THE USE OF IPSILATERAL AND CONTRALATERAL RECORDING OF POST-AURICULAR MUSCLE RESPONSE IN PREDICTING HEARING LEVEL

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by

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LIST OF ABBREVIATIONS

ABR	Auditory Brainstem Response
AEP	Auditory Evoked Potential
AER	Auditory Evoked Response
ALLR	Auditory Late Latency Response
AMLR	Auditory Middle Latency Response
ANOVA	Repeated Measures Analysis of Variance
ASSR	Auditory Steady State Response
CAP	Compound Action Potential
CHL	Conductive Hearing Loss
CN VIII	Eight Cranial Nerve / Vestibulo-cochlear Nerve
DPOAE	Distortion Product Otoacoustic Emission
OAE	Otoacoustic Emission
ORL-HNS	Otorhinolaryngology-Head & Neck Surgery
PAM	Post-Auricular Muscle
PAMR	Post-Auricular Muscle Response
PTA	Pure Tone Audiometry
SNHL	Sensorineural Hearing Loss
S.D	Standard Deviation
S.E	Standard error
SPSS	Statistical Package for Social Science

TDs	Threshold differences (PAMR-PTA thresholds)
CF	Correction factor
WHO	World Health Organization

LIST OF SYMBOLS

dB HL	Decibel hearing level
dBnHL	Decibel above normal adult hearing level
dB SL	Decibel sensation level
Hz	Hertz
kHz	Kilo Hertz
μV	Microvolt
ms	Milisecond
Ω	Ohm
%	Percent

PENGGUNAAN RAKAMAN IPSILATERAL DAN KONTRALATERAL TINDAK BALAS OTOT BELAKANG TELINGA DALAM MERAMALKAN TAHAP PENDENGARAN

ABSTRAK

Rakaman ipsilateral dan kontralateral tindak balas otot belakang telinga (PAMR) menggunakan nada pecah telah direkodkan ke atas 55 orang dewasa (20 orang mempunyai tahap pendengaran yang normal, 15 orang mempunyai masalah pendengaran jenis konduktif dan 20 orang mempunyai masalah pendengaran jenis sensorineural, dengan keseluruhan telinga berjumlah sebanyak 110) untuk menyiasat penggunaan PAMR untuk meramalkan tahap pendengaran. Semasa fasa pertama kajian, PAMR direkod secara ipsilateral menggunakan tiga kadar ransangan (6, 11 dan 17/s) pada beberapa tahap keamatan bunyi yang berbeza (60, 40, 20 dB SL dan ambang pendengaran) dan pada empat frekuensi oktaf yang berbeza (500, 1000, 2000 dan 4000 Hz). Fasa kedua kajian melibatkan rakaman ipsilateral dan kontralateral PAMR pada tahap ambang pendengaran bagi beberapa kumpulan subjek dewasa iaitu kumpulan dewasa yang mempunyai pendengaran yang normal, kumpulan dewasa yang mempunyai masalah pendengaran jenis konduktif dan kumpulan dewasa yang mempunyai masalah pendengaran jenis sensorineural. Hasil dapatan fasa pertama kajian mendapati bahawa kebanyakan PAMR berbentuk dwifasa dengan puncak petama kependaman direkodkan di antara 13.1 dan 17.7 ms, manakala puncak kedua kependaman direkodkan di antara 16.77 dan 22.2 ms, dimana nilai kependaman tersebut bergantung pada tahap keamatan bunyi, nilai frekuensi nada pecah dan tona otot belakang telinga. Kajian menunjukkan bahawa tiada perbezaan yang signifikan didapati terhadap komponen puncak PAMR (kependaman dan amplitud) apabila kadar ransangan ditingkatkan dari 6 ke 17/s ($P>0.05$), kecuali pada 500 Hz ($P=0.03$). Analisis korelasi terhadap nilai ambang pendengaran PAMR dan nilai ambang pendengaran yang diperolehi daripada ujian audiometri nada tulen (PTA) menunjukkan nilai korelasi terbaik dicapai pada kadar ransangan 11/s (ICC=0.62-0.82), pada nilai frekuensi 500, 1000 dan 4000 Hz. Dalam fasa kedua kajian, korelasi terhadap nilai ambang pendengaran PAMR dan PTA dicatat tertinggi bagi kumpulan SNHL (ICC=0.81-0.93), diikuti dengan kumpulan konduktif (ICC=0.77-0.94) dan kumpulan pendengaran normal. Secara statistik, rakaman kontralateral PAMR menunjukkan nilai ambang pendengaran yang lebih rendah berbanding rakaman ipsilateral. Kesimpulannya, nilai ambang pendengaran yang diperolehi menerusi PAMR berjulat 20 dB SL merentasi kesemua frekuensi dengan nilai ramalan yang lebih tepat diperolehi pada frekuensi nada pecah yang lebih tinggi (4 kHz) bagi kedua-dua mod rakaman (ipsilateral dan kontralateral). Hasil kajian ini menunjukkan bahawa PAMR berupaya meramalkan tahap pendengaran dikalangan dewasa berpendengaran normal dan dewasa yang mempunyai masalah pendengaran.

THE USE OF IPSILATERAL AND CONTRALATERAL RECORDING OF POST-AURICULAR MUSCLE RESPONSE IN PREDICTING HEARING LEVEL

ABSTRACT

Ipsilateral and contralateral recording of tone burst evoked post-auricular muscle response (PAMR) were recorded in 55 adults (20 with normal hearing, 15 with conductive hearing loss and 20 with sensorineural hearing loss) to investigate the use of PAMR in predicting hearing level. In the first phase of this study, ipsilateral PAMR were elicited with three stimulus rates (6, 11 and 17/s) at several intensity levels (60, 40, 20 dB SL and at thresholds level) and at four octave frequencies (500, 1000, 2000 and 4000 Hz). In the second phase, thresholds level of ipsilateral and contralateral recordings of PAMR were recorded in normal, conductive and sensorineural hearing loss group. The findings of the first phase showed most of the PAMR were biphasic with the first peak latency of between 13.1 and 17.7 ms, while the second peak latency occurred between 16.7 and 22.2 ms, depending on the stimulus intensity, tone burst frequency, and post auricular muscle tone. There were no significant difference of PAMR peaks components (latency and amplitude) as the stimulus rates increased from 6 to 17/s (P>0.05), except at 500 Hz (P=0.03). The correlation analysis showed the best correlation value between PAMR and PTA thresholds at stimulus rate of 11/s (ICC=0.62-0.82) at frequency of 500, 1000 and 4000 Hz. In the second phase, the correlation between PAMR and PTA thresholds were the highest in SNHL group (ICC=0.81-0.93), followed by CHL group (ICC=0.77-0.94) and normal hearing group. Statistically, contralateral recording of

