6	44.2%
	3	00:56:27	86.3	98.6	54.8	15.9%
	Average	01:41:28	89.1	103.5	55.1	
Basketball	1	02:15:21	85.0	101.8	57.4	28.2%
	2	02:00:04	84.1	99.6	58.9	20.3%
	Average	02:07:43	84.6	100.7	58.2	
Football	1	03:37:24	84.8	104.6	56.5	43.2%
	2	03:24:18	85.6	103.9	60.1	48.9%
	3	02:59:13	86.0	103.4	63.9	47.0%
	Average	03:20:18	85.5	104.0	60.2	
Average		02:25:06	86.6	103.0	57.8	

Table 4. *Noise Levels During Transportation (LAeq, dBA).*

	Line	Duration	LAeq	LASmax	LASmin	Dose (%)
Bus	1	42:43.8	74.6	83.4	67.2	0.8%
	2	18:12.3	75.5	82.0	64.5	0.4%
	3	16:03.4	75.9	83.2	68.7	0.4%
	4	24:31.5	75.1	84.9	68.0	0.5%
	5	20:02.4	75.3	83.4	66.3	0.4%
	6	26:06.1	75.0	86.1	64.6	0.5%
	7	41:15.2	77.9	86.7	69.3	1.7%
	Average	26:59.2	75.6	84.2	66.9	
Train	1	44:36.0	69.0	77.7	55.9	0.2%
	2	35:26.3	80.2	98.7	66.9	2.4%
	3	1:36:17.4	76.2	93.2	54.2	2.6%
	Average	58:46.6	75.1	59.9	59.0	
Average		36:31.8	75.5	85.9	64.6	

Noise Levels at Transportation Locations

The transportation noise levels measured on buses (seven lines) and trains (three lines) used by students are reported in Table 4. For the bus, the time to complete a route for each line varied, but on average, it was around 27 minutes long. In the dBA analysis for the bus, an average level of 75.6 dBA was measured, with levels ranging from 74.6 dBA to 77.9 dBA. An average level of 75.1 dBA was measured on the train, with levels ranging from 69 to 80.2 dBA. Results from the Kruskal-Wallis analysis with average dBA as the dependent variable and transportation locations as the grouping variable showed no significant difference in noise levels across the transportation locations [H(9) = 9.0, p = 0.437].

