

THESIS

MUSICAL AUDITORY DISCRIMINATION AND PERCEPTION OF MANDARIN CHINESE  
TONES IN TAIWANESE CHILDREN  
WITH COCHLEAR IMPLANTS

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Music

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Fort Collins, Colorado

Fall 2012

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## ABSTRACT

### MUSICAL AUDITORY DISCRIMINATION AND PERCEPTION OF MANDARIN CHINESE TONES IN TAIWANESE CHILDREN WITH COCHLEAR IMPLANTS

A relationship between auditory perception of speech and music for English speakers with hearing loss has been found in previous studies. When they more accurately discriminated stress and accent patterns in English, they also had better musical rhythm perception. However, people who speak a different language from English may show dissimilar results. The purpose of this study was to find out if performance on the melodic and rhythmic tests of the Primary Measures of Music Audiation (PMMA) were significantly and positively related to performance of the Mandarin Chinese tonal test in the Mandarin Lexical Neighborhood Test (M-LNT). Twenty-six Taiwanese children between the ages of 10 to 12 participated in this study. All of them were wearing cochlear implants due to their hearing loss. During this study, each participant took three auditory tests, which were the melodic, rhythmic and Mandarin Chinese tonal tests.

The results showed that in these Taiwanese participants, when they more accurately discriminated either the melodies or the rhythms on the PMMA, they also recognized Mandarin Chinese tones in M-LNT better. Furthermore, the performance of the melodic auditory perception on the PMMA significantly predicted the performance on the Mandarin Chinese tonal recognition in the M-LNT. Gender difference in this study was not a significant factor. These findings support the importance of melodic and rhythmic auditory training for Mandarin Chinese tonal discrimination and speech and language learning

## ACKNOWLEDGEMENTS

I am grateful for the opportunity to do my thesis and study the audiology, and speech and language in children that I am very interested in. I would like to express my gratitude to all those who gave me support to complete this thesis. I would like to give my special thank you to my advisor, Dr. Michael Thaut, for your encouragement, immense patience and invaluable guidance throughout the research process; to my committee members, Dr. Blythe LaGasse, and Dr. Nathalie kees, for your time and continued support over the past few years in the music therapy program; to the otolaryngological surgeon, Dr. Che-Min Wu, and the audiologists, Ming-Wei Huang and Cheng-Pei Wu, for helping me recruit and screen participants; I would also like to express my thanks to my friends and family who provided me so much support and understanding on this wonderful journey. Thank you all for making this thesis possible.

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## CHAPTER 1: INTRODUCTION

### 1.1 Purpose

The present study investigated whether better performance on the melodic and rhythmic scores in the Primary Measures of Music Audiation (PMMA) also was significantly related to better performance on the Mandarin Chinese tonal score in the Mandarin Lexical Neighborhood Test (M-LNT). The study also examined if the melodic and rhythmic scores in Taiwanese children who utilize cochlear implants for hearing impairments could also predict the Mandarin Chinese tonal score

### 1.2 Need for the study

Some researchers have claimed that people with hearing loss and cochlear implant (CI) recipients, with better musical auditory perception also have a greater ability to recognize speech sounds in English speakers (Darrow, 1984; Gfeller & Lansing, 1991; Gfeller, Turner, Woodworth, Mehr, Fearn, Witt, & Stordahl, 2002; Olszewski, Gfeller, Froman, Stordahl, & Tomblin, 2005). However, there are many linguistic and cultural differences between Taiwanese and American, so there is a need for the expansion of research to examine the differences in how people from other cultures perceive music and speech. Furthermore, with a variety of historical influences from China and Japan in the last three hundred years, the Taiwanese people received different music learning experiences and appreciation (Hsiao,

2006; Shih, 2004). Traditional Chinese music, such as Nanguan music, Beiguan music, and Taiwanese opera, were a mainstream until the Japanese occupation (Shih, 2004). Under the Japanese rule, Traditional Chinese music was suppressed. Instead, western music and instruments were promoted through school and education. Differences in music aptitude may exist also because most Taiwanese residents speak Mandarin Chinese and Taiwanese as their primary languages as opposed to English. Due to these differences, the results of the previous studies on American children cannot be generalized to Taiwanese children

Moreover, several previous studies in Taiwan have focused on the effect of musical exercises on children with a variety of special needs to determine if music would improve their cognitive, social and speech and language skills (Chan, Ho, Cheng & Su, 2005; Chen, 2008; Cheng & Chen, 2009; Chien, 2005; Kang, 2005). Of these studies, one specified and demonstrated that music exercises improved speech and language abilities in Taiwanese children with hearing loss. In Chien's (2005) study, the speech and tone intelligibility of children with severe hearing loss was improved after they received tone awareness and vocal exercises. The participants in this study went through a series of exercises, such as sound differentiation, breathing training and singing exercises associated with tonal discrimination. The results of this study indicated that the speech intelligibility of children with hearing loss may benefit from organized music exercises integrated speech training. Throughout the process in Chien (2005) the participants improved their sound, phonemic and tonic awareness,



and better vocal control. Chien's (2005) study involved several music elements in her experiment. However, this study did not explain which variable had the greatest influence on speech pronunciation. Therefore, the present study will attempt to find and clarify the role of the relationship between music and speech auditory perception. It will explore whether or not Taiwanese CI children who have better abilities to discriminate melody and rhythm also have better Mandarin Chinese tonal recognition.

In a comparison between Taiwanese normal-hearing children and children with cochlear implants, only one study has explored acoustic relationships between recognition of melody in familiar songs, tone of Mandarin Chinese perception, age of children, hearing history and music involvement (Hsiao, 2006). This study included children with cochlear implants with two different speech processing strategies, including Spectral Peak (SPEAK) and Advanced Combined Encoder (ACE). This meant they used different information-coding techniques in cochlear implants. These children in the age range of 7 to 15 were tested with a set of Mandarin Melody Recognition Test (MMRT) and a closed-set Mandarin Tone Test (MTT) (Hsiao, 2006). The MMRT contains lyrics from a variety of songs requiring cognitive abilities and musical experiences to complete the discrimination of dissimilar songs. A broad age range of participants might affect the results of the experiment.

As for the MTT speech and language test developed in China, the test includes only 6 single-vowel syllables with the four tones, including the first, second, third and fourth tones.

Given that the unlike tones and accents are a result of regional, culture and historical factors, finding an appropriate speech and language test designed by Taiwanese experts is needed for the present study. Looking at a test from a practical standpoint, most Chinese words are composed of three elements, including vowel, consonant and tones. A change in one of these three elements can completely vary a word's meaning (Chien, 2005). Having the ability to correctly discriminate these three components is one of the key points for effective communication in Mandarin Chinese. Therefore, using a test with more combinations of vowels and consonants is important as well.

Because of the problems with these previous tests, the present study will use Mandarin Lexical Neighborhood Test and Primary Measures of Music Audiation to examine a potential relationship among the recognition of Mandarin Chinese tones, and melodic and rhythmic perception in Taiwanese children with cochlear implants. The researcher believes these tests to be superior because the Mandarin tonal test contains more vowels and consonants than previous studies and they are designed by Taiwanese. The music auditory test is a standardized and computerized test, which will be explored in greater depth in chapter 3

### 1.3 Background

Hearing impairment is hearing loss caused by congenital or acquired factors (Hearing Loss Association of America, 2010). The number of people with hearing impairment in

Taiwan has grown in the last decade. In 2010, there were 117,103 out of 23 million people in Taiwan affected by hearing impairment. It is one of the top 3 causes of physical and psychological disabilities in Taiwan (Directorate General of Budget, Accounting and Statistics, Executive Yuan, R.O.C., 2010). Similarly, the number of cochlear implant users has increased steadily from 1600 to 2000 Taiwanese people in the last four years, and nearly two-thirds of these are adults (Frontier Foundation Taiwan, 2010; Liu, Liu, Wang, Kuo, & Huang, 2009).

Cochlear implants can improve the hearing and speech abilities of people with severe (71-90 decibel) or profound (90 decibel or greater) hearing loss by electronic and audio mechanism (Hearing Loss Association of America, 2010; Gfeller et al., 2002; Yang & Wu, 2005). In general, rhythm recognition is better than melodic perception and pitch discrimination for people with cochlear implants (Gfeller & Lansing, 1991; Gfeller, Woodworth, Witt, Robin, & Knutson, 1997). Regarding the relation between musical perception and speech perception in people with severe to profound hearing loss, or cochlear implants, there is a positive correlation between recognition of rhythm and what is called the suprasegmental parts of speech, which include vocal features such as accent and syllable length (Darrow, 1984; Gfeller & Lansing, 1991). The better the recognition of syllable length and accent pattern in words and sentences, the more rhythmic and melodic features these CI users perceive. Because music and speech are composed of similar elements, this supports their relationship and influence on the process of speech learning (Thaut, 2008).

Speech is divided into two parts, segmentals and suprasegmentals, both of which people with hearing impairment have difficulty in producing and perceiving (Crystal, 1991; Gold, 1980; Northern & Downs, 2002). Segmentals are the production of phonemes. Suprasegmentals are the features of vocal expression, such as stress, duration, frequency, rate and nasality in speech (Crystal, 1991; Gold, 1980). Previous studies (Darrow, 1984; Gfeller & Lansing, 1991) have revealed that suprasegmental identification in speech correlates with the identification of musical elements. Because music and speech have similar elements such as frequency, rhythm and accent, the ability to perceive them may correlate. People having difficulty in identifying musical characteristics may also struggle with the perception of speech and language.

