A Study of Tone Acquisition in a Mandarin-speaking Child under Three

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Abstract

How children acquire their L1 has been predicted and explained under different hypotheses. One is the *independence hypothesis* [1] and the other is the *hypothesis of early interaction* [2]. The former claimed that L1 development is constrained by biological maturational processes, with no link to perceptual mechanisms, that is, language development is independent of linguistic environment. The latter was that perceptuo-motor attunements already operate in L1 development, so the ambient and environmental effects can be traced from an early age. Our study attempts to explore which perspective is involved in the process. We conduct an investigation on the acquisition of tone in early language development by using longitudinal data of one Mandarin-speaking child living in Changsha. The tonal acquisition process was analyzed from statistical and phonetic aspects to investigate whether Mandarin-learning infants' tonal development reflect universal or language-specific effects. Our findings reveal that the infant gains a full mastery of tone system of Mandarin till she grew to two years old, or even four months later. Also, as the subject gets more exposure to her mother tongue, her tone production gets approaching to adults', which indicates the effect of ambient language. All these lend adequate support for the hypothesis of early interaction

Index Terms: tone acquisition, children under three, southern Mandarin, the hypothesis of early interaction

1. Introduction

When it comes to phonetic and phonological acquisition, suprasegmental features are generally recognized to be acquired earlier than segmental features. Most research on infants' phonetic and phonological development concentrated on segmental features, while little attention was paid to the prosodic development of infants especially for languages other than English. Even for the small number of investigations conducted on tones, they are mostly on pitch perception at the babbling stage. For the few studies on pitch contour production at the babbling stage, they are limited to intonation like [3]. In the study of tone pattern (Japanese) available from [4], the data were not longitudinal and acoustic analysis .

The most salient result on tonal acquisition study is that tones are acquired before segmental inventories and the rising tone is acquired last. Previous Mandarin and Cantonese studies agree that children have more or less mastered the tones at a stage when segments are still quite far from adult forms [5, 6, 7].

Moreover, the issue of independent and interactional development in children's phonetic acquisition has been addressed in a huge bulk of empirical studies on the acquisition of segmentals, but little is known about suprasegmentals, such as tone in Mandarin. Whether tone in the infant's vocalizations shares some, if any, properties in the one-word stage and beyond? What kinds of mechanism are involved when the child is approaching the adult tonal system? The present study is an attempt to answer these questions.

Since the study mainly focuses on the issue of Nature or Nurture especially on verifying the *independence hypothesis* [1] and the *hypothesis of early interaction* [2], the research questions for the present study are designed as follows:

(1) At what age does the Mandarin-speaking child acquire the Mandarin tones?
(2) Of the four tones, which tone is acquired first? Is the acquisition of the rising and dipping tones more challenging for the Mandarin-speaking child under three ?
(3) Does the infant's Mandarin tone development support the independence hypothesis or the hypothesis of early interaction?

2. Method

2.1 Subject

The subject, P, was born in Changsha. At home, her parents communicated with her in Southern Mandarin. The data ranged from 01;00 to 02;04 with 14 hours of audio recordings, including 2294 recognizable utterances, in which 1268 syllables were analyzed.

2.2 Data analysis

We extracted the utterances by excluding her physiological sounds like crying, laughing, creaky and breathy ones and CV syllables were extracted by means of the narrow-band spectrogram of PRAAT aided by perception.

Since the children's vocal-cords are still in the process of maturation, and their vocalizations may be influenced by different physical and mental states even within the same session, hence, there was a necessity of F0 normalization. The method of turning normalized F0 values into relative pitch values (T values) according to scale is shown in the formula below [9, 10]:

$$T = \frac{\lg x - \lg(\min - St\min)}{\lg(\max + St\max) - \lg(\min - St\min)} \times 5 \quad (1)$$

'x' is any given point of a pitch contour, 'min' represents the minimal data of all measure points, 'Stmin' means the standard deviation of the minimal data, and 'max' means the maximal data of all, 'Stmax' represents the standard deviation of the maximal data. The output (T) is a value from 0 to 5, which is similar to the 5-point pitch scale proposed by [11].

To ensure the reliability of data analysis, we invited three postgraduate classmates majoring in Mandarin Phonetics to accomplish double-check. The intra-reliability was 96.65% and the inter-reliability was 92.5%.

The infants' tonal patterns were analyzed in terms of accuracy rate, which was calculated by using the formula below:

$$ACC_i = \frac{C_i}{O_i} \times 100 \quad (2)$$

ACC_i is the percentage of accurate production of each target tone; C_i is the total accurate tone production, O_i is the total of corresponding attempts.

There is a general agreement on F0 as perceptual correlate of tones: the relative F0 level, F0 change direction and F0 change magnitude. [12] extracted three perceptual dimensions labeled "height", "direction", and "contour". He interpreted the "height" dimension to average F0, the "direction" dimension to reflect F0 change direction, and the "contour" dimension to reflect F0 change magnitude.

