A Quantitative Comparison of Traffic Noise During, Before and Long Before the Pandemic Using A-Posteriori Heuristic Calibration

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Abstract

One of the prominent effects of lockdown periods is the restrictions on human movement and activity, and consequently potentially reduced noise levels. This study aims to quantify the possible changes in noise in Vienna (Austria) in two lockdown periods (in March and December 2020) compared to normal conditions (recorded in 1980, 1981, 1983, 2011, and 2012) at two traffic stations (Freyung and Schottentor) and a walking area (Graben). To calibrate the data collected by three different microphones, an a-posteriori heuristic calibration was used. The results show that the noise level in lockdown II is lower than all periods at all stations (except in one traffic station in 1980). At both traffic stations, the noise level in 2011 is almost equal to and higher than that of lockdown I and the early 80's noise level, respectively.

Introduction

Noise is an unwanted sound. The World health organization (WHO) defines sounds above 65 dB as noise pollution. Researches have shown that exposure to high-intensity or long-term noise can cause problems such as stress, lack of concentration, communication problems, fatigue due to insomnia, heart problems, cognitive deficits, and hearing loss [1, 2]. Hence, the study of noise level changes over the past decades has been noticed in several studies. For example, Ögren and Barregard [3] compared noise levels from 1975 to 2010 in Gothenburg, Sweden. In this study, instead of using measured audio signals or sound pressure levels (SPL), the noise level is estimated based on traffic flow, population, and other noise-related factors. They have found that the amount of noise in the city has increased throughout the study period. In another work, the authors studied changes in traffic noise in the city of Nis in Serbia in 2008, 2009, 2010, and 2011 [4]. They found that traffic noise has increased over the years, largely due to the increase in motor vehicle traffic.

The coronavirus, known as COVID-19, infected many people around the world in 2020. To control the outbreak of COVID-19, governments were forced to establish lockdown measures. During the lockdowns, human movement and social activity in the outdoor environment decreased significantly. As a result, noise pollution, especially traffic noise, was expected to decrease. [5-11] have shown a reduction in noise level in the lockdown period compared to pre-lockdown. Munoz, et al. [11] assessed changes in environmental sounds during, before, and after the lockdown period in southern France. They found that the average SPL at monitoring stations decreased by between 4 and 6 dB during the lockdown period. There was also a decrease in noise levels in the post lockdown period compared to the pre-lockdown period. But this reduction was less than the one observed during the lockdown period (4-6 dB vs. 1-2 dB).

However, not all studies have concluded a reduction in noise during the lockdown period. For example, Terry, et al. [12] have shown that noise level has increased in some park areas during the lockdown in USA. They have also reported that the increase in noise is not limited to recreational environments, but the traffic noise level has also increased by about 4-6 dB during the lockdown period. They speculated that the increase of noise is due to increased vehicle speeds as a result of reduced traffic congestion during the lockdown.

In Vienna, Austria, two lockdown periods were applied between March 16 to April 20 (lockdown I) and November 17th to December 6th (lockdown II) which are included in this study. During these two periods, people were only allowed to go out from 6 am to 8 pm for professional activities, necessary purchases, assisting others, and working out alone or in the company of people living in the same household. To investigate the extent of noise changes in Vienna, in this study, we compared the noise levels in these two lockdown periods with normal conditions in 2011 and 2012, and in 1980, 1981, and 1983.

Data

Information on the availability of study data is provided in Table 1. These audio signals were recorded at two traffic stations in Freyung and Schottentor with the following latitude and longitude coordinates: (48.2137567°, 16.3614594°) and (48.2116073°, 16.3657546°)). In addition to these two stations, audio signals were recorded at a walking area called Graben (which has been a pedestrian area since 1971) in the city center of Vienna. However, the number and duration of recordings at these stations vary. There are 11, 18, and 6 signals recorded at Schottentor (from 1980, 2011, 2012, lockdown I, and lockdown II), at Graben (from 1980, 1981, 2012, lockdown I, and lockdown II), and at Freyung (from 1983, 2011, lockdown I, and lockdown II). These audio signals are recorded for a total of 82:41, of 145:24, and of 41:58, respectively.

