UNCOMFORTABLE LOUDNESS LEVEL IN NORMAL HEARING ADULTS DERIVED FROM THE AUDITORY STEADY STATE RESPONSES

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ABSTRACT

Determination of the frequency-specific uncomfortable loudness level (ULL) is an important requirement for hearing aid fitting. Subjective ULL assessment procedures are of limited value in neonates, infants, babies, toddlers and un-cooperative children and adults. Alternative objective techniques such as physiological measures have been used in order to predict subjective ULLs.
In this study is established whether the Auditory Steady State Responses (ASSR) can be used to predict uncomfortable loudness levels (ULLs) in a group of normal hearing adults. Subjective ULLs were obtained using standard procedures. Objective ULL were obtained from parameter-intensity functions using amplitude and phase of the ASSR.
Preliminary result shows that the best predictions of the subjective ULL were using individual phase-intensity functions. Poor predictions were obtained from the amplitude-intensity functions due to high inter-subject variability. The best predictions were considered sufficiently accurate to warrant further investigation in patients with varying degrees of hearing loss.

INTRODUCTION

Recent years our attention has focused in obtaining an objective measurement of loudness sensation.

A principal aim in the adjustment of a hearing aid is to prescribe the enough gain to make speech audible. Accurately measurements of ULL determine the appropriate output and compression characteristic of the hearing aid. Most prescription formulas derive the Maximun Output of the hearing aid from the measurement to the ULLs. The main consequence of setting the maximum output too high is the problem of aided loudness discomfort for high-level sounds.

ULL usually are obtained by psychophysical procedures. In this test, all patients are required to assign a category to sound from very soft to uncomfortably loud. The clinicians usually do not measure across the full continuum. End points are estimated in order to reduce the time of the clinical examination. However, subjective techniques cannot be used in all patients such as newborns or uncooperative patients.

An important alternative is to predict the ULLs from objective techniques. Acoustic reflex have been proposed in the past in order to obtain an objective measurement of ULL. The principal lack of this procedure is that in a large proportion of subjects this technique may be absent due to abnormal middle ear function.

Other alternative approach is to use Auditory Brainstem Response. However, the ABR technique has limitations. The major disadvantage is that they can only provide an estimation for the high frequencies.

PROCEDURE

In our study, we use the ASSR since they are more frequency specific than ABRs and they are less time consuming since both ears can be stimulated simultaneously. Two tone of 500 Hz and 3 kHz were presented binaurally through earphones. The responses for each tone were obtained in independently recordings. Each stimulus consisted of a carrier tone modulated in amplitude at the following rates in red for the right ear and in blue for the left. The active electrode was fix in the vertex.

Subjective ULL were measured using the procedure recommended by the British Society of Audiology. The same acoustic stimulus employed for the SSR recordings were used to obtain the ULLs for each patient. Stimulus intensity were re-calibrated in dB referred to the ULL for each ear tested.

SUBJECTS

In the study, participated 8 individuals with ages ranged from 18 to 37 with a mean of 24 years. Each subject underwent a complete audiological evaluation before the Evoked Potentials examination. All subjects reported a normal auditory function.

Table 1: Characteristics of study group.

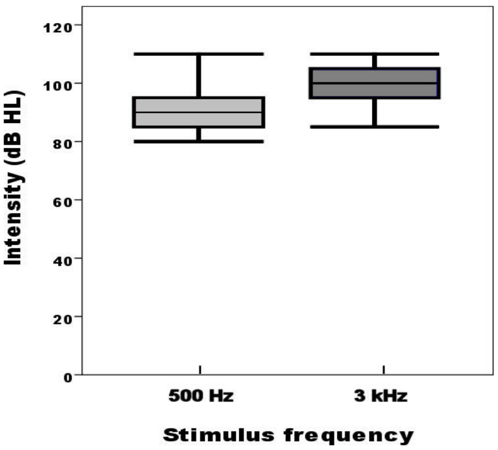
FRE-QUENCY	MEAN THRESHOLDS (dB HL)		SD (dB)	
	MALE SUBJ.	FEMALE SUBJ.	MALE SUBJ.	FEMALE SUBJ.
250	19,2	18,2	5,1	4,9
500	12,8	13,2	4,6	3,1
1000	10,0	8,2	4,3	4,2
2000	5,3	6,4	3,6	5,6
3000	4,7	3,9	4,7	5,2
4000	4,6	3,5	6,3	6,0

RESULTS

The next figure, we represent the measurement of the subjective ULL displayed in box plot by the stimulus frequency. The mean ULL for all subjects study for the left ear were 91 dB HL while for the right ear the mean

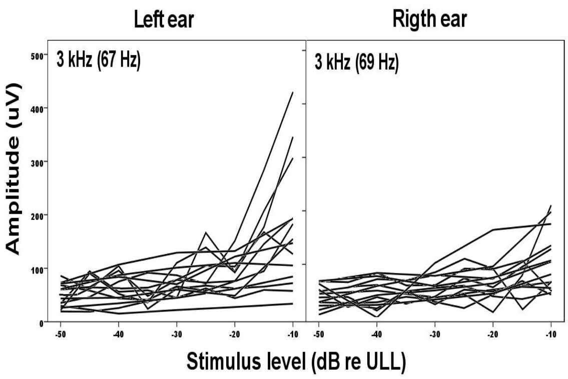
ULL was 102 dB HL. In conclusion, significant differences were found between both stimulus frequencies.

