Acoustics 2019
Sound Decisions: Moving forward with Acoustics

Restaurant acoustic comfort assessment methods

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ABSTRACT
Restaurant noise, in terms of its 'comfort' for both diners and staff has been a topic of discussion for some years amongst older members of society and there are a number of technical papers on the subject. The Australian Acoustical Society (AAS) has a café and restaurant rating acoustic index (CRAI) based on a subjective ranking from 1 to 5. But an objective method of rating and assessment is preferred to allow effective comparison between sites, and different methods may be available. This paper provides an objectively based rating system based on the difference between the measured sound level in a dining location and the maximum ambient sound levels required for normal speech by males and females. Other aspects of architectural acoustics, such as reverberation time, and spectral content have yet to be included but can be added if the rating develops further. The rating is from 0 to 20, with the highest rating number relating to acceptable hearing and speech comfort. It is not intended to be a definitive work on the subject but intended to get to an improved and objective approach, which may or may not become an agreed standard method.

1 INTRODUCTION

Sound levels in restaurant dining areas are a common discussion point among diners. It has been regularly discussed in mainstream media and semi-professional journals over a long period of time. As recently as September 2019 there was an article on the subject in Fairfax-Nine media (Sakkal, 2019). The Guardian on-line has also had articles on the subject (Bramley, 2019). The AAS has a subjective ranking system for café and restaurants it calls the CRAI (AAS website), which has a subjective ranking from 1 to 5. Some social media platforms in other countries, such as *SoundPrint* (Marx, 2018), include a restaurant sound level score for potential diners, but the basis of this is thought to be subjective.

Good science and good acoustics includes the use of measurable and repeatable physical properties to describe a specific environment and it is considered that restaurant and café noise should be no different. If an objective method could be developed it would allow for effective comparisons between different sites. This paper has been prepared to initiate development of a rating system which is objective, based on measurements of sound levels and other conditions in restaurants. The overall approach is based on the use of Standards and standard methods for measurement of sounds and recommended objective sound levels for different types of areas, in this case restaurants and dining rooms.

As the end-users of the rating scheme will be the general public, which has no understanding of how decibels are derived or their relative value, it is intended that the ranking will be an integer based number from 1 to 10, with 10 being the highest acoustic comfort and 1 being the lowest. There could be some debate about whether it should be reversed, but generally a rating scheme is usually based on the understanding that a higher number for a value such as comfort, means a more comfortable situation than a lower number would provide.

There is also intended to be an opportunity to make the assessment able to be determined by an application module (App) on a smart mobile phone, perhaps with an improved microphone. This would be expected to provide a wider application and quicker take-up among the general public than would be likely to occur if acousticians only were involved. While that may reduce the potential income available from assessment activities, it may also in the long-run result in a higher number of requests for professional assistance to advise on how to improve the rating. Overall the aim is to be as simple as possible in calculation of the rating.

2 BASIS OF THE RATING – SOUND LEVEL OF SPEECH AND FREQUENCY CONTENT

The starting point for the rating is the signal to noise ratio, or the difference between the ambient sound level required for optimal listening accuracy and speech sound level. As a starting point, an optimum speech level is reported to have a SNR of 15 dB when the background sound level is above 40 dBA (Brixen, 2016). AS/NZS 2107:2016 (Standards Australia 2016) recommends a sound level of 45 to 50 dBA for restaurants and dining rooms. The method involves measurement of the ambient sound level in a restaurant dining area, which is then compared to the AS/NZS 2107 recommended level. (In this paper ambient means the total sound level occurring at the location without people at the table speaking, as described in AS1055:2018 (Standards Australia 2018). It does not mean background.) If an increase in the vocal spectrum is required to achieve the 15 dB difference, the increase is used in the calculation of the rating.

The level of speech varies as a function of effort and distance from the speaker. Table 1 shows one list of sound levels at different receiver distances for different levels of speech. (The results appear to be for adult males, with adult females typically lower by 2 to 3 dB and children at a similar level as males, for normal to raised.)

