

# Development of Tone Sensitivity in Young Chinese Children

Candise Chen<sup>1</sup>, Min Wang<sup>1</sup>, Hua Shu<sup>2</sup>, Han Wu<sup>2</sup>, Chu Chu Li<sup>2</sup>

<sup>1</sup> Department of Human Development, University of Maryland, College Park, U.S.A.

<sup>2</sup> State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, China

candisec@umd.edu, minwang@umd.edu, shuh@bnu.edu.cn, wuhan\_86@126.com, aimer2006@126.com

## Abstract

We examined the development of tone sensitivity in young children who speak Beijing Mandarin as their native language. Participants included children at age 3 and 5 and adults. Analyses showed that 5-year-olds performed better than 3-year-olds in lexical tone, tone sandhi, and the neutral tone. In the lexical tone task, the older children also showed better performance in the four conditions which varied by whether onset or rime is the same or different (e.g. onset+rime+, onset+rime-, onset-rime+, onset-rime-). These results implied that by age 5, Chinese children began to develop sensitivity to lexical tone, tone sandhi, and the neutral tone.

**Index Terms:** tone, phonology, first language acquisition

## 1. Introduction

The current study examined three types of tones in Mandarin Chinese: lexical tones, tone sandhi, and the neutral tone. There are four lexical tones in Mandarin Chinese. The first tone is called the high-level tone and labeled as 1. The second tone, 2, is the high-rising; the third tone, 3, is the falling-rising; and the fourth tone, 4, is the high-falling. Tone is attached to the rime, which consists of the vowel and the ending nasal consonant in some cases. An alternation in the tone of a syllable results in the change in its meaning. For example, the syllable /ma/ can have four possible meanings when a different tone is attached to it: /ma/1 妈 “mother”, /ma/2 麻 “linen”, /ma/3 马 “horse”, /ma/4 骂 “scold”.

Research has shown that Chinese infants began to discriminate between lexical tones (speech) and musical tone (non-speech) as young as 6-9 months of age [1]. Following the developmental trajectory, researchers have found that 3-year-old children could not process rime and tone independently while 5-year-olds could (e.g. separate the fourth tone from /bu/4 不 “not”) [2]. When children enter elementary school and receive instruction in phonological decoding, their tone processing abilities would improve [3]. The current study compared tone sensitivity among children in two age groups: 3 and 5, with adult participants serving as the control group.

Besides the lexical tones, there are other types of Chinese tone such as tone sandhi and the neutral tone. The development of sensitivity to these tone properties in young children has not received much attention in the literature. Tone sandhi is defined as tonal modification on a syllable in a disyllabic word [4]. This tonal alteration is performed for phonotactic purposes and does not change the meaning of the word. There are two categories for tone sandhi. In the first category, the third tone becomes a second tone before another third tone, if they are in one meaningful unit such as disyllabic words or phrases [5]. For example, /hen/3 很 “very” and /hao/3 好 “good” combine to form /hen/2/hao/3 很好 “very good”. The second category concerns two lexical items that follow their own rules: /bu/4不 “not” and /yi/1 一 “one”. Thus, /bu/4 becomes the second tone if followed by a fourth tone. For instance, /bu/4 不 “not” and /yao/4 要 “need” combine to

form /bu/2/yao/4 不要 “do not need”. /yi/1 becomes the fourth tone before all the tones except the fourth tone. /yi/1 becomes the second tone when followed by a fourth tone [5]. For example, /yi/1 and /zu/3 组 “group” combine to form /yi/4/zu/3 一组 “one group”; /yi/1 and /kuai/4 块 “piece” combine to form /yi/2/kuai/4 一块 “one piece”.