Mandarin Chinese is a tonal language that is divided into four tones with different frequency and contour tones (Crystal, 1991; Newnham, 1987). The pitch of the tones for the majority of Mandarin words fluctuates and changes as people pronounce them. Most of the Chinese words are composed of consonant, vowel and tone. The tones play significant roles because the same word with different tones may indicate different meaning and cause further lexical change. In several studies, it appeared that people with hearing impairments have difficulty differentiating between the four tones even while wearing a cochlear implant or hearing aid (Chiang, 2006). Hearing impairments may further impact their abilities to read and learn academic skills, which then hamper the development of the language,

communication, and social skills during childhood.

Less volitional communication and less social interaction are problems needing to be dealt with for people with hearing loss as a result of the lack of auditory feedback and unintelligible speech. The earlier hearing loss is detected, the earlier the treatments can be given. Early intervention may stop children from missing their critical period for development of cognitive abilities. Due to the issues associated with hearing loss, finding acoustic relationships between music and speech perceptions is critical before creating efficient and effective music-related treatments for children with hearing impairments.

#### 1.4 Hypotheses

1. The first null hypothesis: there will be no correlation between test scores on the ability to discriminate tones of Mandarin Chinese and test scores on performance in a melodic perception test.
2. The second null hypothesis: there will be no correlation between test scores on the ability to discriminate tones of Mandarin Chinese and test scores on rhythmic perception.
3. The third null hypothesis: There will be no prediction capability of the performance in test scores of the melodic and rhythmic test scores for the Mandarin Chinese tonal test.

## 1.5 Delimitations and Limitations

Participants with cochlear implants and normal cognitive functioning were between 10 to 12 years of age, which means fourth to sixth graders in Taiwanese elementary education were enrolled in this study. This age range was chosen to ensure some proficiency in writing skills in Mandarin Chinese phonetic symbols, skill in English listening and their skills in verbal expression. 26 participants who used cochlear implants produced by the same cochlear implant manufacturer (Cochlear Corporation) were enrolled in this study. Each participant had at least one year of cochlear implant experience. In addition, they have had no formal musical training for more than one year. Limitations included a small sample size, age limitation, the total length of cochlear implants experience and attitudes of the participants, for example, whether the participant “took the test seriously”. Purposive and convenience sampling was utilized in this study. Specifically, participants were selected from just one hospital. Because the sample was taken from the same hospital and was not random, this group can not represent the general population with cochlear implant and normal cognitive functioning for the entire age group of the Taiwanese elementary school system. However, the sample may be a good representation of Taiwanese CI children of the ages 10 to 12.

## 1.6 Definitions of terms

**Acoustics of phonation:** “The periodic vibration of the vocal folds known as phonation provides the most important and acoustically efficient sound source in the vocal tract” ( Clark & Yallop, 1990, pp. 237 ).

**Affricate:** “It refers to a sound made when the air-pressure behind a complete closure in the vocal tract is gradually released” (Crystal, 1991).

**Alveolar:** “It refers to a sound made by the blade the tongue (or the tip and blade together) in contact against the alveolar ridge” (Crystal, 1991).

**Bilabial:** “It refers to a sound made by the coming together of both lips” (Crystal, 1991).

**Cochlear Implant:** “Cochlear implants are medical devices that bypass damaged structures in the inner ear and directly stimulate the auditory nerve. They are surgically implanted to improve hearing in people with severe or profound hearing losses. They can create a range of sound, but do not replace normal hearing” (Hearing Loss Association of America, 2010).

**Decibel (dB):** The unit commonly used to measure the intensity of sound (Bess & McConnell, 1981, p. 45).

**Dental:** “It refers to a sound made by the tongue tip and rims against the teeth” (Crystal, 1991).

**Frequency:** “A physical parameter of sound defined as the number of vibration per second” (Northern & Downs, 2002, p. 6).

**Fricative:** “It refers to sounds made when two organs come so close together that the air moving between them produces audible friction” (Crystal, 1991).

**Fundamental frequency:** “Its frequency of vibration is defined as that of the lowest frequency of the sine waves which compose it.” (Clark & Yallop, 1990, p. 215 ).

**Hearing Impairment:** “Generic term used to describe all persons with hearing loss, includes two million deaf people and 22 million hard of hearing people in the United States” (Hearing Loss Association of America, 2010).

**Hearing level:** Ratio in dB of the sound pressure level produced by an audiometer to its reference zero level at a given setting for a frequency or intensity dial; usually referred to as the decibel reading in the hearing loss dial of the audiometer. (Bess & McConnell, 1981, p. 296).

**Hertz (Hz):** The term used to express frequency is cycles per second (Bess & McConnell, 1981, p. 45).

**Intensity:** “The physical measurement of the strength or magnitude of a sound” (Northern & Downs, 2002, p. 7).

**Labiodental:** “It refers to a sound in which one lip is actively in contact with the teeth” (Crystal, 1991).

**Loudness:** “The psychological correlate of intensity is ‘loudness’” (Northern & Downs, 2002, p.7).



**Lateral:** “It refers to a sound where the air escapes around one or both sides of a closure made in mouth” (Crystal, 1991).

**Mandarin :** “ Historically, Mandarin refers to the dialect of northern China used by public officials (i.e., Mandarins) in the capital city of Beijing prior to the early twentieth century, It evolved into the so-called standard Chinese in modern times” ( Hsu, 2002, p.6).

**Mandarin Lexical Neighborhood Test:** “The new Mandarin Lexical Neighborhood Test (M-LNT) is expected to be useful for evaluating spoken word recognition in children with hearing loss. Also, the M-LNT provided reliable information about spoken word recognition abilities of children with cochlear implants” (Yang & Wu, 2005, p.11).

**Melody:** “A coherent succession of pitches” (Randel, 2003, p. 499).

**Nasal:** “It refers to sounds produced while the soft palate is lowered to allow an audible escape of air through the nose” (Crystal, 1991).

**Palatal:** “It refers to a sound made when the front of the tongue is in contact with or approaches the hard palate” (Crystal, 1991).

**Primary Measures of Music Audiation:** “The Primary Measures of Music Audiation (PMMA) is designed to diagnose and measure music potential. It is the only brief, longitudinally valid music aptitude test for Grades K through 3” (Gordon, 1979).

**Pitch:** “The psychological perception of the frequency of a stimulus” (Northern & Downs, 2002, p.7).

**Rhythm:** “Rhythm covers all aspects of musical movement as ordered in time” (Randel, 2003, p. 723).

**Segmentals:** The features of smallest units in speech (Crystal, 1991).

**Suprasegmental:** The features of intonation and vocal expression in speech (Crystal, 1991).

**Segmentation:** “Through extensive listening experiences, the infant learns where the boundaries of speech sounds and words occur in the connected speech” (Northern & Downs, 2002, pp.17).

**Tone:** “Tones—such as high, low, falling, rising—which are functional in the language. In this sense, tone is not synonymous with pitch, since a tone in a linguistic system will be realized in such a way that it contrasts with other tones in the system while varying according to context” (Clark & Yallop, 1990, pp. 339).

**Velar:** “It refers to a sound made by the back of the tongue against the soft palate, or velum” (Crystal, 1991).

## CHAPTER 2 : REVIEW OF RELATED LITERATURE

Human beings learn speech and language via a variety of sensory input, such as visual, auditory and tactile perceptions. Lacking one of these senses will cause difficulties in learning speech and language. However, children with hearing deficits can improve their hearing abilities and speech and language skills by means of residual hearing and early intervention (Adamek & Darrow, 2008; Bess & McConnell, 1981; Chang, 1996). According to Taiwanese law, People with Disabilities Rights Protection Act, Taiwanese children with special needs which include children with hearing loss, have rights to receive early intervention services and other necessary supports (Ministry of Interior, R.O.C., 2009). They also have the right to learn with children without disabilities, and join resource class programs that provide individualized classes and trainings for students with disabilities (Ministry of Education, R.O.C., 2010). Music class is included in regular or resource class programs and music therapy services can be added in an individualized education plan. The purpose of this study was to explore whether or not Taiwanese CI children who have better abilities to discriminate melody and rhythm also have better Mandarin Chinese tonal recognition so that instructors can come up with an effective music training plan.

### 2.1 Hearing loss

To begin to investigate relationships between music and Mandarin Chinese auditory

perceptions, it is important to establish some background of hearing loss. The types of hearing impairment can be interpreted in three different ways. It can be divided into a conductive hearing loss, a sensorineural hearing loss or a mixed loss (Bess & McConnell, 1981; Northern & Downs, 2002). Conductive hearing loss is characterized by sound waves not being sent from the external ear to the middle ear. Sensorineural hearing loss is caused when injury to hair cells of the inner ear disables transduction of sound, or it can also be caused by damage to auditory pathways in the brain affecting auditory perception. The combination of these two types of hearing loss is a mixed hearing loss (Bess & McConnell, 1981; Northern & Downs, 2002). Average hearing thresholds above 50 dB are most likely due to sensorineural or mixed losses. (Northern & Downs, 2002)

From the speech-language aspect, a prelingual loss and a postlingual loss are types of hearing loss discussed in hearing loss related literatures (Adamek & Darrow, 2008). In general, a prelingual loss is regarded as a congenital hearing loss; postlingual loss is considered an acquired hearing loss. Unilateral and bilateral hearing losses are the other ways to interpret the difference of hearing impairment. Unilateral hearing loss means that only one ear has hearing loss and the other ear still functions normally. Hearing loss in both ears is bilateral hearing loss. In children, unilateral hearing loss is more common than bilateral loss (Northern & Downs, 2002). There are five different degrees of hearing loss from slight to profound, which may affect the development of speech.

