VARIETY OF ACOUSTIC STIMULI USED IN VISUAL REINFORCEMENT AUDIOMETRY

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Thesis
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VARIETY OF ACOUSTIC STIMULI USED IN VISUAL REINFORCEMENT AUDIOMETRY

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ABSTRACT

VRA is a test that requires behavioral responses to sound stimuli. In general, the behavioral response is to turn the child's head to the sound source. This test is suitable for children aged 6-24 months. Sound stimuli used in the test are transmitted via the speakers or earphones encourage the child to respond by shifting his eyes or turning his head. When the child responds to the stimuli, he/she is rewarded with an interesting visual display, such as a lighted or animated toy.

The conventional method of VRA by the use of narrow band noise (NBN) and warble tone for stimulation sometimes is not attractive and the response of the children occurs in a short time. In this study, the researcher created the new tool which includes audio and video signals together. Then the test results between the VRA using the new tool is compared to the VRA using traditional tool in 38 normal hearing children, aged between 6-24 months. Test results have shown that the response to sound stimuli by using the traditional and new tool were not significantly different at frequency 500 Hz, 1000 Hz and 2000 Hz at p-value < 0.05. However, at 4000 Hz there was significant difference at p-value < 0.05. When considering the number of head turns, the results showed that VRA with the new tool provided greater responses, than the VRA with the traditional tool.

These findings suggested that this new tool can be used as an option for VRA testing instead of the traditional tool, moreover, this new tool also helps to attract the child's longer attention during the test.

KEY WORDS: VISUAL REINFORCEMENT AUDIOMETRY/ACOUSTIC STIMULI

60 pages

เสียงกระตุ้นที่ใช้ในการตรวจการได้ยินชนิดให้แรงเสริมทางสายตา

VARIETY OF ACOUSTIC STIMULI USED IN VISUAL REINFORCEMENT AUDIOMETRY

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วท.ม. (ความผิดปกติของการสื่อความหมาย)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์: กฤษณา เลิศสุขประเสริฐ, M.A., มนต์ทิพย์ เทียนสุวรรณ,Ph.D.

บทคัดย่อ

การตรวจการได้ยินชนิดให้แรงเสริมทางสายตา (Visual reinforcement audiometry (VRA)) เป็นวิธีการตรวจที่ต้องใช้การสังเกตพฤติกรรมการตอบสนองของเด็กโดยการหันหาเสียง การตรวจนี้เหมาะสำหรับเด็กที่มีอายุระหว่าง 6-24 เดือน โดยการปล่อยสัญญาณเสียงผ่านลำโพงหรือหูฟังในระหว่างการตรวจ เมื่อเด็กตอบสนองโดยการหันหาเสียงถูกต้องเด็กจะได้รับแรงเสริมทางสายตาเป็นภาพตุ๊กตาที่มีแสงไฟหรือของเล่นที่มีการเคลื่อนไหวเพื่อดึงดูดใจให้เด็กหันหาเมื่อได้ยินเสียง

สัญญาณเสียงเดิมที่ใช้ในการตรวจมักไม่สามารถดึงดูดความสนใจของเด็กได้ยาวนาน การตอบสนองของเด็กมักเป็นการตอบสนองช่วงสั้นๆ ทำให้ผลการตรวจที่ได้ไม่สมบูรณ์ ส่งผลให้การวินิจฉัยและการช่วยเหลือล่าช้า การศึกษานี้มีวัตถุประสงค์เพื่อสร้างเครื่องมือที่รวบรวมสัญญาณภาพและสัญ ญาณเสียงที่สร้างขึ้นใหม่เข้าไว้ด้วยกัน จากนั้นนำไปทดสอบเปรียบเทียบกับการใช้เสียงเดิมและเสียงใหม่ในกลุ่มตัวอย่างเด็กปกติที่มีการได้ยินปกติอายุระหว่าง 6-24 เดือนจำนวน 38 คน พบว่าค่าการตอบสนองต่อเสียงเดิมและเสียงใหม่ไม่มีความแตกต่างกันที่ความถี่ 500 Hz, 1000 Hz และ 2000Hzแต่ที่ความถี่ 4000 Hz มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ เมื่อพิจารณาจำนวนครั้งของการตอบสนองต่อเสียงพบว่าการตอบสนองต่อเสียงใหม่มีค่ามากกว่าการตอบสนองต่อเสียงเดิมอย่างมีนัยสำคัญทางสถิติที่ระดับนัยสำคัญ $P < 0.05$

อุปกรณ์เสริมใหม่ชนิดนี้สามารถใช้เป็นตัวเลือกในการทดสอบVRAแทนการใช้สัญญาณ เสียงเดิม อีกทั้งยังสามารถดึงดูดความสนใจของเด็กให้ยาวนานขึ้นในระหว่างการทดสอบ

60 หน้า

CONTENTS

CONTENTS (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF ABBREVIATIONS

ABR	auditory brainstem response
ADV	android virtual device
COR	conditioned orientation reflex
OAEs	otoacoustic emissions
TEOAEs	transient-evoked otoacoustic emissions
DPOAEs	distortion-product otoacoustic emissions
BOA	behavioral observation audiometry
VRA	visual reinforcement audiometry
CPA	conventional play audiometry
NBN	narrow band noise
MRL	minimum response level
CHL	conductive hearing loss
SNHL	sensorineural hearing loss
VVRA	video visual reinforcement audiometry
CVRA	conventional reinforcement audiometry

CHAPTER I
INTRODUCTION

1.1 Background of study

The evaluation of hearing for young children is divided into physiologic hearing tests and behavioral hearing tests. The physiologic hearing test procedures do not require the participation of children. Physiologic hearing tests include acoustic immittance measurement, otoacoustic emissions (OAE), and auditory brainstem response (ABR).

Acoustic immittance measurement is a test that measures the function of the Eardrum and middle ear, including acoustic stapedius reflex. This test measures the energy flows, or the movement of air, from the outer ear to the eardrum, ossicles, middle ear muscles, cochlea, cranial nerve 7-8, and the brainstem. The results of this test suggest the pathology of the middle ear and the acoustic reflex thresholds [1].

OAEs determine the function of outer hair cells in the inner ear by measuring the resonance transmission occurring from the inner ear to the middle ear and outer ear, respectively. There are two types of OAEs including spontaneous OAEs and evoked OAEs. Spontaneous OAEs do not require auditory stimulation during the test, but evoked OAEs need auditory stimulation. Evoked OAEs include transient-evoked otoacoustic emission (TEOAEs), distortion-product otoacoustic emission (DPOAEs), and stimulus-frequency otoacoustic emission. These tests take less time and are an effective method for the detection of hearing loss in very young children[2].

ABR are brain waves that occur when the ear is stimulated by an acoustic signal. The stimulation can be clicks, tones and speech sounds. Electrodes can be mounted around the skull at various positions, including the midline (anterior to posterior center of the head), forehead, vertex, and earlobes in order to pick up neural responses after the acoustic stimulation. A sedation may be needed in case natural sleep is not possible [3].

All of the methods above are not true hearing tests, though they provide useful information about the middle ear, inner ear, and auditory brainstem functions, respectively. ABR provides an estimation of hearing sensitivity, which is important for determining the hearing levels in children. However, the tests that provide the true hearing level are behavioral hearing tests. For behavioral hearing tests, an audiologist needs to observe the child’s behaviors when the child responds to sounds. Three types of behavioral hearing tests are: behavioral observation audiometry (BOA), visual reinforcement audiometry (VRA), and conventional play audiometry (CPA) [4].

BOA is used by releasing the sound stimuli through the loudspeakers without visual reinforcement during the test. The audiologist has to observe the child’s behavioral response to the sound stimuli. The child’s behaviors include eye blinking, arousal from sleep, eye widening, and body movement. A major advantage of the BOA is the effective method for screening the hearing of the children in a limited time. This is also a test that does not require special tools. The disadvantage of the BOA is test bias, but this is difficult to estimate. The child might lose his/her attention, or might respond in various ways to the stimuli. The tester must be experienced in observing the behavior of children [5].BOA is appropriate for neonates and infants [6].

The VRA is suitable for children, from about six months old to two years old. Sound stimuli are transmitted via the speakers or insert phones, encouraging the child to respond by shifting his/her eyes or turning his/her head [7-8]. When the child demonstrates the correct response, he/she is rewarded with an interesting visual display, such as a lighted or animated toy. The results from VRA indicate the child’s hearing level separately, in each ear. If there is asymmetrical hearing loss or unilateral hearing loss, most of the children will localize to the better ear. However children with unilateral hearing loss can localize to the sound source, but slower than normal hearing children [5].

In older children, they may learn to be conditioned to responding to sound stimuli by putting a toy in a box or assembling a jigsaw when they hear the sound. During testing, the child will receive reinforcement, which may be visual (animated light toys) or social (verbal praise or smiles) [9]. This test is suitable for children from age 30 months to 5 years [10]. The behavioral hearing tests in young children seem to be rather difficult, when compared with the hearing tests in adults due to of a child’s limitations in responding to acoustic signals. This is especially true in very young children, as they may not understand the conditioning procedure. Children also might not cooperate in hearing tests. Generally, the physiologic hearing tests are more often the test of choice. They are preferred over behavioral hearing tests because they do not require cooperation from the child. However, the results are limited because the value is just an estimation. It is well known that the gold-standard for hearing tests in children are behavioral hearing tests because the test results are derived from the responses of the children themselves. The results can be identified across frequencies in each ear, which is very useful in performing hearing aids fittings. They are also a guideline for describing aural rehabilitation activities.

In conventional play audiometry, children must cooperate with the test. Children aged 6 months to 2 years are too young to cooperate with the CPA. They also may not understand the conditioning of the test. This is why the VRA is recommended for young children.

ASHA's guidelines suggest that the information from the VRA test should be separated by each frequency in each ear via loud speakers, bone vibrator, or insert earphones [11]. The conventional method of VRA, by using narrow band noise (NBN), and warble tone for stimulation, is sometimes not attractive and the response of the children occurs in a short amount of time. For these reasons, it will take more time to diagnose hearing impairment in children [12-13]. Application of attractive sounds, such as toys, animals, and environmental sounds, to stimulate the child during the test, may provide better responses [14-15].

1.2 Statement of the problem

At present, there is some development of a sound stimulus, such as animal sounds and toy sounds, by playing a recording on a compact disc. However, the practical application of those sounds is inconvenient because the audiologist has to control not only the audiometer, but also search for the selected sounds by operating the CD player, and provide reinforcement during the test. In addition to developing a sound stimulus that has come before, there is also developing reinforcements. For many years, there has been a development of 3D animation used as reinforcement in the VRA testing. But there is a delay in providing a visual animation because of the complexity of the computer system [16]. This delay in reinforcement is a problem.

In this study, the researcher intends to create a new tool, which includes audio and video signals, together, which can be operated conveniently. Then, this study intends to compare the efficacy of VRA by using traditional tools versus the new tool, in normal children between ages of 6 months and 24 months.

1.3 Purpose of the study

1.3.1 Create a new visual reinforcement instrument, composing of a variety of acoustic signals, corresponding to the frequency of sounds used for hearing tests, including 500, 1000, 2000 and 4000 Hz.

1.3.2 Create a new animation reinforcement, corresponding to acoustic signals.

1.3.3 Compare the minimal response level, using the traditional and new tool.

1.3.4 Compare the number of head turns in children, using the traditional tool and the new tool.

1.4 Research questions

1.4.1 Are the newly created sound stimuli appropriate for young children?

1.4.2 Can the newly created sound stimuli be used, instead of the original stimuli?

1.4.3 Do the new instruments improve children's attention spans during the test?

1.4.4 Is there any difference in the number of head turns?

1.5 Expected outcomes of the research

1.5.1 New acoustic stimuli are appropriate for young children.

1.5.2 New acoustic signals can be used, instead of the original stimulus.

1.5.3 The new instrument improves children's attention spans during the test.

1.5.4 The number of head turns using the new tool, are greater than the number of head turns using conventional tool.

1.6 Organization of the study

This study is organized into six chapters. Chapter I is the introduction. Chapter II describes literature review and the previous research studies. The methodology is described in detail in Chapter III. The results of this study are summarized in Chapter IV. Chapter V is a discussion of the study results. The last chapter, Chapter VI, is the conclusions.

CHAPTER II
LITERATURE REVIEW

This chapter includes hearing development, developments of auditory behavior response, and behavioral hearing tests in young children.

