Difference Limen for Level of Music

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A psychoacoustic experiment has been conducted to determine the difference limen (DL) of the level of music reproduced in a listening room. The effects of three factors on the DL were measured using up to twelve trained subjects. The factors were music motif (Mozart, Elgar, Smashing Pumpkins), listening level (50, 60, 65, 70, 80 dB, A-weighted L_{eq}) and dynamic range. It was hypothesised that the DL would reduce with reduced dynamic range or increased listening level. However, both hypotheses are rejected: listening level was the only significant factor, with a mid-range level of 65 dB giving the lowest mean DL of 1.5 dB. This rises to a mean DL of 2.1 dB at listening levels of 70 and 80 dB. These figures are larger than has previously been assumed and are about the same size as the spatial standard deviation in strength across classical concert halls. The results should be of use to designers of concert halls, recording studios and other spaces for critical listening to music.

INTRODUCTION

When a sound source operates in a room, the sound pressure level will vary across the room. If the room is intended for critical listening (an auditorium or a listening room, for example) then the room designer will usually seek to minimise or at least control this variation. What should be the target for controlling the spatial variation of level? What would be perceived as a 'large' change in level? One way of answering these questions is to look for the smallest change in level which can be perceived: the difference limen (DL). This has been measured many times using simple signals like sine waves, but not, so far, with music as the source signal. The data for single-frequency measurements show quite a large variance across different experiments. Luce and Green [1] plotted results from six different studies showing difference limen (DL) against sensation level (SL) for a 1 kHz tone. Generally, DL decreased as SL increased, but the change was not monotonic in all experiments. The mean DL was 0.9 dB at 50 dB SL, and 0.6 dB at 70 dB SL.

Generally, smaller DLs are produced for continuous signals than for transients. Music is a much more complicated signal than a sine wave, so we should expect changes in its level to be harder to judge. In the architectural acoustics literature, various values for the DL with music have been assumed, though 1 dB seems to be typical [2]. The work reported here seeks to provide for the first time a difference limen measured with music in a realistic room acoustic. The results will be of interest to room acoustic designers who would like to know how audible a measured or predicted change in sound level might be—from one place in a room to another, or from one room to another, or from one design to another, for example.

METHOD

The music was reproduced to subjects through stereo loudspeakers in a listening room. An efficient adaptive psychometric method was used to conduct the test [3]. The stimulus is played to the subject at two different listening levels and their task is to say whether they perceive a difference in level. The test was controlled by a computer program that varied the difference between the two levels in each presentation according to the subject's last response. This allows it to approach the subject's DL to within a pre-determined level of accuracy (0.5 dB) in the minimum number of presentations.

Three parameters were varied, one at a time: music motif, listening (sensation) level and dynamic range. It was hypothesised that the DL may vary with music motif (perhaps across genres), that it would decrease as listening level increases, and that music with a smaller dynamic range would produce a smaller DL.

Three different musical motifs were used: Mozart (Horn Concerto: Rondeau: Allegro vivace), Elgar (Enigma Variations: Nimrod) and Smashing Pumpkins (Mellon Collie: Thru the eyes of Ruby). When the motif was varied, the listening level was fixed at 70 dB (A-weighted L_{eq}) at the listening position and the music was uncompressed. Five different listening levels were used: 50, 60, 65, 70 and 80 dB (A-weighted L_{eq} at the listening position). When the level was varied the motif was fixed at Mozart and the music was uncompressed. The effect of dynamic range was measured by electronically compressing the music and characterised by the difference L_1-L_{99}, measured at the listening position. The values used were 16 (uncompressed), 13.5, 12, 9.5 and 8 dB (all Mozart at 65 dB listening level).

All the subjects were acousticians or acoustics students, all had normal hearing at standard audiometric frequencies and all were experienced participants in psychoacoustic tests. Each subject completed a training programme, consisting of four consecutive measurements of their DL for a fixed combination of the parameters. Twelve subjects began the training programme; between four and seven subjects completed all tests for each parameter.

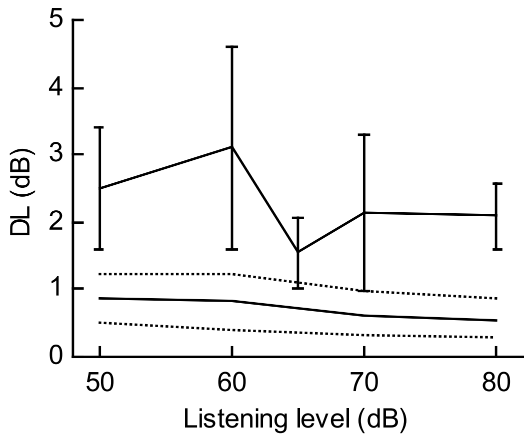

FIGURE 1. DL against level for music (upper line, ± one standard deviation); and for 1 kHz sine wave (lower lines: minimum, mean and maximum, after [1]).

RESULTS AND DISCUSSION

Three separate two-way analyses of variance (ANOVA) were conducted. Each ANOVA examined the variance due to one parameter compared with the variance between subjects. The results are summarised in Table 1. It is clear that the only factor significant at the 10% level was listening level.

There was some evidence of interaction between subjects and each of the factors. An interaction between music motif and subject, for example, implies that some subjects found it easier to hear changes in level in one motif, while other subjects found another motif easier. There is also tentative evidence that more complex music produces a larger DL. The rock music track gave 1.4 dB, as against 2.5 dB for Elgar and 2.6 dB for Mozart. However, these effects are not significant at the 10% level.

Perhaps surprisingly, the hypothesis that dynamic compression would reduce the DL is also rejected. This implies that it is not simply the range between the minimum and maximum levels in music that controls its amplitude perception. Finer detail, like the rate of amplitude change, as well as the rhythmic and tonal complexity, is likely to be more important.

Because level is the only significant factor here, we proceed to average across the other factors to produce the graph of DL against level in Fig. 1. The mean DL is seen to be considerably larger than both the commonly assumed DL for music of 1 dB, and the mean DL for a sine wave. For all listening levels except 65 dB, the DL is also greater than or equal to the spatial standard deviation of strength *G* measured in three halls by Bradley [4]. This suggests that, for Bradley's halls at least, judgements of sound quality between seats would be made primarily on criteria other than sound level.

Table 1. ANOVA results.

Factor	n	P-value
Music motif	3	0.21
Subject (music tests)	7	0.74
Dynamic range	5	0.19
Subject (range tests)	4	0.31
Listening level	5	0.06
Subject (level tests)	5	0.12

CONCLUSIONS

The difference limen for the sound pressure level of music has been measured. It was found to vary significantly with listening level, but the musical motif and its dynamic range were not significant. The size of the limen is significantly larger than that previously assumed. Future work might reveal whether it varies with other factors, such as reverberation.

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