國立交通大學

外國文學與語言學研究所

碩 士 論 文

雙語人之感知磁吸效應- 腦事件相關電位研究

The Perceptual Magnet Effect on Bilinguals- an Event-related Potentials Study

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摘　　　要

從語音範疇內部結構的研究中，我們知道 Kuhl(1991)所提出的感知磁吸效應很令人深思，人們會就其音類範疇的典型音展現出類化能力。也就是說，人在音類的感知上是以一個典型音為基準，與它相鄰近的音都會被視作是同一個音，儘管聲學物理性有其差異性，但人的感知是會去忽略的。然而，前人的研究著重在單語，操弄兩種語言系統的雙語人的感知研究付之闕如。我們的研究發現，國台雙語人在相似音[i,u,a]皆展現感知磁吸效應。相似音的語音感知並不會受到語音生成類化的侷限。

更近一步以腦事件相關電位研究探討之，從鄰界面國語[a]與鄰界面台語[a]的 MMN 腦波反應來看，證據顯示支持了雙語人的感知磁吸效應，並且雙語人的兩種語言間相似音的感知是不會有所干擾。最外軌的刺激音(如圈軌 3 跟圈軌 4)引發最大的 MMN 振幅，相對地，這些圈軌音觸發較早的時間潛伏期。這意謂著，國台雙語人可以察覺比之圈軌 1 和圈軌 2 這些鄰近中心典型音還外軌的刺激項。即便處在國台[a]兩個相似音鄰界面中，雙語人仍舊可以區辨各自音類範疇的刺激音項，而不混淆。此為雙語人能在兩種語言系統下各自展現感知磁吸效應的有力證據。

The Perceptual Magnet Effect on Bilinguals: an Event-related Potentials Study

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ABSTRACT

The perceptual magnet effect proposed by Kuhl (1991) is well considerable through the studies of the internal structures of phonetic categories, indicating that humans show a similarity adoption for the prototypes of speech categories. That is, the surrounding referent sounds would be regarded perceptually as the same with the center perceptual prototype in each category; however, previous studies just focus on monolinguals and the perception of bilinguals is unknown. In our findings, bilingual speakers of Mandarin and Taiwanese show the perceptual magnet effect respectively on similar vowels of [i,u,a] on Mandarin and Taiwanese. Perception of two similar vowels is not confined by the bilinguals' assimilation of production.

Furthermore, speaking of ERPs study, evidence of MMN activation on both Mandarin and Taiwanese Interface dimension of [a] not only supports the perceptual magnet effect but also demonstrates that there is no interference on perception of two similar vowels for bilinguals. The Outer Orbit stimuli (Orbit 3 and Orbit 4) evoke larger MMN amplitude whereas they took earlier MMN latency. That is to say, Mandarin-Taiwanese bilinguals can detect the more deviant stimuli in the outer than Orbit 1 and Orbit 2, which are adjacent to the prototype. Even on the interface of Mandarin [a] and Taiwanese [a], bilinguals get no trouble in discriminating stimuli within each interface of a language. It is hard evidence that the perceptual magnet effect functions both on Mandarin and Taiwanese.

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呂老師為人古道熱腸，樂天的個性傳播給學生的是--在研究過程中不畏艱難往前衝的力勁；這樣的勁道的確是學生們背後的支持力量，使這一路走來的研究過程中，即使顛簸，卻也能竭力而行，柳暗花明又一村，終至開花結果，乃至落英繽紛。假使，本人的論文研究有其貢獻，這都得歸於呂老師起初的帶領。

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這一路走來，不管挫折或煎熬都已過去，回憶總會是美好的。感謝神。

CONTENT

FIGURE

TABLE

CHAPTER ONE

INTRODUCTION

1.1 Background

Language is systematically organized and foreign accent is a phenomenon resulted from the differences of two language subsystems. When it comes to language differences, it mostly occurs to people that the differences of word formation, syntax, phonology and other kinds through cross-linguistic comparison. That is, among thousands of languages around the world differing in linguistic properties, each language has its own phonetic and phonemic inventories as well as the phonological, syntactic and morphological uniqueness. Thus, the shift of two language systems possibly generates foreign accent, which comes from the inequality of two linguistically systematic mechanisms. Take phonology as an example, which is the arrangement of sound patterns of a language, two languages would be different from their phonological systems. If a learner is learning a second language, he or she will have to know the differences. Otherwise, the learner will speak with an accent. "French, Japanese and Indians will speak English in a very different manner. They will not only speak with an accent, but they will insert, delete and substitute phonemes and they will make grammatically odd sentences." (Dirk Van Compernille, 2001)

Since language is a systematic organization, it is obvious and doubtless that phonemic inventories of linguistic systems differentiate on the basis of their phonemic organizations. "It is well known that speakers substitute sounds of their own languages for sounds of foreigner languages they attempt to speak. The result is that they typically have ' foreigner accent.'"(Hyman, 1975) In this aspect, sound substitutions happen when one language has no the phonemes of another language, and then speakers would tend to substitute the nearest equivalent sounds. The organizations of two phonemic systems construct the foundation of differences and result in the possible foreign accent.

Even though we zoom in on the phonetic categories in a specific language, systematic organization of language also exits on phonetic segments. Research shows that many of them exhibit internal structure. As Kuhl (1991) proposed the perceptual magnet effect and claimed that there is a prototype in each category which functions like a perceptual magnet for other category members and neighboring stimuli members of a category are assimilated toward the prototype. With the research on the vowel /i/, the study revealed the perceptual and cognitive investigation into categorization of phonetic segments.

With the concept of perceptual magnet effect, the related neuroscience research on vowel categorization provides neural evidence as well. The neural studies using high-tech equipment such as functional magnetic resonance imaging (FMRI) and Magnetoencephalography (MEG) conduct investigations into the human cognition, and correlations between the brain activation and the equipment analysis are studied. In neural methods, the relationship between Brain and language is also speculated. Neuroscience research results show that it is due to the perceptual magnet effect that less neural activation was found for prototypical vowels than non-prototypical ones, and that within two synthesized categories, the perceptually neural discrimination demonstrated that the central category stimuli merged towards a prototype, which shed light on the perceptual magnet effect (Guenther, Nieto-Castanon, Ghosh & Tourville, 2004; Roberts, Flagg & Gage, 2004).

Arguably the perceptual magnet effect is a well-development concept towards the phonetic internal categories; however, whether there exists a perceptual magnet effect in Mandarin or Taiwanese remains unknown. Even in English-speaking world, some couldn't find hard evidence in support of the perceptual magnet effect when Australian English vowels were investigated (Thyer, Hickson & Dodd). Furthermore, whether the perceptual magnet effect exerts influence on bilinguals is of interest.

Therefore, here in this study, we conduct investigations to test if there is the perceptual magnet effect on Mandarin and Taiwanese, and how the perceptual magnet effect exerts influence on bilinguals.

1.2 Motivation

Although the research of the perceptual magnet effect is well developed, yet it needs more cross-linguistic studies to strengthen. Kuhl (1991) claimed there was a perceptual magnet effect in phonetic category and it was in evidence both in perception and neuroscience experiments. However, due to some negative results in duplicated research (Thyer, Hickson & Dodd), we have a strong desire to detect if there really exists a perceptual magnet effect in Mandarin (and Taiwanese). Thus, we can be more confident of saying that the perceptual magnet effect is language universal.

Meanwhile, how the perceptual magnet effect influences the two similar categories on bilinguals appeals to us. As Flege (1987) proposed "equivalence classification" indicating that the interaction of two similar categories would result in less achievement in second language (L2) similar phonetic norms; moreover, it might affect the speakers' first language (L1) in return, we would like to know how the perceptual magnet effect would function in two language phonetic systems on bilinguals. Will bilinguals possess two perceptual magnet effects in two similar phonetic categories of languages? Or, will the perceptual magnet effect of L2 no longer exist for the equivalence classification instead? Or, will there be no perceptual magnet effect even in L1?

Due to the unclear issues arisen by the previous research, we investigate.

1.3 Outline of the thesis

This thesis consists of six chapters, which of them are Introduction, Literature Review, Experiment 1: Production, Experiment 2: Perception, Experiment 3: Event-related potentials (ERPs), and Conclusion. In Chapter Two, Literature Review, we review previous research on the perceptual magnet effect and studies of language interference as well as neuroscience investigation, ERPs on Mismatch Negativity. We state the methodological experiments and results in Chapter Three, Four and Five before general discussion on experiments is concluded in Chapter Six, Conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews previous studies about the interference of languages, the perceptual magnet effect and the Event-related Potentials (ERPs) study. Experiments of categorization of speech stimuli provide evidence for the proposed hypothesis and ERPs studies also show supportive implications. However, while language interference is discussed, how the perceptual magnet effect exerts influence on bilinguals is unknown for lack of investigation.

2.2 Perceptual magnet effect

Patricia K. Kuhl (1991) proposed a hypothesis called "perceptual magnet effect", indicating how a category prototype functioned and what the internal structure of a phonetic category was with a category prototype. In her research, a phonetic perceptually prototype was generated from the subjects' ratings of "Goodness" and that perceptually prototype was served as a referent like magnet attracting the neighboring category members towards it. Within the category, the closer the category stimuli were towards the prototype, the harder the discrimination succeeded between the prototype and the nearer category stimuli. It was the perceptual magnet effect that worked and made the prototype a representative of a category, which assimilated the surrounding category members as like similar ones.

In Kuhl's research in 1991, a category prototype was perceptually resulted from subjects' ratings of Goodness and that confirmed prototype was then used for the ongoing studies. First of all, Kuhl synthesized a set of sound category /i/ according to the formant frequencies acquired by Peterson and Barney. These synthesized category stimuli were for selecting a prototype and a non-prototype of /i/. Later, the prototype was served as a referent point in the center as well as the non-prototype and then a set of synthesized stimuli was produced around the center point by four orbits from the center to the outer boundary. Each orbit had 8 different variants according to the mel distance. The distances in mels from the center to the outer are 30,60,90, and 120. Thus, each prototype condition and non-prototype condition had 32 variants respectively. In the following, these variants in each condition (prototype vs. non-prototype) were rated by subjects from 1 point to 7 points as what score each stimulus deserved when they listened to all of them. The result showed that the prototype as the referent point got highest ratings than did the non-prototype. Meanwhile, the ratings for the variants close to the prototype tended to be higher than the others. With increase in distance from the prototype, the ratings decreased.

Later in her experiment, the discrimination task was carried out in the two conditions (prototype and non-prototype) for testing the hypothesis whether the vowel category was internally structure and the perceptual magnet effect was spectacularly observed. As either a prototype or a non-prototype is being a referent point in the center, subjects discriminated whether a stimulus is the same with the referent or not. In Prototype condition, the stimuli surrounding the prototype were perceptually regarded as the same with the prototype whereas they were not in Non-prototype condition. That is, the stimuli closer to the prototype were hard to discriminate from the prototype and were similar to it. On the other hand, discrimination was more successful when outer stimuli were compared with the prototype. As a result, the perceptual magnet effect was proposed for it demonstrated the internal structure of a category and the surrounding category members of a prototype were perceptually assimilated to it.

In a word, the perceptual magnet effect showed the internal structure of a category and exerted influence on the category members. As results generated from experiments by Kuhl, the hypothesis was confirmed that a prototype of a category functioned as a magnet exercising “the perceptual magnet effect” for influencing its surrounding members as assimilation.

2.3 Event-related potentials

"The brain is a real-time processor and its functions can therefore be best studied with tools that allow tracking of neural activation with the millisecond time scale relevant for cortical dynamics during perceiving, speaking and moving." (Hari, Levanen & Raij, 2000) With electroencephalography (EEG) or functional magnetic resonance imaging (FMRI), investigation of human cognition and language can be in evidence especially for its high timing or spatial resolution.

In fact, the event-related Potentials is a non-invasive technique that measures the neural activation in the brain with EEG. With a cap where electrodes are located, EEG is recorded through the electrodes around the head when stimuli are given (which of them are called "events"). The brainwaves of certain stimuli (events) are analyzed for further investigation. Language studies related to the use of ERPs has been conducted and neural correlations between language and the brain have been constructed. The two major components of ERPs measurements for auditory phonetic research are 1) the evoke response that peaks ~ 100ms post-stimulus onset (N100) and 2) the mismatch negativity response (MMN). These two measure components have been used for investigating the relation between auditory sounds and the brain cognition.

N100 is a auditory-evoked response to all the sounds while MMN is a frontal negative detection of difference with respect to a standard sound (Picton, Alain, Otten, Ritter and Achim, 2000). The elicitation of MMN can be done by many kinds of stimulus change, such as frequency, duration, intensity and etc. These features are also linguistic properties that can be used for language studies. As Aaltonen, Eerola, Hellstrom and Lang investigated the perceptual magnet effect, they used MMN as a criterion to testify their research data.

Picton, Alain, Otten, Ritta and Achim (2000) mentioned the classic paradigm of MMN in ERPs that:

> The classic paradigm for recordings the MMN involves presenting a regular train of auditory 'stand' stimuli in which occasional 'deviant' stimuli differ from the others in terms of some physical attribute such as frequency. These stimuli are presented to subjects who are awake but attending to something other than the auditory stimuli.

A repeating stimulus is served as standard stimulus when deviant stimuli are occasionally displayed. Watching silent movies is a way to distract the participants' attention to sounds and it becomes the classic design of MMN.

The amplitude of the MMN and the latency of MMN evoked by stimuli are the spectacular observation when different stimuli are compared to investigation. The more deviant the stimulus it is, the larger amplitude it evokes. With the latency of MMN, it is believe that the difficulty of discrimination is correlated with the timing of the discrimination process.

2.4 Language interference

When two languages encounter, their phonetic subsystems interact (Flege, James E, Schirru, Carlo & Mackay, Ian R. A.). As Flege (1987) investigated the production of the first language (L1) and the second language (L2) between English and French speakers, he proposed a hypothesis called "equivalence classification", saying the interaction of two languages on bilinguals had an influential effect on their productive performance of phonetic categories. This hypothesis was confirmed by evidence of the production of "new" and "similar" phones in languages he investigated and it exhibited the interaction of two phonetic categories in languages when they meet.

Before the tested hypothesis "equivalence classification" in his paper, the definition of the similar and new phones was given. " 'New' L2 phones have no counterpart in the L1 and so, by definition, differ acoustically from phones found in L1… 'Similar' L2 phones, on the other hand, differ systematically from an easily identifiable counterpart in L1." For instance, /u/ existed in English and French, it was regarded as similar phones for these two languages. Contrarily, /y/ was the phone of French and was a new phone to English speakers. In his research, most experienced English speakers of French tended to approach the phonetic norm of French whereas the less experienced English speakers of French did not. Even so, as the mechanism of equivalence classification worked, new L2 phones were said to eventually be more authentic than similar L2 phones because equivalence classification limited the approximation of L2 similar phones.

However, Chiou (1998) and Luo (2002) didn't think new phones would be more authentic eventually than similar L2 phones when their Chinese subjects of English didn't show any evidence. Moreover, in Luo's research, new phones [I]and [U] were hard to produce authentically than similar phones [i] and [u] for her Chinese subjects of English.

For the subjects examined in Chiou's and Luo's researches, their Chinese subjects of English were not likely to be equal to the most experienced English speakers of French in Flege's research mentioned above. Instead, compared with the selection standard of subjects in Flege's research, the Chinese subjects were supposed to be less experienced even in Luo's research. Whether a speaker is experienced bilingual or not, some other factors should be also considered. (Flege, Schirru & Mackay, 2003; Piske, Flege & Mackay, 2002) That is probably the reason why Chiou's and Luo's findings were not supporting to Flege's. The subjects' experiences in L2 would show distinguishable contrast.

As equivalence classification functioned when two phonetic categories met, in addition, Flege also found that L2 effect would influence the subjects' L1 vowel production despite the fact that it seemed to be language specific. For English subjects, learning French would not affect speakers' production of L1 English similar vowel /u/. On the opposite, learning English did affect the production of L1 French similar vowel /u/ for French speakers.

To sum up, equivalence classification generated the interactive result of phonetic categories on bilinguals for their production of "new" and "similar" phones.