Based on the five different degrees—slight, mild, moderate, severe and profound—of hearing loss, the speech and language skills of children vary (Adamek & Darrow, 2008; Bess & McConnell, 1981). The labels of the five degrees may change with different researchers, but the estimation of the effects for each level, however remain similar. Depending on the degree of hearing loss, children show various abilities to recognize sounds.

Slight hearing loss is identified by hearing thresholds between 27 and 40 dB. Children with slight hearing loss have difficulties in hearing instant, faint speech, (Adamek & Darrow, 2008; Bess & McConnell, 1981), music and lyrics (Adamek & Darrow, 2008). Mild hearing loss is identified by hearing thresholds between 41 and 55 dB. The effective conversational comprehension hearing distance of children with mild hearing loss is limited to 3 to 5 feet, and their voice quality and speech production exhibit difficulties (Adamek & Darrow, 2008; Bess & McConnell, 1981). However, wearing hearing aids can benefit those children. With a hearing threshold of 56 to 70dB, children are considered to suffer from moderate hearing loss, and they can only perceive very loud auditory stimuli which results in their having poor language understanding, weak articulation and limited vocabulary. When hearing thresholds are between 71 to 90 dB, it is considered as severe hearing loss. Children with severe hearing loss only hear shouted voices at a very close distance, and they manifest pitch, rhythm, breath control, and consonant discrimination issues in their speech. With profound hearing loss at a hearing threshold of 91dB or more, children only hear the loudest sounds, and they are

considered deaf. It is necessary to use assistance, mostly cochlear implants, to provide auditory sensation. These children mainly learn language by vision if assistive devices are not used as an intervention in early childhood. (Bess & McConnell, 1981).

Children with hearing loss may also benefit from musical experiences. From a musical standpoint, percussion or low frequency instruments, such as drums and brass, are appropriate for both moderate and severe hearing loss; furthermore, rhythmic learning is the primary domain for children with profound hearing loss (Adamek & Darrow, 2008). In general, low-frequency sounds are more easily perceived by those who are affected by hearing loss, rather than high-frequency sounds. Melodic discrimination is more difficult than rhythmic discrimination. Therefore, instructors may consider using the strengths of this population to improve their hearing skills when designing a music exercise.

## 2.2 Conduction and properties of sound

The generation of hearing sensation called sound is comprised of two elements, vibration and propagating medium (Clark & Yallop, 1990). The basis of sound is vibration which is transmitted through media to the ear. Generally, air molecules are vibrated by a moving object. These molecular vibrations are transmitted through air to the auditory system and produce a hearing sensation. The human auditory system is divided into the peripheral auditory system and the central auditory system (Bess & McConnell, 1981; Guyton & Hall,

2006; Hsiao, 2009). The peripheral auditory system is formed by the outer, middle and inner ear. The outer ear is further divided into two parts which are the pinna and the external auditory canal. The primary functions of the outer ear are: 1) keeping the auditory canal clean, 2) protecting and lubricating the auditory canal, 3) amplifying sounds, and 4) localizing sounds (Hsiao, 2009). Cilia inside the external auditory canal move earwax and dust out of the ear to keep the ear canal clean. Earwax secreted in the external auditory canal helps the canal stay lubricated and protects it from foreign materials, such as insects and bacteria. In addition, the ear canal can amplify sounds between 2500 and 4000 Hz from two to four times louder (Hsiao, 2009). Based on how long it takes for a sound to reach both ears, the ear canal helps determine the location of the sound. Sounds are collected by the outer ear and sent to the middle ear.

The middle ear includes the tympanic membrane, three tiny bones and the eustachian tube (Bess & McConnell, 1981; Hsiao, 2009). With these components, the middle ear efficiently transforms and amplifies sound energy and sends it to the inner ear. The eustachian tube connects the middle ear to the throat, so the air is allowed to flow back and forth between these two regions to keep the balance of pressure. Eustachian tube dysfunction can cause hearing loss. The tympanic membrane, also called eardrum, consists of collagen fiber layers that makes the eardrum very elastic (Hsiao, 2009). Due to tympanic membrane elasticity, the different frequencies of sound cause different areas of the tympanic membrane

to vibrate. Moreover, the vibration of the ear drum causes the three tiny bones to move back and forth (Bess & McConnell, 1981; Hsiao, 2009). These three tiny bones, malleus, incus and stapes, transforms acoustic energy into mechanical energy. Because the stapes is connected with the oval window of the inner ear, a series of movements between these three bones further brings about vibrations into the inner ear. In addition, sounds are amplified through the large surface of the tympanic membrane into the small surface of the oval window.

The inner ear, similar to the outer ear, is divided into two parts, the cochlea and the vestibular system (Bess & McConnell, 1981; Guyton & Hall, 2006; Hsiao, 2009). There are hair cells and lymph fluid in the inner ear, so it is regarded as a hydraulic system. The cochlea is involved in hearing and the vestibular system is responsible for body balance. Regarding the conduction of sound, the cochlea plays an important role in transforming sound vibrations into chemical signals. These chemical signals further cause nerve impulses which are transferred into the central nervous system. Looking at the cross section of the cochlea, there are three spaces in the cochlea, and these three spaces are divided by two membranes, Renssner's membrane and basilar membrane. These spaces from the top to the bottom are called scala vestibule, scala media and scala tympani. Inside the scala media, there is a receptor organ of hearing called the organ of Corti. The hair cells of the organ of Corti transduce vibrations of the fluid into electrical signals which are further bilaterally transmitted by nerves through central auditory pathways (the medulla, pons and midbrain) to



the auditory cortex (Bess & McConnell, 1981; Guyton & Hall, 2006; Hsiao, 2009). A further question is how human beings are able to detect and discriminate different sound frequencies associated with speech perception. The following theories explain mechanisms in the inner ear, which are related to pitch perception.

### 2.3 Theories of hearing

Determination of intensity and frequency of sound are associated with the extent of vibration of hair cells within organ of Corti and amplitude pattern of vibration of the basilar membrane (Guyton & Hall, 2006; Bess & McConnell, 1981). The amplitude of vibration of hair cells and the total number of excited nerve fibers are correlated with the intensity of a sound. As for pitch perception, there are four main theories as follows (Bess & McConnell, 1981).

The place theory, also known as Helmholtz resonance theory, states that different pitches are perceived by particular hair cells (auditory neurons) on the basilar membrane of the cochlea (Bess & McConnell, 1981). In terms of the location of the maximum amplitude on the basilar membrane, high-frequency sounds are related to the base of the cochlea, and low-frequency sounds are more involved with the apex of the cochlea. In other words, each hair cell acts independently, and different hair cells correspond to different pitches. It is not like the volley theory that hair cells work as a group to process sounds, which will be

explained later.

In 1886, William Rutherford proposed the frequency theory in which the rate of vibration in Hertz can translate into an equal discharge rate in times per second across the auditory nerve (Bess & McConnell, 1981). Acoustic stimuli are not comprehended until the whole transmission enters the brain. However, this theory can not account for high-frequency sounds above 1000Hz due to the limitation of discharge rates (Bess & McConnell, 1981).

The volley theory, proposed by Wever, states that the different hair cells are activated together and their firing rate are summated in order to process high-frequency sounds up to 5000Hz (Bess & McConnell, 1981). Hair cells take turns firing, which solve the problem of neuronal refractory period, and this method is called the volley principle.

The traveling wave theory, proposed by Georg von Békésy, indicates that the pattern of vibration of the basilar membrane determine frequency perception of sounds. (Bess & McConnell, 1981).

The characteristic—different frequencies discerned in specific regions—is called a tonotopic organization which also occurs in the primary auditory cortex. (Guyton & Hall, 2006) Using at least six various tonotopic maps on the primary and secondary auditory cortex, the brain recognizes different frequencies and sequential sound patterns. Throughout these different theories, it is clear to see that the basilar membrane and hair cells in the inner ear are primarily in charge of pitch perception. Human beings will have difficulties in discriminating

pitches and tones of speech if there is damage to either one of them.

## 2.4 Perception of prosody

Duration, loudness and pitch of a spoken language are the three basic components of prosody (Clark & Yallop, 1996). These three elements underlie suprasegmentals of speech, such as stress, accent and tones.

Duration is a period of time that a sound lasts (Clark & Yallop, 1996). Duration of each syllable varies based on the stress, the context of speech, the rate of articulation, and the structure of the articulators. Because of this characteristic, finding relative duration is more practical than absolute duration in speech intelligibility, phonology and phonetics. Loudness is related to the measurement of sound intensity. Intensity is power per unit area with the unit of measure transformed into the decibel (dB) (Clark & Yallop, 1996). Similarly, intensity of each word is not constant, and it changes based on a sequence of syllable phonemes. Pitch is associated with the vibration frequency of speech sounds, and it is used to express what word in a sentence or context that a speaker emphasizes.

As for the pitch of sounds, spoken language is composed of multiple simple harmonic motions, that is, speech sounds are not pure tone (Clark & Yallop, 1996). Speech sounds usually consist of several vibrations with different frequencies in which the lowest one is called the fundamental frequency (F0), and the next three successive vibrations are

considered formants (F1, F2, F3). A sound spectrum of several formants can be visualized through a spectrogram of which F1, F2, F3 are most important for the acoustic analysis of vowels. Overall, pitch discrimination of speech is associated with F0, and vowel perception correlates with the patterns of F1, F2 and F3.

