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NOISE CONTROL FOR A BETTER ENVIRONMENT

A restaurant noise study of continuous and transient noise phenomena

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ABSTRACT

A restaurant that the author (TAB) works at part time involves a wealth of opportunities to study different types of restaurant noise that change throughout the business day. Measurements use a RadioShack model 3300099 Digital Sound Level Meter and a SoundMeter X (Version 10.2.2), (application by faberacoustical.com that can be downloaded free from the App Store onto an iPhone). Professional analysis tools are also available. The restaurant has many different areas that might be of interest for studying both continuous and transient noise phenomena. Acoustical noise measurements include the following locations: the dishwasher's sink (sounds of dishes being washed), the surrounding grill area (sounds of cooking food and moving pans), the bar, the main dining area, and the high-top tables near the bar (to measure the rise and fall of sound levels as conversations ensue). Noise measurements include the prep area, the "to-go" phone, back sink, patio, behind the bar, host stand, "to-go" room, foyer, banquet room and main seating area. Transient noise as well as averaging sound levels over longer (between 15 seconds to 1 minute) will be presented for different times in the day for slow periods, mediums crowds, and full capacity seating.

Keywords: Restaurant, Transient Noise, Sound Level Meter
I-INCE Classification of Subject Number: 07

1. INTRODUCTION

An analysis of restaurant noise was motivated in part by the lifestyle of one of the authors (TAB) who has strong interests in music, in art and literature and has a keen interest in

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physics. During TAB's mentorship/internship doing physical acoustics experiments in the Physics Department at the United States Naval Academy (Fall-Spring 2018-2019) there was growing interest in measuring the intricate background noise at a local restaurant, where this author was part-time employed. A literature search revealed a recent article [See Ref. 1] that discussed measuring restaurant noise in a large variety of establishments using a sound level meter. The authors of this paper became interested in furthering that study with an emphasis on studying both steady state and transient noise in a restaurant environment. The unnamed restaurant graciously gave TAB permission to data log the restaurant sounds / noise in typical hours of operation and was free to make measurement in the seating areas, the hostess stand, the to-go phone and carry-out, the various dining areas, the kitchen spaces, areas near the bar and food preparation locations, etc.

A RadioShack model 3300099 Digital Sound Level Meter and a SoundMeter X (Version 10.2.2) (an "app" application by faberacoustical.com that can be downloaded free from the App Store onto an iPhone) were used to make all the measurements presented in the paper. The authors purchased some professional software tools to allow the iPhone "sound level meter" to become a data logging device to record WAV files for further analysis in Mathematica™ version 9. In the next section we will present an experimental overview of the measurements that were made and later analyzed.

2. EXPERIMENTAL OVERVIEW

Inside the restaurant, measurements of the background noise activity were made with the data logging device set on C weighting and fast response. This setting was chosen as one was most interested in studying the so-called background transient effects. The following locations were chosen for this paper: the host stand, seating areas 1,2,3 and 4, bar locations 1,2 and 3, the expo (the assembly food line), the dishwasher area and the kitchen. The recordings took place when the restaurant was busy. A sound system is always playing pre-recorded popular contemporary "background" music which is very noticeable, pleasant and was not considered annoying or harsh. There is continual talking and overlapping conversations going on and there are very noticeable and distinct transient sounds. These sounds might be paper rustling, glasses or plates clinking or crashing, chairs moving, and voices that suddenly increase in volume quickly and then blend into the background. None of the transients are unusual but during recording and playing the sound back, the measurements of the variable sound levels make one aware that the background is quite an orchestration of restaurant sounds.

Recording times at each location were not predetermined. Fifteen WAV files were recorded with various lengths of time between 20 seconds up to almost 170 seconds in some cases. In the analysis presented here, a sound recording of 5 seconds was chosen from each of the 15 files. In some cases we purposely select a certain 5 second interval because it included the transient information we were most interested in. We now outline the description of each 5 second record.

2.1 Outline of the description of each 5 second sound tracks

WAV file 1, host stand 1
-Transient at 2.4 s: A host is moving menus.
-Transient at 3.2 s: A host is moving menus.
-Background: is a mixture of guest conversations and restaurant's music.

WAV file 2, host stand 2
-Transient at 2.3 s: A host is moving paper.
-Transient at 2.9 s: A host is moving paper.
-Transient at 3.4 s: The clink of a fork on a plate.
-Background: is all conversation between guests and servers; there is no music.

WAV file 3, seating area 1
- No transients in wav file 3.
-Background: is majority conversation and restaurant music.