A syllable with a neutral tone is pronounced with a shorter duration and a reduced pitch range than a syllable with one of the four lexical tones [5]. There are six categories of syllables which carry the neutral tone. The first category is the “suffix” type in which the suffix /zi/3 子 or /tou/2 头 carries the neutral tone when combined with a monosyllabic noun. Two examples are /bi/2/zi/ 鼻子 “nose” and /shi/2/tou/ 石头 “rock”. Also belonging to this category is the suffix /men/2 which carries the neutral tone when combined with a pronoun to indicate a group of people. For example, /men/2 们 “plural -s” combines with /ta/1 他 “him” and becomes /ta/1/men/ 他们 “they”. The second category is the “reduplication” type in which repeated second syllables carry the neutral tone; for example, /xing/1/xing/ 星星 “star” and /xie/4/xie/ 谢谢 “thank you”. The third category consists of a group of frequently used disyllabic words in which the second syllable carries the neutral tone. Two examples are /shi/4/qing/ 事情 “matters” and /guan/1/xi/ 关系 “relations”. Unlike the previous categories, the third category does not have a particular rule that children can memorize and apply to the syllable with the neutral tone. Children may only come to realization that these words must be pronounced with a neutral tone on the second syllable through extensive language exposure. The fourth category includes prepositions, /li/3里 “in”, /shang/4 上 “on”, /xia/4 下 “below”, /mian/4 面 “side”, and /bian/1 边 “side”, which are combined with a noun to indicate position or direction. Two examples are /jia/1/li/ 家里 “in the house” and /shu/1/shang/ 书上 “on the book”. The fifth category consists of prepositions, /lai/2 来 “coming” and /qu/4 去 “going”, which are combined with a verb or adjective to indicate a trend or process. Two examples are /jin/4/lai/ 进来 “coming in” and /chu/1/qu/ 出去 “going out”. The sixth category includes auxiliaries, /liao/3 着 “-ing”, /zhao/2 了 “-ed”, and /guo/4 过 “-ed”, which carry the neutral tone when combined with a verb to indicate past or present tense. Two examples are /ku/1/zhe/ 哭着 “crying” and /xue/2/guo/ 学过 “studied”.

To our best knowledge, no study has examined the developmental stages of tone sensitivity beyond lexical tones in Chinese children. It is still unclear that at what age children start to acquire tone sandhi and the neutral tone. Therefore, the current study sought to fill in these gaps in the literature. Previous study have found that children master the lexical tones by age 2-3 [5]. On the other hand, tone sandhi is a more difficult tonal feature than the neutral tone because, in tone sandhi, children need to know which syllable requires tonal alteration and what is the correct tone to assign to that syllable. Therefore, we predicted that children’s sensitivity of lexical tone develops first, following by their sensitivity to the neutral tone, and finally their sensitivity to tone sandhi.

## 2. Method

### 2.1. Participants

Participants consisted of three age groups of monolingual Chinese speakers: 3, 5, and adults. All participants speak Beijing Mandarin as their first language. Nineteen 3-year-olds ( $M_{\text{age in months}} = 45.0$ ,  $SD = 2.47$ , 11 boys and 9 girls) from the same kindergarten participated in the study. Forty-three 5-year-old children ( $M_{\text{age in months}} = 65.8$ ,  $SD = 2.43$ , 19 boys and 24 girls) were recruited from two different kindergartens. In one kindergarten 12 children participated while in the other 31 participated. Twenty-five adults ( $M_{\text{age in years}} = 23.0$ ,  $SD = 1.88$ , 7 males and 18 females) who are all students from Beijing Normal University participated.

### 2.2. Measures and Procedures

Children’s sensitivity to the lexical tones was measured by the oddity task adapted from Wang, et al. [6]. Children heard three syllables through a pair of headphones connected to a laptop computer. At the same time, children also saw signs of 1, 2, and 3 on the computer screen that corresponded to each syllable, respectively. Children were instructed to choose which one of the three syllables did not share the same tone with the other two by pressing the key labeled 1, 2, or 3. There were four conditions in the tone task. In the first condition, the three syllables share the same onset and rime (e.g. /hua/1, /hua/2, and /hua/1). In the second condition, the three syllables have the same rime but different onsets (e.g. /gua/1, /hua/4, and /kua/1). In the third condition, the three syllables have the same onset but different rimes (e.g. /hua/4, /hao/3, and /han/4). In the fourth condition, the three syllables have different onset and rime. (e.g. /hua/1, /shen/1, and /chi/2). There were five practice items and 48 test items, 12 in each condition. Comparing performances across conditions within each age group allowed us to examine the development of tone sensitivity in relation to the processing of segments.

