

Effect of Audiometric Configuration on Auditory Steady-State and Brain-Stem Response Thresholds

Thesis submitted for partial fulfillment of
The Master Degree of Audiology.

By

Hany Ibrahim Ahmed Khirallah
(M.B.,B.ch)

Supervised by

Prof. Dr. Adel Ibrahim Abdel Maksoud

Professor of Audiology
Otolaryngology Dept.
Faculty of Medicine
Ain Shams University

Dr. Eman Abdel Badie Mohamed

Consultant of Audiology
Hearing & Speech Institute

Dr. Nithreen Mohammed Said Abdel Salam

Lecturer of Audiology
Otolaryngology Dept.
Faculty of Medicine
Ain Shams University

**Ain Shams University
2010**

-

تأثير الشكل العام لتخطيط السمع على حساب مستوى فحص السمع المباشر بواسطة الحافز ذو الحالة المستقرة وفحص السمع بالكمبيوتر

رسالة مقدمة توطئة للحصول على درجة الماجستير في السمعيات

من

الطبيب/ هاني إبراهيم أحمد خيرالله

تحت إشراف

أ.د. عادل إبراهيم عبد المقصود

استاذ السمعيات - قسم الأنف والأذن والحنجرة

كلية الطب - جامعة عين شمس

د. إيمان عبد البديع محمد

استشاري السمعيات

معهد السمع والكلام

د. نثرين محمد سعيد عبد السلام حسين

مدرس السمعيات - قسم الأنف والأذن والحنجرة

كلية الطب - جامعة عين شمس

جامعة عين شمس

2010

بسم الله الرحمن الرحيم

قالوا سبحانك لا علم لنا الا ما علمتنا انك
أنت العظيم الحكيم

صدق الله العظيم

آية 32 سورة البقرة

Acknowledgement

First and foremost, I give thanks to **Allah**, for giving me the strength to finish this work.

I would like to express my deepest gratitude to **prof. Dr. Adel Abdel Maksoud**, Professor of Audiology, Faculty of Medicine, Ain Shams University for his expert guidance, continuous advice that added a lot to this work.

I will never forget the continuous kindly support of **Dr. Eman Abdel Badie**, consultant of Audiology, Hearing & Speech Institute.

I would like also to thank **Dr. Nithreen Abdel Salam**, lecturer of Audiology, Ain Shams University, for her supervision, advice and time spent for revision of this work.

I would like to thank all professors of Ain Shams University and members of Audiology Unit of Hearing & Speech Institute for their advice and support.

Last but not least, I would like to thank my family for their ultimate support and encouragement.

Hany Ibrahim
2010

Contents

Page

Acknowledgement.....	i
Abbreviations	ii
List of tables.....	iv
List of figures	vi
Introduction and rationale	1
Aim of the work	3
Review of literature	4
Objective methods for detection of hearing threshold	4
Click evoked ABR.....	5
Tone burst ABR.....	9
Otoacoustic emissions.....	10
Auditory steady-state response.....	13
Definition.....	13
Principle.....	14
Generators.....	16
Stimulus parameters.....	18
Recording parameters.....	30
Identification and Discription.....	42
Factors affecting	47
ASSRs and behavioral thresholds in different studies.....	53
ABR and ASSRs threshold in different studies.....	56
Clinical Applications, advantages and disadvantages of ASSR....	58
Applications.....	58
Advantages.....	62
Disadvantages.....	64
Material and methods	66
Results	75
Discussion	98
Conclusions	107
Recommendations	108
Summary	109
References	113
Arabic summary	129

List of tables

No		Page
1	Age (years) and gender distribution in the three study subgroups.	75
2	Pure-Tone audiometric thresholds in the three study subgroups.	76
3	Auditory Steady-State Response (ASSR) thresholds at different frequencies in the three study subgroups:	77
4	Comparison between right and left ears in PTA thresholds at different frequencies in normal hearing subgroup:	78
5	Comparison between right and left ears in PTA thresholds at different frequencies in sloping hearing loss subgroup	78
6	Comparison between right and left ears in PTA thresholds at different frequencies in flat hearing loss subgroup	79
7	Comparison between right and left ears in ASSR thresholds at different frequencies in normal hearing subgroup	79
8	Comparison between right and left ears in ASSR thresholds at different frequencies in sloping hearing loss subgroup	80
9	Comparison between right and left ears ASSR thresholds at different frequencies in flat hearing loss subgroup	80
10	Comparison between right and left ears in ABR thresholds at different frequencies in the three subgroups	81
11	Comparison between behavioral pure tone audiometry and ASSR thresholds at different frequencies in normal hearing subgroup	82
12	Comparison between PTA and ASSR thresholds at different frequencies in sloping hearing loss subgroup	83
13	Comparison between PTA and ASSR thresholds at different frequencies in flat hearing loss subgroup	84
14	Comparison between PTA and ASSR thresholds in all subgroups	85