WAV file 4, seating area 2
-Transient at second 2.9: Guests clinking a glass against a plate.
-Background: is mostly conversations with a small amount of restaurant music.

WAV file 5, tuning fork test. (Let f_o = fundamental frequency)
-There are no restaurant noise transients in wav file 5
The spectrogram for wav file 5 shows two pure tones, (f_o and ~ 6.5 f_o)

WAV file 6, bar 1
-Transient at 0.9 s: The singer of the song playing in the restaurant, the vocalist, crescendos on the first beat.
-Transient at 3.5 s: The singer of the song playing in the restaurant, the vocalist, crescendos on the third beat.
-Background: is majority music with a small amount of conversation.

WAV file 7, dishwashers
-Transient at second 2.2: The dishwasher is throwing a pot into the sink.
-Transient at second 3.3: A server throws silverware into the dish bin.
-Transient at second 4.4: The dishwasher is putting a plate into the dish bin.
-Background: is conversation, lots of yelling order numbers between staff.

WAV file 8, expo 1 (assembly food line)
-Transient at second 4.8: Expo worker is moving a plate across the line.
-Background: consists of conversation between staff and the sound of food being made (for example, fryers frying, ovens humming, plates clinking against other plates).

WAV file 9, host stand 3
-Transient at second 0.4: A customer and server are having a conversation about the specials.
-Transient at second 1.4: A host is talking.
-Transient at second 2.3: The singer of the song playing in the restaurant, the vocalist, crescendos on the first beat.
-Background: is mostly music and conversation between customers and employees.

WAV file 10, bar 3
-Transient at 2.4 s: The mint bowl in pushed into the microphone by a customer.
-Transient at 2.8 s: The mint bowl is pushed into the microphone by a customer.
- Background: is a majority of conversation with a small amount of restaurant music,
Also, there are a lot of glasses and flatware clinking against plates.

WAV file 11, bar 3
-Transient at 2 s: Made by the crinkle of a mint wrapper.
-Transient at 3.5 s: Made by the shuffle of menus at the nearby table.
-Background: is mostly the restaurant's music with a small amount of conversation.

WAV file, expo 3 (assembly food line)
-Transient at 1 s: The chef is yelling across the kitchen to an expo worker.
-Transient at 2-2.2 s: An expo worker is yelling across the kitchen to the chef.
-Background: is the sound of the ovens cooking, plates clinking together; expo workers and chefs are yelling orders across the kitchen.

WAV file 14, host stand 4
-Transient at second 1.4: The mint bowl is sliding across the countertop.
-Background: is majority of conversation; there is no music, but guests, hosts, and servers are talking amongst themselves.

WAV file 15, kitchen
-Transient at 3.7 s: A busser is talking and stacking plates.
-Background: is mostly dishwashers cleaning, expo workers yelling, and servers talking.

(16)WAV file 16, seating area 4
-Transient at 1.3 s: The dish of sugar packets is moved.
-Transient at 1.8 s: The dish of sugar packets is moved.
-Transient at 3.6 s: The pepper shaker is dropped into the metal storage area.
-Background: is mostly guest conversations and the restaurant's workers usual activities.

2.2 Converting the WAV files to decibel levels versus time.

The data logger's voltage versus time wave file was calibrated using the Radio Shack digital sound level meter and a 256 Hz tuning fork signal which slowly decayed in time. It was determined that the calibration curve to be fit to a function in the following form

$$L\ dB = 22.99\ Log_{10}(V_{rms}) + 118.2$$

Therefore, if the data recorder signal can be converted to a root-mean-square rms) value V_{rms} then a conversion to the desired sound level $L\ dB$ in decibels is possible.

Using the Mathematica software, a three cycle average was attempted using the following trial sinusoidal exponential decaying function of time

$$v(t) = sin\left(\frac{2\pi\ 50\ t}{sec}\right) exp\left(-\frac{t}{100\ T}\right)$$

corresponding to a frequency of f=50 Hz and period T=1/50 s. A moving average is performed considering a 5 second sound recording sampled at a rate of 48000/s . Considering a data record of $5 \times 48000 = 240000$ points, we now compute the number of points needed in our moving average. Three cycles of a signal for f =50 Hz yields a time duration of 3T=(3/50) s, corresponding to 3T / (1/48000) s = 2880 points. The moving average was accomplished rounding up to 3000 points. Next the root-mean-squared average was performed using a moving mean squared average and the result was square rooted to complete the rms calculation on the digitized trial $v(t)$ data set. Results showed that the rms calculation was accurate so that one could perform the algorithm on the actual WAV files. The results are shown below:

3. EXPERIMENTAL RESULTS

3.1 Background and transient noise levels vs. time

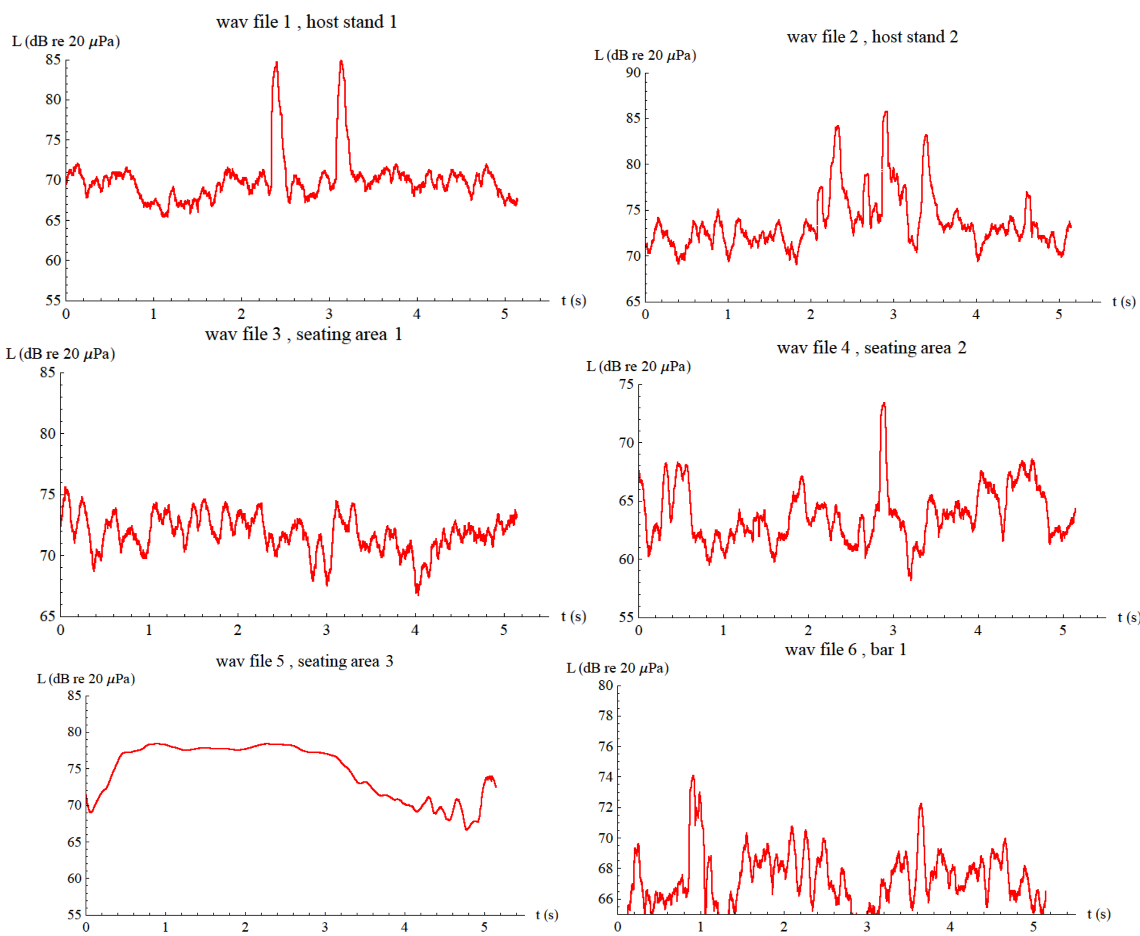

Figure 1. The WAV files 1 through 6 are now computationally transformed to show a calibrated sound pressure level using $L = 20\ Log_{10}(\frac{p_{rms}}{p_o})$ *where* $p_o = 20\ \mu\ Pa$ *.*