PAMR showed lower thresholds than ipsilateral recording, particularly at higher frequencies. To conclude, the hearing thresholds obtained by PAMR were within 20 dB SL across the test frequencies with better estimates at the higher tone burst frequency (4 kHz) for both modes of stimulation (ipsilateral and contralateral). The findings of the current study demonstrate the ability of PAMR in predicting behavioural hearing levels among normal and hearing impaired adults.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Hearing organ, known as cochlea is amongst the earliest functioning organ developed in human. The importance of hearing is most prominent in developing speech during childhood. Loss of hearing may result in difficulties in many aspects of life. Globally, hearing loss affects about 10% of the world population to some degree (Oishi and Schacht, 2011). Hearing handicapped contributed to the largest percentage of handicapped in the world. Therefore, having an effective audiological test is vital for audiologist.

Currently, the two most frequently used objective methods for assessing hearing sensitivity are the auditory brainstem response (ABR) and auditory steady state response (ASSR). Auditory evoked potentials like ABR can provide an objective estimation of the hearing thresholds across frequency depending upon the acoustic stimuli being used. Having an objective hearing test is beneficial for testing patients if the outcomes of subjective hearing tests are doubtful and questionable. A new test called the post-auricular muscle response (PAMR) is another auditory evoked potential that can be recorded by measuring the electrical activities evoked in the post-auricular muscle (PAM) located just behind the pinna in response to click, tone burst and chirps stimuli (Yoshie and Okudaira, 1969; Vaughan and Ritter, 1970; Buffin et al, 1977; Patuzzi and O’Beirne, 1999; and Agung et al, 2005). The PAMR can be reliably recorded in most normally hearing adults when the recording parameters are optimized (O'Beirne and Patuzzi, 1999; Patuzzi and O'Beire, 1999; Purdy et al, 2005).

For estimating hearing thresholds, the stimulus can be presented either ipsilaterally (to the test ear) or contralaterally (to the opposite ear). In most electrophysiological tests, contralateral recordings produce lower responses than the ipsilateral recordings (Hall, 2006). In this regard, the clinical application of contralateral response is of little interest. With regard to PAMR, there is evidence that PAMR evoked at suprathreshold levels was significantly larger for contralateral recording than that of ipsilateral recording (Zakaria and Patuzzi, 2007). The contralateral recording of PAMR for estimating thresholds has not yet been investigated.

1.2 Research questions and problem statements

Findings by Patuzzi and collegues on the new method to record the postauricular muscle response have shed a new perspective on the great potential and the usefulnes of PAMR in predicting hearing level. At present, despite of its recordable response using variuos types of stimuli, little is known regarding the performance of tone burst PAMR in predicting behavioral hearing thresholds. Other than that, no research has been conducted to investigate the effects of stimulus rates on PAMR thresholds. In addition, the contralateral recording of PAMR has not yet fully explored. Hence, the research questions are as follows::

1. *Is there any effect of stimulus rates on PAMR peaks (latency and amplitude)?*
2. *Is there any effect of stimulus rates on PAMR thresholds?*
3. *What is the suggested stimulus rate to be used to optimize PAM recording?*

4. *Is there any correlation between the hearing thresholds recorded by the ipsilateral and contralateral recording of PAMR with pure tone thresholds using tone burst stimulus?*
5. *What is the range of PAMR thresholds as compared to PTA thresholds?*

1.3 Aims and objectives of study

1.3.1 General Objective

The general objective of this study is to determine the use of ipsilateral and contralateral recordings of tone burst postauricular muscle response (PAMR) in predicting hearing level among normally hearing adults and adults with hearing impairments.

1.3.2 Specific Objectives

Specifically, the proposed research aim:

1. To compare latencies and amplitudes of PAMR peaks (Pi and Ni) at three different stimulus rates in normally hearing participants

2. To determine the correlation between PAMR thresholds and PTA thresholds at three stimulus rates at specific frequencies in normally hearing participants

3. To compare ipsilateral and contralateral PAMR threshold at specific frequencies in normal, conductive and sensorineural hearing impaired groups

4. To determine the correlation between ipsilateral/contralateral PAMR thresholds and PTA thresholds at specific frequencies in the tested groups

5. To compare threshold differences (PAMR minus PTA) at specific frequencies among the tested groups

6. To provide correction factors of PAMR at specific frequencies for estimating behavioral hearing thresholds

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of the auditory system

2.1.1 Anatomy of the auditory system

The auditory system consists of peripheral and central, is one of the most complex sensory systems in human. The peripheral auditory system, as shown in Figure 2.1 includes the outer, the middle and the inner ear which function to transduce the external sounds to the brain. The outer ear includes pinna and ear canal. The skin of ear canal is innervated by four cranial nerves which are the trigeminal, facial, glossopharyngeal and vagus nerves. The middle ear includes the tympanic membrane and air space chamber which houses the three ossicular chains (malleus, incus and stapes). The manubrium of malleus is attached to the tensor tympani muscle and stapedius muscle to the stapes. Both are innervated by trigeminal and facial nerves respectively. The inner ear comprises of two parts which are the cochlea for hearing and the vestibular apparatus for balance. Both systems are separate, yet both are encased in the same bony capsule and share the same fluid systems. The cochlear has a little more than two and a half turns. Anatomically, the cochear has three fluid-filled compartments which include scala tympani, scala media and scala vestibule. The scala tympani and scale media are separated by the basilar membrane, meanwhile the Reissner’s membrane separate the scala vestibule from the scala media. The perilymph fluid in the scala tympani and scala vestibule are similar to that of the extracellular ionic fluid which has high content of sodium and low content of potassium. The endolymphatic fluid in the scala media is similar to the intracellular fluid which has high content of potassium and low contents of sodium. The fluid space of scala tympani and scala vestibule communicates with the cerebrospinal fluid space through the cochlear aqueduct. The fluid space in the scala media communicates with the endolymphatic sac through the endolymphatic canal. Hair cells are organized on the basilar membrane in one row of inner hair cells and 3 – 5 rows of outer hair cells. The hair cells in the cochlear differ from the vestibular hair cells in that they lack in kinocilium. Each inner hair cell is innervated by type I auditory nerve fibres while the outer hair cells are innervated by type II auditory nerve fibres. The afferent nerve fibres terminate directly onto the outer hair cells and while the other efferent nerve fibres terminate on the dendrites of the type I fibres that innervate the inner hair cells.