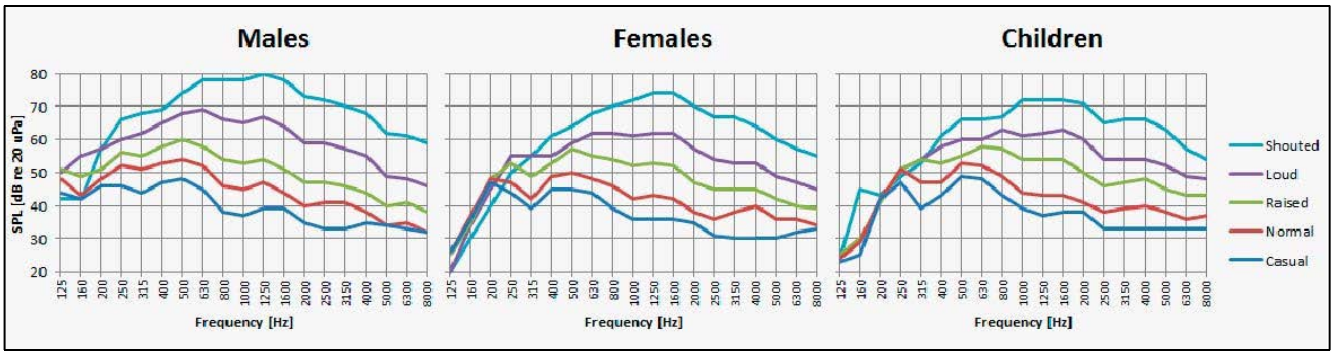
Table 1: Sound levels of speech of different effort at different distances

Speech level	Speech level [dBA re 20 µPa]			
Listening Distance	Normal	Raised	Loud	Shout
0.25	70	76	82	88
0.5	65	71	77	83
1	58	64	70	76
1.5	55	61	67	73
2	52	58	64	70
3	50	56	62	68
5	45	51	57	63

(Brixen, 2016).

From the table it can be seen that average speech level is a function of listening distance. There is nearly 20 dB difference between normal speech and shouting.

The spectrum of speech is the next aspect to be considered and covers a wide range of the complete audible frequency spectrum. This spectrum varies as the level of effort increases, usually to overcome the ambient sound level or to be heard at a longer distance. Typical speech spectra are shown in Figure 1.



Source: (Brixen EB, 2016)

Figure 1: one-third octave band spectrum sound levels of speech at different levels of effort

The next aspect in developing the rating is to compare the different sound and spectrum levels for different levels of intensity or effort. From Table 1 it can be seen that for a listener at 1m distance at normal speech the sound level is 58 dBA. When spectrum sound levels from Figure 1 are summed, they confirm this value for males, while for females it is 55 dBA and for children it is 57 dBA. These spectrum levels are used in calculating the rating.

3 SETTING THE SIGNAL-TO-NOISE RATIO FOR A 'COMFORTABLE LEVEL'

It was initially considered that for an optimum listening environment, the signal to noise ratio (SNR) should be 15 dB (Brixen, 2016). The minimum of the male and female spectrum sound levels for the different voice effort levels were taken from Figure 1 and 15 dB subtracted from each one-third octave band sound level. Those values were then summed to give the A-weighted sound level. Table 2 shows the results for this for the Normal voice level. One-third octave band sound levels were used to allow for consideration of when the total sum may achieve the 15 dB SNR but the sound level in some bands may not. The results are shown in Table 2 and graphed in Figure 2. The flat spectrum for 45 dBA as the medium range of objective background sound levels for restaurants is also shown in the table and figure.

