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RESTAURANT ACOUSTICS: A SOUNDSCAPE EXPLORATION AND CASE STUDIES

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ABSTRACT

The soundscape of restaurants has been a hot topic as the idea of controlling noise and the physical environment becomes more prevalent.

A soundscape method has been used to study over 40 restaurants. The general strategy is outlined, which includes identifying the acoustic communities and acoustic taxonomies associated with dining with the sound levels and frequency content of the sounds in the spaces, The acoustic itineraries of participants are observed and how they interact with the space. Acoustical measurements made in the spaces simulate actual source and receiver locations. Appropriate architectural interventions are developed for the spaces. Case studies of specific restaurants are presented that have varying degrees of acoustic treatment and still have acoustic difficulties. The idea of "Near STI" and "Far STI" is explored and how it relates to the desirable and undesirable communication paths that exist, not only in restaurants but everywhere communication exists. A case study of acoustic design from the planning stages is presented, as well as challenges in implementation acoustical strategies on the construction site are presented as an example of how one might proactively design and construct a restaurant space to maintain compatibility in an urban environment.

Keywords: *acoustics, restaurants, soundscape, noise control*

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1. INTRODUCTION

Restaurants are an essential part of many cultures, allowing friends and family to gather together, eat nourishing food, celebrate major life events and milestones and provide a backdrop for business, life, love and togetherness.

At the heart of the experience is the communication that takes place, between staff and patrons to ensure the correct order is taken, between families and friends, whether a casual meal, a birthday or religious celebration, or a business meeting taking place.

When the restaurant space itself is appropriately designed, these communication interactions can take place effortlessly and effectively. However, many restaurants suffer from acoustic defects such as excessive loudness, excessive reverberation, harsh reflections that result in poor intelligibility and comprehension for staff and patrons. Recent research from Steffens [1] has looked at a 15 min time interval and the reverberation time while the restaurant is occupied. A questionnaire was given to patrons in 12 restaurants. It was found that loudness measurements and more reverberant conditions impact the perceived pleasantness and eventfulness of the restaurant.

Lindborg [2] performed a survey of 112 restaurants and looked at interior finishes, sound levels, loudness, fluctuation and sharpness calculated from audio recordings, percent occupancy and the cost of the food on the menu. In general, it was found that less expensive restaurants had higher noise levels, and more expensive restaurants were less loud. Astolfi and Filippi [3] studied restaurant acoustics and used the Speech Intelligibility Index (SII) as a measure of speech privacy and intelligibility in 4 pizzerias. They used values of 0.45 or greater as being a target valued for fair intelligibly at one's own table, and lower than 0.20 to nearby tables for good privacy.

The soundscape method outlined in Siebein's presentations [4-6] attempts to understand the complex sound field of restaurants, through an understanding of its various user groups, how they inhabit the place through space and time, identifying the specific source-path-receivers, and looking at speech intelligibility in the near and far fields of the space.

2. ACOUSTIC COMMUNITIES

The acoustic communities or various user groups inhabit restaurants for different purposes. In general, it was found that the acoustic communities tended to be the Patrons, the Wait Staff, and Food Preparers. The Patrons could be families, friends, colleagues, business acquaintances, etc. that are in the restaurant to share a meal, converse, and recreate with their peers. The Waitstaff include the Hosts, Waiters, Busboys and other team members who interact with the patrons or help clean the restaurant. The Food Preparers are the various cooks, chefs, sous-chefs, sommelier and other staff involved with the food and drink preparation.

3. ACOUSTIC ITINERARIES

The Acoustic Itineraries are the typical paths that the acoustic community may inhabit throughout the restaurant. Each acoustic community will inhabit parts of the restaurant. The Patron may enter the front entrance, check in at the host stand, wait in the waiting area, proceed to their table, where they sit for a while, and then proceed to the restroom, and then return to their table where they finish the remainder of their meal, and then leave out the side entrance after they finish their meal. An example of some itineraries of the acoustic communities are shown in Figure 1.

