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Perception of High Frequency Fricative of Mandarin Chinese and English: A Case Study of Hearing Impaired Children

聽障兒童研究：中英文高頻擦音接收之比較

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中文摘要

Peng et al (2004) 的文章指出發音能力與接收性及表達性語言程度有一定的關聯存在，藉這一點，有必要深入調查聽障孩童們對於中文和英文的語音接收能力之相關性。對於配戴電子耳的聽障兒童來說，在接收高頻率的子音方面有較大的困難度。除此之外，根據第二語言習得的理論---語言轉移，在習得第二語言的語音層面往往受到母語語音的影響 (Parker and Riley, 2010)。並且，第二語言之語音接收也受到第一語言的聲韻系統和語音細節的影響 (Best, et al, 2003)。因此，本篇研究嘗試調查聽障兒童接收中英文高頻子音的程度關聯。根據過去的期刊文獻，本研究假設聽障兒童在接收中英文高頻子音方面，應有相似的程度表現。此研究中，十五位配戴電子耳的聽障兒童為受試者，四十個英文字詞和四十五個中文字詞（其中各有十五個非實驗字詞）在聽力隔音室中錄製且經過後製處理。實驗採一對一進行，過程中，運用麥金塔電腦播放測驗詞給受試者。此實驗結果和 Gay (1970) 的研究結果相似，在 CV 或是 VC 環境中，母音對於接收中英文高頻擦音 /s/ 的程度無規律影響。另外，本研究發現，在英文的 VCV 環境中，對於接收高頻擦音有較差的表現。然而，在 VCC 環境中，有相對較好的表現結果。另一方面，在中文 C#CV 和 V#CV 環境中，聽障兒童接收高頻子音的表現較不一致。此初期研究發現，配戴電子耳的聽障兒童對於接收中英文高頻擦音有相似的表現，另外，雖然聽障被視為一種語言缺失，在對於語言習得和學習的形式上，還是有著與正常聽力兒童相似的歷程。

關鍵字：聽障兒童，語言接收，比較語音學

Abstract

According to Bradlow and Bent (2002), the limited experience of L2 sound system and higher level of L2 linguistic sources lead to a dysfunctional L2 speech perception for non-native listeners. Given the linguistics limitation of L2, Best (2003) further claims that the L2 speech perception is influenced by the phonology system of the native language and the phonetic details of L1 phoneme. As for the development of speech perception for hearing-impaired children, Ling (2007) suggests that every speech pattern learnt by the children provides a set for the further development of speech sounds. Most importantly, he claims that the earlier the hearing-impaired children wear hearing aids or cochlear implants, the more normal the path of spoken language development they can follow. Past literature has mainly explored hearing-impaired children's speech production or perception of either Mandarin Chinese or English. According to Peng et al (2004), children with cochlear implants whose first language is either Mandarin Chinese or English have a comparatively low degree of managing fricatives. In addition, Ling (2007) claims that /s/ and /z/ are the most difficult sounds for hearing-impaired to perceive. Based on the past researches, this preliminary research aims to investigate the speech perception correlation between Mandarin Chinese /s/ and English /s/. It is assumed that the high degree of correlation can be found due to the similar phonetic environment these two sounds share. In this research, fifteen elementary school hearing-impaired children with cochlear implants (CI) are recruited. The forty English stimuli and forty-five Mandarin Chinese stimuli which both included fifteen filters, are played through a Mac laptop to subjects one by one at each time. The results surprisingly indicate the low degree of perception correlation between Mandarin Chinese /s/ and English /s/ among the subjects. Even though the perception correlation is not found, the outcome is similar to Gay (1970)'s findings. The vowel effect toward /s/ perception is inconsistent in both Mandarin Chinese and English under not only CV condition but also VC condition. In English, the perception rate is comparatively low under the VCV condition. And under VCC condition, there is a high range of perception rate. On the other hand, under V#CV or C#CV conditions, the perception rates of Mandarin Chinese /s/ are inconsistent as well.

