Published in final edited form as:
J Child Lang. 2009 September ; 36(4): 909. doi:10.1017/S030500090800929X.

Age-related Changes in Acoustic Modifications of Mandarin Maternal Speech to Preverbal Infants and Five-Year-Old Children: A Longitudinal Study

Huei-Mei Liu,
Department of Special Education, National Taiwan Normal University

Feng-Ming Tsao, and
Department of Psychology, National Taiwan University

Patricia K. Kuhl
Institute for Learning and Brain Sciences, University of Washington, USA

Huei-Mei Liu: liumei@ntnu.edu.tw; Feng-Ming Tsao: tsaosph@ntu.edu.tw; Patricia K. Kuhl: pkkuhl@u.washington.edu

Abstract

Acoustic-phonetic exaggeration of infant-directed speech (IDS) is well documented, but few studies address whether these features are modified with a child's age. Mandarin-speaking mothers were recorded while addressing an adult and their child at two ages (7-12 months and 5 years) to examine the acoustic-phonetic differences between IDS and child–directed speech (CDS). CDS exhibits an exaggeration pattern resembling that of IDS—expanded vowel space, longer vowels, higher pitch, and greater lexical tone differences—when compared to ADS. Longitudinal analysis demonstrated that the extent of acoustic exaggeration is significantly smaller in CDS than in IDS. Age-related changes in maternal speech provide some support for the hypothesis that mothers adjust their speech directed toward children as a function of the child's language ability.

Introduction

Despite documentation of the near-universal linguistic and prosodic features contained in infant-directed speech (IDS) (Fernald & Simon, 1984; Snow, 1994), there is little data on how adult speech directed toward children is modified as children develop. IDS has been characterized as communication that is listener-oriented, and communication that attracts infants' attention; it is also hypothesized to assist language development (Cooper, Abraham, Berman, & Staska 1997; Fernald, 1991; Grieser & Kuhl, 1988). The language abilities of preschool children are still developing; age-related changes in maternal speech addressing children could therefore be examined if a longitudinal design was used to record mothers talking to the same child at different ages during childhood.

Studies have demonstrated a general tendency for adults to adjust the linguistic complexity of IDS, especially the semantic and pragmatic features, in accord with an infant's age and stage of language development (Brousseau, Malcuit, Pomerleau, & Feider, 1996; Cross, 1977; Murray, Johnson, & Peters, 1990; Snow, 1994). However, some studies show no age-related adjustments in the syntactic features of IDS (e.g., Kavanaugh & Jirkovsky, 1982; Newport,

Correspondence concerning this article should be addressed to Huei-Mei Liu, Department of Special Education, National Taiwan Normal University, Taipei, TAIWAN. liumei@ntnu.edu.tw.

Gleitman, & Gleitman, 1977). Whether maternal speech input is generally fine-tuned to a child's age or language level is therefore still debatable.

The prosodic features of IDS also exhibit age-related changes (e.g., Garnica, 1977; Kitamura & Burnham, 2003; Stern, Spieker, Barnett, & Mackain, 1983), but the association may not be straightforward. In a longitudinal study (Stern et al., 1983), the pitch range in IDS was more exaggerated for infants at specific ages (four-month-old) than for either younger (newborn) or older children (12 & 24 months). An explanation offered for this age-specific prosodic modification is the child's linguistic development: a lower level of IDS stimulation is sufficient to keep a newborn alert, whereas greater diversity in pitch is needed to encourage four-month-old infants to vocalize, and IDS is neither the primary cue to alertness nor vocalization in older infants (Stern et al., 1983). Another study (Kitamura & Burnham, 2003) reported that mothers adjust their pitch level and pitch range to infants at birth, 3, 6, 9, and 12 months to indicate the mother's communicative intent. For example, mothers tend to use higher mean F0 to convey a positive affect in their phrases addressed to 6- and 12-month-olds, and use more directive utterances with greater F0 range and lower mean F0 in speech directed towards 9-month-olds. These studies support the idea that maternal speech patterns complement infant's changing language abilities during the first year of life.

Studies of age-related changes in CDS for children beyond two years of age have also produced mixed results. Garnica (1977) found that mothers used higher pitch, wider pitch range, more final-rising in imperative sentences, and more whispers when interacting with two-year-olds than with five-year-olds. In contrast, Warren-Leubecker and Bohannon (1984) reported no age-related changes; mothers modified their prosody equally when speaking to two- and five-year-olds. In a small group of longitudinal subjects, Japanese parents tended to use higher pitch in IDS than ADS when addressing their 0;0-1;6 children. While parents' pitch height decreased with infant age from 0;0-1;6, parents did not elevate pitch significantly when addressing their 1;7-5;0 children (Amano, Nakatani, & Kondo, 2006).

The speech recording conditions provide one possible explanation for this inconsistency among studies. Garnica (1977) collected maternal speech samples in the laboratory as mothers helped their five-year olds perform a highly structured task, and this more information-oriented activity may have elicited speech that did not emphasize IDS characteristics. In contrast, Warren-Leubecker and Bohannon (1984) recorded speech samples during free play at the child's home, in which a higher proportion of social regulatory speech was elicited. Mothers generally use social regulatory speech more when talking to younger children than to older children, and also use a greater pitch range in regulating children's social behaviors than in informational speech (Fernald, 1991). It is possible therefore that both the pragmatic context of recordings and children's ages affected the pitch features of maternal speech.

