A Study of Segmental and Syllabic Intervals of Canonical Babbling and Early Speech*

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ABSTRACT

Interval or duration of segments, syllables, words and phrases is an important acoustic feature which influences the naturalness of speech. A number of cross-sectional studies regarding acoustic characteristics of children's speech development found that intervals of segments, syllables, words and phrases tend to change with the growing age. One hypothesis assumed that decreases in intervals would be greater when children were younger and smaller decreases in intervals when older (Thelen ,1991), it has been supported by quite a number of researches on the basis of cross-sectional studies (Tingley & Allen,1975; Kent & Forner,1980; Chermak & Schneiderman, 1986), but the other hypothesis predicted that decreases in intervals would be smaller when children were younger and greater decreases in intervals when older (Smith, Kenney & Hussain, 1996). Researchers seem to come up with conflicting postulations and inconsistent results about the change trends concerning intervals of segments, syllables, words and phrases, leaving it as an issue unresolved. Most acoustic investigations of children's speech production have been conducted via cross-sectional designs, which involves studying several groups of children. So far, there are only a few longitudinal

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studies. This issue needs more longitudinal investigations; moreover, the acoustic measures of the intervals of child speech are hardly available. All former studies focus on word stages excluding the babbling stages especially the canonical babbling stage, but we need to find out when concrete changes of intervals begin to occur and what causes the changes. Therefore, we conducted an acoustic study of interval characteristics of segments and words concerning Canonical Babble (CB) and early speech in an infant aged from 0;9 to 2;4 acquiring Mandarin Chinese. The current research addresses the following two questions:

1. Whether decreases in interval would be greater when children were younger and smaller when they were older or vice versa?
2. Whether the child speech concerning the acoustic features of interval drifts in the direction of the language they are exposed to?

The female infant whose L1 was Southern Mandarin living in Changsha was audio- and video-taped at her home for about one hour almost on a weekly basis during her age range from 0;9 to 2;4 under natural observation by us investigators. The recordings were digitized. Parts of the digitized material were labeled. All the repetitions were excluded. The utterances were extracted from 44 sessions ranging from 30 minutes to one hour. The utterances were divided into segments as well as syllable-sized units. Age stages are 0;9-1;0,1;1-1;5, 1;6-2;0, 2;1-2;4. The subject was a monolingual normal child from parents with a good education.

The infant was audio-and video-taped in her home almost every week. The data were digitized, segments and syllables from 44 sessions spanning the transition from babble to speech were transcribed in narrow IPA and coded for analysis. Babble was coded from age 0;9-1;0 , and words were coded from 1;0 to 2;4, the data has been checked by two professionally trained persons who majored in phonetics. The present investigation is a longitudinal analysis of some temporal characteristics of the child speech during the age periods of 0;9-1;0, 1;1-1;5, 1;6-2;0, 2;1-2;4.

The answer to Research Question 1 is that our results are in agreement with neither of the hypotheses. One hypothesis assumed that decreases in intervals would be greater when children were younger and smaller decreases in intervals when older (Thelen ,1991); but the other hypothesis predicted that decreases in intervals would be smaller when children were younger and greater decreases in intervals when older (Smith, Kenney & Hussain, 1996). On the whole, there is a tendency of decrease in segmental and syllabic duration with the growing age, but the changes are not drastic and abrupt. For example, /a/ after /k/ in

Table 1 has greater decrease during 1;1-1;5, while /a/ after /p/, /t/ and /w/ has greater decrease during 2;1-2;4. /ka/ has greater decrease during 1;1-1;5, while /ta/ and /na/ has greater decrease during 2;1-2;4.Across the age periods, interval change experiences lots of fluctuation all the time.

The answer to Research Question 2 is yes. Babbling stage is a period in which the children's acoustic features of intervals of segments, syllables, words and phrases is shifted in the direction of the language to be learned, babbling and children's speech emergence is greatly influenced by ambient language. The phonetic changes in terms of duration would go on until as late as 10-12 years of age before reaching adult-like levels. Definitely, with the increase of exposure to ambient language, the variation would be less and less until they attain the adult-like competence.

Via the analysis of the SPSS 15.0, the decrease of segmental and syllabic intervals across the four age periods proves to be of no significant difference ($p>0.05$). It means that the change of segmental and syllabic intervals is continuous. It reveals that the process of child speech development is gradual and cumulative.

Key Words
segment, interval, monosyllabic words, continuity

1. Introduction

Interval or duration of segments, syllables, words and phrases is an important acoustic feature which influences the naturalness of speech. A number of cross-sectional studies regarding acoustic characteristics of children's speech development found that intervals of segments, syllables, words and phrases tend to change with the growing age. One hypothesis assumed that decreases in intervals would be greater when children were younger and smaller decreases in intervals when older (Thelen ,1991), it has been supported by quite a number of researches on the basis of cross-sectional studies (Tingley & Allen,1975; Kent & Forner,1980; Chermak & Schneiderman, 1986), but the other hypothesis predicted that

decreases in intervals would be smaller when children were younger and greater decreases in intervals when older (Smith, Kenney & Hussain, 1996). The longitudinal analysis of certain acoustic characteristics of the speech of L2 children over a period of about one and half a year showed that some older children gained rather substantial decreases across time compared to younger children. Researchers seem to come up with conflicting postulations about the change trends concerning intervals of segments, syllables, words and phrases, leaving it as an issue unresolved. Most acoustic investigations of children's speech production have been conducted via cross-sectional designs, which involves studying several groups of children. So far, there are only a few longitudinal studies. This issue needs more longitudinal investigations; moreover, the acoustic measures of the intervals of child speech are hardly available. All former studies focus on word stages excluding the babbling stages especially the canonical babbling stage, but we need to find out when concrete changes of intervals begin to occur and what causes the changes.

