# DINNER CONVERSATION (AN OXYMORON?)

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In a recent popular movie "My Dinner with André," the two main characters converse onscreen for an hour and a half in a restaurant. It is with good reason that the conversation was filmed in an abandoned hotel without other patrons present, since in most modern restaurants such an exchange would be difficult at best. Architectural design in general and restaurant design in particular tends to emphasize the visual. Form follows fashion rather than function in the world of architecture. The acoustical features of the built environment are usually noticed only when associated with performance venues. Yet the acoustics of everyday spaces: restaurants, offices, theaters, sports arenas, and our dwellings affect their use and enjoyment. This is particularly true for the elderly who gradually lose their hearing acuity (due in part to exposure to noise) in the high-frequency ranges so necessary for the understanding of speech.

There is an increasing awareness of the importance of noise in restaurants. Michael Bauer, the food editor for *The San Francisco Chronicle*, publishes a guide to the 100 top restaurants in that area. Reviewers are outfitted with sound level meters to measure background levels and a noise level rating is included in their reviews (1 bell for < 65 dBA, 2 for 65–70, 3 for 70–75, 4 for 75–80, and a bomb for levels above 80 dBA). These ratings can be found online by going to the sfgate.com site and following the links to "Food and Dining." Sadly, only one restaurant on the list received a one-bell rating.

## Speech intelligibility

The ability to hear and understand the spoken word, known as speech intelligibility, is an area of great interest in acoustical engineering. It finds application in classroom, auditorium, and office design, as well as in sound system design. And to those of us who enjoy an occasional evening out at a quiet restaurant, where the ability to carry on a conversation with one's dining partner in the presence of the noise generated by other patrons is highly prized, it is of particular significance.

Speech intelligibility, as it turns out, is dependent on the interior design of the restaurant, and can be greatly influenced by the choice of surface materials used within the space. Intelligibility depends on the masking effects of extraneous sounds on the speech we hear. Masking can be caused by noise from background sources or by reflections of the original spoken words. Speech intelligibility is measured in a number of ways, the simplest of which is a test given to subjects wherein they are asked to identify words or sentences in the presence of a masking noise. Charts such as those shown in Fig. 1 result, showing the percentage of syllables or sentences correctly identified. Our brains are excellent computers and we are more successful in identifying sentences than we are with single-syllable sounds since we use partially understood words to intuit the rest. This is illustrated clearly in the figure. Notice that even when the noise is louder than the signal (the signal-to-noise ratio is negative), we can still understand sentences pretty well.

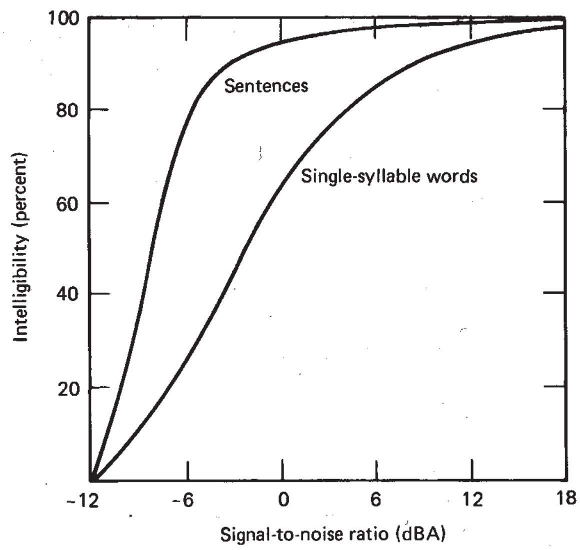


*Fig. 1. Percent of words and sentences correctly identified in the presence of background noise (Kinsler, et al., 2000) ©John Wiley & Sons, Inc. Reproduced with permission.*

There is some imprecision involved with the definition of what constitutes signal and what constitutes noise. Clearly, the noise must have a similar spectral content as the signal or else the ratio, which is the signal level minus the noise level in dB, would not be meaningful. For this simple analysis we will consider the direct field sound, which travels directly from the source to the receiver (Eq. 1), to be the signal. The farther the receiver is from the talker the lower this level becomes. The original sound energy is distributed over the surface of a sphere expanding away from the talker, a phenomenon called

$$L_p = L_w + 10 \log \left[ \frac{Q}{4 \pi r^2} \right] + K \qquad (1)$$

where

$L_w$ = sound power level of a talker
= 70 dBA for typical conversation
(dB re $10^{-12}$ W)

$L_p$ = sound pressure level (dB re 2 x $10^{-5}$ Pa)

$r$ = measurement distance (m or ft)

$K$ = 0.1 for $r$ in m, or 10.5 for $r$ in ft
(for standard conditions)

$Q$ = source directivity (2 for on-axis voice) geometric spreading. It is modeled in terms of the sound power level of the source and the sound pressure level at the receiver. When the distance between the source and the receiver doubles, the sound level is reduced by 6 dB.