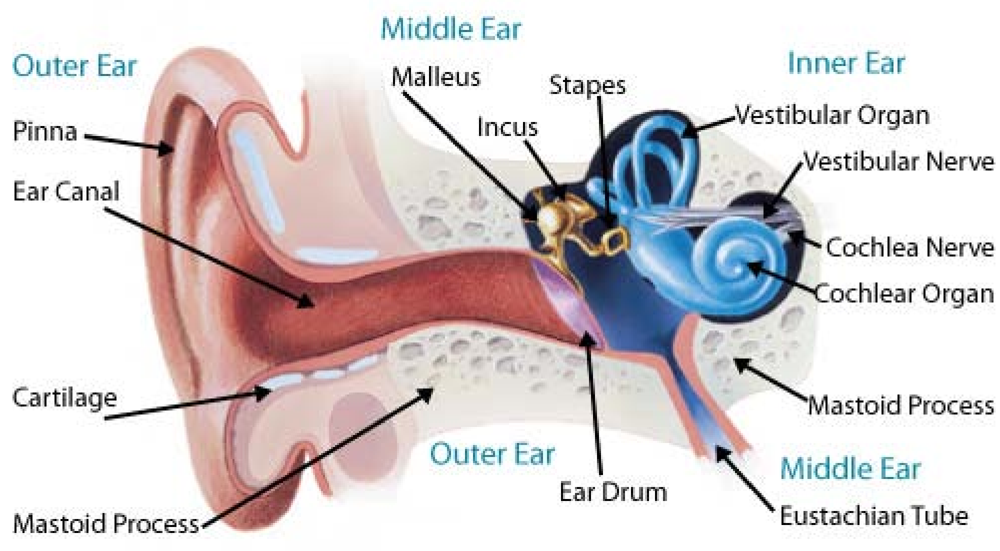


Figure 2.1: A schematic representation of the peripheral auditory system, including outer ear, middle ear, cochlea (inner ear), and distal portion of the eighth cranial nerve. Adapted with permission from www.casciwow.com

2.1.2 Physiology of the auditory system

The process of hearing begins with the occurrence of sound, where the sound is initiated with an event which causes a motion of vibration in the air. The vibrations of air will move the sound waves to stimulate the hearing organ. In the human ear, a sound wave is conducted via two routes that are the air conduction and bone conduction. The sounds will be transmitted through four separate medium along the auditory system before a sound is perceived. The outer ear provides air conduction transmission of sound followed by the mechanical transmission in the middle ear and cochlea. Finally, the neural transmission occurs in the end portion of cochlea towards the brain.

Incoming sound waves are collected by the pinna, which will then be funnelled into the external auditory canal until they strike the eardrum making the eardrum to move forward and backward. At this point, the sound energy travelled via solid medium; the ossicular chain in the middle ear which consists of three little bones, malleus, incus and stapes. The ossicular chain transfers energy from a solid medium to the fluid medium of the inner ear via the stapes which is attached to the oval window. The movement of the oval window creates motion in the cochlear fluid and along the Basilar membrane. The motion along the basilar membrane excites at the frequency specific areas of the Organ of Corti, which in turn stimulates a series of nerve endings. With the initiation of the nerve impulses, another change in medium occurs; from fluid to neural. Nerve impulses are relayed through the VIII C.N., through various nuclei along the auditory pathway to the areas at the brain. It is the brain that interprets the neural impulses and creates a thought, picture, or other recognized symbol.

2.2 Overview of hearing loss

The World Health Organisation (WHO) (2008) reported as of 2004 that hearing loss caused moderate to severe disability in 124.2 million people (107.9 million of who are in low and middle income countries). Of these, 65 million were suffering from acquired hearing loss since childhood. About 3 per 1000 in developed countries and more than 6 per 1000 in developing countries have congenital hearing loss. As far we are concern, hearing loss increases with age. In those between 20 and 35 years old, the rate of hearing loss is 3% while in those 44 to 55 years old, it is 11% and in those 65 to 85 years old, it is 43% (Lasak, JM; Allen, P; McVay, T; Lewis, D 2014).

Hearing loss can be categorized by which part of the auditory system that is damaged. There are three basic types of hearing loss: conductive, sensorineural and mixed hearing loss.

2.2.1 Conductive hearing loss

Conductive hearing loss happens when there is a blockage to the air transmission of sound pathways, resulting in sounds not transmitted effectively trough the ear canal to tympanic membrane and ossicular chain in the middle ear. Conductive hearing loss usually cause a reduction in sound intensity and inability to hear soft and faint sound. This type of hearing loss can usually be corrected medically or surgically. Basically, there are many causes of conductive hearing loss such as middle ear fluid, infection, allergy, poor eustachian tube function, tympanic membrane perforation and many more.

2.2.2 Sensorineural hearing loss

Sensorineural hearing loss (SNHL) is caused by the lesion in any part of the inner ear structures such as the cochlea, vestibule-cochlea nerve and central auditory pathway. The majority of SNHL cases is caused by abnormalities in the hair cells of the organ of Corti. Most of the time, SNHL is permanent. SNHL reduces the ability to hear faint sounds. Individual with this type of hearing loss often have problem to hear in noisy places even when the speech sound is loud enough to hear, it may still be unclear or sounded muffle. SNHL may be congenital or acquired. Some possible causes of acquired SNHL include illnesses, ototoxic drugs, genetic, aging, head trauma, and noise induce.

2.2.3 Mixed hearing loss

Mixed hearing loss is a combination of conductive and sensorineural hearing loss at the same time. Both middle ear and inner ear are involved. The treatment for mixed hearing loss usually starts with medical regiment for the conductive component first before proceeding with hearing aid use.

2.3 Overview of the audiological test

Hearing status can be determined by using subjective and objective measurements. Subjective hearing test require the subject's cooperation during the test meanwhile objective hearing test require very minimal or almost no cooperation from the subject. Objective tests are useful if the subjective test cannot be conducted in a reliable manner.

2.3.1 Pure tone Audiometry

The pure tone audiometry is the standard behavioural assessment of an individual's hearing. The hearing thresholds obtained during the pure tone audiometry are recorded on an audiogram. Usually, pure tone audiogram is easy to obtain and it provides information about the peripheral hearing acuity across the frequencies of the speech spectrum. The information on the degree, types and configurations of hearing loss give a quick inferences which, when viewed in conjunction with the patient's case history, can help lead to a diagnosis and rehabilitation process in the future.

