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Achieving acoustical comfort in restaurants

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The achievement of a proper acoustical ambiance for restaurants has long been described as a problem of controlling noise to allow for speech intelligibility among patrons at the same table. This simplification of the acoustical design problem for restaurants does not entirely result in achieving either a sensation of acoustical comfort or a preferred condition for social activity sought by architects. In order to more fully study the subjective impression of acoustical comfort a large data base from 11 restaurants with 75 patron surveys for each (825 total) was assembled for analysis. The results indicate that a specific narrow range of reverberation time can produce acoustical comfort for restaurant patrons of all ages. Other physical and acoustical conditions of the dining space are shown to have little to no consistent effect on the registration of comfort. The results also indicate that different subjective components of acoustical comfort – quietude, communication, privacy – vary significantly by age group with specific consequences for the acoustical design of restaurants for different clienteles.

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Introduction

This study utilizes a compilation of data from students' final projects for a spring 2014 seminar conducted in the Department of Architecture, University at Buffalo. The seminar was entitled "Aural Architecture" from a book by Brian Blesser and Linda-Ruth Salter and thus investigated what they defined as "the properties of a space that can be experienced by listening."[1]

In preparation for the final project students read and presented reports on recently-published papers covering the study of acoustics in restaurants. Papers included a study by Astolfi and Fillippi that found that good speech intelligibility by people at their own tables as well as speech privacy from people at adjacent tables could be achieved through control of reverberation, absorption and seating density.[2] Nahid and Hodgson reported from their study that optimal conditions for verbal-communication quality could be achieved with a reduction in spatial volume, the use of physical barriers and absorptive treatments.[3]

Of particular interest was a paper by Jens Holger Rindel which seeks to define acoustical quality in restaurants.[4] Rindel developed a formula from his study:

$$N_{max} = V/20\ T.$$

This relationship defines the recommended maximum quantity of persons (N_{max}) for sufficient quality of verbal communication in terms of the cubic volume V (m^3) and the reverberation time T (seconds). When the Sabine equation for reverberation time, $T = .16\ V/a$, is substituted into Rindel's formula we found that it reduces to:

$$N_{max} = 0.3\ a$$

Rindel's paper continued to define acoustical quality according to the ratio of actual patrons (C, for capacity) to the recommended maximum number of persons for sufficient quality of verbal communication (C/N_{max}). Since a ratio less than 1 represents good quality, this ratio was inverted by the class so that a higher value indicates higher quality (Q) such that:

$$Q = N_{max} /C = 0.3\ a/C$$

Rindel's measure of acoustical quality is directly proportional to the total amount of sound absorption divided by the total number of occupants. This value (a/C) is identified as "a_p" (absorption per person) for inclusion in the analysis with other more common acoustical and physical measures of the subject spaces.

The Restaurants

The students each selected three restaurants from a list prepared by the author. They contacted the owners to describe the project and to request permission to conduct the study including distribution of a patron survey. As they encountered some resistance to the survey, some needed more than three choices to find a willing participant.

Eventually, 17 restaurants were identified by the class (one for each student). Studies were completed and final reports submitted. For this compilation six of the restaurant reports produced by the students were eliminated for a variety of reasons of unsuitability of the locations for study. Restaurant No. 12 had four separate dining spaces, each with different acoustical conditions; the returned surveys were undifferentiated as to their source space. Restaurants Nos. 13 and 14 – a Japanese noodle bar and a Chinese fast-food venue – had cooking areas within the dining space with very loud (>82 dBC) exhaust fans in range hoods. Restaurant No. 15 had large windows fronting a busy street, with the glass about 5 meters from the curb, resulting in a loud, intermittent background noise. Restaurants Nos. 16 and 17 – a large dining hall in a dormitory and a student center dining lounge – had surveys returned from only young diners, almost entirely under 25 years of age. The remaining 11 restaurants, quite fortunately, represent a large range of sizes, acoustical conditions, and ages of diners, and no extraneous noise.

The Survey

A patron survey was prepared by the class for distribution by waiters at each of the study locations (Fig. 1). Managers were directed to give willing patrons the survey only during times when the restaurant was busy, notably 75% full or more. (We trust this directive was followed but do not have verification in all cases).