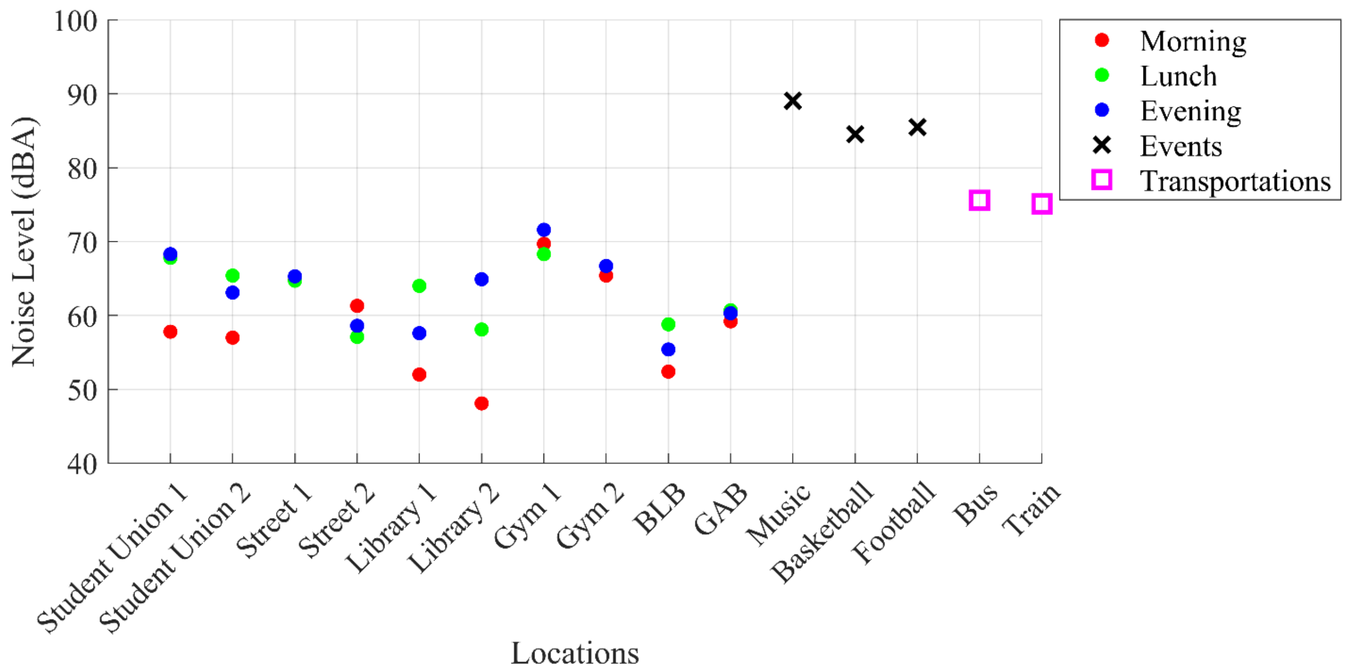

Figure 5. *Scatter plot of average noise levels (LAeq, dBA) by location and period across 15 places.*

For transportation (Figure 4), based on Z-weighted measurement in octave bands from 31.5 Hz to 16,000 Hz, the loudest noise was recorded between frequencies 31.5 and 63 Hz for all transportation, with noise levels decreasing as frequency increased. None of the transportation locations exceeds the REL limit according to the noise dose calculations.

Summary Across Locations

The summary of the noise levels (dBA) across all 15 different locations is reported in Figure 5. The average noise levels (dBA) were highest in the events group (86.6 dBA), followed by transportation (75.5 dBA) and on-campus locations (61.7 dBA). To determine if there were significant differences in noise levels across the three location groups (on-campus, events, and transportation), a Kruskal-Wallis test was performed, and results showed noise levels significantly differed by the three-location groups [$H(2) = 34.498$, $p < 0.05$]. Post-hoc comparisons using the Mann–Whitney U test showed noise levels significantly differed between on-campus locations and events ($p < 0.05$), between on-campus locations and transportation ($p < 0.05$), and between events and transportation ($p < 0.05$).

Kruskal–Wallis H tests were performed to compare the noise spectra across locations and revealed significant differences in noise levels at all frequency bands from 31.5 Hz to 16,000 Hz (all $p < 0.05$). Specifically, the bus showed the highest noise level at 31.5 Hz, whereas Music event 1 exhibited the highest noise levels from 63 Hz to 16,000 Hz across all campus locations.

Table 5. *Descriptive Statistics of Noise Levels (LAeq, dBA).*

	Location	Mean	Median	IQR	Skewness	Kurtosis
1	Union 1	64.6	67.7	8.8	-0.8	1.9
2	Union 2	61.8	63.0	4.2	-0.9	2.7
3	Street 1	64.9	64.7	0.9	0.9	2.5
4	Street 2	59.0	58.6	3.4	0.3	1.6
5	Library 1	57.9	57.6	7.5	0.7	2.5
6	Library 2	57.0	58.1	16.8	-0.2	1.5
7	Gym 1	69.9	69.7	2.4	0.5	2.1
8	Gym 2	66.3	66.3	1.4	0.2	2.1
9	BLB	55.5	55.4	5.8	0.1	1.6
10	GAB	60.1	60.1	1.4	-0.1	1.4
11	Music	89.1	87.9	5.0	0.5	1.5
12	Basketball	84.6	84.6	0.9	0.0	1.0
13	Football	85.5	85.6	0.9	-0.4	1.5
14	Bus	75.6	75.4	1.9	0.5	2.7
15	Train	75.1	76.2	10.2	-0.3	1.5