In addition to prosodic modifications used when addressing infants, recent studies show that the acoustic-phonetic features of IDS are exaggerated when compared to ADS. The acoustic vowel space enclosed by the three point vowels (/i/, /a/, and /u/) is expanded in IDS vs. ADS across many languages (e.g., English, Swedish, Russian, Mandarin) (Burnham, Kitamura, & Vollmer-Conna, 2002; Kuhl et al., 1997; Liu, Kuhl, & Tsao, 2003). Liu et al. (2003) show that the vowel expansion in IDS does not differ with infant's age during the first year of life; that is, the vowel space area of IDS is similar in Mandarin IDS to 6-8 and 10-12 month-olds. No studies have examined vowel expansion for older children. Moreover, it has been shown that the degree of vowel space exaggeration in IDS is positively associated with infants' speech discrimination performance for native phonetic contrasts in both age groups, suggesting that IDS's more clearly articulated speech may facilitate infants' early phonetic learning (Liu et al., 2003). If phonetic exaggeration facilitates language learning at all levels (e.g., articulation, semantics, and pragmatics), vowel space expansion observed in IDS should extend beyond the

first year of life because preschool children's language skills are still developing. Alternatively, the extent of vowel acoustic expansion in maternal speech may be reduced as children age because the expansion may especially support phonetic learning and five-year-old children's phonetic development is quite advanced.

The exaggeration seen in IDS for vowels, and observed across languages, is not limited to vowels. Additional phonetic features in different language systems have also shown this exaggeration. For example, lexical tones, essential phonetic units signaling syllable lexical meaning in tonal languages, are also exaggerated in IDS. Maternal speech in Mandarin and Thai, both tonal languages, shows an elevated pitch and expansion of the pitch contours over syllables, phrases and sentences (e.g., Grieser & Kuhl, 1988; Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002; Liu, Tsao, & Kuhl, 2007). However, the prosodic modifications made by mothers to emphasize the distinctions that are critical phonetically did not distort the F0 contour shape that is crucial to lexical meaning at the syllable level. For example, the “turning point,” the point in time at which the F0 direction changes from falling to rising in the vocalic segment, a feature critical to lexical tone, is not altered in IDS (Liu et. al., 2007). Thus the modification of IDS selectively emphasizes phonetic differences for young children.

Age-related changes in IDS pitch height and range that have been observed in tone languages show interesting differences that merit further study. Pitch modifications in suprasegmental units (i.e., words and phrases) in Thai IDS were shown to change with age during the second-half of the first year of life (e.g. Kitamura and Burnham, 2003), but infant age during the first year did not affect pitch modifications for lexical tones at the syllable level in Mandarin IDS (Liu et. al., 2007). No studies have explored both segmental (e.g., vowel) and suprasegmental (e.g., lexical tone) modifications beyond the child age of 1 year.

The present study had two goals. First, we examined whether the acoustic-phonetic features of vowels and lexical tones are modified in Mandarin CDS addressed to five-year-old children relative to ADS. There are inconsistent findings about whether CDS to five-year-olds exhibits any prosodic modifications (e.g., Amano et al., 2006; Garnica, 1977). Second, we examined whether the extent of acoustic-phonetic modification in maternal speech addressing children varies with age using a longitudinal design at two ages: preverbal infants vs. five-year-olds.

Regarding the first goal, we hypothesized that CDS would differ from ADS, reflecting the fact that at the age of five, children are still developing their language abilities. Regarding the second goal, we hypothesized that there are age-related differences in the acoustic-phonetic features of maternal speech addressed to children at the pre-verbal versus five-year-old stage. Specifically, the extent of speech exaggeration, measured both in vowels (i.e, vowel space and duration) and in lexical tone at the syllable level (i.e., pitch height and range), were hypothesized to be reduced as a function of age as children develop from 7-12 months to 5 years of age. A strength of the design used to test the hypothesis in the present experiment is the use of both acoustic parameters of vowel expansion and lexical tone expansion in Mandarin CDS as dependent variables and a longitudinal design which reduces speaker variation in the acoustic measures collected at different ages. In our previous cross-sectional study using a large sample (n = 32) of mothers of 6-8 and 10-12 month-old infants, and the same recording materials and measures, the IDS acoustic measures did not significantly change with infant age (Liu et. al., 2007; Liu et al., 2003). Therefore, IDS from mothers of 7-12 month-old infants were combined to examine the age-related differences between pre-verbal IDS and five-year-old CDS in this longitudinal study.

Methods

Participants

Seventeen mother-child dyads participated in the speech recordings at two times, when the children were 7-12 months (mean = 9.7 months; range = 6.8 to 12.0 months; boys = 10, girls = 7) and 5 years of age (mean = 5.1 years; range = 5.0 to 5.3 years). All participants were recruited from the list of the House Registry Offices of Kaoshuing, a metropolitan area in Taiwan. A language background questionnaire was administrated before the speech recording to verify that mother-child dyads used Mandarin-Chinese as the dominant language in their homes. Infants had no known physical, sensory, or mental disabilities.

