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台灣華語字彙產製之音韻變化性

Phonological variability in word production in Taiwan Mandarin

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論文提要內容（共一冊，17,863 字，分五章）

本篇論文是針對六位以台灣華語為母語的嬰幼兒，採長期觀察的方式，研究台灣華語字彙產製的音韻變化性(phonological variability)，並詳細描述單音節詞和雙音節詞之中音節類型出現的頻率、變化性、以及代換模式。本研究同時要用 Jakoson (1968)的音節標記理論來檢驗各種音節類型中的共通性。

本研究一共觀察了有六位年齡在十一個月至兩歲的嬰幼兒長達一年。以兩個禮拜一次的頻率收集嬰幼兒和母親之間的自然對話，並利用錄製回來的影音檔做譯寫和分析。

結果顯示小朋友的音韻變化是很常見的，且是有規則可循的。小朋友的音韻變異量的高峰(variability peak)會出現在當小朋友的音韻發展從一個階段進展到另一個階段的時候，而本篇論文顯示與當小朋友由單字期(one-word stage)進展到雙字期(two-word stage)以及字彙量有大幅上升的時期符合。華語音節習得的部分，結果顯示 CV 是頻率最高、變化性最低，且最常被拿來替換的音節類型。CVG 也是頻率高的音節類型之一，但他的變化性也很高，主要是因為韻尾省略(coda-dropping)的現象在小朋友的早期發展很常見的關係，所以 CVG 雖然頻率高但是變化性也很高而且是最常被取代的音節類型之一。

最後，將所有的結果拿來檢驗 Jakoson (1968)的音節標記理論，結果發現頻率高以及變化性低的音節類型都是無標記(unmarked)的音節類型，相反的頻率低以及變化性高的音節類型則都是有標記的(marked)音節類型，此外小朋友會用無標記的音節類型來取代有標記的音節類型。

關鍵詞：兒童語言發展、音韻變化性、音節習得、頻率、代換模式、台灣華語

Abstract

The purpose of this study is to discuss the issue concerning phonological variability of children acquiring Taiwan Mandarin. Two aspects are including in the following: the phonological variability of words and the syllable types composed the words. The overall variability pattern, the frequency, variability rate, and substitution pattern of syllable type were analyzed.

Six participants are investigated in the study, aged between 0;11 to 2;0. A longitudinal observation study is conducted by the author and the research team.

The results showed that phonological variability is common in early phonological development. The increase in variability reflects the reorganization of phonological system, where children started to produce two-word utterances and the amount of different words was increased. As for the syllable type analysis, CV presented the highest in frequency, the lowest in variability rate, and also was used to replace other syllable type more often. CVG was one of the most frequently used syllable type; however, the variability rate of CVG was also high. The reason may due to the fact coda-dropping is a very common phenomenon in children's development.

The results in this study were examined in the markedness theory of syllable proposed by Jakobson (1968). The results showed that syllable types with higher frequency and lower variability rates were unmarked syllable types, while syllable types with lower frequency and higher variability rates were marked syllable types. Furthermore, children tended to use a more unmarked syllable to replace a more marked syllable.

Keywords: phonological development, syllable acquisition, phonological variability, frequency, substitution pattern, Taiwan Mandarin.

Chapter 1

Introduction

The purpose of this thesis is to discuss the issue concerning phonological variability of children acquiring Taiwan Mandarin. Two aspects are included in the following: the phonological variability of words and the syllable types composed the words.

Early works on child phonology have focused on examining the order of acquisition of segments, namely, individual speech sounds involving consonants, vowels and their substitution patterns. However, less is known about the whole-word pattern of acquisition. This 'whole-word' system was proposed by Ferguson & Farwell (1975) who suggested that the minimal unit of lexical representation for children in the earliest stages of language development is the syllable or word, not the phoneme. Both phonological variability and syllable analysis of words fit in the whole-word system, so it is important to investigate these two aspects in phonological acquisition from the whole-word point of view.

In early phonetic and phonological development, children begin by babbling, and then they acquire their first words in just a few months, and finally, they begin to put words together into sentences. During the process, children's early attempts at words often sound quite different from adult pronunciations (Menn & Stoel-Gammon, 2009). A child's first words often show many substitutions of one feature for another or one phoneme for another. These substitutions are simplifications of the adult pronunciations, which make articulation easier until the child achieves greater and more mature articulatory control. There is one problem that occurs during this period, which, however, has often been ignored in studies of language development; that is, phonological variability in the acquisition process.

In phonological development, variability can be defined as repeated productions of the same target words, and can be attributed to factors described in normal acquisition and use of speech (Holm *et al*., 2007; Macrae, 2013; McLeod & Hewett, 2008; Sosa & Stoel-Gammon, 2006 & 2012).Variability within individuals occurs in two different forms. First, children have different realizations of a particular phoneme for *different lexical item*, which refers to inter-word variability. For example, the phoneme /k/ in [kar] 'car' may be realized as [k], but in producing the word 'cat', the phoneme /k/may be pronounced as [t]. This phenomenon shows that children have not mastered the phoneme /k/. Secondly, children have different realizations for multiple productions of *the same lexical item*, which refers to intra-word variability (Ferguson & Farwell, 1975; Sosa & Stoel-Gammon, 2006 & 2012). For example, when a child attempts to produce /bebɪ/ 'baby', he or she may realize / bebɪ / as [bɪbi], [bibi], or [meɪbi] (Sosa & Stoel-Gammon, 2006). The present study will focus on the last aspect of phonological variability, which describes individuals' repeated productions of the same lexical item. A child may produce one word consistently and another word variably. However, the variation is not unlimited; it appears to be quite principled (McLeod & Hewett, 2008). Therefore, it is important to investigate the value of phonological variability and to see what phonological variability might reveal about phonological development of children.

Studies have shown that phonological variability is most likely to occur when one or more aspect of the word is unstable in child's phonological system; that is, phonological elements were presented in a child's speech, but not yet mastered (Holm *et al*., 2007; Leonard *et al*., 1982; McLeod & Hewett, 2008). McLeod and Hewett (2008) examined variability and accuracy of words containing consonant clusters in children, aged 2; 0-3; 4. They found that 53.7% of all target words produced by all participants were variable. Compared to the study of Holm *et al*. (2007), 13% of the target words were produced variably by children aged 3; 0-3; 5, and only some of the target words contained consonant clusters. Although some of McLeod and Hewett's participants were younger than the study of Holm *et al*., the different results from the two studies still indicated that words containing consonant clusters are produced with more variability. Words contained complex syllable structure are more difficult for children to produce, so children would use some strategies like dropping codas, or syllable substitution to make their articulation easier, resulting in phonological variability of words.

1.1 The research background

This section presents the research background of the phonological variability and syllable acquisition. To investigate the area of phonological variability, the first issue needed to be concerned is the relationship between age and variability pattern. However, it is still a question whether or not the phonological variability patterns of children decrease or increase when children grow older. One potential pattern of variability would be a steady linear decrease over the second year of life until children's productions become stabilized. Holm *et al.*, (2007) examined the consistency of word production in children aged between 3; 0-6; 0, and found that age has a significant negative effect on variability; that is, when children grow older, their word variability tends to decrease. The study of Macrae (2013) is consistent with the previous study, in which children younger than three years old show the same decreasing variability with increasing age.

On the contrary, some researchers have suggested that variability is relatively low during the very early stage of lexical development, and then increases as the number and phonetic diversity of the words the child attempted increase (Ferguson &

Farwell, 1975; Vihman, 1993).

Sosa and Stoel-Gammon (2006) investigated the patterns of intra-word production variability of English-speaking children aged 1;0-2;0. Longitudinal data from four children were analyzed to determine variability at each age. The percentage of intra-word variability for each child at each age was calculated. The results showed that children even at two years of age still display a considerable amount of intra-word variability (variability rates above 20% at the final data collection session). The pattern of variability observed in these children showed peaks and valleys rather than steady decreases in variability.

The second problem is the concern as to whether vowel difference should be included in the calculations of accuracy and variability. Typically, vowel productions are better than consonant productions and many studies excluded vowel difference from analysis (Ferguson & Farwell, 1975; Leonard *et al*., 1982; Sosa & Stoel-Gammon, 2006 & 2012). For example, [ta] and [te] would be considered as the same phonetic form of a word. Other studies included vowels in their data analyses (McLeod & Hewett, 2008; Schwartz *et al*., 1980). Ingram (2001) pointed out that pervasive vowel errors in children's production will require the inclusion of vowels. Bernthal *et al*. (2009) also suggested that by excluding vowels in calculations of word variability and accuracy in young children, researchers are ignoring an important area of phonological development. Since this study intends to investigate whole-word variability, repeated productions of a target word will be determined to be variable if differences are present in every aspect of the word including features, vowels, and consonants contained in the word. Furthermore, previous work did not talk about the individual difference of the pattern of phonological variability, so this thesis would not only investigate the overall pattern but also the individual pattern of variability.

1.2 Syllable analysis

Many researchers have proposed that children acquire CV syllable first since CV syllable is the core syllable which is the most unmarked syllable (Ingram, 1978; Stark, 1980). Jakobson (1947, 1968) also proposed that children acquire CV syllable, and gradually followed by more complex syllable type. The studies of Ingram (1978) and Stark (1980) both showed that children acquire CV and CVCV form first since young children often use augmented or truncated words in their early speech (Allen & Hawkins, 1978 & 1980), and V, VC, and CVC forms are the next types. This coda-dropping phenomenon is considered very common in phonological acquisition. However, some studies have found that word-final clusters were acquired several months earlier than word-initial clusters (Lleo & Prinz, 1996), and syllable-final consonants were mastered earlier than syllable-initial consonants (So & Dodd, 1995).

In order to solve the inconsistence of acquisition order in syllables, researchers have studied the effect of frequency in the acquisition of syllable. Bernhardt and Stemberger (1998) proposed that there is a tendency for the less complex or more natural syllable structures to occur frequently in a language, and to be mastered earlier. However, in the case of children acquiring Taiwan Southern Min (Tsay, 2007), CVC is the second most frequent syllable in children's speech, but the error rate of children producing CVC syllable is 98%.

Since the acquisition order of syllables, the relationship between frequency and the acquisition of syllables still remain in much debate, it is necessary to investigate the acquisition of syllables of different languages in the world.

The syllable types and syllable structure in Mandarin are relatively simple compared to other languages. For example, English allows three consonant clusters in the syllable onset, and Mandarin only allows two consonants in the onset-position and the glide [j], or [w], and [ɥ], which are the phonetic variant of high vowels [i], [u], and [y], so they are even not considered as phonemes in Mandarin consonants (Duanmu, 2007; Lin, 2007; Wan, 1999). By investigating the acquisition of syllable from a language that has a lot of difference from languages such as English, this research aims to add cross-linguistic studies on literature of phonological acquisition and hope to clarify questions that were raised by former researchers.

There are only a few studies concerning the issue of acquisition of syllable in

Mandarin. It is still an issue whether the acquisition of Mandarin syllable has the same pattern as that of other languages is still not clear. The present study might hope to investigate the issues concerning phonological variability and syllable acquisition from children's natural production.

1.3 Research questions

The present study aims to investigate the intra-word production variability of six Taiwan Mandarin children, aged 0;11 to 2;0, excluding the pre-meaningful speech. Furthermore, since children's early lexicon representation is the whole word, the syllable types and structures in children's speech are also of interest. A longitudinal observation study of typically developing children acquiring Taiwan Mandarin has been conducted.

The research questions to be addressed contain three parts and are described as follows:

(1) Regarding the phonological variability: how prevalent is variability in children's speech during their early stage of phonological development? What are the patterns of phonological variability of children? Is the variability pattern a linear decrease over time or a linear increase over time? Or there are no regular patterns of phonological variability?

(2) Regarding the syllable type: what is the general syllable type used among children? What is the most frequent syllable type used by the participants? What is the rank-order of frequency in different syllable types? What are the variability rates of different syllable types? Do syllable types that have higher frequencies present lower variability rates? Is there a relationship between the frequency of syllable types and its variability rate?

(3) Regarding substitution pattern: are there any syllable substitution patterns in children's production of variable forms of same words? Which syllable types are more unstable and are replaced by other types more often? Which syllable types are more likely to be chosen to replace the unstable ones? What kind of strategy would participants use to replace the syllable types they are not mastered yet? Would they replace the syllable types they are not mastered with more frequent ones? Are there obvious individual differences among children's substitution strategies?

1.4 Organization of the thesis

The thesis is organized as follows. Chapter one has laid out the introduction to the present study and the questions pertinent to the data analyses. In Chapter 2, firstly I will introduce the development speech production in first-language acquisition in 2.1, and the factors of phonological variability will be introduced in 2.2. Introduction to

Mandarin syllable will be introduced in section 2.3. Syllable acquisition in cross-language studies will be presented in 2.4. Chapter 3 contains the methodology of this study. Section 3.1 is the data collection methods. How I obtained the speech tokens will be introduced in this section. Section 3.2 is the data analysis which explains how the data were arranged. Chapter 4 will present the results and analysis in tables and graphs. The overview of the overall data will be presented in section 4.1. Section 4.2 will present the pattern of phonological variability pattern of each participant. Section 4.3 will present the results of syllable analysis, including the general syllable type participants produced, the frequency of syllable types in different syllable positions, and the variability rate of different syllable types. Section 4.4 will present the substitution pattern between different syllable types. The relationship between frequencies of syllable types and its variability rates as well as the relationship between frequencies and substitution pattern will be summarized in section 4.5. The discussion and explanation is provided in chapter 5. Section 5.1 summarizes the findings in chapter 4. Section 5.2 presents the discussion on variability pattern. Section 5.3 presents the discussion on syllable type analysis. Section 5.4 will be the concluding remarks.

Chapter 2

Literature review

In this section, I will introduce the universal process of children's speech production in 2.1. Second, I will introduce the factors of production variability of children in 2.2. Introduction to Mandarin syllable will be introduced in 2.3. Syllable acquisition in cross-language studies will be presented in 2.4.

2.1 The development of speech production

Children's productions of sounds begin with simple cries at birth, and they progress through several stages until they can produce complex babbling and adult-like intonation patterns. Many researchers proposed that children across the world acquire different languages by similar steps (Lenneberg, 1967; Kaplan & Kaplan, 1971; Stark, 1980). The six stages of children's early vocalization are shown in the following (Stark, 1980):

Stage 1: Reflexive vocalizations (0; 0-0; 2) -Most of the production are crying, fussing sounds, and vegetative sounds like coughing and sneezing. Some vowel-like sounds may occur.

Stage 2: Cooing and laughter (0; 2-0; 4) - Infants interact with adults or older kids by using cooing sound and laughter.

Stage 3: Vocal play (0; 4-0; 6) - Infants begin to test their articulatory organs and use them to produce sounds.

Stage 4: Reduplicated babbling (0; 6 and older) -The sequences of consonant-vowel (CV) syllables and adult-like intonation begin to appear at this stage.

Stage 5: Non-reduplicated babbling (0; 10 and older) - Strings of sounds and syllables uttered with a rich variety of stress and intonation patterns are appeared. In addition to consonant and vowel sequence, other syllable types also appear such as consonant-vowel-consonant (CVC) syllable.

Stage 6: Single word production - Infants begin to produce protowords, and words used as symbols and refer to recurring objects or events.

Although researchers commonly refer children's different vocalization period as 'stages', these vocalization types typically overlap from one stage to another. For example, consonant and vowel sequence has become a unit in the speech production in stage 4. The production of CV sequence may appear in the previous stages such as in vocal play stage; the production of CV sequence may also continue to appear into stage 5 (Stark, 1980).

2.1.1 Whole-word representation

The following section will present the whole-word representation and its measurement.

2.1.1.1 Ferguson and Farwell (1975)

Ferguson and Farwell (1975) proposed that the minimal unit of lexical representation at early developmental stages is the whole word or syllable rather than the segments or the phonemes. In other words, young children are able to be aware of relatively large phonological units, such as syllables or words, at early stages of phonological development. Ferguson and Farwell proposed this ‘whole-word’ system of phonological representation based on two observations. The first is the variability of individual phonemes in different contexts. For example, a child may have produced initial [b] correctly in a specific set of words; however, when the initial [b] occurs in contexts other than the specific set, the child may produce the initial [b] in many different forms. This pattern of production suggests that the child has not mastered /b/ as an individual phoneme, but rather only mastered [b] when it occurs in specific words.

The second evidence supporting the whole-word representation is the prosodic variability (Ferguson, 1986). Ferguson and Farwell described a young girl who used ten different pronunciations of the word ‘pen’ in a one half-hour session. They suggested that this variation, in which multiple tokens of the same word are produced differently at the same point of time, may be referred to as intra-word variability. Aslin and Smith (1988) also supported the whole-word representation system of young children. They proposed that young children's representation of lexicon is holistic in nature. Only later can they analyze a string of new sounds based on phonemic units. For example, in early phonological process, the representation of [dɔg] 'dog' is not organized as a sequence like [d] + [ɔ] + [g]. Instead, words are represented as overall acoustic shape. The common assumption regarding the development of phonemic categories is that as the amount of vocabulary in children's lexicon grows, there is a need to discriminate the speech sounds efficiently in production and also in perception. As the result, the growth of children's lexicon leads to the development of phonemic representation. Therefore, children's phonological development can be viewed as a gradual process from a more holistic level to a more segmental level; that is, from whole-word representation to phonemic representation (Nittrouer *et al.*, 1989; Waterson, 1971; Walley, 1993). When, precisely, the transition begins is not known, but assumption has been made that phonemic representation begins to emerge when a child has between 50 and 100 words, and the process may not be complete until much later in childhood, perhaps as late as 7;0 or 8;0 (Leonard *et al.*, 1980).