Keyword：*hearing-impaired children, speech perception, comparative phonetics*

目　次

I. Introduction

Phonemic identification and speech perception are the first and decisive factors for second language acquisition by non-native learners. Without a functional L2 speech perception, it blocks and interferes the higher level of language processes. Previous studies have investigated the L2 speech perception. According to Bradlow and Bent (2002), the limited experiences of L2 sound system and higher level of L2 linguistic sources lead to a dysfunctional L2 speech perception for non-native listeners. Given the fact that the L2 linguistic environment, specifically the sound system, is unable to serve as the effective clues for L2 speech perception, it then suggests that the L2 speech perception is influenced by the phonology system of the native language and the phonetic details of L1 phonemes (Best, C.T., 2003). Hence, the more similar the L2 speech sounds to the L1 speech sounds, the more likely they will be identified by the non-native listeners.

As for the development of L1 speech perception on children, it is suggested that children are able to comprehend most of the speech at age one (Ling, 2007). Unlike the normal hearing children, the development of speech perception of hearing-impaired children is often delayed. However, according to Ling (2007), the earlier the hearing-impaired children wear hearing aids or cochlear implants, the more normal the path of spoken language development they can follow. After wearing the aided device, hearing-impaired children will go through a process of speech rehabilitation. They are trained to produce and perceive their native languages with the help of speech pathologists. Hence, their speech intelligibility can be developed to the similar level as the normal hearing children do. Ling (2007) claims that every speech pattern learnt by children during the period of their speech development provides a set for the further development of speech sounds. It indicates that children mainly depend on the previous acquired speech pattern for perceiving further new sounds.

Previous researches have mainly explored hearing-impaired children’s production and perception of either Mandarin Chinese or English. Peng et al (2004) claims that children with cochlear implants whose first languages are either Mandarin Chinese or English have comparatively low degree of managing fricatives to other manner of articulation such as stops, glides, and nasals. Moreover, Ling (2007) proclaims that /s// and /z/ are the most difficult sounds for hearing-impaired to perceive. Consequently, the high frequency fricative consonants of the two languages

seem to be a great challenge for hearing-impaired children with cochlear implants (CI) to perceive.

This paper aims to explore the perception correlation between Mandarin Chinese /s/ and English /s/ from the second language perspective. English /s/ has dynamic functions. The sound itself can have the deciding rule to the meanings in terms of morphology. In morphology, it can be an inflectional marker to represent plural nouns ---{girl}+{s}. It also serves as the marker of third person singular subject when regular verbs are in present tense --- {walk}+{s}. Hence, without perceiving English /s/ accurately, it might lead to some comprehension barrier to the higher level linguistic processing. Based on the previous researches, it is further assumed that once hearing-impaired children with cochlear implants are able to produce the /s/ sound of Mandarin Chinese, the perception of /s/ sound of both Mandarin Chinese and English are highly correlated because these two sounds share similar phonetic environment.

II. Compare Mandarin Chinese /s/ and English /s/

When it comes to sound perception, the properties of the sounds are one of the major factors influence listeners' perception performance. As a result, the starting point of the research is to compare Mandarin Chinese /s/ to English /s/ from the aspect of phonetics. The two factors use to analyze speech sounds are the articulate gestures and the acoustic properties. Articulation explores how the vocal tract produces sounds. And acoustics mainly deals with the waveform of sounds. Thus, by comparing the articulation gestures and acoustics properties of Mandarin Chinese /s/ to those of English /s/, it gives much more credible information to examine the correlation between perceiving Mandarin Chinese /s/ and English /s/.

