Proceedings of The Institute of Acoustics

GOOD ACOUSTICS FOR PERFORMERS

G.M. Naylor and R.J.M. Craik

Department of Building, Heriot-Watt University, Chambers St. Edinburgh

INTRODUCTION

Most research on platform acoustics has tended to perpetuate the habits formed in investigations of audience preference, devising parameters to describe energy ratios within room impulse responses [1,2]. However, the needs of performers differ fundamentally from those of the audience, and thus acoustical influences operate in different ways. The performer's requirements are mainly informational; he must hear himself sufficiently to enable correct pitching of notes and judgement of timbre, phrasing, etc., and he must get enough clues from other players to allow reasonably accurate synchronisation.

An orchestral musician receives at least two classes of signal, which affect his performance in different ways; one from his own instrument (the 'SELF' signal), and one from the player(s) he is trying to synchronise with (the 'OTHER' signal). There are often further signals present (held chords, figurations) which merely mask the information in the SELF and OTHER signals. These are termed 'interference' signals. The SELF and OTHER signals have their information content reduced by masking each other and by masking by interference signals. These masking interactions will be affected by the musical material and by the way the room modifies the signals involved.

MTF MODEL

This paper describes the factors affecting the ability of a musician to get ensemble information from the OTHER signal ('Hearing-of-OTHER'). The cues for synchronisation are contained mostly in attack transients, therefore the prime concern is good reception of the amplitude variations in other players' outputs. For this reason, this research has utilised a Modulation Transfer Function (MTF) approach. MTF concepts have been used with great success in predicting speech intelligibility [3], and they offer a consistent way of dealing with both room- and signal-dependent effects on ensemble. Fig. 1 shows an outline model of the masking between the various signals in MTF terms. Modulations of OTHER are degraded by the MTF of the transmission path, and then masked by SELF and interference modulations. To predict performer preference some weighting has to be applied to the resulting overall MTF (which will vary with modulation frequency) to produce a single figure.

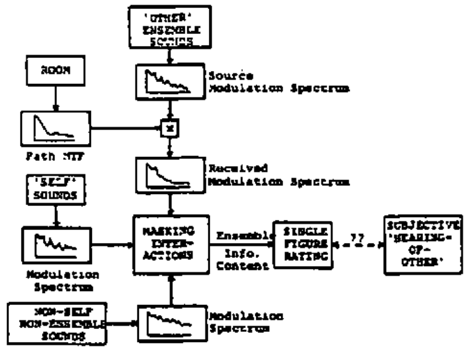

Fig 1. MTF modelof 'Hearing-of-OTHER'.

EXPERIMENTS

Using sound field simulation methods, musicians performed tasks of ensemble in variable acoustical and musical conditions, and made subjective judgements about them. The simulation arrangement enabled control of the level and delay of reflections and reverberation for the subject's own sound (SELF) and for the sound of his 'colleague' (OTHER, pre-recorded anechoically and reverberated during the trials). The (variable) reverberation time was the same for both signals. Subjects repeatedly played a 30-second piece under different conditions, and rated each trial for 'Hearing-of-OTHER' ("Your ability to gain from the other player the information necessary to support satisfactory ensemble"). They made ratings on a scale of categories labelled with adjectives (3 categories in experiment 1, 5 in experiment 2). The ratings were scaled from 0 to 1 for analysis.

Effects of level difference and musical material

Anechoic conditions were used in this experiment so that the only variation was in the level at which the pre-recorded accompaniment was heard. Three types of accompaniment were used; unison (11 subjects), one line of counterpoint (8), or three lines of counterpoint (4). Each subject completed 5 trials for each of 7 levels of OTHER. Subjects were violinists and 'cellists.

For each type of accompaniment, the mean value of 'Hearing-of-OTHER' across all subjects, as a function of the level difference between SELF and OTHER, is closely described (r = 0.98-0.99) by a curve of the form

$$\text{Hearing-of-OTHER} = \frac{1}{1 + 10^{-(L_o - L_s + k_s)/10}} \quad (1)$$

L_o and L_s are the average levels (L_{eq}) of OTHER and SELF respectively (each measured at the subjects ears with no other signal present). k_s is a shift factor dependent on the type of accompaniment. Eqn. 1 corresponds to the standard form of the MTF for a system exhibiting only signal-to-noise degradation, with the S/N ratio replaced by $L_o - L_s + k_s$. The subject uses differences in pitch, temporal development and arrival direction to help his detection of features in OTHER when masked by SELF. Hence the subjective masking is less than that measured by L_o-L_s, by an amount which is constant for each type of accompaniment. k_s represents this improvement. It is smallest for unison (when OTHER and SELF are most similar) and largest for triple counterpoint. Fig. 2 shows these results.

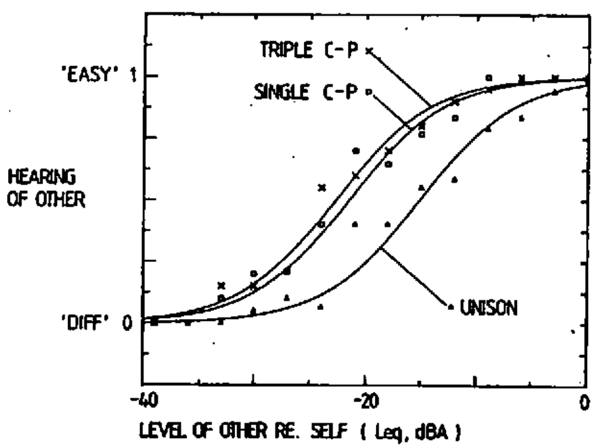

Fig 2. Hearing-of-OTHER plotted against level difference between SELF and OTHER. Curves are best-fit MTF's.