2.1.1.2 Ingram (2001)

Ingram (2001) proposed four measures of whole-word productions to estimate children’s whole-word abilities. Firstly, the Phonological Mean Length of Utterance measures the length of a child’s words and the number of correct consonants. Secondly, the Proportion of Whole-Word Proximity may capture how well a child approximates the target words. Thirdly, the Proportion of Whole-Word Correctness determines the proportion of a child’s words that are produced correctly out of the entire production. And fourthly, the Proportion of Whole-Word Variation provides a method for quantifying the amount of intra-word phonological variability exhibited by children.

In order to obtain the phonological variability of children, the fourth measure proposed by Ingram (2002), the Proportion of Whole-Word Variation, was adopted in this study. The relation between variability and phonological representation is still not clear. However, one hypothesis is that a decrease in intra-word variability would reflect the emergence of a segmental phonological representation. On the other hand, an increase in variability might reflect that the phonological system is not stable when it starts to undergo reorganization, a transition from whole-word representation to segmental representation (Sosa & Stoel-Gammon, 2006).

2.1.2 Syllable

Jakobson's early work (1947, 1968) proposed a universal order of acquisition of syllable structure. He indicated that children begin the processes of phonological acquisition with the CV or CV reduplicated syllable and gradually followed by more complex syllable such as CVC and CVCV (where the second consonant-vowel combination is different from the first one). He also proposed 'markedness theory of syllable' which was summarized below:

(1) The open syllable is more unmarked than the closed syllable.

(CV→CVC, CV→V)

(2) The syllable with onset is more unmarked than those without onset.

(CV→V, CVC→VC)

(3) Syllable contained consonant cluster is marked.

(CV→CCV, VC→VCC)

Stark (1980) proposed the order of stages in the speech production before infants begin to produce their first word. In the stage called canonical babbling, infants in their 6-month-old start to produce sequences of identical CV syllables with adult-like timing such as [mama] or [baba]. At around 12 or 13 months, syllable strings with varying consonants and vowels, like [bagidabu] emerge as the more frequent type in infants' speech. When infants are 10-month-old, syllables like V, VC, and CVC start to emerge in infants' production.

Allen and Hawkins (1978, 1980) proposed that young children acquiring English tend to use the form of disyllabic trochaic feet. They observed that children often use augmented (CVC→CVCV) or truncated words. Furthermore, this early syllable structure might be a universal tendency; that is, children all over the world acquire languages with uniformity. Demuth and Johnson (2003) also found that children acquiring different languages use similar rules to truncate adults' target forms. They examined the phonological acquisition of French in longitudinal data from one French-speaking child, aged 1; 3-1; 5, and found that the child's early words were all reduplicated CVCV forms. The examples of English and French children are presented as below:

English [bənæ nə] → [ˈnænə] 'banana'

French [paˈtat] → [pəˈtæ:] 'potato'

Child acquiring English produced [bənæ nə] as [ˈnænə], and child acquiring French produced [paˈtat] into [pəˈtæ:]. Both English and French children truncated trisyllabic word into disyllabic word.

2.2 Factors of phonological variability

Variability appears frequently in the developmental phonology literature, and is often used as a diagnostic marker of phonological disorders. However, less is known about normal patterns of variability. The following section introduces the factors of phonological variability in typically developing children. Studies concerning phonological variability will also be presented.

Production variability has been attributed to a number of different factors which summarized into the following categories: physical factor and phonological factors.

2.2.1 Physical factor

The development of neuromotor control for speech that occurs during the period of early language acquisition can influence children's speech production. Young children have been found to demonstrate high levels of variability in many different aspects of motor control (Green, Moore & Reilly, 2002; Holm, Crosbie & Dodd, 2007; Macrae, 2013; Sosa & Stoel-Gammon, 2012). In general, motor development might be summarized as a process of increasing accuracy and decreasing variability (Stoel-Gammon, 2006)

Green *et al*. (2002) investigated the sequential development of the upper lip, lower lip, and jaw movement of 1-, 2-, and 6-year-olds and adults during speech. The findings revealed that 1- and 2-year-old children's jaw movements were significantly similar to adults'. However, 1-year-olds' upper and lower lip movement patterns exhibited high variability, which would become more adult-like with maturation. These findings suggested that children's early sound acquisition might be influenced by the inconsistent development of articulatory control, with the jaw preceding the lips. For example, it is easier for children to produce sounds formed by using mandible as primary mover like /b/ than those tend to be associated with lip control like /f/. According to Green *et al*. (2002), young children's phonetic inventory was constrained by their dependence on the mandible to approximate adult-like speech targets resulting in the production of predictable speech errors and distortions.

2.2.2 Phonological factors

There are a number of phonological factors of phonological variability to be discussed. The first is phonetic context. The position of sounds in a word may affect the accuracy of production. Kenney and Prather (1986) examined the speech consistency of children aged 2;5 to 5;0. They found that children produced phonemes /t, l, f/ more accurately in word initial than in word final position.

The second phonological factor is phonological overload. It is not surprising that words that are difficult for a child to pronounce will display greater variability. Leonard *et al*. (1982) examined 8 typically developing children ranging from 1; 10 to 2;2 years of age. They found that variability is most likely to occur when more than one phonological or structural feature of the target words that show instability in the child's linguistic system. Furthermore, words with higher variability rates are most often those which have more advanced forms, sounds, or word shapes. Thus, variability can be seen as the result of phonological overload, which results in the simplification or substitution of sounds that are difficult for children to produce.

The third factor of phonological variability is phonological complexity. McLeod and Hewett (2008) examined variability and accuracy in the production of words containing consonant clusters in typically developing children, aged 2; 0 to 3; 4. They found that the children in the study exhibited extensively variability when producing words that contained consonant clusters.

Macrae (2013) investigated word variability and accuracy in children aged 1; 9 to 3; 1. The study used Word Complexity Measure (Stoel-Gammon, 2012) to assign score to a word based on the three levels of complexity: word pattern, syllable structures and sound classes. The results showed that phonological complexity has a significant positive effect on word variability. Words with more complex speech sounds are produced with more variability than those with less complex speech sounds. These studies are consistent with the study of Ferguson and Farwell (1975) which also indicated the effect of phonological complexity on word variability.

The last factor of phonological factor is reorganization of phonological system. Sosa and Stoel-Gammon (2006) investigated the patterns of intra-word production variability of English-speaking children during their first year of lexical acquisition (1;0-2;0). The variability pattern observed by Sosa and Stoel-Gammon (2006) showed peaks and valleys. Three of the four children showed a very noticeable peak in variability. These peaks appeared when these children aged 1; 9 to 2; 0. It was also the time when two-word utterances were first observed in children's speech. The results indicated that an increase in variability might correspond to instability in the phonological system when it undergoes reorganization: a movement from lexically-based system of phonological representation to segmental system. This view is consistent with dynamic systems theory, which proposed that variability is associated with transitions between developmental stages and is a potential force of developmental change (Thelen & Bates, 2003).

2.3 Introduction to Mandarin syllable

There are two parts in this section. The possible syllable types and the tone in Mandarin will be introduced.

2.3.1 Syllable types in Mandarin

All consonants except nasal [ŋ] in Mandarin can appear in the onset position, and only nasals can be in the coda position. Prenuclear glides occurred in syllable initial position serve as an onset of the syllable, or it can occur before the syllable nuclear position. They are not considered as phonemes in Mandarin but can be treated as phonetic variants of high front vowels since the prenuclear glides do not contrast with the corresponding high vowels (Duanmu, 2007, Lin, 2007, Wan, 1999). Throughout this study, the Mandarin phones are presented by IPA system. Table 2.1 shows the description of possible consonant inventory, based on the studies from Lin (2007)

Table 2.1 Mandarin consonants

	Bilabial		Labio-dental	Dental		Post-alveolar		Alveolo-palatal		palatal	Velar	
Stop	p	p^h		t	t^h						k	k^h
Fricative			f	s		ʂ		ɕ			x	
Affricate				ts	ts^h	tʂ	$tʂ^h$	tɕ	$tɕ^h$			
Nasal	m			n							ŋ	
Central approximant	w ɥ					ʐ				j ɥ	w	
Lateral (Approximant)				l								

In Table 2.1, symbols under the same place of articulation share every feature except for aspiration. The one on the left is voiceless unaspirated which is shaded, and the one on the right is voiceless aspirated.

Taiwan Mandarin allows at most four segments in a syllable, and is analyzed as having twelve syllable types: V, CV, VG, GV, VN, CVG, CVN, CGV, GVG, GVN, CGVG, and CGVN. The maximal syllable is CGVX, in which C is a consonant, G is a glide, V is a vowel, and X can be a glide or a nasal. Possible syllable types and examples are shown in Table 2.2.

Table 2.2 Possible syllable types in Mandarin (Wan, 1999:36)

Syllable type	Phonetic Transcription	Gloss
V	i55	dependent
CV	ma55	mother

GV	ja55	push
VG	aj51	love
VN	an55	safe
CVG	maj214	buy
CVN	tjŋ214	top
CGV	ɕjɛ35	shoes
GVG	jɑw35	shake
GVN	wan51	ten thousand
CGVG	tjɑw51	drop
CGVN	t^{h}jɛn55	sky

In traditional analysis, Chinese syllable contains three parts: the first part is the Initial, which is optional and could be a consonant, a glide, or a nasal; the rest of the syllable after the initial consonant is the Final, which contains Medial and Rime. The medial is the glide before the main nuclear vowel. Rime can be further divided into two parts: the Nucleus, which is the main vowel in a syllable, and the Ending, which could be a glide or a nasal. The third part is the Tone, which is considered a property of the whole syllable (Cheng, 1973).

The phonological status of the prenuclear glides [j], [w], and [ɥ] in Mandarin Chinese has been well-studied but still remains as a controversial issue. Traditionally, the prenuclear glides are considered to be part of the final (Cheng, 1973), while Duanmu (1990) suggested that the prenuclear glides are not rime segments but secondary articulation on the onset. Duanmu (2007) pointed out that the

CG(C=consonant; G=glide) sequence, like [s] and [w] sounds in [swan] 'sour', is actually a single sound in Chinese, due to the fact that the lip rounding of [w] starts at the same time as [s]. In contrast, [sw] in English words like 'sway' are two sounds because the rounding of [w] occurs after [s].

Zhu and Dodd (2000) examined the phonological acquisition of Putonghua of 134 children aged 1;6-4;6 in Beijing. From the speech error pattern of syllable-initial consonant deletion, Zhu and Dodd pointed out that children acquiring Putonghua always delete the syllable-initial consonants before the vowels [i], [u], and [y]. This pattern may reflect the flexible function of these three vowels: these vowels have their variants [j], [w], and [ɥ], as mentioned before. Deletion occurs before these vowels suggested that children acquiring Putonghua have the tendency to cluster the prenuclear glides with the nucleus; that is, prenuclear glides tend to group with rime instead of onset in child phonology.

2.3.2 Tone

Syllable is a tone-bearing unit in Mandarin. People speaking tonal languages use tones to distinguish lexical meanings. Mandarin has four lexical tones and one neutral tone. Chao (1956) have provided a 5-point scale to specify the tone values in Standard Mandarin which were widely used and cited in most research on tone languages. Table 2.3 presents the five-point scale proposed by Chao (1956).

Table 2.3 Five-point scale of Mandarin tone

Tone	Chinese Name	Tonal feature	Pitch value
Tone 1	Yinping	High level	55
Tone 2	Yangping	High rising	35
Tone 3	Shangsheng	Low Falling-Rising	214
Tone 4	Qusheng	High Falling	51

The four tones named *yinping*, *yangping*, *shangsheng*, and *qusheng* were described as high level [55], high rising [35], low falling-rising [214], and high falling [51] in the study of Chao (1965).

The neutral tone usually appears in grammatical particles or in unstressed syllable. Phonologically, a neutral tone was a low tone underlyingly (Lin, 2007) and it is usually represented without any numeral citation.

2.4 Syllable acquisition in cross-language studies

In this section, I will review studies of syllable acquisition on different language, including English, German, Dutch, Taiwan Southern Min, and Mandarin. Linguists are interested in whether there are language universals in first language acquisition.

2.4.1 English

Ingram (1978) presented the acquisition order of different syllable structure of his daughter. The child acquired CV and CVCV form first, and then CVC. By the age of 2, she produced most words contained closed syllable, as showed in Table 2.3.

Table 2.4 Acquisition of syllable (Ingram, 1978)

	Monosyllabic words	Disyllabic words
1;3	89% CV	87% CVCV
1;6	mostly CVC	47% CVCV
2;3	Most of the words contained closed syllable	

Ingram (1978) analyzed the monosyllabic and disyllabic token separately. In monosyllabic words, 89% percents of words were CV form at the beginning; however, when the child was one and six months olds, most forms in monosyllabic words was CVC. As for disyllabic words, 87% percents of words were CVCV form when the child was one and three months olds, while only 47% percents of CVCV forms occur in disyllabic words when the child aged 1;6. These previous studies showed that children master syllable onset consonants earlier than coda consonants.

However, Kehoe and Stoel-Gammon (2001) found that codas were produced early than onset by some English-speaking children. The reason might due to the lexical frequency. Stoel-Gammon (1998) analyzed the phonological characteristics of approximately 600 early acquired words and found that the most frequent syllable was CVC, far exceeding the frequency of CV and CVCV forms. The relative frequency of codas in the target language influenced children's babbled productions. Thus, codas were presented in some English-speaking children's first words.

2.4.2 German and Dutch

Lleo and Prinz (1996) examined the acquisition of consonant clusters of five German-speaking children aged from 1;9 to 2;1. Their data showed the following acquisition order: CV>CVC>CVCC>CCVCC. Furthermore, they found that word-final clusters were mastered several months earlier than word-initial clusters for both groups of children.

In order to explain the variance in phonological acquisition within syllable structures, recent researchers studied the effect of frequency on the acquisition of syllable structures. Levelt *et al*. (2000) examined the development of syllable types in longitudinal data of twelve children acquiring Dutch as their first language. The children's ages ranged between 0; 11 and 1;11. The results showed that the input frequency of different syllable structures in Dutch corresponded to the order in which these structures were acquired and mastered.

Table 2.5 Developmental order for the acquisition of syllable types in Dutch

A: > (5) CVCC, VCC> (6) CCV, CCVC

(1) CV > (2) CVC > (3) V > (4) VC > (7) CCVCC

B: > (5) CCV, CCVC > (6) CVCC, VCC

The frequency of syllable types in the speech input appears to determine which learning path is followed. If the child has a choice between different learning paths, the path of the most frequent syllable type is chosen. If there is no noticeable difference between the frequencies of syllable types that correspond to different possible paths, variation is expected and attested. That is, there is a correlation between the frequency of a syllable structure in a specific language and how early that structure is acquired.

2.4.3 Taiwan Southern Min

Tsay (2006) examined the prosodic structure and syllable omission pattern produced by young children acquiring Taiwan Southern Min, aged from 1; 6 to 3; 0. The results showed that over 70% of the attempted target words in children's data were monosyllabic words and disyllabic words were the second frequently used word type, which is contradictory to the findings of Allen and Hawkins (1978, 1980) who proposed that young children acquiring English tend to use the form of disyllabic forms. Tsay (2006) also found that children would use strategies, such as syllable omission, to shorten long utterances. There were three patterns of children's syllable omission: (1) Omission occurred in multisyllabic words more frequently than in monosyllabic word. (2) Word-initial syllables were omitted more frequently than word-final syllables. (3) Syllable types consisting of VN, CVK (K stands for obstruent codas in Taiwan Southern Min [p], [t], [k], and [ʔ]), and V were the common omitted syllable types.

Tsay (2007) examined the issue of the interactions between markedness and frequency in the domain of syllable types of children aged 1;2-4;4 acquiring Taiwan Southern Min. The study was based on the longitudinal data from Taiwan Child Language Corpus (Tsay, in preparation). The results showed that CV was the most frequently used syllable, followed by CVC, CVV, and V. More than 82% to 86% of children's speech was these four syllable types. CV syllable is the core syllable and is considered as the most unmarked syllable across languages. The findings showed that the most unmarked syllable type CV was the most frequent syllable in children acquiring Taiwan Southern Min. However, frequency did not always have a positive correlation with accuracy. For example, CVC was the second most frequently used syllable in children's speech; however, the error rate of children producing CVC syllable was 98%. The most common-error in syllable structure involved coda dropping, which was a regular type in phonological acquisition (So & Dodd, 1995) and as mentioned by McCarthy and Prince (1994), children's early productions were governed by highly-ranked No-Coda constraints, which predicts that CV syllable types appear to be the most common output of syllable errors.