Table 2: Comparison of Minimum male and female A-weighted spectrum level for Normal voice level with 15 and 10 dB SNR and also showing a flat 45 dBA spectrum

1/3rd Octave Band	'Normal' dBA	-15 dBA	-10 dBA	45 dBA
125	9	-6	-1	32
160	23	8	13	32
200	37	22	27	32
250	39	24	29	32
315	36	21	26	32
400	44	29	34	32
500	47	32	37	32
630	46	31	36	32
800	45	30	35	32
1000	43	28	33	32
1250	44	29	34	32
1600	43	28	33	32
2000	39	24	29	32
2500	37	22	27	32
3150	39	24	29	32
4000	38	23	28	32
5000	35	20	25	32
6300	35	20	25	32
8000	31	16	21	32
Total A	54	39	44	45

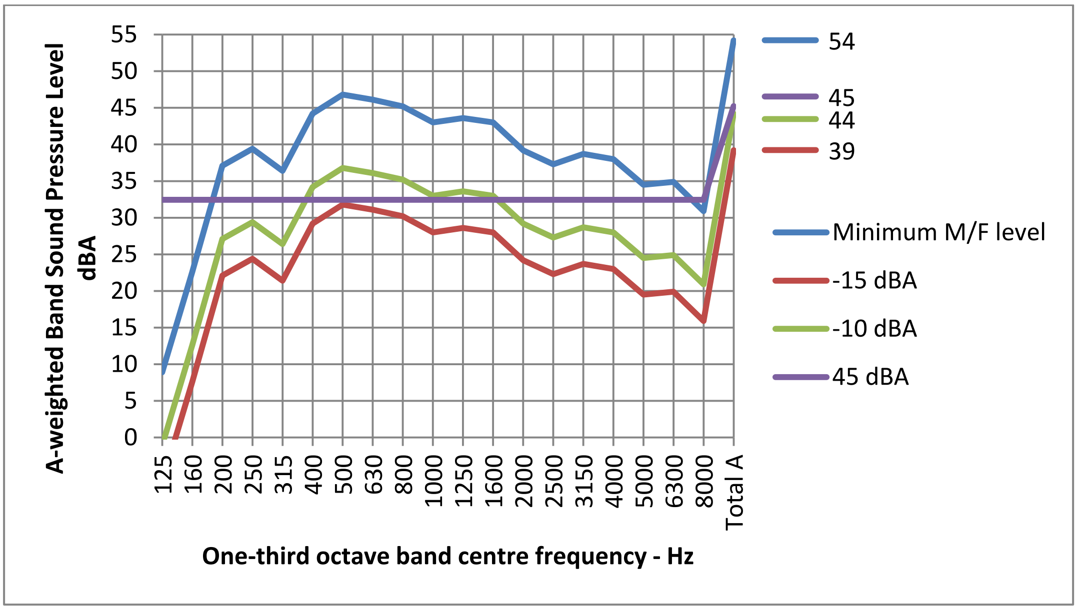


Figure 2: Comparison of Minimum male and female A-weighted spectrum level for Normal voice level with 15 and 10 dB SNR and also showing a flat 45 dBA spectrum

The summed total dBA results for all speech levels are shown in Table 3.

Table 3: Maximum Ambient Sound Levels required for 15 dB and 10 dB Signal-to-Noise Ratio for different speech effort levels

Level of Speech Effort	Maximum Ambient Sound Level – dBA	
	15 dB SNR	10 dB SNR
Casual	34	39
Normal	39	44
Raised	47	52
Loud	55	60
Shout	66	71

The results in the table can be considered as follows: for a 'Normal" voice level of speech effort, to obtain a 15 dB SNR, the maximum ambient sound level has to be no greater than 39 dBA.

These values were then compared to the recommended sound levels for restaurants from AS/NZS 2107 (Standards Australia 2016). The recommended sound levels for restaurant and dining room areas is 40 to 50 dBA for restaurants and coffee shops, and 45 to 55 dBA for cafeterias and food courts. Using this guide, it was considered that 'casual' speech level requiring 34 dBA as an ambient sound level would be too difficult to achieve, but 40 dBA would go close to matching a 'normal' level of conversation at a separation distance of about 1m and this was taken as the starting point for a rating.