The survey includes only six questions. One identifies the patron's age grouping and a second the frequency of dining at the restaurant, intended as an indication of comfort. The second question does not necessarily indicate *acoustic* comfort as the class would decide, so only the age group question was included in data analysis. The other four questions ranked subjective impressions on a scale from 1 to 4 for Quietude, Communication, Privacy, and Comfort. These four questions were presented so that a higher response value indicates that the restaurant appears to be quiet (Quietude); that it is easy to have a conversation with other diners at the table (Communication, assumed to be related to sound level, not personality or the content of the conversation); that the conversations from adjacent tables are not disturbing (Privacy); and that, overall, the restaurant's acoustic environment subjectively appears "comfortable"

Restaurant Code: Survey Number

Circle the number of your answer

What age group below includes you?

1. 25 and under
2. 26-45
3. 46-65
4. 66 and over

About how often do you dine at this restaurant?

1. Less than once a year
2. About once a year
3. About three times a year
4. About six times a year or more

For the following questions, scale your answer from 1 to 4; circle the number

How noisy does this restaurant sound to you?

………1……..…2……..…3…..…...4….
Noisy Quiet

How difficult is it to converse with other diners at your table?

………1……..…2……..…3…..…...4….
Difficult Easy

How disturbing are sounds of conversations from other tables?

………1……..…2……..…3………..4….
Disturbing Not Disturbing

What is your comfort level with the way this restaurant sounds?

………1……..…2……..…3…..…...4………
Uncomfortable Comfortable

(tear here)

This survey is entirely anonymous and is being conducted for a class by students from the University at Buffalo Department of Architecture. If for any reason you do not want your answers included, contact xxx at xxx-xxxx, and indicate the survey code below:

Figure 1: Patron Survey

for whatever aural conditions the patron would associate with the term (Comfort).

The survey data would have benefited from a question regarding Preference: “Do you like the way this restaurant sounds?” Also, some measure of Capacity during the survey might improve verification of the results: “Right now, about how full is this restaurant?”

The Data

The students read one of nine different papers selected by the author from acoustic journals and presented them (in pairs) to the entire seminar. These papers were discussed by the class and information from each was used to identify several acoustical and physical characteristics of spaces whose measures might define the acoustical quality of restaurants. These characteristics were combined with the survey results to create the data set (Fig. 2).