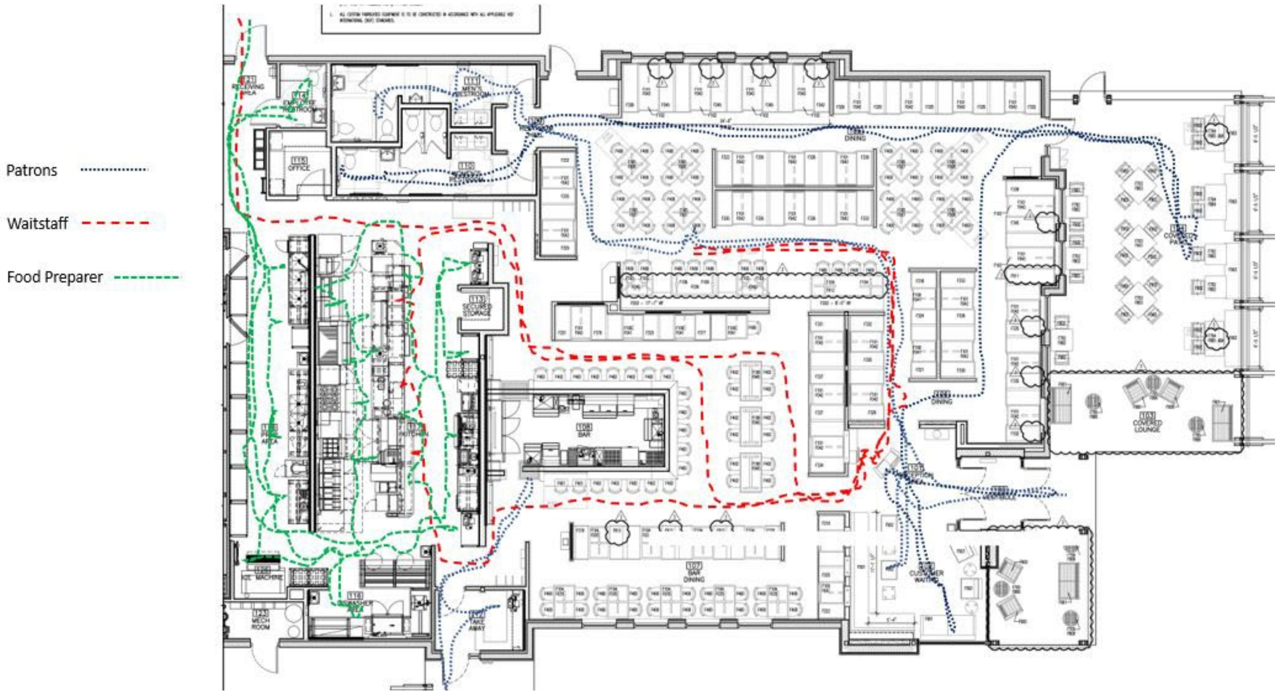

Figure 1. Example of 3 Acoustic itineraries of a group of Patrons, Waitstaff and a Food Preparer

4. ACOUSTIC TAXONOMY OF RESTAURANT

The sounds heard within a restaurant can be grouped into categories based on the 3 main Acoustic Communities, as well as the type of sound produced, whether it be a "human introduced" sound or a "building service" sound. Each sound source has typical sound levels and frequency content associated with them, that fluctuate over time. An example of the acoustic taxonomy of sound sources in a restaurant is shown in Figure 2.

5. ACOUSTIC ROOMS AND NICHES IN RESTAURANTS

An *Acoustic Room* is the *space made by sound* as it *propagates from a source to a listener to its horizon-* the point at which it decays into the background. Ideally the acoustic room in a restaurant is *the space surrounding one's table* and *the horizon is reached before the sound reaches the next table. Acoustic rooms may be purposefully designed or may be a by-product of the floor plan and layout of a restaurant.*

The idea of acoustic rooms is related to the idea of an acoustic niche - in restaurants a design strategy for acoustic intimacy and privacy, semi or fully enclosed booths, full height walls and partial walls with customized music in each booth provide sound buffering between individual booths. An acoustic niche results when one carves out special places within a larger space where communication can occur and where special acoustical attributes can be achieved. This is achieved by creating an acoustic room within a larger architectural room where sound propagation is controlled by reducing, buffering or mitigating sounds propagating within the room and sounds propagating into the room from other spaces.