2.4.4 Beijing Mandarin

Zhu and Dodd (2000) studied the phonological acquisition of Putonghua and found that the children's errors suggested that Putonghua-speaking children mastered syllable elements in the following order: tone was acquired first; and followed by syllable-final consonants and vowels; and syllable-initial consonants were mastered last. In the study, vowels emerged early in the development. Both syllable-final nasals [n, ŋ] appeared in the children's inventory at their 1;6, while the syllable-initial consonants was completed by 3; 6 for 75% of children. It is proposed that the saliency of the components in the language system determines the order of acquisition. Tone is more salient than the three other syllable components, so it is acquired by children earlier. Since syllable-initial consonants are optional, they have the lowest saliency of the four syllable components. So, children would master syllable-initial consonant later.

In sum, at children's early phonological developmental stage, the unit of lexical representation is the syllable or the whole word rather than the phonemes. Inter-and intra-word phonological variability of children serves as evidence of this statement. This study will then focus on intra-word variability produced by children acquiring Taiwan Mandarin. Two aspects are including in the following: the phonological variability of words and the syllable types composed the words. A longitudinal observation was conducted. The overall variability pattern, the frequency and variability rate of syllable type, and the substation pattern of syllable type will be discussed.

Chapter 3

Methodology

There are two parts in this methodology section. The first part includes the data collection, and the second part contains the data analysis. The data have been collected by the author and the research team in the Phonetics and Psycholinguistics Lab at National Chengchi University for many years. The whole study has been sponsored by the NSC research projects, “Consonant Acquisition in Taiwan Mandarin (NSC 100-2410-H-004-187-)” and “Consonant acquisition in Taiwan Mandarin: Evidence from longitudinal and experimental studies (NSC 101-2410-H-004-182-)”, both investigated by Professor I-Ping Wan.

Section 3.1 involves how I recruited the participants and their background information. Furthermore, the procedure and the recording equipments used during the data collection would also be detailed in this section.

For data analysis in section 3.2, I would present the methods of data transcription, the criteria for choosing target words, the formulas used in obtaining syllable type frequency and variability rate, and how the substitution pattern of different syllable types has been organized.

3.1 Data collection

The participated families were recruited from an advertisement posted on a non-profit parent forum called Babyhome (http://www.babyhome.com.tw/). An article was posted on the forum explaining the academic research purpose, the information of the NSC research project, and the age of recruiting children. Parents who wanted to participant in the research filled out the registration form we designed on “Google doc spread sheet,” which is an online questionnaire and can be customized in several ways. Sixteen families were enrolled under the study.

Some of the children in the NSC research project lived with their grandparents who spoke Taiwan Southern Min, so the children might produced Taiwan Southern Min during the observation. Furthermore, some of the parents used English to communicate with their children, so the children might also produced English sometimes. In order to rule out the influence of languages other than Mandarin Chinese, these children would not be included in this study. At the end, only six children fit in this study, from which I collected four children, and the other two were collected by the research team. There were in a total number of 5868 tokens produced by six participants, among which 2088 tokens were transcribed by the assistants in the research team.

3.1.1 Participants

The background of the six children enrolled in this study shared several similarities. All of them were the only child in their family. They only lived with their parents, and they were all taken care by their mothers in the day time. All mothers used Mandarin Chinese to communicate with their children, so these children's first language was Taiwan Mandarin.

All of them were from middle class family in Taipei. Two of them were boys and the other four were girls. Their ages were between 0; 11 to 1; 1 at the beginning of observation. Since every child's phonological development was inconsistent, I selected the age when they were in non-reduplicated babbling stage and have already produced their first meaningful word. The observation continued for twelve months. At the end, the participants' ages were between 1; 10 to 2; 0. All participants were healthy and appeared to have normal hearing, as determined through parental interviews and observation of children during data collection.

The participants' background information is presented below.

Table 3.1 Participants' age and recording duration

Participants	**Gender**	**Age range**	**Duration**
#1	M	1;1-2;0	12 months
#2	F	1;0-1;11	12 months
#3	F	0;11-1;10	12 months
#4	M	0;11-1;10	12 months

#5	F	0;11-1;10	12 months
#6	F	1;1-2;0	12 months

3.1.2 Procedures

The data collection started from December 2011 to August 2013. There were eight research assistants in the research team. Every other week, two assistants were sent to a child's house in order to record the spontaneous speech between the child and the mother.

On average, the recording was about sixty minutes for one time. Sometimes the recording time might be shorter if the children were tired, hungry, or cried. The activity during recording was not limited. It could be share-book reading, eating, or playing with toys. During the recording, in order to create a more natural context, the mothers were encouraged to play with their children just like the way they always did when they were home by themselves. Sometimes the assistants would also interact with the children, using toys to attract children's attention and encourage them to talk. Children played with their mothers for the most of the time, since they were the people children were more familiar with. According to Lewedage *et al*. (1994), children produce well-formed syllables more frequently in home environment when familiar adults are present than in lab settings.

No specific or systematic planning of elicitation was done during the recording, except for natural elicitations in daily life. For example, when the mother and the child were doing share-book reading activities, sometimes mother would ask the child to name pictures. The goal was to ensure that the data of this study was elicited from spontaneous speech, a method which increases the chances for variability since it involves the planning of longer utterances, including the need for syntactic planning and communicative intent (Dodd *et al*., 1989). The target words for analysis were selected in these spontaneous speeches. Therefore, the number and type of errors might be larger than a carefully controlled experimental task. However, it could reflect processes of phonological acquisition that occur in a more natural context. As Ingram (2011) have claimed that syllables are best studied from words taken from a spontaneous sample because they more directly reflect a child's preferred usage.

Children's vocalizations were audio recorded during observations of their natural daily activities in their homes. One of the assistants held the video recorder and the other held the sound recorder during the recording. The assistant who held the video recorder had to make sure to film the children's face, mouth, and the objects they played with. The assistant who held the sound recorder had to stay near to the children.

The participants were all paid volunteers and have had signed the human subject consent forms. At the end of the research project, the families would receive an album of video recordings as a souvenir. The rewards and cost were supported by the NSC research projects (NSC 100-2410-H-004-187- and NSC 101-2410-H-004-182-).

3.1.3 Recording equipments

Video-recording and sound-recording equipments were both used in this study. Sony DCR-SR40 Handycam digital video camera recorder and the Sony ICD-UX513F digital voice recorder were used during the recording. The sizes of these equipments were small, so it is easy to carry. The equipments were provided by the lab and also sponsored by the two NSC research projects..

The video camera helped us record children's gestures, lip movement and things they played with. The video could provide us some clues to decode the referential meaning of children's utterance. The sound recorder provided us high quality sound files which could help us distinguish the sounds children uttered.

3.2 Data analysis

The participants in the observation period were around one-word stage, but their utterances were longer than two syllables, so the study will analyze children's monosyllabic and disyllabic words separately in different sections. The following section includes how the data have been transcribed, coded, classified and analyzed.

3.2.1 Transcription and coding

The data from the recording were transcribed by the author and the assistants of the research team. If there were disagreements, the tokens would be discussed or checked by another team member. All of the assistants are native speakers of Taiwan Mandarin and have good training in transcribing children's speech.

Inter- rater reliability and intra-rater reliability were assessed for the identification of participants' consonant and vowel productions in IPA broad transcription. The inter-transcriber and intra-transcriber reliability of the transcription reached a percentage higher than 90% under the study, as shown in Table 3.2

Table 3.2 Inter- and intra- transcriber reliability

	Inter-transcriber (2088 tokens)	Intra-transcriber (3780 tokens)
Consonant	97.5%	99.4%
Vowel	91.6%	94.1%

The current study did not deal with the acquisition of segments, so only broad transcription applied to all words and phrases children produced during the recording. Transcriptions included the standard set of symbols used for adult Mandarin phonemes.

The utterances of words and phrases would be transcribed into four parts: actual produced words in IPA transcription, tone, possible meaning and number of occurrences. The transcribed examples are shown below in Table 3.3.

Table 3.3 The sample of coding

IPA transcription	Tone	Possible meaning	Occurrence
[ts^{h}atɕ^{h}i]	[55-]	fork	3
[ts^{h}atɕi]	[55-]	fork	6
[pijɑw]	[35-51]	no	7
[tatɕi]	[51-]	here	3
[tɕ^{h}jotɕ^{h}jo]	[21-35]	ball	3

The first column represented children's actual produced words which were transcribed with IPA symbols. The second column marked the tone of produced words. The tones were coded with [55], [35], [21], [51], representing level tone, rising tone, falling rising tone, and falling tone respectively. The neutral tone was coded without any tone number. The third column marked the possible meanings of each word children produced which could be inferred by contexts, children's gestures, or the repetition of adult's speech. If the utterance was meaningless or unable to infer from the context, we would leave this column blank. The meaningless token would not be included in the study. The last part was the number of occurrence of each word. For example, in the first and second row of the sample, this child produced 'fork' as [ts^{h}a55tɕ^{h}i] for 3 times and as [ts^{h}a55tɕi] for 6 times.

3.2.2 Criteria for target words

The following are some criteria for choosing target words that children produced for analysis. The criteria were adopted from Sosa and Stoel-Gammon (2012). Firstly, the sound quality of words must be fair and clear. Whispered speech and overlapping speech of adults would be excluded. Background noise from toys and rustling noise from contact with the sound recorder resulted in blurred and fuzzy sound would also be excluded. Secondly, the meaning of the words must be clear. Words that would only be considered for analysis if a Mandarin gloss could be identified, or if the meaning of words could be inferred by careful examination from the context as well as the reaction or repetition of adults' speech. For example, if a child pointed at a toy car and uttered [tɤ55 tɤ55], we would suggest that its intended meaning is 'a car'. Thirdly, target words with fewer than three useable tokens, although initially transcribed, would not be included in the final analysis.

Imitated words would be included in this study, as is often done in this type of study (Ferguson & Farwell, 1975; Macrae, 2013; McLeod & Hewett, 2008). Ferguson and Farwell (1975) argued that a high percentage of what young children say is imitated and children can imitate words spoken by adults with a considerable separation in time, so it is difficult to exclude imitation from analysis. Imitated words were defined as productions that occurred within 2 seconds of immediately preceding adult utterances that contained the same target words (Sosa & Stoel-Gammon, 2012).

Since the study focuses on children acquiring Taiwan Mandarin, English and Taiwanese produced by children, although meaningful, would not be included in the study.

3.2.3 Variability rate

To answer the research question concerning variability rate, the analysis of production variability rate would be undertaken.

Phonological variability refers to the different realizations for multiple productions of a same lexical item produced by children. Whether productions of an individual form would be considered the same or different would be determined by the phonetic transcription of the word. Words that displayed consonant, vowel, or overall syllable structure differences would be considered as different phonetic forms, but tone difference is not included. Demuth (1993) mentioned that every mother's motherese would be slightly different since the way mothers adopted to simplify and reduplicate words would have individual style, especially in the acquisition of tone. For example, care-taker may use [pa21pa35] or [pa51pa] to refer to 'father'. Children's production of tone is correct or not would depend on their different motherese. Therefore, tone difference in the variable repeated form of the same word would not be included in the calculation of variability rate of individual word. The sample of phonological variability is shown in Table 3.4

Table 3.4 Phonetic forms and tokens of the word [k^haj55]

Target word	IPA description	Tokens
k^haj 55 'open'	t^ha55	1
	taj55/taj51	3
	tej55	1
	k^haj55	8
	4 distinct forms	13 tokens

Table 3.4 shows the multiple production of the same word [k^haj55] 'open'. Although [taj55] and [taj51] have different tones, they were still counted as the same form in this study. However, [taj55] and [tej55] would be counted as different forms since their vowels were different.

Variability rate would be measured by the percentage of word variability which is calculated for each child at each age. Measures of overall variability for each child at each age, variability of each word as well as variability of each syllable type would be calculated. The method was adopted from Ingram's (2002) Proportion of Whole-Word Variation measure.

Variability for individual words would be calculated by dividing the number of different phonetic forms of each word by the total number of productions of that same word during the same age. The number was then multiplied by 100 to determine the percentage of variability rate. The formula is presented below.

$$\text{Variability rate of word} = \frac{\text{Different phonetic forms (forms)}}{\text{Total productions (tokens)}} \text{X100\%}$$

In table 3.4, the child used 4 different phonetic forms for 13 production of the word ‘open’, so the variability rate for the word ‘open’ was 30.7% (4/13x100). Since the term in the numerator reflects the number of *different* phonetic forms of a word, it can never be equal to one; there are either zero different form (complete consistency), or two different forms or more. So, if the child used only one phonetic form for 13 productions of the word ‘open’, then the number of different forms was zero. The percentage of variability rate for that word would be 0% (0/10x100). Thus, variability rates may range from 0% to 100%.

Variability for individual syllable type would also calculated by dividing the number of different syllable types of target syllable type by the total number of production of the target syllable type. The formula is presented below.

$$\text{Variability rate of syllable type} = \frac{\text{Different syllable type}}{\text{Total productions of target type}} \text{X100\%}$$

Overall variability for each child at each age would be calculated by dividing the number of different phonetic forms by the total number of word tokens produced during the recording at that age. For example, 17 word tokens were included in the analysis for participant #1 at age 1;2, in which he used 11 different phonetic forms in producing these 17 tokens, resulting in an overall variability level of 64.7 % (11/17x100) at this age.

The variability rate could help us understand how prevalent variability is in children's speech. By estimating the variability rate we could know whether a certain type of syllable is mastered by the children or not.

3.2.4 Syllable type frequency

Evaluating the frequency of different syllable types in children's speech could reveal children's preference and show the mastery of each syllable types. If the frequency of a certain syllable type is low, it might be explained that the syllable type is more problematic to children and has not been acquired yet. For example, if the frequency of CGVN (C = consonant, G = glide, V = vowel, N = nasal) was observed to be lower than other syllable types when children were one year old, it would imply that the children have not acquired syllable type CGVN yet and they might use other syllable type to replace it, such as CV or CGV, resulting in production variability and the low frequency of CGVN. So we could predict that syllable types with lower frequency would have higher variability rate.

The frequency of each syllable type children produced would be computed by the formula presents below.

$$\text{Percentage} = \frac{\text{Tokens of a syllable type}}{\text{Tokens of all syllable type}} \text{ X100\%}$$

The numerators would be the tokens of a particular syllable type. The fraction would be presented as a percentage. The frequencies of all syllable types could be ranked into an ordering. The ordering of syllables' frequencies could be used to compare to those in variability rates.

3.2.5 Substitution pattern of syllable type

The multiple forms children produced for a target word would be further analyzed. Since children's productions of words were not mature and stable, children might use many different phonetic forms to produce a word. The evaluation of substitution pattern could demonstrate which syllable types were more likely to be used to replace immature types, and which syllable types tended to make more error.

Note that there are some syllable omission and syllable contraction patterns in the observation data: 0.6% of the data are syllable omission and 0.4% of the data are syllable contraction. Since the main purpose of this study is to look at substitution types, the patterns involving omission and contraction would not be included.

The substation pattern would be shown in a matrix, in which the row represents the syllable types of target words, and the column represents the actual produced syllable types. The example of the matrix is presented in Table 3.5.

The matrix presents the token and percentage of the substitution between different syllable types. The percentage on the rightmost column represents the frequencies of syllable type which are used to replace others, and the percentage on the bottom row represents which syllable type is replaced by others more often. For example, in table 3.5, 59% of target syllable types are replaced by CV syllable; CVG syllable are replaced by others more often since CVG syllable has higher percentage than other syllables. Some columns are left blank which mean that children did not use the particular syllable to replace target syllable type.

Table 3.5 The sample matrix of substitution pattern in different syllable types

Target / Realized	**V**	**CV**	**GV**	**VG**	**VN**	**CVG**	**CVN**	**CGV**	**GVG**	**GVN**	**CGVG**	**CGVN**	**Total**	
V		**2**	**4**	**--**	**--**	**--**	**--**	**--**	**1**	**--**	**--**	**4**	**11**	**9%**
CV	**--**		**-**	**-**	**-**	**34**	**5**	**2**	**--**	**8**	**20**	**3**	**72**	**59%**
GV	**--**	**--**		**--**	**--**	**--**	**--**	**2**	**2**	**-**	**-**	**2**	**6**	**4.9%**
VG	**--**	**--**	**--**		**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
VN	**--**	**--**	**--**	**--**		**1**	**--**	**--**	**--**	**--**	**--**	**--**	**1**	**0.8%**
CVG	**--**	**1**	**--**	**--**	**--**		**--**	**--**	**--**	**--**	**2**	**1**	**4**	**3.2%**
CVN	**--**	**--**	**--**	**--**	**--**	**--**		**--**	**--**	**--**	**--**	**1**	**1**	**0.8%**
CGV	**--**	**3**	**--**	**--**	**--**	**1**	**--**		**--**	**--**	**5**	**17**	**26**	**21.3%**
GVG	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**		**--**	**--**	**--**	**--**	**--**
GVN	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**		**--**	**1**	**1**	**0.8%**
CGVG	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**		**--**	**--**	**--**
CGVN	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**		**--**	**--**
Total	**--**	**6**	**4**	**--**	**--**	**36**	**5**	**4**	**3**	**8**	**27**	**29**	**122**	
	--	**4.9%**	**3.2%**	**--**	**--**	**29.5%**	**4%**	**3.2%**	**2.4%**	**6.5%**	**22.1%**	**23.7%**		

Chapter 4

Results and Analysis

This section will present the results and overall analysis of the data. The analysis will follow the research questions presented in chapter 1. The overview of the overall data will be presented in section 4.1. Section 4.2 will present the overall pattern of phonological variability pattern of each participant. Section 4.3 will present the results of syllable analysis, including the general syllable type children are likely to produce, the frequency of syllable types in different syllable positions, and the variability rate of different syllable types. Section 4.4 will present the substitution pattern between different syllable types. Last but not least, the relationship between frequencies of syllable types and its variability rates as well as the relationship between frequencies and substitution pattern will be summarized in section 4.5.