Pure tone is generated by an audiometer and presented to the subjects via headphones or in some cases through loudspeakers. The standard procedure of measuring hearing levels includes the air conduction and bone conduction audiometry. Clinical masking will be applied when there are the possibilities of sound presented to the test ear will cross over to the non-test ear, thus is then perceived as a false response.

2.4 Overview of auditory evoked responses (AERs)

Auditory evoked responses is a very small electrical voltage within the auditory system that is stimulated or evoked in response to sound stimuli and can be recorded by electrodes placed usually at specific places on the scalp, for example at high forehead and near to the ears, and at the earlobe. The response reflects the neuronal activities on the auditory nerves, cochlea nucleus, superior olive and inferior colliculus of the brainstem. The sound stimuli that can be used to elicit AERs range from click, tones, chirps, and even speech sounds which are fed through acoustic transducers. An array of electrodes which are plugged into the preamplifiers transfers the neural activities to the filters and an analogue-to-digital converter and finally to the computer for analysis. Figure 2.2 below shows the schematic diagram of instrumentation used to record AERs. When the sound stimuli were presented through a transducer (monoaural or binaural), PAMRs were recorded from behind the ear using bio-amplifier for main isolation, amplification and filtering. Then the PAMRs were averaged and analysed using a personal computer which was fitted with data acquisition hardware, running averaging and analysis software.

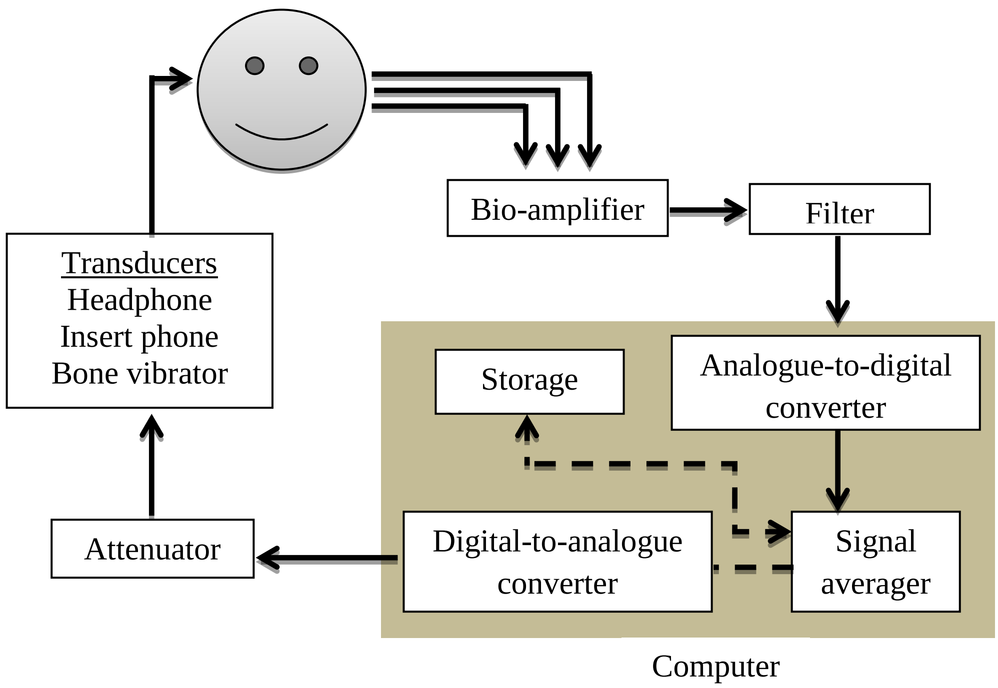


Figure 2.2: Schematic diagram of instrumentation used in AERs recording

As illustrated in Figure 2.3, the earliest response within 5 ms post-stimulus presentation is called electrocochleography (ECochG), followed by the auditory brainstem response (ABR), which is within 10 ms time window. Both responses are generated by the inner ear and auditory nerve, followed by auditory middle latency response (AMLR) that occurres within 50 ms. The AMLR reflects the activities within the auditory brainstem. The later response is the auditory late latency response (ALLR) which comes from the activities in the higher auditory portions of the brain such as the cerebral auditory cortex.