Although both Chinese and English sibilant fricatives are transcribed as /s/ in IPA, these two sounds can have phonetically disparity (Li et al.,2007). The most salient similarity they share is that they, according to the manner of articulation, are fricatives. According to Ladefoged and Wu (1984), they are defined as sibilant fricatives because when they are being produced, speakers' upper and lower teeth are nearly closed together. Due to this narrow channel between the teeth, it gives these two sounds their sibilant characteristics. In addition to the sibilant characteristics, both Mandarin Chinese /s/ and English /s/ are voiceless sounds. It means that the air does not vibrate when it comes out from the vocal folds. In other words, when the vocal folds are apart, the air from the lung is able to have a more free way to come out

through the pharynx into the mouth (Ladefoged and Johnson, 2004).

In addition to articulation gestures, acoustics properties of target sound play an important role in the sound perception as well. Normally, there are three measurement to describe acoustic properties, namely, amplitude (dB), frequency (Hz), and duration (Behrens and Blumstein, 2004). Unlike the analysis of articulation gestures, it is more complicated to delineate the acoustic properties of any sounds because they will be changed due to the adjacent sound environment. For example, listeners might expect a lower center frequency of an /s/ when it is preceded by a rounded vowel like /u/ (Ohala, 1993).

1. Mandarin Chinese /s/

Although Chinese /s/ has the apparent fricative manner, it is arguable to describe its place of articulation because it varies through different speakers. For example, in Proctor et al's experiment (2012), only one participant out of four produced Mandarin Chinese /s/ as a dental fricative. Others produce it as an alveolar fricative. The results are in accordance with Ladefoged and Wu (1984), and Brunner et al's (2005) explanation which the constriction site of Chinese /s/ is highly depending on speakers. Hence, Chinese /s/ is being described as dental/alveolar fricative (Li, Edwards and Beckman, 2007). Furthermore, compared to other Chinese fricatives, /s/ is being produced with the most anterior location between the teeth and the tongue tip (Proctor et al., 2012). Thus, /s/ has the smallest frontal cavity which the area is in between the tongue constriction and the teeth (Toda and Honda, 2003). Besides, Proctor (2012)'s findings indicate that when producing Mandarin Chinese /s/, the back of the tongue remains stationary. Due to this reason, it is the less palatalized Mandarin Chinese sibilant fricatives (Toda and Honda, 2007). In other words, there is a large hollowness in between the center of the tongue and the palatal (Ladefoged and Wu., 1984; Proctor et al., 2012). As a result, Chinese /s/ is also called a flat post-alveolar /s/ by Ladefodge and Maddieson (1996).

Shu (2010) analyzes the general acoustic properties of Mandarin Chinese /s/ under three measurements, namely silence duration, amplitude rise time, and frication duration. The silence time of Chinese /s/ is 0 ms and the standard deviation (SD) is 0. It meant that there is no airstream being blocked by the articulators in between VCV (vowel-consonant-vowel) sequences. For the amplitude rise time, the initial and medial positions of Chinese /s/ are respectively 74.4 (SD 44) ms, and 62.1 (SD 30) ms. The results indicated that Chinese /s/ takes 74.4 ms to rise to the peak energy from the

onset of frication duration in the initial position and 62.1 ms in the medial position. Lastly, the frication duration of Chinese /s/ are 177.9 ms (SD 52) in the initial position and 157.3 ms (SD 37) in the medial position. The times referred to the consecutive length of having the tumultuous property. In addition, the frication duration is important for people to perceive sibilant fricatives. The general frequency of Chinese /s/ is averagely 8000 Hz for male speakers and 10000 Hz for female speakers.