4.1 Background information of the data

Two male and four female children were adopted in the study. The observation started at the age of 0;11 to 1;1 in the beginning and ended with 1;10 to 2;0. The children enrolled were all in non-reduplicated babbling stage in which children started to produce different syllable types, and they have already produced their first meaningful word.

The observation lasted for a year. As mentioned in chapter 3, only sounds that have clear meaning could be included in the analysis. Tokens without clear meaning or tokens that were acoustically unrecognizable would not be included. There were in a total number of 5868 tokens. However, utterances which consisted of more than two syllables and utterances showed syllable omission and syllable contraction would further be excluded from this study because not all of the participants producing utterances contained more than two syllables with recognizable meaning during the one-year observation, and only two participants produced syllable omission and contraction utterances (there were 0.6% of syllable omission, 0.4% for syllable contraction, and 0.1% for trisyllables in the data). So, after excluding the above types, there were a total number of 5788 tokens which could be analyzed in this study. Table 4.1 provides the information of participants, including gender, age, the duration of observation, and the total tokens participants uttered.

Table 4.1 Information of participants

Participants	**Gender**	**Age range**	**Duration (months)**	**Tokens**
#1	M	1;1-2;0	12	1287
#2	F	1;0-1;11	12	1198
#3	F	0;11-1;10	12	1663
#4	M	0;11-1;10	12	547
#5	F	0;11-1;10	12	606

#6	F	1;1-2;0	12	487
			Total	5788

As shown in Table 4.1, the most productive children were participants #1, #2, and #3 who produced more than 1100 tokens, while participants #4, #5, and #6 produced the least number of tokens which were under 700 tokens. Participants #1 and #4 were added for counterbalancing the gender differences.

Although participant #3 started the observation from younger age, she produced much more speech tokens than the other five participants. At the beginning of the observation, participant #3 produced only one speech sound with referential meaning, which was [mama] ‘mother’; however, when she was at the age of 1;3, she has already produced 105 meaningful words in a one hour recording session. It seemed that children’s productivity and age are not exactly positively correlated.

In the observation data, words participants produced would be further divided into monosyllabic and disyllabic words. Table 4.2 shows the tokens of each word type children produced.

Table 4.2 Tokens of different word types

	Monosyllabic words	Disyllabic words	Total
#1	362	925	1287
#2	424	774	1198
#3	681	982	1663
#4	117	430	547

#5	209	397	606
#6	187	300	487
Total	1980	3808	5788

As shown in Table 4.2, all of participants preferred producing disyllabic words than monosyllabic words. There were 3808 tokens of disyllabic words, and only 1980 tokens of monosyllabic words. Each of disyllabic word has two syllables, so the 3808 disyllabic words would have 7616 syllables. Thus, there were in total of 9596 syllabic tokens (1980+3808x2=9596) in the data.

4.2 Phonological variability

In children's early production, they tend to produce a target word with many different phonetic forms. The variability rates of each participant at each age were calculated in order to see whether there were some patterns in their variable production. Table 4.3 shows the number of different target words and number of words that have variation forms of each participant at each age.

Table 4.3 Number of target words and variation words of participants at each age

	Participants					
Age	#1	#2	#3	#4	#5	#6
0;11	N/A	N/A	1(0)	7(0)	2(0)	1(0)
1;0	N/A	9(1)	8(2)	15(6)	0(0)	1(0)
1;1	28(9)	12(1)	17(5)	18(5)	3(0)	2(0)
1;2	18(7)	14(4)	13(5)	5(2)	17(0)	8(0)
1;3	22(6)	9(2)	34(11)	3(2)	4(1)	3(0)
1;4	27(6)	22(4)	79(20)	11(4)	7(1)	6(1)

1;5	28(7)	49(12)	98(26)	7(1)	19(3)	25(6)
1;6	30(8)	77(10)	114(24)	7(0)	18(1)	30(5)
1;7	35(6)	82(22)	87(27)	20(5)	64(5)	27(1)
1;8	37(7)	66(12)	82(23)	21(6)	41(2)	27(4)
1;9	50(9)	76(16)	63(20)	16(4)	73(12)	48(9)
1;10	95(14)	87(15)	74(18)	33(6)	72(16)	38(5)
1;11	72(11)	86(11)	N/A	N/A	N/A	N/A
2;0	63(10)	N/A	N/A	N/A	N/A	

The number of words that had variation forms presents in parentheses. For example, participant #1 produced 28 different words at 1;1, and among which, nine words showed phonological variability, which means participant #1 used more than one phonetic forms to produce these 9 words. If the number in parentheses was zero, it means that children did not produce any variation forms. For example, participants #3 only produced one word at the beginning of the observation which was [ma55ma55] 'mother'. She produced this word two times during the observation at 0;11, and did not have any variation form. Based on Table 4.3, all of the participants gradually produced more and more amount of different words as they grew older, but the amount of variation form did not gradually increase.

Variability rate differed considerably both across children and across ages, ranging from 0% (participant #4 at 1; 6) to 45.8% (participant #3 at 1; 2). At the level of the individual word, variability rate could range from 0% to 100%, so a high overall variability rate did not indicate instability in the child's production of all words at that age. Some words might be more stable, while others were highly variable. Table 4.4 presents two words with different level of variability rate produced by participant #1. The marker of tone was omitted in the table because the child produced all of the variation forms with the same tone, which is the level tone.

Table 4.4 Production of [xwa55] and [tʂ^{h}ɤ55tʂ^{h}ɤ55] of participant #1 at 1; 3

Target word	**IPA transcription**	**Number of Occurrences**
[xwa55]	wa	2
'flower'	xa	10
Variability	2 forms	2/12x100=16.7%
Target word	**IPA transcription**	**Number of Occurrences**
[tʂ^{h}ɤ55tʂ^{h}ɤ55]	tɕytɕy	2
'a car'	tɕ^{h}ɤtɤ	1
	t^{h}ut^{h}u	9
	tyty	3
	tutu	2
	t^{h}ɤt^{h}ɤ	13
	ɕɤɕɤ	1
	tɕ^{h}ɤtɕ^{h}ɤ	2
	ts^{h}uts^{h}u	2
	tʂ^{h}ɤtʂ^{h}ɤ	2
	tɕ^{h}utɕ^{h}u	2
	tɤtɤ	1
Variability	12 forms	12/40x100=30%

Based on Table 4.4, participant #1 used two different phonetic forms to produce the word [xwa55] 'flower'. The variability rate of [xwa55] 'flower' reached only 16.7% at the age of 1;3. However, participant #1 used 12 different phonetic forms to produce the word [tʂ^{h}ɤ55tʂ^{h}ɤ55] 'car' also at his 1;3. The variability rate was up to 30%.

The following section will introduce the patterns of overall phonological variability of each participant.

4.2.1 Overall variability pattern

Individual patterns of overall variability are shown for each child at each age in Figure 4.1.

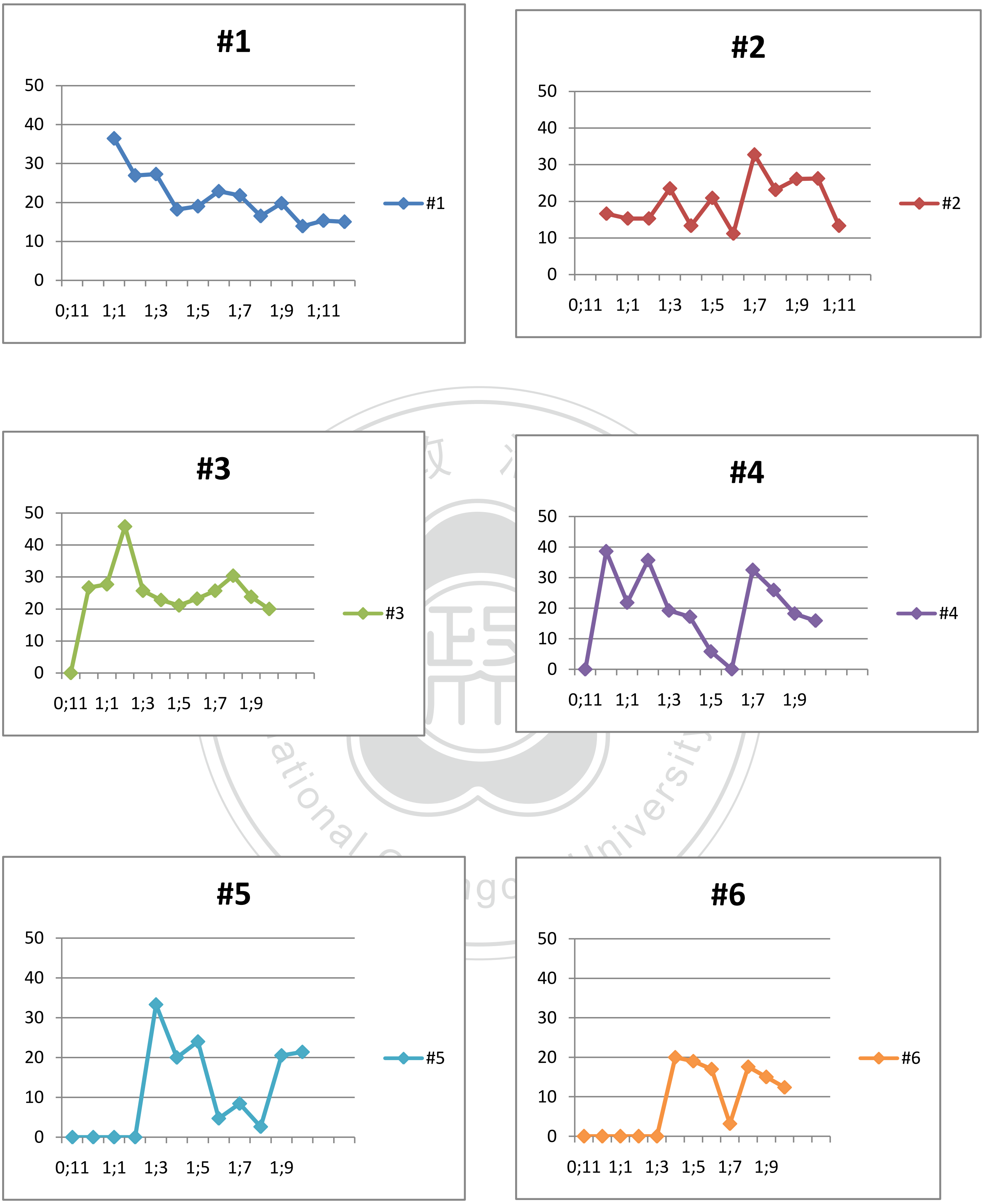

Figure 4.1 Overall variability patterns of each participant

Based on Figure 4.1, although each participant exhibited a somewhat unique pattern of variability, some generalizations were evident. First of all, the overall variability patterns of six participants all showed peaks and valley. None of them showed a decreasing or increasing linearity in their variability patterns. Secondly, the variability rates of most of the participants gradually decreased as they grew older and older. Thirdly, although every participant showed the various forms at different age, they all had a noticeable variability peak. For participants #1, #3, and #4, the variability peaks appeared at 1;0 to 1;2, which was relatively early compared to other participants.

As for differences, firstly, these six participants could be divided into three groups: participant #1 had slightly different behavior comparing to other participants. Participants #2 and #3 were "early talkers". They were productive and uttered their first meaningful words at earlier age, which was one-year-old for participant #2, and 11-month-old for participant #3. Participants #4, #5, and #6 had much more similar developmental process.

The variability peak of participant #1 appeared at the very beginning of the observation, and the variability rates for participant #1 exhibited a much more regular decreasing pattern than others. By looking carefully into the observational data, we found that participant #1 tended to produce the same target words at every age. For example, [tɕʰjow21 tɕʰjow35] ‘ball’, [tʂʰɤ55 tʂʰɤ55] ‘car’, and [kɑw55 kɑw55] ‘building blocks’ appeared at almost every age in the observation data. Table 4.5 presents the tokens and variability rates of these three words.

Table 4.5 Number of forms/tokens and variability rates for words of participant #1

		1;1	1;2	1;4	1;6	1;9
[tɕʰjow21 tɕʰjow35]	Form/token	2/4	2/3	0/2	2/6	0/6
‘ball’	Variability	50%	66.6%	0%	33.3%	0%
[tʂʰɤ55 tʂʰɤ55]	Tokens	N/A	2/3	3/12	2/10	0/4
‘car’	Variability	N/A	66.6%	25%	20%	0%
[kɑw55 kɑw55]	Tokens	5/11	2/3	2/6	N/A	0/7
‘building blocks’	Variability	45.5%	66.6%	33.3%	N/A	0%

Table 4.5 shows the different forms, tokens and variability rates for [tɕʰjow21 tɕʰjow35] ‘ball’, [tʂʰɤ55 tʂʰɤ55] ‘car’, and [kɑw55 kɑw55] ‘building blocks’ produced by participant #1 at different age. Different forms referred to the use of more than one phonetic form to produce a word, and if the child used only one phonetic form to produce the word, the number of different forms is 0. The variability rates for these three words gradually decreased as participants #1 grew older, and there were no variable forms for these three words at 1;9, that is, participant #1 used one form consistently to produce the words, resulting in a lower overall variability rates.

For participants #2 and #3, they reached their variability peaks at their 1;7 and 1;2 respectively. It was also the time when these two participants started to produce two-word utterances, such as [aj51 ni21] ‘love you’ and [pɑw21pɑw21 na35] ‘baby takes (something)’. The onset time of two-word utterances of participants #2 and #3 occurred earlier than previous study suggested by Stoel-Gammon (2006). Although participants #2 has produced two-word utterances at 1;6, almost all of her productions were two-word utterances and sometimes even three-word phrases when she was at 1;7, in which the variability peak appeared,. Participant #3 started to produce two-word utterances as early as she was 1;2. Although she only produced one two-word utterance, which was [ma21ma35 tswɔ35] ‘mother sits’, she gradually produced more and more two-word utterances.

Participants #4, #5, and #6 were less productive in our study groups. They did not consider as fast talkers. Participant #4 was productive at the beginning of the observation but the variability rates were also high. The variability peak appeared at the very beginning of the observation. However, the variability rates gradually decreased and even reached 0% at the age of 1;6. At the age of 1;7, the variability rates once again increased when participant #4 entered two-word stage.

The production of participants #5 and #6 were very small and the variability rates were 0% at the beginning. The low variability rates at their early stage did not mean that their productions were stable; instead, the reason was due to the small amount of utterances, as shown in Table 4.3 presented earlier. Participants #5 and #6 produced only 0 to 3 words at the beginning. The variability rates were low because they barely uttered more than 2 words in the one-hour observation. The variability peaks appeared at their 1;3 and 1;4 respectively. Although these two participants did not utter any two- word utterance at the end of the observation, they apparently produced much more different words after they went through the variability peaks. The number of words participant #5 produced increased to 19 words and participant #6 increased to 25 words.

To sum up, the findings generally confirm the study of Stoel-Gammon and Sosa (2006) which showed that an increase in variability might correspond to instability in the phonological system when it undergoes reorganization. In this study, it is the time when the onset of two-word utterances and the increased amount of words appeared.

4.3 Syllable analysis

In this section, the tokens of different syllable types in different syllable position were calculated in order to see the general syllable types produced by children. The frequency and variability rate of each syllable type would be discussed in this section.

The frequencies of syllable types would inform which syllable type is more frequently used and which type is less used. The variability rates of each syllable type would show which syllable type is not stable.

4.3.1 Frequency of syllable type

It is mentioned that the tokens collected in this study included monosyllabic words and disyllabic words. To see whether different types of tokens affect the development in syllable acquisition, monosyllables and disyllables would be analyzed separately. During the observation, we found that not all of the participants could produce utterances longer than two syllables, so the tokens analyzed here were all one-to-two syllabic utterances. The frequency of monosyllabic words and disyllabic words will be presented in section 4.3.1.1 and 4.3.1.2 respectively.

4.3.1.1 Monosyllabic words

Table 4.6 and Figure 4.2 provide the tokens of each syllable type in monosyllabic words. The bar graph in Figure 4.2 was used to compare the differences among frequencies of syllable types.