2.1 Hearing development (Embryology of the ear)

A child's hearing system develops early, starting in the womb of the mother, in the first month after fertilization. The stage of development is detailed in several steps as follows: auditory system develops from the ectoderm of the embryo surface in the head of otic placodes. Otic placode is the first step to develop into the structures of the inner ear, including the cochleovestibular neurons which will develop into cranial nerve eight in the future. The otic placode cell proliferations, then the edge of the placode is moving closer together until it forms a bag, inside, filled with water. At this stage, the otic placode becomes otic vesicle. The development of the embryo at this stage occurs in the third week after fertilization.

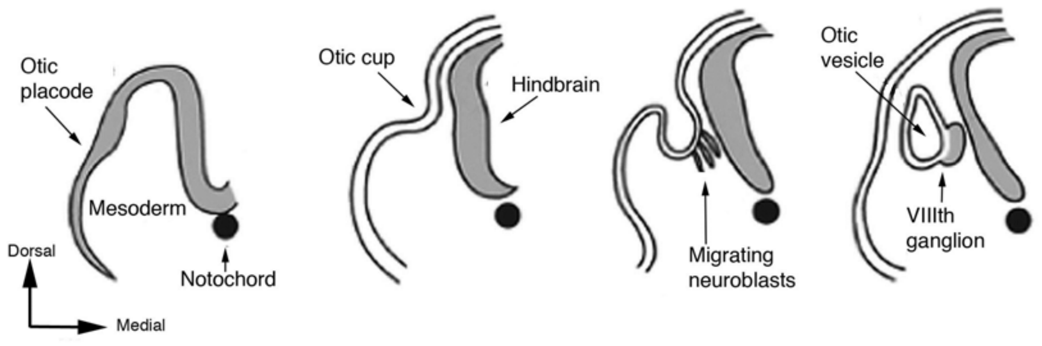


Figure 2.1 The otic placode cell proliferation [17].

During the fourth week after fertilization, neuroblasts will develop into the first phase of the vestibulocochlear ganglion. At this stage, the otic vesicle develops further, by increasing the number and the size of the cells which will develop into the endolymphatic sac, utrical and saccule. During the fifth week of pregnancy, the otic vesicle grows by expanding the tissue, which is opposite of the saccule. It becomes the endolymphatic sac in the future. Subsequently, during weeks 5-7, the cochlea has developed organ of corti. During this period, cochlear ganglion neuron begins contact with hair cells. When entering week 7, the growth of otic vesicle begins to develop a semicircular canal, first with anterior and posterior semicircular ducts, then followed by a lateral semicircular duct. Strial cell in the organ of corti begin to develop during the 9th week of pregnancy.

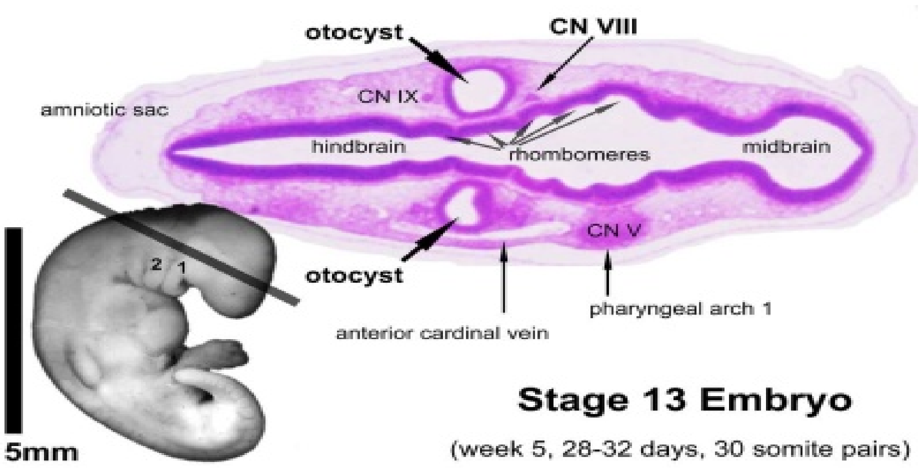


Figure 2.2 The growth of an embryo development during the 5th week [18].

Three types of strial cells, including marginal, intermediate and basal cells, are formed completely in the 12th week. After week 19, stria vascularis are developed with the same structure as adults. Ossification of the bony labyrinth occurs during weeks 16-24 of pregnancy, and cochleae are fully developed, until the size of an adult, at 16-17 weeks gestation. The auditory function will start after the completion of the hearing system, at the age of 20 weeks gestation [19].

Middle ear and outer ear develop from pharyngeal arches 1 and 2. Eustachian tube develops from the first pharyngeal pouch with the most significant growth in the last 16-28 weeks. During the prenatal period, the middle ear cannot work as usual because it is filled with amniotic fluid. Therefore, the sound must go through the bone to the cochlea. Basic components of the outer ear are complete at the end of th 8^{th} week of pregnancy. The outer ear will grow to the same size as an adult when the child is 9 years old [19-20].

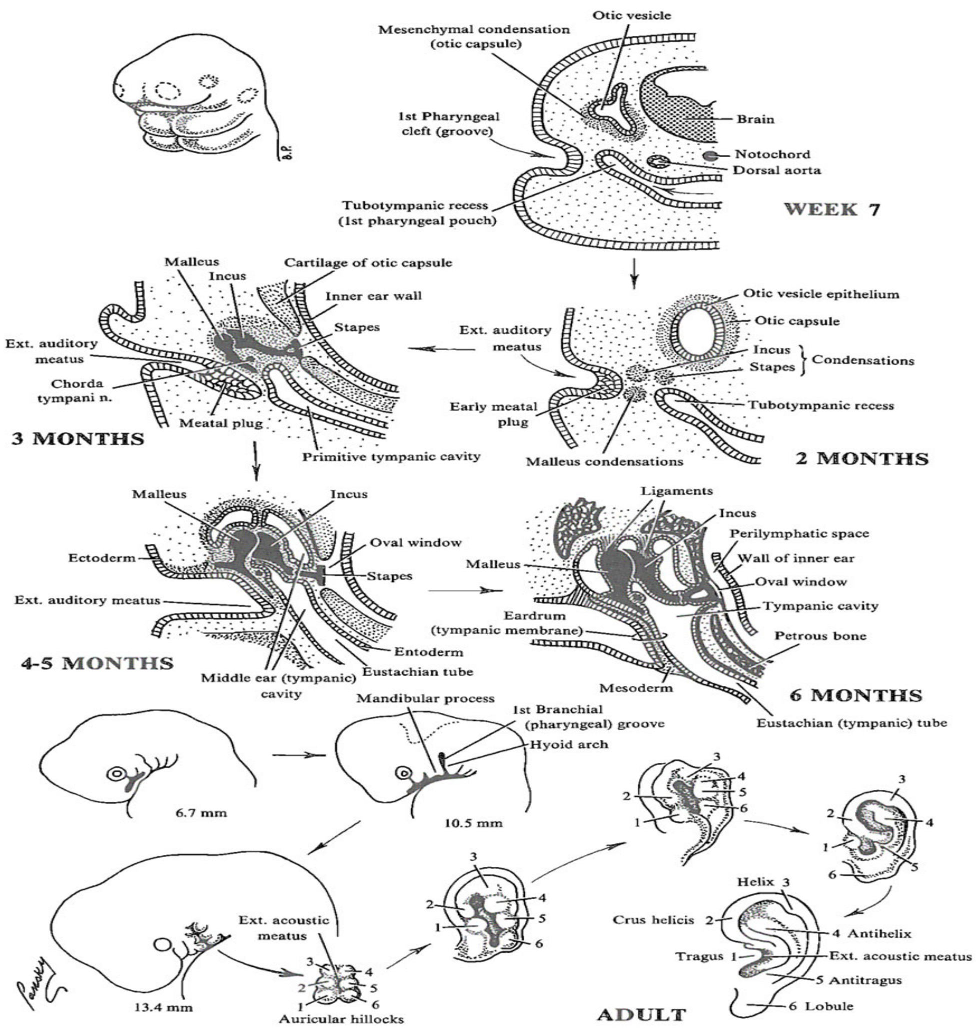


Figure 2.3 The external ear and middle ear development [21].

2.2 Development of auditory behavioral response

Behavioral responses to sounds in children can be divided into reflexive behavior and attentive behavior. Reflexive behavior is a behavioral response that occurs without any control from the brain. It consists of a jerk of the arms or legs, a startle, auropalpebral reflexes, and a twitching face. Attentive behavior is intended behavioral response. These include changes in respiratory rate, vocalization, stopping vocalization, crying, eyes widening, head turning to the sound source, and changing facial expressions. The most common attentive response to the sound stimuli is to turn the head to the sound source. Children aged 0-6 months will require a rather loud sound to encourage a response. Behavioral responses that are seen in children of this age include arousal from sleep, eye-blinking immediately after hearing the sound stimuli, or a slight shudder.

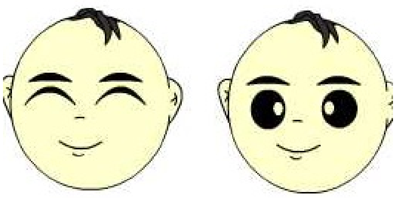


Figure 2.4 Newborn arousal from sleep

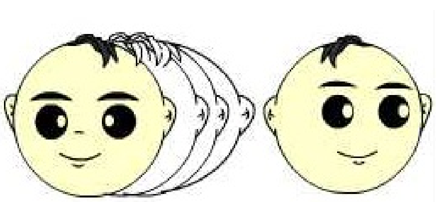


Figure 2.5 3-4 Months: Rudimentary head turn

When children aged 4-7 months recognize their mother's voice, the response may be to stop crying, or stop playing and start listening. Children in this age range begin to turn toward the sound source, with the decreased volume of activation compared to the previous 4 months. There is greater development in the ability to coordinate muscular action at this age. This results in a head turn to a sound source in the lateral plane with wobbly style, with a degree in turn of less than 90 degrees. At age of 6 months, the child can have better muscle control, thus turning his/her head to localize to sounds much better, but he/she still is unable to turn his/her head at a higher or lower level. Children at this age can turn to the sound field, where the sound stimuli are either speech or narrow band noise.

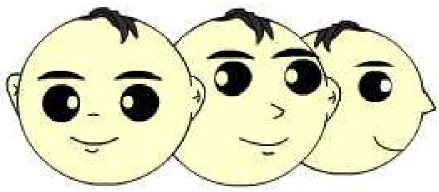


Figure 2.6 4-7 months: Localization to side only

When entering the age of 7-9 months, children can turn their heads to the sound source at below eye level, but the nature of this turn is to the lateral plane and then down at the sound source. This behavior is called indirect fixation of the sound source.

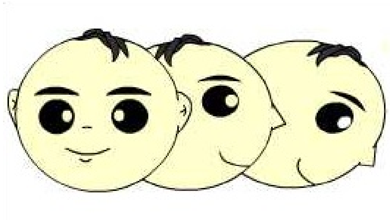


Figure 2.7 7-9 months: Localizes to side and directly below

Children aged 9-13 months is a period when they begin to recognize their own names and hearing tests are often used to call the child’s name. At the age of 13 months, the child is able to turn his/her heads to the indirect fixation in response to signals that are presented above the eye level. Moreover, children at this age have a lot of attention to sounds in the environment, resulting in a quick and clear response.

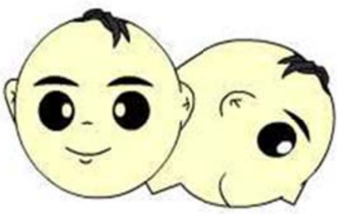


Figure 2.8 9-13 months: Localizes to side and below

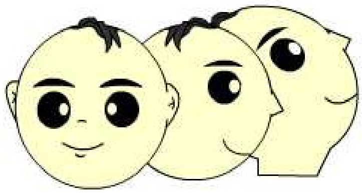


Figure 2.9 13-16 months: Localizes to side, below, and indirectly above

The ability to find the direction of the sound is completely developed when children are aged 13-24 months. During 18 months of age, the child recognizes simple words. The hearing tests at this age are often used to ask simple questions such as “Where is the doll?” or “Where is daddy?” When the child is 24 months, he can respond to sounds by following the simple instructions such as picking up a toy when the child hears the command [22].