2.5 Summary

In this chapter, the perceptual magnet effect was introduced along with the neuroscience research, ERPs, which provides non-invasive information with neural activities. Mismatch negativity demonstrated the correlation between language and the brain. Meanwhile, when two similar phonetic categories encountered, "equivalence classification" was proposed for the language interference effect. However, how perceptual magnet effect exerts influence on two similar categories towards bilinguals has been unknown so far.

CHAPTER THREE

EXPERIMENT 1：PRODUCTION

3.1 Goal

This production experiment is conducted for two main purposes. One is to compare the production similarities and differences of bilinguals and monolinguals on Mandarin and Taiwanese, and the other is to collect the monolinguals' production data for the preparation of the perception experiment for synthesizing vowels. All the data we collect in this experiment will assist the whole analysis of speech production and perception.

3.2 Method

3.2.1 Participants.

Three groups of people participated in this production experiment. They were grouped as Mandarin monolinguals, Taiwanese monolinguals and Mandarin-Taiwanese bilinguals according to their language backgrounds and their language dominance. All of them had no any reported history of speech and hearing disorders.

For the group of Mandarin monolinguals, they were 5 male native speakers of Mandarin studying in college, who were unable to speak Taiwanese. Although they may comprehend Taiwanese a little, they were unable to communicate with people in

Taiwanese. Except for the English education in public school, they were not English majored students and had no any experience of living at foreign countries or studying overseas. Meanwhile, they didn't have any other language learning experience. In addition, their mean age was 19.8 years.

As for the group of Taiwanese monolinguals, they were 5 female native speakers of Taiwanese and their mean age was 64.2 years. They were uneducated and illiterate, who were unable to communicate with people in Mandarin.

The other group, Mandarin-Taiwanese bilinguals, contended 5 male bilingual speakers of Mandarin and Taiwanese. They were students in (above) college and their mean age was 24.6 years. They either acquired their second language (Mandarin) soon after Taiwanese, or learned both of them simultaneously at the little age. They can interchange both of these two languages while speaking. Except for the English education in public school, they were not English majored students and had no any experience of living at foreign countries or studying overseas. They didn't have any other language learning experience, either.

3.2.2 Materials.

Mandarin

1 匹 [p^hi] (classifier)	鋪 [p^hu] “spread”	趴 [p^ha] “lie”
2 滴 [ti] “drop”	督 [tu] “supervise”	搭 [ta] “construct”
3 哩 [li] (onomatopoeia)	嚕 [lu] (onomatopoeia)	拉 [la] “pull”
4 衣 [i] “dress”	屋 [u] “house”	阿[a] (onomatopoeia)

Taiwanese

1 被 [p^hi] “drape”	噗 [p^hu] (onomatopoeia)	葩 [p^ha] (classifier)
2 豬 [ti] “pig”	蛛 [tu] “spider”	焦 [ta] “dry”
3 哩 [li] (onomatopoeia)	推 [lu] “roll past”	啦 [la] (onomatopoeia)
4 伊 [i] “pronoun”	汙 [u] “dirty”	鴉 [a] “crow”

Table 3.1. Mandarin and Taiwanese Texts.

Two language texts were designed into Mandarin text and Taiwanese text, which of them had the same (C)V structures as [p^h-], [t-], [l-] and [v]. Both of Mandarin text and Taiwanese text were all in Tone 1, which was level tone, respectively according to their language systems. The similar vowels [i, u, a] of Mandarin and Taiwanese were then arranged in words of the balanced designed texts.

Chinese characters were also used in Taiwanese text for reminding speakers of the Taiwanese pronunciations. As for the illiterate Taiwanese monolingual speakers, a series of picture aids were created to guide them the pronunciations of the target words.

In the recording, each list in each text was randomly ordered and the words in each list were too.

3.2.3 Procedure.

The production recording was conducted among the three groups of speakers, namely, Mandarin monolinguals, Taiwanese monolinguals and Mandarin-Taiwanese bilinguals. Except for Mandarin-Taiwanese bilinguals, the other groups of speakers just participated in the recording of their own language texts, respectively.

In the part of Mandarin monolinguals, each of them sat in a quieter room and reading lists of Mandarin text were given. Each list was repeated six times at a normal speech. They read through the whole Mandarin text from list to list. Speakers got a little rest between lists and then move to the next list when they were ready. The tokens in total for five speakers were 360, including 120 for Mandarin [i], 120 for Mandarin [u], and 120 for Mandarin [a].

The same procedure went to Taiwanese monolinguals and Mandarin-Taiwanese bilinguals in part. The major difference was that Taiwanese monolinguals got a series of picture aids for pronouncing the target words. The total tokens of Taiwanese monolinguals were then 360, including 120 for Taiwanese [i], 120 for Taiwanese [u], and 120 for Taiwanese [a]. As for Mandarin-Taiwanese bilinguals, 720 tokens were collected, including two pairs of Mandarin (360 tokens) and Taiwanese(360 tokens).

The production of these three groups were recorded directly onto an ASUS laptop with Praat (version 4.3.35) and a SONY microphone (ECM-Z60). (Originally, we recorded speech production with a SONY MZ-R900 MD. However, we couldn't get better formant resolution than what we later did in the present production recording. Instead, we found that directly recording with a laptop made this experiment run progressively and generated better formant resolution.)

3.2.4 Analysis.

Frequencies of the first three formants of vowels in the productions of the three groups of speakers were extracted out from spectrograms generated by Praat. We took the formant values at a steady section of each vowel. Formant charts were created with the measurement of the first formant (F1) and the second formant (F2). Besides, STATISTICA (version 6) was used for statistic results.

3.3 Results

3.3.1 Taiwan Mandarin-Taiwanese bilinguals.

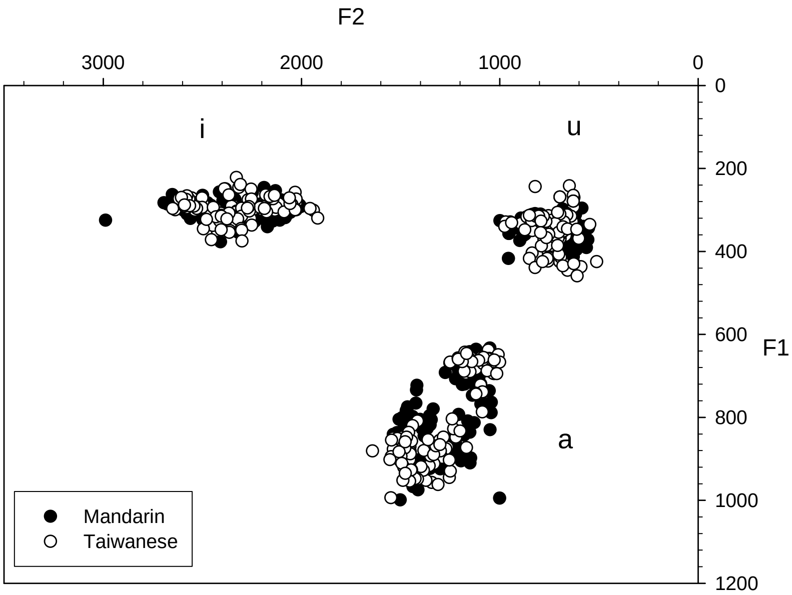

Figure 3.1. The Production of Bilinguals on [i, u, a].

Figure 3.1 was a formant chart by Mandarin-Taiwanese bilinguals, where their productive formant values of Mandarin and Taiwanese lied. The frequency of the first formant was on the vertical axis and the frequency of the second formant was on the horizontal axis. Tokens of similar vowels [i, u, a] were plotted on this formant chart. We can get a closer look in Figure 3.2 that the mean values of similar vowels [i, u, a] of two language productions were demonstrated.

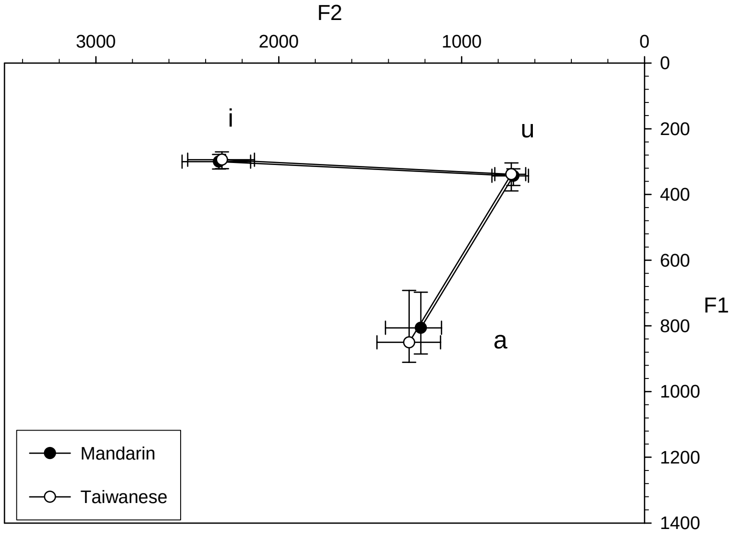

Figure 3.2.　Two Language Vowel Spaces of Bilinguals.

In figure 3.2, statistics showed that there was a significance on F2 for the [i] productions of Mandarin and Taiwanese (F1:t = 1.72, df = 119, p = .087; F2:t = 2.17, df = 119, p < .05).　For [u] productions, there was no any significance both on F1 and F2 (F1:t = 0.12, df = 119, p > .05; F2:t = 0.08, df = 119, p > .05).　For [a] productions, great significance was showed on F2 (F1: t = -1.67, df = 119, p = .096 F2: t = -3.27, df = 119, p< .01).

With Figure 3.2 and statistic results, we can observe that Mandarin-Taiwanese bilinguals had productive similarities and differences on the similar vowels of these two languages.　Our bilingual speakers tended to merge the [u] phonetic categories together for the productions of [u] categories were overlapped.　Meanwhile, significances lied on [i] and [a] phonetic categories, especially for [a].

3.3.2 Mandarin monolinguals vs. Taiwanese monolinguals.

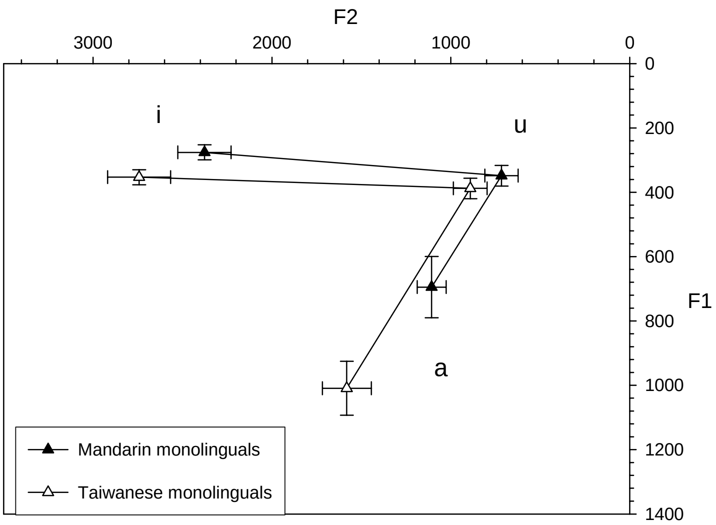

Figure 3.3. The Language Vowel Spaces of Monolinguals.

In Figure 3.3, there were great significances among the three phonetic categories when the productions of Mandarin monolinguals and Taiwanese monolinguals were compared. Statistics results also showed the same. Although Gender difference was one factor that we would consider (for Mandarin monolinguals were males and Taiwanese monolinguals were females), yet we can still infer that the similar vowels of Mandarin and Taiwanese had their phonetic norms by comparing the production results of bilinguals. Because bilinguals may either merge or split two similar phonetic categories and we found that [i] and [a] productions of bilinguals showed significance, we can therefore argue that the phonetic category norms of similar vowels of these two languages had different scope. Even the gender difference was an important interfering factor, we would adopt the statistic results for the argumentation.

3.3.3 Comparisons of monolinguals and bilinguals.

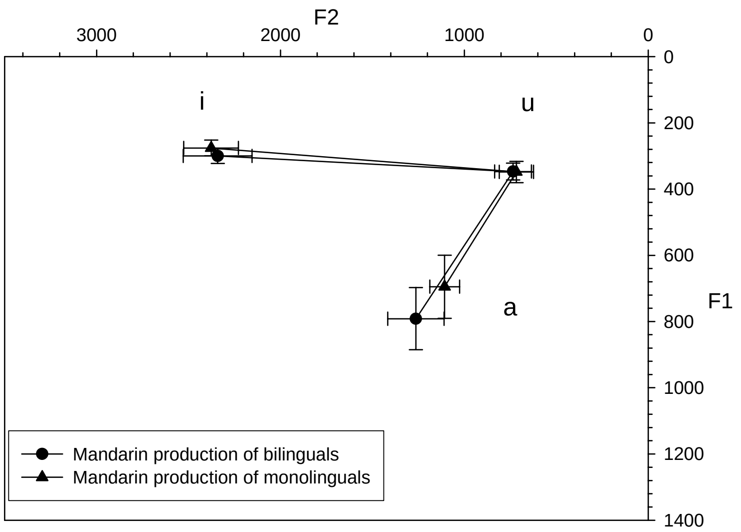

Figure 3.4. The Mandarin Vowel Spaces of Bilinguals and Monolinguals

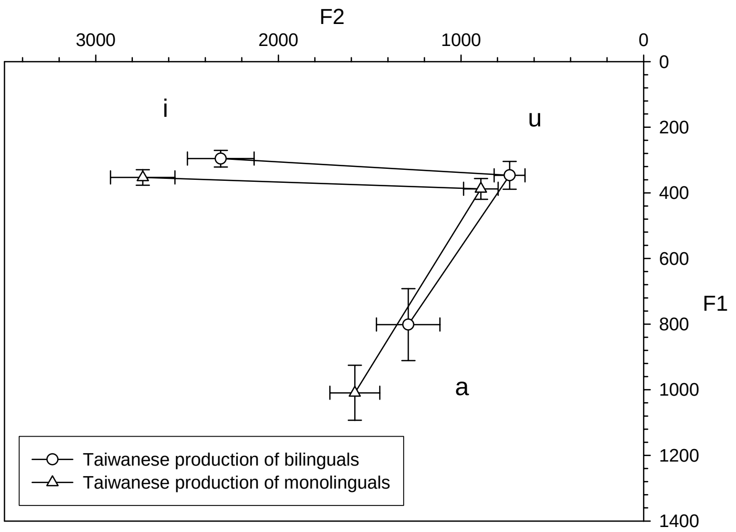

Figure 3.5. The Taiwanese Vowel Spaces of Bilinguals and Monolinguals

Figure 3.4 and Figure 3.5 showed the language production comparisons both between Mandarin-Taiwanese bilinguals and Mandarin monolinguals, and between

Mandarin-Taiwanese bilinguals and Taiwanese monolinguals. In the comparison of Mandarin production (see Figure 3.4), statistic results showed that there was no any significance between the productions of [u] by these two groups of speakers (F1: t = -0.37, df = 119, p > .05; F2: t = 1.47, df = 119, p > .05). Phonetic categories [a] showed great significance both on F1 and F2 (F1: t = 7.50, df = 119, p < .01; F2: t = 10.63, df = 119, p< .01). [i] categories only showed significance on F1 (F1 : t = 10.19, df = 119, p < .01). In the comparison of Taiwanese production (see Figure 3.3b), statistic results showed significances on all the similar vowel categories of both two groups of speakers.

Through all the Figures, we can see the dual language abilities of bilinguals played an important role on the speech production. By comparing Figure 3.4 and 3.5, we can see the Mandarin [i] production by bilinguals was lower than the monolinguals' production for the language interference of Taiwanese (see Figure 3.3 and Figure 3.4). Similarly, the production of Mandarin [a] by bilinguals was more peripheral to the Mandarin [a] production by monolinguals for the interference of Taiwanese.

CHAPTER FOUR

EXPERIMENT 2：PERCEPTION

4.1 Goal

Our goal is to see what the perceptual exemplar of each category is in the three groups of participants and its correlation with participants' production data. Plus, whether Mandarin-Taiwanese bilinguals exert the perceptual magnet effect is our main interest.

This perception experiment contends two experiment parts, which of them are 1) goodness ratings and 2) AX discrimination. Each group of participants of Mandarin monolingual and Mandarin-Taiwanese bilinguals took goodness ratings and AX discrimination in a sequence. After goodness ratings, they took AX discrimination.