It was then considered that a slightly less onerous signal-to-noise ratio of 10 dB, not uncommon in acoustics, might be appropriate and the calculations repeated. The value calculated in Table 3 for maximum ambient sound level with 'normal' speech effort with a 10 dB SNR was 44 dBA, which is close to the mid-range recommended background sound level for restaurants and dining rooms in AS/NZS 2107, rather than the minimum of 40 dBA. The difference between maximum ambient sound levels for Normal and Shout was 27 dB in each case.

Given that the mid-range value of recommended maximum ambient sound levels for 'normal' speech from Table 3 are shown to be 45 dBA with a 10 dB SNR, this was selected in the next part of the development.

4 A RATING SCALE OF 10 OR 20?

Rating scales tend to be that an increase in number means an improved value. This occurs with star ratings for energy and water use and building acoustical performance. Initially the objective for the rating system was considered to be a 0 to 10 numerical rating based on the difference in level between the sound level set for normal conversation with 10 dB SNR and the measured sound level. Given that the range of maximum ambient sound level for normal to shout voice effort level in the table is 27 dB, dividing the 27 dB by 3 would give a number closer to 10. So the next step in the process is to calculate the difference in sound level between the measured value and the calculated maximum ambient sound level for 'normal' speech given in Tables 2 and 3 above, and divide that difference by 3. This is then subtracted from 10 to reverse the order of magnitude to make a lower difference better. A 'normal' level ambient sound level of 44 dBA, with a difference of 0 to the value in the table would have a rating of 10, while an ambient with a shout level of 71 would have a rating of 1.

At this point, it was then considered what would happen if the ambient level was above 70 dBA, which is not uncommon in some higher sound level eating areas? If the difference part of the calculation of the rating was made to subtract the calculated difference from 20, that would give a wider range of options for the higher sound level areas. For example, for an ambient sound level of 71 dBA, shown from Table 3 as maximum ambient level for a shout, the difference to 'normal' is 27. This divided by 3 is 9 and subtracted from 20 to give a rating of 11.

A recent measurement in a club restaurant area over a 5-minute period had an average sound level of 78 dBA, minimum of 66 dBA and maximum of 91 dBA, and hearing someone more than a half-metre away was difficult. While this was admittedly recorded on a smart-phone, it indicates the higher range of sound levels is not uncommon. In terms of this rating system, the measured average is the ambient sound level, the calculated rating is as follows:

Rating for 78 dBA = 20 - (Ambient – Normal level)/3

= 20 – (78-44)/3 = 9

It was also thought that a much higher sound level should be given a further penalty for that fact and its potential for hearing damage when it exceeds 75 dBA. So additional penalties were added to make an ambient sound level of 80 dBA have a rating of 0.

Table 4 has the calculated rating values for ambient sound levels related to levels of speech effort, and higher sound level values for the rating system based on 0 to 20.

Table 4: Total Ambient Sound Levels for 15 dB and 10 dB Signal to Noise Ratio for different speech effort levels with the 0 to 20 Rating value

Level of Speech Effort	Maximum Ambient Sound Level – dBA		Developing Rating Value from 0 to 20		
	15 dB SNR	10 dB SNR	Difference to Normal	Divide by 3	Difference to 20
Casual	34	39	-5	-1.6	22
Normal	39	44	0	0	20
Raised	47	52	8	2.7	17
Loud	55	60	15	5.1	15
Shout	66	71	27	9	11
Higher ambient	Penalty* -8	75	31	10	2*
Levels with	Penalty* -8	80	36	8	0*
penalties	Penalty* -8	85	41	6	-2*

An aspect yet to be considered is the effect of frequency spectrum content being above the recommended level in specific frequency ranges. It may transpire that the approach would be similar to penalties used in environmental sound level assessment for tonal noise. For instance of there is more than 5 dB exceedance in a particular band range then a penalty of -1 point might be added to the developed rating value, depending on the exceedance.

5 CALCULATION SIMPLIFIED

The steps involved in the calculation of the rating are described below.