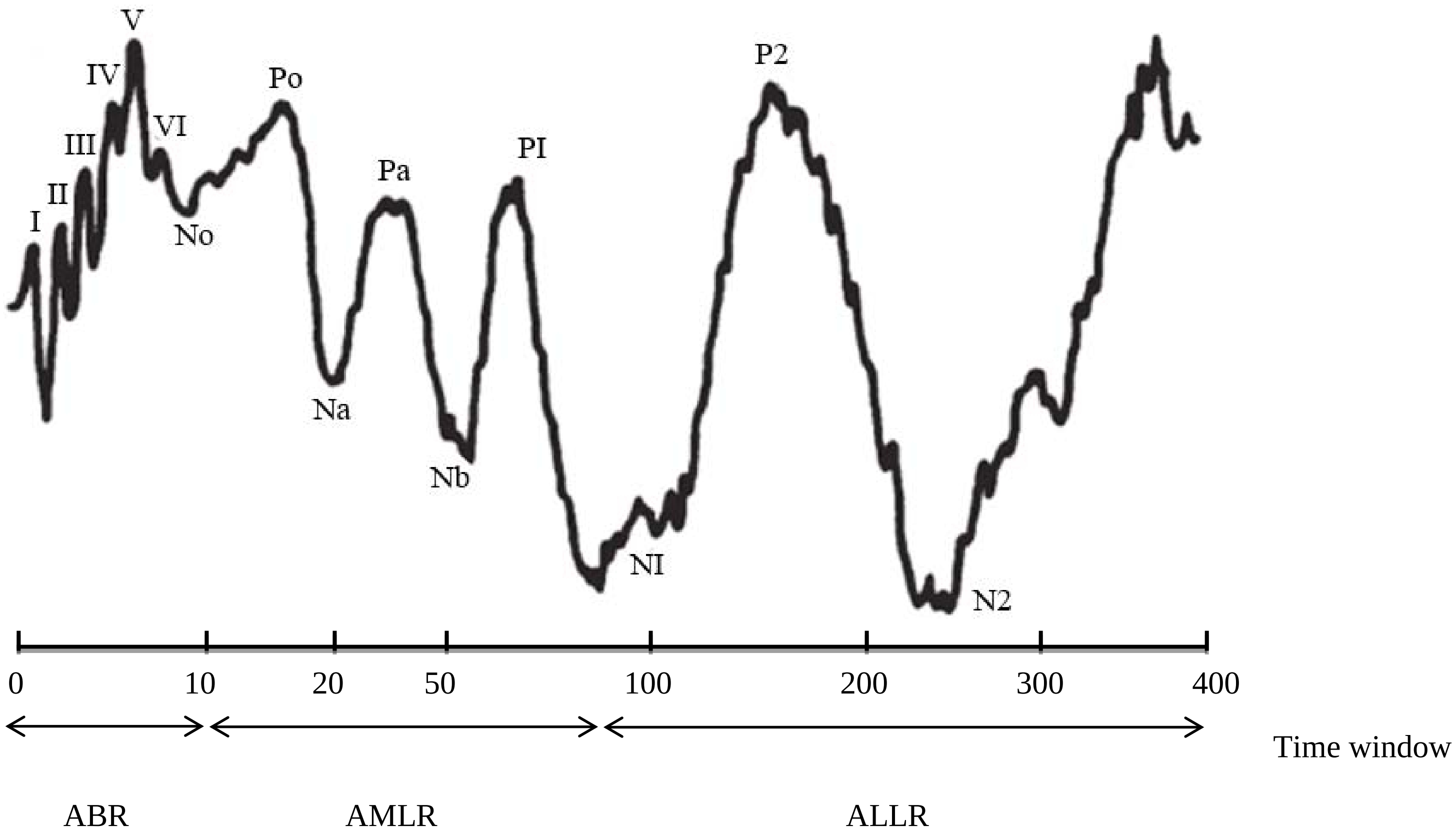


Figure 2.3: Representative waveforms for major categories of auditory evoked responses.

2.4.1 Post-Auricular Muscle Response (PAMR)

The post-auricular muscle response (PAMR) can be defined as a large, bipolar compound action potential (CAP) generated by the post-auricular muscle (PAM) behind each ear in response to a brief acoustic stimulus presented to either ear (Jacobson et al, 1964; O'Beirne and Patuzzi, 1999). Figure 2.4 shows the location of PAM. PAMR can be extremely large relative to the auditory brainstem response (ABR) as it originated from myogenic response and can even be seen on raw traces. At present, the variability of PAMR is greatly reduced by lateral eye movement technique (O'Beirne and Patuzzi, 1999). Typical PAMR was recorded using clicks stimulus (Kiang, 1963; Thornton, 1975; Patuzzi and Thomson, 1999). However, it is possible to record PAMR with other sound stimuli such as tone burst (Patuzzi and O'Beirne, 1999; Patuzzi and Thomson, 2000) and high frequency chirps (Purdy et al, 2005).

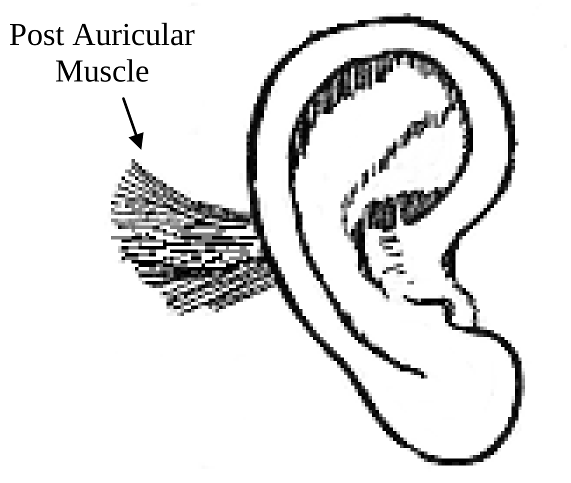


Figure 2.4: Post auricular muscle (PAM).

The peripheral auditory system and low brainstem areas were believed to be responsible for contributing to PAMR (Yoshie and Okudaira, 1969; Gibson, 1975). PAMR is a brainstem reflex and the contributing structures mostly include cochlear nuclei, superior olivary complex, lateral laminiscus and possibly the inferior colliculus. The afferent portion of PAMR is the auditory nerve, while the efferent portion is the facial nerve (Hall, 2006). Since PAMR is of muscular origin (Bickford et al, 1964), it is often larger than other commonly used Auditory Brainstem Response (ABR). Clinically, having a bigger waveform would decrease the number of sweeps required and consequently shorten the testing time.

2.4.2 Basic properties of PAMR

A typical PAMR is either biphasic (Patuzzi and O'Beirne, 1999a, b) or triphasic (Goldstein and Rodman, 1967; Yoshie and Okudaria, 1969; Robinson and Rudge, 1977; and Fraser et al, 1978), depending on the filter bandwidth. The more usual biphasic waveform consists of a negative going peak occurring between 12.5 and 15 ms and a positive going peak between 15 and 18 ms as illustrated in Figure 2.5. The triphasic waveform usually arises from high-pass filtering of the biphasic response (O'Beirne and Patuzzi, 1999), and has peaks that occur at about 8-15 ms, 13-20 ms, and 20-30 ms (Yoshie and Okudaira, 1969). PAMR parameters (amplitude and latency) readings depended upon the frequency, sound level and PAM tone. It has frequency spectrum mostly between 25 and 300 Hz, and broadly centred at 90 Hz. (Patuzzi and O'Beirne, 1999).