Figure 1: The measurement of the subjective ULL by the stimulus frequency.



We obtained a general trend in the data in the carrier frequency of 3 kHz. The amplitude of the ASSR fall in the increment of the stimulus level. This effect is clearly for the left ear than for the right. In the case of 500 Hz carrier frequency, a great variability is observed for both ears. However we can observe a tendency in the decrease of the amplitude of the ASSR as the stimulus level decrease in the right ear.

Figure 2: the amplitude intensity function for each subject for the 3 kHz carrier frequency.



In this figure, we show the inter-subject average amplitude-intensity function. A linear regression analyses was carried on over the data. Linear regression fits the data reasonable well for 3 kHz recordings. Worst results were found for the 500 Hz responses, specially for the right ear were a non-significant correlation was obtained.

Figure 3: the amplitude intensity function for the 500 Hz carrier frequency for the right and left ear.

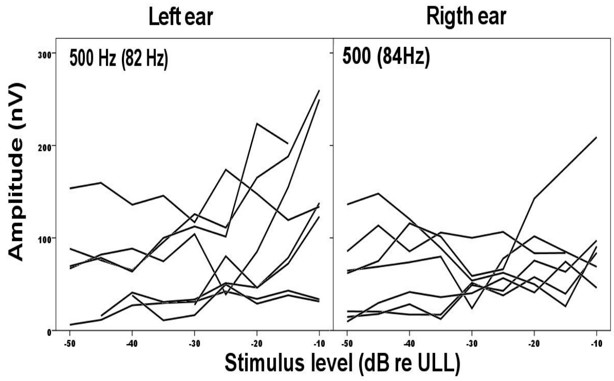
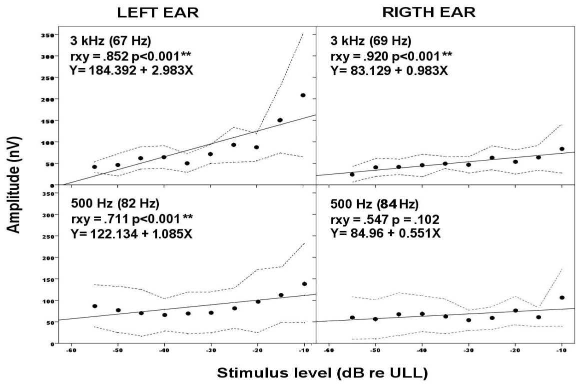
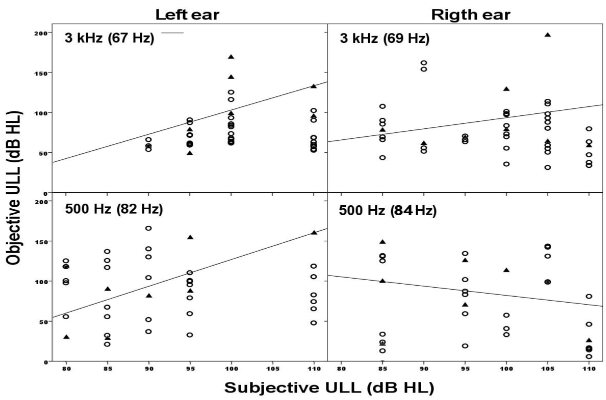


Figure 4: the inter-subject average amplitude-intensity function .



This graph shows objective ULLs predicted from average intensity functions plotted against subjective ULL. In the figure, we represented two subtest. One hand, the open circles indicate data derived using stimuli at levels between 75 and 80 dB HL. On the other hand, filled triangles are the target intensity ULL. We can concluded that the desviation from this line is considerable and no significant difference was found between the two subtest.

Figure 4: objective ULLs predicted from average intensity functions plotted against subjective ULL.



CONCLUSIONS

1. ULL prediction based solely on individual ASSR amplitude-intensity function probed to be problematic.
2. High correlations were found only for the 3 kHz carrier frequencies.
3. Stepper amplitude- intensity function were found for the left ear than for the right ear.
4. A high intersubject variability in the amplitude-intensity function was found.

Further studies are carried out in our lab with a large sample of subject and including in the analysis additional parameters such the phase and latency of the ASSR.

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