15	Correlation between PTA and ASSR thresholds at different frequencies in different subgroups	85
16	Difference between ASSR and PTA thresholds (ASSR-PTA) in the three study subgroups	86
17	Comparison between PTA and ABR thresholds in normal hearing subgroups	86
18	Comparison between PTA and ABR thresholds in slopping hearing loss subgroups	87
19	Comparison between PTA and ABR thresholds in flat hearing loss subgroups	88
20	Comparison between PTA and ABR thresholds in all groups	89
21	Correlation between (PTA and ABR) thresholds at different frequencies in different subgroups	90
22	Difference between ABR and PTA thresholds in the three study subgroups:	91
23	Comparison between ABR and ASSR thresholds at different frequencies in normal hearing subgroup	91
24	Comparison between ABR and ASSR thresholds at different frequencies in sloping hearing loss subgroup	92
25	Comparison between ABR and ASSR thresholds at different frequencies in flat hearing loss subgroup	93
26	Comparison between ABR and ASSR thresholds in all subgroups	94
27	Correlation between (ASSR and ABR) thresholds at different frequencies in different subgroups	95
28	The differences between ABR thresholds and ASSR thresholds	96
29	Cronbach's Alpha Coefficient in normal subgroup	97
30	Cronbach's Alpha Coefficient in slopinghearing loss subgroup	97
31	Cronbach's Alpha Coefficient in flat hearing loss subgroup	97

List of figures

No		Page
1	Auditory steady-state responses	15
2	stimuli used to evoke ASSR	19
3	AM and FM modulated carrier stimulus	22
4	independent amplitude and frequency modulation(IAFM)	23
5	Amplitude-time waveform and frequency spectra of the usual one-carrier stimulus AM1(A), and of the three multiple-carrier stimuli,	26
6	Chirp stimulus	28
7	electrode montage of ASSR- monaural stimulation	31
8	electrode montage of ASSR- binaural stimulation	32
9	Acoustic signals and EEG signal in time and frequency domain.	34
10	Theory of the multiple-stimulus technique	40
11	Statistical tests used to define the presence or absence of a response	45
12	Maturation of ASSR in infancy	48
13	The age related changes in amplitude	49
14	Auditory steady-state response (ASSR) amplitude as a function of modulation frequency (MF).	51
15	Stimulus creation screen MASTR™	70
16	Test screen MASTR™	71
17	Response in the form of polar plot	72
18	Absent response in the form of color coded status indicator plot	72
19	Pure-Tone audiometric thresholds in the three study subgroups	76
20	Auditory Steady-State Response (ASSR) thresholds at different frequencies in the three study subgroups	77
21	PTA and ASSR thresholds in normal hearing subgroup	82
22	PTA and ASSR thresholds in sloping hearing loss subgroup	83
23	PTA and ASSR thresholds in flat hearing loss subgroup	84
24	Comparison between PTA and ABR thresholds in normal hearing subgroup:	87
25	Comparison between PTA and ABR thresholds in sloping hearing loss subgroup:	88

26	Comparison between PTA and ABR thresholds in flat hearing loss subgroup	89
27	Comparison between PTA and ABR thresholds in all subgroups	90
28	Comparison between ABR and ASSR thresholds at different frequencies in normal hearing subgroup	92
29	Comparison between ABR and ASSR thresholds at different frequencies in sloping hearing loss subgroup	93
30	Comparison between ABR and ASSR thresholds at different frequencies in flat hearing loss subgroup	94
31	Comparison between ABR and ASSR thresholds in all subgroups	95