6. COMMUNICATION PATHS IN RESTAURANT

In restaurants, there are desired communication paths and undesired communication paths. Desirable communication paths typically involved the "Near", where talking to friends or family across the table, or

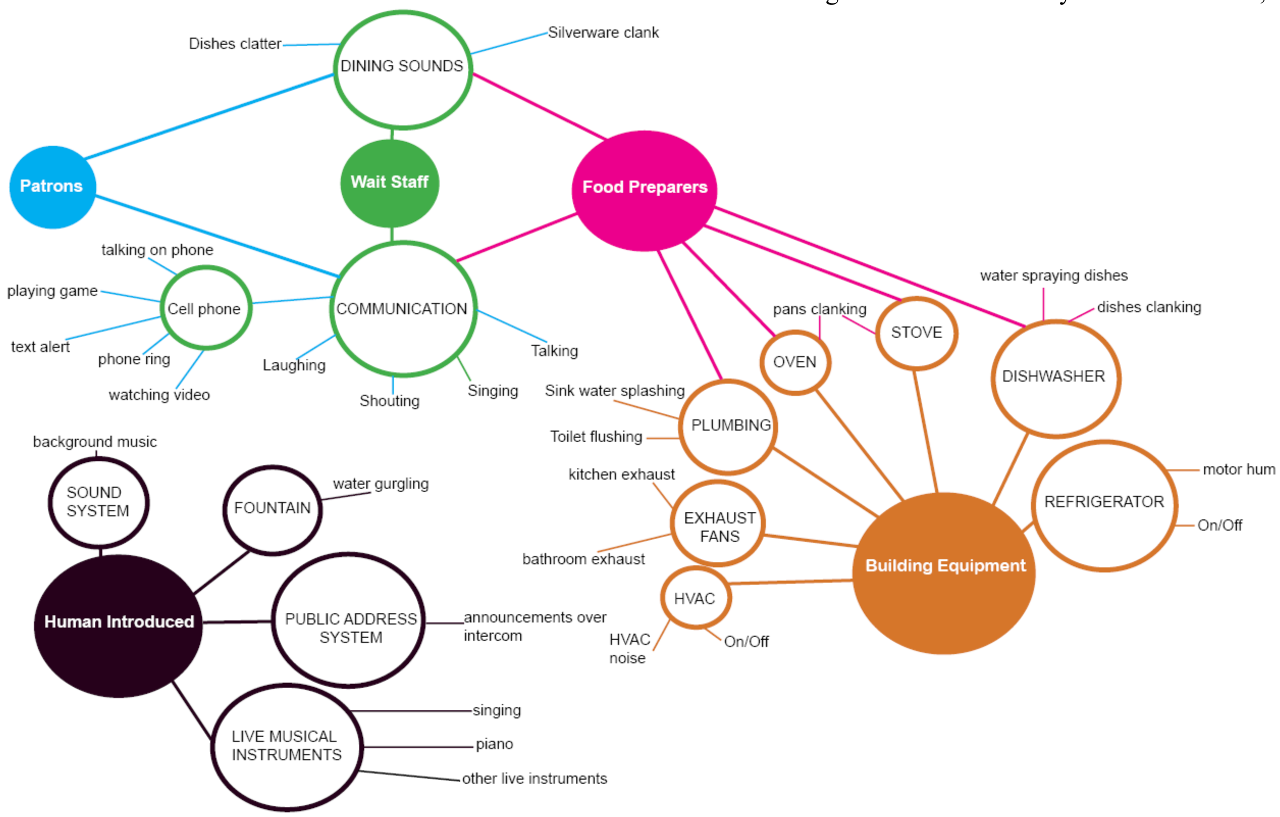

Figure 2. Acoustic Taxonomy of sounds heard in a typical restaurant

speaking to the waiter are desirable and necessary paths that should be clear and intelligible to communicate effectively. Sound paths from the other tables of people talking or waiters at other tables are typically undesired in the "Far" paths. Sounds from diners, wait staff, restaurant sounds, sounds of the kitchen, HVAC equipment, background music, live music and others result in the soundscape of a restaurant. If restaurants are not properly treated, they can result in problematic sound fields marred with acoustic defects.