4.2 Method

4.2.1 Participants.

The participants in this perception experiment were all the same with the production experiment. They were 5 male Mandarin monolingual speakers and 5 male Mandarin-Taiwanese bilingual speakers.

4.2.2 Materials.

Two materials were designed for the two experiment parts, namely, Goodness ratings and AX discrimination, which of them were partially reduplicated according to

Khul's.

4.2.2.1 Goodness ratings.

In goodness ratings, a set of referent speech sounds was created surrounding by a center standard vowel in each phonetic category (Mandarin [i, u, a] and Taiwanese [i, u, a]). From orbit to orbit, the F1 and F2 were decreased or increased in 30 mels, 60 mels, 90 mels and 120 mels (see Figure 4.1). Therefore, there were 33 speech sounds generated in one phonetic category.

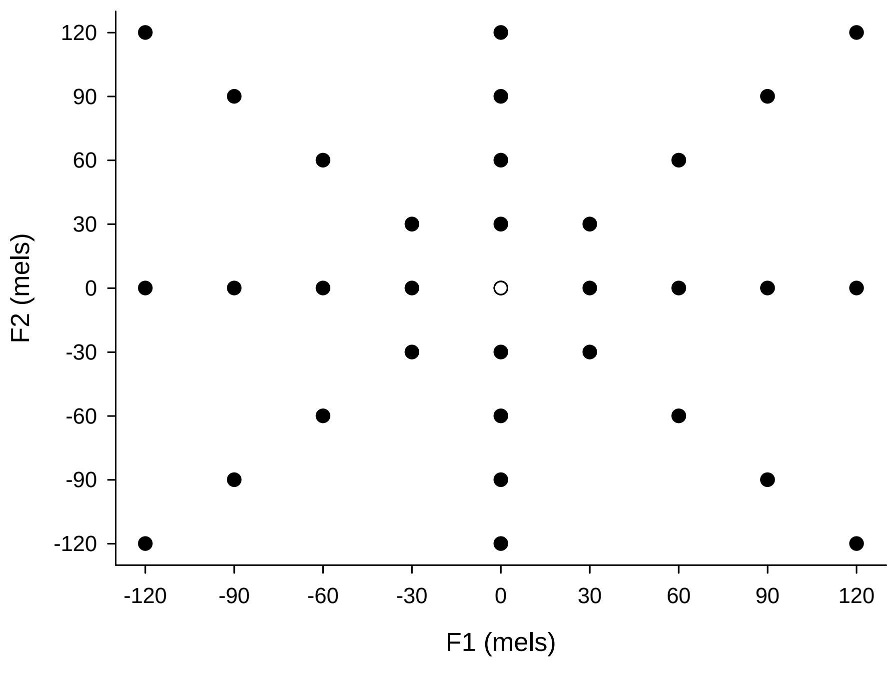

Figure 4.1. The Phonetic Category Prototype

The center standard vowel values (F1 and F2) were created by the productions of Mandarin monolinguals and Taiwanese monolinguals. The formula we adopted for relating frequencies to mel-scale was: mel = $2595*\log_{10}(1+ f/700)$. Vowel syntheses were made by Praat version 4.3.35. The formant values of the center vowels of Taiwan Mandarin and Taiwanese were listed in Table 4.1. The referent surrounding speech sounds were created according to them.

	Mandarin			Taiwanese		
formant	[i]	[u]	[a]	[i]	[u]	[a]
F1	276	349	695	353	388	1009
F2	2377	717	1107	2742	891	1581
F3	3010	2250	2540	3010	2250	2540
F4	3300	3300	3300	3300	3300	3300
F5	3750	3750	3750	3750	3750	3750

Table 4.1. The Formant Values of [i, u, a]

In Table 4.1, the first two formants were created according to the productions of Mandarin monolinguals and Taiwanese monolinguals. As for the other three formants were regularly adjusted at certain values.

Each of the stimuli was synthesized at a sampling rate of 11kHz and its duration was 500 ms. The pitch contour was all the same at 150 Hz.

In the process of experiment, all the stimuli were randomly ordered.

4.2.2.2 AX discrimination.

All the synthetic vowels in goodness ratings were the same in AX discrimination. The major difference was that the discrimination was conducted by the comparison of the center vowel and any one referent in orbits in each phonetic category.

In addition to the discrimination from referent sounds in surrounding orbits, there were also eight speech sounds, which were the same with the center vowel, for discrimination. Therefore, there were five orbit discrimination in each phonetic category, say, O0 (the eight same center vowels), O1, O2, O3 and O4. Plus, we can see whether there was a perceptual magnet effect. In addition, the inter-stimuli-interval was 110 ms and all the stimuli were randomly paired with the center vowel in the AX discrimination in each phonetic category.

The AX discrimination was constructed by C programming language. Participants made a choice of “the same” or “ different” after hearing a pair of compared speech sounds. The response time (RT) was also collected. (see Figure 4.2)

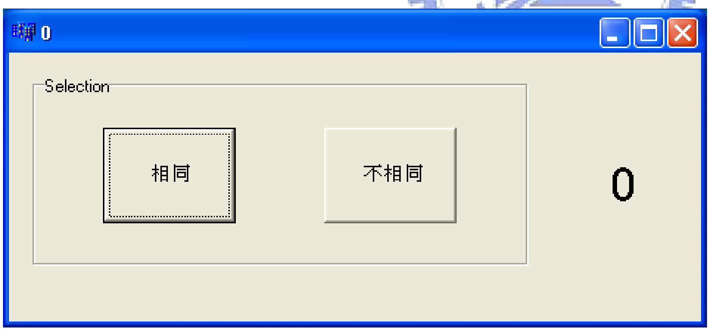

Figure 4.2. AX Discrimination key

4.2.3 Procedure.

Each participant of groups of Mandarin and Mandarin-Taiwanese sat in a quiet room. Perception experiment progressed with an ASUS laptop and a set of Panasonic headphones.

For Mandarin monolinguals, each of them took goodness ratings first. An answer sheet was given and they were asked to circle a score from 1(bad) to 7 (good) for a speech sound they heard. The order of phonetic categories was also randomly selected. Participants did goodness ratings for each phonetic category twice. Second, they took the AX discrimination. They made a choice of “ the same” or “different” after hearing a pair of comparing speech sounds.

For Mandarin-Taiwanese bilinguals, the procedure was the same with the group of Mandarin monolinguals. The difference was that 3 of Taiwan Mandarin-Taiwanese bilinguals did Mandarin section first and then the Taiwanese section later, respectively in goodness ratings and the AX discrimination, and that the others of bilinguals reversed the order in their turns.

4.3 Results

4.3.1 goodness ratings.

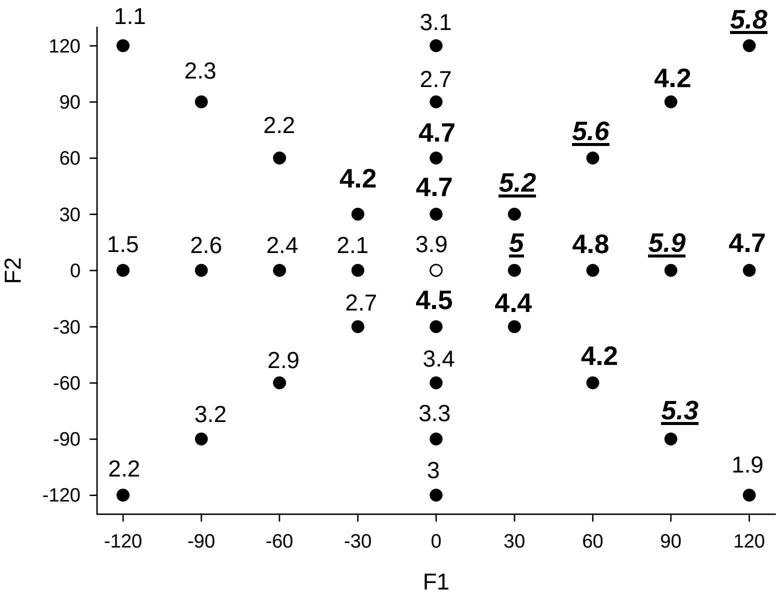

Figure 4.3. Mandarin [a] Goodness Ratings by Monolinguals

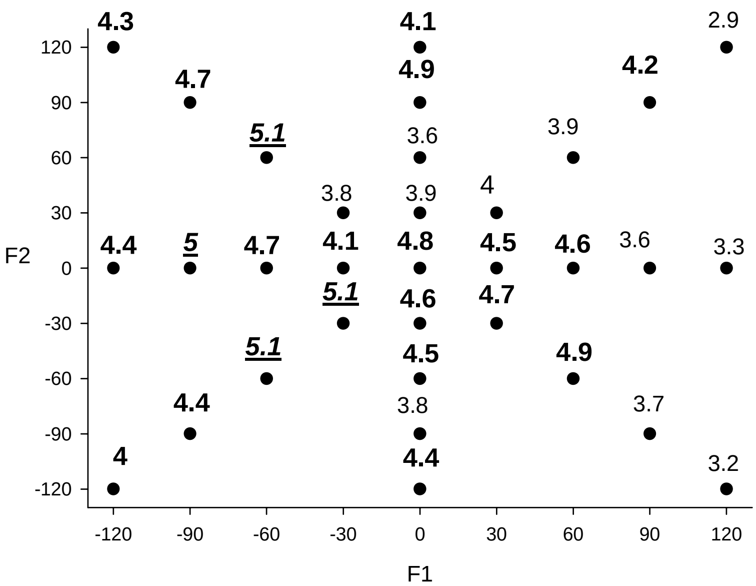

Figure 4.4. Mandarin [i] Goodness Ratings by Monolinguals

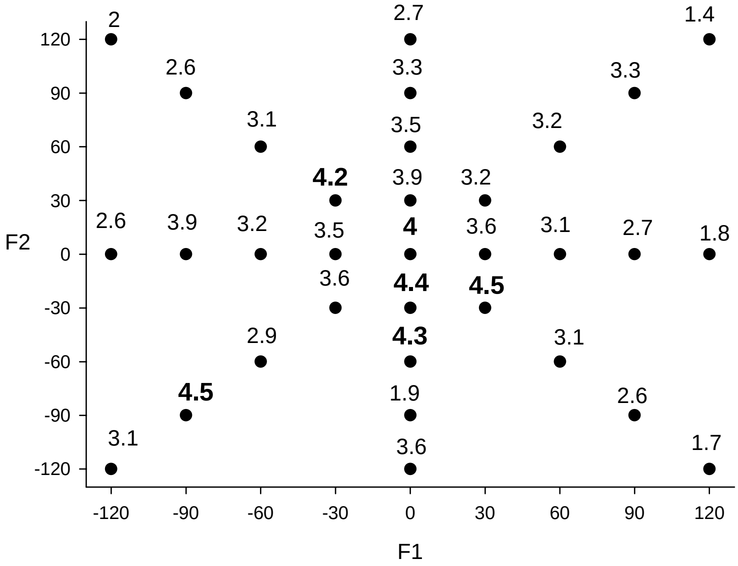

Figure 4.5. Mandarin [u] Goodness Ratings by Monolinguals

In Figure 4.3, 4.4, and 4.5, the production prototype by monolinguals didn't match their perceptual standard point. However, there was not an exact perceptual standard point as shown in Figures. Some referent points got nearly equal scores, but spread randomly. The same situation went to Mandarin goodness ratings and Taiwanese goodness ratings by bilinguals. (see Figure 4.6~ 4.11) If we rearranged the scores from orbit to orbit, statistic results showed no any significance either, except for Mandarin goodness ratings by monolinguals in Figure 4.5 ($F(4,45) = 3.2789$, $p < .05$).