2. English /s/

It is also difficult to define a standard articulator of English /s/ as well. The past literatures have delineated English /s/ as either dental or alveolar fricatives (Li et al., 2004; Toda and Honda, 2007). However, Dart (1998) tries to use a less arguable way to delineate it in the article. The result of the palatograohic experiment said that most of the subjects who are native English speakers tended to produce English /s/ with their articulations where the contact is mostly behind the teeth, yet some might have a contact on the base of the teeth. From the perspective of tongue, it is also arguable to decide which parts of the tongue contact with the upper articulators because the result of the aforementioned article shows that it is either apical or laminal. In other words, the subjects, in order to produce English /s/, made the tip of their tongues or the blade of their tongues approach the upper articulators. In addition, laminal is more common than apical. However, it contrasts with Toda and Hoda (2003)'s definition that English /s/ is apico-alveolar. Consequently, I describe English /s/ as apical/laminal sibilant fricative because this paper aims to give a whole picture of understanding Mandarin

	Place of articulation	Tongue constriction	Frication duration	Average frequency rate	Manner of articulation	Voicing
Mandarin Chinese /s/	dental/alveolar	apical	177.9 ms	8kHz	Sibilant fricatives	voiceless
English /s/	dental/alveolar	apical/laminal	174, 178 ms	3.8kHz-8.5kHz	Sibilant fricatives	voiceless

Chinese and English /s/. Lastly, similar to Mandarin Chinese /s/, English /s/ is less palatalized and has small frontal cavity compared to other English sibilant fricatives (Toda and Honda, 2003).

Table 1. *articulation gestures and acoustics properties of Mandarin Chinese /s/ and*

English /s/.

For the acoustic properties, generally, the major peaks of English /s/ are in the range from 3.5kHz to 8.5kHz (Behrens and Blumstein, 1988; Jongman et al., 2000; Strevens, 1960). At this point, the average frequency rate of Chinese /s/ is similar to that of English /s/. Moreover, as Behren and Blumstein (1988) indicates in the article, the generalized entire length of frication noise for English [s] is 174ms. And is 178 ms for Jongman et al ’s results (2000). Hence, these findings are also similar to that of Mandarin Chinese /s/.

III. Experiment

1. Participants

Fifteen hearing-impaired children with cochlear implants (four boys and eleven girls) from T-Rex Hearing Speech Center (Taichung) and The Children Charity Association (Taipei) participate in the experiment. The average age of the fifteen CI children is 9.2 years old and their native language is Mandarin Chinese. In addition, the average onset age of learning English is 6.9 years old and the average years of learning English is 2.9 years. As for the level of English ability, they are all able to pronounce English phonics correctly. For their hearing ability, the average hearing threshold degree before cochlear implants is 110 dB. After cochlear implants, they have an average hearing threshold is 31 dB. Moreover, they all receive speech therapies after CIs. Asides from the hearing-impaired, they do not have any other disabilities that affect their perception abilities.

2. Materials and Procedures

Forty-five Mandarin Chinese and forty English words are spoken by a male English-major student through GSI 61 two channel clinical audiometer (grason-stalder.com) at T-Rex center. A Sony digital voice recorder is put in the sound-proof room to record the stimuli. The raw stimulus then is edited by using Adobe Audition CC. Each stimulus is normalized to sixty dB and the interval time between two sounds is about five seconds. The total forty-five stimuli are comprised of thirty target words which contain /s/ sound (see Appendix 1 and 2) and fifteen filter

words. Since the research aims to give a general comparison of perceiving Mandarin Chinese /s/ and English /s/ in natural word listening situation, the /s/ sound in each language is followed or preceded by valid vowels or consonants. The experiment is conducted in a room one by one at a time because it simulates the actual speech therapy session. In the beginning, the subject is given two cards which one has a circle sign and the other has a cross sign. If the subject hears the [s] sound, he/she needs to raise the card with circle sign. If not, then raise the one with a cross sign. During the experiment, the stimuli are played by a Mac laptop (Macintosh). For the scoring part, each stimulus is played three times; as a result, one point is given if the subject responds correctly. The total score is ninety. The total score of each word is forty-five. The whole experiment is taken about thirty minutes.