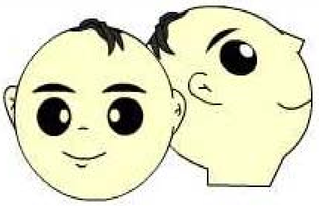


Figure 2.10 16-21 months: Localizes directly all signals to side, below and above

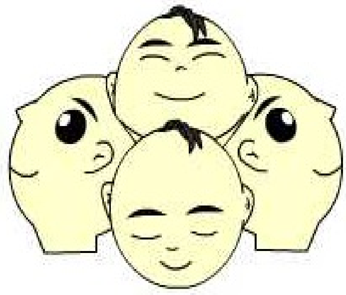


Figure 2.11 21-24 months: Locates directly a sound at any angle

2.3 Behavioral hearing test in young children

For determining the level of hearing in children, especially in children aged 6-24 months, behavioral hearing tests are the gold standard for hearing tests in this group [23]. Behavioral hearing tests can be divided into two categories: the kind that requires reinforcement during the test, and the kind that does not require reinforcement during the test [24]. BOA is a test without reinforcement. A feature that requires reinforcement during the test to help children achieve a greater response is called a conditioned audiometry, which includes VRA and CPA. BOA is a method of testing children aged 6-12 months. It is typically a test by presenting sound stimuli to the child while the child falls asleep, and then observes the change in the response. VRA is used to present the sound stimuli to the child, then observes the child's response to the sound. The response is typically a head turn to the sound source. The child will then receive a visual reward. In CPA, children will be conditioned to hear the sound stimuli. When the child hears the sound, he/she will respond to the sound through playing, for example, puzzles, or adding a toy to the cart or plastic box. However, because the child in this age range does not yet understand conditioning, and might be unable to cooperate during the test, the VRA is recommended.

2.3.1 Visual reinforcement audiometry

The main goal of the hearing test in children is to estimate the level of hearing in children, especially in the frequency range of speech (500-4000 Hz). Therefore, VRA is an effective method to test hearing in children aged 6 months – 2 years. ASHA has recommended VRA test as the first method for testing in children aged 6-24 months, and then continue with tympanometry, acoustic reflex, OAEs and ABR [11]. But for those children who are born prematurely or mentally not developed properly, VRA will be tested in children with the corrected age of 8 months, and in children with a mental age of 6 months [25]. The VRA was first introduced by Liden and Kankunenin in 1969. It has the same basis as the conditioned orientation reflex (COR), which was first found by Suzuki and Ogiba in 1961. Coherence between sound and vision will cause orientation reflex. If the child has seen the pictures, which are interesting enough, and can be linked to the relationship between the sound and visual stimulus, and they understand the conditioning, then the child will be willing to listen, to see the visual of interest. The pattern that occurs is called the conditioned orientation reflex, which is the basis of the VRA. The VRA procedures consist of conditioning, while presenting visual reinforcement to the correct response to the auditory stimuli [26]. An important aspect of the process is to observe the behavioral response to a sound with a specific frequency associated with visual reinforcement [27]. This test can be separated in each ear, and to test the response to the sound stimuli by applying several transducers. The VRA can be divided into two ways, depending on the transducer being used, which can be summarized as follows, the sound field VRA and the closed circuit VRA [28]. But the VRA by using sound field will essentially be described here.

In general, the system of sound field VRA often requires two testers. Tester1 (T1) controls the audiometer and monitors a child’s behavioral response from the outside of the examination room. Tester2 (T2) will be in the examination room with the child in order to control the situation and control the child’s attention during the test. T2 will introduce and explain the appropriate position of the parent and child. If the child is older than 1 year, T2 can have a child sit alone on a small chair, instead of sitting in parent’s lap. They may find suitable toys for he/she to play, to draw the child’s attention during the examination. After that, T2 explains the procedure and practices of the examination to the parent, and at the same time T1 and T2 will observe the child’s behavior. During this same period, T2 may interact with a smile to a child, including talking to, or playing with, the child. Trial conditioning can be done two ways. First, begin with T1 presenting the sound stimuli (1 kHz) with an intensity above threshold and visual reinforcement at the same time. If the child does not turn to the sound source to look at the visual reinforcement, T2 can draw the child's attention to the visual reinforcer. Method 2 can be done by monitoring the head turn of the child to the sound source. If the child can turn his/her head to the sound source correctly, T1 will present reinforcement to the child [29]. Later, when the child understands the conditions, T1 tests again by presenting sound stimuli to the child, which takes about 2-3 seconds. When the child hears and turns his/her head toward the sound source, T1 gives a visual reinforcement for approximately 1-2 seconds to the child as a reward [12]. The duration of the acoustic stimuli presented in VRA testing affects the child's response differently. A study by Culpepper in 1990 shows that if the signal is only present for a shot time (0.5 second), habituation was slower than if the signal is present for long time (4.0 seconds) [30]. In 1959, Carhaart and Jerger also recommended using the signal for VRA testing, presenting only a brief period of time, about 1-2 seconds, as well as the duration of acoustic signal present for the hearing test in adults [31]. In addition, from the study of Culpepper and Thompson in 1994 shows that the period of the reinforcement between 1.5-4 s does not make the results of habituation in children are different [32]. VRA testing sometimes needs only one tester, because if the T2 sits with the child in the examination room, it may make testing difficult because some children may pay too much attention to T2 or feel embarrassed. This results in children that do not listen to the sounds during testing.

Test room setup

The room used for testing VRA should be large enough for a sound field, reinforcement, parents, and children, all together. According to the BSA in 2008, the room used for testing should be at least 4x6 m. The room should have a proper ventilation system, which will help your child feel comfortable during the test. In the examination room, there should be a distracter placed in front of the child. This helps attract the attention of the children, with proper position, in case the test has only one tester. Baskets of toys should be covered with fabric to help reduce the noise caused by the child's play toys [33].

Transducers

There are many kinds of transducers used in the VRA. If it is a closed circuit VRA, earphones, insert earphones or bone vibrators can be used depending on the nature and disorders that occur with children. In the sound field VRA, transducers will be changed to loud speakers. The position of the loud speakers used in the VRA can be 45˚, 60 ˚ or ˚90˚ (not be less than 45˚), when measured from the center of the front. But the most popular position is at the angle of 90 degrees because the child's response can be clearly observed and this allows the child to hear the sound intensity level (dBSPL) equal to the intensity level that coming from loud speakers [33-35].

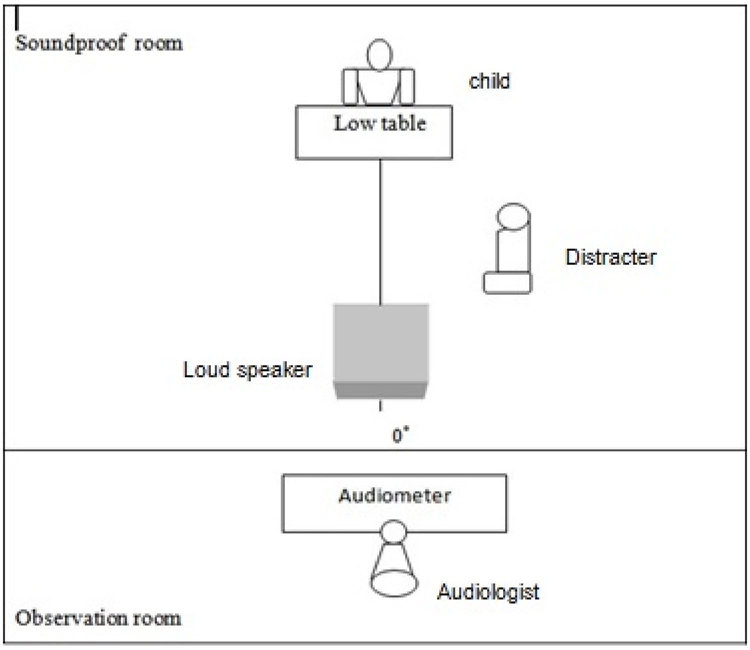


Figure 2.12 The loud speakers setting at 0˚ in VRA testing

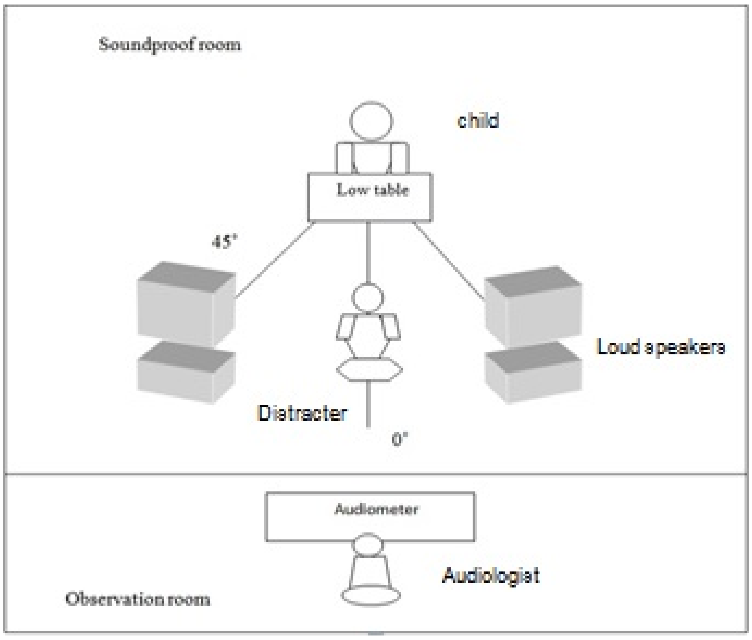


Figure 2.13 The loud speakers setting at 45˚ in VRA testing.

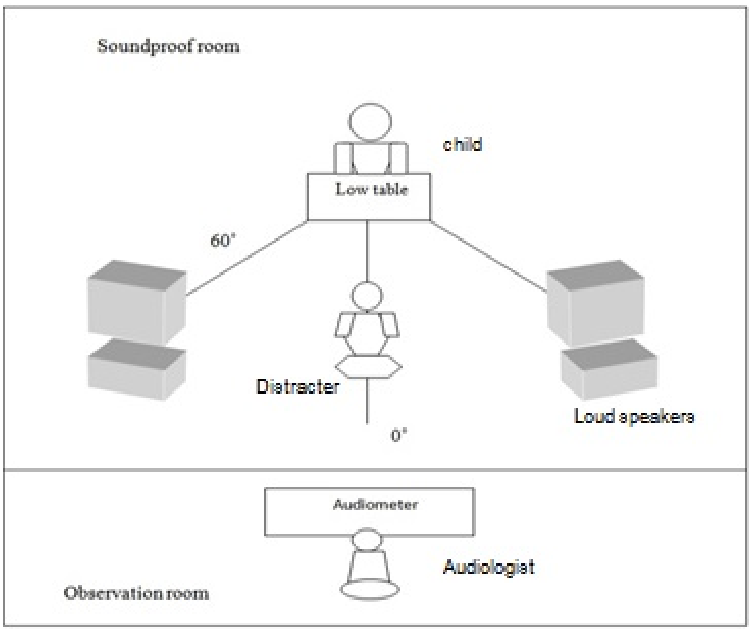


Figure 2.14 The loud speakers setting at 60˚ in VRA testing.

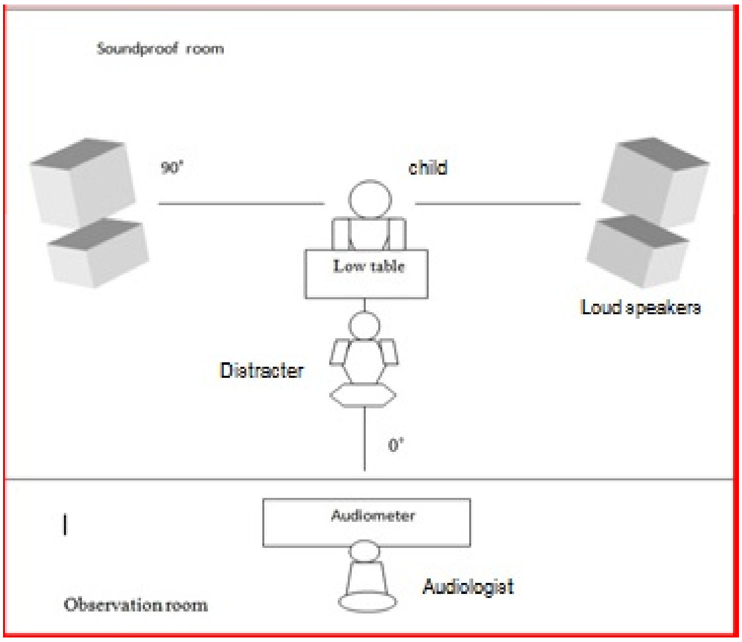


Figure 2.15 The loud speakers setting at 90˚ in VRA testing.