		Restaurant No.										
		1	2	3	4	5	6	7	8	9	10	11
Acoustic Measures	T: Reverberation Time (sec)	0.367	0.458	0.517	0.530	0.711	0.748	0.769	0.825	1.188	1.467	1.518
	B: Background Noise (dBC)	72	78	72	72	82	78	80	73	84	70	81
Basic Measures	L: Length (m)	23.7	11.9	16.7	26.6	17.1	16.3	9.2	10.7	16.8	18.6	13.9
	W: Width (m)	9.6	9.7	8.4	11.2	9.7	5.5	7.3	10.0	15.2	11.6	13.4
	H: Height (m)	3.0	3.1	3.3	2.4	4.6	4.0	3.0	3.6	4.1	6.1	4.6
	C: Capacity (persons)	152	96	70	100	133	60	60	50	210	100	96
Calculated Measures	F: Floor Area (m^2)	228	115	140	298	166	90	67	107	255	216	186
	V: Volume (m^3)	684	356	462	715	764	360	201	385	1,045	1,316	856
	D: Density^{-1} (m^2/person)	1.50	1.20	2.00	2.98	1.25	1.50	1.12	2.14	1.21	2.16	1.94
	P: Proportions (Cavity Ratio)	2.20	2.90	2.95	1.52	3.72	4.86	3.69	3.48	2.57	4.27	3.37
	R: Ratio (Aspect Ratio)	2.47	1.23	1.99	2.38	1.76	2.96	1.26	1.07	1.11	1.60	1.04
	a_T: Absorption, Total (m^2)	298	124	143	216	172	77	42	75	141	144	90
	a_P: Absorption per Person	1.96	1.29	2.04	2.16	1.29	1.28	0.70	1.50	0.67	1.44	0.94
Average Demographics	Age Group	2.480	2.507	2.940	1.933	1.827	2.534	2.160	2.400	1.851	1.630	2.200
	Visits	2.452	3.213	2.490	2.547	2.267	2.702	1.880	2.980	2.014	3.560	2.520
Average Subjective Impressions	Quietude	2.667	2.853	2.930	2.960	2.687	2.982	2.610	2.820	1.486	2.300	2.240
	Communication	2.947	3.213	3.440	3.187	3.280	3.517	2.626	3.300	2.270	2.960	2.440
	Privacy	3.013	3.473	3.440	3.107	3.267	3.466	2.800	3.340	2.757	2.760	2.400
	Comfort	3.240	3.320	3.440	3.373	3.160	3.534	2.933	3.370	2.919	2.800	2.360
Age Group 1: 25 and under	Quietude	2.833	2.938	2.500	2.824	2.778	2.667	2.067	2.750	1.367	2.432	2.571
	Communication	3.278	3.188	4.000	3.088	3.500	3.833	3.000	3.750	2.433	3.023	2.714
	Privacy	3.389	3.500	3.500	2.912	3.306	3.667	2.933	4.000	2.767	2.841	2.714
	Comfort	3.444	3.375	4.000	3.324	3.556	3.667	3.133	3.875	3.067	2.864	2.714
Age Group 2: 26 to 45	Quietude	2.875	2.857	3.000	3.111	3.114	3.217	2.243	2.647	1.741	2.158	2.600
	Communication	3.000	3.381	3.077	3.167	3.500	3.609	2.595	3.088	2.407	3.053	2.800
	Privacy	3.000	3.524	3.077	3.333	3.455	3.522	2.919	3.147	2.852	2.684	2.600
	Comfort	3.500	3.524	3.308	3.444	3.136	3.652	3.027	3.294	3.185	2.842	2.600
Age Group 3: 46 to 65	Quietude	2.607	2.857	2.935	3.176	2.182	2.700	2.579	3.071	1.333	2.250	1.833
	Communication	2.893	3.381	3.478	3.412	2.818	3.350	2.526	3.536	1.733	2.625	2.333
	Privacy	3.000	3.524	3.543	3.176	2.909	3.350	2.684	3.393	2.600	2.625	2.333
	Comfort	3.107	3.524	3.413	3.294	2.818	3.400	2.737	3.500	2.333	2.500	2.167
Age Group 4: 66 and over	Quietude	2.308	2.933	3.000	2.667	1.500	3.333	2.500	2.800	1.000	1.500	NA
	Communication	2.538	3.000	3.615	3.167	2.000	3.444	2.000	3.200	2.000	2.500	NA
	Privacy	2.538	3.267	3.538	3.333	3.000	3.444	1.750	3.200	2.500	2.500	NA
	Comfort	2.923	3.000	3.615	3.667	1.500	3.444	2.250	3.200	1.500	2.250	NA

Figure 2: Restaurant Data

The basic acoustical measure of Reverberation Time (RT-60 at 1,000 Hz) was measured when unoccupied utilizing free online software (Room Equalization Wizard v.5). Background Noise (dBC) was measured for each restaurant when more than 75% occupied, during the dinner hour, utilizing a Radio Shack sound level meter in the center of the space and averaging readings over two minutes. Basic physical measures of Length, Width and Height were developed by drawing three-dimensional models of the space and using the model to define a rectangular solid of equal area and volume. Capacity was determined by a count of seats, including stools at the bar where it was part of the same space as the dining area.

