INTRODUCTION

Loudness measurement serve two important clinical functions in audiological practice: to determine the adjustment of hearing aids (1) and to distinguish the site-of-lesion in sensorineural hearing loss (2). The Contour Test is a well established clinical method to quantitate loudness perception. This test was designed to develop a function that describes the growth of loudness perception as input levels increase from near-threshold to uncomfortably loud.

Several studies have proposed that loudness growth could be estimated using click-evoked ABR (3.4.5). In these studies, the latency or the amplitude of the ABR has been used as an indicator of loudness. The major disadvantage of this procedure is the lack in frequency specificity of the ABR (6).

Auditory steady-state responses overcome in part the limitations of ABR testing. First, the Auditory Steady-State Response (ASSR) are much more frequency specific than clicks used with ABRs (7), secondly they are faster since the two ears can be stimulated at the same time (8) and thirdly they are more objective since the responses can be statistically analyzed (9). An electrophysiological measure of loudness growth could assist audiologist in the estimating of discomfort levels (10) and in the determination of hearing aid characteristics (6). Objective measurement of loudness can be included in the prescription of gain in order to fit hearing aids within the first few month of age.

The purpose of this study is to provide of whether we can establish a relationship between subjective loudness growth derived from the Contour Test and the physiological response obtained from the Auditory Steady State Responses.

METHOD

Subjects

20 individuals participated in this study. Ages ranged from 18 to 37 with a mean of 24 years. This group was divided in 9 men and 11 women. Each subject underwent a complete audiological evaluation before the evoked potentials examination. All subject reported a normal auditory function.

Auditory Steady-State Responses

All the responses were obtained with the AUDIC system (Neuronic S.A., Havana). The EEG was recorded using a forehead to ipsilateral earlobe/mastoid electrode montage, amplified and filtered at 10 Hz to 300 Hz. Impedance values were kept below 2k Ohms. The bioelectric activity was amplified with a gain of 100,000. Between 18 and 42 epochs of 8192 samples (1.37 ms sampling period) were averaged in each response. Artefact rejection was carried out with shorter epoch sections of 512 points. The Fast Fourier Transform (FFT) was calculated on line with each long epoch. When an epoch-averaged electrophysiological activity exceeding ±00 nV, it was rejected. To detect the steady-state responses the Hotelling T2 (HT2) test was used (9). A response was considered present when the F-ratio of the signal to noise was significant at the p<0.05 levels.

Contour Test

Tonal stimuli were 5% warble tones presented at four frequencies (.5, 1, 2 and 4 Khz). Order of frequency presentation was randomized. The stimuli sequencing was in ascending in 5 dB steps. Stimuli were delivered monaurally by the TDH-39 earphone. Subjects were instructed to provide a verbal judgment of the perceived loudness rating in seven categories ranging from very soft to uncomfortably loud. A run began with a stimulus delivered one increment above threshold and continued in an ascending fashion with the subject providing a loudness category for each stimulus. The run terminated when a judgment of uncomfortably loud was given. Each stimulus was tested using four conditions; the value for each loudness category was computed as the median sound pressure level of responses using that category across the four runs.

RESULTS

We select from our data a single case in order to illustrate this presentation. On the left we show the ASSR recorded at four intensities ranging from 80 to 20 dB HL for the four frequencies presented at both ears. Arrows indicate a significant response. In this particular case, clear responses at all carrier frequencies are observed at high intensities levels. As the intensity decreases the amplitude of the responses decreases. On the right we show the results of the Loudness Contour Test for the same subject. As expected the sensation of loudness decreased as the intensity of the stimulus decreased in both ears.

This figure depicts loudness growth for the warble tone stimulus for the five intensities for all subjects studied. Within each stimulus the results show the expected increase in mean levels as loudness categories increased. No significance differences were found between frequencies.

The amplitude-intensity function of the ASSR decreased as the intensity become lower for the four carrier frequency studied. At low intensities amplitudes of the ASSR are closer. At higher intensities the amplitude differences between the carrier frequencies increase.

The table at the right shows the ASSR recorded at intensities ranging from 80 to 10 dB for both ears and the corresponding modulation rate for each carrier frequency. The standard deviations reveal that the between-subject variability was fairly similar for a given intensity level across carrier test frequencies. The variability increase as the intensity level increased. At low intensities the amplitude of the physiological responses seems to be equal over all subjects.

The figure shows a Multiple Regression Analysis explaining a 70% of the total variance. The Predicted Loudness is defined by this equation that include the intensity and the amplitude of the ASSR. The table at the right shows the result from the multiple regression analysis predicting loudness with a high correlation index regardless the frequency.

DISCUSSION

1) In this study we have shown how the perception of loudness obtained from the Contour Test and the amplitudes of the ASSR decreased as the intensity level of the stimulus decreased.

2) The loudness growth function is independent of the frequency of the stimulus. The amplitude of the ASSR depends on the carrier frequency.

3) Our objective was to found a relationship between loudness and the ASSR. In this sense a significant correlation was found.

4) Including the intensity in our equation together with the amplitude of the ASSR we can explain up to a 70% of the total variance.

Finally this preliminary data indicate that the amplitude of the ASSR can be a promising procedure in order to estimate the perception of loudness by electrophysiological responses.

REFERENCES


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