**For each campus location (1─10), six measurements (two per time period: morning, lunch, and evening) were averaged to obtain the reported value. BLB=Business Leadership Building; GAB=General Academic Building.*

The data distributions are reported in Table 5. The locations with the widest distribution were at Union 1 (8.8), Library 1 (7.5), Library 2 (16.8), and Train (10.2) based on the IQR. In Library 2, where the largest difference was observed, the noise difference between evening and morning was 16.8 dBA, with the students' talking observed by the examiner as the primary noise source. Skewness was ±1.0 for all locations. All locations were measured twice, except for the school events. The difference between the first and second measurements was 0.32 dBA ($SD = 2.19$). A Wilcoxon signed-rank test showed that there was no significant difference between the first and second measurements ($Z = -0.5$, $p = 0.617$).

Discussion

The present study measured noise across different campus locations, school events, and transportation services to analyze the noise levels and spectra to which college students are exposed. For on-campus locations, noise levels were significantly higher in the evening compared to the morning. Noise levels significantly differed among the school events, transportation locations, and on-campus location groups. While most of the measured noise levels were within acceptable limits, one school event exceeded the REL, making ongoing noise monitoring and educational approaches to NIHL necessary.

The present study found that on-campus locations were significantly noisier in the evenings than in the mornings. On-campus locations surveyed included the student union, gym, library, streets, and academic buildings. Locations such as student unions are popular places on college campuses where many students spend considerable amounts of time eating, studying, and socializing. In addition, there is typically free WiFi available to students. A previous study by Lim et al. (2023) analyzed the correlation between WiFi access and noise in public spaces on a campus and found that the more students connected to WiFi, the higher the noise levels measured. These results are consistent with those in the current study, where higher noise levels were measured during lunch and evening hours when many more students gather compared to the morning hours. While the noise levels for on-campus locations were within permissible guidelines, many students were also observed using personal listening devices (PLD) to listen to music or watch videos. Although the students' PLD levels were not measured in the current study, previous work indicated that preferred volume levels with in-the-ear (earbud) headphones are approximately 10 dB higher in noise than in a quiet environment (Hodgetts et al., 2007), and the preferred listening levels in noise were measured at a mean of 86.1 dBA (Williams, 2005). Thus, there is still a need to educate students on the risks of NIHL.

In the library and academic buildings where students take classes and study, none of the recorded noise levels exceeded the noise standards. Even though there was no significant difference in gym levels compared to other on-campus locations, gym levels were, on average, 8 dB louder. The structural characteristics of the gymnasium with a ceiling and hard reflective surfaces contributed to longer reverberation times, which may increase perceived sound levels, as Al-Arja (2020) supported. Although currently measured noise levels are not associated with NIHL risk, reverberation can still increase listening effort (Kyong et al., 2020); therefore, room acoustics may still be important.

UNT has a world-renowned school of music, and musical performances are prevalent across campus. The present study assessed the noise levels experienced by audience members at three campus music events and found that the noise levels of the performances ranged from 86.3 to 93 dBA. This range is similar, albeit narrower, compared to the levels previously observed by Laitinen et al. (2003), who measured sound levels between 82 and 99 dBA during a group performance. While the present study focused on audience member noise exposure, many previous studies have documented the risks of NIHL in student musicians (Phillips et al., 2008; Phillips et al., 2010; Gopal et al., 2013; Tufts & Skoe, 2018). It should be noted that the levels measured during the present study are not reflective of what the musicians experience, and it is likely student musician risk for NIHL is much greater. For example, one previous study reported that the average noise level in practice rooms was between 87 and 95.2 dBA (Phillips & Mace, 2008). In addition to individual practice, student musicians often perform in groups such as orchestras or ensembles. In one study, 14 students exceeded the NIOSH maximum allowable daily exposure during an ensemble rehearsal (Washnik et al., 2016). In the current study, Music Event 1 was the only event that exceeded the REL limit. Therefore, music performances may lead to a potential risk of NIHL for audience members, and likely the student musicians, and a program for hearing protection should be considered.