Table 2.1 Compare the advantages and disadvantages of various speakers

Position of loud speakers	Advantages	Disadvantages
0˚	Imitation of one to one communication, The child does not need to make a head turn to the sound source. It is just a change of behavior when he/she hears the sound. Consume only one loud speaker.	Audiologists need some experience and attempt to observe the child's behavior.
45˚	The child's response becomes more definite when compare to 0˚	Require two loud speakers The child's react only visual response without head turning
60˚	Same as the position of 45˚	Same as the position of 45˚
90˚	Head turning to the sound source can be observed most clearly	Not appropriate for children who have additional handicaps

Test stimuli

In theory, the auditory stimuli used to determine a child's hearing can be a pure tone, which is the same as in adults. In 1978, Wilson and Moore studied by using VRA testing in young children and adults using the presence of pure tone frequency 500Hz, 2000Hz, and 4000Hz through the loud speakers. They found that the test results were not significantly different [36]. But it was found that a problem occurred when using a pure tone for a sound stimuli. That means, the child would hear a sound stimuli softer than usual due to the sound field acoustic [29]. However, the audiologist would select the appropriate sound stimuli that had been modified, by adding a bit of interest into a pure tone, such as a pulsing or a warbling. In addition, speech signals and NBN are other signals of choice. Among the 3 types (pure tone, NBN, warble tone) of sound used for VRA testing, it was found that the NBN is a sound that children were most interested in, and responsive to, compared to the warble tone and pure tones [37]. The results obtained from the use of the NBN as sound stimuli may help understand the frequencies characteristic of hearing loss [38]. Speech signals are useful in confirming the consistency of previous results, and sometimes it is used as an initial stimulus for VRA testing because the children are familiar and it helps attract the attention of children as well.

Typically, warble tone, narrow band noise and speech signal were used in VRA, but in recent years there has been a study of the use of other sounds in VRA. Vieira et al. (2007) conducted a study on the Minimum Response Levels (MRL) through the use of VRA in 50 normal hearing children and in 25 children with hearing loss. The sound stimuli were different. It was found that when using the Sonar system MRL value at frequency 500 Hz. and 2000 Hz., it decreased in normal hearing males. MRL value of sonar system is less than modulated tone with a statistically significant difference when tested in children with normal hearing, who were younger than 2 years old. It also found that the MRL of sonar system and modulated tone were decreased when the child grows up [39].

Studies have shown that the children were more likely to respond to the complex stimuli, rather than responding to a pure tone. For example Moore and Thompson in 1975 studied the correct head- turn as a function of reinforcement conditions. They found that the mean number of correct head-turns was greater in complex reinforcement than simple reinforcement [40]. Morgan also studied the response to the sound stimuli of children in VRA testing between the use of speech noise and 2000 Hz warble tone for sound stimuli. The results show that using speech noise as an acoustic stimulation allows the training process to be accomplished more quickly, and more threshold of the hearing, which is more accurate [41]. Better responses to sounds in children tend to increase with age. Bench et al. (1997) explained that children younger than 6 months, and 6 months old infants, did not respond to tonal stimuli. However, younger infants showed better response to broad-spectrum noise than 6 month old infants did with speech stimuli [42].

Test sequence

Determining the MRL for VRA testing will begin at either 500 Hz or 2000 Hz. Choosing the initial frequency for testing is determined by the nature of the child's problem, whether they have conductive hearing loss (CHL) or sensorineural hearing loss (SNHL). If a child has a cold or a problem in the middle ear, the audiologist will start experimenting with the frequency at 2000 Hz, and then go to test at the frequency 500 Hz, because patients with CHL will hear better at higher frequencies. In the case of children with SNHL, the audiologist will begin testing at the frequency 500 Hz, and then go test at the frequency 2000 Hz, because patients with SNHL will hear better at lower frequencies [43].

Distracters

In VRA testing, some toys can be used as distracters, which attract the child's attention to the front. This allows clearer observations of the child's head turns. Toys that can be used should be simple, not noisy or distracting. They must not distract the children so much that they do not turn their head to the sound source. Example toys that can be used as a distracter are magnetic boards, puppets or blocks of form that can be connected to each other [44].

The child's response

The responses of children during the VRA reflect that children hear the sound, and then turn their heads to localize the sound source correctly [45]. But the essence of the VRA is the observation of the child's behavioral response to the sound. These responses include getting goggle eyes, vocalization, stopping to listen, or changing their facial expressions [29]. According to a study by Schmida et al in 2013, to consider the behavior as a response to sound stimuli, the child must turn their head to the sound source within 4 seconds of the stimulus presentation [46].

Reinforcement

There are many types of reinforcement. The selection of equipment depends on the needs of the tester, and the budget. Some clinics use flashing colored lights. Some use a doll that can open or close its eyelids. Others use a box with a light that shows what it is inside it when it lights up. But the most common and often used toy is one that is lighted and animated. Moreover, in 1977, Moore, Wilson and Thompson summarized the results of their study. Regarding the reinforcement used in VRA, lighted and animated toys are appropriate for children aged 5 months and up. Some clinics will randomly choose many kinds of toys as a reinforcement to help attract the child's attention better [47-48]. Although the toy with lights and movement are interesting enough for most children, they may not be suitable for some children, such as children with Down's syndrome, or children who are visually impaired. Therefore, this group requires a change in visual reinforcement. One that may be used is a video image display on the LCD, which can be adjusted.

Different kinds of visual reinforcement affect the interests of the child during the test. Kelly Clarke studied in 2006 by comparing the use of toy and video reinforcement to motivate a child. The subjects were 85 children with an age range between 16 and 24 months. The researcher measured the number of threshold estimation on different kinds of reinforcements. The result showed that the average response on the video reinforcer was 3.4, and was 5.4 for the toy. No statistically significant difference in relationship between the numbers of responses, age groups, or the gender of the participants. The responses of children with hearing loss decreased when compared with the responses of normal children. They also found that when the level of hearing loss increased, the children's responses declined [49]. Lowery et al. (2009) compared the use of animated toys and videos in VRA, they found that there were no significant differences between the video (VVRA) and conventional reinforcement (CVRA) for the total number of head turns, the hit rate (correct head turns), the false alarm rate (incorrect head turns), or sensitivities. Overall results showed no difference between the two reinforcement conditions in infants 7-16 months of age. The results of this study suggested that infants 7-16 months responded similarly to VVRA and CVRA as measured by response consistency, false alarm rate, and overall test sensitivity. They concluded that video visual reinforcement audiometry an alternative for testing hearing in children [50]. When Schmida et al in 2003 studied children aged 19-24 months, the results showed that the average number of head turns for video visual reinforcement audiometry is greater than conventional visual reinforcement audiometry. (15.2 for video reinforcement and 10.8 for conventional reinforcement)

Karzon and Banerjee in 2010 studied the effectiveness of using animated toys versus video reinforcement in children, with an age range between 16-24 months in visual reinforcement audiometry. Participants in this study were 137 of 145 children. The aim of this study was to evaluate whether animated toys or video reinforcement affected the number of estimated thresholds. They found the significant higher thresholds with animated toys (M= 5.52 thresholds) than with video. (M= 3.47 thresholds) The results were consistent with findings by Zimmerman, Christakis, and Meltzoff in 2007. They found that 90% of children aged 24 months watched the television an average of 1.5 hours per day. For this reason, the children in this study were more familiar with 2D animation rather than animated toys, resulting in the lowering of threshold estimation [51].

The use of a new and different reinforcement, versus a traditional one, helped children pay more attention during the test. This mirrors a previous study by Thompson, Thompson and McCall in 1992, which concluded that using a novel reinforcement makes children, age range 1-2 years, pay more attention during the test and make habituation slower. Children aged 2 years achieved habituation faster than 1 year old children [52]. Primus and Thomson found in 1985 that after the children under the age of 2 years had achieved habituation from the first VRA test, testing the

VRA again using the same reinforcement increased an average of only 2.8 times. But if the change is a new type of reinforcement, this will contribute to the response of the children increasing by an average of 12.8 times [53]. In 1977 More et al. studied the responses of children aged 12-18 months to sound stimuli. The children were VRA tested using different reinforcements. The types of reinforcement used in this study consisted of an animated toy, a flashing light, social reinforcement, and no reinforcement. The study found that reinforcements that made the most responses were animated toys with minor flashing lights, social reinforcement, and no reinforcement respectively [54].

Recently, there have been new kinds of visual reinforcement. They are pictures and cartoon movies, which are displayed through an LCD monitor. The responses of children to be taken into account in determining the MRL were the children's head turn. It also included behavioral response that could be easily seen, such as goggle-eyes or crying. The child's response during the VRA testing, which uses a picture or a cartoon movie as a reinforcement showed that the numbers of responses were equal to or greater than the numbers of responses when using conventional reinforcement [8]. In addition, the results above were consistent with the study of the Wener and Kopyar in 1994 which found that children aged between 2-12 months took a look at the video reinforcement longer than the animated toy reinforcement [55].

Determination of MRL

MRL is the lightest volume of sound that children respond to. But at this level, it may not be the lightest volume that the children heard (that's the threshold of hearing). Assessment of the MRL value can be used with the same approach to find the threshold in the routine audiometry by presenting sound stimuli at supra threshold level, which can be changed depending on individual characteristics. Subsequently, the volume presentation is decreased, 10dB descending at a time until the child does not respond. Then it is presented in an ascending increment of 5 dB [56-57]. The number of responses considered to be the MRL when the child can detect sounds at least 50% of the time. However, evaluating the MRL value may not be as stringent. Steps to finding the threshold for the routine audiometry include making adjustments as appropriate for each child [58]. MRL values obtained from the VRA testing are higher in younger children compared to older children. It was also found that the MRL value is higher when using a pure tone as a sound stimulus, when compared to the noise and speech stimuli [59].

CHAPTER III
MATERIALS AND METHODS

The purpose of this study was to create a set of new tools which include audio and video signals, together, for convenient operation and to enhance the interests of the children during the test. VRA, across frequencies, between the traditional and new methods, were compared. The analysis of mean and standard deviation was applied to calculate the minimal response level, and the numbers of correct head turns between NBN stimuli (500-4000 Hz.) and the new stimuli. A comparison was done of the median of minimal response level values and the number of correct head turns between two stimuli, by Wilcoxon signed ranks test.

3.1 Subjects

The number of samples size used in this study was calculated by using a formula

$$N = \sigma_d^2 \frac{(Z_\beta + Z_{\frac{\alpha}{2}})^2}{difference^2}$$

where:

N = sample size, σ = standard deviation of the within-pair difference, Difference = clinically meaningful difference, Z_β = corresponds to power (0.84 = 80% power)

$Z_{\frac{\alpha}{2}}$ = corresponds to two-tailed significance level (1.96 for α = 0.05), σ = 11.351, Difference = 5 (20% of the average 26.71) [60].

$$N = 11^2 \frac{(0.84+1.96)^2}{25}$$

The result of the calculation was N = 38

Subjects in this study were 38 children, aged between 6-24 months, from the Audiology Clinic, in the Department of Communication Sciences and Disorders and preschool day care, Faculty of Medicine, Ramathibodi Hospital Mahidol

University. All the subjects had normal hearing (normal TEOAEs both ears, just heard level ≤ 25 dB both ears) without any medical problems. The data collection was done after being approved by the Human Research Ethics Committee. Parents signed consent forms to participate in the research.

3.2 Research material

3.2.1 Process of creating a new tool

3.2.1.1 Select the environmental or animal sounds which are familiar to children aged 6-24 months, and then analyze those sounds by using a computer program (Cool editor pro), and choose the sounds with peak frequency close to 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. (2 acoustic signals for each frequency) Then, set the volume of the acoustic signals that have been selected to every sounds to an equal volume.