Since children’s sensitivity of tone sandhi has not been studied in the literature, a new assessment was developed. Real Chinese disyllabic words were used in this measure. First, children heard two syllables separately and saw two images on the screen, a blue speaker on the far left of the screen and a red speaker on the far right. Then children were told that these two syllables would combine to make a word and their task was to judge which one of the two choices sounds more like what they would hear in everyday speech. The correct choice has tonal alternation on the correct syllable while the wrong choice does not have tonal modification. At the same time, they saw on the screen that the images of the two speakers were put together to form a new image, indicating the two syllables forming a new word. Finally, children heard two disyllabic words and saw signs of “1” and “2” corresponding to the choices, respectively. Children made a response by pressing the keys labeled “1” or “2” on the keyboard. There were two categories in this task. The first category assessed children’s sensitivity to the third tone sandhi rule. The second category assessed children’s knowledge of the tone sandhi rules with /bu/4 不 “not” and /yi/1 一 “one.” There were 4 practice items and 20 test items, 10 in each category.

The neutral tone task employed the same procedure as that in the tone sandhi task. There were six categories in this task. The first category consisted of words ending with suffix /zi/3, /tou/2, and /men/2. Suffix /zi/3 and /tou/2 carry the neutral tone when combined with a noun while suffix /men/2 carries the neutral tone when combined with a pronoun to indicate a

group of people. The second category consisted of words with two repeated syllables in which the second syllable carries the neutral tone. The third category consisted of group of frequently used words in which the second syllable carries the neutral tone. The fourth category consisted of nouns ending with a preposition carrying a neutral tone to indicate direction or position. The fifth category consisted of verbs ending with a preposition carrying a neutral tone to indicate the action of coming or going. The sixth category consisted of verbs ending with tense-marking auxiliaries /liao/3, /zhao/2, and /guo/4 that carry the neutral tone. /liao/3 and /guo/4 indicate the past tense whereas /zhao/2 represents the present tense. There were four practice items and 30 test items, five in each category.

Children were tested individually in a quiet room. All the auditory stimuli were pre-recorded by a female native speaker of Beijing Mandarin. Presentation of the stimuli was controlled and randomized by E-prime.

## 3. Results

### 3.1. Exploratory Data Analyses

Since the 5-year-old children were from two kindergartens, different instruction styles and neighborhood environment may influence test outcomes. Independent sample *t*-test showed that there was no significant difference in performance on all three tasks between children in one kindergarten and those in another (lexical tones:  $t(41) = -0.757$ , *ns*), tone sandhi:  $t(41) = -1.442$ , *ns*, the neutral tone:  $t(40) = -0.604$ , *ns*). Therefore, we combined the data from both groups for the following analyses. The data reported below are all accuracy rates. Accuracy data that was below or above two standard deviations of the cell mean were removed from analyses. Table 1 showed the performance of age 3 and 5 and adults on lexical tones, tone sandhi, and the neutral tone.

Table 1: *Descriptive statistics for the dependent variables*

Age	Lexical Tonne		Tone Sandhi		Neutral Tonne	
	M	SD	M	SD	M	SD
3	.281	.111	.550	.093	.418	.153
5	.485	.142	.644	.210	.582	.215
Adult	.957	.062	.938	.076	.833	.099

Table 1 showed that the adults performed close to ceiling in all three tasks. These results suggested that the experiments may be challenging for children, but they are reasonably easy for adults. Since the focus of the current study is on young children, we will not include the data from the adult participants in the following analyses. Since there were three answer choices in the lexical tone task, the chance level is at 0.33. For both the tone sandhi and the neutral tone tasks, there were two choices and the chance level is at 0.5. Using one-sample *t*-test, we put 0.33 as the test value to examine whether children’s performance on the lexical tone task is different from chance level. Results showed that the performance of the 3-year-olds was below chance level and the mean difference is marginally significant ( $t(19) = -1.922$ ,  $p = 0.71$ ). In comparison, the 5-year-olds performed significantly above chance level ( $t(43) = 7.166$ ,  $p < 0.001$ ). To examine children’s performance on tone sandhi and the neutral tone, we put 0.5 as the test value in one-sample *t*-test. Results indicated that the 3-year-olds’ performance on tone sandhi is significantly above chance level ( $t(19) = 2.349$ ,  $p < 0.05$ ) whereas their performance on the neutral tone task is significantly below chance level ( $t(19) = -2.344$ ,  $p < 0.05$ ). On the other hand, the

5-year-olds performed significantly above chance level for both tone sandhi ( $t(43) = 4.498, p < 0.001$ ) and the neutral tone ( $t(42) = 2.459, p < 0.05$ ).

