



# Vowels and Tones in Infant Directed Speech: Hyperarticulation for Both, but Different Developmental Patterns

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## Abstract

A number of studies have shown that mothers hyperarticulate vowels in their Infant Directed Speech to their 6-month-old infants. Here we investigate the possibility that such hyperarticulation might also occur for lexical tone for mother-infant dyads in tone language environments, and possible changes in mothers' vowel and such tone hyperarticulation in IDS across the infant's first year. IDS from a total of 22 native Cantonese speaking mothers was recorded, 11 when their infants were 3-, 6-, and 9-month-old, and another 11 when their infants were 6-, 9-, and 12-month-old, and mothers asked to use nine target words in their speech; one for each of the three corner vowels /i/, /a/ and /u/, and another six for each of the Cantonese tones on the vowel /i/. Vowel hyperarticulation was investigated using first and second formant values, and tones using fundamental frequency onset and offset [1]. Preliminary results for 5 mothers presented here indicate that both vowel and tone hyperarticulation occur, but that while vowel hyperarticulation emerges around 6 months and increases from 6 to 9 to 12 month, tone hyperarticulation occurs only at 6 and 9 months. The results suggest that, as for vowels, tone space is hyperarticulated in IDS, but returns to Adult Directed Speech levels earlier for tones than vowels. Possible reasons for this are discussed, as are future studies with other tone languages with smaller tonal inventories.

**Index Terms:** Infant directed speech, vowel hyperarticulation, and tone.

## 1. Introduction

Vowel space is measured by plotting the first ( $F1$ ) and second formant ( $F2$ ) values of a given language's corner vowels, usually /i/, /u/, and /a/. Vowel hyperarticulation is measured by comparison of vowel space in a target register, e.g., Infant Directed Speech (IDS), and a comparison register, e.g., Adult Directed Speech (ADS). Vowel hyperarticulation is a well-established component of IDS. Kuhl and colleagues have found consistent vowel hyperarticulation in IDS across several languages such as in American English, Russian, Swedish and Mandarin [2, 3]. In a series of studies, Burnham and colleagues found that mothers hyperarticulate only to infants and not to pets, despite similarities in speech directed to both audiences such as heightened affect (communication of emotions) and augmented pitch modulation (gaining attention of the listener) [4], but there is a trend for mothers to hyperarticulate to parrots – animals capable of mimicking speech [5]. Moreover, speakers show vowel hyperarticulation when speaking to foreigners, despite the fact that there is no heightened affect or heightened pitch modulation [6]. There is also some evidence that vowel hyperarticulation in IDS is implicated in linguistic development – infants of mothers with higher vowel hyperarticulation showed better perceptual discrimination of consonants [3]. Taken together these

studies suggest that mothers and others are sensitive to the speech learning capabilities of their audience implicitly and adjust their speech to reflect this.

The first aim of this study is therefore to investigate whether mothers are sensitive to changes in infants' speech capabilities over age. The studies of vowel hyperarticulation in IDS have so far only concerned IDS to 6-month-olds and it is not clear whether vowel hyperarticulation emerges earlier than 6 months and continues beyond this age, especially given that developmental research has shown that between 6 and 10 months, infants appear to have grasped basic vowel awareness of their native language [7]. In the current study IDS to 3-, 6-, 9- and 12-month-olds is investigated in order to provide insight into what is happening to IDS before, during, and after critical periods of infant language development.

While vowels and consonants are used to comprise words in all languages, there is a third aspect, lexical tone [9], which is also used to distinguish words in tone languages such as Mandarin and Cantonese, which comprise over 70% of the world's languages [10], spoken by over half of the world's population [11]. However, to date, no study has examined whether the psychoacoustic space expansion shown in IDS for vowels extends to tones in tonal languages. Thus there is a complete lack of understanding of the tonal characteristics of IDS. A recently developed method for mapping Cantonese tones by fundamental frequency ( $F0$ ) onset and offset [1], allows examination of the possibility of tone space stretching analogous to vowel hyperarticulation in a tone language such as Cantonese. The second aim of the study is therefore to examine whether tone space expansion occurs in IDS in the tone language Cantonese.