Table 4.6 Tokens and percentages of syllable types in monosyllabic words

	V	CV	VG	VN	GV	CVG	CVN	GVG	GVN	CGV	CGVG	CGVN
Tokens	93	667	27	25	75	549	127	108	26	189	65	29
Percentage	4.7%	33.7%	1.4%	1.3%	3.8%	27.7%	6.4%	5.5%	1.5%	9.5%	3.3%	1.5%
Total tokens												1980

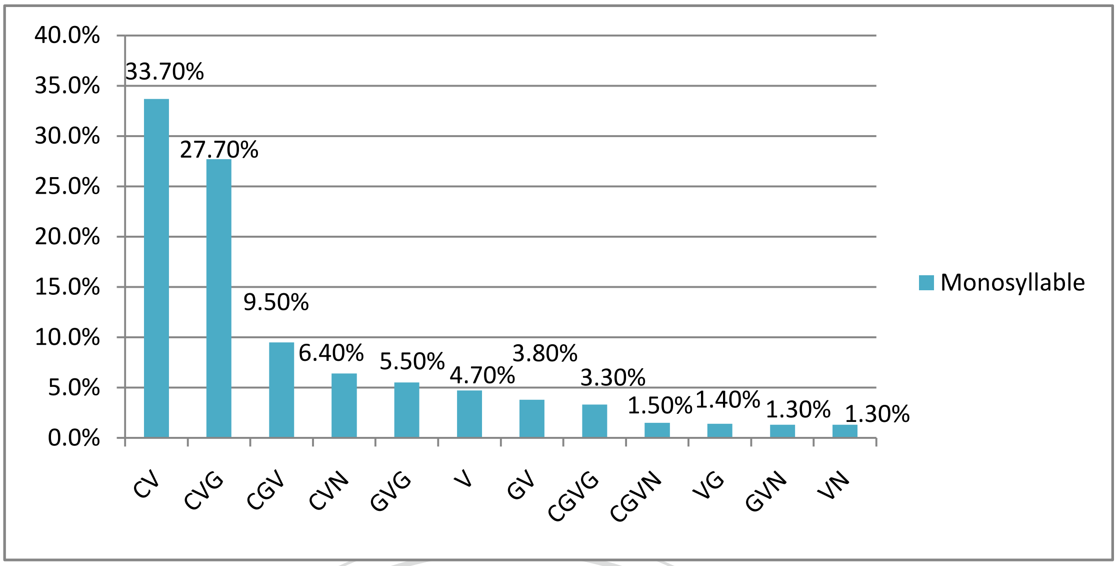

Figure 4.2 Percentages of syllable types in monosyllabic words

The results are statistically significant ($\chi^2_{11,0.001}$=153.9, p<.001). Based on Figure 4.2, CV was the most frequently used syllable type in monosyllabic words, accounted for 33.7 percent of the total 1980 syllables. CVG and CGV ranked as the second and third place, with the usage of 27.7 percent and 9.5 percent of utterances respectively. CVN ranked as the fourth place, with the usage of 6.4 percent. As for the least frequent syllable types, VN, GVN, VG had percentage less than 2 percent. Clearly, the findings indicate that children prefer to use CV syllable the most. The frequency ranking according to Figure 4.2 would be CV>CVG>CGV>CVN.

In order to see whether there are individual differences between participants, the frequencies of syllable types produced by each participant were also calculated, as showed in Table 4.7.

Table 4.7 Percentages of syllable types of each participant in monosyllables

	V	VG	VN	CV	CVG	CVN	CGV	GV	GVG	GVN	CGVG	CGVN
#1	6.9%	0.5%	1.3%	41.1%	24%	5.5%	7.2%	3.5%	4.4%	1.4%	1.9%	1.9%
#2	8%	1.6%	0.7%	31.6%	29.4%	3.7%	8.5%	6.3%	5.8%	1.4%	1.6%	0.9%
#3	2.4%	1.6%	2.5%	32%	24.4%	9.8%	10.3%	3.5%	5%	1.3%	4.8%	2.2%
#4	3.4%	3.4%	0%	47.8%	19.7%	0.8%	10.3%	0.8%	7.7%	0%	6%	0%
#5	4.3%	1.4%	0%	16.3%	41.6%	7.7%	12.4%	3.3%	8.1%	0.9%	3.3%	0.5%
#6	2.1%	0%	0%	40.1%	32.6%	3.7%	10.2%	1.6%	3.7%	2.1%	2.1%	1.1%

Based on Table 4.7, half of the participants produced all the syllable types in Mandarin. Participants #4, #5, and #6 produced only 9, 11, and 10 syllable types respectively at the end of the observation.

For the most frequently used syllable type, participant #5 presented slightly different pattern comparing to other participants. CVG was the most frequently used syllable types by participant #5, accounted for 41.6% of the utterances, and then followed by CV and CGV, accounted for 16.3% and 12.4% of the utterances. The least frequent syllable type produced by participant #5 in monosyllables was VN, CGVG, and GVN. The other participants showed similar pattern: CV was the most frequently used syllable type, followed by CVG and CGV.

To sum up, CV, CVG, and CGV were used more frequently than other syllable types in monosyllables of all participants. As for the least frequent syllable type, although every participant showed slightly difference, VG, VN, GVN, CGVN had lower frequency in all participants' production.

4.3.1.2 Disyllabic words

In this section, syllable types in different syllable position of disyllabic words and the preferred syllable combination were analyzed. The syllable-initial position in the disyllabic words is referred to as 1st syllable and the syllable-final position is represented as 2nd syllable in Table 4.8.

Table 4.8 and Figure 4.3 present the tokens and frequencies of syllable types in disyllabic words. The results in first syllable are statistically significant ($\chi^2_{11,0.001}$=318.4, p<.001). The results in second syllable are also statistically significant ($\chi^2_{11,0.001}$=212.2, p<.001).

Table 4.8 Tokens and percentages of syllable types in disyllabic words

1st syllable	V	CV	VG	VN	GV	CVG	CVN	GVG	GVN	CGV	CGVG	CGVN
Tokens	255	2122	11	21	182	473	154	3	19	448	70	50
Percentages	6.7%	55.7%	0.3%	0.6%	4.8%	12.4%	4%	0.07%	0.5%	11.8%	1.8%	1.3%
Total tokens												3808
2nd syllable	V	CV	VG	VN	GV	CVG	CVN	GVG	GVN	CGV	CGVG	CGVN
Tokens	134	1760	13	15	224	499	173	185	21	513	118	153
Percentages	3.5%	46.2%	0.3%	0.4%	5.8%	13.1%	4.5%	4.9%	0.8%	13.5%	3.1%	4%
Total tokens												3808

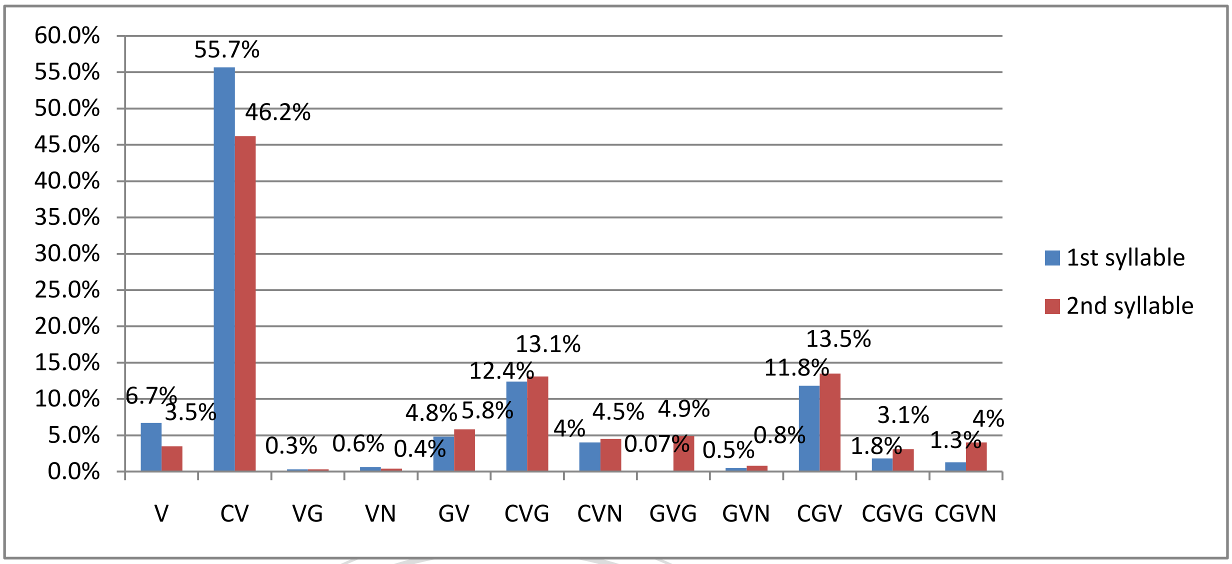

Figure 4.3 Percentages of syllable types in disyllabic words

In Figure 4.3, the bars on the left named 1st syllable show all syllable types' frequencies of the first syllable in disyllabic words, and those named 2nd syllable in the right represent the frequencies of the second syllable in disyllabic words. Frequency of each syllable type would be calculated separately as different categories, but they were put together in the same graph for easier comparison.

Figure 4.3 shows that CV, CVG, CGV had the highest frequency in both first syllable and second syllable in disyllabic words, among which CV was the most frequently used syllable types, accounted for 55.7 and 46.2 percent of the production in first and second syllable respectively. The frequency of CV was three times higher than other syllable types. The frequencies of syllable types in disyllabic words were similar to the results in monosyllabic words, in which CV, CVG, and CGV were also the most frequently used syllable types. The ranking of frequencies of syllable types is

CV> CVG, CGV> GV, V in disyllabic words.

For the least frequent syllable types, VG, VN, and GVN had frequency less than one percentage. The frequency of GVG was also less than one percent in first syllable, but reached 4.9% in second syllable. Words children produced contained GVG syllable were mostly [pu35 jɑw51] ‘no’, so the production of GVG was mostly limited to second syllable, resulting in its lower frequency in first syllable.

Comparing the frequencies of syllable types between different syllable positions, the results show that all syllable types appeared in the second syllable more frequently than in first syllable except for CV, V, and VN. Furthermore, half of the syllable types appeared less than 4% in first syllable. Table 4.9 and Table 4.10 present the frequencies of syllable types of each participant in first and second syllable of disyllabic words.

Table 4.9 Percentages of syllable types of each participant in 1^{st} syllable

	V	VG	VN	CV	CVG	CVN	CGV	GV	GVG	GVN	CGVG	CGVN
#1	4.9%	0%	0.1%	61.6%	11.4%	1%	8.4%	10.6%	0.2%	0.2%	1%	0.6%
#2	7.8%	0.6%	0.5%	49.6%	15.8%	8.4%	10.3%	3.2%	0.1%	0.5%	1.9%	1.2%
#3	7.3%	0%	0.8%	57.9%	9.9%	3.7%	11.2%	4.2%	0%	0.7%	2.3%	1.9%
#4	7.4%	0%	0.5%	53.3%	10%	0.5%	26.7%	0.7%	0%	0%	0.9%	0%
#5	8.3%	0.8%	0.8%	46.3%	17.9%	10.1%	6%	2.5%	0%	1.5%	2.3%	3.5%
#6	4.3%	1%	1%	62%	11.7%	0.7%	13.7%	1.7%	0%	0%	3.3%	0.7%

Table 4.10 Percentages of syllable types of each participant in 2nd syllable

	V	VG	VN	CV	CVG	CVN	CGV	GV	GVG	GVN	CGVG	CGVN
#1	1.2%	0.3%	0.1%	52.6%	14.9%	4.3%	8.3%	11.4%	1.2%	0.4%	1.6%	3.6%
#2	5.7%	0.1%	0%	43.2%	10.3%	8.5%	14%	6.1%	4.9%	0.1%	5.8 %	1.3%
#3	3.4%	0.1%	1.3%	43.1%	14.7%	4.2%	12.5%	5.1%	5.7%	0.9%	2.6%	6.4%
#4	0.5%	0%	0%	56.3%	10.7%	0.5%	27.4%	0.7%	1.4%	0%	1.6%	0.9%
#5	9.3%	2%	0.3%	28.5%	16.9%	5.5%	10.1%	2.3%	14.9%	1.8%	4%	4.5%
#6	2.3%	0%	0%	53.7%	8%	0.7%	15.7%	3.3%	5%	0%	3%	8.3%

The results in two syllable position of all participants were similar. CV, CVG, and CGV were the most frequently used syllable types produced by all participants in both syllable positions.

There were in a total number of 3808 disyllabic tokens in the data, and among which, there were 95 types of different syllable combinations in the data (see appendix A). Table 4.11 shows the frequencies of syllable combinations that ranked first five in disyllabic words.

Table 4.11 The overall frequencies of syllable combinations

Syllable combination	Token	Percentage
CV-CV	1417	37.2%
CGV-CGV	293	7.7%
CVG-CVG	252	6.6%
CV-CVG	168	4.4%
CV-CGV	136	3.6%
Subtotal	2261	59.5%

The top five frequencies of syllable combinations were accounted for 59.5% of the total syllable combination. CV-CV, CGV-CGV, and CVG-CVG were the top three combinations that were used by participants. CV-CV was most frequently used syllable combination, accounted for 37.2%, and the rest of combinations were accounted for more than 3.5%.

The results shows that syllable combinations that showed higher frequency are those with consonant-vowel reduplicated forms, such as CV-CV, CGV-CGV, and CVG-CVG. Furthermore, the syllable types that composed the top five frequencies of syllable combinations are those with higher frequency in both first syllable and second syllable in disyllabic words, as shown in Figure 4.3.

The frequencies of syllable combination of each participant were also calculated (see Appendix B). Participant #2 produced the largest amount of different types of combination. She produced 69 types of different syllable combination, and participant #6 only produced 36 types of different syllable combination. The following table shows the top five frequencies of syllable combination of each participant.

Table 4.12 The frequencies of syllable combinations of each participant

Participant #1		
Syllable combination	Token	Percentage
CV-CV	427	46.2%
GV-GV	84	9.1%
CVG-CVG	77	8.3%
CV-CVG	47	5.1%

CGV-CGV	43	4.6%
Subtotal	678	73.3%
Participant #2		
CV-CV	247	31.9%
CV-CGV	42	5.4%
CGV-CGV	45	5.8%
CVN-CVN	38	4.9%
CVG-CV	37	4.8%
Subtotal	409	52.8%
Participant #3		
CV-CV	331	33.7%
CV-CVG	67	6.8%
CGV -CGV	57	5.8%
CVG-CVG	52	5.3%
CV-CGV	49	5%
Subtotal	556	56.6%
Participant #4		
CV-CV	208	48.4%
CGV-CGV	108	25.1%
CVG-CVG	41	9.5%
V-CV	26	6%
CV-CGV	8	1.9%
Subtotal	391	90.9%
Participant #5		
CV-CV	68	17.1%
CV-GVG	51	12.8%
CVG-CVG	35	8.8%
CV-CVG	19	4.8%
CV-V	18	4.5%
Subtotal	191	48.1%
Participant #6		
CV-CV	136	45.3%
CGV-CGV	30	10%
CV-CGVN	24	8%
CVG-CVG	10	3.3%
CVG-CV	9	3%
Subtotal	209	69.7

Base on Table 4.12, the top five frequencies of syllable combinations of all participants were accounted for more than 45% of their utterances. The top five frequencies of combinations produced by participant #4 were even accounted for 90% of her utterances.

CV-CV was the most frequent combination of all participants. The percentages of CV-CV were much higher than other combinations produced by all participants. CGV-CGV was appeared in the top-five list of all participants except for participant #5, and CVG-CVG was also appeared in the list except for participant #2.

4.3.2 Variability rate of syllable type

As mentioned in section 4.3.1, words participants produced could be divided into two types: monosyllabic and disyllabic words. The variability rates of each syllable type in different word position were calculated to see which syllable type presents much higher variability rates. Variability rates of different syllable types in monosyllables and disyllables will be presented in 4.3.2.1and 4.3.2.2 respectively.

4.3.2.1 Monosyllabic words

Figure 4.4 presents the variability rates of syllable types in monosyllabic words.

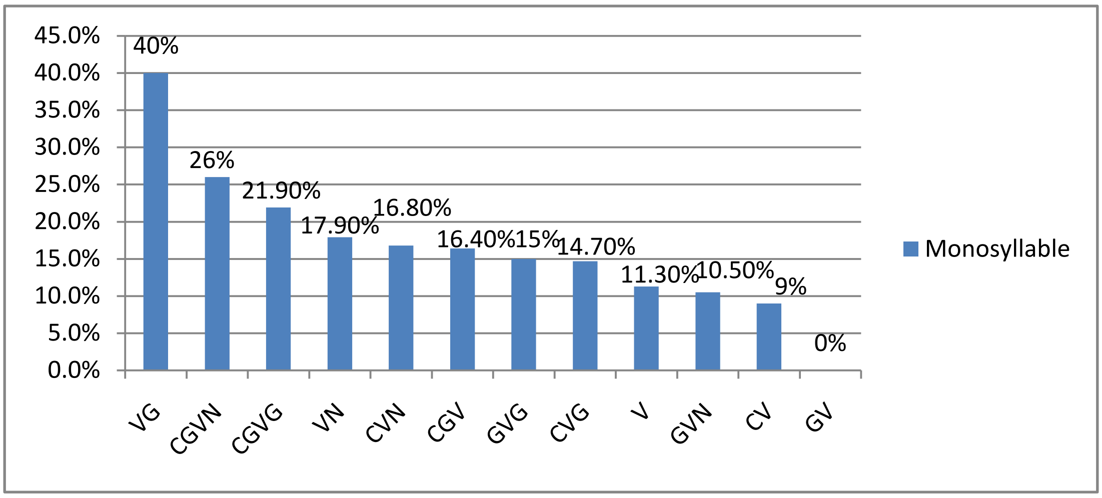

Figure 4.4 Variability rates of syllable types in monosyllabic words

The results are statistically significant ($\chi^2_{11,0.001}$=64.39, p<.001). Based on Figure 4.4, the syllable types that had higher variability rates were VG, CGVN, and CGVG. All of these three types reached over 20 percent of the utterance. VG had the highest variability rates. It accounted for 40 percent of the total number of monosyllabic tokens. CGVN had second higher variability rate, which reached 26%. GV showed no variable form in monosyllabic words, so the variability rate was 0%. CV also showed low variability rates which only reached 9% of the utterances.