Clark and Yallop (1996, pp.332) indicated that the fundamental frequency is “the number of times per second that the vocal folds complete a cycle of vibration”. Pitch control is affected by several factors, such as the larynx, the vocal fold, and subglottal pressure, which result in diversity in F0 depending on gender, or changes in age or physical conditions. Nevertheless, F0 does significantly alter with pitch, but not different vowels. (Lee, 1999). In Mandarin Chinese, F0 is the key point for tonal discrimination (Cheng, 2006; Lee, 1999).

## 2.5 Perception of tones in Mandarin Chinese

In Mandarin Chinese, each word includes three elements (Table 1) — vowel (final sounds), consonant (initial sounds) and pitch patterns—which make up about 1300 different individual sounds (Huang, 2004). Unlike English, in Chinese, each character has an individual syllable, and meaning. The meaning of characters may change when they combine with each other (Cheng, 2006). Moreover, the role of tones is very important for semantic understanding. When vowels and consonants combine with different tones, they produce various meanings and explanations. The acoustic features of the Mandarin four tones are

illustrated in a graph as follows (Figure 1) (Ministry of Education, R.O.C., 2010). The first, second, third and fourth tones are thought of as high level (first), high rising (second), low falling (third), and high falling (fourth) sounds (Chen, Chung, & Lee as cited in Chien, 2005). The features of Mandarin four tones are analyzed in terms of different aspects of sound as follows.

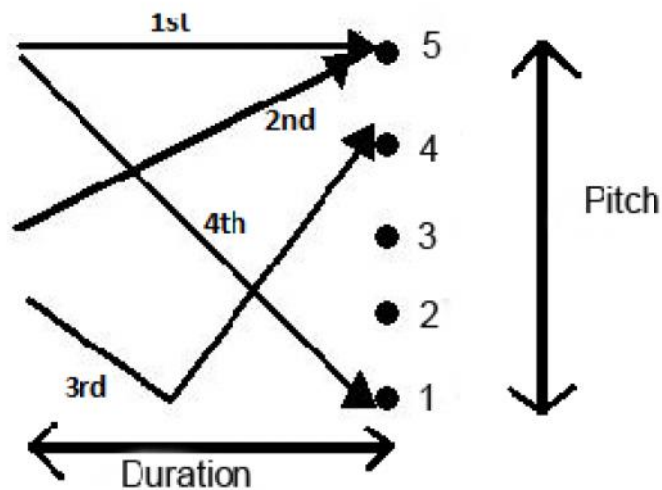
In terms of pitch, the fundamental frequency of the first tone stays steady at 244 Hz (Chen as cited in Chien, 2005). The second tone rises from 185Hz to 320 Hz. The third tone goes from 240 Hz down to 125 Hz, then up to 214Hz. The fourth tone drops from 320 Hz down to 210Hz.

Referring to duration, the order of the four tones from short to long is the fourth (238ms.), the first (603ms.) and the second (603ms.), and the third tone (668ms.) (Chen as cited in Chien, 2005). However, some researchers believe that the first tone is longer than the second tone. The duration of four tones is relative, but not absolute (Tseng as cited in Chien, 2005). Furthermore, the turning point of the fundamental frequency is different between the four tones, and becomes especially important for distinguishing between the second and third tone. The turning point of the third tone (falling down then rising up to a higher level than the starting point) happens at a place 75% of the way through the duration of the tone. It happens at a place 25% of the way through the duration of the second tone.

**Table 1:**

**Mandarin Chinese phonetic symbols and Romanization adapted from Ministry of Education, Republic of China (2010).**

	Romanization	Mandarin Chinese phonetic symbol
Consonants	b, p, m, f, d, t, n, l, g, k, h, j(i), ch(i), sh(i), j, ch, sh, r, tz, ts, s	ㄅ ㄆ ㄇ ㄉ ㄊ ㄋ ㄌ ㄍ ㄏ ㄎ ㄗ ㄐ ㄑ ㄒ ㄔ ㄕ ㄖ ㄙ ㄗ ㄘ ㄙ
Vowels	yi, wu, yu a, o, e, é ai, ei, au, ou an, en, ang, eng er	ㄧ ㄨ ㄩ ㄚ ㄛ ㄜ ㄝ ㄞ ㄟ ㄠ ㄡ ㄢ ㄣ ㄤ ㄥ ㄦ
Tones	First, second, third, and fourth tones	一   /   ∨   \



**Figure 1: Pitch Contours of the four tones in Mandarin Chinese. Figure based on Ministry of Education, Republic of China (2010).**

## 2.6 Speech and language development of Mandarin Chinese speakers with hearing impairment

Speech and language errors can be broken down into segmentals and suprasegmentals. Both segmental and suprasegmental errors are common in children with hearing impairments (Gold, 1980). Segmental deficits include substitutions, omission and misarticulation of consonants, and distortion, neutralization, substitution and diphthongization of vowels. Suprasegmental faults contain inappropriate speech rates, emphasis on words, pauses between and within phrases, and duration of phonemes (Gold, 1980). Both of the segmental and suprasegmental deficits cause failure to have clear vocalizations.

Improper speech rhythms, the prolongation of sounds, pauses and stresses often occur in Mandarin Chinese children with hearing impairments. Omission, substitution, nasal sounds,

replacement of different sounds and neutralization are also noticed in segmental issues (Lee, 1999; Chung as cited in Chien, 2005). There are an increasing number of studies asserting that children speaking native Mandarin Chinese with hearing loss have difficulty in Chinese perception and production of speech. Their speech is less intelligible than children with normal hearing.

Chang (2000) depicted that in terms of the place of articulation, for native Mandarin Chinese children with moderate to profound hearing loss, the order of difficulty in consonant productions from easy to hard are: 1) velar, 2) bilabial, 3) alveolar, 4) labiodental, 5) prepalatal, 6) supradental and 7) dental. In methods of articulation, the order of difficulty in consonant productions from easy to hard is: 1) lateral, 2) nasal, 3) stop, 4) fricative, and 5) affricate. Moreover, the production of the first and fourth Mandarin tones are easier than the second and third tones. Liu (1996) believed that affricate consonants are harder than other consonants. She also noted that in vowels, the diphthongs are easier than single and retroflex vowels.

In comparison with children with normal hearing, when children with hearing impairments talk with others, the number of the vocabulary variations and the length of sentences are fewer and shorter (Lin & Chi, 2002). In addition, there are more chances for children with hearing loss to use wrong or inappropriate vocabulary.



Children with hearing loss also have difficulty in discriminating the Mandarin four tones (Chang,1996; Hsuan & Lin, 2002; Liu, 1996; Ou, 2002; Wang, Liu, Chan, & Huang, 1998; Yang, Huang, Sher, Lin, & Wu, 2003). There are several factors that correlate their abilities to perceive the Mandarin four tones, such as the age of receiving cochlear implants and auditory training, which are explained later.

In comparing auditory perceptions between the four tones, the first and the fourth tones are quicker to be identified than the second and third tones (Ou, 2002). However, children with hearing loss showed more confusion distinguishing between the first and fourth tone, and the second and third tone (Chang,1996). Production is similar to the perception of the four tones. In general, pronouncing the first and the fourth tones is easier than the second and the third tones for children with hearing impairments (Chang, 2000).

In regards to the age of the child when he or she received cochlear implants, the earlier the cochlear implants are inserted, the more effective they are (Bess & McConnell , 1981; Hsuan & Lin, 2002; Liu, 1996; Northern & Downs, 2002; Wang, Chan, & Huang, 1998; Yang et al., 2003). Meanwhile, early and intense auditory and oral training can greatly improve listening and speaking skills in cochlear implant recipients (Chang, 1996). A lack of response to sounds is a common characteristic for Children with hearing loss when they do not receive appropriate auditory and oral training. According to the curriculum guidelines for schools for the hearing impaired in Taiwan, students in grades 1 to 3 are required to take auditory and

communication trainings at least 200 minutes per week, which is more time than required for older students. This indicates the importance of early school-age intervention. It is more beneficial for children with hearing loss to have audio and oral training and perceive different acoustic stimuli in their surroundings at an early age.

## 2.7 Cochlear implants

Cochlear implants (CI), invented for people with profound hearing loss in the 1970s, relays and converts acoustic input to the auditory nerves without passing through hair cells in the cochlea (Northern & Downs, 2002). There are three main manufacturers around the world—Advanced Bionics of the United States, Cochlear Ltd. of Australia, and Med-EL of Austria (Wang, Liu, Chan, & Huang, 2009). Cochlear implant devices are divided into external and internal parts. The external part includes a directional microphone, a speech processor, a transmitter and a transmitting coil. The internal part consists of an array of electrodes, a receiver and a stimulator (Northern & Downs, 2002). Sounds are collected by a directional microphone, then analyzed, filtered and encoded through a speech processor. The encoded digital signals are sent to a receiver and stimulator placed under the skin. The encoded digital signals are converted into electrical current in order to activate auditory nerves by which auditory signals are transmitted to the brain (Northern & Downs, 2002).

There are several parameters related to cochlear implant mechanisms that can affect the

quality of perception for cochlear implants, such as duration of cochlear implant use, age of onset of hearing loss, the number of channel processors, insertion depth, speech coding strategies and the pulse rate of electrical stimulation (Cheng, 2005, Marschark, Rhoten, & Fabich, 2007 ). The more channel processors cochlear implants have, the better the auditory perception will be. Recipients with deeper insertions of cochlear implants also can more precisely discriminate sounds. With the higher pulse rate of electrical stimulation, recipients can have better acoustic information (Cheng, 2005). In addition, these variables are associated with reading, writing and language skills (Marschark et al., 2007). The more children use their cochlear implants, the better their writing and reading skills become. Children with later onset hearing loss have better language abilities.