- Step 1: Measure the ambient sound level for a period of 3 to 5 minutes at the location of dining. Obtain the one-third octave band sound levels from 125 to 8000 Hz. Compare these levels to that set for maximum ambient sound level identified for normal level of conversation effort with SNR 10 dB, shown in Table 5. This includes data for the example given from the measurement in the previous section.
- Step 2: Calculate the difference to the total sound level of 44 dBA for normal. Compare spectrum levels also and consider if a significantly higher value occurs in particular frequency bands, whether to apply a penalty.
- Step 3: Divide the difference by 3.
- Step 4: Subtract the difference of the total sound level from 20 to obtain the rating value.
- Step 5: If the measured sound level exceeds 75 dBA, add 8 dB penalty. For the example in Table 5 the rating result is 9 but a penalty of – 8 is added for exceeding 75 dBA to give a result rating of 1.

The rating is then provided.

If the total A-weighted sound level is satisfactory for ‘normal’ speech level but individual one-third octave bands exceed the relevant band level, an additional penalty may be included but this has yet to be developed further.

Table 5: Maximum Ambient Sound Spectrum Levels for 10 dB SNR with Normal Speech level of effort, for comparison with measured sound levels

1/3rd Octave Band Hz	Normal 10 dB SNR dBZ	Example 1	Differ-ence	Rating	1/3rd Octave Band Hz	Normal 10 dB SNR dBZ	Example 1	Differ-ence	Rating
125	16	56	40	6.6	1250	26	67	41	6.2
160	27	68	41	6.2	1600	26	66	40	6.7
200	36	73	37	7.7	2000	25	64	39	7.1
250	34	72	38	7.5	2500	20.5	62	41	6.3
315	30	70	40	6.8	3150	20	63	43	5.7
400	35	72	37	7.7	4000	20	60	40	6.7
500	35	74	39	6.9	5000	20	60	40	6.8
630	34.5	73	38	7.2	6300	22	60	38	7.3
800	28.5	69	40	6.6	8000	22	56	34	8.6
1000	26	67	41	6.3	**Total A**	**44**	**78**	**34**	**1.0**

6 OTHER ISSUES

The intent of the rating so far has been to start the rating development by provide a simple rating system based on the measured sound level and one-third octave band spectrum, and their difference level to a recommended maximum ambient sound level spectrum. The exact features of the spectrum have yet to be included or finalised. However one approach has been considered in three examples. Table 6 provides three example spectra to compare with the 'normal' maximum ambient band sound level. The first example is similar to the 'normal' but exceeds it in some bands. Example 2 exceeds the 'normal' level in mainly low frequencies but has the same total sound level as 'normal'. Example 3 exceeds the 'normal' level in mainly higher frequencies but also has the same total sound level. If the rating is calculated based on the total sound level only they would all be 20. But if a penalty is applied to bands exceeding a limit the same as used in tonality criteria assessment in environmental noise, as in Appendix D of AS1055:2018, the rating is reduced. Figures 3 and 4 show these graphically.