4.3.2.2 Disyllabic words

Each of the disyllabic tokens was also analyzed separately in two syllable positions: first syllable and second syllable. Figure 4.5 presents the variability rates of syllable types in different syllable positions, and their percentages are proved to be statistically significant (1st syllable: $\chi^2_{11,0.001}$=48.2, p<.001; 2nd syllable: $\chi^2_{11,0.001}$=50, p<.001).

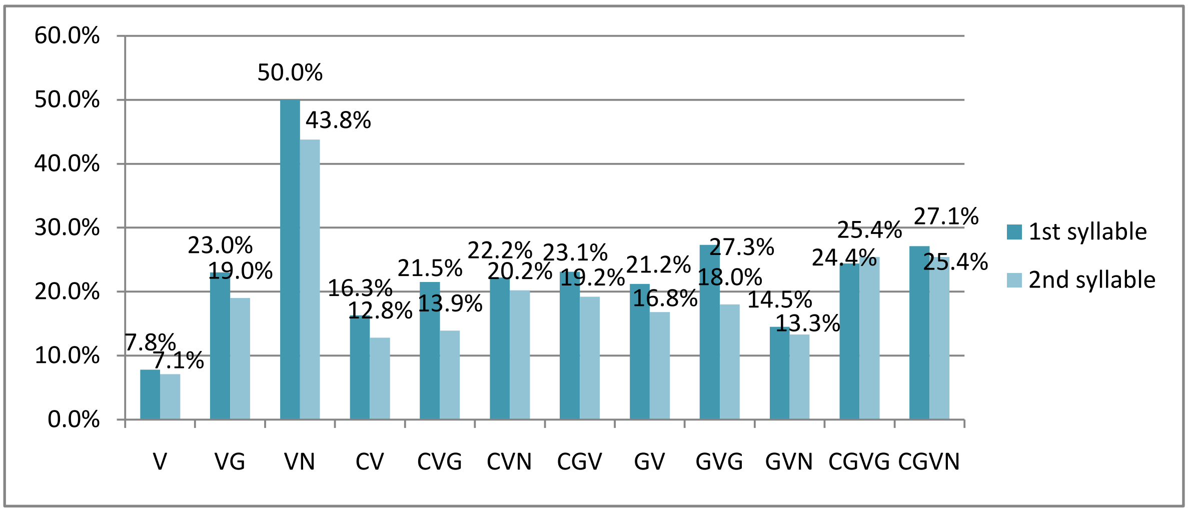

Figure 4.5 Variability rates of syllable types in different word position

Figure 4.5 shows that all the syllable types in first syllable presented much higher variability than in second syllable. The ranking of variability rates of syllable types in the first syllable were VN>VG>CGVN>GVG, and of the second syllable were VN>CGVG=CGVN>CVN. V and CV presented the lowest variability rates in both syllable position.

Noted that the variability rates of GV in monosyllabic words was 0%, but reached 21.6% and 16.8% in two syllable positions of disyllabic words. Carefully examined the observation data, we found that words children produced contained GV syllable were mostly [ja55] 'duck' or [jɛ35] 'grandfather' in monosyllabic words, and [ja55ja55] 'duck' or [jɛ35jɛ35] 'grandfather' in disyllabic words. When producing disyllabic words, children tend to replace first syllable with syllable type V. For example, participant #1 produced [[jɛ21jɛ35] as [i21jɛ35] or [e21jɛ35], so the variability rates of GV were higher in disyllabic words, and especially in the first syllable in disyllabic word.

Comparing the variability rates of syllable types in monosyllables and disyllables, the results show that CGVG and CGVN had the higher variability rates, and CV had much lower variability rates among others.

4.4 Substitution pattern

When a syllable type has not fully mastered and stable yet, children would make consistent errors. They might use different syllable type to produce the target type. The syllable type's substitution pattern was studied in order to see whether or not children would use a more unmarked syllable type to replace a more marked one.

4.4.1 Overall substitution pattern

The substitution pattern in Table 4.13 shows the target syllable types and the realized types in a matrix. For instance, if a child wrongly produced [njow21njow35] 'a cow' as [njo21njo35], the error's target syllable type in the first syllable is CGVG and the CGV would be the selected syllable type that realized in the substitution process.

There were in a total of 2624 syllable substitution errors in the overall data. Table 4.13 shows the matrix in specific numbers of these substitution errors. In the matrix, the upper row represented the target syllable types and the left column represents the realized syllable types. The percentages on the right-hand side indicated which syllable type was more likely to replace other syllable types, and the percentages in the bottom row represented which syllable type was more frequently replaced by others.

Table 4.13 The substitution pattern of syllable types

Target / Realized	V	CV	GV	VG	VN	CVG	CVN	CGV	GVG	GVN	CGVG	CGVN	Total	
V		130	20	3	15	13	5	2	16	2	4	2	212	8%
CV	7		--	--	--	585	274	163	16	1	138	33	1217	46.3%
GV	5	6		--	--	12	6	111	114	115	2	4	375	14.2%
VG	2	1	--		--	35	--	--	3	--	--	--	41	1.6%
VN	--	3	--	1		1	2	--	2	--	--	1	10	0.4%
CVG	--	36	--	--	--		13	19	2	--	25	2	97	3.7%
CVN	--	16	--	--	--	4		--	--	1	--	28	49	1.8%
CGV	4	15	3	--	--	34	14		6	--	388	134	598	22.6%
GVG	--	2	--	--	--	--	--	2		1	1	--	6	0.2%
GVN	--	--	2	--	--	--	5	--	1		--	11	19	0.7%
CGVG	--	--	--	--	--	4	--	--	--	--		3	7	0.3%
CGVN	--	1	--	--	--	--	9	1	--	--	--		11	0.4%
Total	18	210	25	4	15	688	328	298	160	120	558	218	2642	
	0.7%	7.9%	0.9%	0.2%	0.6%	26%	12.4%	11.3%	6.1%	4.5%	21.1%	8.3%		

Based on Table 4.13, the most frequently used syllable type which children chose in replacing other types was CV, accounted for 46.3% in all the tokens. CGV and GV ranked as the second and third most frequently used syllable type with the usage of 22.6% and 14.2% respectively.

The syllable types that were most frequently replaced by others were CVG and CGVG with the usage of 26% and 21.1% respectively. Although CVG is a highly frequent syllable type as mention in section 4.3.1, it was one of syllable types that were often replaced by others. The finding shows that when children producing words contained syllable types they are not mastered yet, they prefer to replace the immature syllable types with CV the most. Furthermore, CVG and CGVG might consider being less stable syllable types for children since these two syllable types are more likely replaced by others.

4.4.2 Monosyllabic words

Figure 4.6 shows the substitution pattern of syllable types in monosyllabic words.

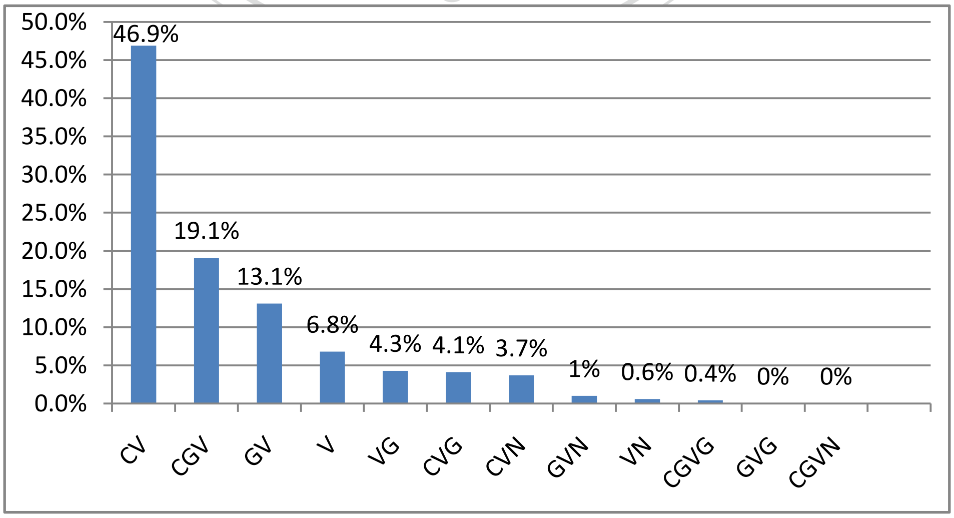

Figure 4.6 Percentages of realized syllable types in monosyllabic words

CV was the first choice to replace other syllable types, accounted for 49.6%. CGV and GV were also frequently used in replacing immature syllable types, accounted for 19.1% and 13.1% respectively. GVG and CGVN were never used to replace other syllable types in the monosyllabic words. The percentage of VN and CGVG were lower than 1% so these two types were also seldom used in replacing other syllable types.

Figure 4.7 shows the frequencies of syllable types that were replaced by others in monosyllabic words.

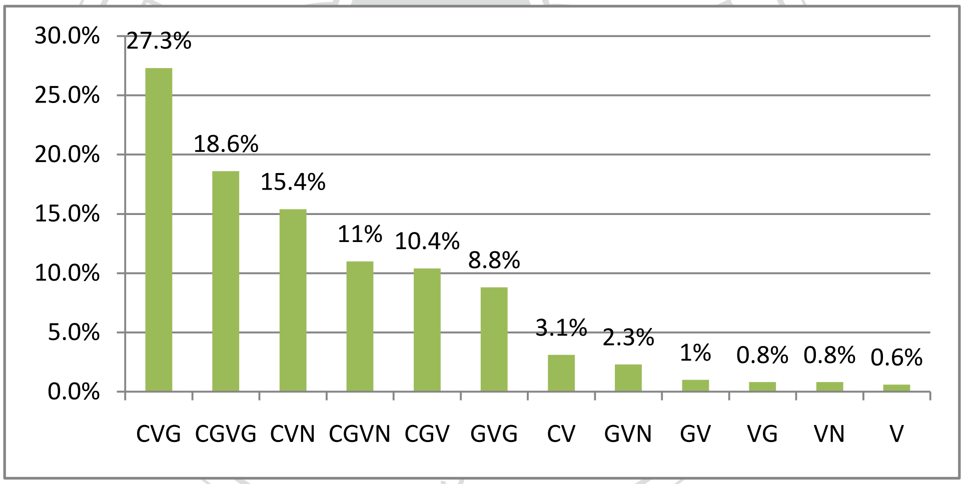

Figure 4.7 Percentages of replaced syllable types in monosyllabic words

As for syllable types that were replaced by others, CVG ranked first, accounted for 27.3%, and followed by CGVG and CVN with the percentage of 18.6% and 15.4%.

4.4.3 Disyllabic words

For disyllabic words Figure 4.8 and Figure 4.9 show the frequencies of syllable types that were used to replace others and syllable types that were replaced by others.

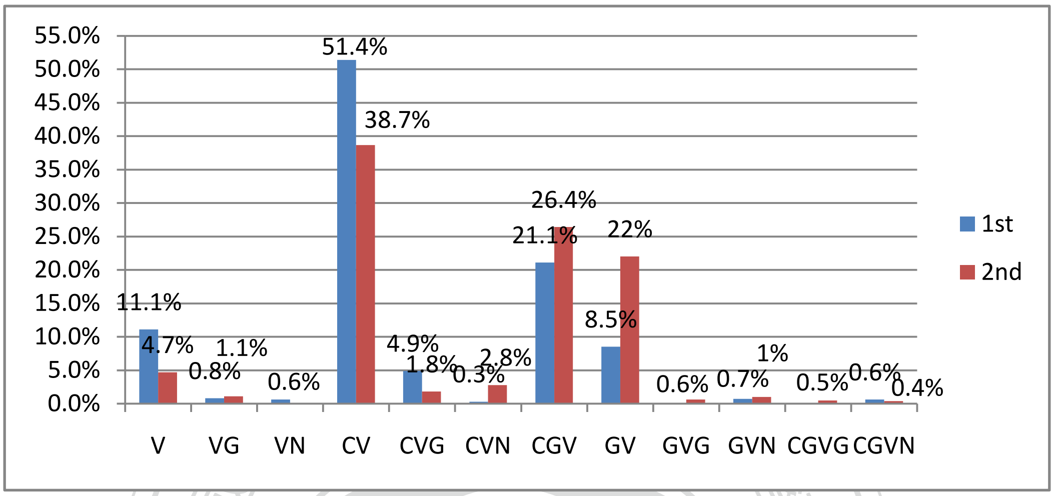

Figure 4.8 Percentages of realized syllable types in disyllabic words

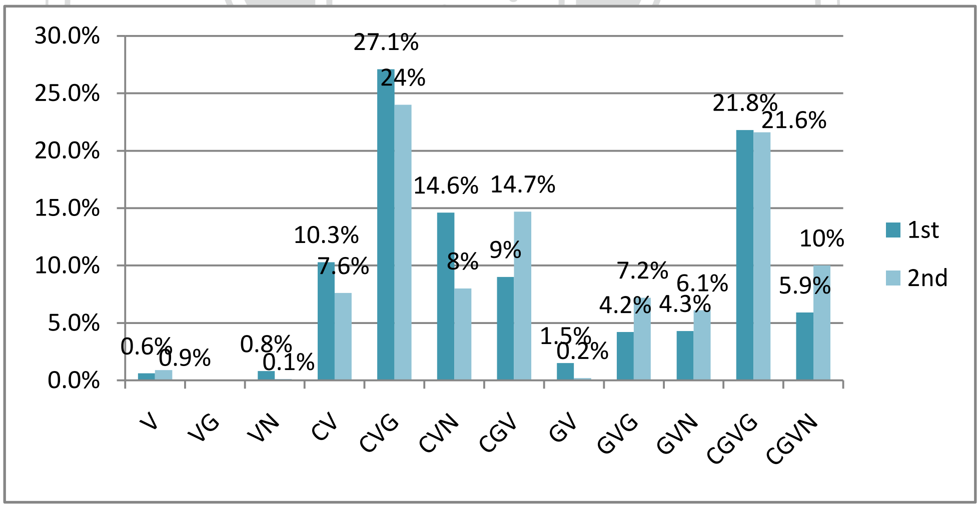

Figure 4.9 Percentages of replaced syllable types in disyllabic words

The syllable type that was most frequently used to replace others was CV in both first and second syllable, accounted for 51.4% and 38.7% respectively. CGV ranked as second place in both first and second syllable. As for syllable types that were often replaced by others, CVG and CGVG had the highest frequency in both syllable position.

To sum up, the results show that no matter in which syllable position, CV is the most frequently used syllable type in replacing others, and CVG is the syllable type that was most frequently replaced by others.

The following table presents the most frequently used substitutes for each syllable type.

Table 4.14 Preferred substitutes of each syllable type

Target	Realized	Example
CV	V	‘this’ tʂɤ51→i51
GV		
VG		
VN		
V	CV	‘peach’ t^hɑw35→t^ha35
CVG		
CVN		
CGV		
GVG	GV	‘sheep’ jɑŋ35→ja35
GVN		
CGVG	CGV	‘bear’ ɕjoŋ35→ɕjo35
CGVN		

Based on Table 4.14, there were similar patterns for the substitution of each syllable type. Firstly, children preferred to use simpler syllable types to replace others. For example, CVN was replaced by CV which contained fewer segments than target syllable. For those contained only two segments, V which contained only one segment then became the most preferred substitute. Secondly, the substitution pattern often involved coda-dropping. For example, CVG was frequently replaced by CV; CGVG was frequently replaced by CGV. Both of their substitution involved dropping the coda consonant. The findings indicate that when children producing syllable types they are not acquired yet, they tend to simplify the syllable by only dropping the coda consonant. The results also support the study of Duanmu (2007) who proposed that the prenuclear glides are not rime segments but secondary articulation on the onset. For example, the substitute of CGVG was CGV instead of CVG. The fact that deletion happened after the prenuclear glides indicated that children did not group the prenuclear with the nucleus in Taiwan Mandarin.

4.5 Relationship between frequency, variability rate, and substitution pattern

This section summarized and compared the results mentioned before. I will present the relationship between frequency and variability rate in 4.5.1, and the relationship between substitution pattern and variability rates in 4.5.2.

4.5.1 Variability rate and frequency

In order to answer the research question concerning the relationship between syllable type frequency and speech variability, the variability rate of all syllable types in monosyllabic tokens were calculated.

From comparing Figure 4.2 and Figure 4.4, it is found that syllable types that had higher frequency presented lower variability rate. The ranking of syllable type frequency in monosyllabic tokens was CV> CVG> CGV> CVN. These syllable types presented low variability rates. CV was the most frequent syllable type in children's speech and it also had lower variability rates which only accounted for 9% in monosyllabic words. The variability rates of the other three syllable types were 14.7% for CVG, 16.4% for CGV, and 16.8% for CVN. For syllable types whose frequencies were less than 2% in monosyllabic words, such as VG and CGVN, they presented higher variability rates. The findings show that syllable types with higher frequency may present lower variability rate.