## 2.8 Listening levels and hearing development

Detection, discrimination, recognition or identification, and comprehension are the four levels of listening skills which are associated with speech and language development and aural awareness (Adamek & Darrow, 2008; Chiang, 2006; Thaut, 2008). Detection is the ability to detect if sounds are absent or present. Discrimination refers to sound differentiation, such as the differentiation of two tones in Mandarin Chinese. Recognition refers to sound identification by which people understand the meaning of each word. Comprehension, the highest level of listening, is the ability to judge the context of speech

(Chiang, 2006). Adamek & Darrow (2008) indicated, with respect to music perception, that people with hearing loss can gain detection and discrimination abilities as they grow up; however, they may not have proper identification and comprehension of auditory input without musical training.

Northern and Downs (2002) stated that a young child with normal hearing can hear the frequencies from 20-20,000 Hz and the frequency range of hearing declines with age. The speech frequency extends from 500—3500 Hz. People with hearing impairments exhibited difficulties in the four levels of hearing in speech as mentioned above (Chiang, 2006). Northern and Downs (2002) indicated that as a result of hearing loss, the shortage of stable auditory clues perplexes children in learning prosody, literal meaning, grammar, intonation and emotional meaning of speech. Furthermore, it brings out difficulties in speech intelligibility.

Regarding the relation between hearing development and development of oral communication, there is no standard norm to refer to the relationship between the maturational process of auditory perceptual skills and language development (Bess & McConnell, 1981). However, auditory responses are dominated by particular auditory perceptual skills according to age, which influence speech and language development (Bess & McConnell, 1981; Northern & Downs, 2002). For instance with infants under the age of 1, four rules of development underlie their auditory perception: 1) Low frequency sounds

(below 4000Hz) produce arousal more easily than high frequency sounds (above 4000Hz), 2) speech sounds also cause more response than pure tones, 3) responses to meaningful sound resources take the place of reflexive responses by 3 to 4 months of age, and 4) the ability to localize sounds gains precision in the second half of the first year.

The hearing mechanism of infants is fully developed at birth. Nevertheless, the extent to which auditory perceptual skills are acquired is dependent upon the interplay between surroundings and children. With a lack of frequent environmental interaction, the brain may have difficulty processing and labeling a diversity of auditory stimuli. It may further affect speech learning. Indeed, auditory and tactile sensory feedbacks may have a significant impact on speech production (Guenther as cited in LaGasse, 2009). In general, hearing loss delays speech development and reading and writing skills in children across cultures.

## 2.9 Musical perception in children with hearing impairments

Even though there is variability that may impact auditory perception and communication in cochlear implant recipients, it appears that most of children experience positive effects on listening skills, speech and communication after they use cochlear implants. In Taiwanese with severe or profound hearing loss, difficulty with auditory perception and communication decreased from 62% to 6.9% after receiving their cochlear implants (Liu et al., 2009). In addition, the percentage of Taiwanese cochlear implant recipients using verbal language

increased from 34% to 44%, and sign language fell from 13.11% to 3.28% after cochlear implants were inserted.

Several extant studies indicate the relationship of music and speech among people with hearing impairment, cochlear implants (CI) and normal hearing (NH). In general, NH people have greater melodic or rhythmic perception than CI users (Gfeller & Lansing, 1991; Gfeller, Woodworth, Witt, Robin, & Knutson, 1997; Olszewski et al., 2005; Vongpaisal, Trehub, & Schellenberg, 2006). Some research points out that people with hearing impairments perform rhythmic discrimination better than melodic discrimination (Dorman, Basham, & McCandless, 1991; Gfeller, 1991; Gfeller et al., 1997; Looi, McDermott, McKay, & Hickson, 2008). These studies show that people with CI can identify if two short pieces of music have the same rhythm or melody. However, the average accuracy rate for rhythmic discrimination is higher than melodic discrimination.

There is no significant difference in beat identification, metric accent responses and tempo changes between children with hearing impairments and normal hearing (Darrow, 1984). Also, gender and age do not apparently impact their performance in rhythmic identification and discrimination. However, normal hearing children perform better than children with hearing loss in rhythmic duplication. Moreover, recognition of syllable length and stress pattern has a positive correlation with melodic rhythm identification and rhythm pattern maintenance in children with hearing loss.

According to Gfeller and Lansing (1991), adults with CI discriminate rhythm more precisely than melody. Also, there is positive correlation between accent recognition of words in sentences and the ability to distinguish melodies. The extent to which CI recipients listen to music after using cochlear implants is associated with the ability to discriminate pitch and melodies. When the amount of time CI recipients spend listening to music increases, it can improve their abilities to recognize the music. Likewise, there is a positive correlation between familiar melody recognition, sentence of speech and letter identification (Olszewski et al., 2005). In his study, CI adults with a greater ability to recognize familiar melodies could more accurately understand sentences. CI children with a greater ability to recognize familiar melodies could more precisely identify letters and words. Even if using different coding strategies (MPEAK and F0F1F2) of cochlear implants, participants exhibited greater rhythmic perception than melodic perception (Gfeller et al., 1997). Both of the MPEAK and F0F1F2 coding strategies catch sounds by using a feature-extraction method, but the frequency range of sounds that they receive are different. The number of electrodes that they include is different as well. There was no significant difference between the two coding strategies in pitch and melodic discrimination. Nonetheless, participants with the MPEAK strategy demonstrated better performance than with the F0F1F2 strategy.

Looi, McDermott, McKay, and Hickson (2004) also indicated that speech process strategies of cochlear implants, age and musical experience did not significantly affect pitch

discrimination. They also found that CI participants in their studies had more difficulty in recognizing songs with complicated melodies than pitch tests. In addition, their study asserted that there is a positive correlation between recognition of pitch and melody for CI recipients.

People using CIs showed greater accuracy in the discrimination of instruments in close-set rather than open-set tests (Dorman et al., 1991). Moreover, it is easier for CI users to identify a single note rather than a sequence of notes, such as a scale played in an ascending or descending way. Similarly, CI users can detect a semitone change when they only need to compare two single notes (Vongpaisal et al., 2006). It is hard for them to discriminate pitch changes while pitch intervals of melodies are small. However, some researchers believe that auditory training associated with music, voices, abstract and environmental sounds can improve speech and sound identification (Rochette & Bigand, 2009). In Rochette and Bigand's (2009) study, after attending auditory training, children with hearing impairments showed an improvement in the discrimination of different sounds and phonemes.

In contrast, a study by Ford (1985) pointed out that regular musical exposure does not greatly influence the auditory perception of children with hearing loss. According to Ford (1985), when children only receive musical stimuli and activities in a school setting, there was no enhancement of the ability to differentiate pitch relationships. However, the author



of this study also claimed that instead of merely attending music events or classes, intense music trainings may efficiently improve pitch perception in children with hearing loss. Increasing the amount of time that hearing impaired children participate in intense music therapy is significant for pitch recognition, which may also positively affect the development of speech (Ford, 1985).

The purpose of this study was to determine if Taiwanese CI children have better performance in the melodic and rhythmic tests can also have better performance in the Mandarin Chinese tonal test. The small age range of participants, the PMMA and M-LNT tests used in this research will address some confounding variables and restrictions revealing in the previous studies.

## CHAPTER 3: METHODOLOGY

### 3.1 Participants

Thirty-one CI users participated in this study, but five of them were excluded from the final analyses because they did not meet the criteria for participants of this experiment. For this study, twenty-six children, 14 males and 12 females, were recruited from the Chang Gung Medical Foundation in Taiwan. These Children were native Taiwan Mandarin speakers diagnosed with prelingual hearing loss. Each child used a cochlear implant produced by Cochlear Corporation. Table 2 shows characteristics of participants. The age range of participants with normal intelligence was from 10 to 12 years old (mean age =11.45 years).

**Table 2:**  
**Characteristics of Participants**

	N	Mean Age	Max.	Min.	Years of CI use
Gender					
Male	14	11.4	12	10	8.6
Female	12	11.5	12	10	7.3

The length of cochlear implant experience for each subject was at least one year. The average years of CI use was 8.6 years for male, and 7.3 years for female. Moreover, the participants of the study did not have formal musical training for more than one year. Convenience and purposive sampling was used in this experiment, meaning that all

participants were selected from one place, the Chang Gung Medical Hospital in Taiwan, and all participants wore cochlear implants due to their hearing loss.

### 3.2 Mandarin Lexical Neighborhood Test

The Mandarin Lexical Neighborhood Test (M-LNT) was used to assess the tonal discrimination. The M-LNT is a standardized test designed by Hui-Mei Yang and Jiunn-Liang Wu in Cheng Kung Hospital for assessing the ability to identify the tones and phonemes of Mandarin Chinese in children with cochlear implants.

Compared with other extant Mandarin Chinese assessment tools in Taiwan, the M-LNT is a standardized and computerized test. In contrast to closed-set tests, the M-LNT is an open-set test which is closer to real situations in the daily lives of children (Yang & Wu, 2004). Therefore, there were no choices, or visual and verbal cues provided for participants to answer in this experiment. The following shows the evaluation of the reliability and validity for this test in the previous study.

There are four pairs of tests in the M-LNT, and it includes an easy and a hard category in each pair of tests (Yang & Wu, 2004). In total, there are four different sets of tests regarding the discrimination of monosyllabic words. Each set has 50 questions which include the three elements of Mandarin Chinese—vowel, consonant and tone. Regarding the reliability and validity of this test, the creator, Yang and Wu (2005), indicated that Taiwanese children with

CI had better performance in the easy category than the hard category. There was a significant difference in the percent of words and phonemes of correct identification between the easy and hard categories ( $F=46.579$ ,  $p < .001$ ). Each subcategory of either the easy or hard categories was significantly correlated with each other ( $p < 0.1$ ). This meant difficulty levels between each subcategory of the easy category or the hard category almost equivalent. Appendix B is an example of this test.