In examining the early part of speech development, we come to think of an interesting phenomenon called babble. Babbling is defined as reduplicated sequences of consonants and vowels. According to Oller et al., 1976), if a vocalization consists of a consonant and a vowel, infants have entered the babbling stage. Canonical bubbling (CB) is characterized by the production of well-formed syllables that have adult-like spectral properties (Kent & Bauer 1985; Oller 1986). The current research addresses the following two questions:

1. Whether decreases in interval would be greater when children were younger and smaller when they were older or vice versa?
2. Whether the child speech concerning the acoustic features of intervals drifts in the direction of the language they are exposed to?

2. Method

This part is devoted to Methodology including the description of the subject, the explanation of how the phonetic transcription was done and the use of the equipment and the script.

2.1 Subject

The female infant whose L1 was Southern Mandarin living in Changsha was audio- and video-taped at her home for about one hour almost on a weekly basis during her age range from 0;9 to 2;4 under natural observation by us investigators. The recordings were digitized. Parts of the digitized material were labeled. All the repetitions were excluded. The utterances were extracted from 44 sessions ranging from 30 minutes to one hour.

The utterances were divided into segments as well as syllable-sized units. Age stages are 0;9-1;0, 1;1-1;5, 1;6-2;0, 2;1-2;4. The subject was a monolingual normal child from parents with a good education.

Table 2-1 Frequency of /a/ in each month

Month	0;9	0;10	0;11	1;0	
Frequency	17	113	213	191	
Month	1;2	1;3	1;4	1;5	
Frequency	385	58	161	59	
Month	1;6	1;7	1;8	1;9	2;0
Frequency	69	192	115	284	82
Month	2;1	2;2	2;3	2;4	
Frequency	228	189	140	256	

In late babble from 0; 9 to 1-year old, the number of /a/ tokens is 17; 113; 213 and 191. In the first word stage from 1;2 to 1;5, the number of /a/ tokens is; 385; 58; 161 and 59 respectively. In early speech development stage from 1;6 to 2;0, the number of /a/ tokens is 69; 192;

115; 284 and 82, in the extended early speech stage from 2;1 to 2;4, the number of /a/ tokens is 228; 189; 140 and 256.

2.2 Phonetic transcription

The transcription was completed by us researchers. The data have been checked by two professionally trained persons who majored in phonetics. The intra-rater reliability was 98% and inter-rater reliability was 91%.

2.3 Equipment and the script

The camcorder is Sony HDR-HC1; the recorder is Sony IC RECORDER ICD-SX35. Cool Edit Pro.2.0 is used in dealing with the sound document.

We chose the unaspirated stops /pa/, /ta/, /ka/; nasals /ma/, /na/; glides /ja/, /wa/ from the stages of babble and early speech. Those chosen are the ones that appear in both stages. It is very hard to match the aspirated voiceless stops because of their low frequency.

We used Praat to have done the textgrids and a reliable script to get the data for further analysis. The script for measuring intervals was used. The starting and ending times of vocalic nuclei and consonants were measured from high-resolution gray-scale digital spectrograms using standard measurement criteria (Peterson & Lehiste, 1960). The measures were made while viewing a spectral peak display and a grayscale spectrogram. In addition to the application of the script, the hand measurements of steady-state times were also used to guarantee the precision and accuracy of the data if necessary. The technique that seemed to produce the best results defined steady state as the center of the sequence of seven analysis frames(56 ms) with the minimum slope in log *F 2*-log *F1* space (Miller, 1989).

3. Result and Discussion

In this section, we present the findings of the acoustic study of some vowels and consonants spanning from late babble to early speech development. We document and discuss the results of the acoustic study of some vowels and consonants.

3.1 Intervals of the Vowels

Several studies have suggested that CB and early speech development are closely related. According to Oller (1980), this is the first stage in which the child produces syllables that conform to natural language restrictions, the syllables that could be accepted from a phonological point of view. The onset of canonical babbling is a landmark event in infants' vocal development for spoken languages (Ejiri ,1998).

Here we choose several vowels from both late babble (0;9-1;0) and word stage (1;2-1;5, 1;6-2;0, 2;1-2;4) to study the changes of the interval.

Table 3-1 Mean intervals (ms) of /a/ preceded by /p/, /t/, /k/, /m/, /n/, /w/, /j/

Stage \ Sound	/p/	/t/	/k/	/m/	/n/	/w/	/j/
0;9-1;0	211	370	310	181	185	266	185
1;2-1;5	214	327	185	175	260	207	202
1;6-2;0	202	339	177	146	140	227	186
2;1-2;4	158	187	150	132	112	175	178

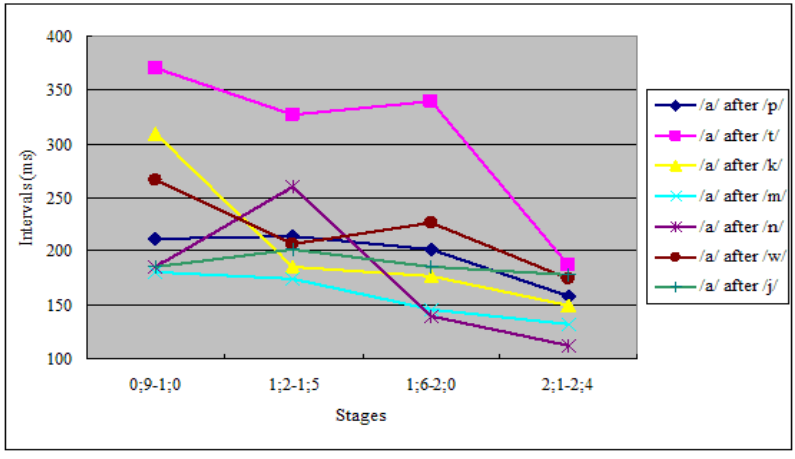

Figure 3-1 Mean intervals (ms) of /a/ preceded by /p/, /t/, /k/, /m/, /n/, /w/, /j/