Signals at traffic stations collected in 1980 and 1983 (in 2011, 2012, and two lockdown periods) were recorded in the morning (in the afternoon). Signals in Graben collected in 1980, 1981, 1983, and lockdown periods (in 1980, 1981, 1983, 2011, and 2012) were recorded in the afternoon (in the evening).

In the first period (i.e., 1980-1983), a Nagra IV-S tape recorder [13] at a tape speed of 38 cm/s together with an unknown microphone were used, digitized with a sampling rate of 96 kHz. In the second period (in 2011 and 2012) a Roland R-44 solid-state recorder [14] at a sampling rate of 48 kHz together with a Schoeps MSTC 64 Ug ORTF-microphone [15] were used. In the lockdown periods, a Roland R-05 solid-state recorder [16] at a sampling rate of 96 kHz together with an AKG CK91 ORTF microphone setup [17] were used.

Regarding observational data, the sound pressure level is measured for 50 seconds by SPL meter at the Freyung station in 2011 (see Table 1). This data is then used for regression-based calibration of data recorded in 2011 and 2012.

Table 1: Total duration, month, and day time of recordings at each station in study periods. Day time are reported in minutes: seconds. (M), (A), and (E) stand for morning, afternoon, and evening, respectively. L I and L II stand for Lockdown I and Lockdown II in 2020.

Year / Station	Audio signals				SPL meter observation
	1980 and/or 1981 and/or 1983	2011 and /or 2012	L I	L II	2011
Schottentor	1:48 (Aug.) (M)	45:54 (Sep.) (A)	16:2 (Apr.) (A)	18:39 (Dec.) (A)	-
Freyung	2:49 (Mar.) (M)	21:38 (Sep.) (A)	7:17 (Apr.) (A)	10:14 (Dec.) (A)	0:50
Graben	49:57 (Aug., Jul., and Dec.) (A and E)	58:45 (Jul. and Aug.) (E)	27:4 (Apr.) (A)	9:02 (Dec.) (A)	-

Method

In the first step, all audio signals were converted to the mono channel by averaging samples across channels and were resampled to 48 kHz. Then, the data recorded by the microphones (in Pascal) were converted to sound pressure level (SPL) [18]. This conversion has been performed on all data by assuming a time weighting of 125 milliseconds. Time weighting is performed by applying a low-pass filter with one real pole at $-1/\tau$ (here τ is 0.125). It is worth noting that this time constant is taken from the SPL meter, which was used during data recording in 2011 at the Freyung station. No frequency weighting was used in this conversion which is called flat or Z frequency weighting.

Since the measurements were recorded by three different microphones in different periods, they had to be calibrated before analyzing the calculated SPLs. To perform the calibration, we have used comparatively two approaches including a heuristic method and peak normalization.

The heuristic method consists of two steps. In the first step, 2011 and 2012 data were calibrated based on the coefficients obtained from a linear regression between the measurements of the Schoeps MSTC 64 Ug ORTF microphone and the observations of the SPL meter. The observational data used is available for 50 seconds. To reduce the calculation error, these observations were converted from sub-seconds time scale to seconds. That is, the calibration was performed based on 50 paired samples of SPL meter data and microphone measurements. Since the audio signals were recorded in 2011 and 2012 with the same microphone, the coefficients obtained for 2011 were also applied to the 2012 recordings.

Because the measurements in 2020 were recorded with different microphone (AKG CK91 ORTF), it was not possible to perform the latter method for the calibration. Therefore, assuming that the data for 2011 and 2012 are correctly calibrated, as the second step of the heuristic method, we calculated the bias between the peaks of a reference signal (i.e., church bell) found in 2020 and 2011 and applied it to the data in 2020. Since this reference signal (and any other common reference signals) was not found in 1980-1983 recordings, these recordings were used without any calibration.

Because this limitation itself can cause errors, in the second method we have used the peak normalization approach to calibrate all data. As the name implies, all recordings were normalized by dividing the audio signals by the maximum sound pressure measured by each microphone.