Infants were recruited from middle-class families. Mothers typically were high school and 4-year-college graduates (*M* = 13.2 years, *SD* = 1.91) and fathers had similar educational backgrounds (*M* = 13.51 years, *SD* = 2.01). The average annual household income for the participants placed them close to Taiwan's average household income.

Speech stimuli

Speech samples were collected from all mother-child dyads and mother-experimenter dyads, using 12 Mandarin Chinese pre-selected bi-syllabic target words. These target words were constructed as (C)VCV(V) and contained the 3 corner vowels, /i/, /a/, /u/, with 4 lexical tone patterns equally distributed in the first syllable, such as /i2ma1/ (Aunt), /ma3t■^{h}ㄟ1/(Wagon), /u1ku☜1/ (Tortoise) (the tone numeral was attached to the end of each syllable). The tonal contexts were matched for target syllables—the tone pattern of the second syllable in the bi-syllabic words was always the high flat tone, Tone 1, to minimize the effects of neighboring syllables on the tone of the target syllable (i.e., the first syllable). That is, the tones of the bisyllabic words that contain the vowel /i/ in the first syllable were [11], [21], [31], and [41], and the same situation was applied to target words with /a/ and /u/ in the first syllable. All selected target words were nouns in Mandarin Chinese, including people's names, objects, and animal names.

Recording procedure

Each mother was audio-recorded when talking to a native Mandarin-speaking adult and to her child in a quiet room in the speech laboratory. A high-quality digital audio tape recorder (SONY TCD-D100), with 16-bit resolution, a sampling rate of 44.1 KHz and a microphone (SONY ECM-MS907) were used for recording. In this semi-structured situation, pre-selected toys and pictures corresponding to individual target words were provided during the speech recording to help mothers easily use the target words in mother-child interaction. Multiple speech samples of each target word were collected during recording for each speech style. The equipment, materials and procedure were held constant in the two speech recording settings at the two ages (infancy and childhood). During the IDS recording, mothers were told that the goal of the study was mother-child play and were encouraged to talk as freely and naturally as they did at home.

During ADS recordings, mothers talked with the experimenter about their child's interest in the same set of pre-selected toys and pictures while their infant (child) was playing with an adult in the adjacent room. The ADS samples were recorded at both child ages to examine the reliability of acoustic analysis at the two time points. Acoustic measures of ADS were not predicted to show any age related differences. The recording sequence of IDS (or CDS) and ADS samples was counterbalanced across all subjects.

Acoustic analysis

The KAY Elemetrics Computerized Speech Laboratory (CSL) software was used to conduct the acoustic analysis. The vowel and tone in the first syllable was the target unit for acoustic

analysis. The acoustic-phonetic measures included: vowel duration, vowel formant frequencies (first two formants), and mean F0 and F0 range for pitch contours in Mandarin lexical tones at the syllable level. To measure the vowel features, narrow-band spectrograms, FFT spectra, and autocorrelation LPC spectra were used to judge the locations of formants. The onset of each vocalic segment was marked when both formants (F1 and F2) were visible on the spectrogram. Vowel offset was marked at the point where F2 and/or F1 were no longer visible. Each vowel's duration was measured from vocalic onset to offset. Vowel formant frequencies were measured at the cursor that marked the onset, central (i.e., vowel steady state), and offset positions of the vocalic segment. Averaged (across the three measuring points) F1 and F2 values, representing the dynamic pattern of vowel-formant change, were used to calculate acoustic vowel space areas for individual mothers in each speech condition. The F1 and F2 of vowels were viewed as Descartes' coordinates on the x-y plane; the area of vowel space compassing /i/, /a/, and /u/ was equal to the triangular area constructed from the three (F1, F2) pairs of each point vowel in the x-y plane. The vowel space area was calculated using the following equation:

Vowel triangle Area = ABS {[F1i*(F2a - F2u) + F1a*(F2u - F2i) + F1u*(F2i - F2a)]/2}, where "ABS" is absolute value, "F1i" symbolizes the F1 value of vowel /i/, "F2a" symbolizes the F2 value of vowel /a/, and so on.

For the lexical tone analysis, the F0 value measured in the initial, middle, and final positions of the vocalic segment in each syllable, along with the highest and lowest (valley) points of the F0 contour of vowel, were measured to track the overall pitch contour of individual lexical tones. The "turning point," an essential temporal cue for tone distinctions (Liu et al., 2007), was calculated as the relative timing of the point where the pitch contour changes direction from falling to rising, [(*the duration of onset to valley* ÷ *duration of vowel*)* 100%].

A second well-trained phonetician analyzed 5% of the speech samples, randomly selected to validate the inter-rater reliability of acoustic analysis. The inter-rater reliability for the acoustic analysis procedure was high (r = .92).