Figure 3-1 shows that intervals of /a/ tend to decrease as age grows. The decreases in intervals for /a/ after /p/, /m/ and /j/ from 0;9-1;0 to 2;1-2;4 are gradual. The mean intervals of /a/ following /p/ are 211, 214, 202 and 158; for /a/ after the nasal /m/, the intervals are 181, 175, 146 and 132 respectively; the intervals of /a/ preceded by the approximant /j/ are 185, 202, 186 and 178 from 0;9 to 2;4. But /a/ after the other consonants such as /t/, /n/, /w/ has more fluctuation. /a/ after /k/, for example, has greater decrease from 310 to 185 in the former two periods, while /a/ after /p/, /t/ and /w/ has greater decrease from 202 to 158; 339 to 187; 227 to 175 respectively during the following two stages. The segmental intervals, on the whole, is on the decrease.

In terms of intervals of /a/ preceded by plosives /pa/,/ta/,/ka/, nasals /m/,/n/ and approximants /w/, /j/, the following paired sample T-test is used to analyze the tendency.

Table 3-2 Paired sample T-test result of intervals (ms) of /a/

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	LateBabble1 - EarlyWords1	.027048	.119698	.026120	-.027438	.081533	1.036	20	.313
Pair 2	LateBabble2 - EarlyWords2	.020182	.098590	.029726	-.046052	.086415	.679	10	.513
Pair 3	LateBabble3 - EarlyWords3	-.004417	.069099	.019947	-.048320	.039487	-.221	11	.829

In Pair 1, /a/ is preceded by the plosives in /pa/, /ta/, /ka/; in Pair 2, /a/ is preceded by the nasals in /ma/, /na/ ; and in Pair 3, /a/ is preceded by the approximants in /wa/, /ja/. From the table above, t=1.036, 0.679 and -0.221, Sig values are 0.313, 0.513 and 0.829 respectively. This means that intervals of the central /a/ are not statistically significant ($p>0.05$) from late babble to early words stages. Thus, it can be concluded that the change of interval decrease of /a/ is continuous regardless of the consonants preceding it.

Table 3-3 and Figure 3-2 indicate the decreasing tendency of monosyllabic intervals with the increased age as follows.

Table 3-3 Mean intervals (ms) of monosyllables /pa/,/ta/, /ka/,/ma/,/na/,/wa/,/ja/

Stage \ Sound	/pa/	/ta/	/ka/	/ma/	/na/	/wa/	/ja/
0;9-1;0	275	437	355	283	276	354	269
1;2-1;5	261	369	221	251	314	311	282
1;6-2;0	239	397	223	227	208	343	284
2;1-2;4	234	245	200	203	160	311	242

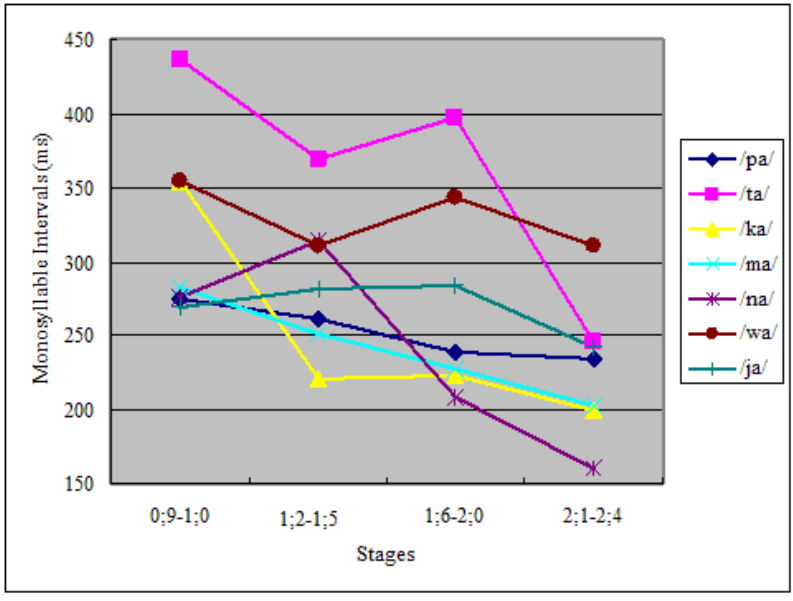

Figure 3-2 Mean intervals(ms) of monosyllables /pa/,/ta/,/ka/,/ma/,/na/,/wa/,/ja/

The change of interval decrease for /ma/ and /pa/ is steady and gradual from 0;9-1;0 to 2;1-2;4. To put it in detail, the mean intervals of /ma/ are 283, 251, 227, 203 and /pa/ 275, 261, 239, 234. Yet /ka/ has greater decrease from 355 to 221 during the age stage of 0;9-1;5, /na/ declines from 314 to 208 in the age period of 1;2-2;0, /ta/ has greater decrease from 397 to 245 during the age period of 1;6-2;4. The data indicate that the patterns of interval decrease in segments and syllables prove to be unsystematic.

Paired sample T-test is used to analyze the tendency of monosyllabic intervals from late babble to early words.

Table 3-4 Paired sample T-test result of monosyllabic intervals(ms)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair1	LateBabble1 -EarlyWords1	.023959	.058911	.012560	-.002160	.050079	1.908	20	.070
Pair2	LateBabble2 -EarlyWords2	-.00392	.03659	.010563	-.027165	.019331	-.371	11	.718
Pair3	LateBabble3 -EarlyWords3	.016143	.059135	.015804	-.018000	.050286	1.021	10	.326

*Pair 1. Plosive + /a/. Pair 2. Approximant +a/. Pair 3. Nasal + /a/.