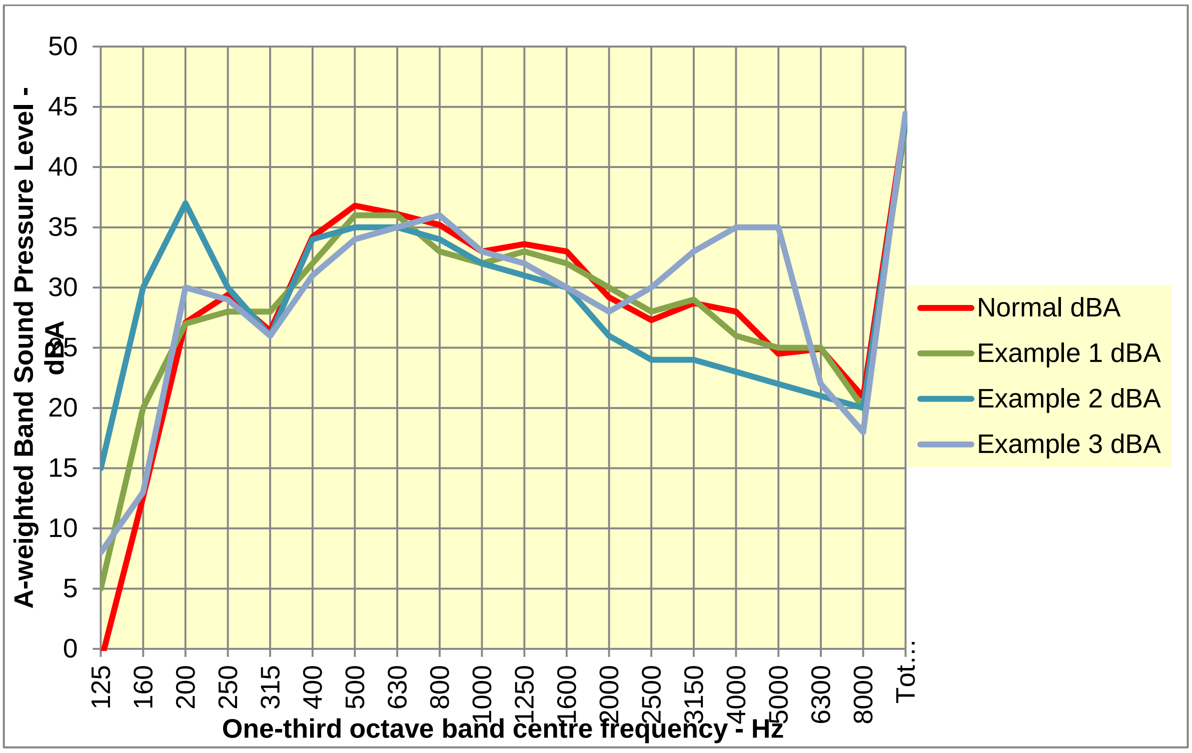


Figure 3: Comparison of 'normal' maximum ambient spectrum with three examples having the same total sound level but different band spectrum levels

Table 6: Consideration of spectrum sound levels exceeding 'normal' band level but the total does not exceed. Highlighted cells indicate exceedance of criterion.

Frequency Band	Normal dBA	Example 1 dBA	Example 2 dBA	Example 3 dBA	Difference to Normal 1	Difference to Normal 2	Difference to Normal 3	Difference Penalty Criterion
125	-1	5	15	8	6.1	16.1	9.1	15
160	13	20	30	13	7.4	17.4	0.4	8
200	27	27	37	30	-0.1	9.9	2.9	8
250	29	28	30	29	-1.4	0.6	-0.4	8
315	26	28	26	26	1.6	-0.4	-0.4	8
400	34	32	34	31	-2.2	-0.2	-3.2	8
500	37	36	35	34	-0.8	-1.8	-2.8	5
630	36	36	35	35	-0.1	-1.1	-1.1	5
800	35	33	34	36	-2.2	-1.2	0.8	5
1000	33	32	32	33	-1	-1	0	5
1250	34	33	31	32	-0.6	-2.6	-1.6	5
1600	33	32	30	30	-1	-3	-3	5
2000	29	30	26	28	0.8	-3.2	-1.2	5
2500	27	28	24	30	0.7	-3.3	2.7	5
3150	29	29	24	33	0.3	-4.7	4.3	5
4000	28	26	23	35	-2	-5	7	5
5000	25	25	22	35	0.5	-2.5	10.5	5
6300	25	25	21	22	0.1	-3.9	-2.9	5
8000	21	20	20	18	-0.9	-0.9	-2.9	5
Total A	44	43	44	44	-1	0	0	
Penalty Rating	20	20	20	20	0	-2	-3	
Penalised Rating		20	18	17				

