Prediction of Loudness Growth in Subjects with Sensorineural Hearing Loss Using Auditory Steady State Response

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Introduction

- Sensation of loudness is a subjective response to the physical dimension of sound intensity (Moore, 1989).

- Loudness perception involves a two-stage process:
  First: the stimulus evokes a loudness sensation.
  Second: the listener assigns a judgment relative to the magnitude of the sensation (Jenstad et al., 1997).

Introduction

Loudness measurements serve two important clinical functions in audiological practice:

- To determine the adjustment of hearing aids.
- To distinguish the site of lesion in SNHL (Zenker, 2002).

Introduction

- Subjective judgment of loudness is often obtained to define the most comfortable level, or the most uncomfortable loudness level.
- Among the approaches of determining loudness growth function, categorical scaling is the most frequently used due to short completion time and the simplicity of the patient task (Allen et al., 1990).
- Contour Test offers a viable approach to clinical measurement of loudness perception (Cox , et al., 1997).

Introduction

- Subjective methods for judgment of loudness are of little or no value for the assessment of very young children, older patients or those with attention-deficit. Therefore an accurate, reliable and precise objective measure is needed.

Introduction

- Objective methods for estimating loudness growth using electrophysiological measures as Click-evoked ABR and OAEs have been proposed (Picton et al., 1976, Neely et al., 2003 & Epstein and Florentine, 2005).
- However, these methods are limited because they require frequency-by-frequency and/or ear-by-ear testing. The major disadvantage of procedures based on ABR measurements is the lack of frequency specificity of this response (Ménard et al., 2008).

Introduction

- Auditory steady-state response (ASSR) is an electrophysiological response of the brain to regularly repeating auditory stimuli (Picton et al.,2003).
- ASSR seems promising for estimating the physiological threshold and for more complex auditory exploration (Ménard et al.2008).

Aims of The Work:

- To establish whether there is a relation between loudness growth derived from the contour test and the ASSR in normal hearing subjects and subjects with SNHL.
- To use the amplitude of the ASSR to predict loudness at different frequencies.

Subjects &Method:

This study consists of two groups:

- Group I: 15 adult subjects with normal hearing.
  (hearing threshold< 20dBHL).
- Group II: 15 patients with bilateral moderate SNHL.

Subjects & Method

All subjects were submitted to:

1- Full audiological history and otological examination.

2-Basic audiological evaluation including: Pure tone audiometry, Speech audiometry and Immittance test.

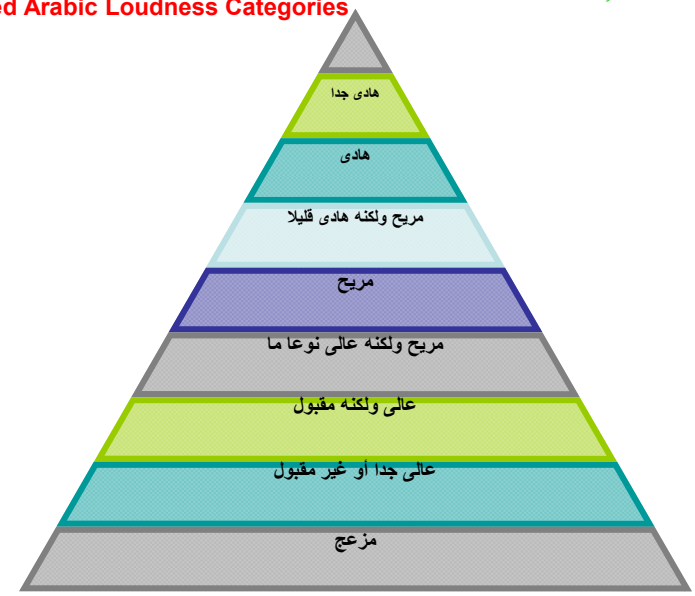
Subjects & Method

3- Contour Test to obtain the loudness growth:

- Methodology of the Contour test recommended by Cox et al., (1997) was applied.
- Subjects were instructed to provide a verbal judgment of the loudness perceived according to eight categories applied by the modified Arabic form (Elshintinawy and Kolkaila,1999).