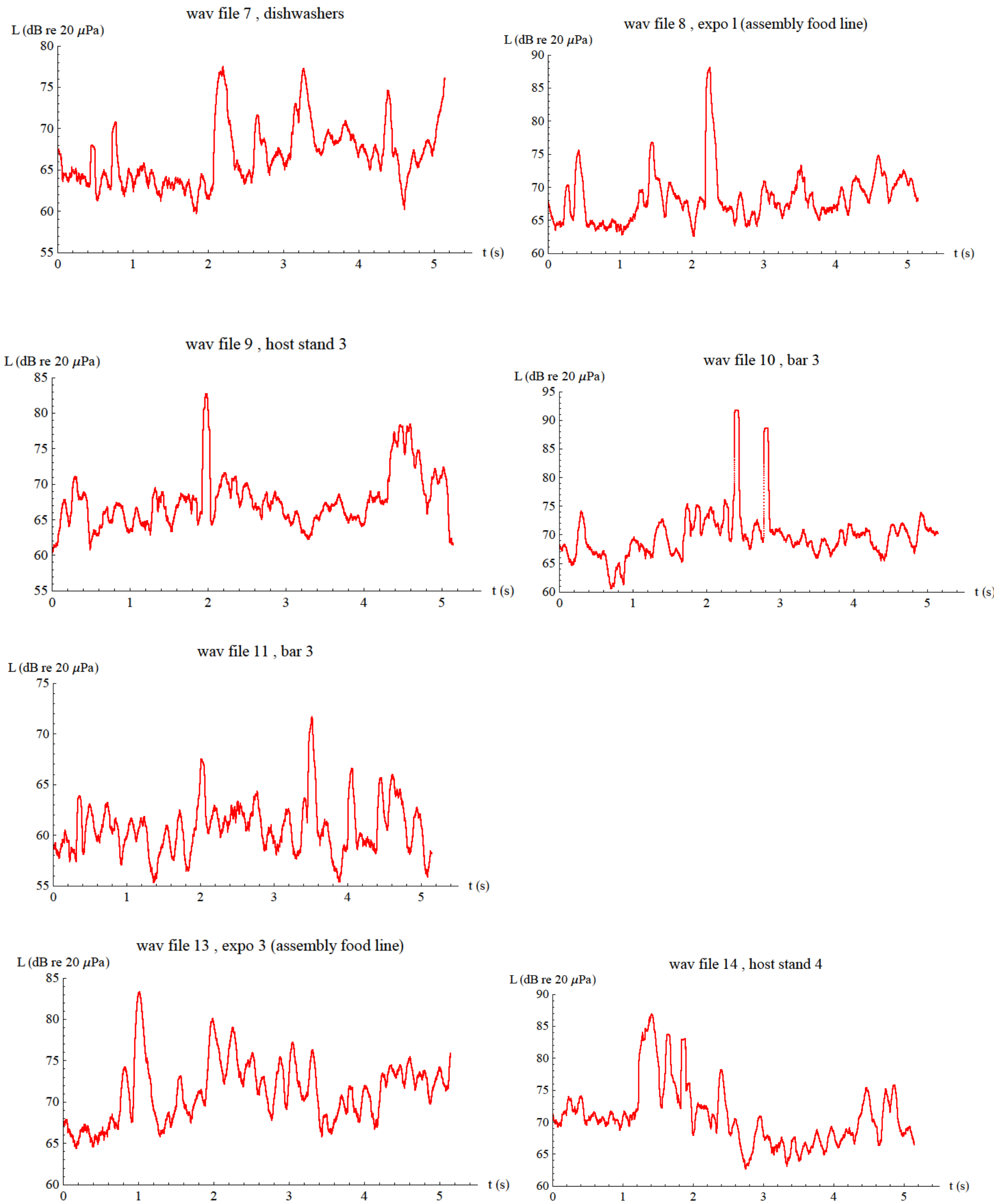

Figure 2. The WAV files 7- 11, and 13, 14 are now computationally transformed to show a calibrated sound pressure level using $L\ = 20\ Log_{10}(\frac{p_{rms}}{p_o})$ *where* $p_o = 20\ \mu\ Pa$ *.*

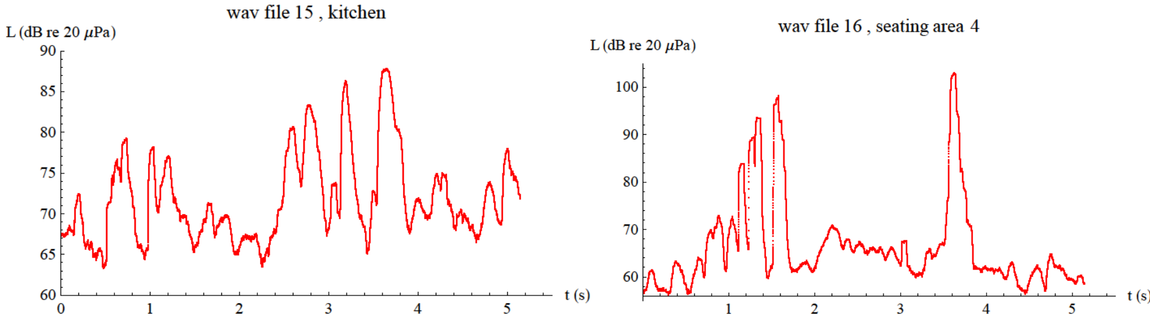

Figure 3. WAV files 15 and 16 exhibit some of the large transients in the overall data collection of the restaurant noise. Note that the range of the data logger is 130 dB re 20 *μ Pa.*