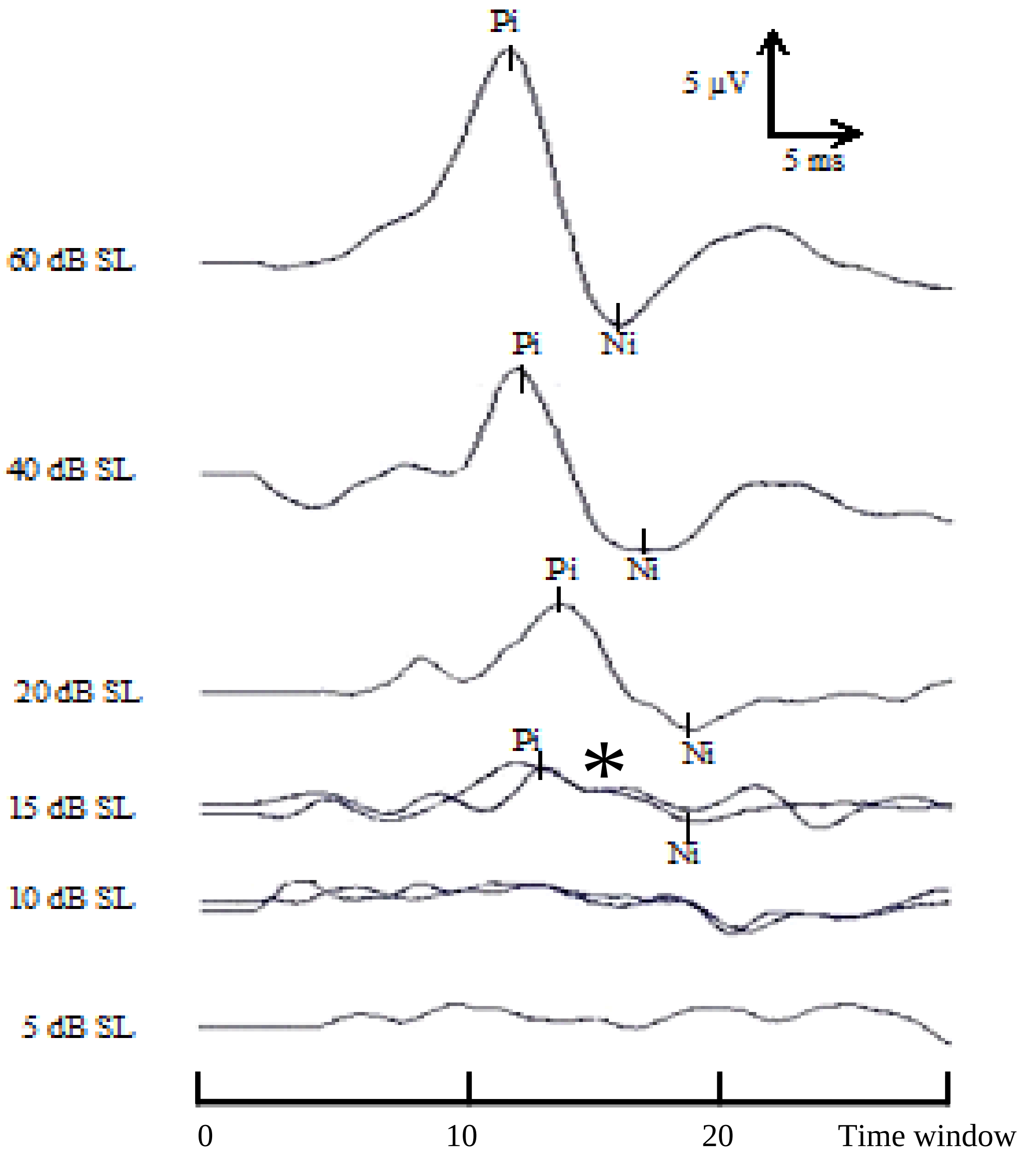


Figure 2.5: Biphasic PAMR waveforms at different intensity levels.Pi are the negative-going peaks that usually occur between 12.5 to 15 ms and Ni is the positive-going peaks that occur between ms 15 to 18 ms after stimulus onset. The estimated hearing threshold was marked by asterisk.

With the optimized recording parameters, reliable PAMR can be recorded in normally hearing adults (O'Beirne and Patuzzi, 1999; Patuzzi and O'Beirne, 1999; Purdy et al, 2005). Patuzzi and O'Bierne (1999) who studied the basic property of PAMR found that the distribution of PAMR around the post-auricular muscle area and the dorsal surface of pinna produce the greatest PAMR. The optimum way to record PAMR is by placing the active electrode directly over the PAM and the reference electrode at the rear pinna. This strategy will improve signal to noise ratio by reducing the low frequency background electrical noise from the frontalis muscle of the forehead and from the jaw and neck. This electrode positioning also reduces interference from the adjacent electrical equipment since the differential recording pair are so close together, thus the blink artefact will be eliminated. Nevertheless, this placement is more convenient.

Like other auditory evoked potentials, the variability of PAMR could be affected by numerous factors. One of the prominent factors is the PAM tone where PAMR amplitude alters with different PAM tone. When PAM is in a relax condition, PAMR recorded will be small. Other factors such as head and eye position also contributed to PAMR. With the eyes turned hardly to the stimulated PAM, the PAM tone will be increased, resulting in amplitude growth as seen on the traces (see Patuzzi and O'Beirne, 1999a). The state of the subject and more importantly the filter bandwidth also play major effect on PAMR. Previous studies that used click stimuli found that larger amplitude are recorded with neck traction (Cody and Brickford, 1969), head lowering (Yoshie and Okudaira, 1969; Dus and Wilson, 1975), teeth gritting (Dus and Wilson, 1975; Gibson, 1978), propping the head forward (Yoshie and Okudaira, 1969; Thornton, 1975), pushing the head against a force (Clifford-Jones et al, 1979), or lateral eye movement (Patuzzi and O'Beirne,1999b; Patuzzi and Thomson, 2000).

In the earlier studies of PAMR, many researchers ‘missed’ or overlooked the effects of eye movement on PAMR. In animals like the guinea pigs, they can twitch their ears in response to the presence of sounds. This visible movement is known as the Preyer reflex. In human, this movement is not visible since the muscle controlling the pinna is too stiff. Furthermore, there is no neural circuitry around the pinna. Thus, many of the reserchers were unaware of the correlation between the eye movement and PAMR amplitude. Patuzzi and O’Beirne (1999) contended that PAMR findings would be highly erratic without the adequate control on eye movement. The amplitude of PAMR increased with increasing gaze angle, maximally with 70 degree angle. With eyes turned to the stimulated PAM, the PAMR was often so large, easily identified and even stably recorded with 20 averages. This is putting PAMR at advantage as it requires less averaging thus shortening the testing period.

The observations on the correlation between PAMR to behavioural audiometry from early studies suggest that PAMR thresholds were well correlated with PTA. Thornton (1975) found that PAMR thresholds were within 10 dB of subjective thresholds in subjects with normal and abnormal hearing thresholds. Consistent with Thornton’s (1975) result, Yoshie and Okudaira (1969) found that the click evoked PAMR thresholds ranged from 0 to 20 dB in normal-hearing subjects. Later, Patuzzi and Thomson (2000) demonstrated that PAMR waveforms can be elicited using tone burst with frequencies up to and above 8 kHz, and PAMR thresholds were within 30 dB of the subjective threshold. As a result, the PAMR can be used to rapidly determine the hearing threshold level across the frequency of speech spectrum. Therefore, an objective audiogram can be obtained within minutes. This shows that PAMR has great potential for hearing screening as long the eye rotation technique can be applied.

