Effects of the frequency of amplitude-modulated signals on the auditory evoked response

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The relationship of the N_1P_2 voltage of the auditory averaged evoked response elicited by amplitude modulation has been studied. The stimuli were monaurally presented steady tones of 0.5, 2.0, and 4.0 kHz at 60-dB HL, with 10-dB ramp modulations every 5 sec. The amplitude of the response decreased as the frequency increased.

The effects of the frequency of transient signals on the averaged auditory evoked response (AER) amplitude have been observed by Antinoro & Skinner (1968), Evans & Deatherage (1969), and Rothman (1970).

Generally, the data indicate a negative relationship between frequency and AER amplitude, e.g., the amplitude decreases progressively as the frequency increases. The observers are of the opinion that the AER amplitude is related to the number of neural units activated in the cochlea. Lower frequencies produce a much greater disturbance of the basilar membrane than do higher frequencies.

This hypothesis would predict that an increase in intensity of a continuous tone, which is physiologically reflected in an increased number of fibers activated, would result in a proportionally similar frequency effect. The study reported here was designed to investigate the effect of the frequency of amplitude-modulated (AM) tones on the amplitude of the averaged auditory evoked response.

METHOD

The Ss were four young adults with hearing within normal limits for the stimuli used in the study. Tones were generated by a custom-built audiometer. The continuous signals were pure tones of 0.5, 2.0, and 4.0 kHz, at an intensity of 60-dB HL. At 5-sec intervals, the intensity was increased 10 dB. The amplitude-modulated signals had a rise

time of 25 msec and a duration of 300 msec. The tones were presented monaurally through headphones while Ss were seated in a sound-attenuated chamber.

Electroencephalic activity was recorded from solder electrodes at vertex, referred to left mastoid with a forehead ground. Responses were summated over 70 presentations by a Nuclear Datal Enhantetron 1024 and written out by an X-Y plotter. The analysis time was 4 sec. The amplitude of the first negative and second

Fig. 1. Amplitude change (re 0.5-kHz response) as a function of the frequency of amplitude modulated tones is plotted for four Ss.

positive waveform peaks was measured. The decrease in voltage at 2.0 and 4.0 kHz was assessed relative to the 0.5-kHz amplitude.

RESULTS

The results are summarized in Fig. 1. The relative decrease in voltage is plotted as a function of frequency. The amplitude difference values averaged over the four Ss resulted in a mean decrease of 3.4 microV for 2.0 kHz and a mean decrease of 4.5 microV for 4.0 kHz re: 0.5-kHz amplitude.

DISCUSSION

A general finding that amplitude decreases as frequency increases has led to the assumption that the increased neural units stimulated by the lower frequency are responsible for the differences in the audioelectroencephalogram. A similar frequency effect was noted by Lenhardt (1971) for frequency-modulated tones. A tone that swept from 0.5 to 0.55 kHz elicited a mean increase of 3.4 microV over a tone that swept from 2.0 to 2.2 kHz. The identical N_1P_2 voltage found in this study, using another method of stimulation (AM) within a frequency region, adds credibility to the assertion that the frequency effect is, indeed, real.

In summary, the explanation relating the increased amplitude to increased neural activity at the cochlea is applicable to transient signals of different frequencies, steady tones with frequency modulation, and steady tones with amplitude modulation. At this time, the evidence is not conclusive but suggestive. The averaging technique is still not appropriate for measuring the effect of frequency without confounding it with other parameter changes. In judging the importance of the findings, stimuli frequency, if not critical, should be low to elicit the greatest evoked signal in the background noise. Clinically, a response elicited with a low-frequency stimulus but not with a high-frequency stimulus at the same intensity may not be exclusively a result of a loss of acuity but due to the nature of the AER.

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