VI. Result

1. Mandarin Chinese /s/

The perception rate is based on the score of actual correct perception of the target stimuli among fifteen subjects to the full score. The results of perception rate of Mandarin Chinese stimuli under CV condition are shown in Table 2. When /s/ is followed by /i/ vowel, the perception rate is 71% same as followed by /a/ vowel. When /s/ is followed by /e/ vowel, the perception percentage is 53%. In addition, when /s/ is followed by /o/ vowel, the perception rate is 42%. However, the percentage rates within /su/ category are 33% for “su qi”, 26% for “suo fang”, 86% for “sui ran”, “sui bian”, 68% for “sun zi”, and 64% for “sun hai”.

Mandarin Chinese Word	Pin Yin	CV Condition	Perception Rate
四 月 ‘april’	si4 yue4	[si]	71%
俗 氣 ‘cheesy’	su2 qi4	[su]	33%
縮 放 ‘scale’	suo1 fang4	[su]	26%
雖 然 ‘although’	sui1 ran2	[su]	86%
隨 便 ‘at random’	sui2 bian4	[su]	86%
孫 子 ‘grandson’	sun1 zi3	[su]	68%

損 害 ‘damage’	sun3 hai4	[su]	64%
搜 查 ‘search’	sou1 cha2	[so]	53%
僧 人 ‘monk’	seng1 ren2	[se]	42%
搔 癢 ‘scratch’	sao1 yang3	[sa]	71%

Table 2. the perception rate of Mandarin Chinese stimuli in CV condition.

The perception results of Mandarin Chinese in C#CV condition are indicated in Table 3. However, one thing needs to be noted is that some of the phonological environments in Mandarin Chinese are different from those of English. In English, it is valid to have a CCV sound environment within a syllable. Yet, since Mandarin Chinese is a monosyllabic language, each single character is a syllable. Due to this reason, the consonant cluster situation cannot exist within a character. As a result, in order to have similar environment to English /s/, the first consonant is the final sound of a character which is followed by the initial /s/ of another character. Under this condition, when /s/ is in between /ng/ and /a/, the perception rate is 55%. In addition, when it is in the middle of /s/ and /i/, the perception rate is 75%.

Mandarin Chinese Word	Pin Yin	C#CV Condition	Perception Rate
驚 悚‘horrible’	jing1 song3	[ŋ#so]	35%
贈 送 ‘present’	zeng4 song4	[ŋ#so]	46%
清 掃 ‘sweep’	qing1 sao3	[ŋ#sa]	55%
運 動 賽 ‘sport game’	yu4 don4 sai4	[n#sa]	62%
噴 灑 ‘spout’	pen1 sa3	[n#sa]	48%
分 散 ‘split’	fen1 san4	[n#sa]	71%
金 絲 雀 ‘canary’	jin1 si1 que4	[n#si]	75%

Table 3. the perception rate of Mandarin Chinese in C#CV condition.

Similar to C#CV condition, Mandarin Chinese only allows the V#CV condition to exist instead of VCV condition which is found in English. The results in Table 4 show are the perception rates under this condition. First, even though /s/ is preceded

by /u/, the perception rates are different due to the following vowels. When /s/ is in between the following environments: /u/ and /u/, /u/ and /o/, /u/ and /a/, /u/ and /i/, the perception rates are 42%, 75%, 44%, 57% respectively. When /s/ is in between /o/ and /a/, the perception rate is 43%. Moreover, when /s/ is in between the following environments: /i/ and /e/, /i/ and /a/, /i/ and /u/, the perception rates are 64%, 66%, 28% respectively. Lastly, the perception rates are the same as 75%, when /s/ is in between /a/ and /u/, /e/ and /e/ environments.