Results

Did mothers modify the acoustic-phonetic features of maternal speech when addressing their five-year-old children, compared with ADS? Did speech modifications in language addressed to children vary with the child's age? To address these questions, the acoustic-phonetic features of maternal speech of 17 mother-child dyads were analyzed twice, first when infants were 7-12-months of age and again when they reached the age of 5-years. Table 1 lists the vowel space, vowel duration, pitch height and pitch range of ADS, IDS and CDS.

1. Vowel characteristics

a. Vowel space area—The vowel space area containing /i/, /a/, and /u/ in the two speech conditions were compared at both ages. Compared to ADS, maternal speech addressing both preverbal infants and preschool children exhibited an exaggeration of vowel space. A one-way repeated-measure ANOVA (IDS, CDS, ADS-infancy, ADS-childhood) on vowel space areas showed a significant speaking style effect, $F(3, 48) = 14.83$, $p < .001$, $\eta_p^2 = .481$. The Bonferroni *post-hoc* test (p = .01) shows the order of vowel space: IDS ≈ CDS > ADS-infancy ≈ ADS-childhood. Thus, the results show that, in infancy, the vowel space of IDS is significantly larger than ADS. The expanded vowel space is also seen at 5 years of age; the vowel space of CDS is significant larger than ADS. The vowel space of maternal speech directed to preverbal infants is similar to the vowel space of CDS, suggesting that vowel area in maternal speech addressing children is not greatly reduced with children's ages.

b. Vowel duration—Mothers elongated vowels when talking with their pre-verbal infants and their five-year-old children when compared to ADS. A one-way repeated-measures ANOVA (IDS, CDS, ADS-infancy, ADS-childhood,) on vowel duration showed a significant style effect, $F(3, 48) = 34.26$, $p < .001$, $\eta_p^2 = .682$. Bonferroni *post-hoc* analyses ($p = .01$) showed the order of vowel duration: IDS > CDS > ADS-childhood ≈ ADS-infancy. Mothers spoke more slowly with their pre-verbal infants than with their five-year-old children. The vowel duration of IDS was significantly longer than ADS-infancy. The same pattern was shown with five-year-old children; the vowel duration of CDS was significantly longer than ADS-childhood. The results show a significantly reduced durational modification in maternal speech addressing five-year-old children when compared to 7-12 month-old infants.

2. Lexical tone characteristics

a. Mean F0—Compared to ADS, mothers raised their pitch (i.e., mean F0) when talking with their pre-verbal children and five-year-old children. A one-way repeated-measure ANOVA (IDS, CDS, ADS-infancy, ADS-childhood) on pitch showed a significant style effect, $F(3, 48) = 59.65$, $p < .001$, $\eta_p^2 = .788$. The Bonferroni *post-hoc* analyses ($p < .001$) showed the pitch height order: IDS > CDS > ADS-infancy ≈ ADS-childhood. Therefore, there is an age-related F0 change in maternal speech at different ages: mothers used a higher pitch in IDS when compared to CDS. The mean F0 of ADS did not significantly vary with age. Figure 1 illustrates the mean F0 of individual lexical tones.

Considering the individual tones, the mean F0 was significantly greater in IDS than CDS (one-way ANOVAs all reached a significance level of $p = .05$ for each individual tone). The results also demonstrated a consistent order of mean F0 among the four lexical tones across the two ages, i.e., Tone 4 > Tone 1 > Tone 2 > Tone 3. The mean F0 difference between high (i.e., Tones 1 & 4) vs. low tone (i.e., Tone 3) pairs were significantly more exaggerated in IDS when compared to CDS for Tone 1 vs. Tone 3, $t(16) = 3.29$, $p = .004$, and Tone 4 vs. Tone 3, $t(16) = 3.69$, $p = .002$.

b. F0 range—Compared to ADS, Mandarin-speaking mothers used greater pitch fluctuation (F0 range) at the syllable level in IDS and CDS. A one-way repeated-measure ANOVA (IDS, CDS, ADS-infancy, ADS-childhood) on F0 range showed a significant style effect, $F(3, 48) = 21.03$, $p < .001$, $\eta_p^2 = .568$. The order of F0 range in the Bonferroni *post-hoc* analysis ($p < .05$) is: IDS > CDS > ADS-infancy ≈ ADS-childhood. Mothers used a more exaggerated F0 range in IDS than in CDS and larger F0 range in CDS than ADS-childhood, while the F0 range of ADS did not vary with age. The results show age-related changes in F0 range and a reduced F0 range modification in speech addressing older children. For the individual tones, Figure 2 illustrates the F0 range of different speech styles. For the individual tones, the F0 range was significantly greater in IDS than in ADS (measured in infancy), a greater F0 range was observed in CDS than in ADS (measured in childhood) (all one-way ANOVAs reached significance at $p < .001$). Moreover, the F0 range of individual tones was significantly greater in IDS than in CDS (all reached the significance level of $p = .05$), with the exception of the flat level tone, Tone1, $F(1, 16) = 3.63$, $p = .075$, showing an age-related change of F0 range in maternal speech directed to infants and children. A consistent order of F0 range among the four lexical tones occurred in both IDS and CDS: Tone 4 > Tone 3 > Tone 2 > Tone 1.

c. F0 Turning point—The results show that duration is increased significantly in IDS and CDS as opposed to ADS, and this raises an interesting question regarding the "turning point," the point at which the F0 contour direction changes from falling to rising in Tones 2 and 3, in IDS and CDS. In ADS, the turning point distinguishes two tones with similar pitch contour, Tone 2 (rising) and 3 (dipping), and we predicted that it would also do so in IDS and CDS.