Independent sample  $t$ -test was conducted to compare performance of the two age groups. Results showed that the 5-year-olds performed significantly better than the 3-year-olds on all three tasks: lexical tones ( $t(60) = -5.553, p < 0.001$ ), tone sandhi ( $t(60) = -2.447, p < 0.05$ ), and the neutral tone ( $t(59) = -2.991, p < 0.01$ ). These results suggested that 3-year-old children show sensitivity to tone sandhi and by age 5, their sensitivity to lexical tones and the neutral tone began to develop as well.

### 3.2. Repeated Measures ANOVA

A 2 (age 3 vs. 5) x 4 (tone conditions) repeated measures ANOVA was carried out to examine the development of lexical tone sensitivity in relation to the processing of segmental units. Age was treated as a between-subject variable while tone condition was a within-subject variable. The four conditions were: (1) syllables have the same onset and rime but different tones (onset+rime+); (2) the same onset but different rimes and tones (onset+rime-); (3) the same rime but different onsets and tones (onset-rime+); (4) different onsets, rimes and tones (onset-rime-).

There is a significant main effect for tone conditions ( $F(3, 58) = 14.805, p < 0.001$ ). Post-hoc analyses showed that all of the children performed significantly better in onset+rime+ than the other three conditions: onset+rime- ( $t(61) = 7.274, p < 0.001$ ), onset-rime+ ( $t(61) = 5.807, p < 0.001$ ), and onset-rime- ( $t(61) = 6.596, p < 0.001$ ). They also had higher accuracy rates in onset+rime- than onset-rime+ ( $t(61) = -2.344, p < 0.05$ ). However, there is no significant difference in accuracy rates between onset+rime- and onset-rime- ( $t(61) = -1.495, ns$ ). Similarly, no significant difference in performance was found between onset-rime+ and onset-rime- ( $t(61) = 0.728, ns$ ). There is a significant age effect ( $F(1, 60) = 30.008, p < 0.001$ ). Post-hoc analyses showed that the 5-year-olds performed significantly better than the 3-year-olds across all four conditions: onset+rime+ ( $t(60) = -7.631, p < 0.001$ ), onset+rime- ( $t(60) = -2.319, p < 0.05$ ), onset-rime+ ( $t(60) = -3.325, p < 0.01$ ), and onset-rime- ( $t(62) = -2.285, p < 0.05$ ).

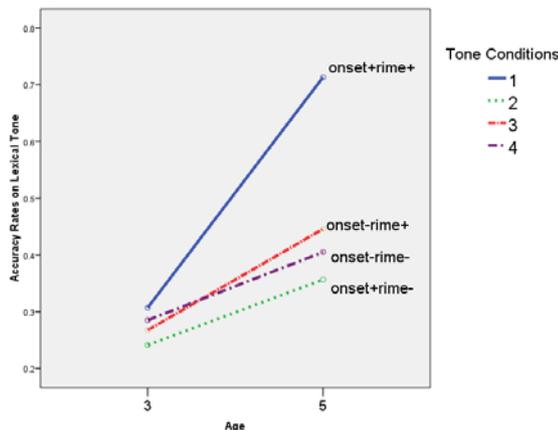


Figure 1: Interaction between age and tone conditions.

There is a significant interaction between age and tone conditions ( $F(3, 58) = 8.276, p < 0.001$ ) (Figure 1). Table 2 showed the paired sample  $t$ -tests comparing performance across tone conditions within each age group. Results showed that the 3-year-olds' performance did not differ significantly across conditions. However, in the age-5 group, accuracy rates were consistently higher in onset+rime+ than the other three conditions.

Table 2: Paired sample  $t$ -test across tone conditions.

