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Relating design features, room characteristics, and occupancy to noise levels in restaurants

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ABSTRACT

High noise levels in restaurants present a growing concern that has received increasing media attention, as they can interfere with customers' abilities to communicate and with their comfort. This project seeks to understand how assorted factors contribute to higher sound levels in restaurants, including the restaurant's materials, room volume, layout, other noise sources, seating density, and, in particular, occupancy. Acoustic impulse response measurements have been taken under unoccupied conditions in three different casual sit-down restaurants to determine reverberation time and background noise. Other information on restaurant layout, seating density, and other noise sources has also been collected. Finally, both sound levels and occupancy in the restaurants have been logged over time while the restaurants were in business. Analyses are presented, aimed at understanding how room setup, acoustic conditions, and occupancy conditions influence resulting noise levels in restaurants.

Keywords: Restaurants, noise, occupancy

1. INTRODUCTION

Ambient levels in restaurants can be high and with architectural trends toward open spaces and hard, reflective surfaces, the problem is only getting worse. Conversation can be extremely difficult, especially for those with impaired hearing (1). A-weighted sound levels vary widely with values in the 40 decibel range all the way up to the 80 decibel range (2) (3). To understand better the typical restaurant sound levels and how they change during operating hours, a study was undertaken to measure the noise in three restaurants in an urban area of the midwestern United States. This study measures occupancy and sound level at a fine time interval scale and seeks to understand how the levels vary spatially in restaurants by measuring at several different locations.

2. METHODS

2.1 Venue descriptions

Three restaurant venues were measured for this study, hereinafter referred to as Venue A, Venue B, and Venue C. Reverberation time measurements were taken using an impulse method at multiple source-receiver locations using a Larson Davis 824 Type I Sound Level Meter. Background noise was also measured in each venue.

Venue A has a volume of 800 m^3, a seating capacity of 75, and contains booths, open seating, and a bar area. The floors and walls are hard and reflective and the tables and seating are either wood, metal, or leather in the case of the booths. The venue features an exposed ceiling and was measured to have a 1.3 s reverberation time (T_{20}) at 500 Hz.

Venue B refers to the main dining area of a restaurant with two dining spaces, joined by a double door. The room is 180 m^3, seats up to 50, and features hard, reflective wood surfaces for flooring, seating, and tables and gypsum walls and ceiling. The measured T_{20} was 1.4 s at 500 Hz.

Finally, Venue C is a 700 m^3 nearly square space with a 60-person seating capacity. It features a bar area, dining area with wooden tables, and a carpeted lounge area with couches for seating. The reverberation time was measured to be 1.3 s at 500 Hz.

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2.2 Occupancy logging

A FLIR ONE® thermal imaging camera was used in conjunction with a smartphone to log the occupancy during the measurement period. This thermal imaging method was utilized to ensure patron privacy at the restaurants. Time-lapse was used to take a snapshot of the room at 10 second intervals and occupancy was manually counted and recorded for each frame. Figure 1 shows a sample of what a frame would look like from each of these restaurants. Occupants are clearly distinguishable but not individually identifiable.

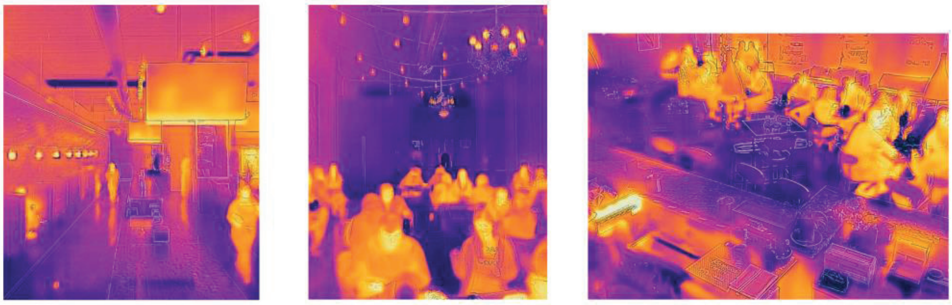

Figure 1 – Infrared time-lapse images to capture restaurant occupancy in Venues A, B, and C (from left to right)

2.3 Sound logging

Sound levels were collected at various locations in each restaurant using Casella dBadge2 Noise Dosimeters or BSWA Type II sound level meters. Between three and six meters were used for each room and data were collected at 10 s intervals for between one and two occupied hours per restaurant. The times were chosen to correspond to portions of the day with higher patron traffic. For each restaurant, the levels of each meter were logarithmically averaged with the others to determine the average level in the restaurant at any given moment.

2.4 Predictive model

Several models exist for predicting the sound level in a room based on knowledge of the room and its occupants. One prediction model proposed in literature specifically related to restaurant noise was published by Jens Rindel that predicted the noise level based on the equivalent absorption area and the number of simultaneously speaking persons (4). This model was applied to the data collected here—with assumptions made about average group size—in order to see how well the equation predicted the noise levels. Since data were available every 10 seconds, the predictive model was calculated for each measurement segment in order to see how the predicted value changed with occupancy and how well it matched the actual measured sound level at that given time.