Now I will turn to the focus on disyllabic words. As mentioned in 4.3.2.2, all the syllable types in first syllable presented much higher variability rates than in second syllable. The variability rates and frequencies of syllable types of different syllable position in disyllable tokens were calculated together. Figure 4.10 presents the overall frequency in disyllabic words. Their percentages have proved to present significant difference ($\chi^2_{11,0.001}$=262.7, p<.001). Figure 4.11 shows the overall variability rates in disyllabic words, and their percentages have proved to present significant difference ($\chi^2_{11,0.001}$=57.7, p<.001).

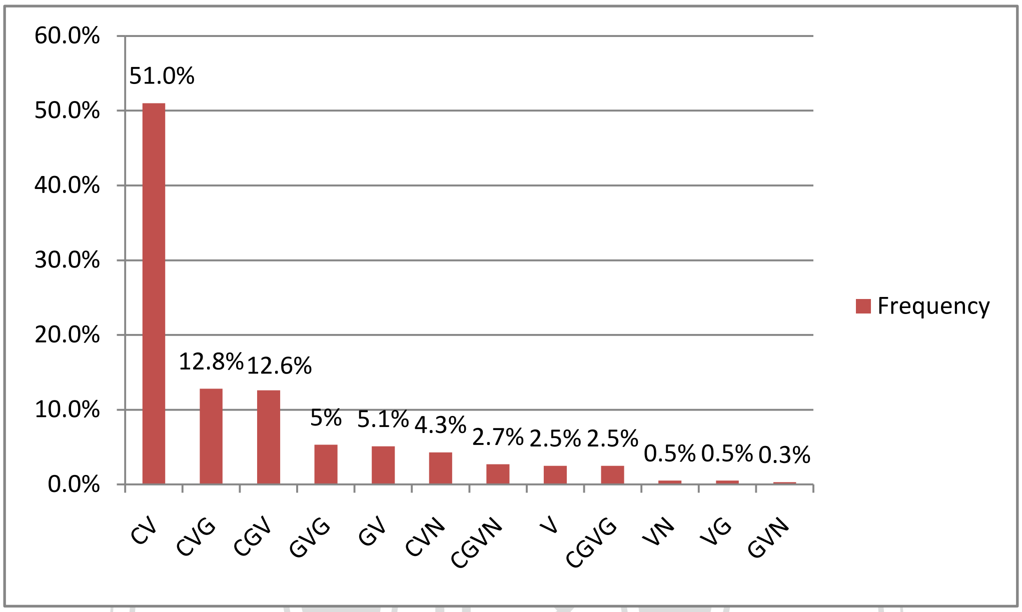

Figure 4.10 Percentages of syllable types in disyllabic words

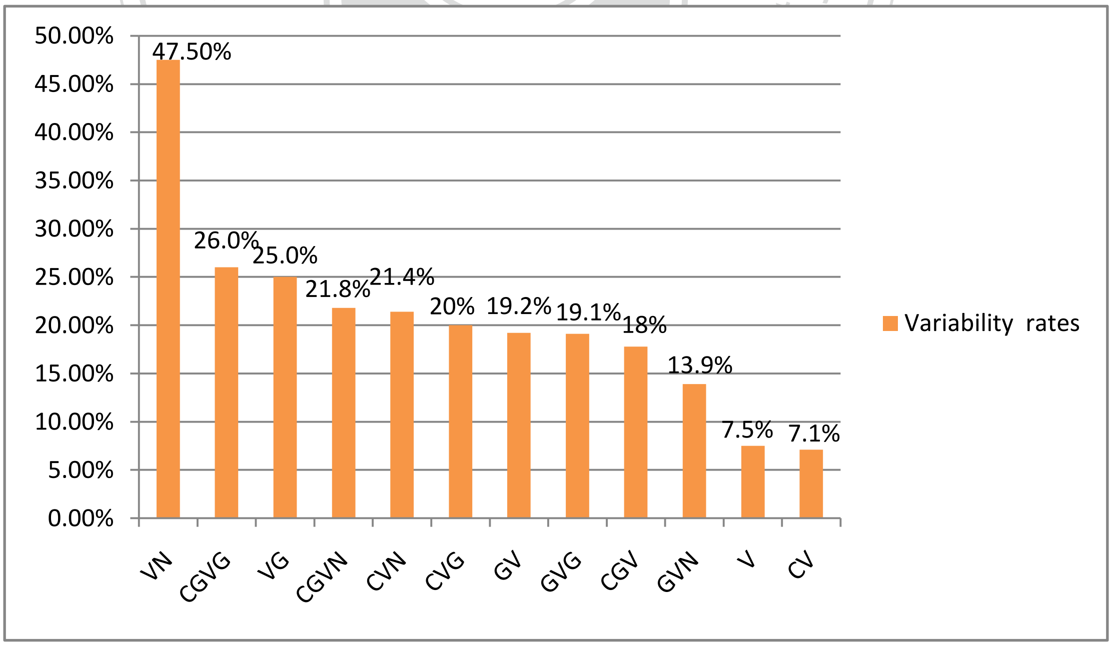

Figure 4.11 Variability rates of syllable types in disyllabic words

Similar to the results of monosyllabic tokens, CV was the most frequently used syllable type in children's speech and it also had lower variability rates which only accounted for 7.1 percent of utterances in disyllabic tokens. CGV ranked as second place in frequency, and also showed low variability rates.

Although CVG was frequently used in children's disyllabic word production, it also showed relative high variability rates in disyllabic words. The data of participants showed that when they produced words with CVG, participants often dropped the final consonant, and the same phenomenon happened in words contained CVN. So the variability rates for CVG and CVN were always higher. The results are consistent with earlier findings which suggested that coda dropping is very common in phonological acquisition (Tsay, 2007; So & Dodd, 1995).

VN and CGVG had the highest variability rates which accounted for 47.5% and 26% respectively. Not surprisingly, these two syllable types were less frequently used syllable types in the data.

To sum up, variability rates were in some extent influenced by frequency. Syllable types with higher frequency presents lower variability rates. The more the children produce a certain kind of syllable type, the lower the variability rate is.

4.5.2 Substitution pattern and frequency

The relationship between syllable type's substitution pattern and frequency is also of interest. Based on Table 4.13, children replaced the syllable types they were not mastered with CV the most, followed by CGV, GV, and V. The overall frequencies of syllable types among all the 9596 tokens was presented in Table 4.15

Table 4.15 Percentages of syllable types in all syllabic tokens

Syllable type	Tokens	Percentages
CV	3975	41.4%
CVG	1639	17.1%
CGV	1510	15.7%
CVN	526	5.4%
GVG	315	3.3%
V	497	5.2%
GV	481	5%
CGVG	253	2.6%
CGVN	232	2.4%
VG	51	0.5%
GVN	66	0.7%
VN	61	0.6%
Total	9596	

Based on Table 4.15, CV was the most frequently used syllable type with the usage of 41.1%, followed by CVG, CGV, CVN, V, and GV. The results show that children do not necessarily replace syllable types they are not mastered yet with more frequent ones. For example, CVG and CVN had higher frequency than CGV and V, but the percentage of substitution of CVG only reached 3.9% and CVN only reached

0.9%. Clearly, CVG and CVN were not frequently used in replacing. As mentioned in section 4.5.1, children tended to drop the coda consonant when producing immature syllable types. That is, they used syllable types without coda consonant to replace others more frequently, so even CVG and CVN had higher frequency, they were not frequently used to replace immature syllable type.

Chapter 5

Discussion

5.1 Summary of the findings

In this study, the phonological variability of word production by six Mandarin-speaking children aged 0;11 to 2;0 is observed. Two aspects are included: the phonological variability of words and the syllable types composed the words. We examined the frequencies, the variability rates, the substitution pattern of each syllable type, and calculated the phonological variability pattern of each participant. There were a total number of 5788 words and 9596 syllabic tokens analyzed in the study. The results and findings are summarized below:

Table 5.1 Ranking of syllable types in different measure

(1)	Syllable type frequency	CV > CVG > CGV
	Syllable combination frequency	CV-CV > CGV-CGV> CVG-CVG
(2)	Syllable type variability rate	Monosyllable: VG>CGVN>CGVG
		Disyllable: VG, VN, CGVN, CGVG
(3)	Substitution pattern	CV>CGV>GV>V

(1) Variability pattern: although each participant showed somewhat different pattern of variability, there were still some similarities. Firstly, the overall variability

patterns of six participants all showed peaks and valleys. Second, the variability rates gradually decreased as the participants grew older, and among six participants, participants #1 had the most regular decreasing pattern. Third, every participant had a noticeable variability peak at different age. The variability peaks correspond with the time when these participants entered a new stage of phonological development.

(2) Syllable type frequency: in both monosyllabic and disyllabic words, CV had the greatest frequency of occurrence, followed by CVG and CGV. CVN and GV ranked as fourth place in monosyllabic and disyllabic words respectively. For the least frequent syllable types, VG, GVN, and VN showed the lowest frequency in bout monosyllabic and disyllabic words. The frequency of GVG was relatively low, accounted for only 0.07% in first syllable, but reached 4.9% in second syllable. The production of GVG was mostly limited to second syllable, resulting in its lower frequency in first syllable. The results of syllable combinations showed that combinations presented higher frequency are those with consonant-vowel reduplicated forms.

(3) Syllable type variability rate: the results showed that the syllable types that had higher variability rates in monosyllabic words were VG, CGVN, and CGVG. In disyllabic words, VN and CGVN presented higher variability rates. CV and V

were the last two in the ranking of variability rates in both monosyllabic and disyllabic words.

(4) Substitution pattern: the ranking of syllable types that were most frequently used to replace other types was CV>CGV>GV>V, and the ranking of syllable types that were most frequently replaced by other types was CVG>CGVG>CVN. The findings suggest that the strategy participants used in replacing others was to simplify the syllable by only dropping the coda consonant.

5.2 Discussion on variability pattern

Ferguson and Farwell (1975) proposed the 'whole-word system of phonological representation.' which claimed that children are able to be aware of relatively large phonological units, such as syllables, at early stages of phonological development. When the amount of vocabulary in children's lexicon grows, phonemic representation develops since there is a need to discriminate the speech sounds efficiently in production and perception. Children's productions of each sound and each word then become more and more stable. As a result, children's phonological development is a process from whole-word representation to phonemic representation. Variability can serve as evidence since the lack of segmental phonemic representation detail in child's underlying phonological representation would result in greater degree in variability.

In this study, the overall variability patterns of each participant were examined.

Each participant in the study presented a certain amount of phonological variability during the observation. However, the variation was not unlimited. In fact, it appeared to be quite principled. As mentioned above, the variability patterns of participants showed peaks and valleys, and every participant had a noticeable variability peak. Although the variability peaks of all the participants appeared at different age, their productions exhibited great differences after the variability peaks. Participants #2, #3, and #4 started to produce two-word utterances and participants #5 and #6 produced much more different words after the variability peaks appeared.

The results may correspond to the study of Sosa and Stoel-Gammon (2006) which proposed that the increase of phonological variability at the onset of two-word combination speech reflects a reorganization of the linguistic system, from one-word stage to two-word stage. Since the phonological system are unstable, variability rates then increase. But according to Vihman (1996), the system would once again stabilize and variability would then decrease. The process may continue until children were 7 years old. Noted that the variability rates of participants were mostly high at early stage during the observation, the reason might due to the fact that the development of neuromotor control for speech is not mature yet. Children at this stage are biologically limited by the neuromotor control ability, so they cannot produce a word with a same form consistently as well as accurately (A. Smith & Goffman, 1998; Walsh& Smith, 2002).

To sum up, examining the overall variability patterns shows us the process of phonological development. At early stage of development, since the speech motor control is not mature, the variability rate is high. When children's lexicon starts to grow, their phonemic representation development then becomes mature, resulting in a more stable production of each word. However, when linguistic reorganization happens, variability rate increases again. This study did not show the once-again stabilized pattern of variability.

5.3 Discussion on syllable type analysis

The study of overall variability pattern aims to investigate the developing process of children's phonological system. Since children's early lexicon representation is the whole-word, the syllable types which composed the variable repeated words in children's speech are also of interest. Phonological variability can be attributed to many factors including the immature of speech neuromotor control, phonological complexity, and phonological overload (Holm *et al*., 2007; Macrae, 2013; McLeod & Hewett, 2008; Sosa & Stoel-Gammon, 2006 & 2012). In this study, the relationship between syllable type frequency and variability rate as well as the substitution pattern were examined.

The findings in this study can be explained by the markedness theory presented by Jakobson (1941/68) which proposed that children would acquire the unmarked form of language first, and only later acquire the more marked ones. Those phonetic forms most commonly found cross-linguistically are considered to be unmarked, and would therefore be the first to be acquired. Those who less frequently attested in the world's languages are considered to be marked, and would be acquired later. Jakobson's markedness theory of syllable can be summarized as below:

(1) Open syllable is more unmarked than closed syllable

(2) Syllable with onset is more unmarked than those without onset

(3) Syllable contained consonant cluster is marked.

5.3.1 Syllable type frequency

In this study, syllable types with higher frequency were CV, GV, CGV, and CVG, while VG, GVN and VN had lower frequency in monosyllabic words as well as in disyllable words. Among the syllable types with higher frequency, firstly, CV and GV are open syllable and they are also the only two open syllables among the 12 syllable types in Mandarin. Secondly, four of these syllable types are syllables contained onset consonants. And thirdly, three of these syllable types do not contain consonant cluster. To sum up, syllable types with higher frequency accord with the unmarked syllable criterion proposed by Jakobson, so it could be generalized that syllable types with higher frequency in this study are more unmarked syllable types.

As for syllable types with the lowest frequency in this study, all of them are closed syllable and two of them have no onset consonant. The frequency of syllable types contained consonant cluster such as CGVG and CGVN, although do not had the lowest frequency, compare to other syllable types their frequencies are still relatively low. So, again, the results might also be consistent with the constraints mentioned above, which stated that closed syllable, syllable without onset, and syllable contained consonant cluster are more marked syllable types.

5.3.2 Substitution pattern

As for substitution pattern, the ranking of syllable types that were most frequently used to replace other types was CV, followed by CGV, GV and V. Noted that the frequencies of these four syllable types were higher than other types; however, syllable types with high frequency did not necessarily used frequently in replacing others. For example, CVG had high frequency, even higher than CGV, but the percentage of CVG used in replacing others only reached 3.9%. The reason may due to the fact that coda-dropping is very common in phonological acquisition (Tsay, 2007; So & Dodd, 1995), and it was also a commonly used strategy by children in this study when replacing other types. For example, CVN was most frequently replaced by CV; CGVG was most frequently replaced by CGV. So, the strategy participants used when replacing immature syllable types was to simplify the syllable by only dropping the coda consonant. That is, syllable types that were most frequently used in replacing others are all open syllables. Furthermore, they are also syllables contained onset consonants. The results accord with McCarthy and Prince (1994), who proposed that children's early productions were governed by highly-ranked No-Coda constraints, which predicts that CV syllable types appear to be the most common output of syllable errors.

Syllable types that were frequently replaced by others were CVG, CGVG, and CVN. All of these syllable types also presents similar features: they are all closed syllables, and one of them contains consonant cluster. So, the findings of substitution pattern may indicate that children have the tendency to replace a more marked syllable type with a more unmarked one.

5.3.3 Syllable type variability

Studies have shown that phonological variability is most likely to occur when one or more aspect of the word is unstable in child's phonological system; that is, phonological elements were presented in a child's speech, but not yet mastered (Holm *et al*., 2007; Leonard *et al*., 1982; McLeod & Hewett, 2008). In this study, syllable types that had higher variability rates in monosyllabic words were VG, CGVN, and CGVG. In disyllabic words, VN and CGVN presented higher variability rates.CV and V were the last two in the ranking of variability rates in both monosyllabic and disyllabic words.

Syllable types presented higher variability rates are more marked syllables. All of them are closed syllables; VG and VN are syllables without onset; CGVG and CGVN are syllables contained consonant clusters. The results are in support of the study of Leonard *et al*. (1982). They suggested that words with higher variability rates are most often those which have more advanced forms, sounds, or word shapes. Among the syllable types with high variability rates, two of them are the most maximal syllable in Mandarin: CGVG and CGVN. So, it is much more difficult for children to master, resulting in high variability rates.

As for VN and VG, although they have relatively simple structure compared to CGVG or CGVN, they are the only two syllable types without onset consonant in Taiwan Mandarin, which are the more marked syllable types. So, it would acquired later by children. As proposed by Macrae (2013), later-acquired sounds are produced less accurately and with more variability than earlier-acquired sounds.

Comparing the syllable type frequency and variability rate, the results show that syllable types with higher frequency would present lower variability rates, and syllable types with lower frequency would show higher variability rates. For example, CV was the most frequently used syllable type in children's speech and it presented the lowest variability rates in both monosyllabic and disyllabic words. The results accord with Sosa and Stoel-Gammon (2012). They suggested that high frequency facilitates both word recognition and word production, that is, the relationship between syllable type frequency and variability rate may respond to the rule that 'practice makes perfect', so the more the children produce a certain kind of syllable type, the lower the variability rate of that type is.