In Pair 1, monosyllables consist of plosives and /a/; in Pair 2, monosyllables are composed of approximants and /a/; and in Pair 3, monosyllables are composed of nasals and /a/.From the table above, t=1.908, -0.371, 1.021, Sig values are 0.070, 0.718 and 0.326 respectively. This means that interval decrease of monosyllables is of no statistical significance ($p>0.05$). Thus, it can be concluded that there is a continuous relationship concerning the change of monosyllabic intervals.

Via the analysis of the SPSS 15.0, the decrease of segmental and monosyllabic intervals across the four age periods prove to be of no significant difference ($p>0.05$). It means that decrease of segmental and monosyllabic intervals in L1 development is gradual. It reveals that the process of child speech development is gradual and cumulative and the stages of language development are continuous.

In order to examine the hypothesis further, we choose /pa/ for further analysis because its production has the highest frequency in both CB/VB and early speech stages.

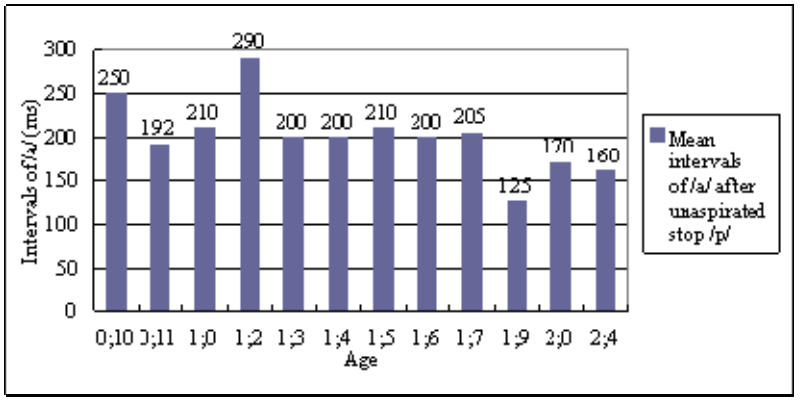

Figure 3-3 Mean segmental intervals (ms) of /a/ preceded by /p/ during 0;10-2;4.

The above figure shows that /a/ after /p/ gains greater increase from 0;11 to 1;2, but it decreases drastically from 1;2 to 1;3; from 1;7 to 2;0, the mean intervals fluctuate a lot, while the change of segmental intervals across all the other age periods is gradual. Judging from the figure in each age period, there is a general tendency to decrease in segmental intervals after 1;9. Table 3-5 and Figure 3-4 in the following show the tendency of the decreases of /i/ in interval with the increased age.

Table 3-5 Intervals (ms) of /i/ after/t^h/,/t/,/tɕ/,/tɕ^h/,/ɕ/

Stage \ Sound	/ t^h /	/t/	/tɕ/	/tɕ^h/	/ɕ/
0;9-1;0	212	221	203	377	112
1;2-1;5	277	241	282	203	183
1;6-2;0	200	278	175	230	200
2;1-2;4	100	190	150	140	93

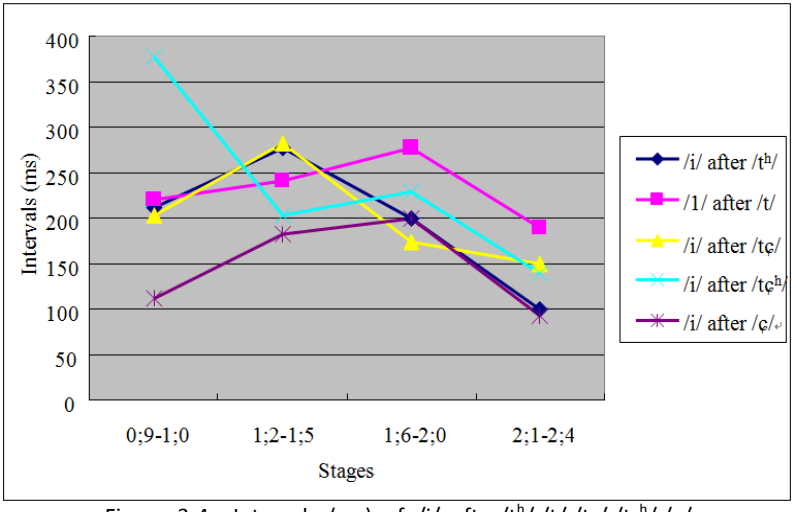

Figure 3-4 Intervals (ms) of /i/ after/t^h/,/t/,/tɕ/,/$tɕ^h$/,/ɕ/

The intervals of /i/ preceded by /t^h/, /tɕ/, /t/ and /ɕ/ increase from 0;9-1;0 to 1;2-1;5, and decline in the 2;1-2;4 period. While intervals of the vowel /i/ following /$tɕ^h$/ is decreasing greatly from 0;9-1;0 to 1;2-1;5, then it follows the same pattern with other segments. The intervals of /i/ after such consonants as /t^h/, /t/, /tɕ/, /$tɕ^h$/, /ɕ/, on the whole, tend to decrease across the four stages.

Paired sample T-test is done in terms of intervals of /i/ preceded by plosives and affricates from late babble to early words.

Table 3-6 Paired sample T-test result of intervals(ms) of /i/

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	LateBabble1 - EarlyWords1	-.056167	.083067	.033912	-.143340	.031007	-1.656	5	.159
Pair 2	LateBabble2 - EarlyWords2	.013667	.264284	.107894	-.263683	.291016	.127	5	.904

* Pair 1. /i/ preceded by plosives. Pair 2. /i/ preceded by affricates.