3.2 Spectrograms for some of the WAV files exhibit background and transient structure

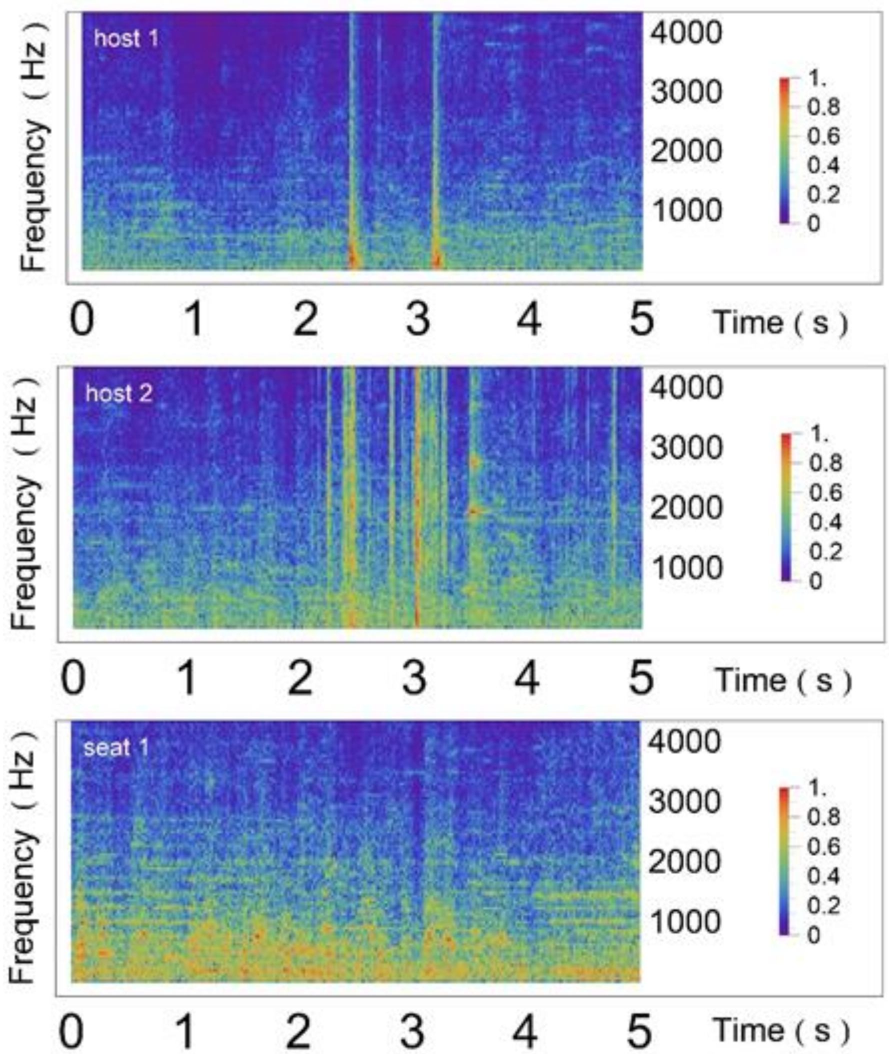

Figure 4. Spectrograms of restaurant noise for host 1, host 2, and for seat 1. Color chart is a relative rms pressure scale.