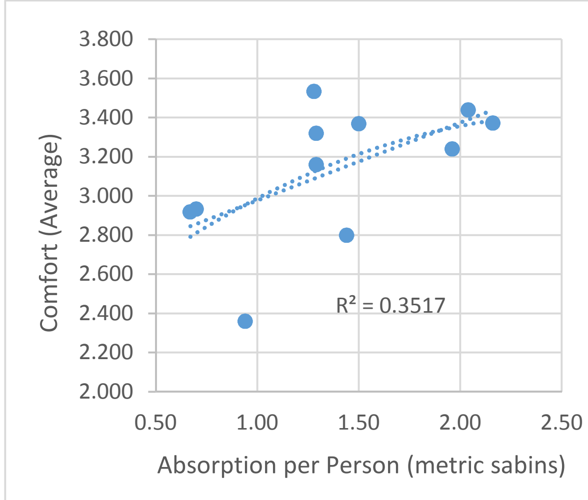

Figure 3: Average Comfort and Absorption per Person

The basic dimensions that were collected and documented in the drawings were used to calculate the physical measures that might affect subjective impressions of acoustical comfort. Floor Area, Cubic Volume, Cavity Ratio (5H x (L+W)/LW), Aspect Ratio (L/W), Total Absorption, the measure of Absorption per Person (after Rindel), and Density Factor were calculated and tabulated. The Density Factor (D) is the inverse-density in m²/person (not people per unit area as usually defines density) and corresponds to a measure of occupant load as used in common building codes.

<u>Analysis</u>

Scatter plots showing the mean-error-squared (r^2 values) for Average Comfort and each of the physical measures were generated from the Microsoft Excel spreadsheet:

- A degree of correspondence is evident between Average Comfort and Absorption per Person, lending some support to Rindel's analysis (Fig. 3).
- The data does not indicate a strong correlation between Average Comfort and Background Noise ($r^2 = 0.140$). This is very surprising considering the number of studies that assume increased noise in restaurants results in discomfort (Fig. 4).
- There is also no evident correlation between Average Comfort and many other room characteristics including Density ($r^2 = 0.082$), Proportions ($r^2 = 0.0122$), and Total Absorption ($r^2 = 0.0396$). However, there is a significant correlation for Average Comfort and Reverberation Time, which also indicates an optimal level between 0.5 and 0.7 seconds (Fig. 5).

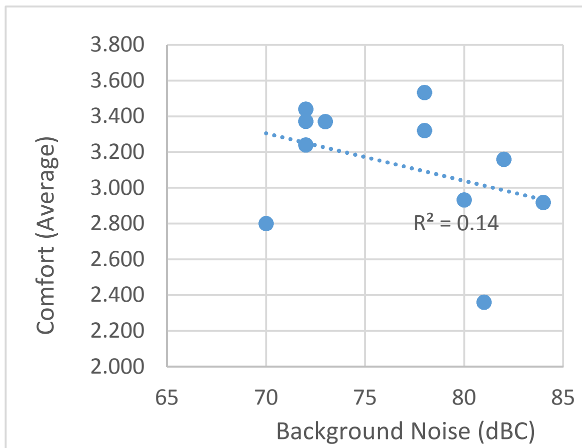

Figure 4: Average Comfort and Background Noise

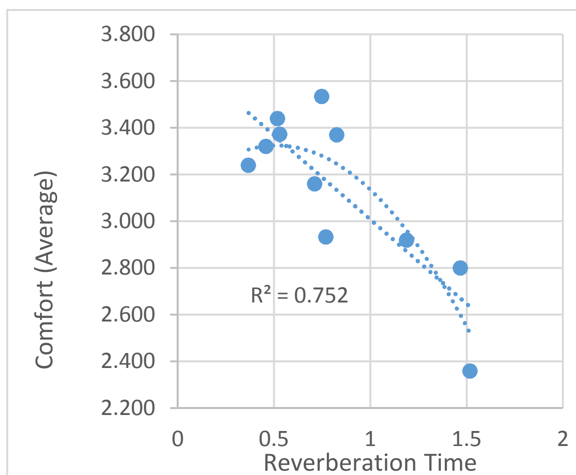

Figure 5: Average Comfort and Reverberation Time

Reverberation Time compared to the averaged responses for the subjective impressions of Communication, Quietude and Privacy yield some interesting correspondences:

- Reverberation Time affects Privacy (lack of disruption due to sounds from other tables) to a large extent (Fig.6).
- Quietude (how quiet the space seems to be) also corresponds with high significance (Fig. 7).
- Communication (ability to converse with other diners at the same table) correlates the least (Fig. 8).
- There is a significant agreement between Average Quietude and Absorption per Person (r^2 = 0.4864) and there appears to be an optimal amount of 1.8 metric sabins per person (Fig. 9). A possible explanation: less absorption would make the restaurant seem too noisy, and more absorption would lend too much clarity to conversations from diners at adjacent tables.