5.4 Concluding remarks

The purpose of this thesis is to discuss the issue concerning phonological variability of children acquiring Taiwan Mandarin. Two aspects are included: the overall variability pattern, and the syllable types that composed the variable phonetic forms of words. The overall variability pattern, the syllable type frequency, variability rates, and the substitution pattern of immature syllable types were examined. From the analysis and discussion, the patterns of variability displayed by these children observed here indicate that variability pattern is influenced by the development of speech neuromotor control, the phonemic representation, and also the linguistic reorganization process. At early stage in phonological development, since the speech motor control is not mature, the variability rate is high. When children's lexicon starts to grow, their phonemic representation development then becomes mature. However, when linguistic reorganization happens, and in this case, the onset of two-word combination and the increased amount of different word, variability rate increases again. Presumably, the system would once again stabilize and variability would then decrease. The process may continue until children were 7 years old. This study didn’t show the once-again stabilized pattern of variability.

Concerning the syllable type frequency, variability rates, and substitution pattern, the results would be in support of the markedness theory of syllable proposed by Jakobson (1941/68). The comparison showed that syllable types with higher frequency as well as syllable types used frequently in replacing others are more unmarked ones. Syllable types with lower frequency and syllable types that were replaced by others frequently are more marked ones. Furthermore, syllable types contained more complex structure, that is, a more marked syllable, would present high variability rates. It would be beneficial for future work to trace patterns of phonological variability for more participants, for longer duration, and carefully examine the development of both variability and accuracy of individual words over time. Furthermore, comparing the syllable types used in motherese and children might also provide different view in the syllable acquisition in Taiwan Mandarin.

All in all, the findings in this thesis provide evidence of the process of phonological variability in Taiwan Mandarin

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Appendix A

The overall frequencies of syllable combination in disyllabic words

Overall frequency			
Ranking	Syllable combination	Token	Percentage
1	CV-CV	1417	37.2
2	CGV-CGV	293	7.7
3	CVG-CVG	252	6.6
4	CV-CVG	168	4.4
5	CV-CGV	136	3.6
6	GV-GV	131	3.4
7	CV-GVG	126	3.3
8	V-CV	99	2.6
9	CVG-CV	87	2.3
10	CV-CVN	81	2.1
11	CV-CGVN	76	2.0
12	CGV-CV	54	1.4
12	CVN-CVN	54	1.4
13	CV-V	51	1.3
14	V-V	44	1.2
15	CVN-CV	43	1.1
16	CVG-GVG	42	1.1
17	CV-CGVG	36	0.9
18	CVG-GV	34	0.9
18	CGV-CGVG	33	0.9
18	CGVG-CGVG	33	0.9
19	V-CGV	27	0.7
20	CV-GV	25	0.7
21	CGV-CGVN	24	0.6
22	V-CVG	22	0.6
23	V-GV	21	0.6
24	CGVN-CGVN	20	0.5
25	CVN-CGV	19	0.5
25	GV-CV	19	0.5
26	CVN-CVG	18	0.5
26	CGV-CVG	18	0.5

27	CVG-V	17	0.4
27	V-CVN	17	0.4
27	CVG-CGV	17	0.4
28	CGVG-CV	16	0.4
29	CVG-CVN	14	0.4
30	CVN-CGVN	11	0.3
30	CGVG-CGV	11	0.3
30	CGVN-CV	11	0.3
31	V-CGVN	10	0.3
31	CV-VG	10	0.3
32	CGV-GV	9	0.2
32	GV-GVN	9	0.2
32	CGVN-CVG	9	0.2
33	VN-VN	8	0.2
34	V-GVG	7	0.2
35	CGVG-V	6	0.2
35	GVN-GVN	6	0.2
36	CVN-V	5	0.1
36	GV-CGVN	5	0.1
36	GVN-CV	5	0.1
36	VG-CV	5	0.1
36	CVG-CGVG	5	0.1
36	VN-CVG	5	0.1
36	CGV-V	5	0.1
37	V-CGVG	4	0.1
37	GV-CGV	4	0.1
37	CGVN-CGV	4	0.1
37	CVG-CGVN	4	0.1
37	GV-GVG	4	0.1
37	VN-CV	4	0.1
38	CVN-GV	3	0.1
38	GV-CVG	3	0.1
38	GV-VN	3	0.1
38	VN-V	3	0.1
38	CGVN-CGVG	3	0.1
38	GVG-GVG	3	0.1
38	VG-VG	3	0.1

39	CGV-CVN	2	0.1
39	V-GVN	2	0.1
39	V-VN	2	0.1
39	CGVG-CVG	2	0.1
39	GV-V	2	0.1
39	GVN-CVN	2	0.1
39	CGV-GVG	2	0.1
39	CGVN-GVN	2	0.1
39	CV-VN	2	0.1
39	GVN-CGV	2	0.1
40	CVN-CGVG	1	0.03
40	CVG-GVN	1	0.03
40	CVN-GVN	1	0.03
40	GV-CGVG	1	0.03
40	GVN-CGVN	1	0.03
40	CGVG-CVN	1	0.03
40	CGVG-GV	1	0.03
40	GV-CVN	1	0.03
40	GVN-CVG	1	0.03
40	CGVG-CGVN	1	0.03
40	CGVN-V	1	0.03
40	GVN-CGVG	1	0.03
40	GVN GV	1	0.03
40	VG-CVG	1	0.03
40	VG-CVN	1	0.03
40	VG-GVG	1	0.03
40	VN-CGVN	1	0.03
Total		3808	100%

Appendix B

The frequencies of syllable combination in disyllabic words of each participant

Participant #1			
Ranking	Syllable combination	Token	Percentage
1	CV-CV	427	46.2
2	GV-GV	84	9.1
3	CVG-CVG	77	8.3
4	CV-CVG	47	5.1
5	CGV-CGV	43	4.6
6	GV-GV	29	3.1
7	CV-CVN	28	3.0
8	CV-CGV	25	2.7
9	CV-CGVN	20	2.2
10	CGV-CV	18	1.9
11	V-GV	13	1.4
12	V-CV	12	1.3
13	CV-CGVG	9	1.0
14	CVG-CV	9	1.0
15	CGVG-CV	8	0.9
16	V-CVG	8	0.9
17	CV-V	6	0.6
18	CGVN-CV	5	0.5
18	CV-GV	5	0.5
18	CV-GVG	5	0.5
18	CVG-CGV	5	0.5
18	CVG-CVN	5	0.5
18	V-CVN	5	0.5
19	CGV-CGVG	4	0.4
19	CGV-CGVN	4	0.4
19	CVG-GV	4	0.4
19	GV-CV	4	0.4
20	CV-VG	3	0.3
20	CVN-CGVN	3	0.3
20	GV-GVG	3	0.3
20	V-V	3	0.3

21	CVG-CGVN	2	0.2
21	CVN-CV	2	0.2
21	CVN-CVG	2	0.2
21	GV-CGV	2	0.2
21	GV-CVG	2	0.2
21	GV-GVN	2	0.2
21	GVG-GVG	2	0.2
21	V-CGVN	2	0.2
22	CGV-CVG	1	0.1
22	CGV-CVN	1	0.1
22	CGV-V	1	0.1
22	CGVG-CGVG	1	0.1
22	CGVN-CGVN	1	0.1
22	CV-VN	1	0.1
22	CVG-CGVG	1	0.1
22	CVG-GVN	1	0.1
22	CVG-V	1	0.1
22	CVN-CGV	1	0.1
22	CVN-CVN	1	0.1
22	GV-CGVN	1	0.1
22	GVN-CV	1	0.1
22	GVN-CVG	1	0.1
22	V-CGV	1	0.1
22	V-GVN	1	0.1
22	VN-CV	1	0.1
Total		925	100%
Participant #2			
Ranking	Syllable combination	Token	Percentage
1	CV-CV	247	31.9
2	CV-CGV	42	5.4
3	CGV-CGV	45	5.8
4	CVN-CVN	38	4.9
5	CVG-CV	37	4.8
6	CVG-CVG	37	4.8
7	CV-CVG	27	3.5
8	V-CV	23	3.0
9	V-V	21	2.7

10	CGV-CGVG	19	2.5
10	CVG-GVG	19	2.5
11	GV-GV	19	2.5
12	CV-GVG	16	2.1
13	CV-V	15	1.9
13	CVG-GV	15	1.9
14	CV-CVN	14	1.8
15	CV-CGVG	13	1.7
16	CVN-CV	11	1.4
17	CGVG-CGVG	9	1.2
17	CVN-CGV	9	1.2
18	CGV-CV	8	1.0
19	CV-GV	6	0.8
19	CVG-CGV	6	0.8
19	V-CVN	6	0.8
20	CGVN-CVG	5	0.6
20	CVG-CVN	5	0.6
21	CV-CGVN	4	0.5
21	V-CVG	4	0.5
22	CGV-CVG	3	0.4
22	CGV-GV	3	0.4
22	GV-CV	3	0.4
22	V-CGV	3	0.4
23	CGVN-CV	2	0.3
23	CVG-V	2	0.3
23	CVN-CVG	2	0.3
23	CVN-GV	2	0.3
23	CVN-V	2	0.3
24	CGV-CGVN	1	0.1
24	CGV-V	1	0.1
24	CGVG-CGV	1	0.1
24	CGVG-CV	1	0.1
24	CGVG-CVG	1	0.1
24	CGVG-CVN	1	0.1
24	CGVG-GV	1	0.1
24	CGVG-V	1	0.1
24	CGVN-CGV	1	0.1

24	CGVN-CGVN	1	0.1
24	CVG-CGVG	1	0.1
24	CVN-CGVN	1	0.1
24	GV-CGV	1	0.1
24	GV-CGVN	1	0.1
24	GV-V	1	0.1
24	GVG-GVG	1	0.1
24	GVN-CGVG	1	0.1
24	GVN CGVN	1	0.1
24	GVN-CVN	1	0.1
24	GVN-GVN	1	0.1
24	V-CGVG	1	0.1
24	V-GV	1	0.1
24	V-GVG	1	0.1
24	VG-CV	1	0.1
24	VG-CVG	1	0.1
24	VG-CVN	1	0.1
24	VG-GVG	1	0.1
24	VG-VG	1	0.1
24	VN-CGVN	1	0.1
24	VN-CV	1	0.1
24	VN-CVG	1	0.1
24	VN-V	1	0.1
Total		774	100%
Participant #3			
Ranking	Syllable combination	Token	Percentage
1	CV-CV	331	33.7
2	CV-CVG	67	6.8
3	CGV -CGV	57	5.8
4	CVG-CVG	52	5.3
5	CV-CGV	49	5.0
6	CV-GVG	44	4.5
7	CV-CGVN	28	2.9
7	CV-CVN	28	2.9
7	V-CV	28	2.9
8	CVN-CV	18	1.8
9	CVG-CV	17	1.7

9	GV-GV	17	1.7
10	CGV-CV	15	1.5
11	CGV-CGVN	13	1.3
11	CGVN-CGVN	13	1.3
11	CVG-GV	13	1.3
12	CGVG-CGVG	11	1.1
13	CGV-CVG	10	1.0
13	CV-GV	10	1.0
14	CV-V	9	0.9
14	CVN-CVG	9	0.9
14	V-V	9	0.9
15	CVG-GVG	8	0.8
15	GV-CV	8	0.8
15	VN-VN	8	0.8
16	CGV-CGVG	7	0.7
16	V-CGV	7	0.7
17	CVG-V	6	0.6
17	CVN-CVN	6	0.6
17	GV-GVN	6	0.6
17	V-GV	6	0.6
18	CGVG-CV	5	0.5
18	CGVG-V	5	0.5
18	V-CVN	5	0.5
19	V-CGVN	4	0.4
19	V-GVG	4	0.4
20	CGV-GV	3	0.3
20	CGVN-CGVG	3	0.3
20	CVN-CGV	3	0.3
20	GV-CGVN	3	0.3
20	GV-VN	3	0.3
20	V-CGVG	3	0.3
20	V-CVG	3	0.3
21	CGV-V	2	0.2
21	CGVN-CGV	2	0.2
21	CV-CGVG	2	0.2
21	GVN-CGV	2	0.2
21	GVN-GVN	2	0.2

21	V-VN	2	0.2
22	CGV-GVG	1	0.1
22	CGVG-CGV	1	0.1
22	CGVG-CGVN	1	0.1
22	CGVG-CVG	1	0.1
22	CGVN-V	1	0.1
22	CV-VG	1	0.1
22	CVG-CGV	1	0.1
22	CVN-CGVN	1	0.1
22	GV-CGV	1	0.1
22	GV-CVG	1	0.1
22	GV-CVN	1	0.1
22	GV-V	1	0.1
22	GVN-CV	1	0.1
22	GVN-CVN	1	0.1
22	GVN-GV	1	0.1
22	V-GVN	1	0.1
Total		982	100%
Participant #4			
Ranking	Syllable combination	Token	Percentage
1	CV-CV	208	48.4
2	CGV-CGV	108	25.1
3	CVG-CVG	41	9.5
4	V-CV	26	6.0
5	CV-CGV	8	1.9
6	CGV- CV	5	1.2
6	CV-GVG	5	1.2
7	CGVG-CGVG	4	0.9
7	CV-CVG	4	0.9
8	GV-GV	3	0.7
8	V-CGVN	3	0.7
9	CV-CGVG	2	0.5
9	VN-CV	2	0.5
10	CGV-CGVG	1	0.2
10	CGV-CGVN	1	0.2
10	CV-CVN	1	0.2
10	CV-V	1	0.2

10	CVG-CGV	1	0.2
10	CVG-CV	1	0.2
10	CVN-CVG	1	0.2
10	CVN-CVN	1	0.2
10	V-CGV	1	0.2
10	V-GVG	1	0.2
10	V-V	1	0.2
Total		430	100%
Participant #5			
Ranking	Syllable combination	Token	Percentage
1	CV-CV	68	17.1
2	CV-GVG	51	12.8
3	CVG-CVG	35	8.8
4	CV-CVG	19	4.8
5	CV-V	18	4.5
6	CVG-CV	13	3.3
7	CVN-CV	11	2.8
7	V-CGV	11	2.8
8	CGV-CGV	10	2.5
8	V-V	10	2.5
9	CV-CVN	8	2.0
9	CVN-CVN	8	2.0
10	CV-CGVG	7	1.8
10	V-CV	7	1.8
11	CV-VG	6	1.5
11	CVG-GVG	6	1.5
11	CVN-CGV	6	1.5
11	CVN-CGVN	6	1.5
12	CGV-CGVN	5	1.3
12	GV-GV	5	1.3
13	CGV-CV	4	1.0
13	CGVG-CGV	4	1.0
13	CGVG-CGVG	4	1.0
13	CGVN-CGVN	4	1.0
13	CGVN-CVG	4	1.0
13	CV-CGV	4	1.0
13	CVG-CGV	4	1.0

13	CVG-CVN	4	1.0
13	CVG-V	4	1.0
14	CGV-CVG	3	0.8
14	CGVN-CV	3	0.8
14	CVG-CGVG	3	0.8
14	CVN-CVG	3	0.8
14	CVN-V	3	0.8
14	GVN-CV	3	0.8
14	GVN-GVN	3	0.8
15	CGVN-GVN	2	0.5
15	CV-GV	2	0.5
15	CVG-CGVN	2	0.5
15	GV-CV	2	0.5
15	V-CVG	2	0.5
15	VG-VG	2	0.5
15	VN-V	2	0.5
16	CGV-CVN	1	0.3
16	CGV-GVG	1	0.3
16	CGVG-CV	1	0.3
16	CGVN-CGV	1	0.3
16	CV-VN	1	0.3
16	CVN-CGVG	1	0.3
16	CVN-GV	1	0.3
16	CVN-GVN	1	0.3
16	GV-CGVG	1	0.3
16	GV-GVG	1	0.3
16	GV-GVN	1	0.3
16	V-CGVN	1	0.3
16	V-CVN	1	0.3
16	V-GV	1	0.3
16	VG-CV	1	0.3
16	VN-CVG	1	0.3
Total		397	100%

Participant #6

Ranking	Syllable type	Token	Percentage
1	CV-CV	136	45.3
2	CGV-CGV	30	10.0

3	CV-CGVN	24	8.0
4	CVG-CVG	10	3.3
5	CVG-CV	9	3.0
5	CVG-GVG	9	3.0
6	CV-CGV	8	2.7
7	CGVG-CGV	5	1.7
7	CV-GVG	5	1.7
7	V-CVG	5	1.7
8	CGV-CV	4	1.3
8	CGVG-CGVG	4	1.3
8	CV-CVG	4	1.3
8	CVG-V	4	1.3
8	V-CGV	4	1.3
9	CGV-GV	3	1.0
9	CV-CGVG	3	1.0
9	GV-GV	3	1.0
9	V-CV	3	1.0
9	VG-CV	3	1.0
9	VN-CVG	3	1.0
10	CGV-CGVG	2	0.7
10	CV-CVN	2	0.7
10	CV-GV	2	0.7
10	CV-V	2	0.7
10	GV-CV	2	0.7
10	CVG-GV	2	0.7
11	CGV-CVG	1	0.3
11	CGV-V	1	0.3
11	CGVG-CV	1	0.3
11	CGVN-CGVN	1	0.3
11	CGVN-CV	1	0.3
11	CVG-CV	1	0.3
11	CVN-CV	1	0.3
11	CVN-CVG	1	0.3
11	V-GVG	1	0.3
Total		300	100%