### 3.3 Primary Measures of Music Audiation

Primary Measures of Music Audiation (PMMA) was used to evaluate the discrimination of tone and pitch. The PMMA was created by Gordon in 1979. The PMMA, a standardized and computerized test, is primarily designed for assessing the ability to discriminate the melodic and rhythmic difference in children under age 9. The PMMA has been used for people with severe and profound hearing loss (Darrow, 1987), and cochlear implant users of different ages from child to adult populations (Gfeller et al., 1997; Gfeller & Lansing, 1991; Looi et al., 2008). Therefore, this test would be suitable for the age range of participants in the present study. The test includes two subtests: 1) a melodic test and 2) a rhythmic test (Gordon, 1979). Each subtest has 40 questions without lyrics. In the tonal test, the pitch range is from C4 (260 Hz.) to F5 (694Hz.), and each time only two to five notes will appear. In the pitch test, the pitch of the notes will be kept at C5 (520 Hz.). Each test of the PMMA requires

20-25 minutes for participants to complete the tasks. This test does not require musical training in participants, and has a simple operating mode for participants of a variety of ages (Gfeller & Lansing, 1991).

### 3.4 Procedure

Participants were tested individually in a quiet environment, sound-isolated chamber. The 70 dB level of loudness was held constant for all participants, unless a participant was unable to hear it at that level, at which time, it was adjusted to 80 dB. Participants were invited to adjust the volume of the speaker and their speech processor before the tests started.

Because there was the limited number of participants, a counterbalanced design was not used in this study. Each subject took the PMMA first, then the M-LNT. Each question of the PMMA was played once, and each word of the M-LNT was presented twice. A ten-minute break was provided between the two tests. There was no feedback during the tests.

The M-LNT and the PMMA were presented via an ASUS laptop with the Windows XP operating system, and the auditory stimuli were played through a GSI 61 clinical audiometer. One speaker was placed directly in front of the participants. Some participants had hearing aids and cochlear implants and they were asked to take the hearing aids off during the experiment. Participants filled out a music background questionnaire before taking the M-LNT and the PMMA. In addition, the researcher explained instructions to the tests and

provide an instruction sheet before participants took the two tests. The practice questions were presented prior to testing.

Before the PMMA started, the investigator read the instructions as follows:

- 1) You will take a musical test, then a Mandarin Chinese tonal test.
- 2) In this musical test you will hear two short-musical pieces for each of the 40 test questions.
- 3) Each piece will be played only once.
- 4) Please listen to each musical piece carefully and compare.
- 5) If you feel it is the same sound please answer, “Same”. If you feel it is a different sound please answer, “Different”.
- 6) You will have two practice questions before taking the musical test.

Before the M-LNT started, the investigator read the instructions as follows:

- 1) In this Mandarin Chinese tonal test, you will hear one word for each of the 50 test questions.
- 2) Each word will be played 2 times.
- 3) Please write down phonetic symbols based on what you hear.
- 4) You will have three practice questions before taking the Mandarin Chinese tonal test.

### 3.5 Scoring and data analysis

One point was given for each correct answer in the M-LNT and the PMMA. The score for the M-LNT ranged from 0 to 50. For the PMMA, the scores ranged from 0 to 40 in each subtest—a rhythmic test and a melodic test. The percentage correct score (PCS) for each test was calculated as follows:

$$\text{PCS} = \text{Correct score} / \text{Maximum score} \times 100\%$$

The primary purpose of this data analysis was to analyze and test the hypotheses of the study. In order to achieve this purpose, two statistic methods, the Pearson correlation coefficient and the multiple regression models, were employed for data analysis.

The Pearson correlation coefficient model was used to test if there was a correlation between the subtests of the PMMA and the tonal test of the M-LNT. The correlation coefficient,  $r_{xz}$ , represented the linear relationship between the melodic test in PMMA and Mandarin Chinese tonal test. The correlation coefficient,  $r_{yz}$ , represented the linear relationship between the rhythmic test in PMMA and Mandarin Chinese tonal test. When this correlation coefficient model would show there are significant relationships between the Mandarin tonal test, the melodic test and the rhythmic test, the researcher would further examine the third hypothesis by using the multiple regression models. The multiple regression model was used to measure the relationship between  $x_i$  and  $y$ . The dependent

variable,  $y$ , represented the tonal score in the M-LNT. The independent variables,  $x_{1i}$ ,  $x_{2i}$  and  $D_i$ , represented the rhythmic score, the melodic score and gender. Hence, the M-LNT score would be regressed on these three independent variables as follows:

$$y = f(x_{1i}, x_{2i}, D_i)$$

Because of the small sample size and the same sample of units, it was appropriate for the researcher to use the  $t$ -test ( $\alpha = 0.05$ ) to determine whether or not the significant difference between the rhythmic and melodic test scores of PMMA.



## CHAPTER 4: RESULTS

### 4.1 Results of the Pearson Correlation Model

The average raw score of M-LNT was 38.23. The average raw scores of melodic and rhythmic tests in PMMA were 29.15 and 27.96. The following percentage correct scores were conversions of the raw scores. Table 3 shows the data description. The average accuracy score of M-LNT was 76.46 (SD = 17.30). For PMMA, the Average accuracy score of melody and rhythm was 72.88 (SD = 11.83) and 69.90 (SD = 10.78) (see Table 2). This implied that participants in this study recognized melodic information more accurately than rhythmic information although this was not statistically significant,  $p > .05$ .

**Table 3:**  
**Mean Scores and Standard Deviations of the Tonal Test of MLNT, Melodic and Rhythmic Test of PMMA**

	N	M	SD	Max.	Min.
PMMA Melodic Test	26	72.88	11.83	97.5	45
PMMA Rhythmic Test	26	69.90	10.78	87.5	47.5
M-LNT Tonal Test	26	76.46	17.30	98	26

Correlations across these three tests are presented in Table 4 that showed the correlation values and significant levels. This correlation analysis indicated that there was a significant positive correlation between the melodic test in PMMA and Mandarin Chinese tonal test,  $r_{xz}$

= 0.66,  $p < .05$ . There was also a significant positive correlation between the rhythmic test in PMMA and Mandarin Chinese tonal test,  $r_{yz} = 0.39$ ,  $p < .05$ . The correlation between the melodic test and Mandarin Chinese tonal test was higher than the correlation between the rhythmic test and Mandarin Chinese tonal test. Similarly, there was a significant positive correlation between the rhythmic test and the melodic test in PMMA,  $r_{xy} = 0.41$ ,  $p < .05$ . These results rejected the first and second null hypothesis and implied that participants in this study perceived Chinese tones more accurately when they perceived melody or rhythm well.

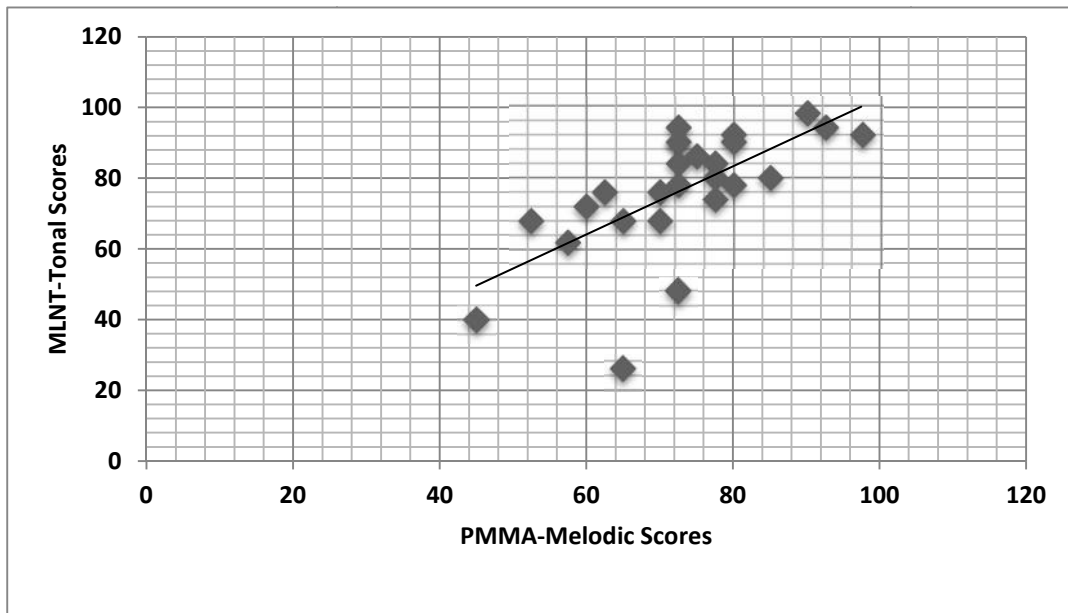
**Table 4:**  
**Correlations between the Tonal Test of MLNT, Melodic and Rhythmic Test of PMMA**

	PMMA-Melody	PMMA-Rhythm	MLNT-Tonal Scores
PMMA Melodic Test	1		
PMMA Rhythmic Test	.41 (2.20) *	1	
M-LNT Tonal Test	.66 (4.29)***	.39 (2.08)*	1