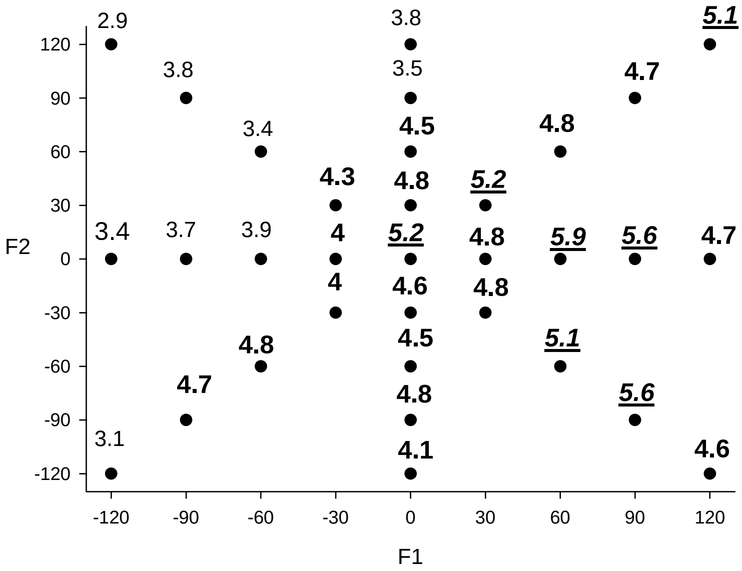

Figure 4.6 Mandarin[a] Goodness Ratings by Bilinguals

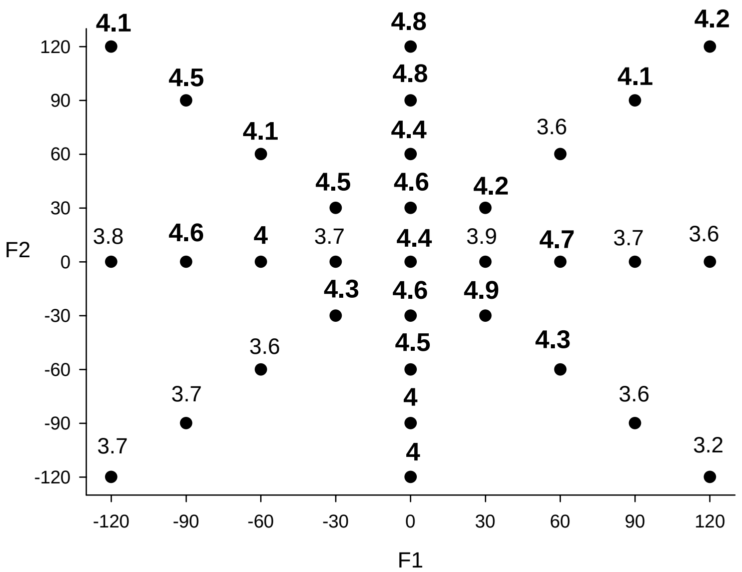

Figure 4.7 Mandarin [i] Goodness Ratings by Bilinguals

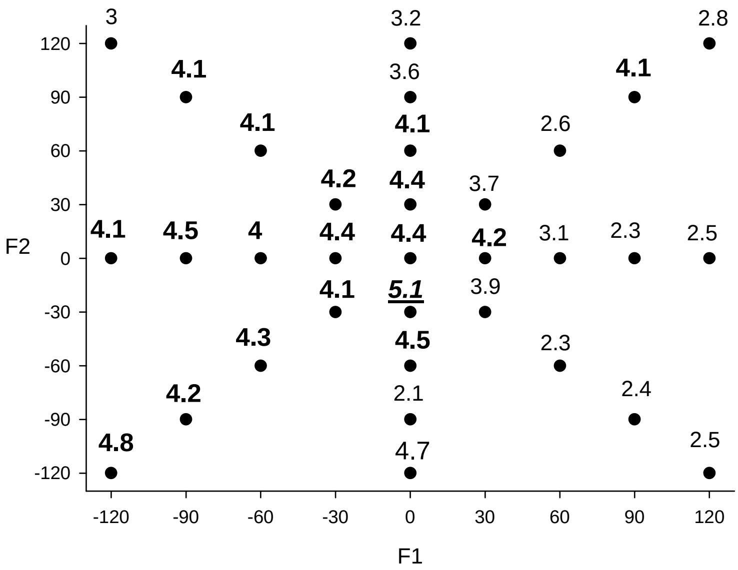

Figure 4.8. Mandarin [u] Goodness Ratings by Bilinguals

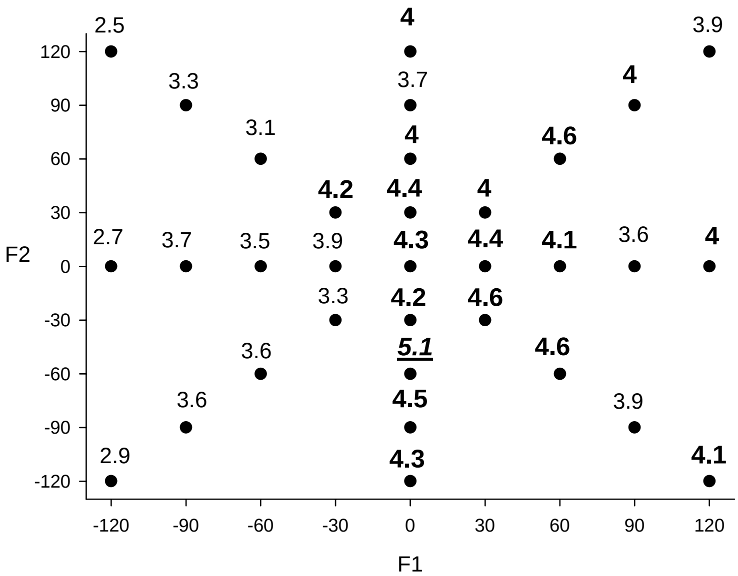

Figure 4.9. Taiwanese[a] Goodness Ratings by Bilinguals

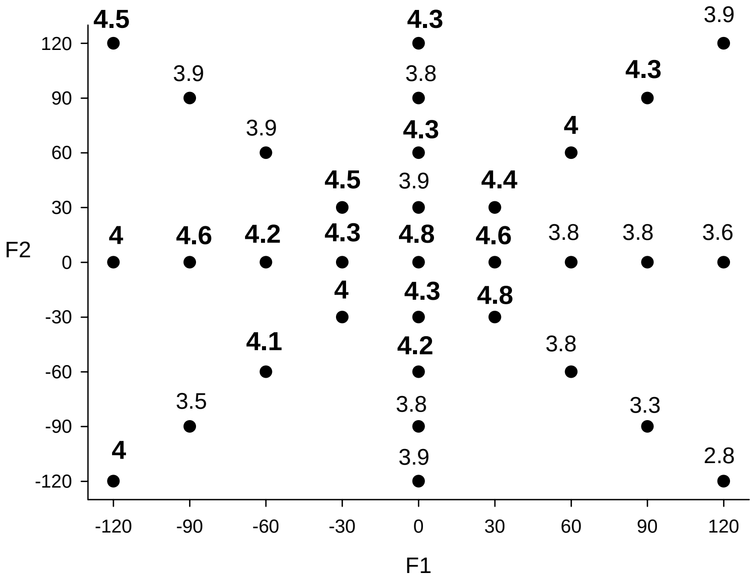

Figure 4.10. Taiwanese [i] Goodness Ratings by Bilinguals.

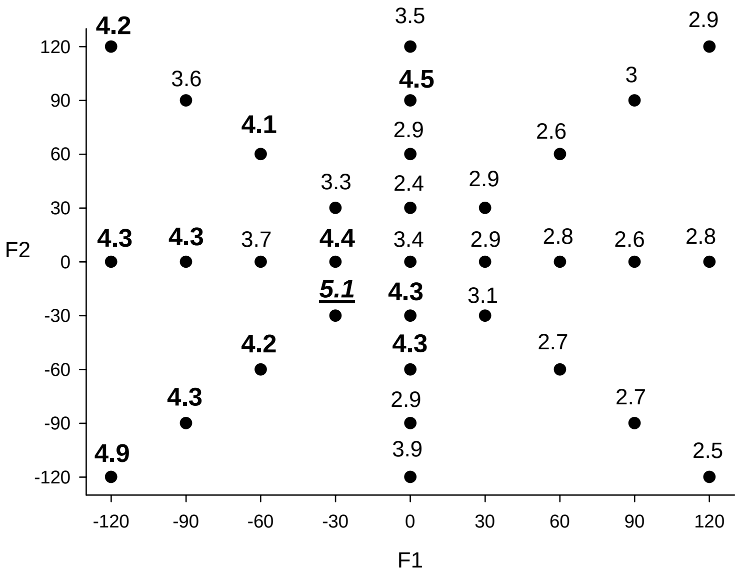

Figure 4.11. Taiwanese [u] Goodness Ratings by Bilinguals.

4.3.2 AX discrimination.

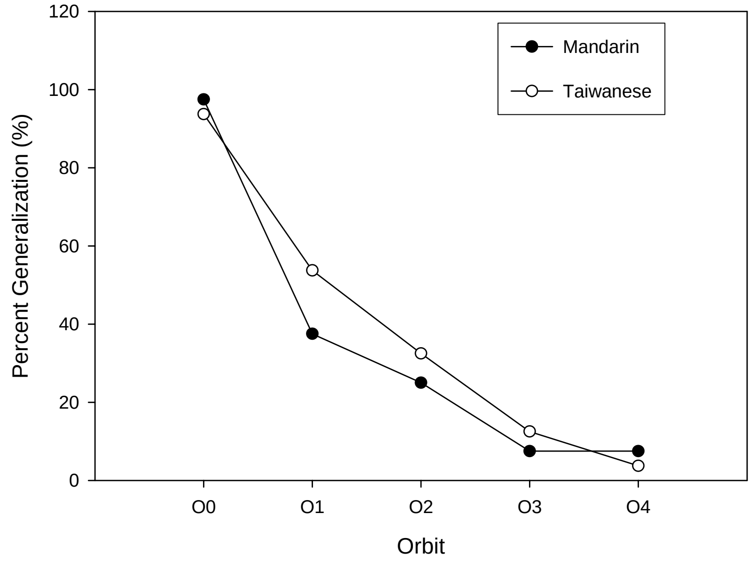

Figure 4.12. Bilinguals' Perception of [a].

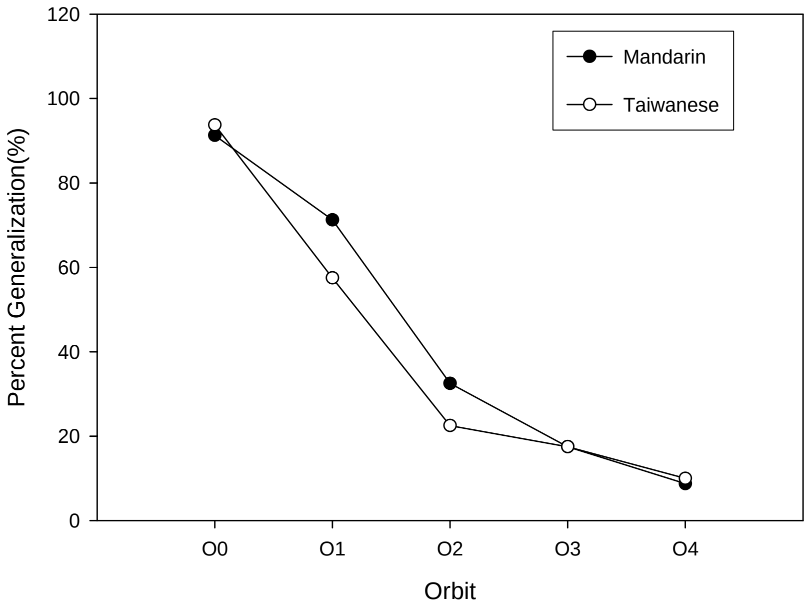

Figure 4.13. Bilinguals' Perception of [i]

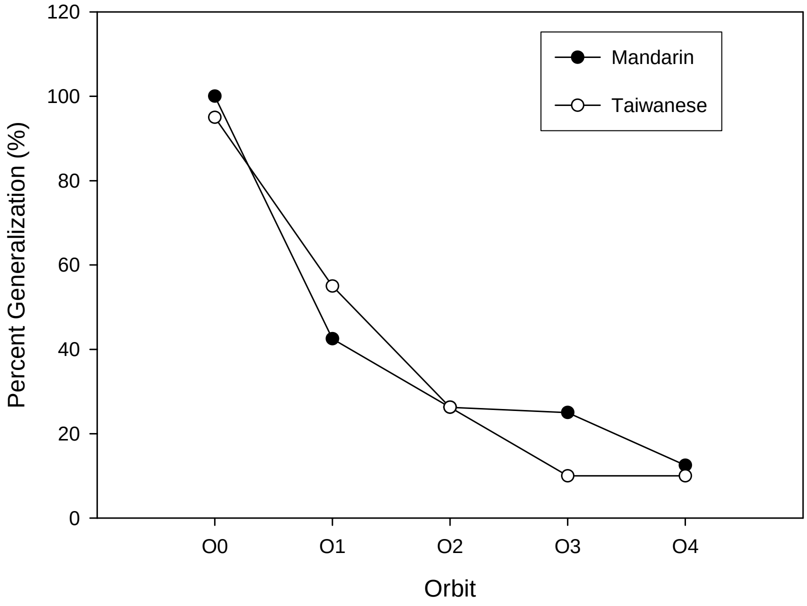

Figure 4.14. Bilinguals' Perception of [u].

Through Figure 4.12~ Figure 4.14, a 2(Language) × 5 (Orbit) two-way ANOVA was performed on the AX discrimination among the Mandarin and Taiwanese perceptions of bilinguals. Statistic results showed that the main effect of Orbit was significant on each of the phonetic categories [a, i, u]. ([a]: $F(4,90) = 81.29$, $p < .01$; [i]: $F(4,90) = 59.20$, $p < .01$; [u]: $F(4,90) = 64.73$, $p < .01$) This supported that bilinguals have the perceptual magnet effect both in Mandarin and Taiwanese. Even though, the center vowels were not synthesized by perceptual prototypes, but by productive prototypes, the perceptual magnet effect existed too. In addition, through the results of goodness ratings, although productive prototypes didn't match the perceptual standard points, yet there seemed no perceptual prototypes that could be obtained from that experiment.

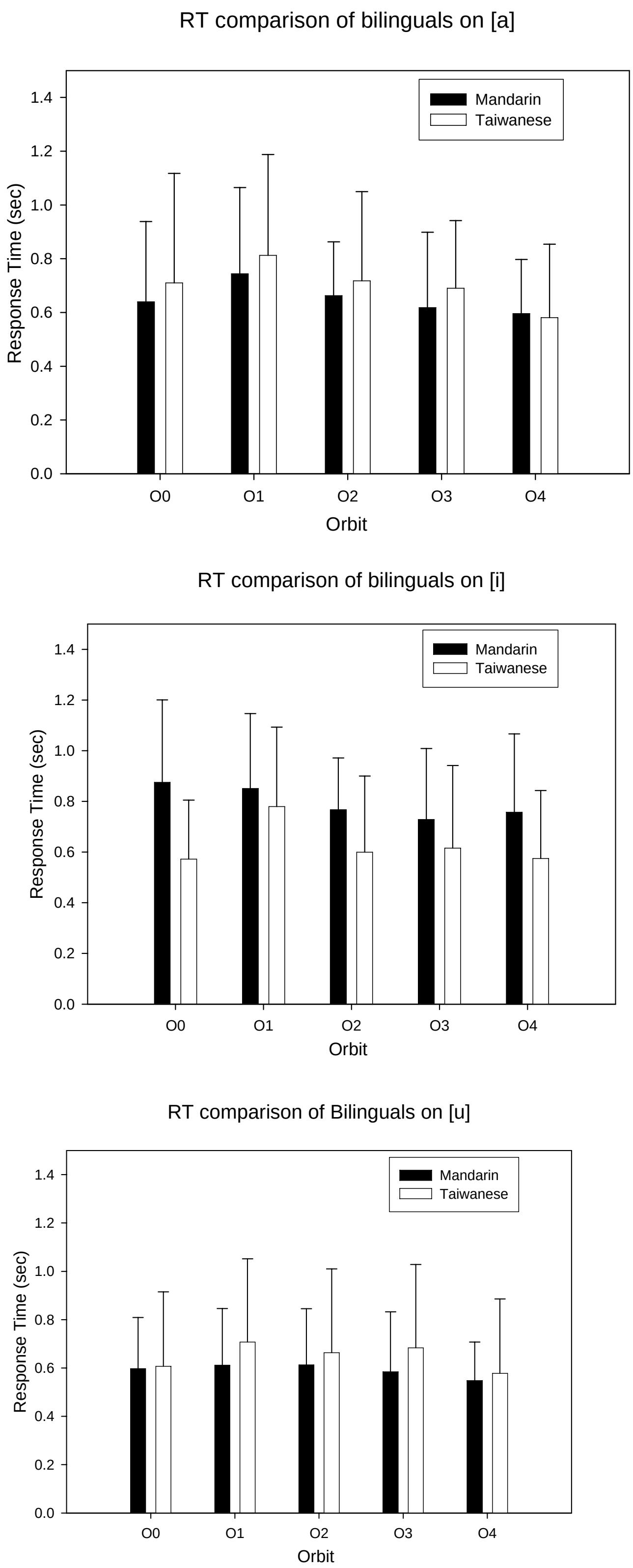

Figure 4.15. RT on [a, i, u] of Blinguals

Figure 4.15 was the response time on [a, i, u] of Mandarin-Taiwanese bilinguals. Statistic results showed that there were no any significance both on the main effect of Language and Orbit, except for the main effect of Language on [i] category ($F(1,90) = 8.45$, $p < .01$).

Figure 4.16 to Figure 4.18 were the perception comparison of Mandarin monolinguals and Mandarin-Taiwanese bilinguals. A 2(Language) × 5 (Orbit) two-way ANOVA was also performed. In [a] and [u] perception, only the main effects of Orbit were significant ([a]: $F(4,90) = 80.76$, $p < .01$; [u]: $F(4,90) = 42.63$, $p < .05$). As for [i], both the main effects of Language and Orbit were significant (Language: $F(1,90) = 5.75$, $p < .05$; Orbit: $F(4,90) = 71.26$, $p < .01$).

Figure 4.19 to Figure 4.21 were the RT comparison of Mandarin monolinguals and Mandarin-Taiwanese bilinguals. Statistic results only showed the main effect of Language on all of the three comparison ([a]: $F(1,90) = 6.51$, $p < .05$; [i]: $F(1,90) = 5.77$, $p < .05$; [u]: $F(1,90) = 4.12$, $p < .05$).

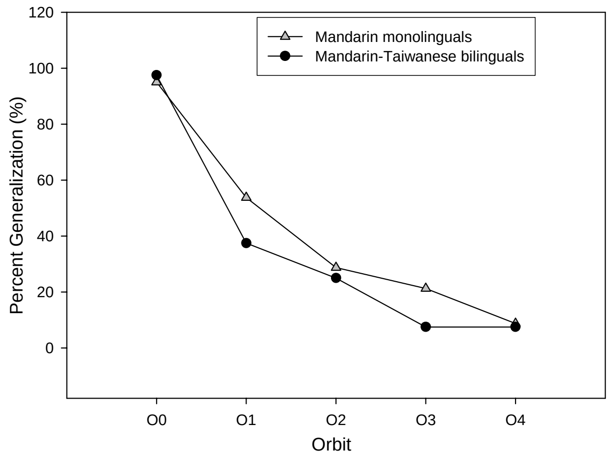

Figure 4.16. Mandarin [a] Perception Comparison

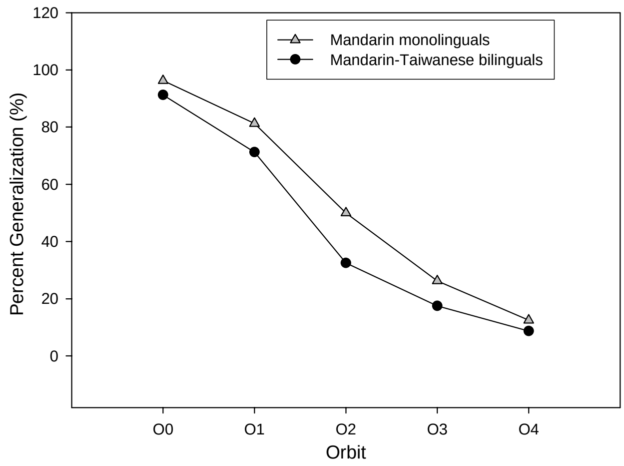

Figure 4.17. Mandarin [i] Perception Comparison.