Results

Calibration

Figure 1 shows the scatter plot between the observed SPL meter (y-axis) and the SPL measured by the microphone (x-axis). The high R-squared value (i.e., 0.81) between these two data assures that the first-order linear equation and its resulting coefficients (i.e., $y = 0.76\,x + 32.62$) can be used to calibrate microphone data in 2011 and 2012.

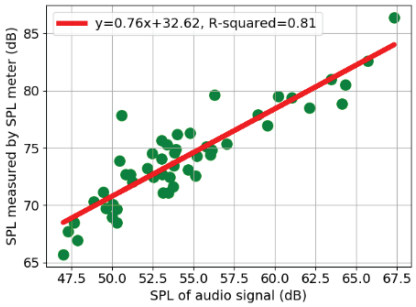

Figure 1: The scatter plot between observed sound pressure level (SPL) by SPL meter (Y-axis) and SPL calculated from audio signal (X-axis) recorded in 2011 at the Freyung station.

Figure 2 shows the audio signal spectrogram which contained church bell (as the reference signal for 2011 and 2020 at the Freyung Station). According to the pattern of church bell signal in 2011 and 2020 shown in Figure 2, we could make sure that this audio feature can be taken as the reference signal for these two years. A comparison of the church bell's peak SPL shows that the maximum level of the church bell SPL in 2020 is approximately 9 dB lower than in 2011. So, by adding

this value to the 2020 data, they were calibrated. As mentioned earlier, due to the lack of a reference signal in 1980s data, they could not be calibrated using heuristic method.

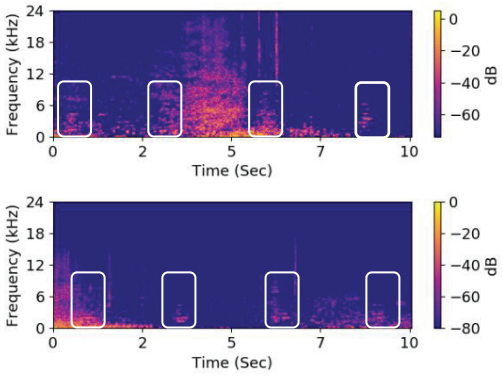

Figure 2: Spectrogram of audio signals that contain the church bell in 2011 (top) and in 2020 (bottom). A nonstationary noise-reduction filter [19] has been used to better display spectrograms.

Noise level comparison

Figure 3 shows the temporal distribution of SPL obtained from raw (in red), peak normalized (in green), and heuristically calibrated (in blue) data.

According to Figure 3A, the median noise level of the heuristically calibrated data (blue box) at the Freyung station has reached its lowest level in the second lockdown period of 2020. In contrast, the highest level of noise at this station was in 2011 with a slight difference compared to the first lockdown in 2020. This year has seen not only the highest median but also the highest minimum and maximum noise levels. Another noteworthy point is that the largest number of low-noise data occurred in 1983 (black circles). Considering the fact that data of both lockdown periods are collected at the same day time, the decrease in the noise level in the second lockdown can be attributed to the increase in the traffic and, subsequently, to the decrease in the engine noise of passing cars. Although traffic information is not available in the vicinity of Freyung Station, Vienna's congestion index (i.e., extra travel time drivers are experiencing on average) shows a 15% increase in traffic in December compared to April in the entire city [20].

Comparison of uncalibrated data (red box) and data calibrated by peak normalization method (green box) shows that there is not much difference between these two data. In both data, the noise level in the first lockdown of 2020 has increased compared to 2011. This is contrary both to our expectations and to similar studies, which have shown the noise level reduced during the lockdown period compared to normal conditions. These results further indicate the necessity of data calibration through the heuristic method.

At the other traffic station (i.e., Schottentor) (Figure 3B), similar behavior of noise level has been recorded. As the lowest noise levels occurred in 1980 and the second lockdown of 2020.

On the Graben area (Figure 3C), similar to traffic stations, the lowest median of noise was in the second lockdown period.