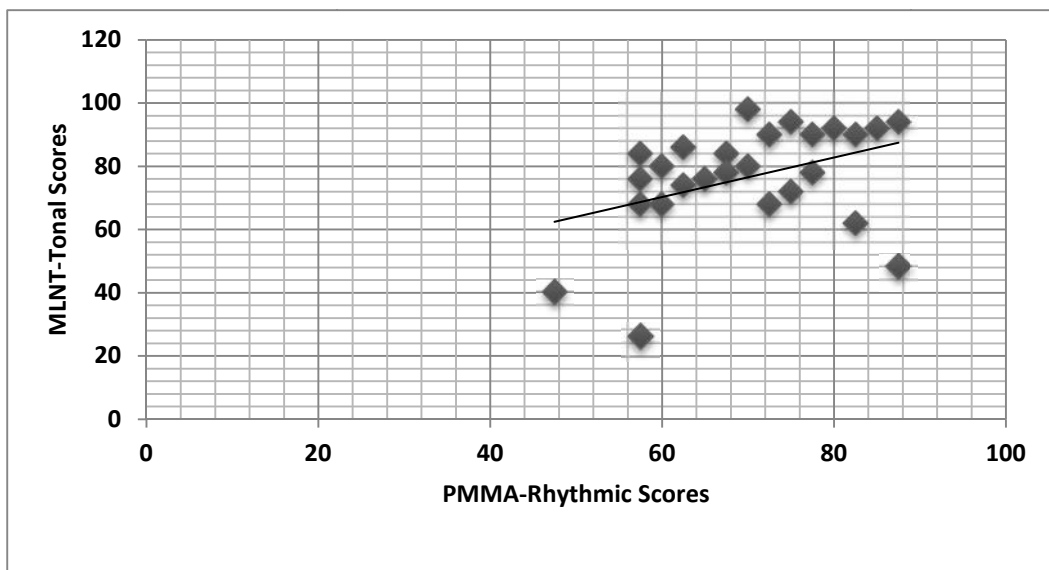
Note. \*\*\* significant at the .001 level, \* significant at the 0.05 level,  
The numbers in parentheses are t-values.

The data indicated that better performance in both the melodic test and the rhythmic test of the PMMA was related to better performance in the Mandarin tonal test of the M-LNT in Taiwanese children who use cochlear implants. In comparison of the melodic and rhythmic tests, when these participants have better performance in the melodic test than the rhythmic test of the PMMA, they have a better chance for better scores in the Mandarin tonal test of

the M-LNT. Also, better performance in the melodic test of the PMMA related to better performance in the melodic test of the PMMA for CI children in Taiwan. Figures 2. and 3. depict the relationship between scores of two subtests of the PMMA and scores of the tonal test in M-LNT.



**Figure 2: Scatter plot of melodic scores in PMMA and tonal scores in M-LNT,  $r = 0.66$ .**



**Figure 3: Scatter plot of rhythmic scores in PMMA and tonal scores in M-LNT,  $r = 0.39$ .**

## 4.2 Results of the Multiple Regression Model

In the current study, because the Breusch-Pagan test indicated that the empirical data violated the assumption of homogeneity of error variance ( $p = 0.02$ ), a multiple regression analysis was run with robust standard errors. The multiple regression analysis with three independent variables (Model 2-1), melodic and rhythmic test of PMMA, and gender is presented in Table 5. This analysis showed the regression model was significant,  $F = 11.84 > F(3, 22, 0.05) = 3.05$ . It also indicated that the coefficient of rhythm,  $\beta_1$ , was .30, and the coefficient of melody,  $\beta_2$ , was .87. This meant 1 unit changed in the rhythmic scores would lead to a .30 unit change in the Mandarin tonal test scores while holding all other variables constant, but this was not significant. One unit changed in the melodic scores would significantly ( $p < .01$ ) lead to a .87 unit change in the Mandarin tonal test scores, holding all other variables constant. The coefficient of gender,  $\beta_3$ , was -6.84. Both of the coefficients,  $\beta_1$  ( $p = .39$ ) and  $\beta_3$  ( $p = .25$ ) were not significant in this model. Goodness of fit for the model 2-1, an  $R^2$  value, was 0.49. The 49% of the variation in the MLNT scores can be explained by the melodic and rhythmic scores in PMMA, and gender. According to the result above, this did not reject the third null hypothesis in this study.

The result indicated that only the performance of the melodic test in the PMMA could effectively predict the performance of the Mandarin tonal test in the M-LNT, and the melodic test of the PMMA could be one of the important factors involved with the different

performance of the Mandarin tonal test of the M-LNT. The other two variables, gender and the performance of the rhythmic test in the PMMA, might not be significant factors that lead to the different performance of the Mandarin tonal test. These three factors—the performance of the melodic and rhythmic tests in the PMMA and gender—could only explain 49% of variance that could predict the performance of the Mandarin tonal test in the M-LNT, therefore, there were some other factors that could be responsible for the different performance of the Mandarin tonal test in the M-LNT.

**Table 5:**  
**Multiple Regression Analysis of Subtests in PMMA and Gender as Predictors of Tonal Test in M-LNT**

Dependent Variable = Tonal Test Scores in M-LNT (n=26)				
Variable	Coefficient	Std. Error	t-ratio	p-value
Const	-4.47	20.45	-0.22	0.83
Rhythm	0.30	0.34	0.88	0.39
Melody	0.87	0.20	4.53	0.00
Gender	-6.84	5.76	-1.19	0.25

\*\*\*

Note.  $R^2 = .49$ , \*\*\* significant at the .001 level

The multiple regression analysis with five independent variables (Model 2-2), melodic and rhythmic test of PMMA, gender, the product of the variable gender and the variable melody, and the product of the variable gender and the variable rhythm is presented in Table 6. This analysis showed the regression model was significant ( $F = 37.02 > F(5, 20, 0.05) = 2.71$ ). It also indicated that  $\beta_1 = .51$  (the coefficient of rhythm),  $\beta_2 = .94$  (the coefficient of melody),  $\beta_3 = 32.07$  (the coefficient of gender),  $\beta_4 = -0.43$  (the coefficient of rhythm\_gender),

and  $\beta_5 = -0.12$  (the coefficient of melody\_gender). The coefficients,  $\beta_1$  and  $\beta_2$  were significant ( $p < .05$ ). The coefficients,  $\beta_3$  ( $p = .48$ ),  $\beta_4$  ( $p = .56$ ) and  $\beta_5$  ( $p = .75$ ) were not significant. Goodness of fit for the model 2-2, an  $R^2$  value, was 0.51. The 51% of the MLNT scores can be explained by the melodic and rhythmic scores in PMMA, gender, the product of the variable gender and the variable melody, and the product of the variable gender and the variable rhythm.

As indicated by the result of the model 2-2 (Table 6), gender did not significantly affect the performance of the rhythmic and melodic test in PMMA for Taiwanese children with CI. That is, female and male participants did not show significant difference in their abilities to discriminate melody and rhythm in the PMMA. This could be also supported by a result of the F test and  $R^2$  value.

The F test was used to test for joint significance of gender, and interaction terms of gender with rhythmic and melodic scores. The result showed there was not significantly different ( $p > .05$ ), which meant between male and female, there were not significantly different effects of the rhythmic and melodic scores on the Mandarin tonal scores. Also,  $R^2$  value only increased from .49 to .51. Therefore, gender might not be an important factor that influenced the different performance in the rhythmic and melodic tests of the PMMA between male and female Taiwanese CI participants in this study.

**Table 6:**  
**Multiple Regression Analysis of Subtests in PMMA, Gender, Rhythm\_Gender ,and**  
**Melody\_Gender as Predictors of Tonal Test in M-LNT**

Dependent Variable = Tonal Test Scores in M-LNT (n=26)					
Variable	Coefficient	Std. Error	t-ratio	p-value	
Const	-24.04	8.18	-2.94	0.00	***
Rhythm	0.51	0.21	2.37	0.03	**
Melody	0.94	0.19	4.99	0.00	***
Gender	32.07	44.71	0.72	0.48	
Rhythm_Gender	-0.43	0.72	-0.59	0.56	
Melody_Gender	-0.12	0.38	-0.32	0.75	

Note.  $R^2 = .51$ ,

\*\*\* significant at the .001 level, \*\* significant at the .01 level



## CHAPTER 5: DISCUSSION

### 5.1 Relationship Between the Performance of M-LNT and PMMA

Results of the correlation model exhibited that better performance in either the melodic test or the rhythmic test of the PMMA related to better performance in the Mandarin tonal test of the M-LNT in Taiwanese children with CI. This implied that when the participants of this study have better abilities to discriminate rhythm and melody, they have better abilities to recognize four tones in Mandarin Chinese.

The multiple regression analysis in the model 2-1 indicated that the performance of test scores in the melodic and rhythmic tests of the PMMA could predict the performance of a test score of the Mandarin Chinese tonal test in the M-LNT. However, of these two variables, only the performance of test scores in the melodic test was a statistically significant factor that brought about the different performance of the Mandarin Chinese tonal test in the M-LNT.

Furthermore, the model 2-2 investigated whether or not prediction capabilities of the performance of the rhythmic or melodic scores in the PMMA for the Mandarin Chinese tonal test in the M-LNT were affected by gender. The result indicated that gender difference in this study was not significant factor that led to the difference performance in the PMMA. Looking at the result from the model 2-1 and 2-2, the performance of the melodic score in the PMMA was one of possible factors that led to the different performance in the Mandarin tonal test no matter what the gender in Taiwanese CI children, and there might be some other factors and

confounding variables that could efficiently predict the different performance in the Mandarin tonal test.