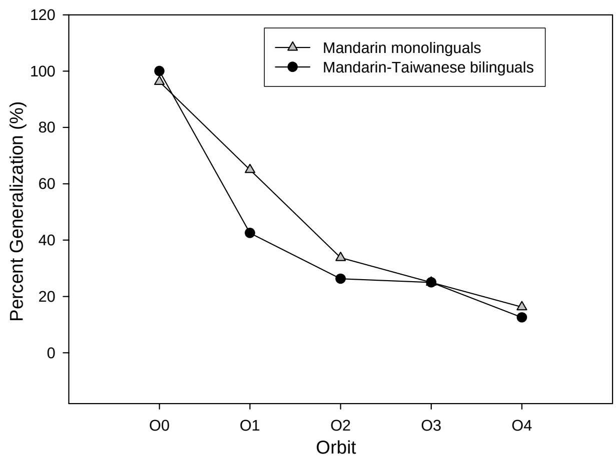

Figure 4.18. Mandarin [u] Perception Comparison.

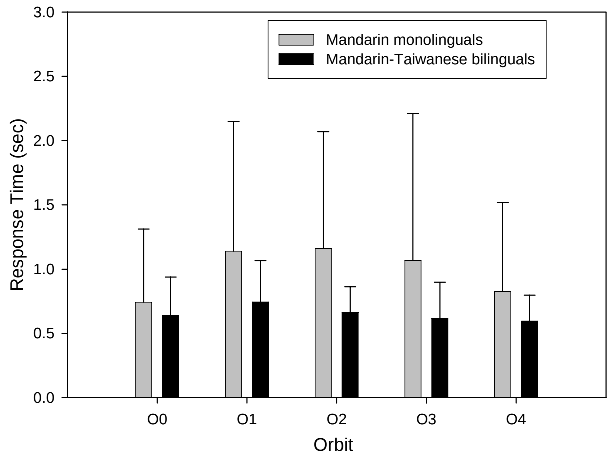

Figure 4.19. RT Comparison on Mandarin [a].

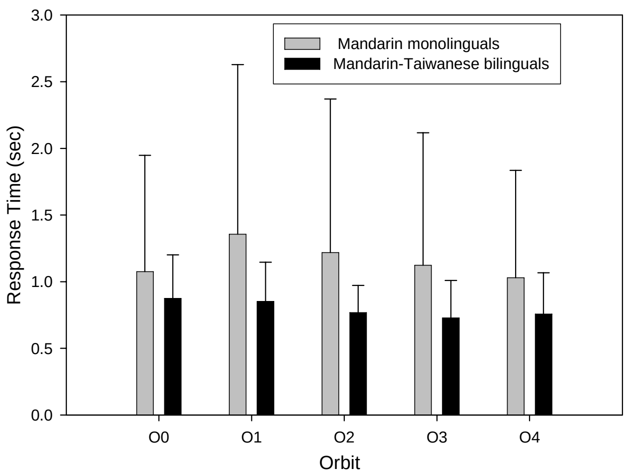

Figure 4.20. RT Comparison on Mandarin [i].

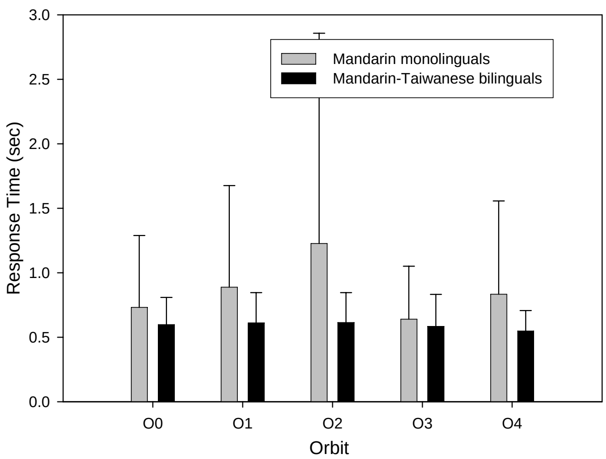

Figure 4.21. RT Comparison on Mandarin [u].

CHAPTER FIVE

EXPERIMENT 3：THE EVENT-RELATED POTENTIALS

5.1 Goal

The Event-related potentials (ERPs) is conducted in this experiment for the study of the perceptual magnet effect on bilinguals. The auditory-evoked component of mismatch negativity (MMN) in ERPs plays a crucial role in sound discrimination since it detects the deviant sounds from the standard one. It is the characteristic of MMN that has been used for the language research as well as neuroscience studies. With respect to the phonetic category, MMN assists researchers to speculate the perceptual magnet effect and the interference of two similar phonetic categories.

Thus, MMN is observed in Experiment 3 when Mandarin [a] and Taiwanese [a] encounter.

5.2 Method

5.2.1 Participants.

Fifteen male bilingual participants who spoke Mandarin and Taiwanese took part in this experiment. They were right-handed and had no any reported history of speech and hearing disorders. Their mean age was 22.8 years.

5.2.2 Materials.

Two dimensional sets of stimulus were created respectively according to the monolingual productions of Mandarin [a] and Taiwanese [a] derived from experiment 1 (Figure 5.1). In each language phonetic category, these two dimensional sets of stimulus were names as 1) Opposite and 2) Interface, which were correspond to their directions while the two language phonetic categories encountered. These two dimensional sets of stimulus in each language phonetic category were synthetically manipulated from orbit to orbit according to their production prototype of [a] (see Experiment 2: Perception). Therefore, four conditions of this experiment were derived as 1) Mandarin Interface, 2) Mandarin Opposite, 3) Taiwanese Interface, and 4) Taiwanese Opposite. The concentric orbit values were displayed as linear relations in Table 5.1.

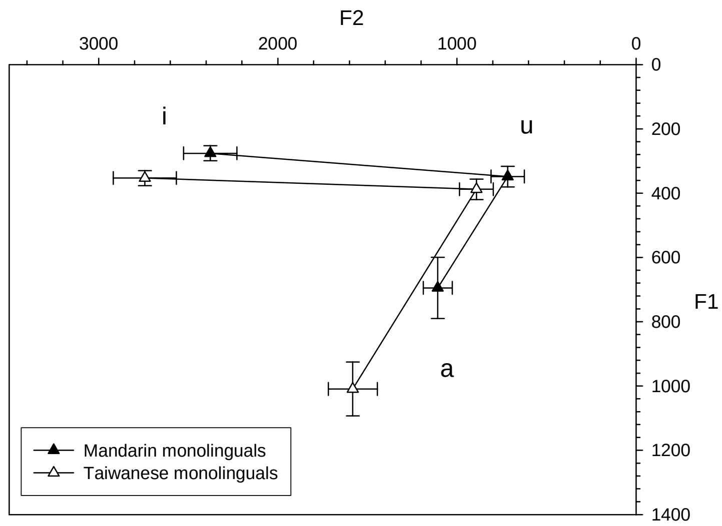

Figure 5.1. The Production of Monolinguals on [i, u, a].

In each condition, its production prototype of [a] was served as the standard stimulus while the other four from orbit to orbit as deviant stimuli according to the synthetic values in Table 5.1. Those stimuli were all 300ms in duration and 60dB. In addition, there were two sections within each condition that, in one section, standard stimulus 80% displayed and two stimuli 20% displayed. The other two stimuli in one condition were displayed in another section with the standard stimulus. The stimuli in each condition were all randomly ordered with an interval of 300ms, however, the deviant stimuli would not be adjacently displayed. It took 10 minutes for one section and 20 minutes totally in on condition.

Mandarin Interface [a]

	prototype	Orbit 1	Orbit 2	Orbit 3	Orbit 4
F1	695(x)	x+30mel	x+60mel	x+90mel	x+120mel
F2	1101(y)	y+30mel	y+60mel	y+90mel	y+120mel

Mandarin Opposite [a]

	prototype	Orbit 1	Orbit 2	Orbit 3	Orbit 4
F1	695(x)	x-30mel	x-60mel	x-90mel	x-120mel
F2	1101(x)	y-30mel	y-60mel	y-90mel	y-120mel

Taiwanese Interface [a]

	prototype	Orbit 1	Orbit 2	Orbit 3	Orbit 4
F1	1009(x)	x-30mel	x-60mel	x-90mel	x-120mel
F2	1581(y)	y-30mel	y-60mel	y-90mel	y-120mel

Taiwanese opposite [a]

	prototype	Orbit 1	Orbit 2	Orbit 3	Orbit 4
F1	1009(x)	x+30mel	x+60mel	x+90mel	x+120mel
F2	1581(y)	y+30mel	y+60mel	y+90mel	y+120mel

Table 5.1. The Interface and Opposite Values of Mandarin and Taiwanese.

5.2.3 Procedure.

Electrodes were used and placed according to the international 10/20 system. The electrodes were placed at FP1, FP2, F7, F3, FZ, F4, F8, FT7, FC3, FCZ, FC4, FT8, T3, TP7, T5, T4, TP8, T6, C3, CZ, C4, CP3, CPZ, CP4, P3, PZ, P4, O1, OZ, and O2. Continuous EEG was then recorded when a participant sat in a room watching a silent movie. A number of stimuli were displayed from section to section through the earphone the participants wore. All the stimuli were 60 dB in display. Participants were asked to pay no attention to the stimuli. Half the participants went for Taiwan Mandarin conditions (Opposite and Interface) first and the others for Taiwanese conditions first. From section to section, participants could take a few minutes break.

5.2.4 Analysis.

The software of Neuroscan was used for EEG data analysis. Several steps of data analysis were followed by the tutorial in order to generate the avg. file where MMN component could be observed. First, eye movement was corrected as VEOG that purified the EEG data before Ocular Artifact Reduction Parameters were set. Each epoch was then extracted as duration of 350ms from pre-stimulus onset 50ms to post-stimulus onset 300ms. Later, Baseline correction was averaged based on the pre-stimulus onset 50ms. Furthermore, Artifact rejection performed through all the electrode channels after filtering was set as 30Hz, 12dB/oct. Finally, epoch brainwaves of different stimulus types were generated after average of stimulus types.

MMN was extracted when the brainwave of standard stimulus was subtracted from that of deviant stimulus. The amplitude and peak latency of the MMN were to our concern. After group average, we got the MMN extracted from orbit stimulus type to orbit stimulus type in the four language conditions, say, Mandarin Interface, Mandarin Opposite, Taiwanese Interface and Taiwanese Opposite.

STATISTICA was used for statistic analysis.

5.3 Results

5.3.1 Mandarin Interface.

The whole-head analysis of 15 participants on Mandarin Interface was grouped as Appendix A. The MMN responses on standard stimulus (prototype stimulus) and 4 deviant stimuli (Orbit 1, Orbit 2, Orbit 3 and Orbit 4) were extracted from all the 30 channels. MMN responses were more activated in locations of frontal and parietal than temporal and occipital (Indeed, there were no MMN responses in occipital.). Plus, FP1 and FP2 were temporarily not put into analysis for the interference of eye movement. Thus, we used two-way ANOVA to analyze the correlation of the other channels arranged by the electrodes as Frontal, Frontal-central, Central, Central-parietal, and Parietal.

First of all, a 3 (Hemisphere) × 5 (Sagittal) two-way ANOVA was used to see the significance. (Left hemisphere: F3, FC3, C3 CP3 and P3; Central hemisphere: FZ, FCZ, CZ, CPZ and PZ; Right hemisphere: F4, FC4, C4, CP4 and P4) (Sagittal 1 was for Frontal as F3, FZ and F4; Sagittal 2 for Frontal-central as FC3, FCZ and FC4; Sagittal 3 for Central as C3, CZ and C4; Sagittal 4 for CP3, CPZ and CP4; Sagittal 5 for P3, PZ and P4.) For the amplitude of the MMN, statistic results showed that the main effect of Sagittal was significant (F (4, 885) = 9.6725, p < .05) while there showed no any significant for the main effect of Hemisphere (see Figure 5.2). The front part it is in the brain, the larger the MMN amplitude it activated.

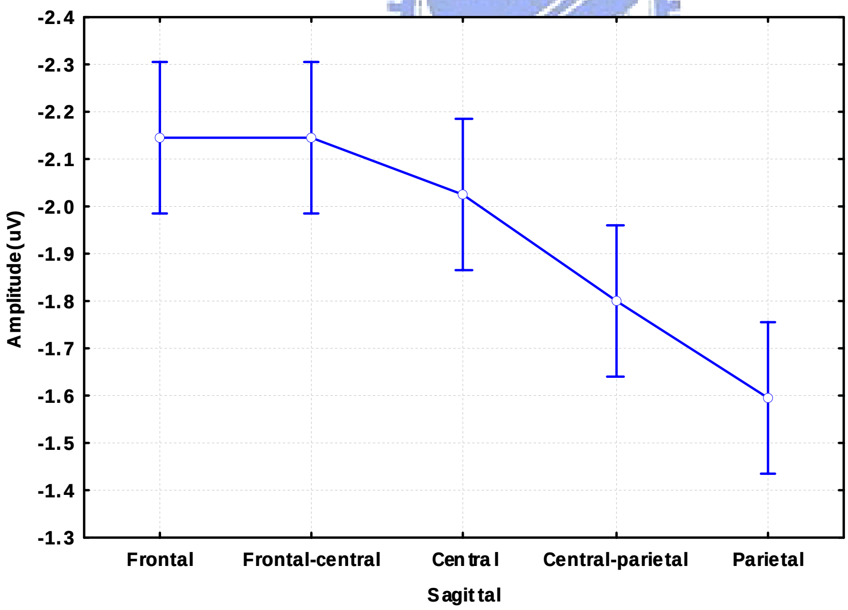

Figure 5.2. The MMN Amplitude of Sagittal on Mandarin Interface.

With respect to its peak latency, statistic results showed that the main effect of Sagittal was significant as well (F (4, 885) = 5.5954, p < .05). Meanwhile, there showed no any significance for the main effect of Hemisphere. Figure 5.3 was the relations of the MMN peak latency and Sagittal. The MMN peak latency activated earlier comparatively in the front part of brain than the later planet.

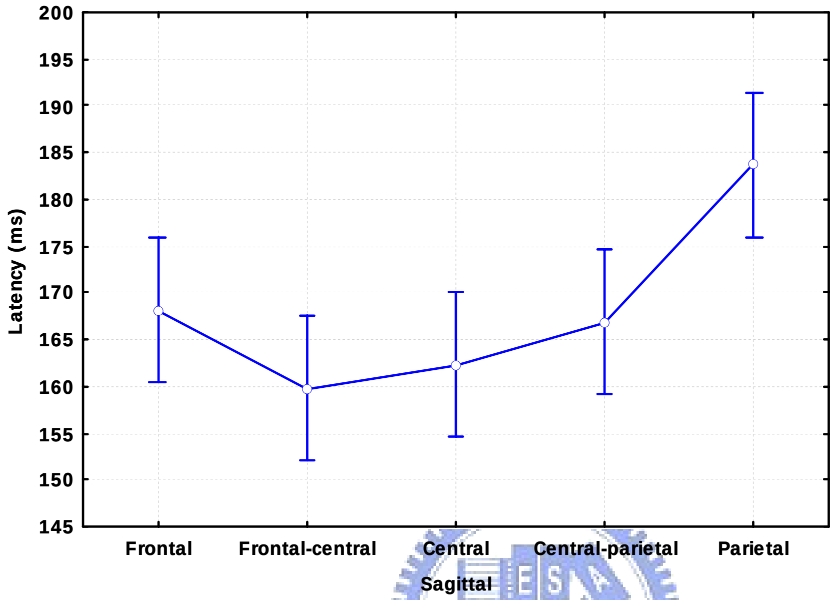

Figure 5.3. The MMN Peak Latency of Sagittal on Mandarin Interface.

After two-way ANOVA of Hemisphere plus Sagittal, another 5 (Sagittal) × 4 (Orbit) two-way ANOVA was used continuously. For the MMN amplitude, the main effect of Sagittal was significant in the former analysis. Moreover, in this analysis, statistic results showed that the main effect of Orbit was significant too ($F(3,880) = 27.147$, $p < .05$). Figure 5.4 was the MMN amplitude of Orbit. The more deviant stimulus it was in the outer orbit, the larger the MMN amplitude it activated.