Referring to the method by [13, 14], the accent range is calculated with the following formula:

Accent range = [12/log (2)] ×[log (max F0 / minF0)]

3. Results

The 4 figures below respectively depict the developmental trend of mean F0 and accent range of the four Mandarin tones.
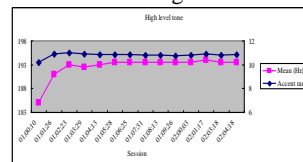

Figure1: *Statistical descriptions of mean F0 and accent range of high level tone.*

The figure above shows that before 01; 02, her development of mean F0 and accent range is not stable. Then the child made great progress and got stabilized at the age of 01;01.
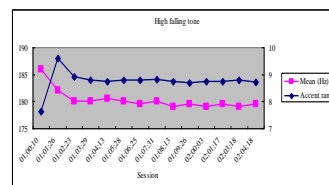

Figure 2 *Statistical descriptions of mean F0 and accent range of high falling tone.*

Figure 2 illustrates the mean F0 and accent range from 01;00;10 to 02;04;18. The age period after 01;02;23 saw a general smooth pitch curve of the tone. Both mean F0 and accent range grow steadily from 01;03, which indicates that the infant has had a full mastery of this tone.
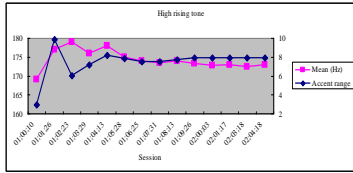
Figure 3 *Statistical descriptions of mean F0 and accent range of high rising tone.*

Figure 3 depicts the developmental trend of mean F0 and accent range of high rising tone. Similarly, mean F0 and accent range have a steady growth from 01;06 to 02;04, which means that the infant has mastered it at the age of 01;06.
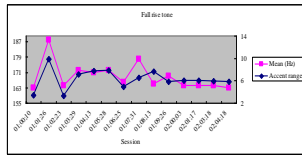

Figure 4 *Statistical descriptions of mean F0 and accent range of fall rise tone.*

The figure above displays the developmental changes of fall rise tone. The subject's mean F0 was irregular before two years and got stabilized four months later. For accent range, it also keeps changing from 01;00 to 02;00, and becomes more adult-like gradually. There are more fluctuations in the development of this tone, which may signify that the infant has more difficulties but she keeps adjusting her production to approach adults' in the acquisition process.
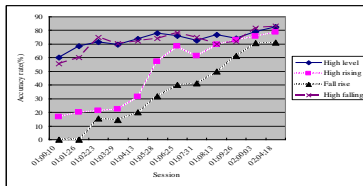

Figure 5: *Tonal accuracy rate in P's production across the 14 sessions.*

The figure above shows the developmental tendencies of the four tones in terms of accuracy rate. It can be learned that high level and high falling tones enjoys a much higher accuracy

percentage, that is,she masters the two tones at 01;01 and 01;02 respectively. The infant takes greater efforts to master the other two tones, with low accuracy rates of 21.1% and 15.4% respectively. Even as she grows to 01;02, the infant still feels hard to correctly produce high rising tone. She finally acquired high rising and fall rise tones after eight-month and four-month progress respectively.

To examine the ambient language effect, we conduct a comparison of F0 features (as represented by T-values), as shown in the figure below:
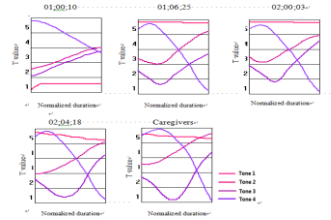

Figure 6: *Comparison in the tone contours of the infant as well as adults.*

The figure above displays the sound patterns of the four tones produced by the infant from 01;00 to 02;04. When the subject was one year old, her tone contours are much deviant from the caregivers'. After two-month progress, Tone 1 and Tone 4 developed greatly to approach adults'. The subject still has difficulty in distinguishing Tone 2 and Tone 3. At the age of 01;06, the contour and T-value of high rising tone are much similar to her parent's. At 02;00, the child has an obvious progress in dipping tone. As the subject grows to 02;04, the four tones are more stablized. On the whole, the subject acquired tone 1 and tone 4 at 01;02, high rising tone at 01;06 and fall rise tone at 02;00 basically and became much mature later.
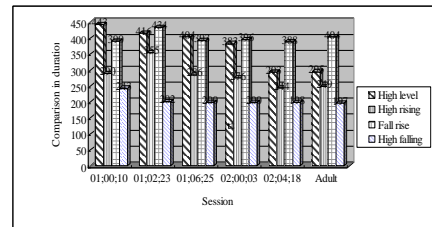

Figure 7: *Comparison in duration of the four tones produced by the infant and her parents.*

The figure above indicates the durational change of the four tones produced by the child and her caregivers. At 01;00, high level tone is the longest, followed by fall rise and high rising, high falling is the shortest, which is quite different from her parents. At 02;00, however, fall rise tone tops first in duration, followed by high level and high rising, and high falling is still the last. After four-month growth, she develops towards the level of adults greatly, which shows the great effect of ambient language.

4. Discussion

Research Question 1: Our findings show that by the end of 02;04, the subject has mastered the tone system. Statistically, the acquiring age of each tone differs and large variations in accuracy rate exist around the acquiring period.

Research Question 2: By the age of 02;04, the child has acquired the high level, high rising and high falling tones, but there is still confusion between high rising and fall rise tones, that is, she often substitutes fall rise tone for high rising tone.

Research Question 3: Our data signify that her tone production development supports the hypothesis of early interaction. As is observed from durational features and T-values, we can see the infant keeps attuning herself to her ambient language over the course of speech development. Meanwhile, mutual attunement of the infant and adults to one another's behavior is a powerful stimulus to the shared intentions of communication. This perceptual tuning directly facilitates L1 phonetic acquisition.

5. Conclusions

In this paper, we have presented longitudinal data of one Mandarin-speaking child from 01;00 to 02;04 to investigate the acquisition of tone in the children's early speech and to examine the acquisition age and order of tones.

Our findings also reveal a strong support for the hypothesis of early interaction. As the subject gets more exposure to her mother tongue, all the values of her tone production get approaching to adults', indicating the effect of ambient language.

6. Acknowledgements

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