Recent developmental research in tone language infants has shown that between 6 and 9 months there is perceptual reorganization for tones [9] analogous to that previously found for consonants [8], and vowels [7]. If mothers change their speech in response to their infants' growing awareness of native speech sounds, then vowel and tone hyperarticulation should occur in IDS to 6 to 10 month olds, but it is not clear whether or why vowel or tone hyperarticulation would occur before or after this period. The third aim of this study is to compare the nature of any tone hyperarticulation with vowel hyperarticulation, and to chart the development of vowel and tone hyperarticulation across the infant's first year. No studies have yet studied even vowel hyperarticulation over age of infants, and it is of particular interest here to determine whether vowel and tone hyperarticulation peak at any particular developmental period in infancy. By including 3 to 12 month olds in the study, it should be possible to determine whether vowel and tone information is exaggerated prior to 6 months, and whether either tone or vowel information continues to be hyperarticulated at 9 and 12 months. It is expected that results will complement developmental data on the perception of native vowels and tones such that we should observe both

one hyperarticulation (if present) and vowel hyperarticulation emerging at around 6 to 9 months.

## 2. Method

### 2.1. Participants and Design

A total of 22 Cantonese mothers and their infants were recruited. All mothers reported using Cantonese as the primary language to their infants, and used Cantonese as their native language. Two mothers reported that they came from Vietnam and spoke Vietnamese as well, and another two mothers reported English as their dominant language of daily use, but not with their infants in the home environment (these mothers' data are not presented here).

Infants were divided into two groups; in one each mother's speech was recorded when their infant was 3, 6, and 9 months old, and in the other when 6, 9, and 12 months old. This design was implemented for two reasons: firstly, it is more time efficient than a single group longitudinal design; and secondly and more importantly it will allow us to specify whether there are any learning, experimenter, or cohort effects due to using the same words over three time frames. The results presented here are of three mothers recorded then their infants are 3-, 6-, and 9-month-old, and two mothers when their infants are 6-, 9-, and 12-month-old. Each mother was also recorded speaking ADS on one occasion.

### 2.2. Materials

A SONY DAT recorder was used to record mothers' speech to their infants. The recordings were then digitally transferred to hard disk using Cool Edit. The speech recordings were normalized in Cool Edit and the analysis was carried out using PRAAT software.

Toys were used as aids for mothers to use in their speech to their infants and carried nine labels in Cantonese which are equivalent to: /daan/ (egg), /wu dip/ (butterfly), /duk sa/ (poisonous snake), /si zi/ (lion), /tsa sei/ (pretending to be dead), /sei/ (four), /si gan/ (clock), /sing si/ (city), /shik mhat/ (food). The first three words contrast the Cantonese corner vowels /i/, /a/ and /u/, while the last six words contrast the six tones of Cantonese, known, in Chao tone numbers [12], as tone 55, 21, 25, 23, 33, and 22 respectively. As we were not able to find a consistent CV context across all six tones appropriate for use in speech directed to infants, two words containing diphthong vowels /ei/ and one with a fricative /k/ final consonant was used.

### 2.3. Procedure

Questionnaires to collect information on infant details including any hearing problems or family history of hearing loss, as well as a detailed questionnaire on mothers' birth place, dialect spoken at home, dominant language and degree of exposure to Cantonese for each infant, together with experiment information and consent forms were distributed then collected from each participant.

During each recording session, mothers wore a lapel microphone attached to the DAT recorder and were instructed to use the nine words labeled on the eight toys in their speech to their infants. All recording sessions, including the ADS, were recorded at the infants' family home in the same rooms across sessions. During IDS recordings, mothers were instructed to use the toys provided while speaking to their infants in the same way they would normally speak to their infants. This occurred when the infants were 3-, 6-, and 9-

months-old in one group and 6-, 9-, and 12-month-old in the second group. Some mother-infant dyads required multiple visits due to various reasons, such as infants being sick, sleepy, or uncooperative. During each time frame all visits and revisits were conducted within a 14-day window, (7 days before and 7 days after the infant was to turn 3, 6, 9, or 12 months old. In the case of ADS, a native Cantonese speaker whose dominant language is Cantonese telephoned the mothers and carried out a normal adult conversation using the same words as the mothers used in the IDS conditions without the toys.