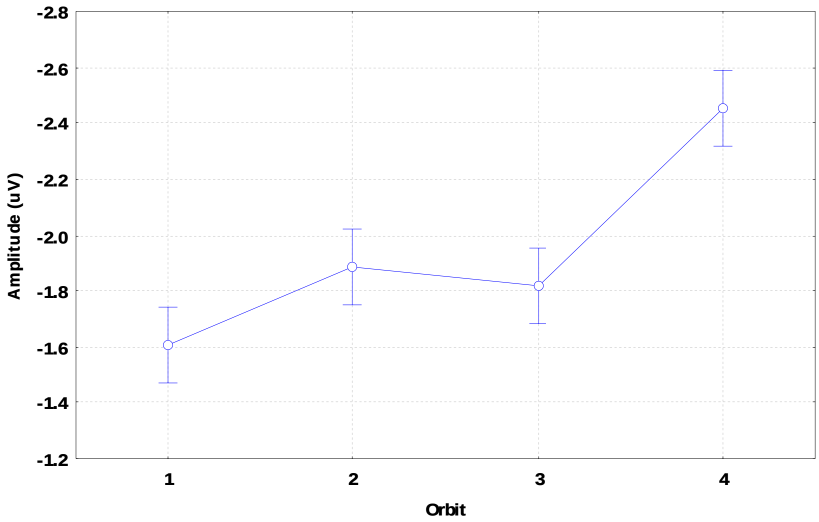

Figure 5.4. The MMN Amplitude of Orbit on Mandarin Interface.

As for its peak latency, the main effect of orbit was significant (F (3,880) = 37.900, p < .05) that the more deviant the stimulus it was in the outer orbit, the earlier peak latency it occurred (see Figure 5.5).

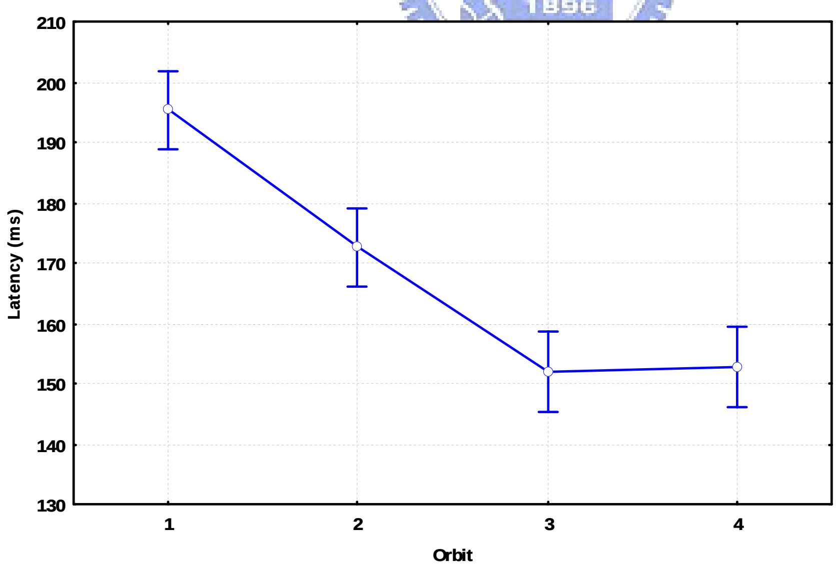

Figure 5.5 The MMN Peak Latency of Orbit on Mandarin Interface.

There showed a main effect of Sagital and Orbit for MMN amplitude only ($F(12,880) = 2.1530$, $p < .05$) as the following Figure 5.6.

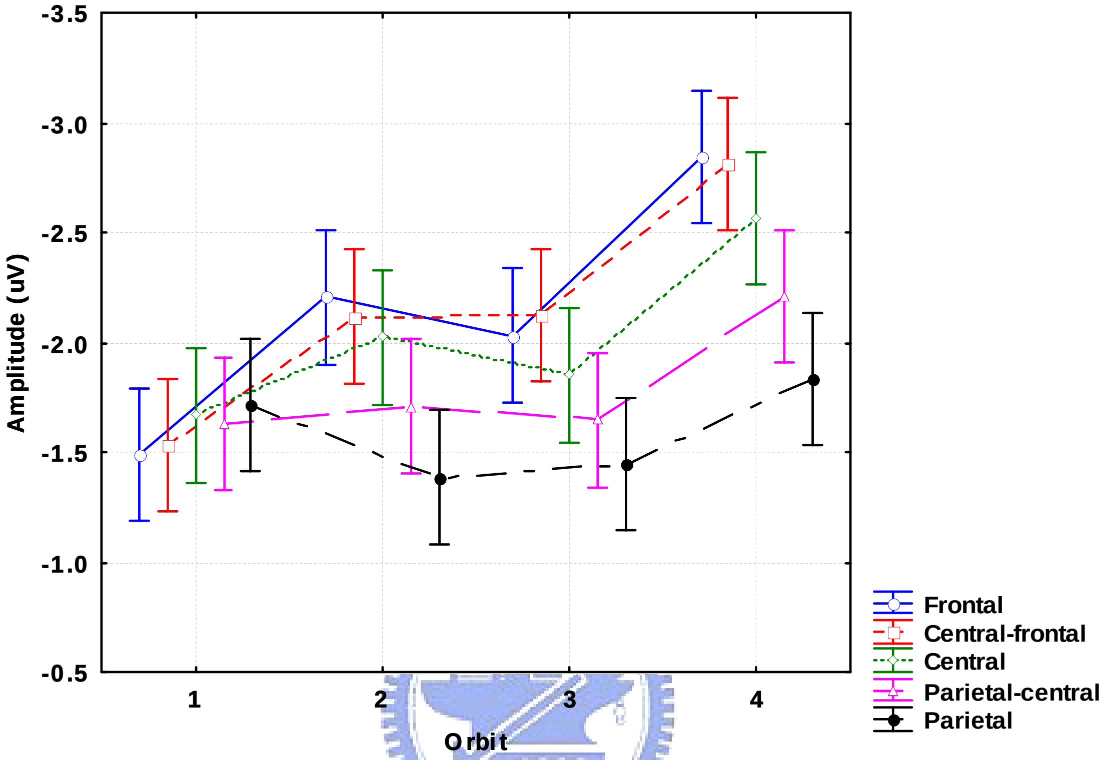

Figure 5.6. The MMN Amplitude of Sagittal and Orbit on Mandarin Interface.

5.3.2 Mandarin Opposite

The whole-head analysis of 15 participants on Mandarin Opposite was grouped as Appendix B. The MMN responses on standard stimulus (prototype stimulus) and 4 deviant stimuli (Orbit 1, Orbit 2, Orbit 3 and Orbit 4) were extracted from all the 30 channels. MMN responses were more activated in location of frontal and parietal than temporal and occipital (Indeed, there were no MMN responses in occipital.). Plus, FP1 and FP2 were temporarily not put into analysis for the interference of eye movement. Thus, we used two-way ANOVA to analyze the correlation of the other channels arranged by the electrodes as Frontal, Frontal-central, Central, Central-parietal, and Parietal.

First of all, a 3 (Hemisphere) × 5 (Sagittal) two-way ANOVA was used to see the significance. (Left hemisphere: F3, FC3, C3 CP3 and P3; Central hemisphere: FZ, FCZ, CZ, CPZ and PZ; Right hemisphere: F4, FC4, C4, CP4 and P4) (Sagittal 1 was for Frontal as F3, FZ and F4; Sagittal 2 for Frontal-central as FC3, FCZ and FC4; Sagittal 3 for Central as C3, CZ and C4; Sagittal 4 for CP3, CPZ and CP4; Sagittal 5 for P3, PZ and P4.) For the amplitude of the MMN, statistic results showed that the main effect of Hemisphere was significant ($F(2, 885) = 5.7676, p < .05$) as well as the main effect of Sagittal ($F(4,885) = 19.214, p < .05$). Middle and right hemispheres comparatively had larger MMN amplitude than left hemisphere did. In addition, the larger MMN amplitude was evoked in the front part of the brain. The MMN amplitude decreased from Frontal to Parietal. (Figure 5.7 and Figure 5.8).

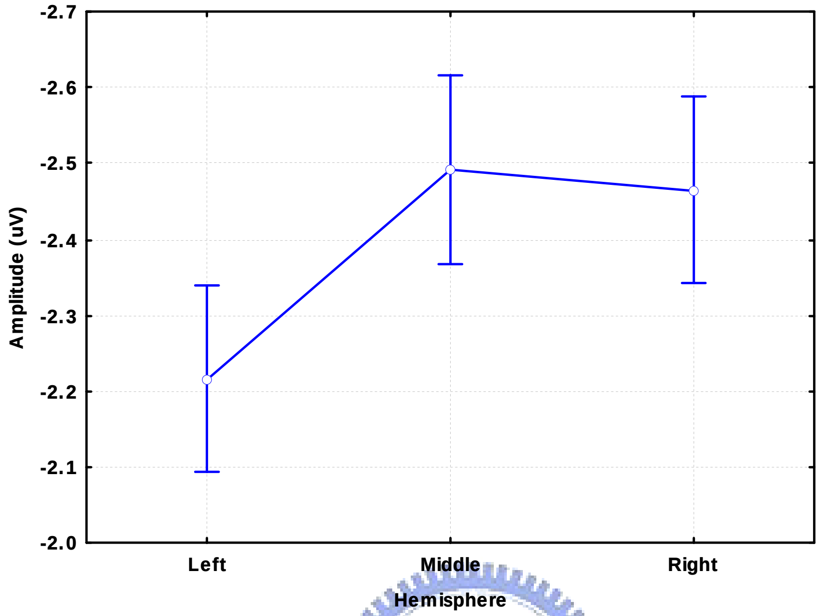

Figure 5.7. The MMN Amplitude of Hemisphere on Mandarin Opposite.

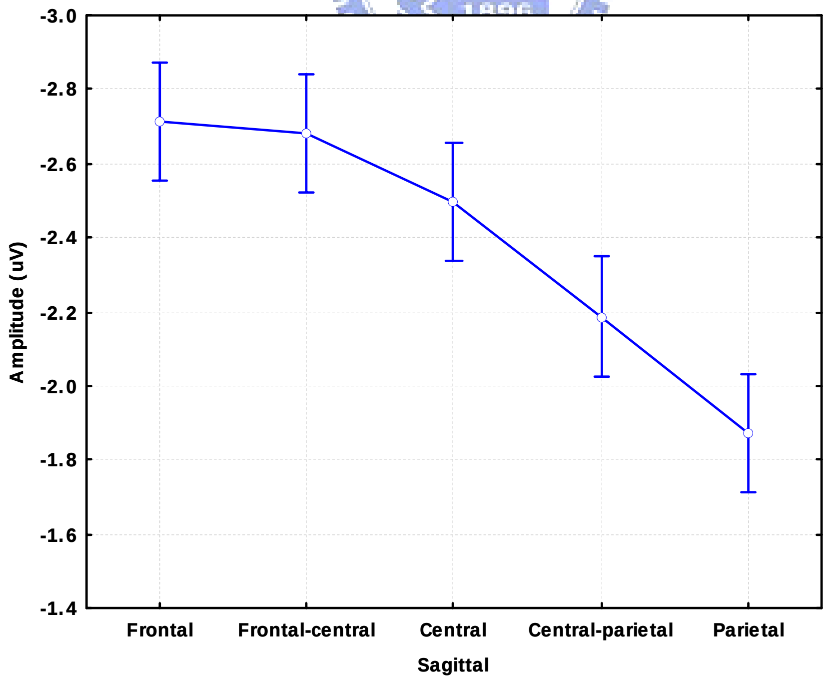

Figure 5.8. The MMN Amplitude of Sagittal on Mandarin Opposite.

With respect to Latency, statistic results showed that the main effect of Hemisphere was not significant and the main effect of Sagittal was significant (Figure 5.9).

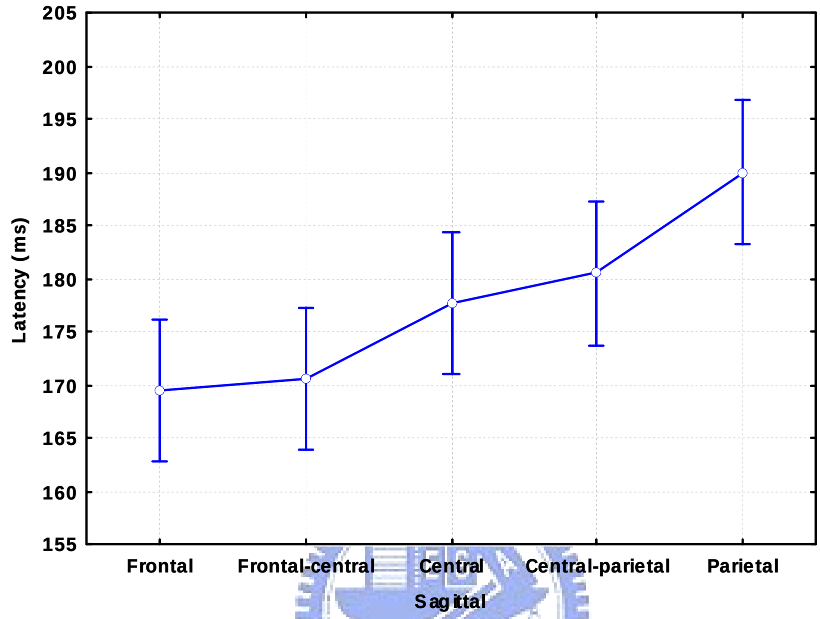

Figure 5.9. The MMN Peak Latency of Sagittal on Mandarin Opposite.

Another 5 (Sagittal) × 4 (Orbit) two-way ANOVA was used continuously after the previous statistic analysis. Statistic results showed that the main effect of Sagittal and the main effect of Orbit were significant. The larger MMN amplitude was evoked in the front part of the brain comparatively than the later part of the brain as Figure 5.8 showed. As for the main effect of Orbit (F (3,880) =14,193, p < .05), the last two orbit deviants got the smaller MMN amplitude than the first two orbit deviants (Figure 5.10). This was different from the result of Mandarin Interface that the most deviant stimulus (say, orbit 4) evoked largest MMN amplitude.

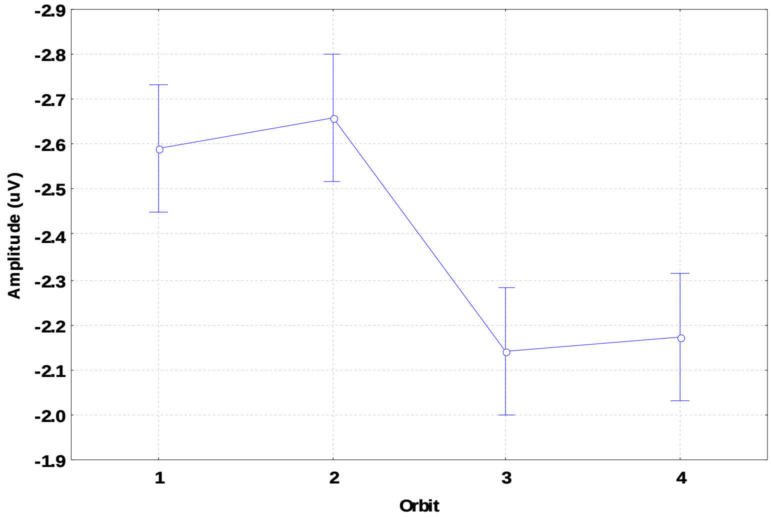

Figure 5.10. The MMN Amplitude of Orbit on Mandarin Opposite.

With respect to Latency, statistic results showed that the MMN latency was earlier in the front part of the brain. The later part it was in the brain, the longer latency it took (Figure 5.9). For the MMN latency of Orbit ($F (3,880) = 20.864$, $p < .05$), the orbit 3 got the earliest MMN latency. The orbit 4 had equivalent MMN latency with the orbit 1 (5.11).