Mandarin Chinese Word	Pin Yin	V#CV Condition	Perception Rate
乳 酸 菌‘lactic acid bacteria’	ru3 suan1 jun4	[u#su]	42%
肉 鬆 ‘meat floss’	rou4 song1	[u#so]	75%
菩 薩 ‘buddhism’	pu2 sa4	[u#sa]	44%
走 私 販 ‘smuggler’	zou3 si1 fan4	[u#si]	57%
小 蘇 打 ‘soda’	xiao3 su1 da3	[o#su]	46%
告 訴 ‘tell’	gao4 su4	[o#su]	77%
瀟 灑 ‘unrestrained’	xiao1 sa3	[o#sa]	43%
黑 森 林 ‘black forest’	hei1 sen1 lin2	[i#se]	64%
一 艘 船 ‘a boat’	yi4 sao1 chuan2	[i#sa]	66%
各 其 所 好 ‘every man has his taste’	ge4 qi2 suo3 hao3	[i#su]	28%
壓 歲 錢 ‘new year money’	ya1 sui4 qian2	[a#su]	75%
大 蒜 ‘garlic’	da4 suan4	[a#su]	68%
垃 圾 桶 ‘wastebasket’	le4 se4 tong3	[e#se]	75%

Table 4. the perception rate of Mandarin Chinese stimuli in V#CV condition.

2. English /s/

In CV condition, as shown in Table 5, the perception rate is 48% when the /s/ is followed by /u/ vowel. When it is followed by /ɪ/ vowel, the rate is 53%. Besides, the perception rate is 57% when the /s/ is before /ɝ/ vowel and the perception rate is 64% when it is followed by /i/; 66% for followed by /ʌ/. Moreover, the perception rate is 68% when /s/ is followed by /ɔ/, /ɛ/, and /e/ vowels. Lastly, the perception rate is 71% when it is followed by /æ/ vowel.

English Word	CV Condition	Perception Rate
suit	[su]	48%
sub	[sʌ]	66%
sore	[sɔ]	68%
sip	[sɪ]	53%
set	[sɛ]	68%
serf	[sɝ]	57%
scene	[si]	64%
safe	[se]	68%
sack	[sæ]	71%

Table 5. the perception rate of English stimuli in CV condition

In VC condition, as shown in the Table 6, the perception rates are 55% when /s/ is preceded by /e/ and /ɪ/ vowels. In addition, when /s/ is preceded by either /ə/ vowel or /ɔ/ vowel, the perception rate is 60% and the perception rate is 64% as preceded by /a/ vowel. The perception rate is 66% when /s/ is preceded by /æ/ vowel. Lastly, the perception rate is 68% when /s/ is after /ʌ/ and /ɔ/ vowels.

English Word	VC Condition	Perception Rate
bias	[əs]	60%
mess	[es]	55%

moss	[ɔs]	60%
hiss	[ɪs]	55%
gas	[æs]	66%
chaos	[as]	64%
dose	[oʊs]	57%

Table 6. the perception rate of English stimuli in VC condition

Asides from CV and VC conditions, the VCV and VCC conditions are shown in Table 7 and 8. When /s/ is in between /u/ and /ɪ/ vowels, the perception rate is 51% and the perception rate is 53% as in between /e/ (first syllable) and /e/ (second syllable) vowels. Similar to this environment, when /s/ is in the middle of /ə/ (first syllable) and /e/ (second syllable), the perception rate is 46%. In VCC condition, the perception rate is 48% when /s/ is preceded by /ɑ/ vowel and is followed by /k/ consonant. Lastly, the perception rates are 66% when /s/ is in between /i/ vowel and /t/ consonant, /ɪ/ vowel and /k/ consonant, /e/ vowel and /k/ consonant, /æ/ vowel and /k/ consonant.