That is, IDS and CDS would not exaggerate the turning point difference between speech styles because exaggerating this cue could perceptually confuse infants regarding lexical meaning.

The results confirmed our prediction, showing that the turning point was not significantly different for the two speaking styles (one-sample *t*-test, p >.1 for each tone pair) in both IDS (Tone 1 = 49.13%, Tone 2 = 25.62%, Tone 3 = 75.33%, Tone 4 = 93.33%) and CDS (Tone 1 = 58.97%, Tone 2 = 29.07%, Tone 3 = 79.34%, Tone 4 = 93.30%). This suggests that the essential temporal cues needed to identify lexical tones are preserved in both CDS and IDS, a pattern that replicates an earlier finding showing that mothers use similar turning points in lexical tones when addressing young infants and adults (Liu et al., 2007).

3. Examining repeat-recording effects on CDS

In addition to the longitudinal data examining the differences between CDS and ADS, and the age-related changes of acoustic features between IDS and CDS, the present study also analyzed speech samples collected from another group of 11 Mandarin-speaking mothers addressing their five-year-old children to examine the potential effect of repeat recordings on acoustic-phonetic features of CDS. As predicted, the results show no significant difference between the two groups of mothers addressing their five-year-old children (one-way ANOVA, all $p > .1$). Thus, the age-related changes of acoustic-phonetic modifications observed between IDS and CDS cannot be attributed to repeat recordings.

Discussion

The results of this study demonstrate that the pattern of acoustic-phonetic exaggeration shown in speech addressed to preverbal infants (Kuhl et al., 1997; Liu, et al., 2003; Liu et al., 2007) also exists in speech addressed to five-year-old children. The longitudinal design used in the present study additionally compared the acoustic-phonetic features of speech addressed to the same children as pre-verbal infants and as five-year-olds. The results show that the extent of the acoustic-phonetic modification in the speech that adults address to children changes as a function of the age of the child—acoustic-phonetic modifications are significantly reduced in CDS when compared to IDS—indicating that a child's age plays a role in maternal speech in infancy and childhood.

The findings that mothers exaggerate vowel space, elongate vowel duration, raise F0 height, expand the F0 range of tone contours and increase the F0 difference between tone pairs when talking with their five-year-old children suggest that speech characteristics may reflect mothers' assessments, though not conscious, of their children's ages and their linguistic abilities. The results are consistent with previous studies showing CDS pitch modifications for five-year-old children (e.g., Garnica, 1977). Compared to ADS, the exaggerated acoustic features in maternal speech directed towards children at two ages appear to amplify, to different degrees, the essential phonetic features for both preverbal infants and preschool children.

A particular strength of this study is the use of a longitudinal design that reduces the possibility that speaker and parenting experience differences account for the age-related changes. Comparing the acoustic features of speech addressed to preverbal infants and five-year-old children highlights the age-related vowel and lexical tone modifications between IDS and CDS. Further longitudinal studies can now examine the association between CDS modifications and direct assessments of children's language abilities during childhood to test how finely tuned CDS modification is to a specific child's language abilities.

What is the function of these acoustic exaggerations in maternal speech to infants and preschoolers? Vowels with longer duration are indicative of “clear” versus “conversational” speech among individual speakers (Picheny, Durlach, & Braida, 1989). In addition to the

temporal cues, a larger vowel space is associated with better speech intelligibility in typical speakers (Bradlow, Torretta, & Pisoni, 1996) and atypical speakers with motor speech disorders (Turner, Tjaden, & Weismer, 1995). Therefore, expanding the vowel space and lengthening vowels in maternal speech implies that Mandarin-speaking mothers are speaking more clearly when addressing their infants and children, making vowels perceptually more distinct from one another for children (Kuhl et al., 1997; Liu et al., 2003). This may be beneficial for infants because it makes phonetic units more distinct (Kuhl et al., 1997), which may account for the association between mothers' speech and infants' enhanced performance in speech discrimination tasks (Liu et al., 2003). For lexical tones, the major acoustic cues for Mandarin-speaking adults' perception of lexical tones are F0 height and F0 range (e.g., Gandour & Harshman, 1978). Exaggerating these features in IDS and CDS could make the tones perceptually more distinct for children. In addition, similar patterns for the F0 turning point across speech styles preserves lexical meaning in maternal speech addressing infants and children (Liu et al., 2007).

Studies on infant speech perception suggest a learning process in which infant perception is shaped by exposure to ambient language (Kuhl, Conboy, Coffey-Corina, Padden, Rivera-Gaxiola, & Nelson, 2008). Early skill in native language speech discrimination can predict the growth of later language development between 13 and 30 months (Tsao, Liu, & Kuhl, 2004; Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005), and mothers' clear speech in IDS and CDS may assist this process.