The noise in our simple example is the total contribution of all the talkers in the room. In this case we assume that this is the reverberant field level, or all the sound that has not come directly from a talker to the receiver. The reverberant level is the sound that has encountered the surfaces of the room one or more times, and it tends to be constant. Clearly, some of the reverberant field sound produced by our subject talker might fall into the signal category and some of the direct field sounds from other patrons might be considered noise. Although we acousticians have a good time arguing about definitions, for purposes of this analysis we will ignore these contributions. The reverberant field level shown in Eq. 2 is only dependent upon the total sound power $L_w$ of all the talkers in the room and the room constant, which is the total amount of absorption due to all the surfaces of the room.

$$L_p = L_w + 10 \log (4/A) + K \qquad (2)$$

where:

$A$ = total area of absorption in the room (sabins)

$= S_1 \alpha_1 + S_2 \alpha_2 + S_3 \alpha_3 + \ldots + S_n \alpha_n$

$\alpha$ = absorption coefficient of individual surface

$S$ = area of surface (sq m or sq ft)

## The cocktail party effect

How does a room get to be noisy? If there is a band present or other music is being played, this sound is treated as noise from the standpoint of understanding speech. Since there is not much we can do about these sources except turn them down, what we want to focus on here is the sound generated by the conversations between other patrons. There is a phenomenon called the cocktail party effect, which is an interesting and amusing exercise in the buildup of a sound field in a room. Let us assume that we are giving a party in a relatively reverberant room and invite a number of people to attend. The room has a carpeted floor, hard walls and ceiling, and some furniture, which contribute 93 metric (1000 sq ft) sabins of absorption (the A in Eq. 2). Before the guests arrive, the two hosts are having a conversation in the living room. They are polite so only one speaks at a time, each generating a sound power level of 70 dB. For the purposes of this calculation we assume that the direct sound transmitted between the talker (with Q = 2) and the listener, is the signal, and the reverberant sound reflected from the surfaces of the room is the noise. Clearly, some of the reflected sound contributes to intelligibility but we are going to ignore that for this simple analysis. Using Fig. 1, for barely adequate (60%) intelligibility, we need a signal-to-noise ratio of at least –6 dB to understand sentences.

The reverberant field level in our living room is

$$L_p = 70 + 10 \log (4/93) = 56.3 \text{ dB} \qquad (3)$$

This means that speech can be understood at a direct field level of 50.3 dB. Assuming the background noise due to other sources is low, two people can converse comfortably at a separation distance of 3.9 m (13 ft).

Our first guests arrive and two groups begin talking, only now two people, one from each group, are talking simultaneously. The reverberant level increases by 3 dB (10 log N), but the direct field remains the same, so the minimum conversation distance drops to 2.7 m (9 ft). When two more couples arrive and pair off, the comprehension distance drops to 1.9 m (6 ft). When four more arrive the distance drops to 1.3 m (4 ft), and so forth.

In practice what happens is that people may choose not just to move closer, but also to talk louder. This raises the overall background noise and forces everyone to elevate their voices so at the end of the evening they all go home with sore throats—a corollary of the cocktail party effect. The point of this example is that more absorption in the room yields a higher signal-to-noise ratio and more people can talk comfortably before the increasing-volume spiral begins to kick in.

## Restaurants

Restaurant design includes a similar problem in speech intelligibility since we want patrons to be able to talk comfortably across a table, but we do not want their conversations understood by someone at a neighboring table. Consequently we need sufficient absorption so that we do not have to raise our voices at a cross-table distance of 1 to 2 m (3 to 6 ft), but we want masking at a table-to-table distance of, say, 3 m (10 ft) and beyond.

Let us imagine a restaurant that has a hard ceiling and walls and some absorption in the furniture for a total of, say, 20 metric sabins. A normal conversational level ($L_w$ = 70 dB) will produce a direct field of 60 dB at 1.2 m (4 ft). With 20 metric sabins, our self-generated reverberant-field noise is 63 dB, our signal-to-noise ratio is - 3 dB, and we achieve 75 percent intelligibility. If there are 20 tables in the room, with one person talking at each table, the reverberant noise level rises by 10 log 20 to 76 dB, a very uncomfortable (4 bells) level, and we can no longer hold an intelligible conversation. This simple calculation tells us something useful—in hard-surfaced restaurants it is very difficult to have a normal conversation across a table. People who enjoy conversing with their dinner companions do not return to these establishments and the restaurant owners ultimately suffer. Yet for some unfathomable reason countless restaurants are designed in this way.

