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THE EFFECT OF VARIATIONS IN THE MICROSTRUCTURE OF INDIVIDUAL LOW FREQUENCY THRESHOLDS AND LOUDNESS FUNCTIONS ON NOISE CONTROL CRITERIA.

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INTRODUCTION

Hearing threshold data, in the conventional audiometric range (125 - 8000 Hz), clearly shows the occurrence of (a) threshold differences between individuals and (b) the presence of sensitivity peaks with threshold variations of several dB's over small frequency intervals; the threshold microstructure (1, 2).

Further investigation of individual threshold microstructures has indicated the existence of similar variations at lower frequencies (25 - 125 Hz). A detailed study of the nature and magnitude of such variations has produced data showing that responses at low frequencies can vary significantly between subjects who otherwise display similar normal audiograms.

These variations are not strictly threshold phenomena but may in fact be reflected at suprathreshold levels. The diversity of auditory response at low frequencies between individuals must therefore be a prime consideration in low frequency noise control criteria.

A description of the variations and a possible explanation is presented.

DETECTION THRESHOLD MICROSTRUCTURE

Examination of individual low frequency detection thresholds has produced sets of data clearly indicating the existence of significant sensitivity variations over 1Hz frequency increments. (Fig. 1)

The microstructure of the detection threshold and near-threshold equal loudness curves do not display any general observable pattern with regard to the magnitude of variations, relationships between sensitivity peaks and troughs, or their shape.

In order to demonstrate the diversity in auditory response between individuals at low frequencies, detection threshold curves, obtained from a group of subjects displaying normal audiograms, are compared in Fig. 2. as a measure of sensitivity. The comparison not only demonstrates sensitivity variations with frequency but also the extent of differences existing between individuals.

EXPLANATION FOR VARIATIONS

The structural complexity of the ear and the complexity of the mechanism of hearing means that it is extremely difficult to isolate non-linearities in its behaviour. Variations in the ears' response over wide frequency ranges, for example the upper and lower frequency bands of the audio spectrum, can be easily explained by the behaviour of the middle ear. Response variations, such as those demonstrated at low frequencies, can only be realistically explained by the behaviour of the inner ear, whose correct functioning involves both mechanical and neural operations. Variations in the microstructure could be explained by non-linearities in either, or a combination of both.

There are reasons to suggest that at least some of the variations are due to irregularities in the mechanical behaviour of the basilar membrane (3, 4). The basilar membrane possesses elasticity and depends on graded variations of stiffness and mass along its length to cause different parts to resonate at different frequencies, resulting in basilar membrane tuning characteristics. Any variations in these physical properties will result in different selectivities for different frequencies. Evidence suggests, however, that mechanical non-linearities are not a general feature of the cochlea and, if they exist, are not necessarily responsible for variations in detection response.

A more likely cause is the behaviour of the neural transduction system. Evidence to show cochlea potential and nerve fibre non-linearities has been found (5), where inflexions in the fibre discharge rate against intensity of stimulation of individual nerve fibres vary between spontaneous activity and saturation (6).

Figure 3 demonstrates predicted response with varying levels of neural activity for a particular nerve patch in the cochlea transduction mechanism. The level of activity required to produce a particular response is dependent on both stimulus intensity and frequency.

The dependency of the response on intensity and frequency can best be explained by nerve fibre activity and differences in nerve fibre sensitivity distributions in particular areas of the cochlea. The presence of less sensitive or even damaged fibres may reduce a particular response and similarly a response may be increased where more sensitive areas exist. This is shown in Fig. 4 (7) where variations in nerve fibre sensitivities and sensitivity distribution result in responses occurring at different levels of stimulation. As fibre distributions vary with basilar membrane position, responses are frequency dependent and can vary over small frequency changes.

The loudness growth with intensity at low frequencies has been shown to be much more rapid than for mid-frequencies and sensitivity variations in the threshold or near threshold region result in an extremely diverse range of individual subjective responses.

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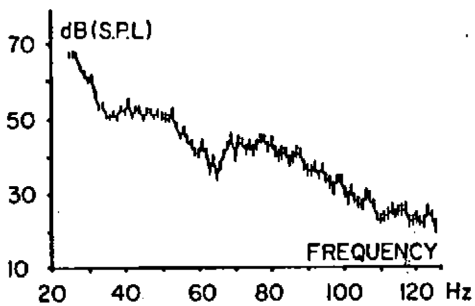

Fig. 1 Low Frequency Detection Threshold Microstructure

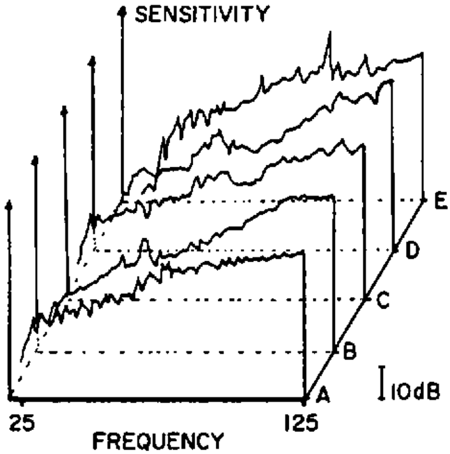

Fig 2. Comparison of Individual Low Frequency Sensitivities

1. ACCEPTED RESPONSE

2. & 3. EXAMPLES OF VARYING SENSITIVITY DISTRIBUTIONS

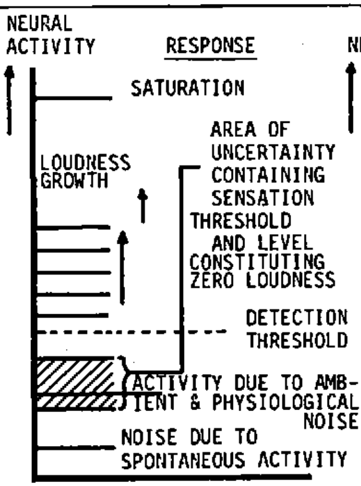

Fig. 3 Predicted Response to Varying Levels of Neural Activity

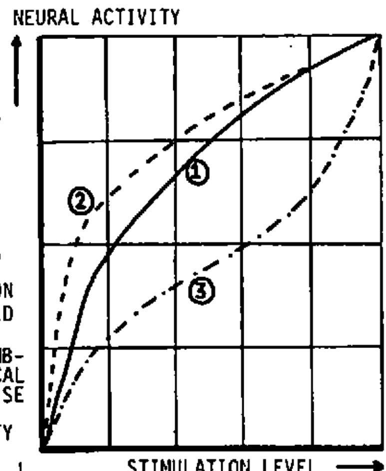

Fig. 4 Neural Activity as a Function of Stimulation Level