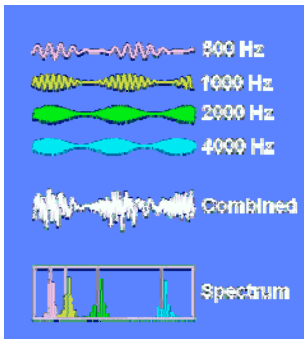
Subjects & Method

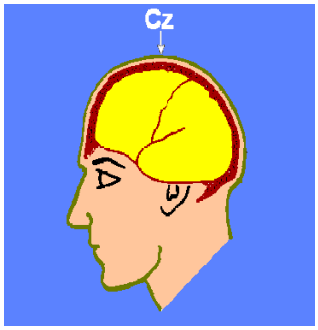
Modified Arabic Loudness Categories



Subjects & Method

4- ASSR Recording Procedure Using Binaural Multiple Paradigm:





Acoustic Stimuli:

Carrier frequencies :
0.5, 1, 2 & 4 Khz.
Modulation rates:
77, 85, 93 &101(Rt)
79, 87, 95 &103Hz(Lt)

Electrode Arrangement:

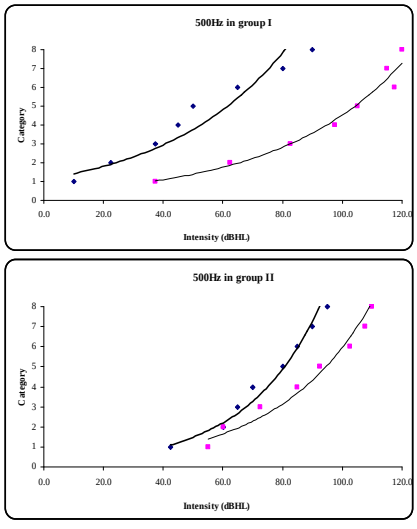
Positive electrode: at high forehead (Fz).

Ground: lower forehead (Fpz).

Negative electrodes: both mastoids (M1& M2).

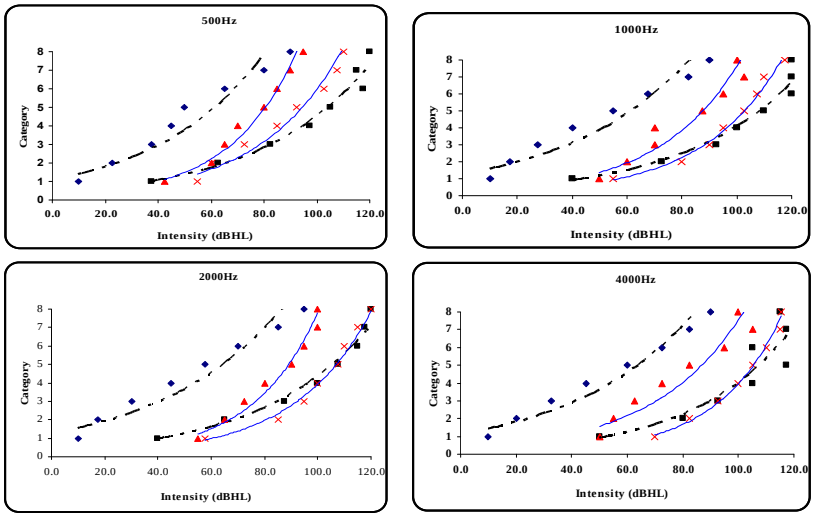
Results & Discussion

The Contour Test for Judgment of Loudness



- The loudness growth function curves in the two groups.
- The points represent the upper and lower limits of the normal range at each category.
- The solid lines represent the best fitted curves to the upper and lower limit values.

The Contour Test data for the two groups

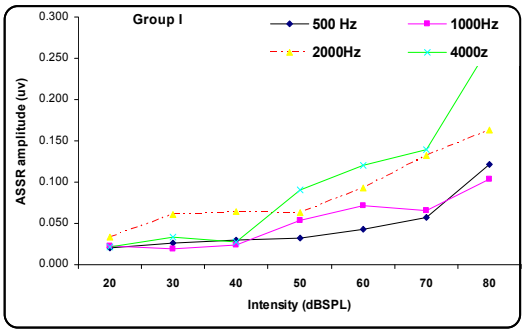


There was an increase of loudness as the intensity level of the stimulus increases

- Large difference was observed in the dynamic range between normal hearing subjects (Group I) and subjects with SNHL (Group II). These results agreed with Sherlock and Formby, (2005) and Zhonghua et al., (2008).