Fig. 3.1 Cool editor proprogram

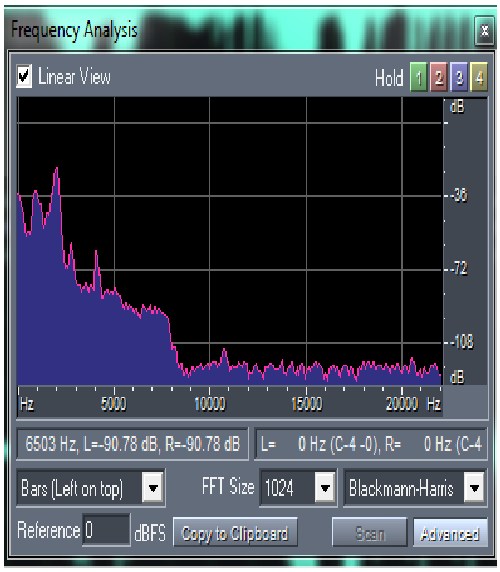


Fig. 3.2 The frequency analysis in the cool editor pro program

3.2.1.2 Create a new animation reinforcement, corresponding to acoustic signals by using a computer program. (Flash)

3.2.1.3 Download free software (Adobe Flash CS3 Professional) from the Internet, and install the program into the computer, which works by using window 7

3.2.1.4 Drawing cartoon characters used in this study, which is the thunderclap, cow, rain, barking dog, duck, frog, birds and cat.

3.2.1.5 Scan comics, drawn earlier, into the computer.

3.2.1.6 Open the flash program, and then take a picture from the library onto the stage.

3.2.1.7 Use the zoom tool to enlarge the pictures for easy customization and editing.

3.2.1.8 Use the line tool to select the color used to draw the line.

3.2.1.9 Use the select tool curve along the curved lines of a scanned image.

3.2.1.10 When the drawing has been completed using the flash program, the next step is to paint it.

3.2.1.11 After the cartoon is drawn, the next step is to make it an animated cartoon, which is started by a click on actionscript 2.0

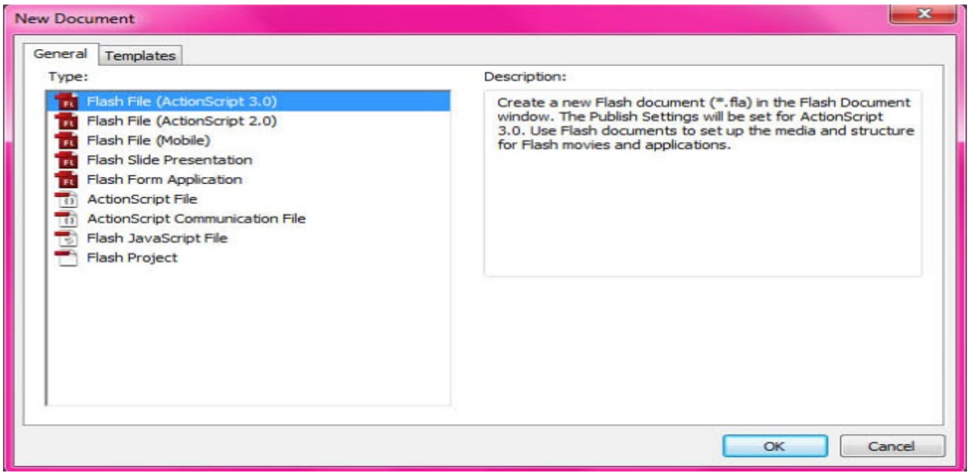


Fig. 3.3 Choosing the actionscript 2.0 of the flash program

3.2.1.12 When the actionscript 2.0 is opened, click to select frame1 and download the cartoon image to frame1.

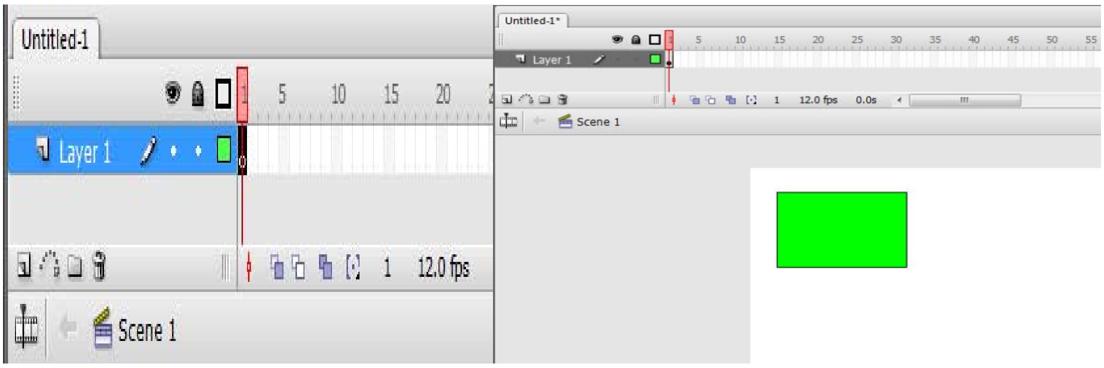


Fig. 3.4 Download picture already drawn into the frame 1

3.2.1.13 Click in Frame 15, and then click on F6, and then continue moving the cartoon picture to the other side of the page

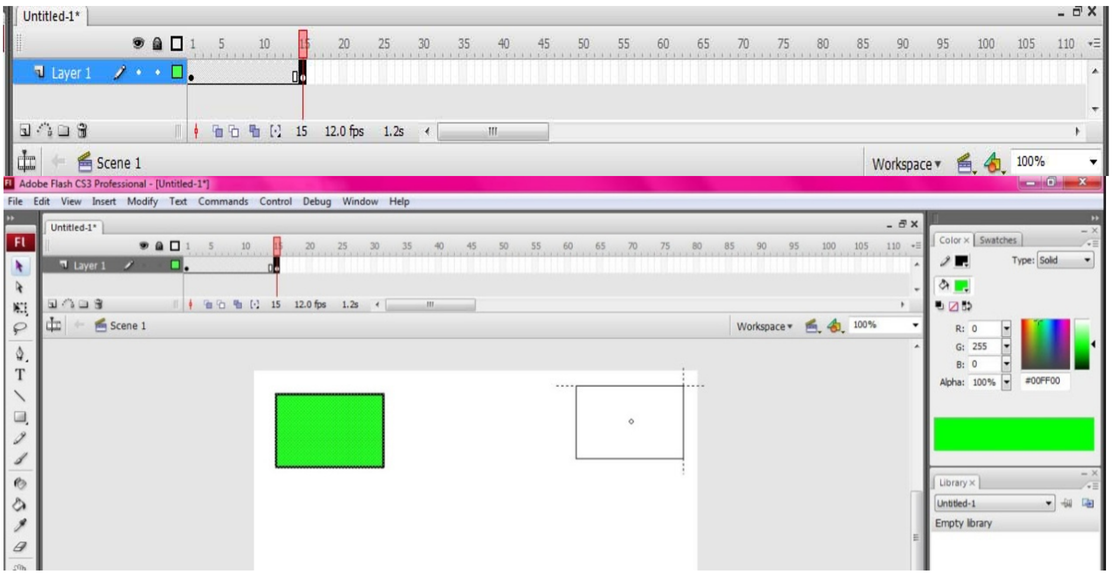


Fig. 3.5 Making motion pictures

3.2.1.14 Animation can be made more smoothly by clicking a frame between frames 1 to frame 15. Select any frame, and then click the right mouse button, and select create shape tween

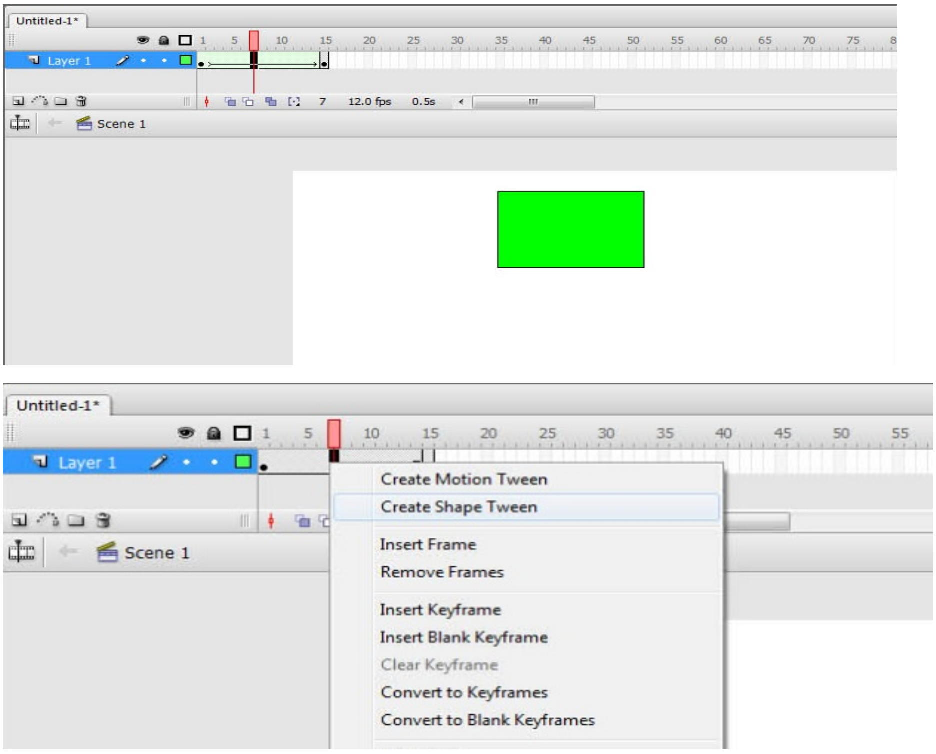


Fig. 3.6 Making animation more smoothly

3.2.1.15 Create the computer application by running the android operating system that combines audio and visual commands together.

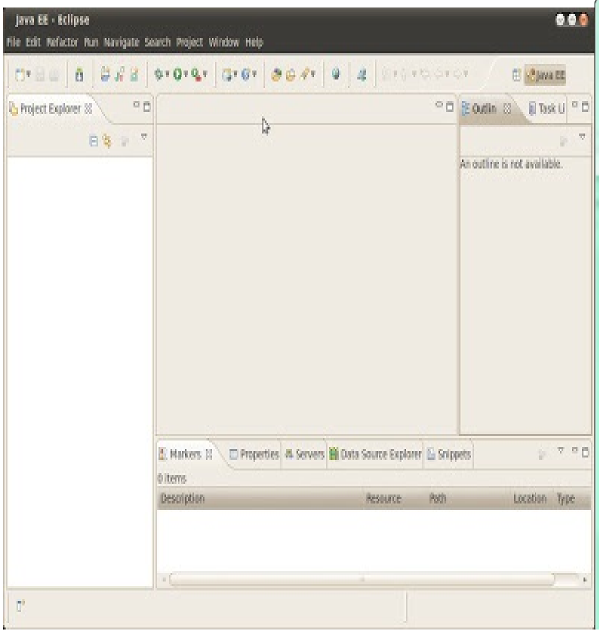
3.2.1.16 To create the application, start by creating an android emulator to simulate the operating android used in tablets called android virtual device (AVD).

3.2.1.17 Download free software (Eclipse) from the Internet, and then install the program into the computer to be used for building the application.

Fig. 3.7 Eclipse program for free download

3.2.1.18 Open the eclipse program, then create a new AVD manager for building application.

3.2.1.19 Open the emulator that is created, and then create a new project by naming this new project the hearing test app.



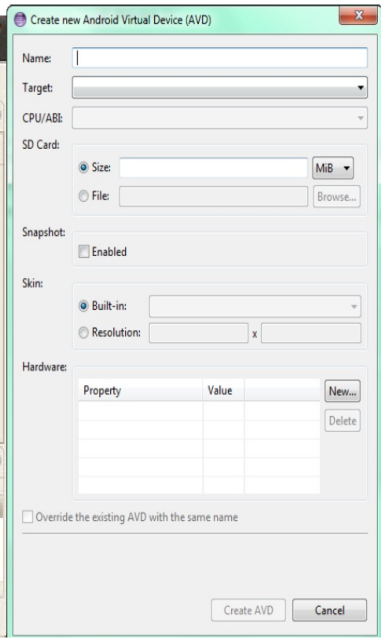


Fig. 3.8 First page of eclipse program

Fig. 3.9 AVD screenshot

3.2.1.20 Make the front page of the application form by editing code XML in file name activity_main.xml or editing from the graphic layout icon.