## 5.2 Other Findings

In this study, auditory perceptions of the rhythmic and melodic tests were both positively correlated with the Mandarin tonal test. This implies Taiwanese CI children have better performance of the melodic and rhythmic discrimination may also have better performance of the Mandarin tonal recognition. The four tones of Mandarin Chinese are associated with suprasegmental of speech. This is consistent with results from Darrow (1984) and Gfeller and Lansing (1991) that suprasegmental aspects of speech perception such as stress and accent patterns are positively correlated with the rhythmic perception in people with cochlear implants and hearing loss.

In addition, the result of correlation in this study is similar to Hsiao's (2006) study. Hsiao (2006) stated that Taiwanese children with CI perform less well than normal-hearing Taiwanese children in recognizing Taiwanese and Western songs, and speech. The performance of song recognition however, was positively correlated with tone recognition in Mandarin Chinese. The songs used in her study included three musical elements, rhythm, melody and lyrics, and participants needed to choose a correct name for each song by these three musical cues. These three musical cues were added in the songs one by one to see

which cuing would be more helpful for participants to recognize these songs.

However, Gfeller and Lansing (1991), and Gfeller et al. (1997) asserted that American children and adults with CI have better rhythmic perceptions than melodic perceptions. This is inconsistent with this study in which Taiwanese Children with CI showed greater accuracy to the melodic rather than the rhythmic test. This may be due to the language environment in a tonal language.

Gender, and Interaction variables of gender and two subtests of the PMMA were not significant in two models. These results further indicated that these three variables did not significantly affect the performance of the Mandarin tonal test. Because there was no significant interaction, this suggested that the slope of the regression between the rhythmic and melodic tests, and the Mandarin tonal test is similar for both males and females. Similar to Darrow (1984), there were no significant effects between gender and rhythmic discrimination in American children with severe to profound hearing loss.

### 5.3 Limitations of the Study and Future Recommendations

The current study exhibited that better performance in the melodic and rhythmic tests could be related to better performance in the Mandarin tonal test in Taiwanese children with CI. Nevertheless, there are still some limitations in this study. First, because of the small sample size and a group in a limited age range of the sample group, it may not be appropriate

to generalize the findings in this study to a whole population in Taiwan. Secondly, parenting and the degree of exposure to music or language may affect participants' auditory and speech development. To improve the participants' speech expression and reception, some parents of participants spent more time talking with their children, correcting their pronunciation and helping them discriminate the meaning of different sounds after the participants received cochlear implants. Also, some participants had more opportunities to attend speech and language therapy, music trainings or music therapy. These may be confounding variables that affected participants' abilities to detect, discriminate and recognize sounds. These auditory skills could be varied based on how parents were involved and interacted with their children in aural rehabilitation and speech and language training. Therefore, future research in this area should consider sample size, age range and parenting to reduce these limitations.

Thirdly, so far there is no commonly accepted test regarding music auditory perceptions in Taiwan. The PMMA has been widely used for exploring ability to perceive rhythm and melody. The test material is primarily designed for assessing music skills. Although participants have had at least two years of learning English in their school, the researcher in this study still explained the meaning of English instructions for each participant before they started to take a test. For some participants, they might not be used to listening to English instructions which might distract and affect their responses. To overcome this limitation, future studies may consider creating or finding an appropriate music test in Mandarin

Chinese.

In addition, the discrimination of the four tones in Mandarin and their relationships with music components have been discussed in this study. However, the finding only implied that better performance in the melodic and rhythmic tests was related to better performance in the Mandarin tonal test in Taiwanese children with CI. The performance of the melodic discrimination was one of possible factors that generally led to the different performance of the Mandarin Chinese tonal recognition. Future studies may further examine a relationship between one of each tone with music components. Furthermore, finding an effect of music training on Mandarin tonal perceptions may be taken into consideration in future research.

#### 5.4 Implications

Music Therapy has been used in various fields for people with different disabilities, such as motor, cognitive, speech and language rehabilitations. Regarding auditory training and speech and language rehabilitation, previous studies indicated that using music as a therapeutic tool can improve hearing abilities for people with CI and hearing loss because some parameters of music and speech are similar. Rochette and Bigand (2009) asserted phonetic discrimination abilities are improved as the ability to discriminate and recognize music sounds increases. The current study provides the insight into the relationship between the music components and the Mandarin tones. In Taiwanese children with CI, when they

have better abilities to discriminate rhythm and melody, they may have more chances to have abilities to more accurately perceive Mandarin tones.

Although, according to the result of this study, only the auditory perception of melody has significant effect on the Mandarin tonal perception, the auditory performance of children with CI in rhythmic and melodic tests or exercises may predict the degree which they listen and recognize Mandarin tones. Furthermore, enhancing their abilities to perceive rhythm and melody may be beneficial to improve their tonal perceptions in Mandarin. In particular, this study found that melody is more positively correlated with the performance of the tonal perception. This could mean a music therapist may consider providing more melodic training rather than rhythmic for children with CI if learning goals particularly focus on tonal discrimination and learning. Neurologic music therapy may offer an effective technique via Auditory Perception Training (APT), one of the standardized clinical methods of NMT.

## 5.5 Conclusion

This study attempted to investigate whether better performance in the melodic and rhythmic tests was related to better performance in the Mandarin tonal test in Taiwanese children with CI. The current results provide evidence that the ability to discriminate tones of Mandarin Chinese is positively correlated with the performance in rhythmic and melodic perception tests. In addition, Taiwanese Children with CI recognized melody more accurately

than rhythm. However, there are no significant interaction effects between male and female.

This study supports future studies in children with cochlear implants about music and speech auditory skills and perception.

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## APPENDIX A

### Background Questionnaire for Inclusion

Date \_\_\_\_\_

Participant's ID# \_\_\_\_\_ Age \_\_\_\_\_ Brand of CI \_\_AB \_\_CC

How long have you used cochlear implants? \_\_\_\_\_

What languages do you usually speak at school?

\_\_\_\_Mandarin Chinese      \_\_\_\_Taiwanese      \_\_\_\_Other

What languages do you usually speak at home?

\_\_\_\_ Mandarin Chinese      \_\_\_\_Taiwanese      \_\_\_\_Other

Do you have general music classes in school?    Yes      No

Do you listen to music in your daily life? Yes    No

If yes, how often do you listen to music? \_\_\_\_\_

Had you had any other music activities in your life except general music classes in school?

Yes    No

If yes, explain what/ when/ how long \_\_\_\_\_

## APPENDIX B

### An Example of Test Instrument: M-LNT

#### Mandarin Chinese Phonetic Symbol

##### Easy Words in Test 簡單字

ㄣㄣㄝ	ㄟㄝ	ㄊㄟㄣ	ㄅㄟㄣ	ㄅㄣㄝ
ㄅㄝ	ㄅㄣㄝ	ㄇㄣㄝ	ㄈㄣㄝ	ㄅㄣㄝ
ㄅㄣㄝ	ㄣㄣㄝ	ㄈㄝ	ㄅㄣㄝ	ㄅㄣㄝ
ㄈㄝ	ㄅㄣㄝ	ㄅ	ㄅㄣㄝ	ㄅㄣㄝ
ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ

##### Hard Words in Test 困難字

ㄅㄣ	ㄅㄣ	ㄈㄣㄝ	ㄅㄣㄝ	ㄅㄣ
ㄅㄣ	ㄅㄣㄝ	ㄈㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ
ㄈㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣ	ㄅㄣㄝ
ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ
ㄅㄣ	ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ	ㄅㄣㄝ

#### Romanization

##### Easy Words in Test

júe	y	xià	t ng	d ng
b	k u	wàng	húang	nòng
tóu	jú	h	long	Rang
méi	oi	zh	shuì	cùo
chóng	fěi	z i	sòng	g a

##### Hard Words in Test

k n	du n	hùo	tè	Zh ng
ch	g i	shéng	qíng	Yíng
m	xián	zòu	y	Lài
cháo	zú	s	fà	R n
w	bì n	zháo	nào	Pài

## APPENDIX C

### Minor Assent Form

#### 未成年受試者同意書

你好,

我叫陳明鈴，很高興認識您，我是科羅拉多州立大學音樂治療的碩士生。

這份研究是測試音樂和中文聲音辨識的關聯性，今天我們即將玩個小遊戲，在電腦上做音樂和中文測試，就好比用滑鼠在電腦上玩遊戲一樣。

你可以自行決定是否參予這項研究測試。

假使您同意，您將會參予兩項測試，一項為音樂測試，而另一項為中文測試。在音樂測試部分，您將會聽到音樂並且回答是非題。而在中文測試部分，您需要從電腦上聽到的寫下注音符號。總測試時間大約一個半小時(測試時間為一小時，準備與解說時間回三十分鐘)。您的名字不須寫在答案紙上或輸入電腦系統中，所以將不會有人知道您如何做的或您所做的。為了答謝您費時參參與這份研究，您在測試後將會收到一份巧克力做為答謝。

您同意這項計畫將不會帶給您任何傷害與利益幫助，並且此研究並將不會強迫您必須參與全程。如果您回答同意，但之後您在任何時間點欲停止參加這個研究測試，只要您跟我說一聲，我將馬上為您停止測試，不管您決定參予或停止這項測試，將不會為您帶來任何困擾與不利結果。此外，在實驗過程中，我們可能為您拍照，但這照片將不會呈現您的臉部特徵，而是採以背後拍攝的方式呈現。

如果您同意參與這項測試，我將會告知詢問您的父母，如果您想要參予這項研究，請在以下空格處填上您的姓名和今天日期。

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未成年受試者簽名

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日期

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研究調查者簽名

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日期