#### 2.3.1. Speech Analysis

After transferring and normalizing the recordings into a computer using Cool Edit, each vowel and tone segment was excised using PRAAT. The first and second formants and *F0*s were extracted using PRAAT for vowel and tone analysis respectively. The vowel triangle areas were converted into Mels (perceptual unit) by using *F1* and *F2* values of /a/, /i/, and /u/ for each mother across three IDS time frames and ADS.

A similar method where *F0* values of tones 1 (55), 2 (21), and 4 (23), the most dispersed tones in Cantonese [1], were plotted by onset and offset was used to specify the tone space area for each mother across the three time frames for IDS and ADS. The areas of the triangles for each mother by the four speech conditions were calculated and compared for analysis. Unlike formants for vowels which were converted to perceptual units (Mels), the *F0* values were not standardized across participants, as it is not clear whether such methods (such as a z-score method) can be used effectively across speech registers. In future analysis we may attempt to standardize within speech registers.

## 3. Results

The results of five mothers are presented here.<sup>i</sup> Plots for vowel and tone hyperarticulation are shown in Figures 1 to 4 and in Table 1 the values for vowel and tone triangle areas for each mother across age (ratio of IDS of each age by ADS), are presented.

While there is no marked hyperarticulation for vowels or tones at 3 months, the results from the two groups combined indicate that there is some degree of tone hyperarticulation at 6 and 9 months, but returns to 3 month levels before 12 months. The results from the two groups also indicate that vowel hyperarticulation emerges at around 6 months and continues to increase through 9 and 12 months.

## 4. Discussion

These preliminary results are consistent with previous studies of vowel hyperarticulation at 6 months [2, 3, 4, 5], but also add to that knowledge by clarifying a pattern and developmental course for the phenomena. The results show that while vowels and tones are not hyperarticulated at 3 months, both tone and vowel spaces are stretched in IDS after that age. Vowel hyperarticulation emerges around 6 months and continues to increase until 12 months. On the other hand, tone hyperarticulation is apparent only at 6 and 9 months, and by 12 months returns to level similar to that at 3 months.

Vowel hyperarticulation, which emerges in IDS to 6-month-olds, continues well into the first year and possibly beyond the maximum age in this study, 12 months. Although,

Table 1. *Vowel and tone areas by mother and conditions (maxima indicated in bold).*

	MC		MK		MJ		MT		MA		By Age	
AGE	Vowel	Tone	Vowel	Tone	Vowel	Tone	Vowel	Tone	Vowel	Tone	Vowel	Tone
3mo	1.19	1.70	1.44	0.60	0.80	6.69					1.14	3.00
6mo	1.15	<b>16.91</b>	<b>3.96</b>	<b>1.50</b>	0.75	<b>6.75</b>	1.96	0.10	1.45	<b>19.77</b>	1.85	<b>9.01</b>
9mo	<b>1.48</b>	1.40	3.85	1.63	<b>1.33</b>	5.29	2.61	<b>2.05</b>	1.27	3.83	2.11	2.84
12mo							<b>3.19</b>	0.60	<b>1.87</b>	5.74	<b>2.53</b>	3.17

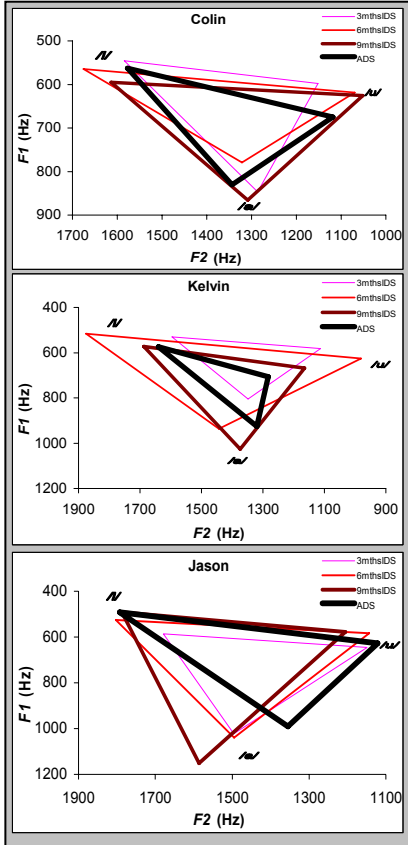


Figure 1: Vowel triangles for mothers in group1.