7. ACOUSTIC METRICS IN RESTAURANTS

Several acoustic metrics are helpful in documenting the sound field of a restaurant.

7.1 Alpha bar

The alpha bar or average sound absorption coefficient is a metric that is used to describe how much sound is absorbed by the finish materials in the room. The values for alpha bar vary from 0 to 1, with 0 being an entirely reflective room and 1 being an entirely absorbent room. The amount of absorbent material in the room increases the value of the average absorption coefficient.

A pilot study had been conducted on 21 rooms that was published in Acoustics Today [4]. Additional facilities were added to this study including cafeteria, retirement center dining facilities and country club dining establishments. Thirty-five restaurants and dining facilities that suffered acoustic defects sufficient to contact our acoustic consulting firm for assistance in remediating were analyzed. Of the 35 restaurants/cafeteria/dining facilities and country clubs that were analyzed, the alpha bar for the base condition varied from 0.05 to 0.23. Rooms in need of acoustical improvements have an average alpha bar of 0.16. Four iterations of treatment were identified that resulted in ranges of alpha bar for restaurants. The 4 categories of treatment include: less than 50% acoustically treated walls or ceiling, more than 50% of the ceiling or walls, 80% of the ceiling and up to 30% of the walls, and 80% of the ceiling and 30% or more of the walls.
Figure 3 shows a graph of the 4 iterations, as well as the untreated condition.

A linear relation between alpha bar and amounts of sound absorbent materials in rooms was found with an $r^2 = 0.82$.

7.2 Speech Transmission Index

The Speech Transmission Index (STI) can be used to determine approximately how many words are heard correctly in a room. Of the rooms that have been analyzed, 13 had data for alpha bar and STI. The STI in untreated, unoccupied rooms varied from 0.39 to 0.75. Even rooms