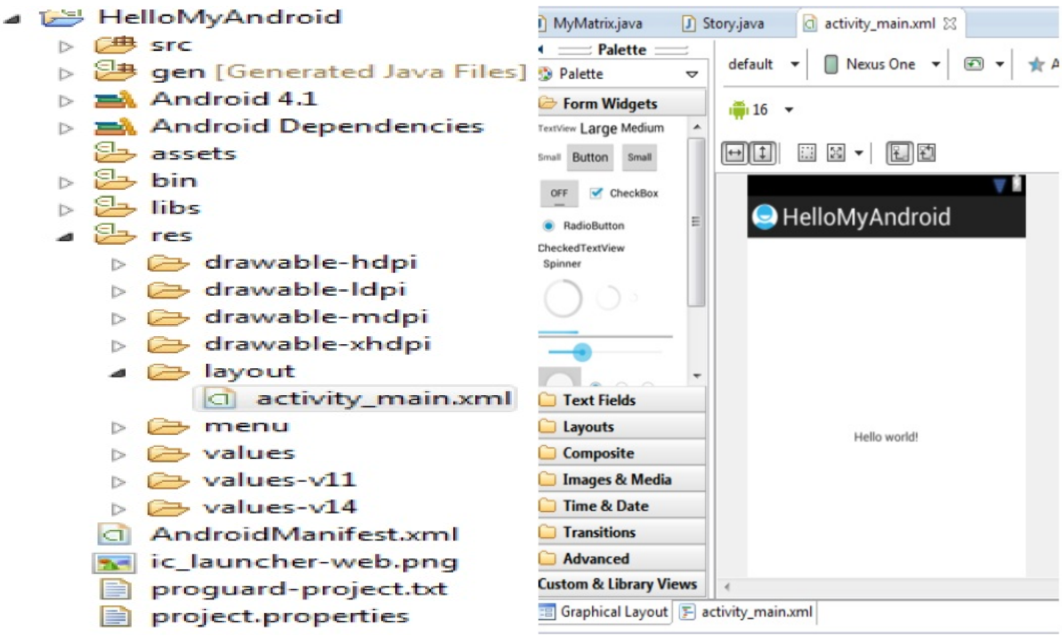


Fig. 3.10 Activity_main.xml icon and page

3.2.1.21 The functions of the application can be created by a written statement, using JAVA language, which is done by writing the command code in the Mainactivity.java icon.

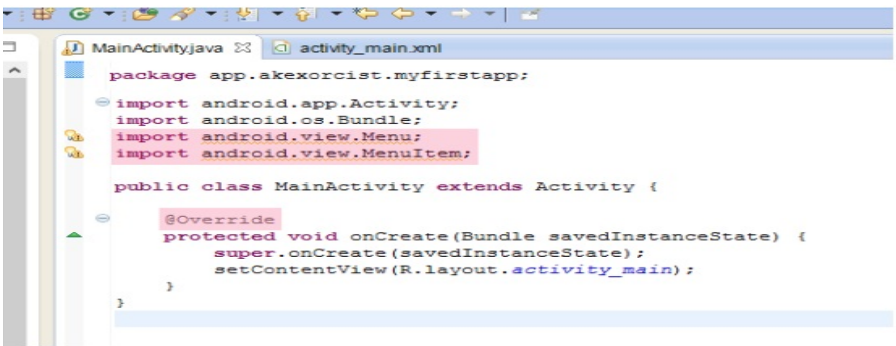


Fig. 3.11 Example code for creating the application by using java language

3.2.1.22 Download the computer application, the new acoustic stimuli, and the animation reinforcement into the tablets. Then install the application in all tablets. The application, now installed on all tablets, can be set to two functions, server and client.

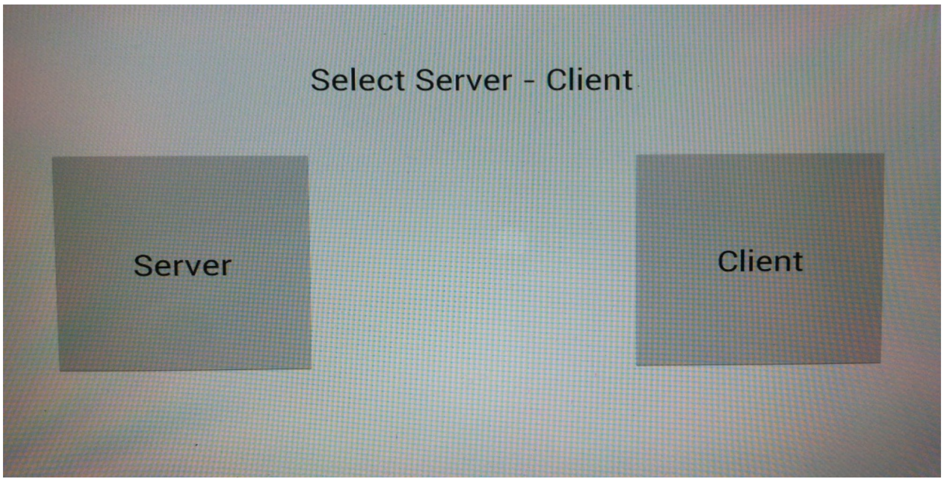


Fig. 3.12 The server function and client function

3.2.1.23 Install the client function in a 9-inch tablet, for use as a receiver; and install the server function in a 10-inch tablet for use as a control.

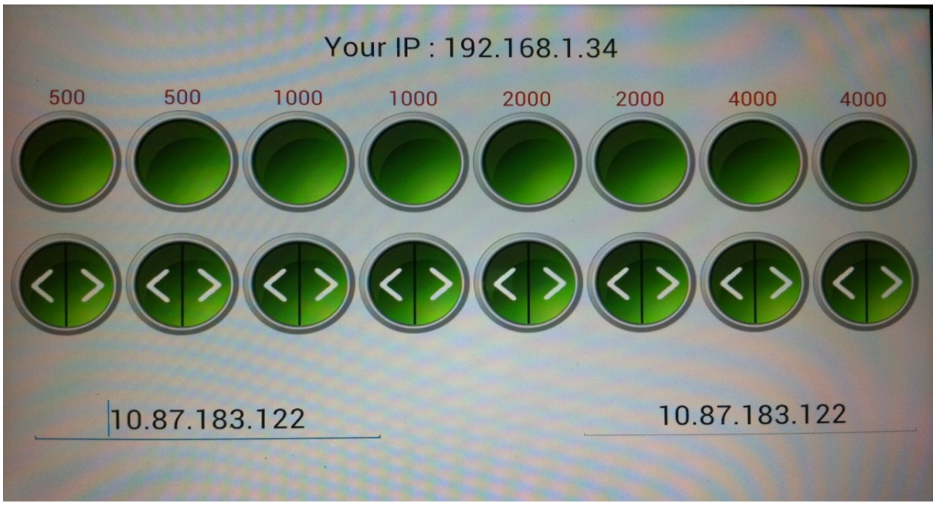


Fig. 3.13 The screen of server function used for control client function

3.3 Research instrumentations

3.3.1 Accuscreen OAEs/ABR Screener.

3.3.2 GSI tympstar.

3.3.3 GSI 61 audiometer.

3.3.4 Frequency analysis by Cool editor pro program.

3.3.5 Creating animations by Flash program (Adobe Flash CS3 Professional).

3.3.6 Creating application by Eclipse program.

3.3.7 Two 9-inch reinforcer tablets PC, and one 10-inch control tablet PC.

All the instruments have been calibrated based on ANSI-S3.6-1996

3.4 Procedure

3.4.1 Control tablet was connected with the audiometer through a cable. The loudness of acoustic signals through the speakers was monitored by controlling the VU meter.

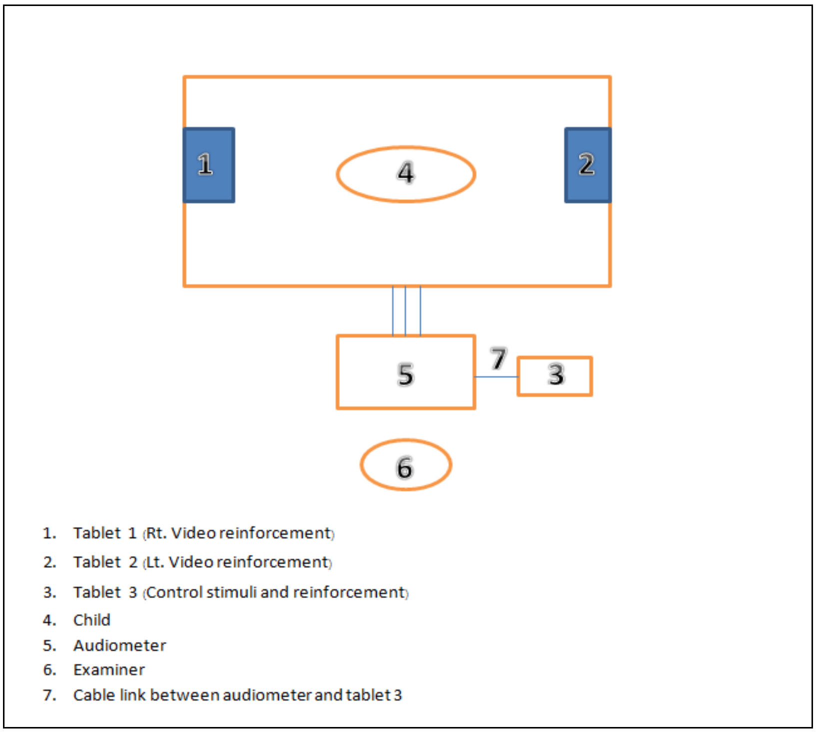


Fig. 3.14 Layout of equipment in test room

3.4.2 Parents sign informed consent form

3.4.3 Researcher interviews parents about the child's health

3.4.4 OAEs test

3.4.5 If the results of OAEs were normal for both ears, then continue with visual screening

3.4.6 The visual screening was done by observing the children behavioral response to the light or pen light movement to left and right (fixation target) [61].

3.4.7 VRA with traditional stimuli and new stimuli. Two series of stimuli were tested randomly

3.4.6.1 Series 1 consists of VRA testing with traditional stimuli, followed by testing with new stimuli.

3.4.6.2 Series 2 consists of VRA testing with new stimuli, followed by testing with traditional stimuli.

A traditional stimulus consisted of NBN 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. New stimuli included the sounds of a cow, a thunderclap (500 Hz), rain, a barking dog (1000 Hz), a frog, a duck (2000 Hz), a bird, and finally a cat (4000 Hz).

3.4.8 In each test, the audiologist searched for the MRL value, by observing the child's correct head turns, to the lowest level of every stimuli. Then the numbers of correct head turns to acoustic signals at comfortable levels were collected until the child demonstrates the signs of habituation. All the results were completed in a recording form

Protocol

3.4.9 Determination of MRL was done by using the same method to find the threshold in routine audiometry (Descending method) [56-57].

3.4.10 The comfortable level was set at 55 dB, which was approximately 20-30 dB above threshold [62].

3.4.11 Duration of acoustic signal presentation was 1-2 s. [31]

3.4.12 Duration of reinforcement presentation was 2-3 s. [32]

3.4.13 The test sequence started at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz respectively.

3.4.14 The correct head turn was within 4 s after stimulus presentation [46].

3.4.15 Habituation was identified when the child did not response to acoustic signal 3 consecutive times [46].

3.4.16 Two series of the test were conducted in the same day with 30 min-1 hrs intermission [50].

3.5 Data analysis

The research data were analyzed according to the purpose of the research as follows:

3.5.1 Means and standard deviations were used to evaluate the minimum response level between the NBN and new stimuli, according to the following frequencies: 500Hz, 1000 Hz, 2000 Hz, and 4000 Hz.

3.5.2 Means and standard deviations were used to evaluate the number of correct head turns to acoustic signals between NBN and new stimuli.

3.5.3 Wilcoxon signed ranks tests were used to compare the median of the minimal response level, between the NBN and the new stimuli, according to the following frequencies: 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

3.5.4 Wilcoxon signed ranks test were used to compare the median of number of correct head turns to sound trials, between the NBN and new stimuli. All data were analyzed by using predictive analysis software statistics version 18. (PASW 18.0) The difference was considered to be significant when $p < 0.05$.

CHAPTER IV
RESULTS

The results of this study were divided into two parts: 1) The results of the creation of new tools, 2) VRA test results when using traditional and new tools, which were detailed as followed:

2.1) MRL values of each frequency in each ear, which was the results of VRA.

2.2) Response to sound stimuli at the frequencies 500-4000 Hz before habituation.

2.3) The difference of MRL values in VRA when using traditional tools and new tools.