The table above shows that t= -1.655, 0,127, Sig values are 0.159 and 0.904 respectively. Therefore, there is no significant difference in intervals of the high vowel /i/ (p>0.05). This means that intervals of /i/ develop continuously, regardless of consonant types before them.

Table 3-7 Intervals(ms) of /ɣ/after/k/

Sound \ Stage	0;9-1;0	1;2-1;5	1;6-2;0	2;1-2;4
/k/	213	203	196	190

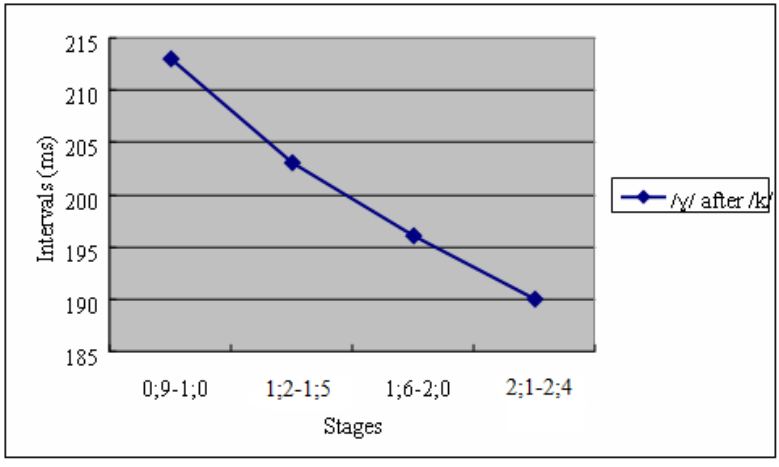

Figure 3-5 Intervals(ms) of /ɣ/after/k/

From the above table and figure, we can learn that the interval of /ɣ/ tends to decrease with the growing age. Intervals of /ɣ/ preceded by the unaspirated velar plosive /k/ keep decreasing from 0; 9-1;0 to 2;1-2;4.

Table 3-8 Paired sample T-test result of intervals (ms) of /ɣ/

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 LateBabble - EarlyWords	.010000	.144719	.064720	-.169692	.189692	.155	4	.885

* Pair 1. /ɣ/ after plosives

According to the Paired samples test, t= 0.155, Sig value of the intervals of /ɣ/ following plosives is 0.885. Thus, interval of the vowel /ɣ/ is of no statistical significance (p>0.05) from late babble to early words. This means that there is a continuous relationship in intervals of /ɣ/. The table and figure below indicate the tendency of interval changes of /u/ with the increased age.

Table 3-9 Intervals (ms) of /u/after/p/, /k/

Sound \ Stage	0;9-1;0	1;2-1;5	1;6-2;0	2;1-2;4
/p/	229	106	140	70
/k/	239	190	149	140

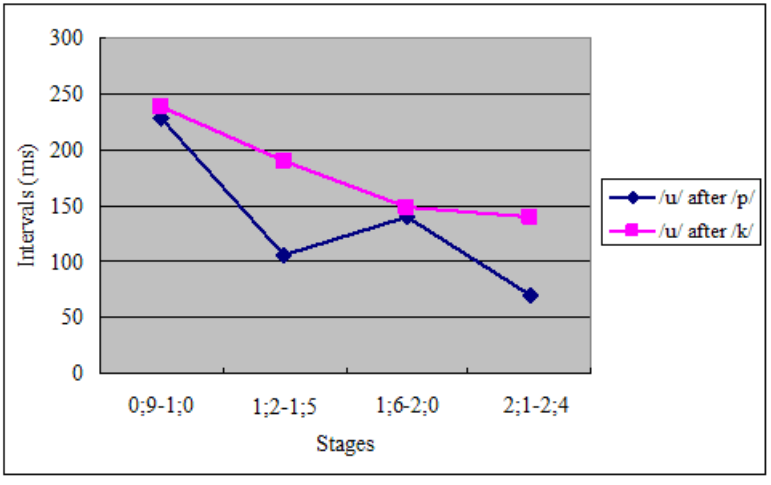

Figure 3-6 Intervals (ms)of/u/after/p/, /k/

The interval of /u/ preceded by the bilabial unaspirated plosive /p/ declines from 0;9-1;0 to 2;1-2;4 with a gradual increase in the 1;6-2;0 stage and a drastic decrease in the 2;1-2;4 stage. The interval of /u/ preceded by the velar unaspirated plosive /k/ keeps decreasing across the four stages. All in all, the intervals of /u/ tend to decrease generally.

Paired samples test is done as far as intervals of /u/ following plosives

concerned from late babble to early words.

Table 3-10 Paired sample T-test result of intervals(ms) of /u/

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 LateBabble - EarlyWords	.070857	.099117	.037463	-.020811	.162525	1.891	6	.107

* Pair 1. /u/ preceded by plosives.

The table above indicates that t=1.891, Sig value is 0.107. Thus, interval changes of the vowel /u/ are of no statistical significance (p>0.05). This indicates that intervals of /u/ develop in a continuous manner. Table 3-11 and Figure 3-7 in the following show the tendency of interval decreases of /o/ with the increased age.