Contrasts	Age 3		Age 5	
	$t$	$p$	$t$	$p$
onset+rime+, onset+rime-	1.564	0.135	8.226	<.001
onset+rime+, onset-rime+	0.848	0.408	6.615	<.001
onset+rime+, onset-rime-	0.664	0.515	7.866	<.001
onset+rime-, onset-rime+	-0.501	0.623	-2.463	0.018
onset+rime-, onset-rime-	-0.942	0.359	-1.188	0.241
onset-rime+, onset-rime-	-0.293	0.773	1.105	0.275

Two 2 (onset+ vs. onset-) x 2 (rime+ vs. rime-) repeated measures ANOVA was carried out to examine the development of lexical tone sensitivity within each age group. In age 3, there is no significant main effect for both onset ( $F(1, 18) = 0.007, ns$ ) and rime ( $F(1, 18) = 0.476, ns$ ). There is no significant interaction between onset and rime ( $F(1, 18) = 0.187, ns$ ). One sample  $t$ -tests showed that children's performance is not significantly different from chance level in onset+rime+ ( $t(18) = -0.609, ns$ ), onset-rime+ ( $t(18) = -1.520, ns$ ), and onset-rime- ( $t(18) = -1.154, ns$ ). Their performance is significantly below chance level in onset+rime- ( $t(18) = -2.325, p < 0.05$ ). These results suggested that sensitivity to the lexical tones may not have been fully developed in 3-year-olds. In age 5, there is a significant main effect for both onset ( $F(1, 42) = 16.496, p < 0.001$ ) and rime ( $F(1, 42) = 56.721, p < 0.001$ ). The 5-year-olds showed more accurate judgment in tone oddity when the syllables shared the same onset than when the onsets were different. Similarly, 5-year-old children showed better performance when the syllables shared the same rime than when the syllables had different rimes. One sample  $t$ -tests showed that children's performance is significantly above chance level in onset+rime+ ( $t(42) = 10.206, p < 0.001$ ), onset-rime+ ( $t(42) = 3.780, p < 0.001$ ), and onset-rime- ( $t(42) = 2.474, p < 0.05$ ). However, their performance is not significantly different from chance level in onset+rime- ( $t(42) = 0.834, ns$ ).

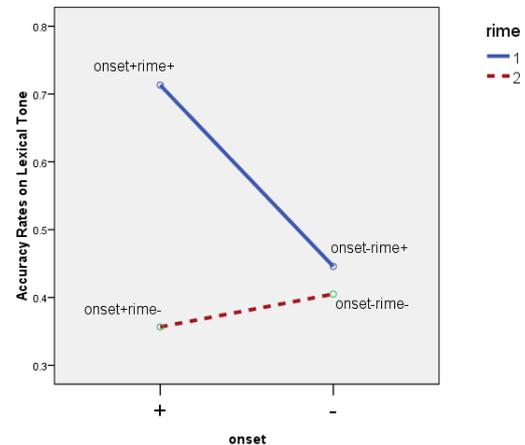


Figure 2: Interaction between onset and rime.

There is a significant interaction between onset and rime ( $F(1, 42) = 27.057, p < 0.001$ ) (Figure 2). Post hoc analyses showed that the mean differences in accuracy rates between onset+rime+ and onset+rime- is significantly different from that between onset-rime+ and onset-rime- ( $t(42) = 5.202, p < 0.001$ ). When the syllables shared the same onset, 5-year-old children performed significantly better when rime was the same than when rime was different. However, when the syllables had different onsets, the 5-year-olds' performance did not differ no matter rime was the same or not.

## 4. Discussion

The current study examined the development of tone sensitivity in young children who speak Beijing Mandarin as their first language. Results showed that 3-year-old children performed at or below chance level on the lexical tone task and the neutral tone task. However, they showed above chance level performance on tone sandhi. In comparison, 5-year-old children performed above chance level on all three tasks. In addition, 5-year-olds showed higher accuracy rates than the 3-year-olds on all three tasks. These results implied that children at age 3 may only have developed sensitivity to tone sandhi. However, by age 5, children begin to develop sensitivity to lexical tones and the neutral tone while their sensitivity to tone sandhi continues to improve.

