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NOISE MEASUREMENTS DURING PERFORMANCES AT AN OPERA HOUSE

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1. INTRODUCTION

Recent developments in concert halls and recording rooms have produced unoccupied background noise levels approaching the threshold of hearing [1]. A recent study looked at the minimum levels in concert halls during performances to try to determine audience noise [2]. However, the measurement was of the lowest level that occurred in each octave band for the duration of the performance, so the resulting spectrum may not have been achieved in practice. It was decided to record performances from the audience position with a calibrated microphone to enable the dynamics of performance and the actual noise profile to be investigated.

The above studies were concerned with either concert halls or recording venues. Staged performances have more activity, and it was decided to investigate if there was a difference in noise during opera, ballet or concert performances.

2. BACKGROUND NOISE

Background noise in an auditorium can mean many things, for example:

1) The quietest achievable noise level.
2) Noise that is continuously present in the building.
3) Noise continually present during the performance.
4) All noises not part of the performance.

To distinguish between the different examples above, (1) will be called the *absolute minimum*. This is of importance for recordings where special care can be taken, such as switching off some plant or restricting access to areas [1]. *Background noise* will be used to refer to example (2), which would be measured in an unoccupied hall in performance condition. This is the most commonly measured and specified noise type. It will often be the subject of performance tests in contracts. (3) will be referred to as the *ambient noise*, which will be the minimum level during an actual performance. This would include any constant sources associated with the performance, such as computers, motors, fans and amplification as well as audience noise. Finally, the *total noise* heard by the audience (example (4)) will include incidental and intrusive noise, such as stage machinery operating, coughs and occasional loud external noises (such as helicopters and fireworks!). The use of these terms differs from BS4142 [3], which is concerned with environmental noise but is one of the few cases where the measurement of background noise is closely specified.

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For most of a performance, noise will be masked by the wanted signal, the performance itself. However, during quiet passages, noises may impinge on the concentration of the audience and distract from the performance. Where the noise is associated with the performance such as mechanical noise by musical instruments, this may not cause distraction. However, a cough by a member of the audience or the noise of stage machinery may destroy the mood. In staged performances, there is more visual activity, and usually more machinery and noise associated with the performance. This may be unavoidable, as in the case of hard dance shoes on a sprung floor. The aim in this project is to measure the ambient noise in a variety of performances and compare it with the background noise. This may establish whether the background, incidental and intrusive noise affects the ambient noise in a performance. This investigation has concentrated on making calibrated recordings of different types of performance in the Royal Opera House, Covent Garden, and interpreting the results.

3. MEASUREMENT

3.1 Performances

Four recordings were made, of performances of opera, ballet, a vocal recital and a final rehearsal of the opera, at the Royal Opera House, Covent Garden in July 1992. The unoccupied noise was measured in November 1992. The Opera was Rossini's Il Viaggio a Reims, a comic opera with a large cast, chorus and medium sized orchestra. The rehearsal started at 10am with photographers taking photographs throughout, creating a noticeable amount of noise, (mainly shutters and winders). The performance was at 7.30 pm. The ballet was La Fille Mal Gardee with soloists and a large corps. The recital was Baritone and piano, with the performers on a temporary stage over the orchestra pit and the main curtain down. In each case, there was a full house and the temperature was high, measuring 27°C at one interval.

3.2 Unoccupied Noise

This was measured over 100 seconds using the same method as for performances, from the seat position of the recital. The stage was set for a new opera production, and the auditorium was not in full performance condition. There was an unidentified fan noise that was considered louder than normal performance conditions.

3.3 Measurement Method

A B&K 2231 sound level meter with 1/2" microphone attached was placed on a tripod at head height roughly equidistant from the four nearest heads in a rear stalls seat. The AC (linear) output of the meter was recorded on a portable DAT recorder. Calibration tones were also recorded.