Table 3-11 Intervals (ms) of /o/after/p/, /p^h/

Stage / Sound	0;9-1;0	1;2-1;5	1;6-2;0	2;1-2;4
/p/	189	176	155	134
/p^h /	180	172	163	145

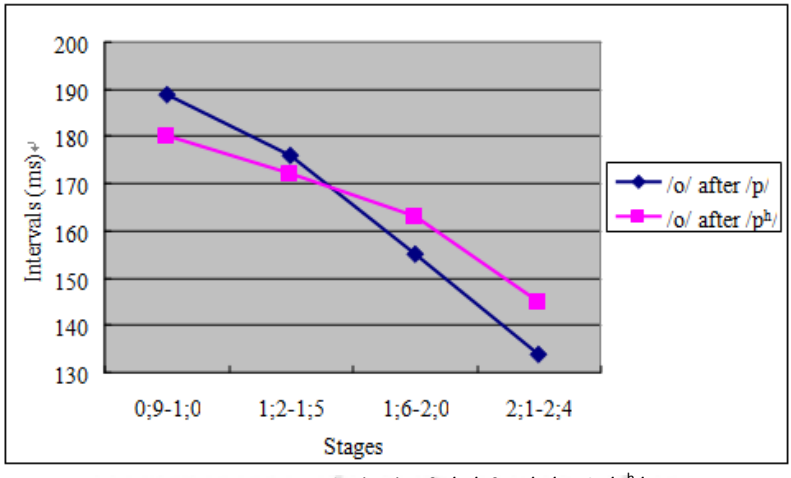

Figure 3-7 Intervals (ms) of /o/after/p/and /p^h/

The intervals of /o/ preceded by the bilabial unaspirated plosive /p/ and its aspirated counterpart /p^h/ keep decreasing from 0;9-1;0 to 2;1-2;4. The interval change of /o/ after /p/ is greater than that of /p^h/ from 0;9 to 1;5, while it is the opposite from 1;6-2;0 to 2;1-2;4.The intervals of /o/ tend to decrease generally.

Paired sample test is used in virtue of intervals of /o/ following plosives from late babble to early words. The table above indicates that t=-1.482, Sig value is 0.277. Thus, intervals of the vowel /o/ are not significant statistically (p>0.05). This means that there is a continuous relationship in interval changes of /o/, irrespective of consonant types preceding them. Intervals of /a/, /i/, /o/, /u/ and /ɣ/ are of no statistical significance from late babble to early words. This means, on the whole, vowel intervals develop along a continuous direction.

3.2 Intervals of the Consonants

Here we divide consonants into several types by manner of articulation, they are unaspirated plosive, aspirated plosive, unaspirated affricate, aspirated affricate, fricative, nasal and approximant. We then analyze intervals of these types of consonants followed by three types of vowels, specifically, they are /a/, /ɣ/ and /i/ . Table 3-12 and Figure 3-8 below demonstrate the tendency of interval change concerning five kinds of consonants preceding the low central vowel /a/ with the growing age.

Table 3-12 Intervals (ms) of the consonants before the vowel /a/

Stage \ Sound	unaspirated plosive	aspirated plosive	unaspirated affricate	aspirated affricate	fricative	nasal	approximant
0;9-1;0	64	47	0	0	66	116	80
1;2-1;5	51	42	70	72	65	92	70
1;6-2;0	49	41	70	60	33	78	50
2;1-2;4	40	40	37	40	30	60	50

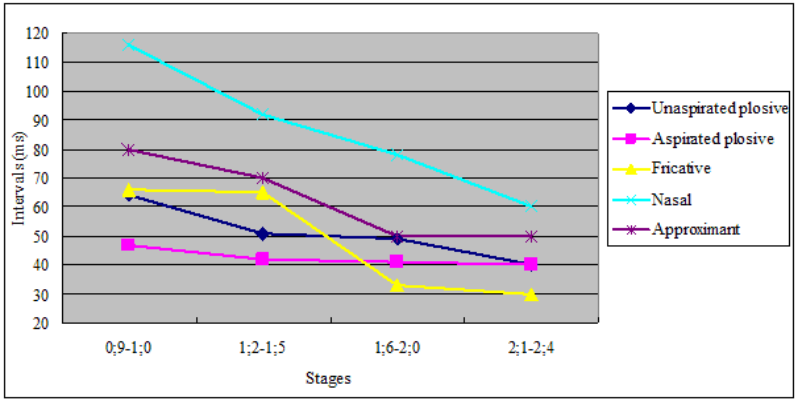

Figure 3-8 Intervals (ms) of the consonants before the vowel /a/

All of them have the trends of decreasing in intervals. Intervals of /n/ preceding /a/ from late babble to the early word stage have the biggest drop off, and the tendency of decline is continuous in the remaining stages, and that decline is great throughout all the stages. Interval changes of approximants have been declining from late babble to the early word stage, intervals of approximants have a sharp decrease from the early word stage to two-year old, after that, from 2;0 to 2;4, there is stability. The intervals of the fricatives preceding /a/ keeps decreasing. Those of the fricatives from late babble to the early word stage maintain the highest level, then there is a steep decline from 1;5 to 2;0. The decline is small from 2;0 to 2;4. Interval changes of the unaspirated plosives are of a big decline from 0;9 to 1;2 followed by a stable stage from 1;2 to 2;0. Then there is a slight decrease in intervals at 2;1 to 2;4. As to the interval change of the aspirated plosives, there is a slight decline from 0;9 to 1;2, then there is not much change during the other stages.

In terms of the intervals of the fricatives, the unaspirated plosives and nasals preceding the central vowel /a/ between late babble and early words are measured, the Paired samples test is used to analyze the tendency.

Table 3-13 Paired sample T-test result of intervals(ms) of the unaspirated plosives, fricatives and nasals preceding /a/

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	LateBabble1 - EarlyWords1	.00000	66.32119	29.65974	-82.34863	82.34863	.000	4	1.000
Pair 2	LateBabble2 - EarlyWords2	12.90909	67.60097	20.38246	-32.50586	58.32404	.633	10	.541
Pair 3	LateBabble3 - EarlyWords3	26.27273	54.91464	16.55739	-10.61943	63.16489	1.587	10	.144

* Pair 1. fricatives preceding /a/. Pair 2. unaspirated plosives preceding /a/. Pair 3. nasals preceding /a/.