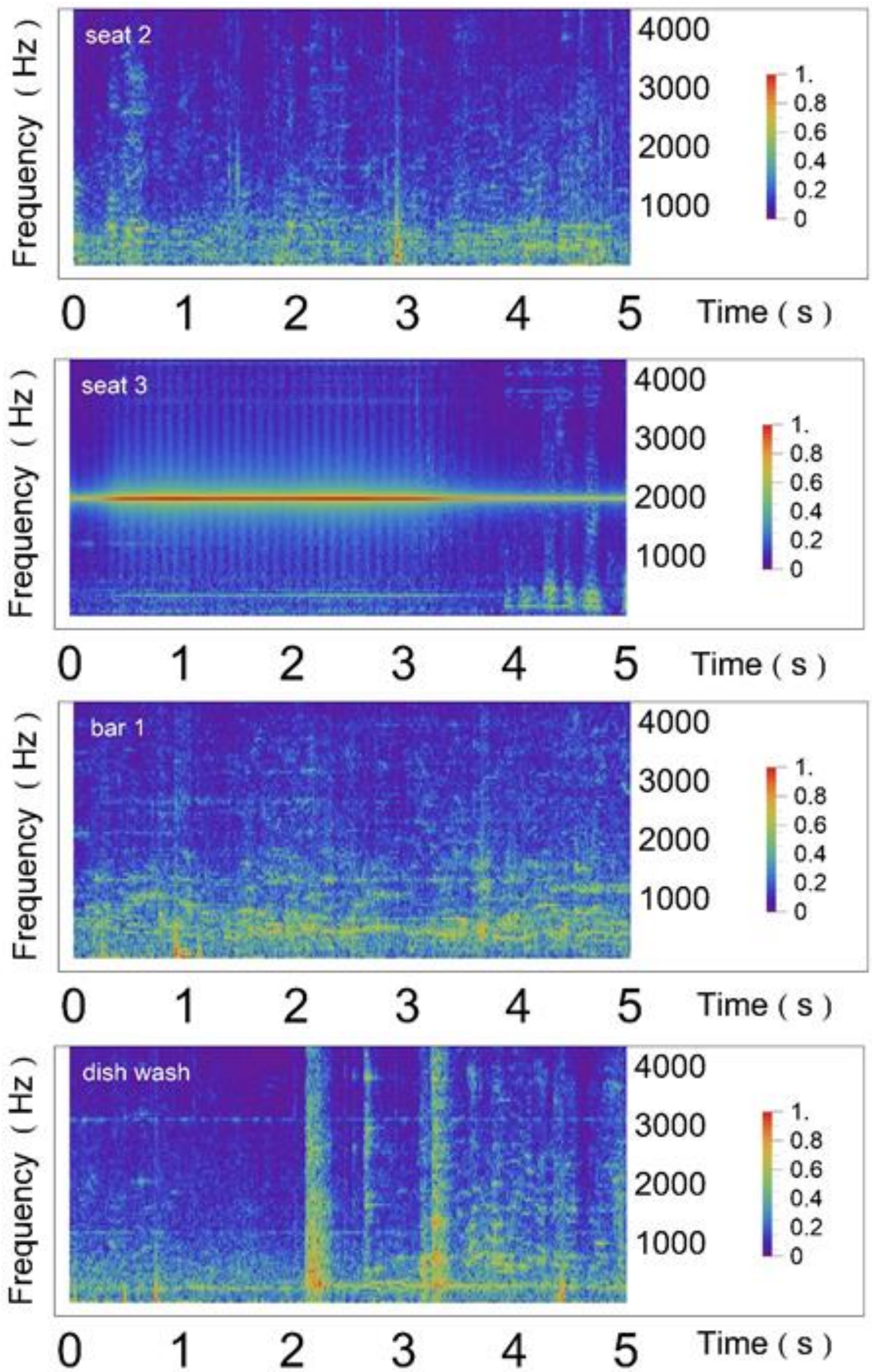

Figure 5. Spectrograms of restaurant noise for seat 2, seat 3, bar 1 and dish wash. Color chart is a relative rms pressure scale.