This order of development is not consistent with our hypotheses. We predicted that tone sandhi would be the most difficult tone feature for children. Unlike the neutral tone in which tonal alternation always involve the second syllable of a disyllabic word, tone sandhi may happen on the first or second syllable. To master tone sandhi, children must know which syllable requires tonal alternation and what is the correct tone to assign on the syllable. However, results from the current study showed that 3-year-old children were capable of this two-step process. An explanation for the early development of tone sandhi sensitivity is the phonotactic properties of the third tone sandhi. The third tone has a low falling contour in connected speech while the second tone has a rising shape. It is more natural to articulate a rising tone following by a low falling tone rather than two low falling tones consecutively. Another explanation is the high frequency of the stimuli. The second category of the tone sandhi task assessed children's knowledge of the rules associated with /bu/4 不 "not" and /yi/1 一 "one." Both words are used frequently in young children's daily oral communication. Although children may not have been explicitly taught the rules of tone sandhi, they have learned that both /bu/4 and /yi/1 requires tonal modification through extensive exposure.

On the other hand, sensitivity to the neutral tone may develop later because some categories in the task may require morphosyntactic knowledge. For example, tense marking auxiliaries /liao/3, zhao/2, and /guo/4 are pronounced with a neutral tone. Three-year-old children may not know the grammar rules governing the correct assignment of tense marker to verbs. Therefore, sensitivity to the neutral tone may emerge later when children develop a better understanding of the syntactic rules in their native language. It is surprising that the 3-year-olds in the current study did not show sensitivity to lexical tones because previous research have found that children mastered all four of the lexical tones by age 2-3 [5]. A possible explanation for this discrepancy is the difference in task demand and difficulty level. Zhu and Dodd [5] studied lexical tone sensitivity by using a picture naming task which is less demanding on children's short term memory in comparison to the tone oddity task. The lexical tone task in the current study presented three syllables to the children at one time. Children must store information about these syllables in their working memory and mapped the syllables onto the corresponding response keys to make a correct judgment. In addition, there were four conditions in the task and they vary by difficulty. The easiest condition consisted of syllables that share the same onset and rime. Children were simply differentiating between the acoustic differences in tonal pitch among the three syllables. However, in conditions in which the syllables have different onsets or rimes, children must be able to process the segment and tone independently to make an accurate judgment. The demand on short term memory and 3-

year-old children's inability to separate onset and rime from suprasegmental processing may account for their below chance level performance in the lexical tone task.

On the lexical tone task, both age groups had the highest accuracy rates in judging tone oddity when the syllables shared the same onset and rime. In addition, the older children performed significantly better than the younger children across all four conditions. However, this difference in accuracy rates between age groups was the largest in the same onset and same rime condition. Within the age-3 group, having the same onset or same rime in the syllable did not give the children any advantage in judging tone oddity. This result is not surprising given that 3-year-olds' performance on the lexical tone task was below chance level. On the other hand, 5-year-old children were more accurate at judging syllables that shared the same onset or the same rime. In addition, when the syllables shared the same onset, the 5-year-olds showed more accurate judgment when rime was the same than when rime was different. However, when the syllables had different onsets, there was no difference in 5-year-olds' accuracy rates no matter the rime was the same or different.

Table 3: Mean accuracy rates across the four tone conditions

	Age 3	Age 5	Mean Difference
Onset+Rime+	0.307	0.713	-0.406
Onset+Rime-	0.241	0.357	-0.115
Onset-Rime+	0.268	0.446	-0.178
Onset-Rime-	0.285	0.405	-0.120

Table 3 showed that for both age 3 and 5, children had the lowest accuracy rates in the onset+rime- condition and the second lowest accuracy in the onset-rime- condition. The syllables in both of these conditions had different rimes. Since tone is attached to the rime, varying the rime across syllables made judgment on tone oddity increasingly difficult for young children. In addition, children in both age groups performed better in onset-rime- than in onset+rime-. This is probably because when both onsets and rimes were different, children could exclude the syllable entirely from tonal processing. However, when the syllables had the same onset but different rimes, children could not completely disregard the segmental information. As a result, the same onset became distracting and interfered with tonal judgment.

## 5. Acknowledgements

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## 6. References

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