The table above shows that t=0.000, 0.633, 1.587, Sig values are 0.1000, 0.541 and 0.144 respectively. This means that the interval changes of consonants are of no statistical significance (p>0.05). Thus, it means that the interval changes of the fricatives, unaspirated plosives and nasals preceding the central vowel /a/ develop continuously.

Figure 3-9 shows the tendency of interval changes of the two types of consonant preceding the central vowel /a/ with the increased age.

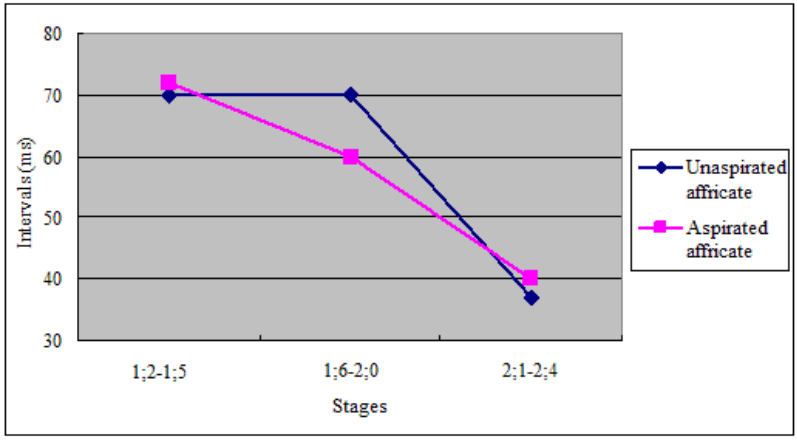

Figure 3-9 Intervals (ms) of the affricates before the vowel /a/

Figure 3-9 shows that there is not much change concerning the intervals

of unaspirated affricates before the vowel /a/ from 1;2-1;5 to 1;6-2;0, from the age of two to 2;1-2;4, there is a big fall in interval. Regarding the aspirated affricates across the three age periods, the intervals keep decreasing consistently.

Table 3-14 and Figure 3-10 below demonstrate the tendency of interval changes of the five kinds of consonants preceding the central vowel /ɣ/ with the increased age.

Table 3-14 Intervals(ms) of the consonants before the vowel /ɣ/

Sound / Stage	unaspirated plosive	aspirated plosive	aspirated affricate	fricative	nasal
0;9-1;0	61	59	125	71	58
1;2-1;5	54	56	97	65	55
1;6-2;0	44	46	86	50	82
2;1-2;4	42	40	78	60	46

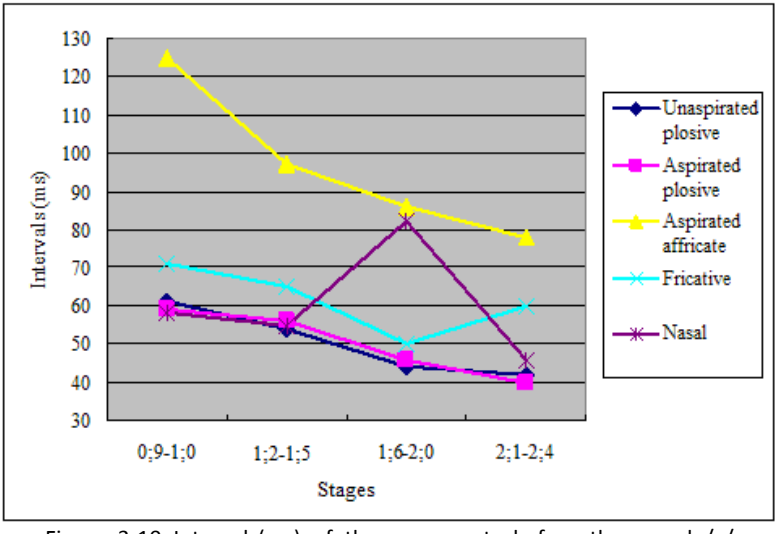

Figure 3-10 Intervals(ms) of the consonants before the vowel /ɣ/

Intervals of the plosives, unaspirated and aspirated, keep declining across the four stages with a greater decrease from 1;2-1;5 to 1;6-2;0. There

is a drastic decline of intervals of the affricates in the 1;2-1;5 stage. Intervals of the fricatives decrease significantly during the 1;6-2;0 stage. There are great changes in interval changes of nasals, that is, the intervals increase dramatically in 1;6-2;0 stage and then decline greatly in the 2;1-2;4 period. Consonantal intervals before /ɣ/, on the whole, tend to decline across the four stages.

Paired sample T-test is done regarding the intervals of the fricatives followed by the back vowel /ɣ/ concerned from late babble to early words.

Table 3-15 Paired sample T-test result of intervals (ms) of the fricatives preceding /ɣ/

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 LateBabble - EarlyWords	5.50000	59.30992	29.65496	-88.87532	99.87532	.185	3	.865

* Pair 1. fricatives preceding /ɣ/

The table above indicates that t=0.185, Sig value is 0.865, which means that interval of fricatives preceding by /ɣ/ is of no statistical significance ($p>0.05$). This indicates that intervals of fricatives preceding /ɣ/ develop in a continuous manner.

Table 3-16 and Figure 4-51 depict the interval development of seven types of the consonants followed by the high front vowel /i/ with the increased age.