3. RESULTS

3.1 Sound levels

The sound levels logged in several locations in each room captured much of the variation of the levels throughout the measurement period. The lowest average level observed was in venue A, which experienced a 67 dBA average level, only a few dB above the unoccupied background noise level (BNL) of 64 dBA. Venue B experienced the highest levels with an average of 77.8 dBA, nearly 18 dB higher than the BNL of 60 dBA. Finally, venue C saw average levels of 71.3 dBA, also significantly higher than the BNL of 58 dBA. Table 1 shows the overall sound levels and distributions throughout the rooms.

Table 1 – Sound Levels in Restaurant Sample

Venue	Average (dBA)	Range (dB)	Std. (dB)
A	67.0	9.7	1.7
B	77.8	17.3	2.7
C	71.3	13.2	2.6

3.2 Occupancy with Sound Level

One of the greatest contributors to noise in restaurants is conversation. Thus, as a restaurant gains a higher patron density, sound levels would be expected to rise in tandem. To explore how true this assumption holds numerically, the normalized, average sound level was plotted with the normalized occupancy of the restaurant over time. Figure 2 shows the two quantities as they rise and fall in each restaurant throughout the measurement period. From the figure, it is apparent that there the two levels trend together strongly. In order to quantify this, correlation coefficients were calculated for each of the restaurants. For Venue A, the correlation ($R = 0.08$) was not statistically significant. For venues B and C, the correlation coefficients were both statistically significant ($p < 0.01$) and had correlation coefficients of 0.43 and 0.62 respectively.

Notably, the average occupancy was not equivalent between restaurants. Venues A and C had between 0 and 12 people during the measurement period with Venue A typically having between 2 and 6 people and Venue C seeing a more equal distribution between 0 and 12. Venue B, however, saw as many as 23 people and held between 7 and 23 occupants at a time with typical occupancy above 15. This venue is the smallest of the three but experienced the greatest patron traffic.

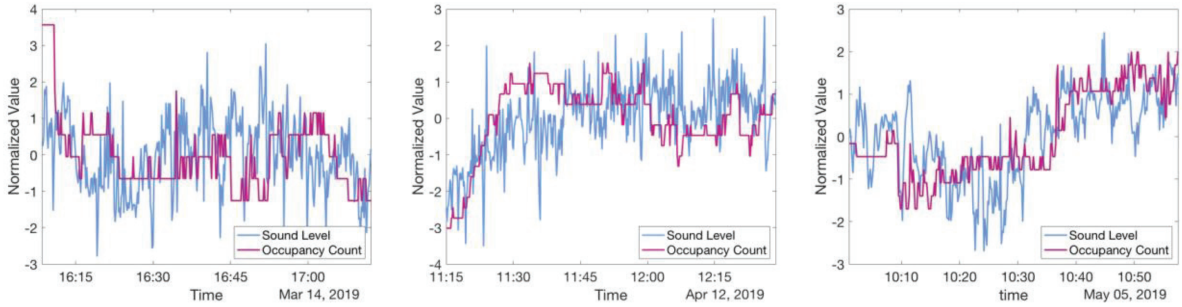

Figure 2 – Sound level and occupancy logged at 10 s intervals in Venues A, B, and C (from left to right)

3.3 Prediction

The prediction model unsurprisingly worked best for Venue B, which experienced higher occupancy and thus occupant density throughout the measurement period. It also experienced the greatest range of occupancy. The average deviation from the predictive model for venue B was 1.9 dB as opposed to a 5.6 dB average deviation for venue A and a 12.7 dB average deviation for Venue C. Likely, the model was unable to accommodate the low occupant density for Venues A and C and thus showed more deviation. A vertical translation of the prediction curve increased the match significantly but the shift had no quantifiably concrete basis. Perhaps a background noise level correction for low occupancy or occupant density would assist in model versatility. More work to fully explore this and other models with all ranges of occupant density could help determine the validity and flexibility of the prediction techniques.

4. CONCLUSIONS

4.1 Final remarks

Overall, occupancy and occupant density are crucial factors relating to the noise levels in restaurants. There is high variability in restaurant noise levels and within only a few hours, restaurants measured saw wide variation in the average level. For the three restaurants measured, sound levels fluctuated significantly during a 1-2 hour measurement period with the smallest range of sound levels experienced being 9.7 dB and the largest range being 17.3 dB. Correlations between sound level and occupancy were significant for two of the three restaurants with correlation coefficients of 0.43 and 0.62.

4.2 Future directions

There is still work to be done in determining the exact relationships between occupancy and sound level. Particularly, background noise level and perhaps octave band levels from non-speech sources should be considered more fully in predictive models. Future work can explore other facets of the sound characteristics within the restaurant such as looking at octave band content and observing low frequency noise with HVAC conditions or speech frequency noise with occupancy. Additionally, subjective surveys could be used in conjunction with the sound measurements to fully characterize the restaurant soundscape. Larger samples of restaurants can enhance understanding of this topic by exploring greater variation in venue size or type. Finally, accurate occupancy count and group size determination is still a significant challenge and machine learning could be explored to address this issue.

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