In the basketball and football games, noise levels were recorded at around 85 dBA for the present study. This finding is similar to that reported by England & Larsen (2014) for college basketball games (84.64 dBA). However, Rabinowitz & Kernodle (2016) reported average noise levels at 92.46 dBA, approximately 7 dB higher than the current study measured. In the student seating section, the average noise level was measured at 96 dBA by Rabinowitz & Kernodle (2016), which is about 11 dBA higher than the current study. These differences were likely due, in part, to the number of spectators present. This is supported by Rabinowitz & Kernodle (2016), who found that larger crowds resulted in louder noise. While the noise limits measured at the sporting event in the present study did not exceed recommended guidelines, there is still a risk for hearing loss. For example, at the football event, fireworks were set off each time the home team scored, and a peak value of 137.5 dB LApk was recorded, which is associated with potential risk. In a study investigating the effect of fireworks on hearing, 56% of 50 patients reported hearing shift, and 64% reported tinnitus (Flockerzi et al., 2023). Acute loud noises can also trigger other hearing complaints (i.e., tinnitus and hearing loss) (Ghazaryan et al., 2024). Because fireworks can cause damage to the inner ear (Liao & Young, 2018), continuous monitoring is necessary, and students should be made aware of the risks at sporting events.

When using bus transportation around campus, the average exposure time to noise was 27 minutes, a relatively short measurement period. The transportation noise measured in the current study did not exceed the acceptable noise standards. However, in all modes of transportation, low-frequency band intensity was higher than the mid- and high-frequency bands. These higher noise levels are likely related to engine and air conditioner noise, which have more energy at low frequencies. The noise measured on the bus was located in the middle of the bus, but due to the location of the engine and air conditioner at the back, students sitting in the back can be exposed to greater noise. For train 1, the noise level was lower than that of other types of transportation. This may be due to the relatively slow speed and the small number of curves. Of particular interest was that most students were observed to be wearing earphones during the measurement, and future work will need to monitor their preferred listening levels while using transportation to assess their potential risk for NIHL.

Whether college campus noise levels differ from other environments where young adults often spend time is unclear due to the lack of comparative studies. However, several studies have reported that noise levels at locations such as restaurants (range from 59 to 80 dBA, Lebo et al., 1994), streets (ranged from 55.8 to 95.0 dBA, McAlexander et al., 2015), and gyms (ranged from 80 to 100 dBA, Angelo & Zannin, 2015) to be either similar or louder than campus noise levels. While direct comparisons may be limited because these noise measurements can be affected by many variables at the time of measurement, understanding that these noise levels are not limited to campuses highlights the need for widespread education on noise exposure prevention for young adults.

Limitations

The current study had some limitations. The noise recordings were randomly measured twice for each campus location, Monday through Friday, from October to December 2023. For these measurements, it was assumed that Fridays would be less crowded than other days. Therefore, additional studies are required to continuously measure noise levels from Monday to Friday at fixed locations rather than randomly on each day. Additionally, 15 locations were selected, including school events, but further research is needed to measure noise in other buildings, dormitories, and other school events. When the noise measurements were taken, the Texas area had a relatively warm climate compared to other states, which may not affect students' outdoor activity patterns. Instead, it should be considered that students move less at the end of the academic semester.

Additionally, the noise measured at each location was for 2 hours, which limits the ability to represent the noise daily at each location. This time frame is limited compared to the proposed noise standards (e.g., OSHA and NIOSH). Nonetheless, 2 hours can be meaningful because students may not stay in one place for 8 hours. While noise accumulation was roughly calculated based on the length of time students stayed at school events, doses could not be calculated for on-campus locations because the length of time students stayed was not measured. Another limitation is that the recordings are limited to the general areas surrounding the microphone; they do not represent individual exposure levels or varying exposure levels if people change their positions during the event. A noise dosimeter may be an alternative to address this noise exposure place limitation. Although descriptive distribution was analyzed, the limited number of measurements may affect the interpretation. Therefore, the results should be interpreted cautiously, and future research may require more measurement.

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