Amplitude-Intensity function for the ASSR

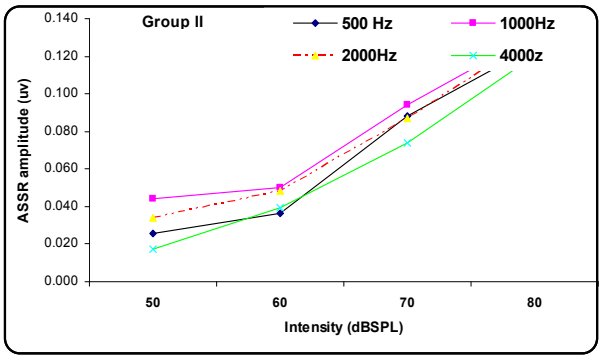
In Normal Hearing Subjects:



- The amplitude of the ASSR increases as the intensity increases.
- The ASSR amplitudes are closer at lower intensities, in contrast to higher intensities the ASSR amplitude differences between the carrier frequencies increases.
- The differences between the amplitude of the ASSR were larger at high frequencies than those obtained at low frequencies. These results agreed with Zenker et al., (2008).

In Subjects with SNHL:

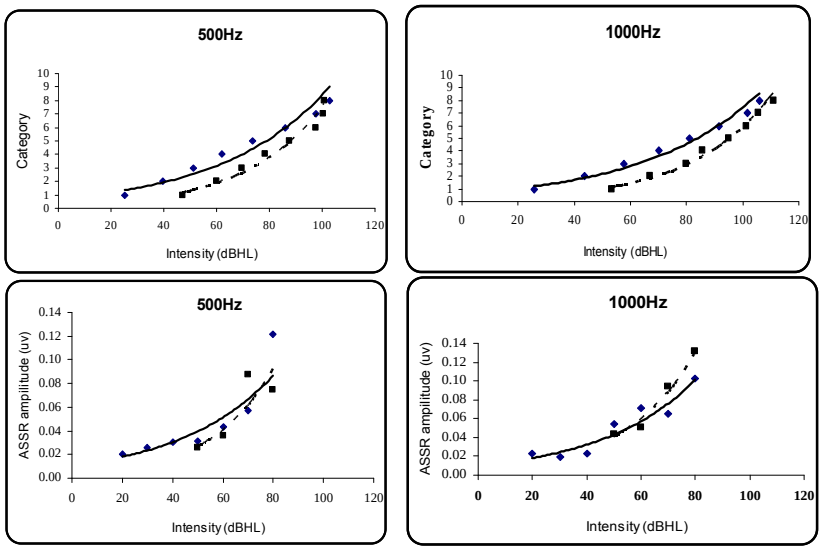
Results & Discussion



- The ASSR amplitudes were closer at lower and higher intensities. Also, there was no difference between the amplitude of the ASSR at high frequencies than those obtained at low frequencies.

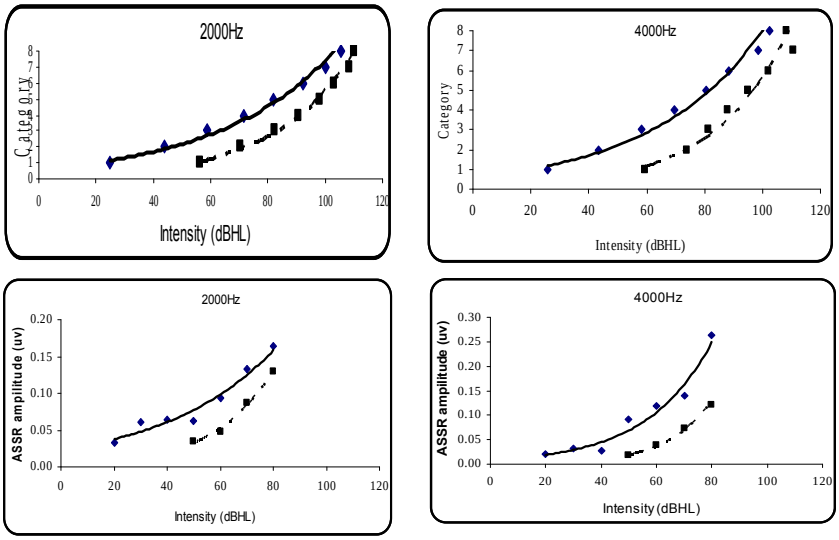
Results & Discussion

Loudness judgment detected by the contour test and ASSR amplitude as a function of stimulation intensity for 500 Hz and 1000 Hz