English Word	VCV Condition	Perception Rate
usage	[usɪ]	51%
essay	[ese]	53%
assay	[əse]	46%

Table 7. the perception rate of English stimuli in VCV condition

English Word	VCC Condition	Perception Rate
oust	[aʊst]	48%
oscar	[ɑsk]	48%
east	[ist]	66%
disk	[ɪsk]	66%

desk	[esk]	66%
ask	[æsk]	66%

Table 8. the perception rate of English stimuli in VCC condition

V. Discussion

1. Perception Correlation

Due to the acoustic and articulate similarities that both English /s/ and Mandarin Chinese /s/ share, the research assumes the perception performance of Mandarin Chinese /s/ is correlated with that of English /s/ among fifteen subjects. The subject s' performance scores are analyzed through SPSS by using Spearman's correlation test to examine the correlation. The result in Table 8 indicates that there is not significant difference (P value > 0.05) between the correlation. Furthermore, the result is not close to the standard linear on the scatter plot in Figure 1. As a result, it presents that the perception of Mandarin Chinese /s/ might not correlate with that of English /s/ individually, vice versa. In addition, the /s/ sound perception of the subjects' native language and foreign language, English, are parallel developed. More importantly, the result concludes that in either Mandarin Chinese or English, the /s/ perception for CI children is unstable during the period of language acquisition. Even though the perception correlation is not being found in this paper, the further perception characteristics of Mandarin Chinese /s/ and English are described on the following sections.

Spearman's Correlation		MC_/S/	E_/S/
MC_/s/	R-value	1.000	.436
	P-Value	.	.104
	Subject	15	15
E_/s/	R-Value	.436	1.000
	P-Value	.104	.
	Subject	15	15

Table 9. Spearman's Correlation Test

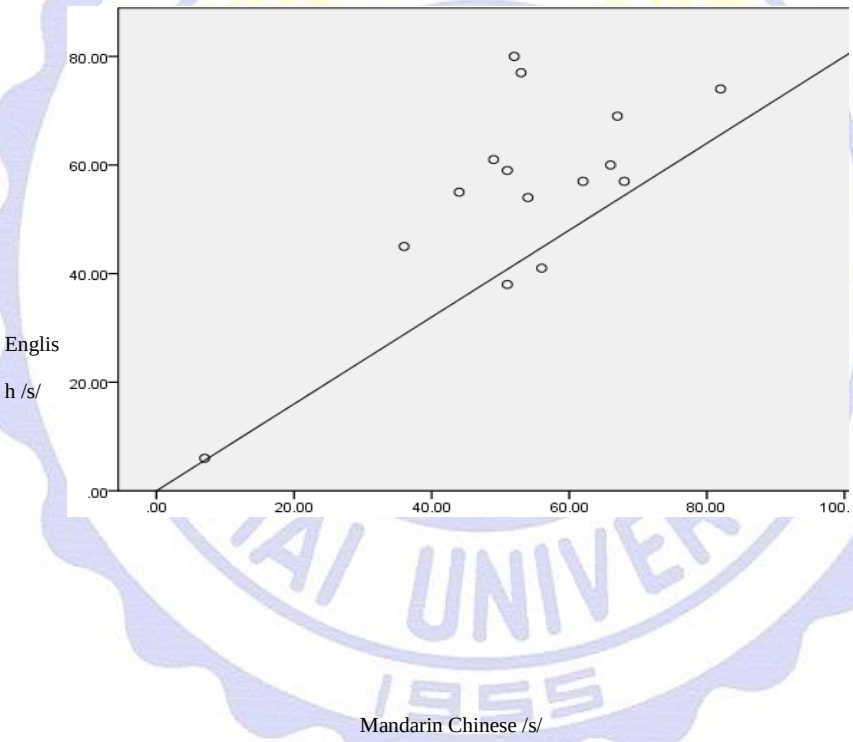

Figure 1. Scatter plot of perception correlation of Mandarin Chinese /s/ and English /s/