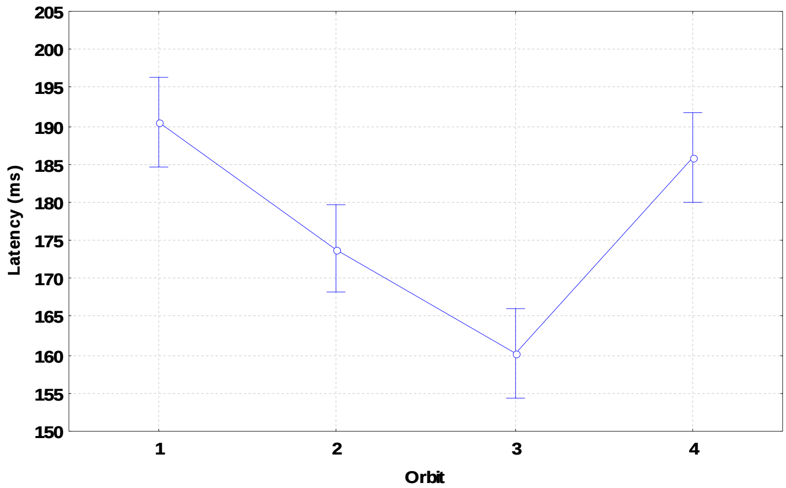

Figure 5.11. The MMN Peak Latency of Orbit on Mandarin Opposite.

5.3.3 Taiwanese Interface

The whole-head analysis of 15 participants on Taiwanese Interface was grouped as Appendix C. The MMN responses on standard stimulus (prototype stimulus) and 4 deviant stimuli (Orbit 1, Orbit 2, Orbit 3 and Orbit 4) were extracted from all the 30 channels. MMN responses were more activated in location of frontal and parietal than temporal and occipital (Indeed, there were no MMN responses in occipital.). Plus, FP1 and FP2 were temporarily not put into analysis for the interference of eye movement. Thus, we used two-way ANOVA to analyze the correlation of the other channels arranged by the electrodes as Frontal, Frontal-central, Central, Central-parietal, and Parietal.

First of all, a 3 (Hemisphere) × 5 (Sagittal) two-way ANOVA was used to see the significance. (Left hemisphere: F3, FC3, C3 CP3 and P3; Central hemisphere: FZ, FCZ, CZ, CPZ and PZ; Right hemisphere: F4, FC4, C4, CP4 and P4) (Sagittal 1 was for Frontal as F3, FZ and F4; Sagittal 2 for Frontal-central as FC3, FCZ and FC4; Sagittal 3 for Central as C3, CZ and C4; Sagittal 4 for CP3, CPZ and CP4; Sagittal 5 for P3, PZ and P4.) For the amplitude of the MMN, statistic results showed that only the main effect of Sagittal was significant ($F (4.885) = 15.913$, $p <.05$) (Figure 5.12). As for Latency, there was no any significance both on Sagittal and Hemisphere.

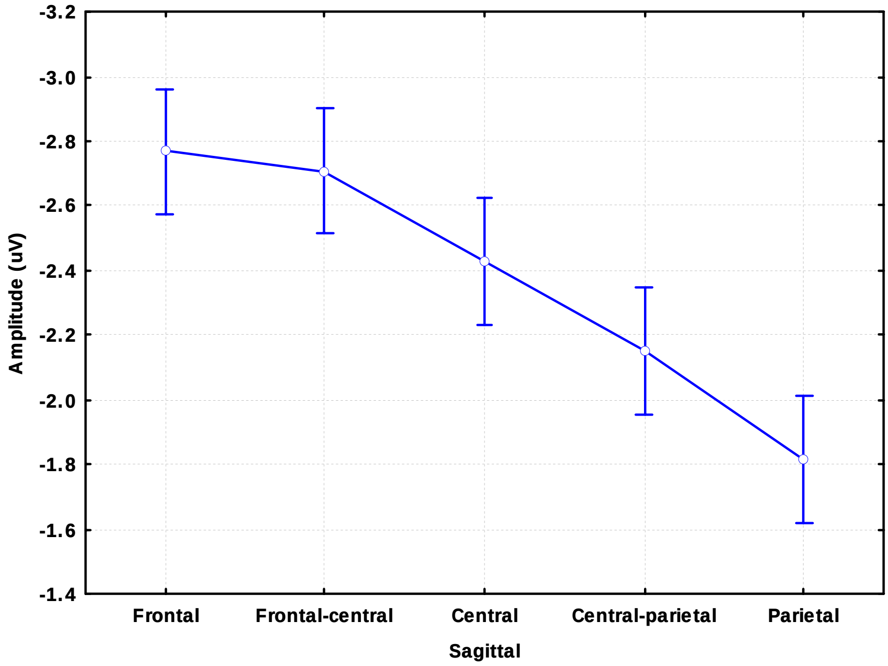

Figure 5.12. The MMN Amplitude of Sagittal on Taiwanese Interface.

Another 5 (Sagittal) × 4 (Orbit) two-way ANOVA was used, showing that the main effect of Sagittal and the main effect of Orbit were significant with respect to the MMN amplitude. As for Latency, only the main effect of Orbit showed significance. The statistic analysis of Sagittal was previously shown as Figure 5.12. Figure 5.13 and 5.14 showed that the MMN amplitude and MMN latency of Orbit (F (3,880) =7.9034, p < .05; F (3,880) = 7.0=6702, p < .05), indicating the correlation between the MMN amplitude and MMN latency. The Outer the most deviant stimulus it was, the larger MMN amplitude it evoked. Meanwhile, the outer the orbit stimulus it was, it took earlier MMN latency comparatively than the center orbit as the orbit 1 and 2.

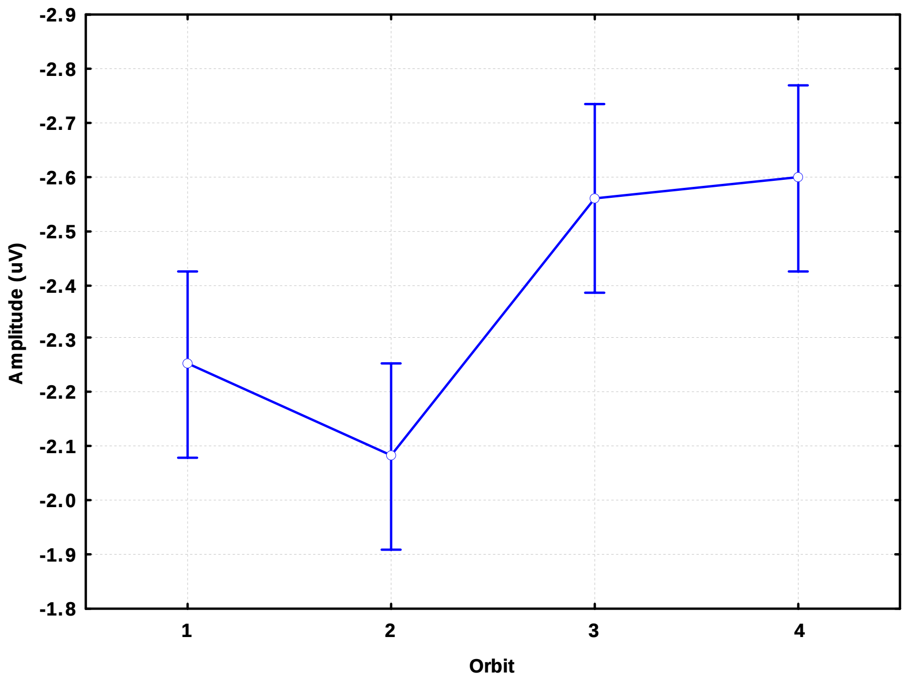

Figure 5.13. The MMN Amplitude of Orbit on Taiwanese Interface.

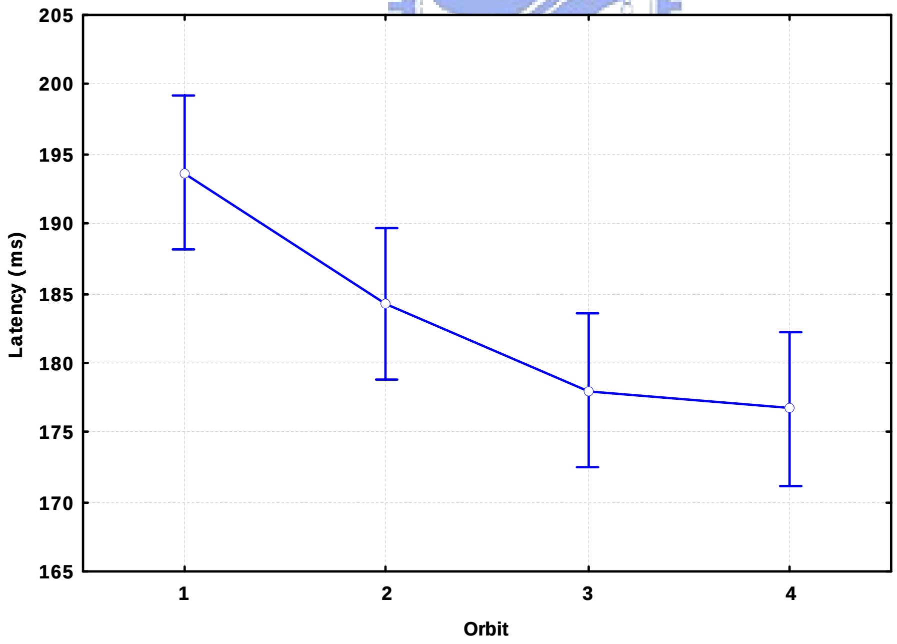

Figure 5.14. The MMN Peak Latency of Orbit on Taiwanese Interface.

5.3.4 Taiwanese Opposite

The whole-head analysis of 15 participants on Taiwanese Opposite was grouped as Appendix D. The MMN responses on standard stimulus (prototype stimulus) and 4 deviant stimuli (Orbit 1, Orbit 2, Orbit 3 and Orbit 4) were extracted from all the 30 channels. MMN responses were more activated in location of frontal and parietal than temporal and occipital (Indeed, there were no MMN responses in occipital.). Plus, FP1 and FP2 were temporarily not put into analysis for the interference of eye movement. Thus, we used two-way ANOVA to analyze the correlation of the other channels arranged by the electrodes as Frontal, Frontal-central, Central, Central-parietal, and Parietal.

First of all, a 3 (Hemisphere) × 5 (Sagittal) two-way ANOVA was used to see the significance. (Left hemisphere: F3, FC3, C3 CP3 and P3; Central hemisphere: FZ, FCZ, CZ, CPZ and PZ; Right hemisphere: F4, FC4, C4, CP4 and P4) (Sagittal 1 was for Frontal as F3, FZ and F4; Sagittal 2 for Frontal-central as FC3, FCZ and FC4; Sagittal 3 for Central as C3, CZ and C4; Sagittal 4 for CP3, CPZ and CP4; Sagittal 5 for P3, PZ and P4.) For the amplitude of the MMN, statistic results showed that the main effect of Sagittal was significant. ($F(4,885) = 15.601$, $p < .05$) and the main effect of Hemisphere was not significant (Figure 5.15). With respect to Latency, there showed no any significant both on Hemisphere and Sagittal although Parietal had later latency comparatively than the first four sagittal planets (Figure 5.16, Sagittal: F (4,885) = 2.1203, p = .07, approaching significance).

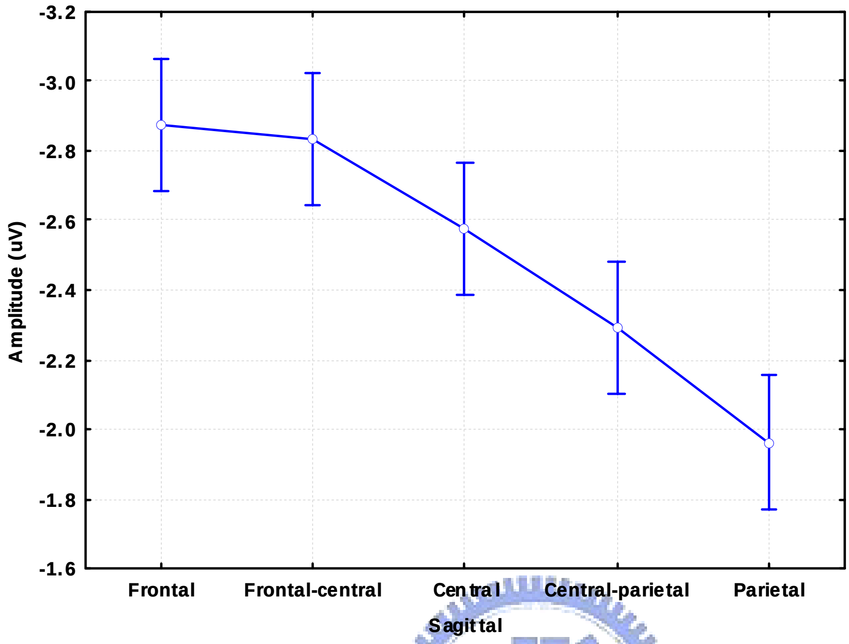

Figure 5.15. The MMN Amplitude of Sagittal on Taiwanese Opposite

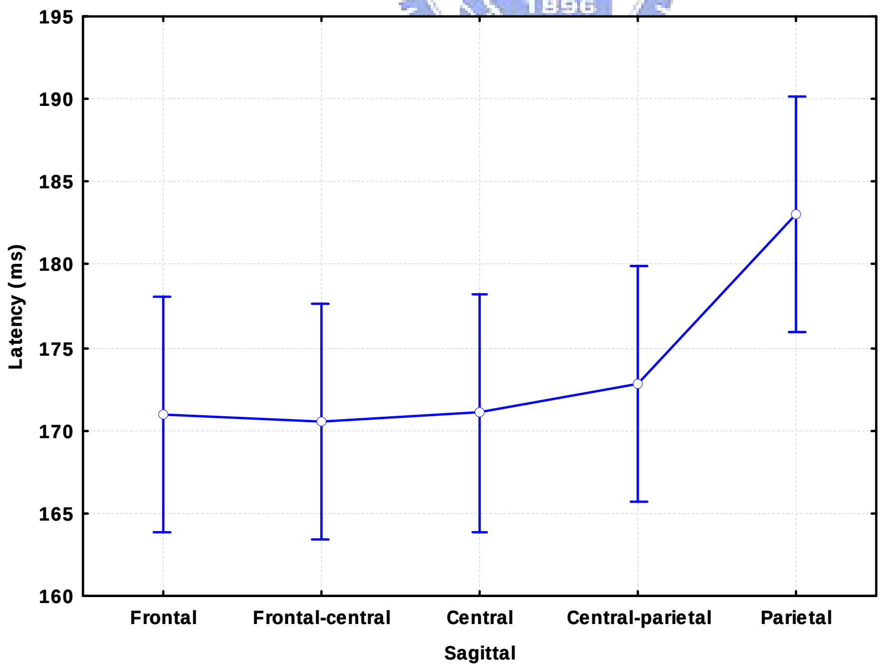

Figure 5.16. The MMN Peak Latency of Sagittal on Taiwanese Opposite.

Another 5 (Sagittal) × 4 (Orbit) two-way ANOVA was used to see the significance of Sagital and Orbit. The statistic analysis of Sagittal had shown in Figure 5.15 and Figure 5.16. Figure 5.17 and Figure 5.18 showed that the MMN amplitude and latency of Orbit for their significance (Amplitude: F (3, 880) = 39.536, p < .05; Latency: F (3, 880) = 9.1113, p < 05). Even the last two orbits (3 and 4) did not evoke the largest MMN amplitude relatively to the orbit 1 and 2; however, they still had earlier MMN latency comparatively than the orbit 1 and 2.

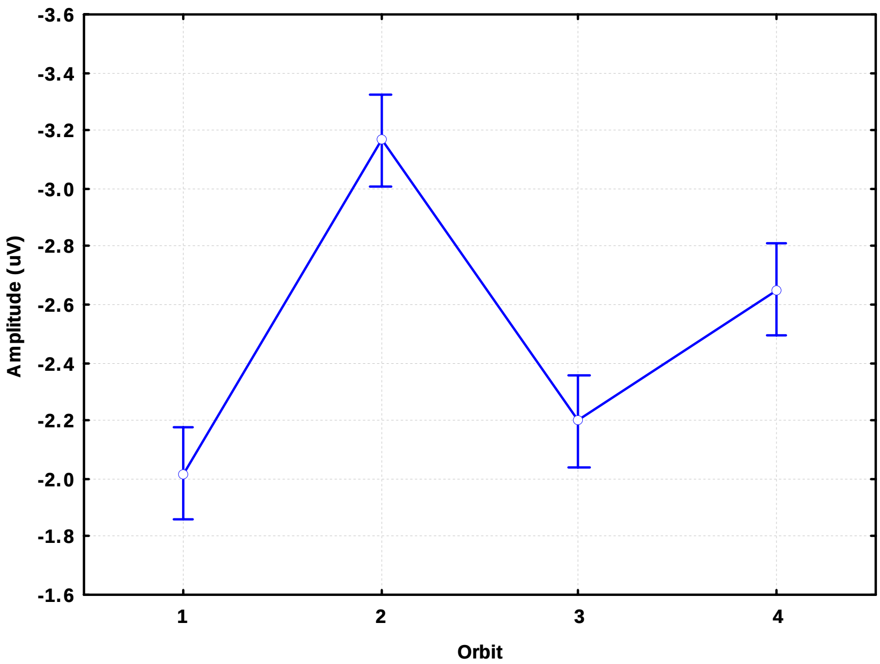

Figure 5.17. The MMN Amplitude of Orbit on Taiwanese Opposite.