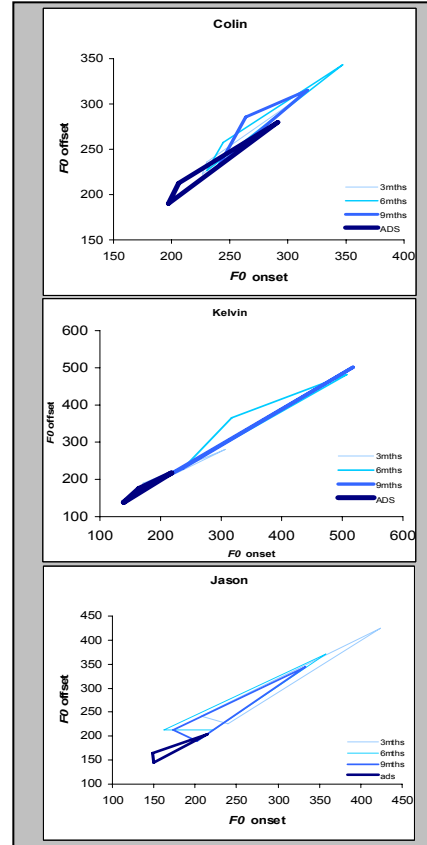


Figure 2: Tone triangles for mothers in group1.

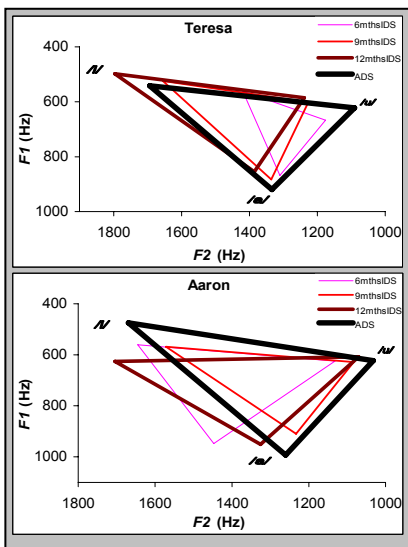


Figure 3: Vowel triangles for mothers in group2.

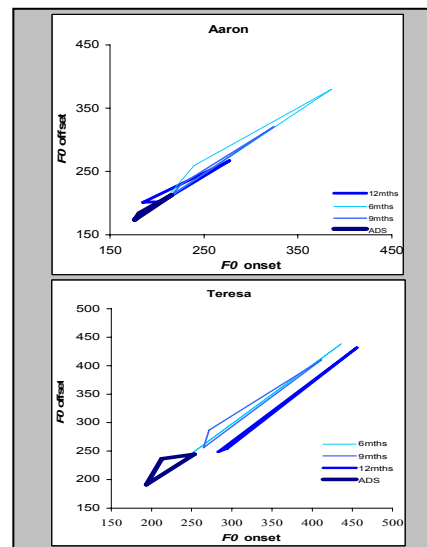


Figure 4: Tone triangles mothers in group2.

like vowels, tones are also hyperarticulated in IDS, the two phenomena follow a different course in that tone hyperarticulation peaks earlier than vowel hyperarticulation and then drops off. However, on the basis of the data here alone it cannot definitely be concluded whether the two types of hyperarticulation are independent phenomena.

This is the first time that hyperarticulation in IDS has been collected in a longitudinal developmental design. The findings here are compatible to some degree with developmental patterns in perception studies demonstrating that within the first 6 to 10 months [7], infants appear to have grasped basic vowel awareness in their native language, and between 6 to 9 months tone environment infants show awareness of tones [13]. Over and above this the apparent differences in the time course for the two types of hyperarticulation beg explanation. It is possible that tone language speaking mothers need to differentiate clearly between *tone* and *intonation*, given the especially exaggerated intonation in IDS. Also given that there are fewer tones than vowels it maybe an easier and or a faster process to specify and convey to a recipient tones than vowels in IDS, and this is supported by studies that show in later development, tone production is completed earlier than vowel production [14].

Future studies should examine whether a similar pattern of tone and vowel hyperarticulation occurs in other tone languages such as Thai and Mandarin to clarify whether the patterns of hyperarticulation found here extend to tone languages with different numbers of tones and vowels.

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## 6. References

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<sup>i</sup> The full set of longitudinal data from some mothers has not yet been completed; full data from five mothers' speech has been analyzed and their results presented here.