2.4.3 Stimuli to evoke PAMR

Over the years, most studies regarding PAMR were conducted using click stimulus. For example; Talaat et al (2010), Agung et al (2005), Purdy et al (2005), Patuzzi and Thomson (2000), O'Beirne and Patuzzi (1999), Patuzzi and O'Beirne (1999a,b), Buffin, Connel and Stamp (1977), Thornton (1975) and many more. Acoustic clicks are known to have a rapid onset and a very broad acoustic spectrum. Due to the wide spread on the basilar membrane, clicks stimulus will elicit synchronous discharges from a large proportion of cochlea fibres (Gorga and Thornton, 1989; Van der Drift et al, 1988a, 1988b). Although click contains a wide frequency spectrum, the response however concentrated at 2 to 3 kHz when being transduced with a conventional headphone. Furthermore, the basal region of the cochlea stimulated first and more synchronously compared to the apical regions. As a result from that, the click evoked AERs reflect activities from the high frequency. PAMR elicited with click stimulus was found to correlate well with the subjective hearing test. Thornton (1975) found that the mean difference between the click-evoked PAMR threshold and the 2 kHz audiometric threshold was 9 dB. Consistent with that result, Yoshie and Okudaira (1969) found that the click-evoked PAMR ranges from 0 to 20 dB in normally hearing adult subjects.

Although the PAMR can be effectively elicited with click signals, lack of frequency specificity is a major drawback for clinical electrophysiological assessment of auditory function in infants and young children and, particularly, for estimation of auditory sensitivity at different frequency region. Currently, the use of tone burst is preferred in estimating the hearing sensitivity especially to fulfil the demands of universal hearing screening. Despite Gibson's (1975) report that tone bursts were relatively ineffective in evoking the response, Patuzzi and O'Beirne (1999) suggest that PAMR can be recorded effectively with tone bursts with frequencies up to 8 KHz and higher, within 30 dB of subjective detection threshold when the stimulus parameters are optimized (Patuzzi and Thomson, 2000). PAMR thresholds estimated using tone-bursts are reproducible and the PAMRs evoked by using tone-bursts of 500 Hz and 1 kHz were just as consistent as those obtained with higher frequencies, with adequate control of eye position.

Chirp stimulus has become popular in early 2000. The chirp stimulus is designed mathematically to produce simultaneous displacement maxima along the cochlear partition by compensating the frequency-dependant travelling time differences (Fobel and Dau, 2004). Theoretically, chirp stimulus optimizes the synchronization across a broad frequency region at high and low intensity levels which yield a more robust response than the conventional clicks stimulus. There are many types of chirp stimulus, for example: O-chirp (derived from OAE data), A-chirp (derived from ABR data), M-chirp (model-chirp) and CE-chirp. The principle in CE-chirp is to ensure all nerve fibres are triggered simultaneously. The apical end of the cochlea will be stimulated first by low frequency sounds, followed by the high frequency. Since all fibres are fired at the same time, the responses will be larger. Subsequently, less averaging is required which result in shorter testing time. In PAMR, only one research has been carried out using chirp stimulus (Agung et al, 2005). The findings of chirp evoked PAMR indicates that high frequency chirps enhanced the PAMR amplitude than clicks and /t/ stimuli. It is postulated that PAMR amplitudes are also enhanced due to the temporal organization of the chirp's spectral energy.

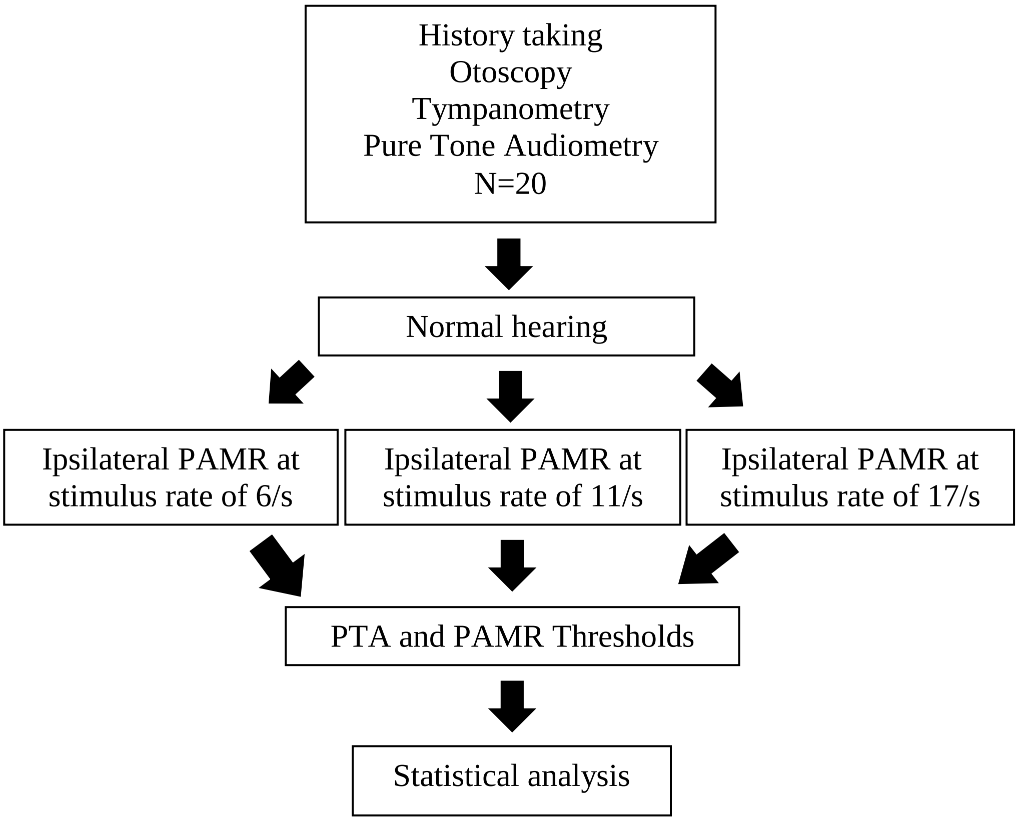
CHAPTER 3

MATERIALS AND METHODS

3.1 Study design

This study consists of two phases: phase 1 and phase 2. Phase 1 employed repeated measures study design, whereas phase 2 was of case control design. Figure 3.1 shows the flowchart of the study method. The details of each phase are described accordingly in this chapter.