Table 3-16 Intervals (ms) of the consonants before the vowel /i/

Stage \ Sound	unaspirated plosive	aspirated plosive	unaspirated affricate	aspirated affricate	fricative	nasal	approximants
0;9-1;0	25	96	83	94	76	100	50
1;2-1;5	43	87	77	80	96	83	83
1;6-2;0	39	70	46	99	113	52	50
2;1-2;4	23	50	44	65	64	60	47

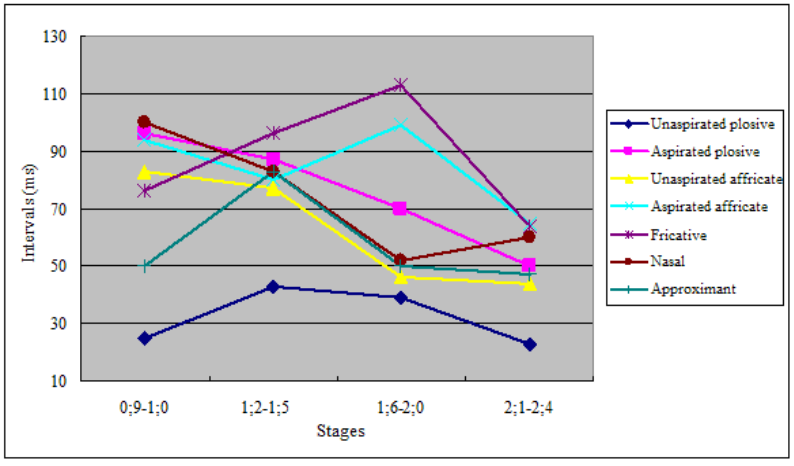

Figure 3-11 intervals of consonants before the vowel /i/

As to the aspirated plosives, its intervals keep decreasing from 0;9-1;0 to 1;6-2;0 and significantly decline during the 2;1-2;4 period. In virtue of unaspirated plosives, the intervals have a greater rise at the age of 1;2-1;5 and drop significantly at 2;1-2;4. Generally, interval of the aspirated plosives is greater than that of the unaspirated ones. There is a drastic decline of intervals of the unaspirated affricates during the 1;6-2;0 stage. Concerning the aspirated affricates, the intervals decrease drastically from 0;9-1;0 to 1;2-1;5 and from 1;6-2;0 to 2;1-2;4. Intervals of the fricatives and approximants nearly follow the same pattern, except for their interval values peak at 113 ms and 83 ms at 1;6-2;0 and 1;2-1;5 stages respectively and then decrease greatly at 2;1-2;4. Intervals of the nasals tend to decrease gradually from 0;9 to 2;0. Consonantal intervals before the front high /i/ follow the same decreasing pattern generally.

According to Paired sample T-test, t=0.279, -0.553, Sig values of the intervals of plosives and affricates preceding /i/ are 0.159 and 0.904 respectively from late babble to early words.

Table 3-17 Paired sample T-test result of intervals(ms) of the plosives and affricates preceding /i/

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	LateBabble1 - EarlyWords1	10.16667	89.12781	36.38628	-83.36723	103.70057	.279	5	.791
Pair 2	LateBabble2 - EarlyWords2	-18.50000	81.95059	33.45619	-104.502	67.50187	-.553	5	.604

* Pair 1. plosives preceding /i/. Pair 2. affricates preceding /i/

The Paired sample T-test result shows that there is no significant difference in intervals of consonants before the high front vowel /i/ ($p>0.05$). This means that consonant intervals develop continuously.Intervals of plosives, fricatives, nasals, affricates preceding /a/, /ɣ/ and/i/ are of no statistical significance from late babble to early words. This signifies that, on the whole, there is a continuous development in changes of consonantal intervals. Our data suggest that there is no significant difference ($p>0.05$) in interval changes across all the age stages, which proves the continuity of the stages in terms of interval change.

4. CONCLUSION

This paper has explored the following two questions: 1) Whether decreases in interval would be greater when children were younger and smaller when they were older or vice versa? 2) Whether the child speech concerning the acoustic features of interval drifts in the direction of the language they are exposed to?

The answer to Research Question 1 is that our results are in agreement with neither of the hypotheses. One hypothesis assumed that decreases in intervals would be greater when children were younger and smaller decreases in intervals when older (Thelen ,1991), but the other hypothesis

predicted that decreases in intervals would be smaller when children were younger and greater decreases in intervals when older (Smith, Kenney & Hussain, 1996). On the whole, there is a tendency of decrease in segmental and syllabic duration with the growing age, but the changes are not drastic and abrupt. For example, /a/ after /k/ in Table 1 has greater decrease during 1;1-1;5, while /a/ after /p/, /t/ and /w/ has greater decrease during 2;1-2;4. /ka/ has greater decrease during 1;1-1;5, while /ta/ and /na/ has greater decrease during 2;1-2;4.Thus, across the age periods, interval change experiences lots of fluctuation all the time.

The answer to Research Question 2 is yes. Babbling stage is a period in which the children's acoustic features of intervals of segments, syllables, words and phrases is continuously shifted in the direction of the language to be learned, babbling and children's speech emergence is greatly influenced by ambient language. The phonetic changes in terms of intervals would go on until as late as 10-12 years of age before reaching adult-like levels. Definitely, with the increase of exposure to ambient language, the variation would be less and less until they finally attain the adult-like competence.

Via the analysis of the SPSS 15.0, the decrease of segmental and syllabic intervals across the four age periods proves to be of no significant difference ($p>0.05$). It means that change of segmental and syllabic intervals is gradual. It reveals that the process of child speech development is gradual and cumulative.

This study is primarily exploratory in nature. The limitation of this research is that it is only based on the utterances produced by one infant. The longitudinal case study of one child is not generalizable for exploring individual differences. The findings of the study will need to be extended to larger groups of infants and could be further tested in larger, more controlled studies of infant utterances. Also future research could focus on the production patterns of infants who are learning other languages.

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