3.4 Analysis

The recordings were played back through a B&K 2143 analyser set to octave band linear averaging at 1.0s and the spectra stored every second. The resulting data file was transferred to a database and spreadsheet for analysis. The results from Act II of the opera, Act I of the ballet and first half of the recital are presented in this paper. These were chosen as the quietest sounding sections. Each recording was analysed from the end of the applause at the beginning

of the act to the end of the music or the start of the applause at the end of the act, whichever was later. This meant that some applause, and in the case of the recital, waiting time between songs, were included. Intervals were not included. The lowest reading in each band, irrespective of time (*statistical minimum*), corresponded to the minimum levels as measured by Newton & James[2], although their measurements were based on 0.125 sec samples. The statistical minimum may not have occurred in the measurement.

The number of samples meeting each NC curve was determined by testing the bands from 63Hz to 8kHz for a given sample against the criterion values.

The quietest sample (*actual minimum*) was taken as the sample with the lowest A-weighted level in the lowest achieved NC band. This is an actual measured sample.

NC curves were chosen for analysis as they are widely used and specified, and were originally intended for occupied rooms, although other criteria could have been used [4],[5],[6],[7]

4. RESULTS

4.1 Objective results.

The number of samples and the percentages meeting NC criteria are shown in Table 1. Figure 1 shows the actual and statistical minima and L_{90} for the unoccupied noise. Similar results for the Opera performance are shown in figure 2. Figure 3 shows the actual minima for all five measurements. The statistical levels for three frequency bands, A-weighted and linear levels for the opera performance are plotted in figure 4. A normal distribution will show up as a straight line on this type of plot (and a steady level will be a horizontal line). Figure 5 shows the A-weighted statistical levels for all five measurements.

4.2 Subjective results.

Most of the audience do not enter a quiet hall. There is a general 'hubbub' which dies down as the performance begins. The quietest moments occurred at pauses in orchestral passages in the ballet and opera, and at the end of a song in the recital. In the opera, the same passage was quietest in rehearsal and performance. On listening to the opera rehearsal, the quietest moment was punctuated by many camera clicks. As a member of the audience, the rehearsal seemed much noisier. In the recital, the audience started to clap or relax, and became noisier, when the singer relaxed at the end of a piece, even if the pianist was clearly still playing. It is important to remember that there are visual as well as auditory cues in any performance.

The temperature during the performances may have contributed to the noise as the atmosphere was very close and not very comfortable.

4.3 Discussion of results.

The decision to use 1s averaging is supported by the lowest samples containing pairs of adjacent results with very similar levels.

Figure 5 shows the opera measurements forming an almost straight line from $L_{99.9}$ to L_1 indicating a normal distribution. The rehearsal and performance lines are almost identical, indicating that final rehearsals may be used in place of performances for measurements of opera. The curve for ballet follows a normal distribution approximately 3 dB above the opera in the range L_{95} to L_{10} but drops from the straight line to almost the same point as the operas at L99.9. The recital curve follows a straight line from L_{95} to L_{10} with the level being approximately 3 dB below the opera level. From L_{95} to $L_{99.9}$ the recital curve is noticeably lower than either of the staged performances. The higher levels for the recital above L_{10} is probably due to the applause. The unoccupied noise shows little variation, as expected.

The probability plot indicates that the sound levels may be considered in three sections: between L_{95} and L_{10} the levels appear to be determined by the performance, with ballet louder than opera, which is louder than recitals. Above L_{10} the levels are probably dominated by applause and below L_{90} by the ambient noise, which in this case is quieter for the recital than the opera or ballet, but is still significantly louder than the background (unoccupied) noise.

The statistical and criterion analysis show that in each performance act analysed there was a period of 2 seconds where the minimum levels occurred, in each case during a musical silence. This would seem to support the idea of a 'moment of silence' induced by the music. However, this minimum level is still above the background noise. In the staged performances the actual minima are almost always about 10dB above the unoccupied minima, suggesting that ambient noise would completely mask background noise. This is not the case for the recital, especially in the 250 and 500 Hz bands. The lower levels for the recital may be due to the staging differences or show that the audience is quieter for concert performances. High temperatures may have increased the audience noise for all of the performances.