PHASE 1



PHASE 2

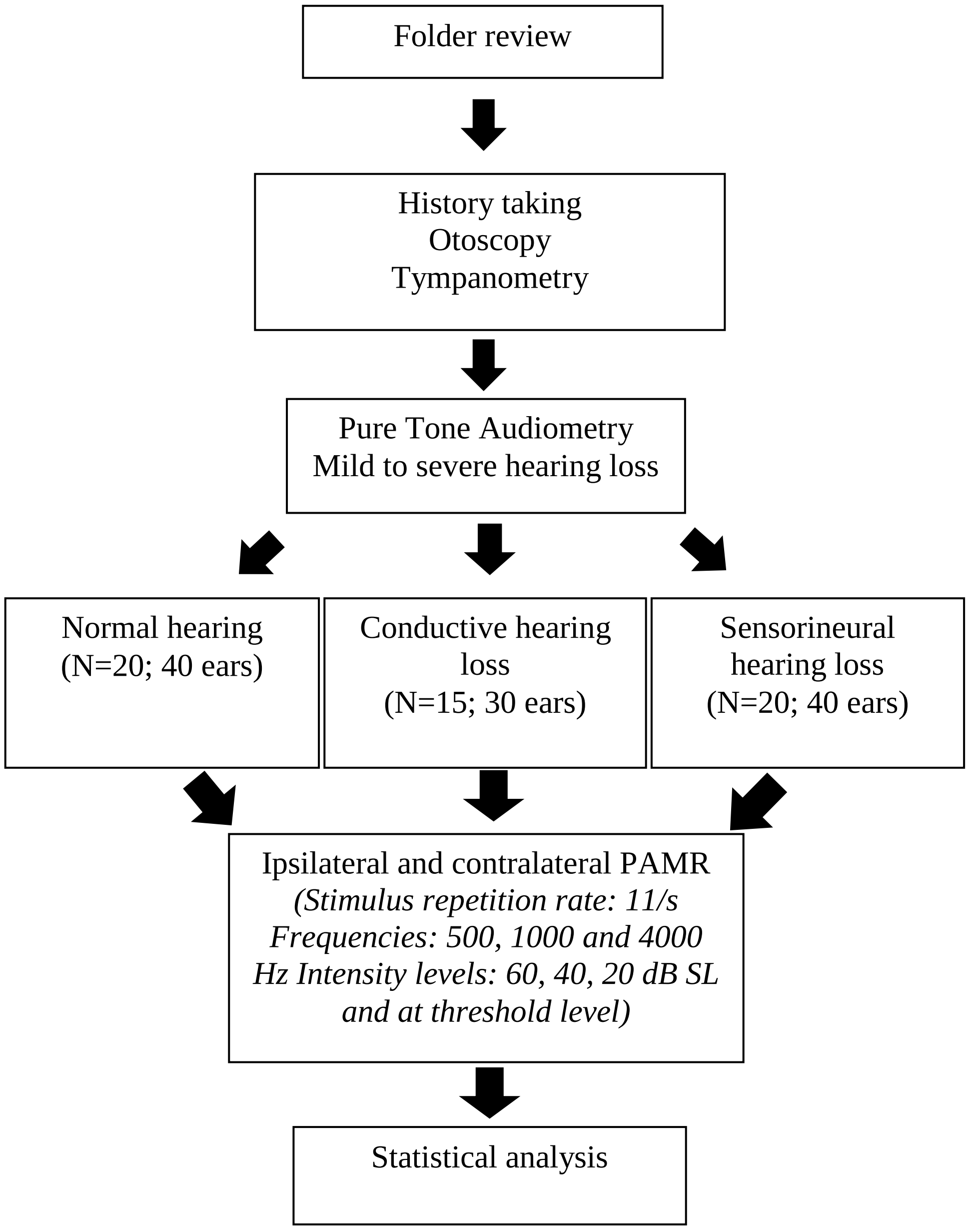


Figure 3.1: Study design flowchart. Phase 1 involved a repeated measure of PAMR on normally hearing participants. Phase 2 involved PAMR recording on adults with normal hearing and hearing loss.

3.2 Phase 1

In this phase, the optimum stimulus rate for PAMR was determined. Ipsilateral PAMR was recorded repeatedly at three different stimulus rate (6, 11 and 17 per second) at suprathreshold and threshold levels for right and left ear.

3.2.1 Participants

Twenty participants (6 males and 14 females) with bilateral normal hearing level (thresholds ≤ 25 dB HL from 250 to 8000 Hz) age ranging from 18 to 40 underwent a series of repeated recording of PAMR. The normal subjects include students, staff, patient's companions and other eligible candidates. All subjects were selected based on the inclusion and exclusion criteria in Table 3.1.

Table 3.1: Inclusion and exclusion criteria for normally hearing subjects.

Normally hearing subjects	
Inclusion criteria	*Exclusion criteria*
Normal and healthy adult age ranging from 18 to 60.	The subjects reported of having nausea, sweating and spinning sensation during the test.
Bilateral normal hearing level (hearing thresholds level were less or equal to 25 dBHL).	During the test, the subject was not able to tolerate the sounds after sometime.
No history of head and neck injury. No history of neurological problem. No history of vertigo or balance problem.	Incomplete data collection. The subject was not able to commit to all tests throughout the sessions.

3.2.2 Procedure

During the appointment, a brief history was taken and all participants were informed about the study. Written consent was obtained and participants were assessed according to the inclusion and exclusion criteria defined in Table 3.1. The process took place at Audiology Clinic, Hospital Universiti Sains Malaysia.

Prior to PAMR recording, otoscopic examination and tympanometry test were conducted to rule out any outer ear or / and middle ear pathology, followed by pure tone audiometry test. All the data were recorded on a special designed form as attached in the Appendix 3 (Form A).

3.2.2.1 Preparation of the participants

The PAMR test was carried out in a sound treated room which offer a quiet and suitable testing environment for PAMR recording. The subject was seated on a chair. The scalps were cleaned with NuPrep gel using cotton pads for optimum impedance recording prior to the electrode attachment. Disposable electrodes were attached to the site according to 10-20 electrode system. Figure 3.2 illustrates the electrode montage of 2-channel recording of PAMR. The reference (negative) electrode was attached to the ear lobe, while active (positive) electrodes were located on the left (A1) and right (A2) PAM. The ground electrode was placed on the forehead. Instructions were given to the participant. A marker X was stick to the wall of both sides at 45 degree azimuth for lateral eye rotation reference purpose. An impedance test was carried out to ensure that the impedance level is less than 5 KΩ for all electrodes, and fairly equal impedance (within 2 KΩ) for all electrodes is desirable for an optimum recording.