In addition to the fact that lockdown has reduced pedestrian traffic and resulting noise, the second period of lockdown was in December, which naturally has less pedestrian traffic than warm periods (first lockdown). The difference between the data recorded in the Graben area and the traffic stations is less noise in 2012 compared to first lockdown in 2020.

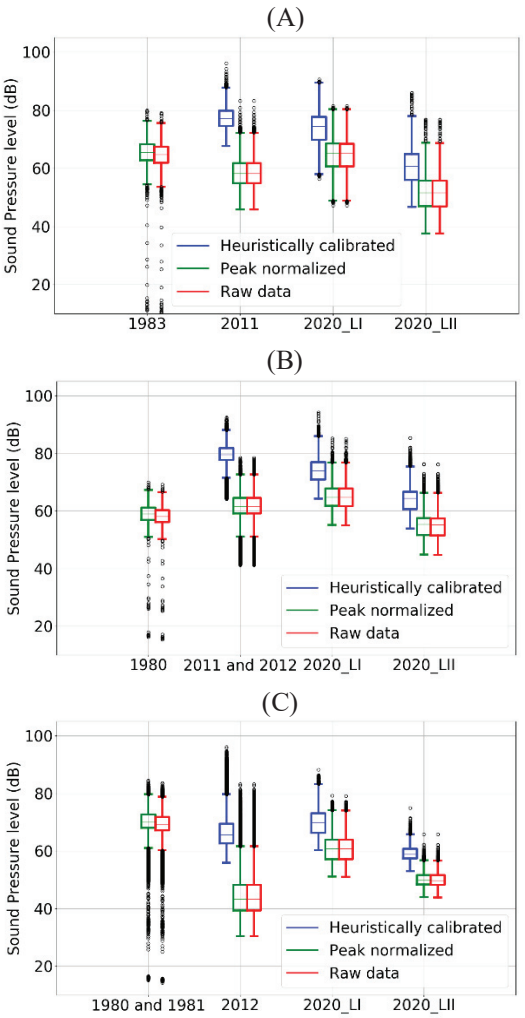

Figure 3: Boxplots of sound pressure level (SPL) calculated for heuristically calibrated (blue), peak normalized (green), and raw (red) data at Freyung (A) and Schottentor (B) stations and walking area in Graben (C). In 2020, the abbreviations LI and LII represent lockdown I and II, respectively. Note that on the X-axis, the first year of data collection is different at each station.

The main reason seems to be the recording of first lockdown data in April, when favorable weather increases the desire to walk in this area. Keeping in mind that the lack of calibration could cause errors in the signals of 1980 and 1981 data, the presence of numerous music instruments and movement through vehicles with higher engine noise, as well as more crowds of local residents in this area could cause higher noise (blue box) in these years in Graben area compared to traffic stations.

Discussion and Conclusions

In this study, we compared noise levels in three periods including normal condition in 1980-1983, normal condition in 2011 and 2012, and two lockdown periods in 2020. Because

the data in each period were recorded with different microphones, the data were calibrated by a heuristic method (which includes regression and bias correction) and the peak normalization.

Before drawing conclusions from the findings of this study, the following points should be considered: (1) measurement signals were not recorded at the same time of year and day which hinders consistent comparison, (2) we considered the church bell in lockdown I to be heard from the same church as in 2011. Of course, it is a rough assumption. And (3) we have not found a reference signal to calibrate data recorded in the early '80s. Therefore, we have used the peak normalization as a comparative method to calibrate the data. But our findings show that there is not much difference between raw and calibrated data through the latter method.

The results of the data calibrated by the heuristic method show that the highest noise level occurred in traffic stations in 2011. In these stations, the lowest level of noise was in the second lockdown 2020 and 1980. Although the reduction in noise levels in the second lockdown is largely due to the movement restrictions to deal with the COVID-19, a comparison of this period with the first lockdown period shows that higher traffic jams (lower engine noise levels) in this period has also been effective in reducing noise levels. In the walking area Graben, data recorded in lockdown I and 1980 are found noisier than in 2011 and lockdown II.

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