Results & Discussion

Loudness judgment detected by the contour test and ASSR amplitude as a function of stimulation intensity for 2000Hz and 4000Hz in the two tested groups



Results & Discussion

- The results of this study showed that the amplitude of the ASSR response increases with increasing levels of intensity for all carrier frequencies studied.
- In general, amplitude was larger for higher intensity levels if compared to lower intensity levels. These results are similar to others reported employing the 40-Hz response (Kuwada et al, 1986; Rodrıguez et al, 1986; Picton et al, 1987 and Barajas et al, 1988) and the multiple ASSR technique (Herdman & Stapells, 2001 Dimitrijevic et al, 2002; Picton et al, 2005 and Vander & Brown, 2005).

- In order to establish a relationship between loudness growth function and the ASSR in normal hearing subjects, we applied a linear regression analysis between the electro-physiological responses (ASSR) and the psychophysical judgment of loudness (Contour test).

In Normal Hearing Subjects:

	1000Hz	2000Hz	4000Hz
Y "intercept"	5.990	5.871	6.174
Slope	9.000	10.938	8.454
Equation	L=5.99+9*Amp.	L=5.871+10.938*Amp.	L=6.174+8.454*Amp.
R	0.546	0.616	0.551
Std. Error of the estimate	0.875	0.823	0.871
Predictors: (Constant), Amplitude of the ASSR			
Dependent Variable :Loudness			

✓A significant relationship between ASSR amplitude and the subjective measurement of loudness (Contour test) was found.

✓This relation was significant at 1000, 2000 &4000Hz. These results agreed with (Zenker, et al.,2008).

- ✓ Furthermore, in order to be able to predict the loudness growth function from the ASSR amplitude, multiple regression analysis was applied on data of normal hearing subjects.
- ✓ The result of predicted loudness was expressed by an equation that includes both the intensity and the amplitude of ASSR.

Predicted Loudness = 3.371+ 1.05 intensity +14.01 amplitude

Predicted Loudness = 3.371+ 1.05 intensity +14.01 amplitude

- ✓ By applying this equation on the SNHL patients we could predict the loudness growth of those patients.
- ✓ Then, independent T- test was applied between the subjective loudness obtained from the contour test and the predicted loudness from ASSR using the previous equation at the 50, 60, 70, 80dB intensity, as well as from the recorded ASSR amplitude.

Comparison between the subjective loudness detected by the contour test and the objective loudness predicted from ASSR:

Intensity		Subjective Loudness	Predicted Loudness	P-Value
50dB	Mean	54.82	55.37	0.08
	(SD)	(2.39)	(2.42)	
60dB	Mean	68.49	67.78	0.58
	(SD)	(13.9)	(2.03)	
70dB	Mean	79.3	78.64	0.59
	(SD)	(13.57)	(2.01)	
80dB	Mean	89.44	90.12	0.55
	(SD)	(11.82)	(3.82)	
Total	Mean	73.39	75.12	0.105
	(SD)	(18.17)	(14.76)	

There was no statistically significant difference between the subjective loudness growth and the predicted loudness (P≥0.05)

Conclusions

- ✓ ASSR amplitude and loudness sensation judgments increase as the stimulus intensity increases for the four studied frequencies in both normal hearing subjects and subjects with SNHL.
- ✓ A significant relationship was found between Loudness and the amplitude of the ASSR in normal hearing subjects and subjects with SNHL.

- ✓ Prediction of loudness from ASSR might provide an objective measurement that could be used to adjust compression functions or maximum amplification levels of hearing aids.
- ✓ Loudness estimation by ASSR can be clinically helpful especially in uncooperative patients where psychophysical measurements can not be obtained.