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"NOISE AND LOUDNESS EVALUATION".

TECHNIQUES OF MAGNITUDE ESTIMATION AND MAGNITUDE PRODUCTION IN LOUDNESS SCALING

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Introduction

The attractiveness of techniques involving direct sensory magnitude assessment lies in the fundamental power function which appears to govern human response to stimuli. The power function produces a linear relationship between the logarithm of the subjective response and the relative energy in the stimulus on some logarithmic scale. The gradient of the relationship will be proportional to the exponent of the power function for that particular modality. In loudness assessment the exponent is generally accepted as being 0.3 (1).

If a variety of complex sounds are to be assessed, a calculation procedure such as perceived noise level (PNL) or effective perceived noise level (EPNL) must be used to estimate the acoustic energy entering the ear by accounting for the ear's frequency sensitivity. The most effective procedure for estimating the effect of noise on man would simply be the one which produced a linear relationship between the logarithm of the subjective magnitude and the procedure, with minimum scatter around the expected slope.

If the sounds to be assessed are restricted to various levels of the same frequency content, the problem of which calculation procedure to adopt does not arise, a simple sound pressure level measurement will suffice. One can then concentrate on the techniques to be used in assessing the magnitude of the subjective response.

Two approaches are commonly used:-

(a) Magnitude Estimation - A subject is asked to describe the loudness of a sound relative to the loudness of a standard sound level, which for convenience is often assigned on arbitrary magnitude.

(b) Magnitude Production - A converse technique in which the subject is given a standard sound level with a declared subjective magnitude and is requested to adjust the level of another sound until its magnitude is a certain multiple of the standard magnitude.

It has been suggested that a methodological bias operates in the techniques outlined above (2). The bias acts in such a way that the judgements in the continuum under control of the subjects i.e. numbers in magnitude estimation and sound levels in magnitude production, are restricted. The result of this bias is that estimation techniques produce characteristically low slopes whilst production techniques give high slopes, Apparently a less biased estimate of the true rate of change would be obtained by combining both techniques. It is not clear whether one bias exactly counteracts the other, however it is clearly unsatisfactory to rely on just one technique alone when estimating the slope of the loudness function.

As little information is available on the magnitude of such a bias and as the implications of such a bias are serious when considering experiments based on just one technique, an experiment was devised to examine its behaviour under various controlled conditions.

The Experiment

A level of 60 dB at 1000 Hz was assigned an arbitrary magnitude of 10 subjective units of loudness. Four separate experiments were performed in which the sound levels were varied over ranges of 73, 63, 43 and 20 dB around the standard level. A series of nine levels were chosen within each range. The subject heard each level twice. Twenty subjects were assigned to each range in which they performed both a magnitude estimation and a magnitude production experiment. Each subject worked within one range only. None of the 80 subjects whose ages ranged from 18 to 22 years had previously taken part in experiments of this type.

Results

To date, analysis has been performed on group data only. Linear regression lines have been obtained between the logarithm of the subjective responses and the sound pressure level of the sounds for both magnitude production and estimation for each range.

The highest range, 73 dB, gave the expected results. The magnitude production data resulted in a linear relationship with a higher slope than the magnitude estimation data. As the range of the experiment decreased however, so did the angular separation (regression angle) between the slopes for each technique. For the minimum range a reversal occurred in which the production slope was lower than the estimation slope.

Figure 1 shows the regression angle as a function of the range of the experiment. The surprising variation of the regression angle with range suggests that for a range of around 40 dB in this particular experiment the methodological bias is negligible.

Figure 2 indicates that when one technique produces a high slope the converse technique will give a lower slope.

Discussion

The inherent bias in the techniques of magnitude production and estimation appear to vary systematically with the dynamic range of the experiment. For a dynamic range of 40 dB the bias appears to be minimal. For this range only, either technique will produce the same result. The magnitude estimation technique with its speed of completion and simple procedure would tend to be used in any analysis.

Experiments involving other ranges would require a balanced design employing both estimation and production to minimize the bias. Because a high slope under one technique is counterbalanced by a low slope under the converse technique and vice versa, the combined experiment should result in slopes which are not strongly dependent on the dynamic range of the experiment nor the experimental technique.