2. Perception of Mandarin Chinese /s/ Sound

In CV condition, the range of perception rate is huge in terms of 26% in /su/ to 71% in /sa/. The results indicate that the following vowel effect is limited because the perception rates are randomized among the following vowel categories. Specifically, in /su/ category, there is also a huge range of perception rate. Based on this, when hearing-impaired children with cochlear implants perceive Mandarin Chinese /s/ in CV condition, they pay attention on /s/ its own acoustic features. In addition, the following vowel does not provide an effective clue for perceiving /s/ as well. Second, under C#CV condition, the following vowel does not play an important role in perceiving Mandarin Chinese /s/ for CI children as well. Similarly, CI children primary perceive /s/ directly based on its own features. In addition, the results showcase that the preceding consonant, to certain degree, seems to affect the Mandarin Chinese /s/ perception because the perception performance is comparatively lower when the preceding consonant is /ŋ/ than that of /n/. Even though the consonant /n/ is a nasal sound, the place of articulation, alveolar ridge, is the same to /s/. Due to the articulation similarity, consonant /n/ then provides a good environment to perceive /s/ sound for CI children. Lastly, when Mandarin Chinese /s/ is put in between two vowels, the results also indicate that the perception performance is randomized because, ostensibly, the perception rates seem to be low when the target sound is followed by /u/ vowel. However, the explanation is contradicted within the categories since the highest perception rate is shown while /s/ is before /u/ vowel. The findings all indicate that no matter what vowels are being preceded or followed by Mandarin Chinese /s/, the vowel effect is limited. When CI children perceive Mandarin Chinese /s/, they seem to weigh perception clue on /s/ its own articulation and acoustics features.

3. Perception of English /s/ Sound

Similar to the results of Mandarin Chinese /s/ sound, the perception performance of English /s/ among fifteen CI children also indicate a similar result to Gay's findings (1970). In CV condition, the vowel effect on /s/ sound perception is inconsistent. Even though this research is conducted on CI children with real-word stimuli instead of synthesized stimuli with filters, the results also indicate that the following vowel effect is limited on perceiving /s/ sound since the perception rates of each stimulus vary throughout vowel environments. In VC condition, the perception percentages of stimuli are among 55% to 66%. This exhibits that the preceding vowels affect the perception of /s/ sound due to the fact that the variance of perception rates is lower than that in CV condition. On the other hand, when /s/ is in between two vowels,

the perception rates are low. As a result, CI children tend to have problem perceiving /s/ sound under the condition. Besides, the vowels in the preceding and following position affect the phonetic features of English /s/ for CI children to distinct. Lastly, unlike VCV condition, the perception performance in VCC condition has a more stable result. No matter what the preceding vowels are, the perception rates are fixed on 66% as /s/ sound is formed to consonant cluster with final consonants which are either /t/ or /k/ sounds. In addition, the result also demonstrates that the final consonant probably has an effect on magnifying the phonetic features of /s/ sound. However, one thing needed to be noted was that the vowels still play a role in perceiving /s/ sound under this condition. Unlike the perception rates with /æ/, /e/, /ɪ/, and /i/ preceded, the performances drop to 48% when the preceding vowels are /ɑ/ or diphthong /aʊ/.

VI. Conclusion

This research aims to explore the perception of high frequency fricative, namely /s/ sound of Mandarin Chinese and English on CI children. The result contradicts the previous literature because it suggests that there is no clearly perception correlation between Mandarin /s/ and English /s/ when the subject are able to produce Mandarin Chinese /s/ and the phonetic environment of these two are similar. However, the reasons might be that the target stimuli of this research are designed within the natural words. Hence, the target sound might be affected by its phonological environment. In this case, the environment between Mandarin Chinese /s/ and English /s/ cannot be balanced. Further researches are needed to control the variance of phonological environment of these two sounds. On the other hand, this research indeed gives a preliminary picture that the vowel effects in perceiving /s/ sound in each of the languages seemed to be minimized. On the contrary, the some certain following or preceding consonant provided perception clue of /s/ sound to CI children. In addition, since this research is served as a fundamental reference, more researches can be conducted to closely examine the perception performance of /s/ sound in Mandarin Chinese and English under different categories.

（報告題名）

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