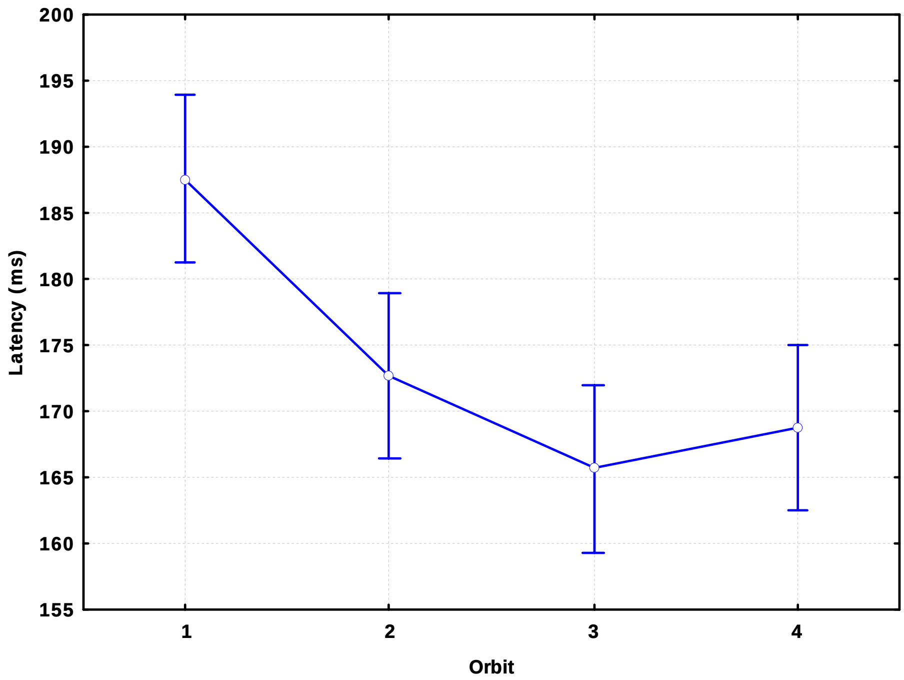

Figure 5.18. The MMN Peak Latency of Orbit on Taiwanese Opposite.

CHAPTER SIX

CONCLUSION

6.1 The perceptual magnet effect

6.1.1 Production and Perception.

The perceptual magnet effect proposed by Kuhl (1991) indicates that human adults and infants show a similarity adoption for the prototypes of speech categories. The surrounding referent sounds would be regarded perceptually as the same with the center perceptual prototype in each category. The idea is well considerable through the studies of the internal structures of phonetic categories. However, previous studies just focus on monolinguals and the perception of bilinguals is unknown. With the present study, we provide an observable overview towards bilinguals' perception and we confirm with the experiments that the bilinguals of our Mandarin-Taiwanese participants also show the perceptual magnet effect on both two languages they acquired.

Although the productions of bilinguals on two similar vowels are merged together, their perceptions of "the perceptual magnet effect" are not mixed. When Flege (1987) proposed a hypothesis of "equivalence classification", the author's focus was just on the speech production and claimed that it would be harder to acquire the similar vowels of L2 authentically and that, moreover, the two similar vowels of two languages would thus split more apart for the discrimination. Compared with our production data, the productions [u] of bilinguals on two languages are merged together and they did not split more apart for discrimination on speech production (Figure 3.1b). However, bilinguals still show the perceptual magnet effect both on Mandarin [u] and Taiwanese [u]. The merging of [u] productions of Mandarin and Taiwanese does not affect the perceptual magnet effect of their own. The perception of one phonetic category (say, the perceptual magnet effect) won't be confined by the production limitation.

6.1.2 the encountering of two similar phonetic categories

ERPs study gives us much evidence to testify the perceptual magnet effect and allows us to speculate the observations when two similar phonetic categories encounter. As results in Experiment 3: the Event-related potentials, the perceptual magnet effect exists both on Mandarin Interface and Taiwanese Interface. The Outer Orbit stimuli (Orbit 3 and Orbit 4) evoke larger MMN amplitude whereas they took earlier MMN latency. That is to say, Mandarin-Taiwanese bilinguals can detect the more deviant stimuli in the outer than Orbit 1 and Orbit 2, which are adjacent to the prototype. Furthermore, even on the interface of Mandarin and Taiwanese, bilinguals get no trouble in discriminating stimuli within each interface of a language. It is hard evidence that the perceptual magnet effect functions both on Mandarin and

Taiwanese.

One might argue why there seems no perceptual magnet effect both on Mandarin Opposite and Taiwanese Opposite when the outer stimulus (Orbit 3 or Orbit 4) does not evoke larger MMN amplitude. If one dimensional direction (Interface) of a phonetic category shows the perceptual magnet effect (especially on the interface of two categories), it might be awkward to claim there is no perceptual magnet effect on the opposite direction of a category. In fact, we have reasons to believe that what seems to be a problem on Mandarin Opposite and Taiwanese Opposite is due to limitation of a phonetic category. As Naatanen, Lehtokoskl, and Lennes et al (1997) claimed in their study that the MMN detection on phonemic traces are language-specific. The Outer orbit 4 (or Orbit 3) might be regarded as outsider of a phonetic category of Opposite and that is why it does not evoke larger MMN amplitude as it is supposed to do. Except for Orbit 4 (or Orbit 3), Orbit 1 and Orbit 2 still evoke smaller MMN amplitude and had late peak latency within Mandarin Opposite and Taiwanese Opposite. That is to say, the adjacent orbit stimuli evoke relative difficult discrimination, where the perceptual magnet effect functions.

To sum up, Mandarin-Taiwanese bilinguals exhibit the perceptual magnet effect both on Mandarin and Taiwanese and they have no misunderstanding when two similar phonetic categories encounter.

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APPNEDIX:

Appendix A:

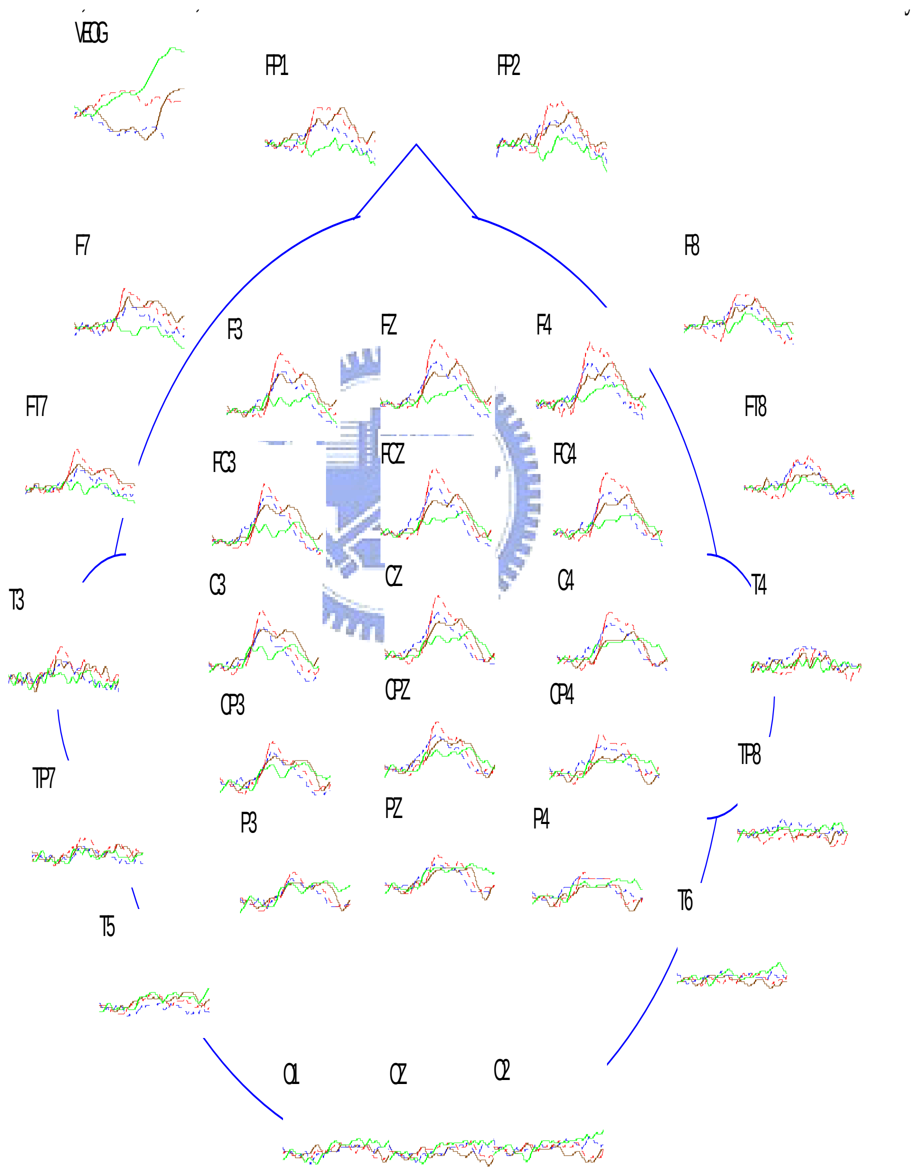
Mandarin Interface

orbit 1

orbit 2

orbit 3

orbit 4



Appendix B:

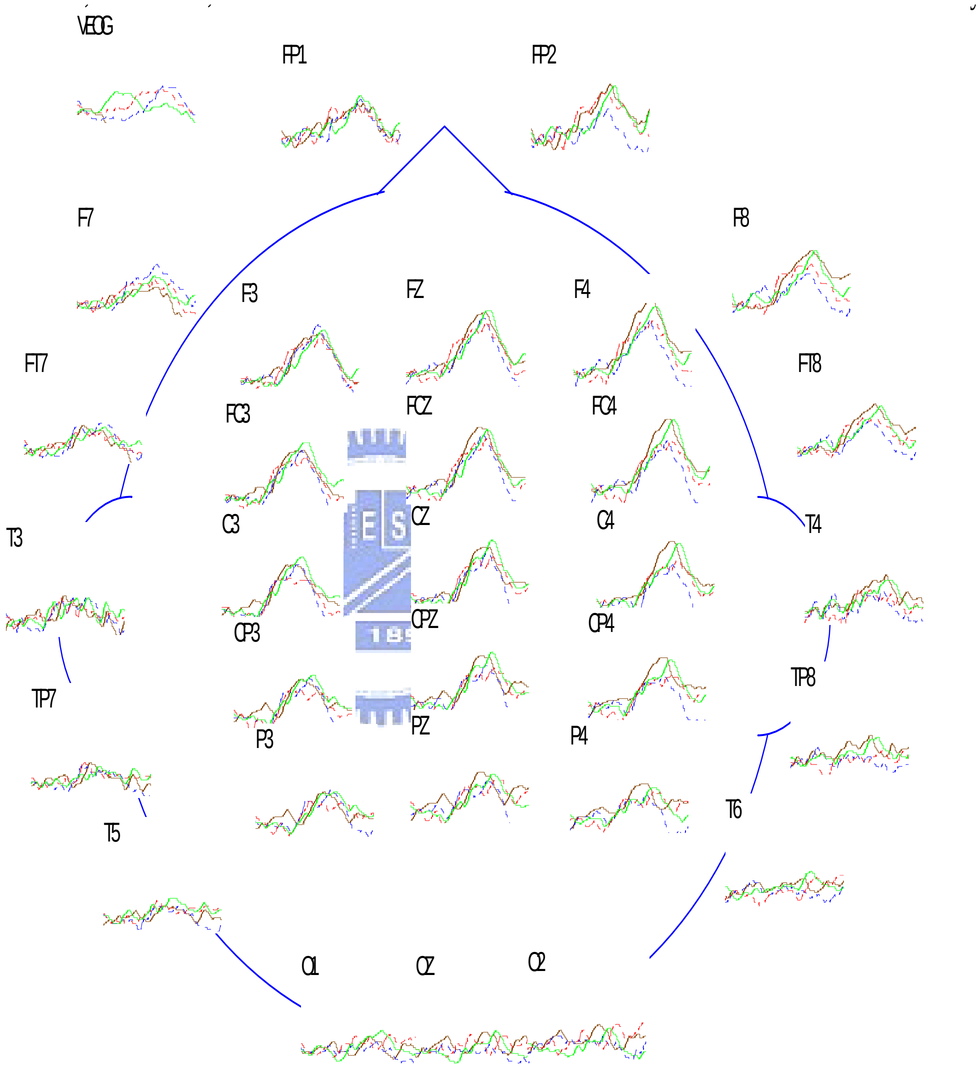
Mandarin Opposite

orbit 1

orbit 2

orbit 3

orbit 4



Appendix C:

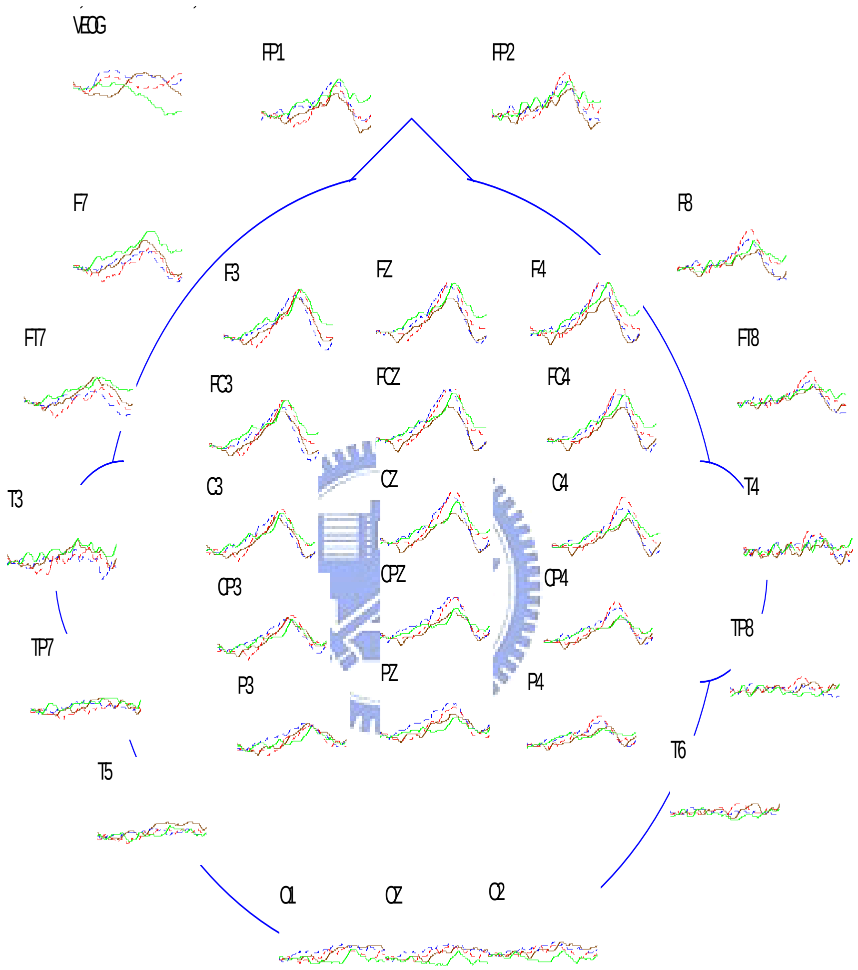
Taiwanese Interface

orbit 1

orbit 2

orbit 3

orbit 4



Appendix D:

Taiwanese Opposite

orbit 1

orbit 2

orbit 3

orbit 4