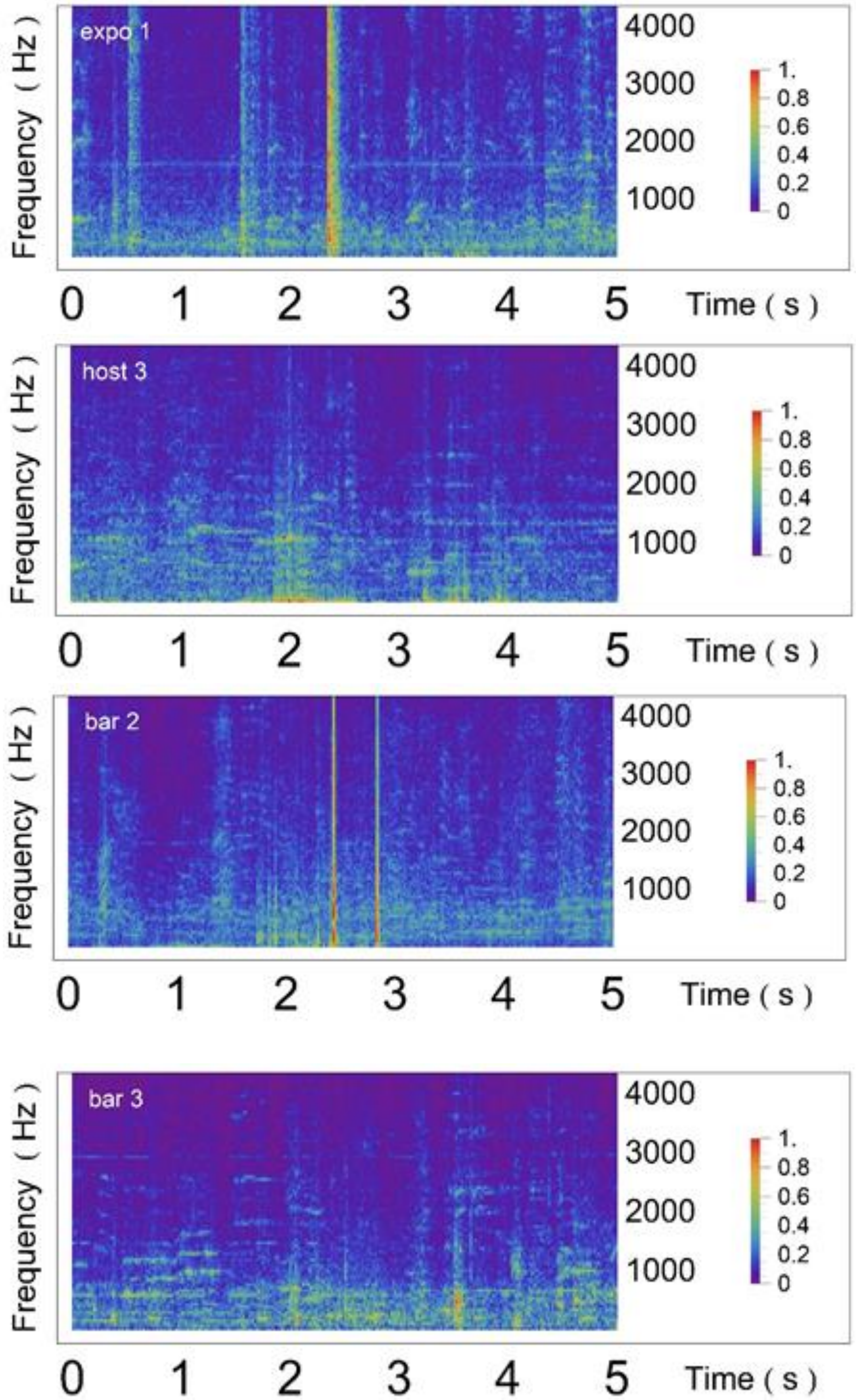

Figure 6. Spectrograms of restaurant noise. for expo 1, host, bar 2, and dish wash. Color chart is a relative rms pressure scale.