We address the problem by adding absorption (such as one-inch-thick fiberglass panels wrapped in cloth) to the walls and ceiling. Carpeting or other thin materials do very little. Now assume that we cover the ceiling with an absorbent material. If it has an absorption coefficient of 0.9, this adds 170 metric sabins to the 13.7 x 13.7 m (45 x 45 ft) room. The 20 table rever-

*"Form follows fashion rather than function in the world of architecture."*

berant noise level drops to 66 dBA (2 bells), which is just low enough to carry on a cross-table conversation. At an adjacent table 3 m (10 ft) away, the direct field level from our conversation is about 54 dB and so it is not understandable. Off-axis directivity losses also may provide some additional isolation.

What we see from these relatively simple calculations is that unless we add absorptive treatment with an area at least equal to the restaurant ceiling area, when the room is full of patrons, conversation across a table will be difficult and the background noise level will be uncomfortable. Second, even when we add this amount of absorption, the environment is not so dead that conversations are easily overheard at a neighboring table. More formally, these two conditions can be stated as follows.

$$L_p(\text{signal}) = L_w + 10 \log \left[ \frac{Q}{4 \pi r^2} \right] \tag{4}$$

and

$$L_p(\text{noise}) = L_w + 10 \log N + 10 \log \left[ \frac{4}{N A_t} \right] \tag{5}$$

where N is the number of simultaneous talkers (or tables) in the room and $A_t$ is the absorptive area per table. The signal-to-noise ratio is the difference between these two equations

$$L_{SN} = 10 \log \left[ \frac{Q}{4 \pi r^2} \right] + 10 \log \left[ \frac{A_t}{4} \right] \tag{6}$$

To ensure adequate communication for a cross-table distance equal to $r_s$ we apply the condition that $L_{sn} > -6$ dB. This leads to the requirement that the amount of absorption per table in terms of the cross-table separation distance must be

$$A_t > 6.33 \, r_s^2 \tag{7}$$

To ensure privacy between tables, we apply the condition that the signal-to-noise ratio $L_{sn} < -9$ dB. This leads to the requirement that the amount of absorption per table, in terms of the separation distance $r_t$ between tables, be limited to

$$A_t < 3.16 \, r_t^2 \tag{8}$$

For a talker-to-listener distance of 1 m, our analysis suggests at least 6.3 sq m (68 sq ft) or more of absorption per table. If we treat the ceiling with a highly absorptive material, the minimum spacing between tables becomes about 2.5 m (8 ft), based on filling the room evenly. At that distance the maximum allowable absorption from Eq. 8 should be no more than 20 sq m (215 sq ft) per table. Normally we design based on Eq. 7 since the requirement in Eq. 8 is easily met. If the cross-table distance is greater than 1 m then the amount of absorption must be increased accordingly.

## Conclusion

To an acoustical engineer the solution to this problem is straightforward. More absorption means a quieter restaurant. People like quiet restaurants. So use more absorption.

To the architect or restaurant designer there is a different equation. The item that gets the architect more work, praise and accolades is a great-looking picture of the restaurant in an architectural magazine. Hard-edged structures with strong design elements look "cool" even if the seats are uncomfortable and the interiors are noisy. Acousticians must help fulfill the architect's visual goals to get acceptance of a solution to the noise problem. We must give architects and designers good-looking absorptive materials with hard edges that can be painted any color and made into any shape desired. We are slowly improving in these areas with perforated metals, absorbent plasters, more interesting ceiling tiles, and fabric-wrapped panels, but there is more we can do. We hope that architects and interior design professionals will discover that good design is not simply visual. Ultimately it is easier to design new materials that solve the architects' problems than it is to design new architects. **AT**

## References


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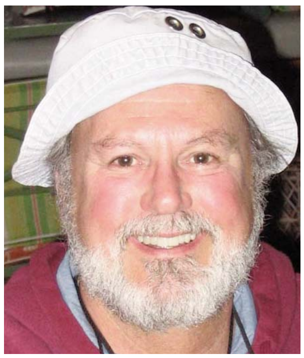


Marshall Long received a B.S.E. from Princeton University in 1965, attended the University of Grenoble in France and the University of Madrid in Spain in 1966, and received M.S. and Ph.D.degrees in engineering from UCLA in 1971. While still a graduate student, he founded his own consulting firm now in its thirty-fourth year. Marshall Long/ Acoustics specializes in architectural acoustics, audiovisual design, noise and vibration control, and other technical areas related to acoustics. He enjoys sailing, judo, soccer, reading, and writing, and is living happily ever after with his family in Sherman Oaks, CA.