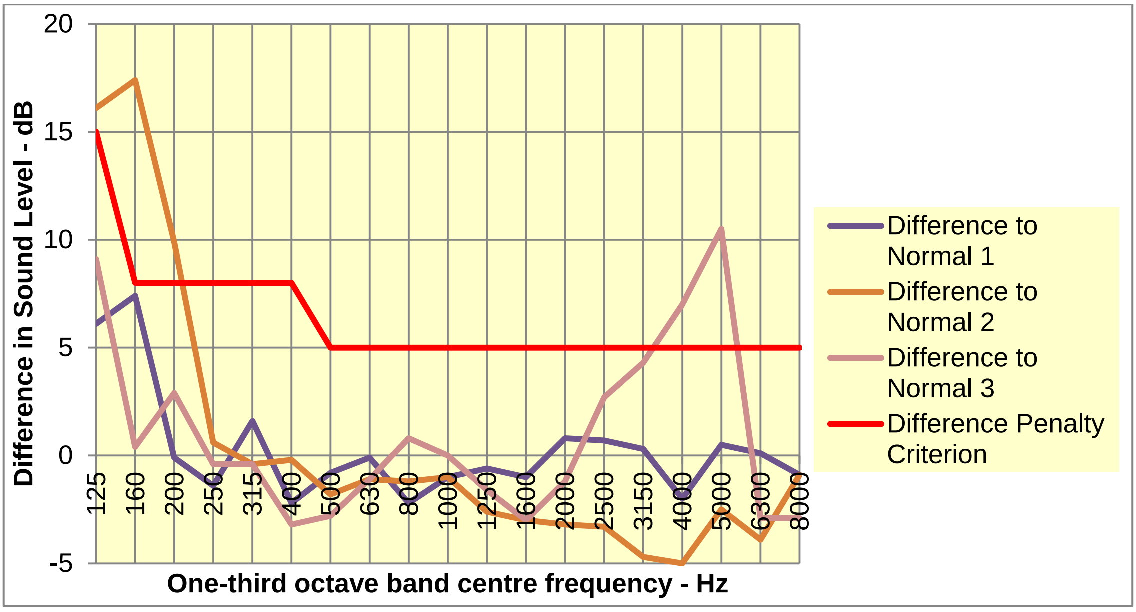


Figure 4: Difference between band sound levels of examples in Table 6 and ‘normal’ band sound levels, with penalty criterion included

For example 2 in Table 6, the “difference” criterion levels were exceeded marginally in three bands, so a penalty of -2 was added to the rating. For example 3 the “difference” criterion levels were exceeded in two bands and one of those bands was double the criterion, so a penalty of -3 was applied. This is subjective at present but could be developed into an objective method for penalty of band level exceedance.

Aspects of audibility in reverberant spaces such as restaurants and dining halls are of course much wider than just sound level and include many aspects related to architectural acoustics, such as reverberation time, time of early and late reflections, and these have been written on by other authors. Many other aspects, not which of least may be the hearing acuity of the diners, could also be relevant. These can all be considered in future development and other approaches and comments welcomed.

Measurements of the spectra of different types of restaurants and dining spaces have yet to be obtained and compared but these will be and presented with the paper at the conference.

7 CONCLUSIONS

The need for an objective method to assess hearing and speech comfort in restaurants is considered relevant given regular comments on the subject in the press, between diners and even in the AAS. Some subjective rating systems for hearing comfort have been used, or just the measured sound levels but the general public and acousticians are not aware of the objective basis of these ratings.

A 0 to 20 rating system has been developed based on the difference in the measured sound level in a restaurant dining location and the maximum sound level developed for a 10 dB signal to noise ratio with a normal level of speech effort by males and females. The rating includes reference to recommended sound levels for restaurants and dining areas in AS/NZS 2107. A rating of 20 means speech is easily heard by most people at normal speech effort levels. A rating of 0 would mean extremely high sound levels for that type of area which could potentially damage hearing in the long-term.

The method is relatively simple and straight-forward and could be developed into an app for suitable mobile phones. However because of its simplicity it is recognised that further development and discussion will be required to consider it acceptable, to include other architectural acoustical aspects, such as reverberation time.

Consideration of the rating system is proposed to the acoustical professional community.

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