What are the explanations for age-related changes? Phonetic exaggeration was reduced in CDS compared to IDS and this could be interpreted as an adjustment to the child's age or linguistic level (Kitamura & Burnham, 2003; Stern et al., 1983). Increased intelligibility in IDS is achieved by exaggerating the acoustic cues to vowels and lexical tones and this could directly enhance the perceptual cues needed for infants to discriminate native-language phonetic differences (Liu et al., 2003). Given that children's language skills are not completely adult-like at the age of five, the enhancement of speech at the phonetic level may continue to play a role in language learning. However, since children are able to produce lexical tones and vowels in Mandarin Chinese by the age of five (e.g., Hua & Dodd, 2000), maternal highlighting of the phonetic units (i.e., vowel and lexical tone) during childhood may not be as important. CDS modification could also be associated with the fact that adults emphasize the semantic and pragmatic features when addressing older children (Brousseau et al., 1996; Cross, 1977; Snow, 1994). At the age of five, CDS, with its higher pitch and exaggerated lexical tones, longer and more exaggerated vowels, could facilitate children's learning of new words and their development of pragmatic skills.

Further study of the association between acoustic exaggeration at the phonetic level in maternal speech to children and those children's language processing skills in childhood will be necessary to assess the value of adults' modifications of speech, and their effects on children. This study analyzed the acoustic modifications of maternal speech at the phonetic level; other linguistic modifications, such as semantic, syntactic, and pragmatic of IDS (e.g., Snow, 1994) would also be of interest. To fully examine the hypothesis that infant- and child-directed speech facilitates language acquisition, longitudinal studies examining long-term relationships between maternal speech at an early age and later children's language performance would provide very valuable information.

Acknowledgments

This research was supported by a research grant from the National Science Council, Taiwan, to Huei-Mei Liu (NSC 92-2413-H-003 -072 & NSC 93-2413-H-003 -019). Patricia K. Kuhl's contribution was supported by the Hsin-Yi Foundation of Taiwan and an NSF Science of Learning Center grant (0354453).

References

Amano S, Nakatani T, Kondo T. Fundamental frequency of infants and parents utterances in longitudinal recordings. Journal of the Acoustical Society of America 2006;119:1636–1647. [PubMed: 16583908]

Bradlow AR, Torretta GM, Pisoni DB. Intelligibility of normal speech I: Global and fine-grained acoustic-phonetic talker characteristics. Speech Communication 1996;20(34):255–272.

Brousseau L, Malcuit G, Pomerleau A, Feider H. Relations between lexical-temporal features in mothers' speech and infants' interactive behaviours. First Language 1996;16:41–59.

Burnham D, Kitamura C, Vollmer-Conna U. What's new, pussycat? On talking to babies and animals. Science 2002;296:1435–1435. [PubMed: 12029126]

Cooper RP, Abraham J, Berman S, Staska M. The development of infants' preference for motherese. Infant Behavior and Development 1997;20(4):477–488.

Cross, TG. Mothers' speech adjustment: the contributions of selected child listener variables. In: Snow, CE.; Ferguson, CA., editors. Talking to children: Language input and acquisition. Cambridge: Cambridge University Press; 1977. p. 151-188.

Fernald A. Prosody in speech to children: prelinguistic and linguistic functions. Annals of Child Development 1991;8:43–80.

Fernald A, Simon T. Expanded intonation contours in mothers' speech to newborns. Developmental Psychology 1984;20(1):104–113.

Gandour JT, Harshman RA. Crosslanguage differences in tone perception: a multidimensional scaling investigation. Language and Speech 1978;21:1–33. [PubMed: 692240]

Garnica, O. Some prosodic and paralinguistic features of speech to young children. In: Snow, CE.; Ferguson, CA., editors. Talking to children: Language input and acquisition. Cambridge: Cambridge University Press; 1977. p. 63-88.

Grieser DL, Kuhl PK. Maternal speech to infants in a tonal language: Support for universal prosodic feature in motherese. Developmental Psychology 1988;24(1):14–20.

Hua Z, Dodd B. The phonological acquisition of Putonghua (Modern Standard Chinese). Journal of Child Language 2000;27:3–42. [PubMed: 10740966]

Kavanaugh RD, Jirkovsky AM. Parental speech to young children: a longitudinal analysis. Merrill-Palmer Quarterly 1982;28(2):297–311.

Kitamura C, Burnham D. Pitch and communicative intent in mother's speech: adjustments for age and sex in the first year. Infancy 2003;4(1):85–110.

Kitamura C, Thanavishuth C, Burnham D, Luksaneeyanawin S. University and specificity in infant-directed speech: pitch modifications as a function of infant age and sex in a tonal and non-tonal language. Infant Behavior and Development 2002;24:372–392.

Kuhl PK, Conboy BT, Coffey-Corina S, Padden D, Rivera-Gaxiola M, Nelson T. Early phonetic perception as a gateway to language: New data and Native Language Magnet Theory, expanded (NLM-e). Philosophical Transactions of the Royal Society B 2008;363:979–1000.