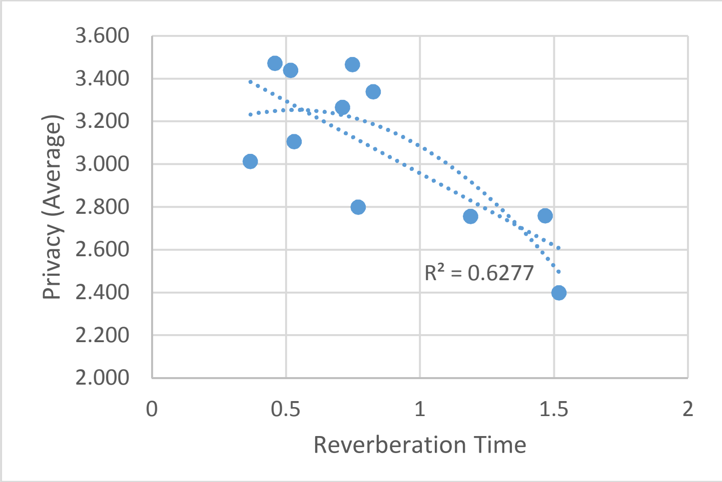

Figure 6: Average Privacy and Reverberation Time

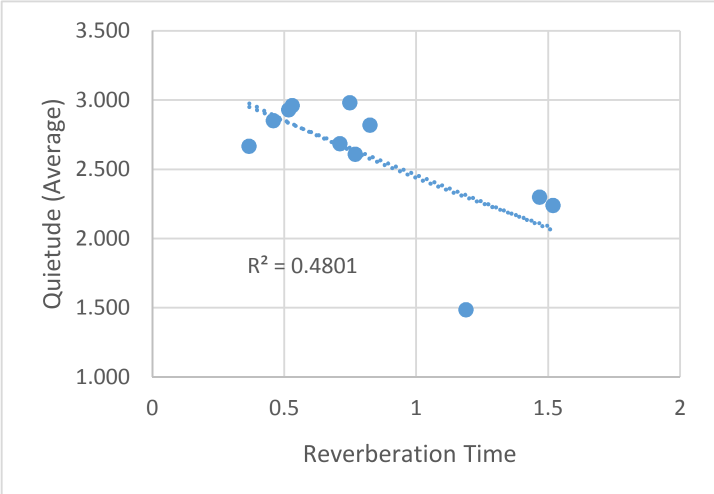

Figure 7: Average Quietude and Reverberation Time

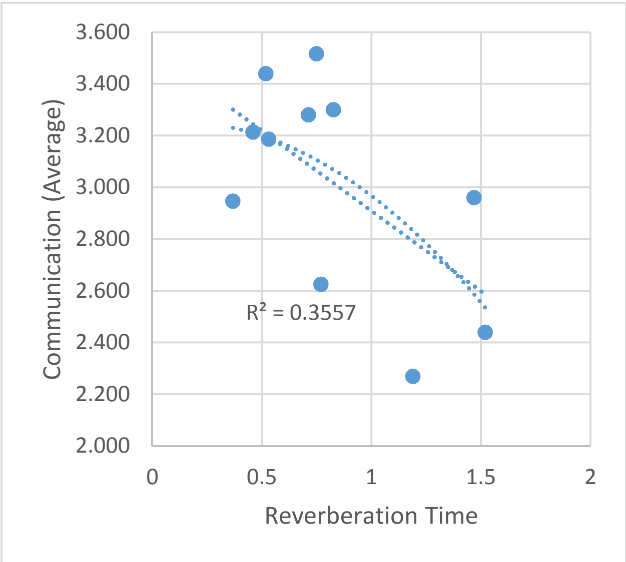

Figure 8: Average Communication and Reverberation Time

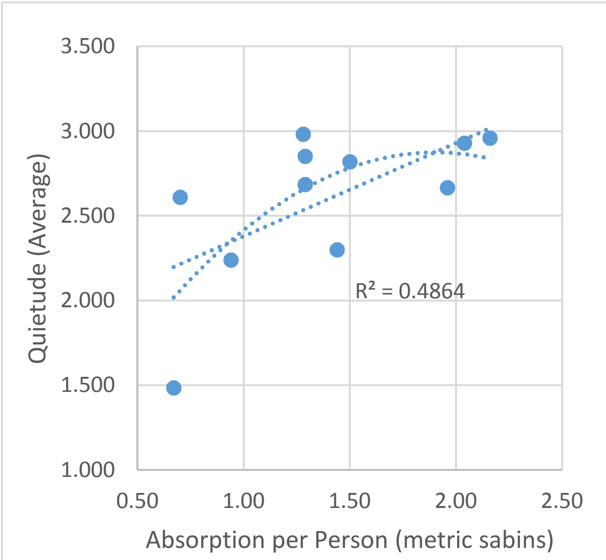

Figure 9: Average Quietude and Absorption per Person

Comfort by Age Group compared to Reverberation Time shows some expected results with strong correlations to the data:

- Age Group 1 (25 and under) has an optimal 0.7 second reverberation time for Comfort.
- Age Groups 2, 3 and 4 (all over 25) all have a constant slope in the plot where higher reverberation time results in less comfort.
- Related to these results is that Comfort in Age Group 1 (25 and under) has no relationship to Quietude ($r^2 = 0.1468$). This may lend some credence to the partying invocation among the young: "Let's make some noise."
- Comfort in Age Group 2 (26 to 45) is strongly related to Privacy (sounds from other tables) compared to other subjective impressions.
- The opposite is indicated for Age Group 4 (over 65) where Privacy is not as important to Comfort as is Quietude and Communication. The general loss of clarity in hearing with age may account for these results.

Summary

There is no apparent correspondence between background noise and the subjective impression of acoustical comfort, at least within the 70-84 dBC range of the data set. There is a strong correspondence between reverberation time and the subjective impression of acoustical comfort.

The data and analysis indicate an optimal range for reverberation time between 0.5 and 0.7 second will provide acoustical comfort for most restaurant patrons. There also appears to be an optimal value of 1.8 metric sabins per person (about 20 sabins/person) for attaining the proper level of background sound.

By inserting these target values into the Sabine equation for reverberation time an equation for optimal ceiling height can be derived based upon a certain selected density of seating:

For V = H x A (height x area); a = a_p x C (absorption per person x capacity); D = A/C.
Therefore, when a_p = 1.8 metric sabins:

T = .16 V/a = .16 (H x A/1.8 x C) = .16 x H x D/1.8; solving for H,
H = 11.25 T/D (for I-P: **H = 400 T/D**)

For example, if a restaurateur desires a reverberation time of 0.7 second and a density factor of 1.9 m^2/person (20.44 ft^2/person) the architect can determine that the optimal height for a desirable acoustical ambiance is about 4.14 meters (13'-7"): H = 11.25 x 0.7/1.9 = 4.14 meters.

Acoustical comfort is defined differently by age group. The youngest Age Group 1 (under 25) seems unaffected by a loud background level. Age Group 2 (26-45) associates comfort with privacy where sounds of conversations from other tables are not disturbing. Age Group 3 (46-65) wants it all – Quietude, Communication and Privacy. Age Group 4 (over 65) prefers a quiet setting and an ability to easily converse with other diners at the same table, but sounds from other tables are not necessarily disturbing.

A good, successful restaurateur begins the design of a new eating establishment by developing the menu selections followed by the range of prices for the offerings. The menu and price determine the target clientele, including age range. Since the architect can see from the data analysis presented here, understanding the ages of the patrons expected by the restaurateur is critical to the design of the proper acoustical conditions for the dining space.

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[1] B. Blesser and L.-R. Salter, Spaces Speak, Are You Listening? Experiencing Aural Architecture, MIT Press, 2007.

[2] A. Astolfi and M. Fillippi, "Good acoustical quality in restaurants: A compromise between speech intelligibility and privacy," *Pro. EuroNoise 2003,* Naples, Italy, S102 (2003).

[3] M. Nahid and M. Hodgson, "Prediction of optimal conditions for verbal-communication quality in eating establishments," J. Acoust. Soc. Am. **129**(4), 2005-2014 (2011).

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