There are differences between the statistical and actual minima. Although these differences are not large (up to 2 dB), this could be important if a hall was to be rated by occupied noise. The samples meeting the lowest NC rating were the lowest dBA levels in each case but there is not enough data to test dBA as an indicator. The rapid rise from the minimum levels to L_{90} suggest that the latter would not be a good indicator for ambient noise in an occupied auditorium. For a performance act of 1 hour, L_{90} would give the lowest 36 seconds which would not detect a 'moment of silence' of 2 seconds where the minimum level occurred. $L_{99.9}$ may be a reasonable indicator but this would require further testing and a meter capable of detecting this to be of any practical use.

The high readings at 16kHz may be due to TV monitors which are used in staged production.

5. FURTHER WORK

In this experiment, standard equipment was used. The SLM was set for a minimum SPL of 20 dB (lin). In the higher frequency bands this was above the measured noise. For future measurements and especially in very quiet concert halls quieter measurement systems will be needed. A dynamic range of 70-80dB in the recording chain is a limit for full range recording of

louder programmes. More processing power would provide greater resolution in time and frequency, giving more detail of impulsive and intrusive noises.

6. CONCLUSIONS

Because of the small number of performances that have been analysed to date, any conclusions must be extremely tentative. There does appear to be a quiet moment of approximately 2 seconds in each act, related to the music, when the minimum ambient level occurs. The ambient level appears to be higher for opera and ballet than for a recital, where the background noise may be affecting the minimum ambient level. However, the measured minimum ambient level was not greatly affected by intrusive noise from photographers. The results so far suggest that the unoccupied noise will be masked by the ambient noise during a staged performance. More analysis is needed to see if the ambient noise of performance does at times approach the unoccupied noise and to relate the perception of noise to the measurements made. This investigation suggests that for performances considerable thought is needed as to what is actually meant by background noise, how it is perceived during performances and therefore how it should be measured. Subjective assessment suggests that intrusive noise (especially impulse sources) do not affect unoccupied or ambient noise measurement and this is another area to be investigated.

7. ACKNOWLEDGEMENTS

We would like to thank Ian Blackburn of the Royal Opera House Development team for supporting this work and making the recordings possible, and the Musicians Union, on behalf of the artists concerned, for their co-operation.

8. REFERENCES

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Noise Measurements during performance

Table 1 - Samples meeting NC Criteria

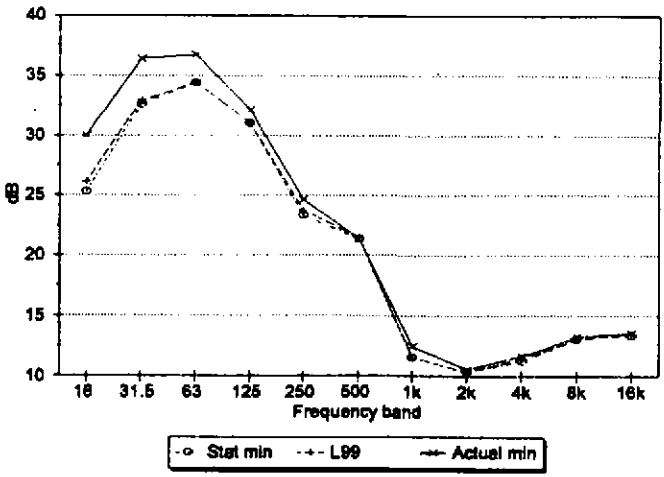
Noise Criteria : Percentages of samples

	NC15	NC20	NC25	NC30	NC35	NC40	NC45
Opera Rehearsal	0	0	0	0.13	0.74	1.61	3.21
Opera Performance	0	0	0	0.23	0.81	1.87	4.04
Ballet Performance	0	0	0	0.16	0.46	0.92	1.59
Recital	0	0	0.38	1.65	3.22	5.53	7.85
Unnoccupied Hall	1	94	97	100	100	100	100