Kuhl PK, Andruski JE, Chistovich IA, Chistovich LA, Kozhevnikova EV, Ryskina VL, Stolyarova EI, Sundberg U, Lacerda F. Cross-language analysis of phonetic units in language addressed to infants. Science 1997;277:684–686. [PubMed: 9235890]

Kuhl PK, Conboy BT, Padden D, Nelson T, Pruitt J. Early speech perception and later language development: Implications for the “Critical Period”. Language Learning and Development 2005;1 (34):237–264.

Liu HM, Kuhl PK, Tsao FM. The association between mothers' speech clarity and infants' speech discrimination skill. Developmental Science 2003;6(3):F1–F10.

Liu HM, Tsao FM, Kuhl PK. Acoustic analysis of lexical tone in Mandarin infant-directed speech. Developmental Psychology 2007;43:912–917. [PubMed: 17605524]

Murray AD, Johnson J, Peters J. Fine-tuning of utterance length to preverbal infants: effects on later language development. Journal of Child Language 1990;17:511–525. [PubMed: 2269697]

Newport, EL.; Gleitman, H.; Gleitman, LR. Mother, I'd rather do it myself: some effects and non-effects of maternal speech style. In: Snow, CE.; Ferguson, CA., editors. Talking to children: Language input and acquisition. Cambridge: Cambridge University Press; 1977. p. 109-150.

Picheny MA, Durlach NI, Braida LD. Speaking clearly for the hard of hearing III: an attempt to determine the contribution of speaking rate to difference in intelligibility between clear and conversational speech. Journal of Speech and Hearing Research 1989;32:600–603. [PubMed: 2779204]

Snow, CE. Beginning from baby talk: twenty years of research on input in interaction. In: Gallaway, C.; Richards, BJ., editors. Input and Interaction in Language Acquisition. NY: Cambridge University; 1994. p. 3-12.

Stern DN, Spieker S, Barnett RK, Mackain K. The prosody of maternal speech: infant age and context related changes. Journal of Child Language 1983;10:1–15. [PubMed: 6841483]

Tsao FM, Liu HM, Kuhl PK. Speech perception in infancy predicts language development in the second year of life: a longitudinal study. Child Development 2004;75:1067–1084. [PubMed: 15260865]

Turner GS, Tjaden K, Weismer G. The influence of speaking rate on vowel space and speech intelligibility for individuals with Amyotrophic Lateral Sclerosis. Journal of Speech and Hearing Research 1995;38:1001–1013. [PubMed: 8558870]

Warren-Leubecker A, Bohannon JN. Intonation patterns in child-directed speech: Mother-father differences. Child Development 1984;55:1379–1385.

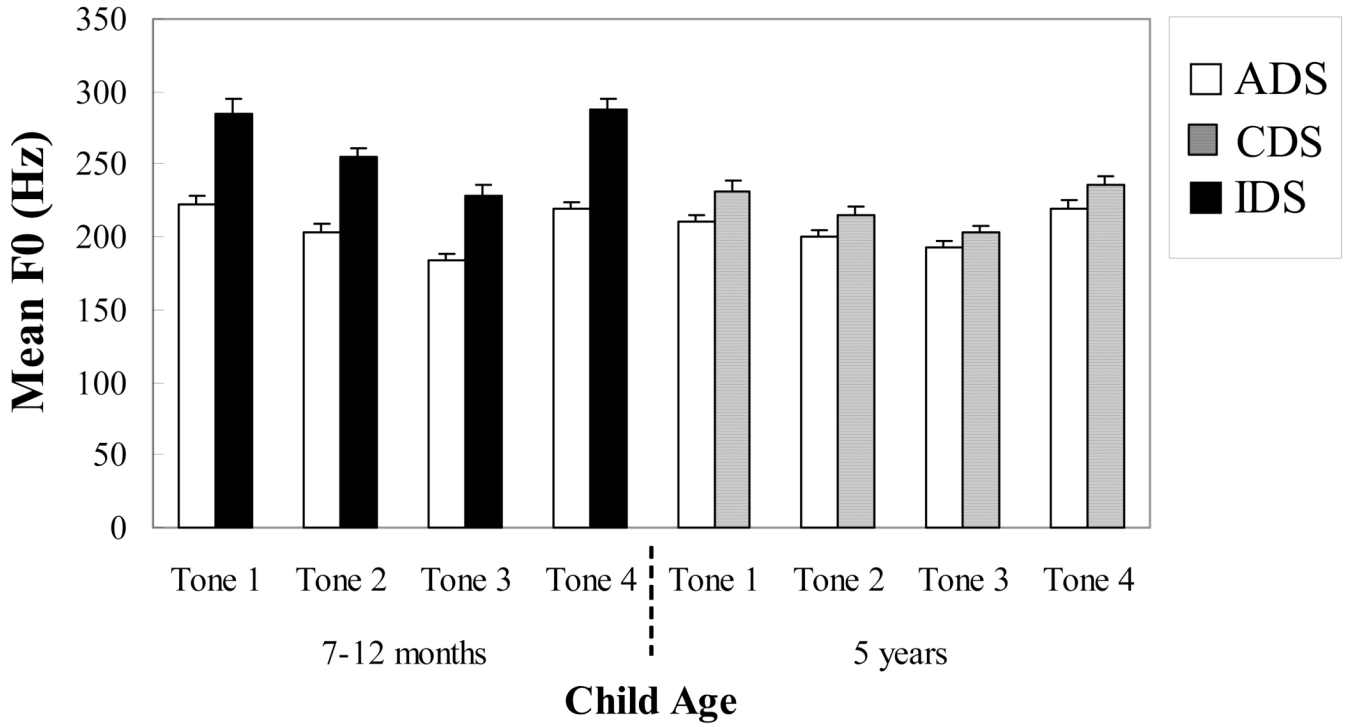

Figure 1.
The mean F0 values of 4 lexical tones in Mandarin ADS, IDS and CDS to children at two ages (SE in error bars).