2.4) The difference of total numbers of responses to sound stimuli in VRA, when using traditional tools and new tools. The study participants were 38 children, aged 6-24 months, with a mean age of 14.87 months, 23 were male and 15 were female.

4.1 The results of the creation of new tools

The results of creating a new tool on the tablet showed that this new device can transmit acoustic stimuli and video signals without the need for connection wires, but it needed to connect to the Internet. This new tool could change the video and acoustic stimuli, based on the needs of the users. It could also record sound stimuli, which were then analyzed up to a maximum of 8 stimuli, and video up to 8 signals. The accessories for the VRA test, which had been created, could be applied with the Audiometer. When working perfectly, the control the video and acoustic stimuli were available, which were used for testing as well.

4.2 VRA test results when using traditional and new tools

4.2.1 VRA test results using traditional tools

The results of the tests could be expressed as the MRL values, separated by a frequency in each ear. The mean and standard deviation of each frequency in each ear were demonstrated in table 4.1. The mean MRL value at 500 Hz was 27.63 and 26.58 dB with SD of 4.149 and 3.874 in the right and left ear respectively. At 1000 Hz, the average score was 28.42 dB in both ears with SD of 4.045 and 4.518 in right and left ears respectively. At 2000 Hz, the average score was 29.34 in both ears with SD of 4.528 and 4.376 in right and left ears respectively. And finally at 4000 Hz, the mean was 28.68 dB and 30.13 dB with SD of 5.158 and 5.389 in right and left ears respectively.

Table 4.1 The mean and standard deviation of the MRL values for each frequency in each ear of 38 children

MRL value	Right ear	Left ear
	Mean± SD	Mean ± SD
500 Hz	27.63 ± 4.149	26.58 ± 3.874
1000 Hz	28.42 ± 4.045	28.42 ± 4.518
2000 Hz	29.34 ± 4.528	29.34 ± 4.376
4000 Hz	28.68 ± 5.158	30.13 ± 5.389

4.2.2 VRA test results using new tools

The results of the tests could be expressed as the MRL values, separated by a frequency in each ear. The mean and standard deviation of each frequency in each ear were demonstrated in table 4.2. The mean MRL value at 500 Hz was 26.97 and 25.39 dB with SD of 3.59 and 3.746 in right and left ear respectively. At 1000 Hz, the average score was 28.03 and 27.63 dB with SD of 2.973 and 4.309 in right and left ears respectively. At 2000 Hz, the average score was 28.16 and 29.47 dB with SD of 4.565 and 4.317 in right and left ears respectively. And finally at 4000 Hz, the mean was 27.24 dB and 27.76 dB with SD of 5.027 and 4.75 in right and left ear respectively.

Table 4.2 The mean and standard deviation of the MRL value for each frequency in each ear of 38 children

MRL value	Right ear	Left ear
	Mean ± SD	Mean ± SD
500 Hz	26.97 ± 3.59	25.39 ± 3.746
1000 Hz	28.03 ± 2.973	27.63 ± 4.309
2000 Hz	28.16 ± 4.565	29.47 ± 4.317
4000 Hz	27.24 ± 5.027	27.76 ± 4.75

4.3 The numbers of responses to the sound stimuli before habituation

4.3.1 The numbers of responses to sound stimuli when using traditional and new tools

The response to be considered in this study was correct head turn to the sound source. Sound stimuli at a comfortable level of 55 dB were presented alternately in right and left speakers. The numbers of correct head turns were counted. The test ended when there was habituation. (No response at least 3 consecutive times of stimulus presentation) The results showed that the children responded to new sound stimuli more than traditional stimuli. The average numbers of correct head turns to new stimuli was 25.61 (range 6-94) while traditional sound stimuli was 15.58. (Range 1-70) The details of all test results were shown in Table 4.3.

Table 4.3 The numbers of responses to sound stimuli when using the new and traditional tools

Stimuli	The number of response to sound stimuli	
	Range of responses	Mean ± SD
Traditional	1-70	15.58 ± 13.042
New	6-94	25.61 ± 16.125

4.4 The difference between the response to sound stimuli when using traditional and new tools

The difference of the MRL between traditional and new stimuli was analyzed by using nonparametric statistics in Wilcoxon signed ranks tests.

The results showed that the response to new sound stimuli was not statistically significantly different (P > 0.05) from the response to traditional stimuli at the frequencies of 500 Hz, 1000 Hz, and 2000 Hz. However, at 4000 Hz, the response to new sound stimuli was statistically significantly different (P < 0.05) from the response to traditional stimuli.

Table 4.4 Comparison of 38 children's responses to traditional and new sound stimuli by using the Wilcoxon signed ranks test.

Tests	MRL		Z	P-value
	New (Mean ± SD)	Traditional (Mean ± SD)		
Right500Hz	26.97 ± 3.59	27.63 ± 4.149	-0.726	0.468
Left500Hz	25.39 ± 3.746	26.58 ± 3.874	-1.732	0.083
Right1000Hz	28.03 ± 2.973	28.42 ± 4.045	-0.600	0.549
Left1000Hz	27.63 ± 4.309	28.42 ± 5.518	-1.342	0.180
Right2000Hz	28.16 ± 4.565	29.34 ± 4.528	-1.732	0.083
Left2000Hz	29.47 ± 4.317	29.34 ± 4.376	-0.200	0.841
Right4000Hz	27.24 ± 5.027	28.68 ± 5.158	-2.40	0.016
Left4000Hz	27.76 ± 4.75	30.13 ± 5.389	-3.175	0.001

4.5 The difference between the numbers of responses to traditional and new sound stimuli

The difference of the numbers of responses to sound stimuli between traditional and new stimuli was analyzed by using nonparametric statistics in Wilcoxon signed ranks test.

The results of the analysis showed that the responses to sound stimuli using the new tool was statistically significantly different ($P < 0.05$) from the responses of the children when using traditional tools.

Table 4.5 Comparison of total numbers of responses to traditional and new sound stimuli by using Wilcoxon signed ranks test.

Test	Numbers of response		Z	P-value
	New (Mean ±SD)	Traditional (Mean ±SD)		
Numbers of response	25.61 ± 16.125	15.58 ± 13.042	-4.910	9.12×10^{-7}

CHAPTER V
DISCUSSION

The purpose of this research is to create a new tool that is supplementary used with the VRA. The new tool which includes video and acoustic signals together and connects to the audiometer in order to control the volume and transducer. Then compare the results of the VRA when using the new tool and the traditional tool, considering the differences in the results of the MRL value and the numbers of head turns. All the results will be discussed as follows:

5.1 The efficiency of the new tool during the VRA testing

The devices of the new tool could be linked to work together very well, especially in a place where there was wifi. This new tool could be used with convenience and versatility because the link between each device required only a wifi signal. Sometimes the new tool did not work properly due to the weakness of the wifi signal, causing linkage disruption. The problem could be resolved in two different ways. The first way is to pay for the Internet, with the option of a daily or a monthly charge. The second is to use a tablet, containing a Bluetooth function. However, because this study was the beginning of the new tool creation, adapting or changing it may be necessary for the improvement of its function in the future.

5.2 The difference of the response to sound stimuli between traditional and new stimuli

The researcher found the MRL to NBN and new stimuli at frequencies 500-4000 Hz, by observing the child’s head turns to stimuli. The correct response was defined as a child’s head turn to the sound source within 4 seconds of the stimulus presentation [46].

5.2.1 The child's response when using traditional stimuli

During the VRA testing, the children's responses to traditional stimuli were between 15-35 dB at frequencies 500-2000 Hz. But at a frequency of 4000 Hz, the responses were rather high, which was in the range 15-40 dB. However, this response was an estimation of actual hearing, which is called awareness threshold. The true hearing level will be less than awareness threshold [33] because all the research participants were already screened for hearing. The results were normal. The response to acoustic stimuli at frequency 4000 Hz was rather high because of the frequency 4000 Hz was used to test for the final sequence. This may have led to children who were bored and had lost interest. Therefore, the level of response was higher than the reality value.

5.2.2 The child's response when using new stimuli

Two new sound stimuli were matched with each NBN frequency. During the test, the audiologist randomly selected the acoustic stimuli used for VRA testing. The results showed that there were no significant differences in the responses of the two types of acoustic stimuli at each NBN frequency. The reason for this was due to the fact that each sound stimuli was selected from the analysis of frequency, and then picked out. Sound stimuli with center frequency corresponded to the NBN frequencies. The VRA tests both traditional stimuli and new stimuli. It is likely the new stimuli can replace the traditional stimuli. The advantage of using new stimuli for testing VRA is that it is able to extend the child's attention span longer.

5.2.3 Compare the differences of responses between the VRA when using traditional stimuli and new stimuli

The results of the statistical calculations showed the VRA test results clearly. The traditional tool's results and new tool's results were not different at frequencies 500-2000 Hz. However, at 4000 Hz, the new stimuli provided a lower awareness threshold than the traditional stimuli did. Consider the average of the responses during the VRA, using traditional and new tools. They differed only 1.44 dB and 2.37 dB in the right and left ears respectively. But in practice, the difference was not enough to declare it an abnormal difference [63]. When a hearing test was performed, the level used to increase or decrease was a 5 dB step [33, 64]. Considering the difference in responses obtained from this study, there was very little difference. (Less than 5 dB) Moreover, when considering the details of the responses to 4000 Hz, the results showed that the average response of the VRA test when using the new stimuli was less than the average response when using traditional stimuli. From the above reason, the MRL value obtained by the use of new stimuli should be used as an awareness threshold of hearing because the MRL is an estimation of the hearing level, which is greater than true hearing level about 5-10 dB [33].

The MRL values from the VRA testing, when using traditional and new tools, were not significant different because the creation of new acoustic stimuli was achieved by using a computerized frequency analysis of the sound in the environment. It was selected, and matched to the center frequency of those sounds with the NBN frequency. Therefore, the acoustic stimuli used in the test were different, but the MRL values obtained from the test were similar.

5.3 Numbers of head turns during the VRA

The results of this study showed the numbers of head turns to acoustic stimuli when using the new tool was greater than the traditional tool. The children demonstrated more interest in localization to the acoustic signal and looking at the reinforcement animation when using the new tool. The reasons why children were more responsive depend on two aspects: the acoustic signals and the visual reinforcement. The acoustic stimuli that were used in the VRA testing were selected from the environmental sounds which were familiar to children. Moreover, these acoustic stimuli were also available in various tones [14]. Looking at the reinforcement, the bright color animations were more attractive to the children than traditional dolls [52]. By the above reasons, the acoustic signals and animation reinforcement of the new tools greatly enhanced the child's attention spans and provide longer responses. The results were consistent with the findings of Bench et al in 1977, Moore and Thompson in 1975, Thompson and McCall in 1992, and Primus and Thomson in 1985.

The VRA testing with traditional tools elicits the NBN signals at 250-4000Hz which were different only in frequencies. Traditional reinforcement can attract the children only at the beginning of the test. Using traditional reinforcement results in quicker habituation. Thus, the audiologist requires more sessions to evaluate young children.

Recommendation and further study

1. Future studies should be conducted on the results of the VRA when using the new tool in hearing loss children.

2. The study compared the sound of the other groups that might be of interest to children in this age range.

CHAPTER VI
CONCLUSIONS

This study was conducted to create a new tool that performs well, alongside the audiometer. The new tool was applied with 38 normal hearing children. Comparing the new tool and the traditional tool, was based on randomly experimenting. The children's responses to the new tool and traditional tool were compared. The data were compared in terms of the minimal response level value (MRL), and the numbers of correct head turns to acoustic stimuli before the children started habituation.

The new tool consisted of 3 computer tablets that could be connected to each other by the use of the Wifi connection utility. To control the work between the computer tablets, programs were made by creating android applications. In addition, the video and acoustic signals that were used in this new tool were also created by using the computer programs.

The new tool can be linked to the audiometer; they work together efficiently. The MRL values obtained from the VRA by using the traditional tool and the new tool were not significant different at low and mid frequencies. Only at 4KHz, was there a significant difference. However, the average difference was 2.37 dB and 1.44 dB in left and right ears respectively. This difference did not reach 5 dB step, thus did not demonstrate any distinction in misdiagnosis. The numbers of correct head turns to acoustic stimuli before habituation, using the 2 types of instruments, are markedly different. The new tool provided better response than the traditional tool. The experimental results confirmed that the new tool can be used with the VRA procedure without any difference from the traditional tool. In addition, the new tools can also help increase the child's attention during the test, and the data from the test VRA was completed faster. This will help the diagnostics, and to help children in a timely manner.