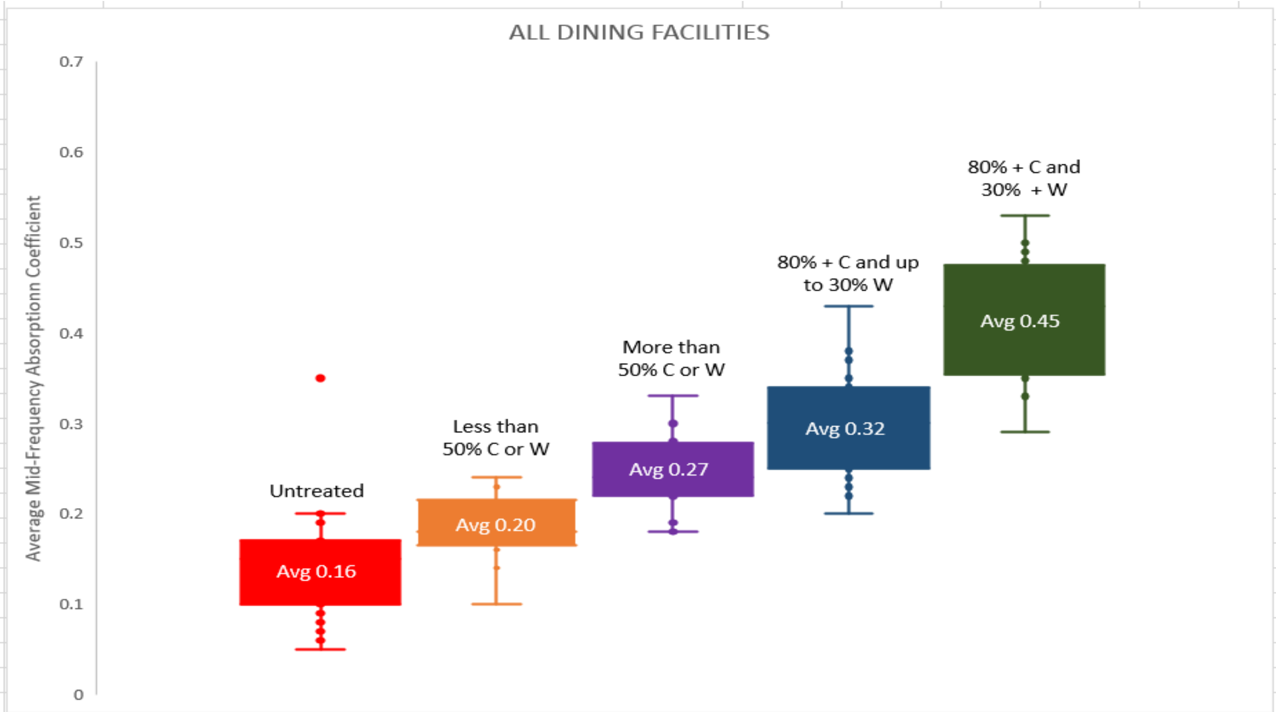

Figure 3. Alpha bar values for untreated conditions and 4 levels of acoustic intervention. The average alpha bar is shown in the middle, the range of values shown under each data plot. C is "ceiling", W is wall."

that had fairly high STI's still warranted acoustic intervention, as there are high STI across the table AND high STI across the room. People hear well across the table from each other ("Near") BUT they also hear well across the room ("Far").

To simulate what might happen to the STI when the restaurants were fully occupied, the STI calculations were performed with occupied restaurant noise spectrum. The background level used in the STI calculation was 69 dBA, this sound level and sound spectra are presented in Michael Erman's book Architectural Acoustics [7] as typical sound levels in restaurants. This is in the middle of sound level data presented by Steffens as between 64-76 dBA as 15 min LAeq's. The STI's in the same restaurant decreased to 0.21 to 0.31 once the background noise was included in the analysis.

As more people enter the restaurant and talk to each other the sounds propagating across the room to other tables in an untreated restaurant increase creating a "din" of background noise that decreases the Far STI's from across the room AND also decreases the Near STI's across the table.

8 CASE STUDY OF NEAR VS FAR METRICS

A case study for an existing restaurant that suffered from acoustic issues was studied with respect to how the acoustic metrics measured in the "Near" and "Far" differed.
Early Decay Time, Reverberation Time, Definition and STI were analyzed.
Source measurements were made with 2 source locations and 4 Far receiver locations, and 5 Near receiver locations were measured.

8.1 Early Decay Time: Near vs Far

It was found that the average Early Decay Times (EDT) for the Near tended to be 0.1 to 0.8 seconds lower than the EDT for the Far condition, depending on the frequency band. The octave bands at 250 Hz and from 1,000 Hz to 8,000 Hz had the largest differences, while the lower frequencies tended to be more similar. The data tended to show that the Near had lower EDT values, while the Far had higher EDT values.

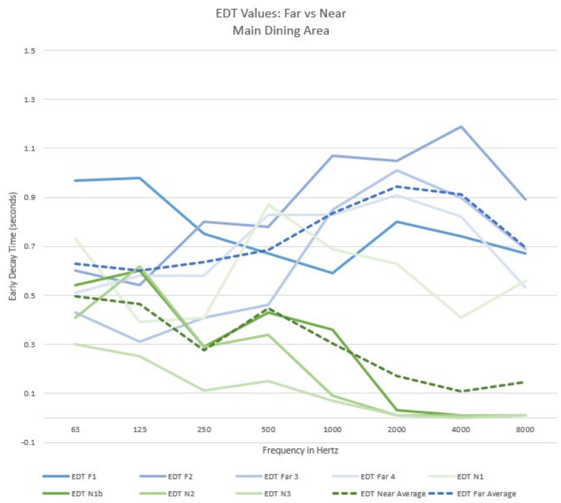

Figure 4. Early Decay Time values plotted for Near vs Far Conditions

8.2 T30 Reverberation Time: Near vs Far

The T30 Reverberation Times for the Near and Far locations tended to show similar results, with the Far having slightly higher values and the Near having slightly lower values. The values had a might tighter spread, with the data varying by approximately 0.03-0.05 seconds across the octave bands.