Noise Criteria : Number of samples

	NC15	NC20	NC25	NC30	NC35	NC40	NC45
Opera Rehearsal	0	0	0	4	22	48	96
Opera Performance	0	0	0	7	25	58	125
Ballet Performance	0	0	0	6	17	34	59
Recital	0	0	8	35	68	117	166
Unnoccupied Hall	1	94	97	100	100	100	100

Figure 1
Unnoccupied noise



Noise Measurements during performance

Figure 2
Opera Performance

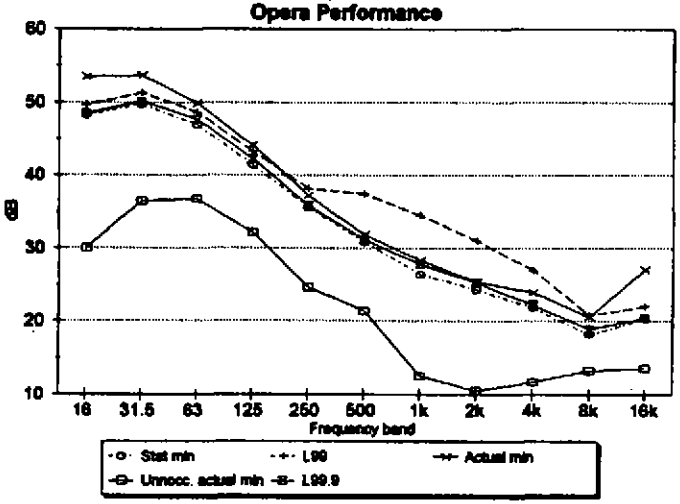


Figure 3
Actual minima

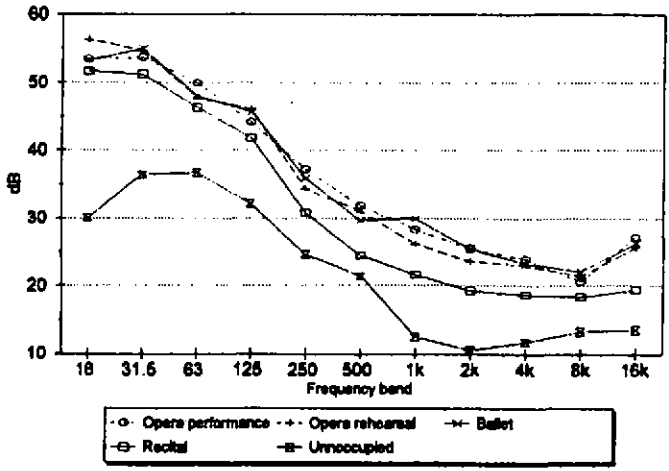


Figure 4
Opera performance Statistical levels

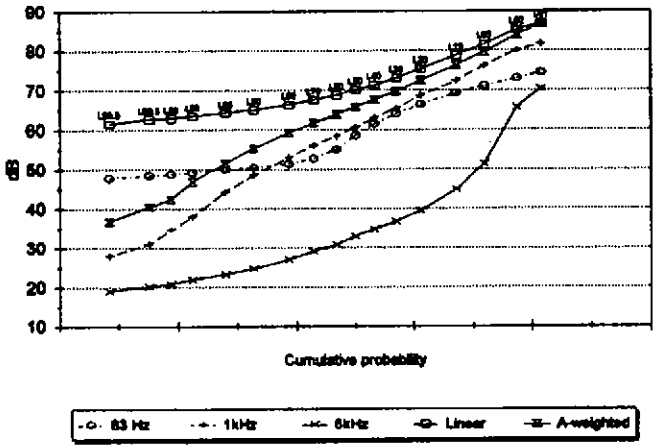


Figure 5
A weighted statistical levels