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APPENDICES

APPENDIX A

แบบบันทึกผลการศึกษา

วันที่.......................... H.N..............................

ชื่อด.ญ/ด.ช. ....อายุ...........................

ผลการตรวจ OAEs...................................ผลการตรวจคัดกรองการมองเห็น...................................

ผลการตรวจ VRA

1. Conventional stimuli

Ear	500 Hz.	1000Hz.	2000Hz.	4000Hz.
Right				
Left				

2. New stimuli

Ear	500 Hz.	1000Hz.	2000Hz.	4000Hz.
Right				
Left				

ตารางบันทึกจำนวนครั้งในการหันหาเสียงของเด็ก

1. Conventional stimuli

	500 Hz.	1000Hz	2000Hz	4000Hz
1				
2				
3				
4				
5				
6				
7				

จำนวนครั้งที่ผู้ป่วยหันหาเสียงได้ถูกต้อง.............

ระยะเวลาที่ใช้ในการทดสอบ เริ่ม..........สิ้นสุด.........

2. New stimuli

	500Hz.		1000Hz.		2000Hz.		4000Hz.	
1								
2								
3								
4								

จำนวนครั้งที่ผู้ป่วยหันหาเสียงได้ถูกต้อง.............

ระยะเวลาที่ใช้ในการทดสอบ เริ่ม..........สิ้นสุด.........

APPENDIX B

THE RAW DATA OF THE VRA TESTING IN CHILDREN DURING THE USE OF TRADITIONAL TOOLS AND NEW TOOLS

Subject (N0.)	Gender	Ear	MRL value at frequencies (dB)								Numbers of response	
			500Hz		1000Hz		2000Hz		4000Hz			
			C	N	C	N	C	N	C	N	C	N
1	M	R	30	25	30	30	30	25	25	25	10	15
		L	25	30	30	35	30	30	25	25		
2	M	R	30	30	35	30	30	30	35	30	21	29
		L	30	25	35	30	30	30	35	35		
3	M	R	30	30	30	30	25	30	25	30	23	22
		L	30	30	25	25	25	30	25	30		
4	F	R	25	30	30	25	30	25	20	20	11	31
		L	25	25	30	30	30	30	30	25		
5	M	R	25	30	30	30	35	35	35	35	6	6
		L	25	25	30	30	30	30	35	35		
6	M	R	25	30	35	30	35	35	35	30	14	34
		L	25	20	30	30	30	30	35	30		
7	F	R	30	25	25	25	30	35	30	25	34	39
		L	25	25	30	25	30	35	30	25		
8	M	R	25	30	30	30	35	35	25	20	15	18
		L	30	30	30	35	30	35	35	30		
9	M	R	35	30	30	25	30	25	30	30	51	47
		L	25	25	35	30	35	30	30	25		

Note: F = Female, M = Male, R = Right, L = Left, C = Conventional, N = New

APPENDIX C

THE RAW DATA OF THE VRA TESTING IN CHILDREN DURING THE USE OF TRADITIONAL TOOLS AND NEW TOOLS

Subject (N0.)	Gender	Ear	MRL value at frequencies (dB)								Numbers of response	
			500Hz		1000Hz		2000Hz		4000Hz			
			C	N	C	N	C	N	C	N	C	N
10	F	R	30	25	35	25	35	30	25	20	5	18
		L	30	30	30	30	25	30	20	20		
11	F	R	25	25	30	25	25	25	20	20	12	20
		L	30	25	20	20	25	30	25	25		
12	M	R	25	25	30	30	30	25	30	25	11	14
		L	25	30	25	30	30	30	30	25		
13	M	R	25	20	25	25	35	30	3O	25	2	8
		L	20	20	25	20	30	25	30	30		
14	M	R	30	25	30	30	25	30	25	30	3	9
		L	30	25	35	30	35	35	35	40		
15	M	R	25	25	25	30	30	30	25	25	1	18
		L	25	20	25	25	30	25	20	20		
16	M	R	20	25	20	25	20	25	20	20	23	22
		L	15	20	20	25	20	25	25	25		
17	M	R	35	35	30	25	30	30	30	30	8	32
		L	30	30	30	30	35	30	30	25		
18	M	R	25	30	25	25	30	25	30	25	11	34
		L	25	25	20	25	20	25	25	20		

Note: F = Female, M = Male, R = Right, L = Left, C = Conventional, N = New

APPENDIX D

THE RAW DATA OF THE VRA TESTING IN CHILDREN DURING THE USE OF TRADITIONAL TOOLS AND NEW TOOLS

Subject (N0.)	Gender	Ear	MRL value at frequencies (dB)								Numbers of response	
			500Hz		1000Hz		2000Hz		4000Hz			
			C	N	C	N	C	N	C	N	C	N
19	F	R	30	25	30	25	25	30	30	30	6	30
		L	30	25	30	30	35	35	30	35		
20	M	R	35	30	25	30	35	25	30	30	8	16
		L	30	30	35	35	30	35	30	30		
21	M	R	30	25	25	30	25	25	30	30	10	11
		L	25	25	30	30	40	35	40	30		
22	M	R	25	30	25	25	30	30	35	30	22	23
		L	30	25	25	20	30	25	40	35		
23	F	R	35	30	30	30	35	30	30	25	15	35
		L	25	30	30	25	35	35	35	30		
24	M	R	25	20	30	25	25	30	25	25	10	13
		L	25	20	30	25	30	25	25	25		
25	F	R	20	20	20	25	25	20	25	20	10	36
		L	20	25	20	25	25	25	25	20		
26	F	R	25	25	30	30	30	25	25	20	13	30
		L	25	25	25	25	30	30	35	30		
27	M	R	30	30	25	25	25	25	40	35	9	14
		L	35	25	25	30	25	25	40	30		

Note: F = Female, M = Male, R = Right, L = Left, C = Conventional, N = New

APPENDIX E

THE RAW DATA OF THE VRA TESTING IN CHILDREN DURING THE USE OF TRADITIONAL TOOLS AND NEW TOOLS

Subject (N0.)	Gender	Ear	MRL value at frequencies (dB)								Numbers of response	
			500Hz		1000Hz		2000Hz		4000Hz			
			C	N	C	N	C	N	C	N	C	N
28	F	R	25	25	25	30	30	35	35	40	4	11
		L	30	25	30	30	25	25	30	25		
29	F	R	25	25	30	25	25	20	30	30	17	17
		L	20	25	30	25	30	20	35	25		
30	M	R	25	30	35	30	30	35	30	30	20	24
		L	30	25	35	35	35	40	35	35		
31	F	R	30	20	30	30	35	30	30	35	9	10
		L	25	25	30	30	25	30	35	30		
32	M	R	25	30	30	25	25	25	25	25	70	94
		L	30	25	25	25	30	30	25	25		
33	F	R	30	25	25	30	25	20	20	20	26	54
		L	25	20	25	25	25	30	25	25		
34	F	R	30	30	30	30	35	35	30	25	17	40
		L	30	35	30	30	30	30	25	20		
35	F	R	25	25	20	25	20	20	25	25	12	17
		L	25	20	25	20	25	20	30	25		
36	F	R	35	30	35	35	35	30	40	35	19	34
		L	30	25	35	30	35	30	25	25		

Note: F = Female, M = Male, R = Right, L = Left, C = Conventional, N = New

APPENDIX F

THE RAW DATA OF THE VRA TESTING IN CHILDREN DURING THE USE OF TRADITIONAL TOOLS AND NEW TOOLS

Subject (N0.)	Gender	Ear	MRL value at frequencies (dB)								Numbers of response	
			500Hz		1000Hz		2000Hz		4000Hz			
			C	N	C	N	C	N	C	N	C	N
37	F	R	30	25	30	35	35	30	35	30	17	31
		L	25	20	25	20	30	30	35	30		
38	M	R	20	30	25	30	25	25	25	25	17	17
		L	25	30	35	30	25	30	25	30		

Note: F = Female, M = Male, R = Right, L = Left, C = Conventional, N = New

APPENDIX G

หนังสือยินยอมโดยได้รับการบอกกล่าวและเต็มใจ
สำหรับผู้เข้าร่วมการวิจัยที่ไม่สามารถแสดงความยินยอมได้ด้วยตนเอง

ชื่อโครงการ เสียงกระตุ้นที่ใช้ในการตรวจการได้ยินชนิดให้แรงเสริมทางสายตา

ชื่อผู้วิจัย นายจิระภัทร สีแสงหน่อม

***ชื่อผู้เข้าร่วมการวิจัย** ....
อายุ ....**เลขที่เวชระเบียน** ....

คำยินยอมของผู้มีอำนาจกระทำการแทนผู้เข้าร่วมการวิจัย

ข้าพเจ้า นาย/นาง/นางสาว .... ซึ่งเป็นผู้มีอำนาจกระทำการแทนนาย/นาง/นางสาว/ด.ช./ด.ญ. .... ในฐานะ ....ได้ทราบรายละเอียดของโครงการการวิจัย ตลอดจนประโยชน์ และข้อเสี่ยงที่จะเกิดขึ้นต่อผู้เข้าร่วมการวิจัยจากผู้วิจัยแล้วอย่างชัดเจน ไม่มีสิ่งใดปิดบังซ่อนเร้นและยินยอมให้ทำการวิจัยในโครงการที่มีชื่อข้างต้น และข้าพเจ้ารู้ว่าถ้ามีปัญหาหรือข้อสงสัยเกิดขึ้น ข้าพเจ้าสามารถสอบถามผู้วิจัยได้ และข้าพเจ้าสามารถไม่ให้ผู้เข้าร่วมการวิจัยเข้าร่วมโครงการวิจัยนี้เมื่อใดก็ได้ โดยไม่มีผลกระทบต่อการรักษาที่ผู้เข้าร่วมการวิจัยได้รับ นอกจากนี้ผู้วิจัยจะเก็บข้อมูลเฉพาะเกี่ยวกับตัวผู้เข้าร่วมการวิจัยเป็นความลับและจะเปิดเผยได้เฉพาะการสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวผู้เข้าร่วมการวิจัยต่อหน่วยงานต่างๆที่เกี่ยวข้อง กระทำได้เฉพาะกรณีจำเป็นด้วยเหตุผลทางวิชาการเท่านั้น

ลงชื่อ...(ผู้มีอำนาจกระทำการแทน)
....(พยาน)
....(พยาน)
วันที่ ....

คำอธิบายของผู้ทำวิจัย

ข้าพเจ้าได้อธิบายรายละเอียดของโครงการ ตลอดจนประโยชน์ของการวิจัย รวมทั้งข้อเสี่ยงที่อาจจะเกิดขึ้นแก่ผู้เข้าร่วมการวิจัยให้ผู้มีอำนาจกระทำการแทนทราบแล้วอย่างชัดเจน โดยไม่มีสิ่งใดปิดบังซ่อนเร้น

ลงชื่อ...(ผู้ทำวิจัย)
วันที่..........................

** ผู้เข้าร่วมการวิจัย หมายถึง ผู้ยินยอมตนให้ทำวิจัย*

APPENDIX H

คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล
๒๗๐ ถนนพระราม ๖ แขวงทุ่งพญาไท เขตราชเทวี กทม. ๑๐๔๐๐
โทร. (๐๒) ๒๐๑-๑๐๐๐

Faculty of Medicine Ramathibodi Hospital, Mahidol University.
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Tel. (662) 201-1000

Documentary Proof of Ethical Clearance
Committee on Human Rights Related to Research Involving Human Subjects
Faculty of Medicine Ramathibodi Hospital, Mahidol University

No MURA2014/93

Title of Project	Variety Of Acoustic Stimuli Used In Visual Reinforcement Audiometry
Protocol Number	ID 02 - 57 - 27
Principal Investigator	Mr.Jiraphat Seesangnom
Official Address	Communication Sciences and Disorders Faculty of Medicine Ramathibodi Hospital Mahidol University

The aforementioned project has been reviewed and approved by the Committee on Human Rights Related to Research Involving Human Subjects, based on the Declaration of Helsinki.

Signature of Secretary Committee on Human Rights Related to Research Involving Human Subjects	Prof. Duangrurdee Wattanasirichaigoon, M.D.
Signature of Chairman Committee on Human Rights Related to Research Involving Human Subjects	Prof. Pratak O-Prasertsawat, M.D.
Date of Approval	March 12, 2014
Duration of Study	6 Months

BIOGRAPHY

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