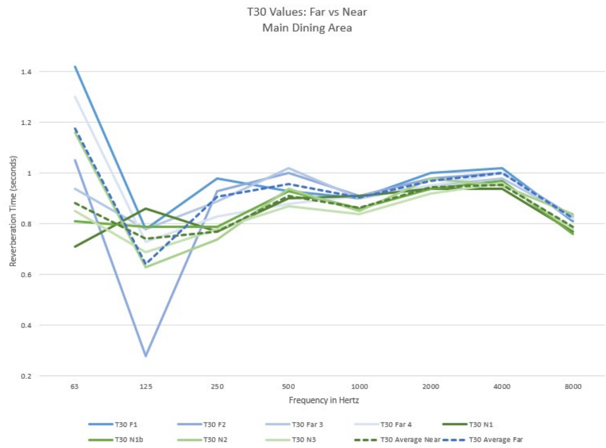

Figure 5. T30 Reverberation Time values plotted for Near vs Far Conditions

8.3 Definition: Near vs Far

Definition was also analyzed in the Near and Far conditions. Similar to the Early Decay Time, the values for the Near tended to be 10-24 percent higher than the Far condition. The average values for Near vs Far varied from 10 to over 20% across the octave bands. Average values for Near vs Far are shown in the dotted lines in Figure 6.

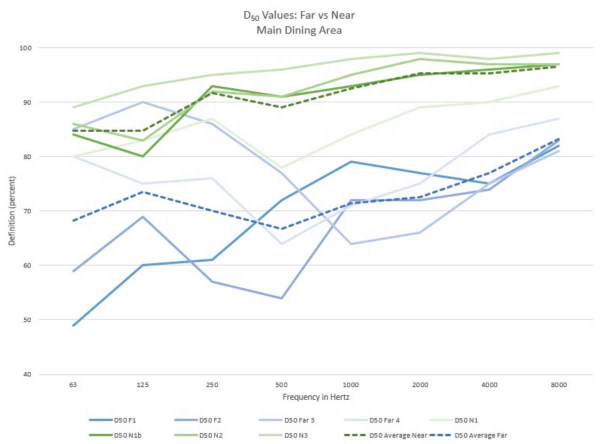

Figure 6 . Definition values plotted for Nar vs Far Conditions

8.4 STI: Near vs Far and Unoccupied vs Occupied

Based on the previous research completed on resturant acoustics and in analyzing other spaces, this special study was conducted using receiver locations for the Near located at the same table as the source, to simulate the sound field when people are speaking to one another at a dining table. Far receiver locations were selected at locations of other tables across the room.

The average "Far" STI was 0.71, and the average "Near" being 0.89 with no background noise. These values are high, suggesting that in this room the Near and Far STI are high when many people are not in the room. This room has an octagnoal dome and refelctive surfaces.

A spectrum for background noise of an occupied resturant [7] was applied to the same source and receiver consitions, the STI values fell substnatially. The average STI for the "Far" condition dtopped to 0.29, and the average STI for the "Near" condition dropped to 0.33.