Abbreviations

- AEP:** auditory evoked potential
- AM:** amplitude modulation
- AM/FM:** amplitude modulation / frequency modulation
- ASSRs:** auditory steady state responses
- ASHA:** American Speech and Hearing Association
- c- ABR:** Click- auditory brain stem response
- C3:** Cervical vertebrae 3
- C4:** Cervical vertebrae 4
- C7:** Cervical vertebrae 7
- CF:** Carrier Frequency
- Cz-Mi:** vertex-ipsilateral mastoid
- dB:** decibell
- dBHL:** decibel hearing level
- dB nHL:** decibel normal hearing level
- dB SPL:** decibel sound pressure level
- DPOAEs:** distortion product otoacoustic emission
- EEG:** electroencephalography
- FM:** frequency modulation
- F:** Frequency
- FFT:** Fast Fourier Transformation
- IAFM:** independent amplitude and frequency modulation'
- I:** Intensity
- kH:** kilo hertz

MASTER: multiple auditory steady-state response

MC: multi carrier

MEG: magnetoencephalography

MF: Modulation Frequency

MLRs: middle latency responses

MM: mixed modulation

Ms: millisecond

MSC: magnitude-squared coherence test

nV: nanovolt

OAEs: otoacoustic emission

PC: phase coherence test

PTA: pure tone audiometry

OHCs: outer hair cells

S: second

SNR, S/Ns: signal to noise ratio

tb-ABR: tone burst auditory brain stem response

UNHS: Universal Newborn Hearing Screening

INTRODUCTION AND RATIONALE

Over the past decades, the need for objective audiometric techniques in practice has increased. This is partly the result of the growing target population for objective technique after the world-wide introduction of hearing screening in newborn. The most commonly applied technique in this young population is click-evoked auditory brainstem response (c-ABR). However, for an efficient hearing aids fitting, hearing threshold estimates at different octave frequencies are required. Tone-burst-evoked (tb-ABR) and auditory steady-state responses (ASSRs) can provide frequency-specific hearing threshold estimates (**Luts & Wouters, 2005**).

ASSRs are the periodic electrical responses of the brain to auditory stimuli presented at a rate fast enough to cause an overlap of a successive responses (**Stapells et al., 1984; Maiste & Piston, 1989**). In other words, it is a far field response measured in the background electroencephalogram (EEG) that is elicited by ongoing AM/FM modulated tone that is frequency specific and ear specific from 250 to 8000 Hz at intensity levels that far exceed the output limits of standard ABR (**Ballay et al., 2005**).

The ASSR technique has several advantages over tone-burst-evoked ABR. Firstly; test clinical duration can be shorter (**Stapells & Oates, 1997**). Secondly, because of the continuous nature of the stimuli used to elicit ASSRs the maximum output level is less restricted compared to tone-burst-evoked ABR. Finally, determination of the ASSR is a statistical finding and doesn't depend on subjective visual examination of the wave forms or response pattern (**Cohen et al., 1991**).

ASSRs thresholds have been shown to be highly correlated to behavioral thresholds in adults and older children, (**Johnson&Brown, 2001; Dimitrijevic et al., 2002; Herdman&Stapells, 2003**) However, individual studies show some variance in the mean difference between ASSR and behavioral thresholds. For example,

Dimitrijevic et al. (2002) reported mean difference of 4 to 17 dB between them whereas **Picton et al. (1998)** found these differences to be ranged from 12 to 27 dB.

It is important to determine whether audiometric configuration has an effect on the correlation between ASSRs and behavioral thresholds (**Vander Werff and Brown, 2005**) and if ASSRs technique is an accurate estimate of audiogram configurations (e.g., rising audiogram, steeply sloping losses, or flat losses). Sloping losses perhaps, present this greatest concern that ASSRs thresholds obtained to high frequency stimuli may actually represent the response of neighboring low-frequency nerve fibers, therefore underestimating the behavioral threshold at the nominal test frequency.

In this study, we are trying to explore the correlation between multiple-stimulus frequency ASSR thresholds and audiometric thresholds and how much it is affected by the audiometric configurations (flat and sloping sensorineural hearing losses).

It is well known that standard ABR is an accurate estimation of frequencies range (2 to 4 kHz), so Second goal in this study is to compare hearing thresholds estimated by ASSR to hearing threshold estimated by ABR.

AIMS OF THE WORK

1- To examine the correlation between auditory steady-state response (ASSR) and behavioral thresholds in normal hearing-adults and in subjects with sensorineural hearing loss with two common audiometric configurations (flat and sloping).

2- To compare hearing thresholds estimated by ASSR and hearing thresholds estimated by standard ABR .