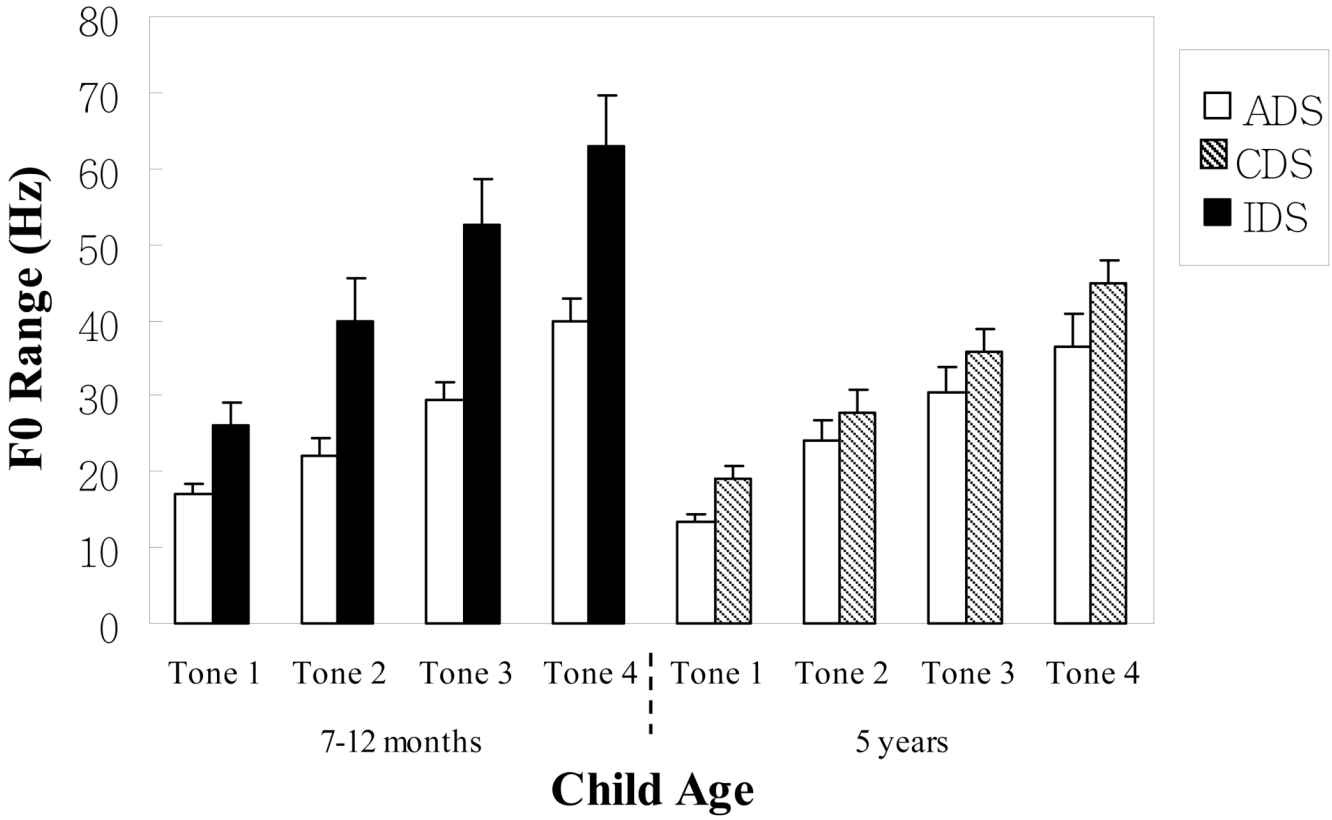

Figure 2.
The F0 range of 4 lexical tones in Mandarin ADS, IDS and CDS to children at two ages (SE in error bars).

Table 1

Means of acoustic features of Mandarin ADS and IDS measured at two ages (Standard deviation in parentheses)

	Infancy		Childhood	
	IDS	**ADS**	**CDS**	**ADS**
Vowel Space (Hz^2)	631844 (131790)	496068 (75797)	559333 (102114)	462113 (98448)
Vowel Duration (ms)	248.02 (55.30)	167.77 (19.37)	184.17 (22.16))	158.51 (12.66)
Mean F0 (Hz)	263.97 (29.25)	207.31 (20.55)	221.20 (23.7)	205.87 (19.33)
F0 Range (Hz)	45.34 (14.35)	26.07 (9.67)	31.88 (9.24)	27.19 (7.02)