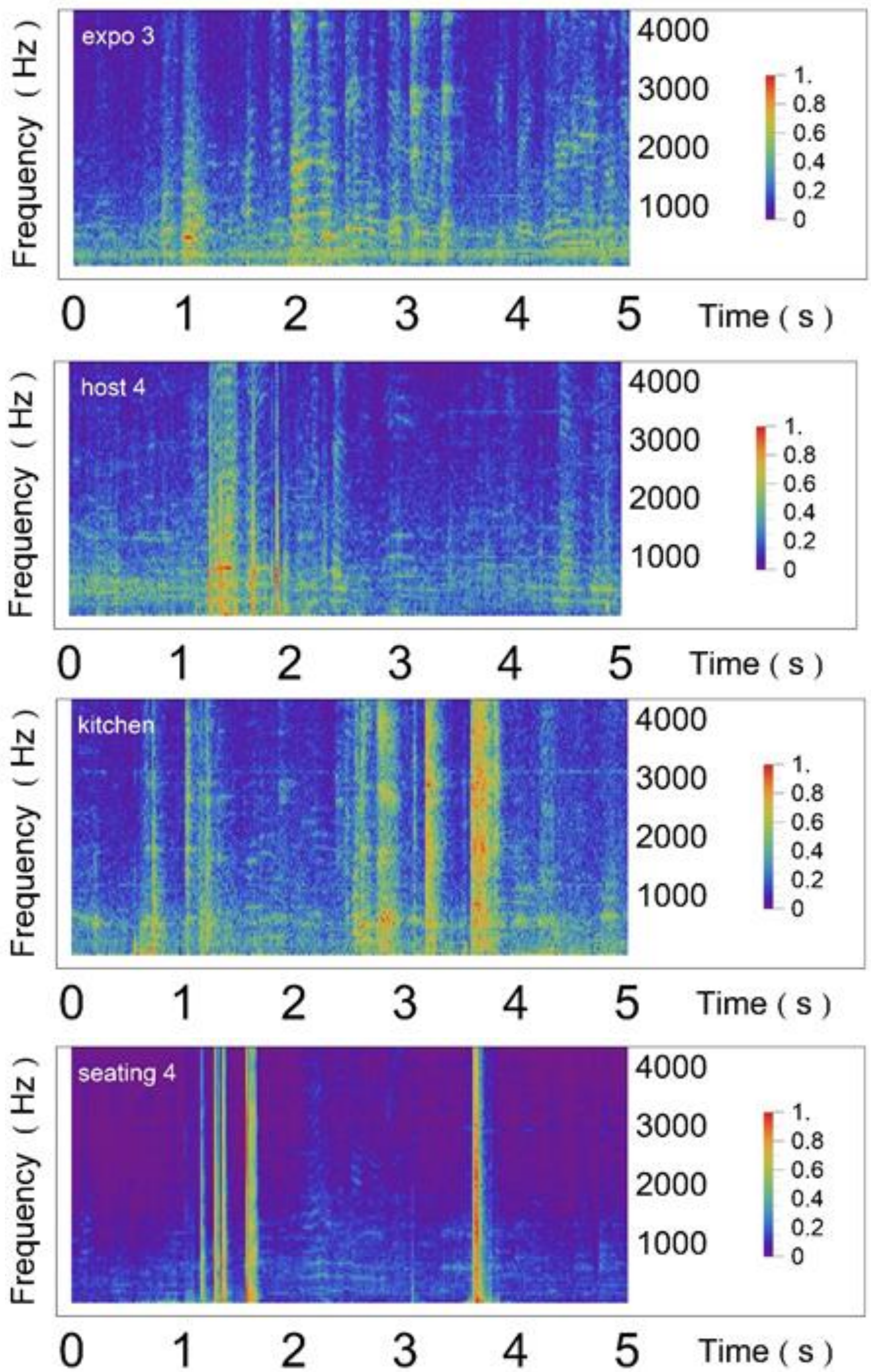

Figure 7. Spectrograms of restaurant noise for expo 3, host 4, kitchen and seat 4. Color chart is a relative rms pressure scale.

6. STATISTICAL RESULTS AND CONCLUSIONS

A statistical "logarithmic" average sound pressure level was computed for each separate WAV file. Each file has a record length of $m = 5$ s / (1 / 48000) s or $m = 240000$ samples. Using

$$I_i = I_{reference} \times 10^{L_i/10} \quad (1)$$

for each of the i = 1,2,3,…, m samples for L_i , the average intensity is $I_{ave} = \frac{1}{m}\sum_{i=1}^{m} I_i$. Then, the logarithmic average intensity level (in dB referenced to $I_{reference}$) is given by

$$L_{ave} = 10\ Log\left(\frac{1}{m}\sum_{i=1}^{m} I_i\right) = 10\ Log\left(\frac{1}{m}\sum_{i=1}^{m} 10^{L_i/10}\right) \quad (2)$$

where $L_i = 20\ Log\ (p_{i\ rms}/p_{reference})$ in dB re 20 μ Pa was computed for each separate WAV file shown in Figures 1,2 and 3. Each record contains m =5 s/(1/48000) s or m = 240000 samples. The statistical "logarithmic" average sound pressure level L_{ave} is computed for each separate WAV file using Equation 2. A list of the logarithmic average dB levels for the 15 WAV files are given below with the WAV file number listed first, followed by L_{ave} .

Table of the WAV file number with the logarithmic average level in dB re 20 μ Pa

{1,72.2},{2,75.4},{3,72.1},{4,64.6},{5,76.0},{6,67.8},{7,68.4},{8,72.1},{9,69.0},{{2,75.4},{3,72.1},{4,64.6},{5,76.0},{6,67.8},{7,68.4},{8,72.1},{9,69.0},{10,75.8},{11,61.8},{13,73.1},{14,75.1},{15,76.3},{16,85.8}

These results indicate that for this particular restaurant, the location of the sound recorder, along with the mixture of background and transient noise yield a rich complexity to categorizing the effects the transient behaviour might have on an individual patron. A complete study of the problem might include calibrated spectrograms displayed on a decibel scale and fast Fourier transform analysis of individual transients in the recorded WAV files. It is estimated that the calibration of the recorded WAV files is about +/- 2 dB.

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8. REFERENCES

The following selected references should be helpful to the reader for further background on the research.

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