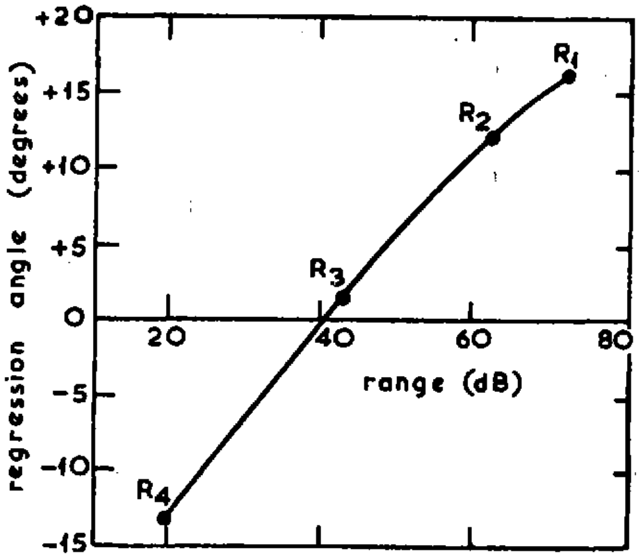

Fig. 1 Regression angle versus dynamic range of experiment.

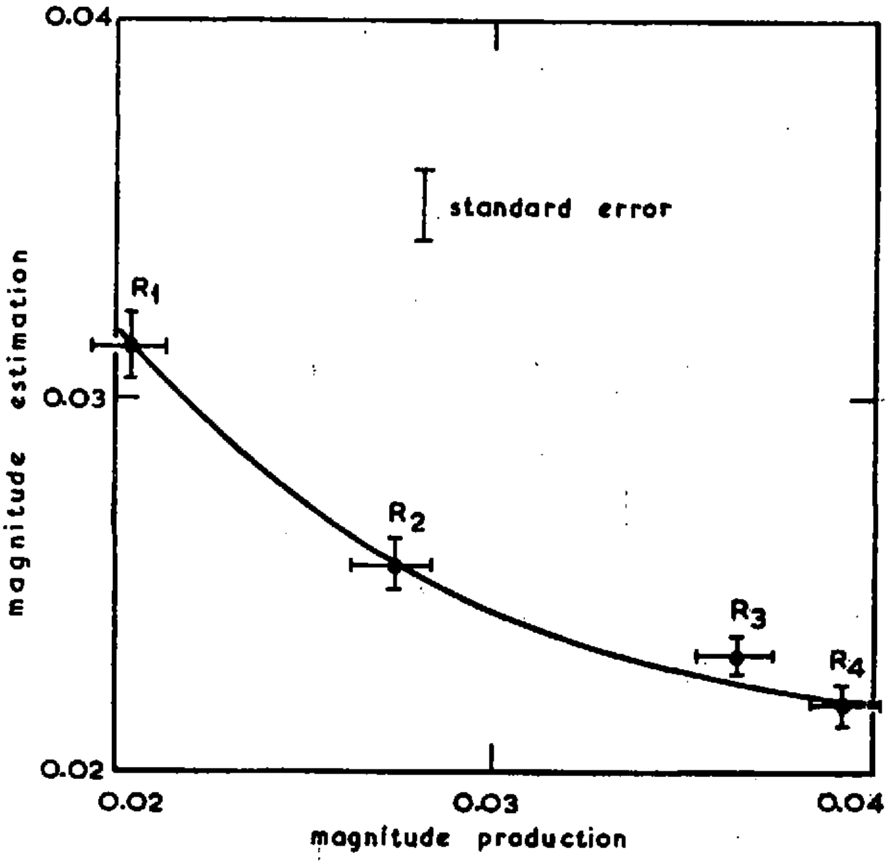

Fig. 2 Relationship between the slopes for the two techniques.

References

(1) S S Stevens (1955) 'The Measurement of Loudness', J. Acoust. Soc. Amer., 27, 815-829.

(2) S S Stevens and H B Greenbaum (1966) 'Regression Effect in Psychophysical Judgment', Perception and Psychophysics, 1, 439-446.