Effects of the room and signal levels

For this experiment room effects were included in the simulation, and both SELF and OTHER signals were reverberated. The impulse response transmitting the OTHER signal was varied by changing the reflection delays and levels, the reverberation time and level, and the total level of OTHER. 'Interference' musical sounds were also introduced at a variable level. 23 subjects took part (11 violinists, 6 'cellists, 3 oboists, 3 clarinettists), and each completed 4 repetitions of each of 19 conditions. The accompaniment was a single line of counterpoint.

An overall MTF expression was derived to include all these effects. The MTF of a system combining both path and noise degradation is given by the product of the MTF's for each type of loss[4]. The overall MTF, M_{TOT} may thus be expressed as

$$M_{TOT} = \frac{1}{1 + 10^{-(L_o-L_s+k_s)/10} + 10^{-(L_o-L_i+k_i)/10}} \times \overline{M}(\text{Path}) \quad (2)$$

The first term is for a system having two masking noises (SELF and interference). An improvement factor k_i is needed for interference masking, as was previously required for the masking by SELF. Estimates of k_s and k_i were derived from the experimental data. $\overline{M}$(Path) is the measured MTF of the impulse response transmitting the OTHER signal, averaged over the octave centre frequencies from 0.25-16 Hz. This averaging is an estimate of the required weighting for a single-figure index. In Fig. 3 the subject-averaged 'Hearing-of-OTHER' ratings are plotted against the measured M_{TOT} values for the 19 conditions, with a logarithmic regression line (r=0.99). In addition speech intelligibility curves from the literature are shown[4,5]. (Articulation Index (AI) and weighted MTF (WMTF) parameters are both roughly equivalent to M_{TOT}).

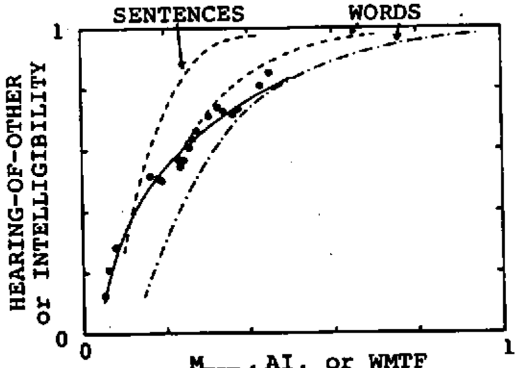

Fig 3. 'Hearing-of-OTHER' plotted against M_{TOT} (—•—), and Speech Intelligibility results (—·—·— ref. 4, --- ref. 5).

The results for music are quite similar to those for intelligibility of words. The present experiment however encompassed more complex masking situations than have been used with speech. The shape of the curve in Fig. 3 indicates a degree of 'redundancy' in the information passing between musicians, since considerable degradation of transmission can occur with little loss of understanding.

RELATIVE IMPORTANCE OF DIFFERENT VARIABLES

Level differences between the various signals seem to have more effect on 'Hearing-of-OTHER' than do changes in the impulse response transmitting the OTHER sound. Fig. 4 shows a tentative contour map of equal 'Hearing-of-OTHER' derived from the experimental results. The x-axis is the level difference, OTHER re. interference, and for the y-axis, the centre-time t_c has been used as a general measure of the 'reverberance' of the OTHER impulse response. A small change of level difference has as much effect as a large change of t_c. A similar picture emerges for the effect of SELF sound level.

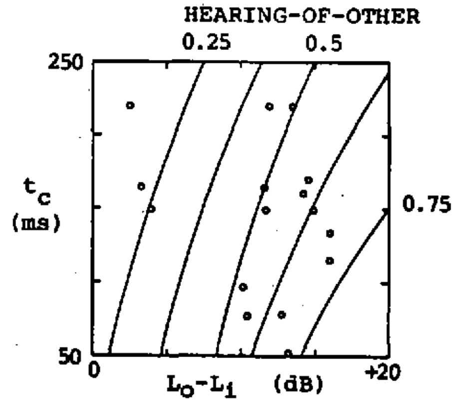

Fig 4. 'Hearing-of-OTHER' as a function of t_c and level difference.

CONCLUSIONS

The results of this study show that an MTF-based approach to acoustical effects on ensemble may be more productive than a conventional approach. The MTF model accounts for a wide range of effects and can be used to directly relate objective measurements with subjective preference. The results are similar to speech intelligibility results.

Total levels of the SELF, OTHER and interference signals are generally more important than temporal details of the transmitting impulse response. Closer study of the MTF model indicates that when 'Hearing-of-OTHER' is hard, extra OTHER energy is welcome even if it is caused by more reverberation. Reducing late energy will only improve 'Hearing-of-OTHER' when audibility is already adequate. Reflectors around concert platforms probably achieve the desired effect by increasing the total level of sound on stage rather than by increasing the early/late energy ratio.

ACKNOWLEDGEMENTS

We are grateful to all the musicians who took part in the experiments. This research was funded by the Science and Engineering Research Council.

REFERENCES

1. Marshall, A.H., D. Gottlob and H. Alrutz "Acoustical Conditions Preferred for Ensemble", JASA 64, p.1437, 1978.
2. Gade, A.C. "Subjective Room Acoustic Experiments with Musicians", Rep. No. 32, Technical Univ. Denmark, 1982.
3. Steeneken, H.J.M. and T. Houtgast "A Physical Method for Measuring Speech Transmission Quality", JASA 67, p.318, 1980.
4. Houtgast, T. and H.J.M. Steeneken "The Modulation Transfer Function in Room Acoustics as a Predictor of Speech Intelligibility", Acustica 28, p.66, 1973.
5. French, N.R. and J.C. Steinberg "Factors Governing the Intelligibility of Speech Sounds", JASA 19, p.90, 1947.