This suggests that in this room, when few people occupy the space, it is likely easier to hear and understand the voices coming from one's own table. One will also likely be able to clearly hear voices from other tables, which is not desirable. When many diners are present, the STI values drop for both the Near and Far, suggesting that while one might not be able to undestsnad what is being said at tables farther away, they will also have difficulty in understanding what is being said at the same table they are sitting at, making effective communication in this room very

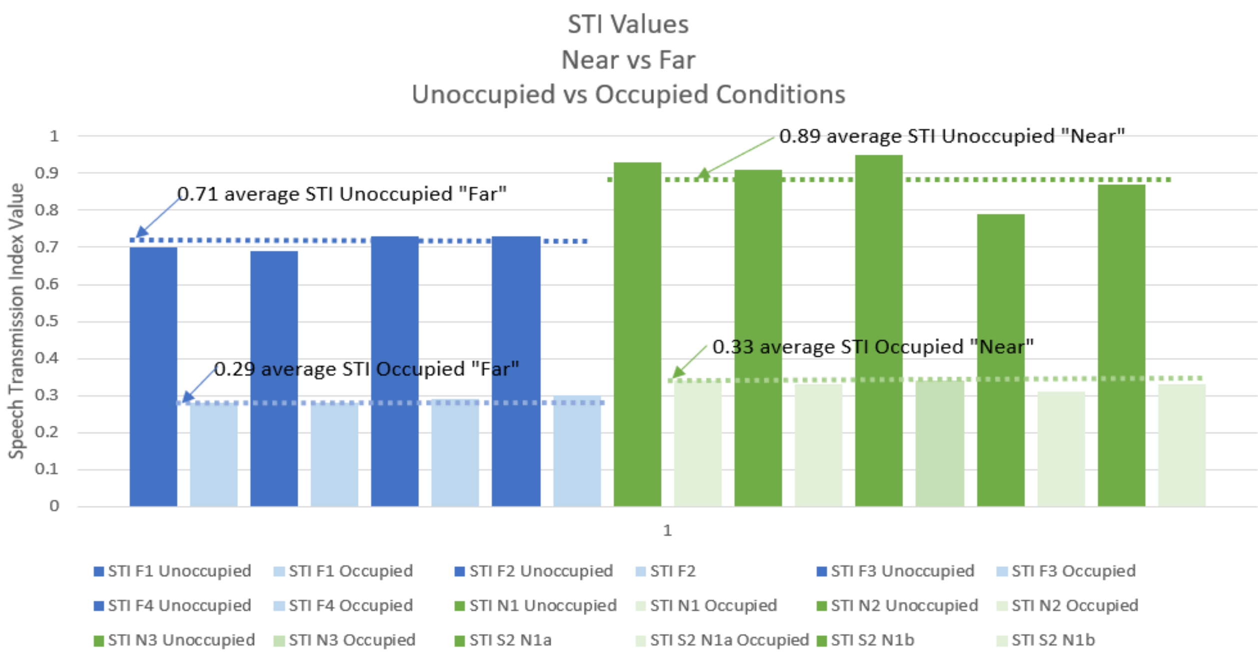

Figure 7. STI values for "Near" and "Far" conditions, calculated for Unoccupied and Occupied conditions. The average Unoccupied conditions for Near vs Far have a difference of 0.18, while the average Occupied condition have a difference of just 0.04.

challenging.

8. CONCLUSIONS

The complex soundscape of restaurants are crucial in understanding to begin to assist in providing comfortable environments to dine, discuss, and celebrate. The acoustic design and interventions should be strategically integrated. If acoustic material is located in areas that are not identified as critical surfaces, acoustic defects may still be present and necessitate acoustic design interventions.
Enough surface area of absorbent material is typically necessary to reduce Reverberation Time, increase alpha bar, and increase STI, even when occupied.
Multiple uses of the space may require more shaping/diffusion/AV design. If a restaurant is used as a night club, bar or venue where amplified music is played at loud levels, increased sound absorbing material may be needed to tone down the excessive loudness
The design of sonic niches where appropriate can help increase acoustic privacy and intimacy in a restaurant.
High STI's in less occupied rooms become low STI's when many diners are present.
All of these items lead *to creating restorative soundscapes* in dining facilities *so that the dining spaces truly become the backdrop for communication and living that they aspire to be.*

9. ACKNOWLEDGMENTS

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