

## The comparison of vowel space in infant-directed speech and read speech

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### Introduction

Infant-directed speech contains modifications, which (in contrast to adult-directed speech (ADS)), includes syntactic and semantic simplifications [1, 2], as well as overemphasised intonation contours, decelerated rate of speech and increased pitch ( $F_0$ ) [3, 4, 5]. Studies on the acoustic properties of infant-directed speech (IDS) have also shown that acoustic changes such as broader range in  $F_0$  and more increased  $F_0$  in speech to infants are observable in diverse languages including in tonal and non-tonal languages [5, 6, 7, 8].

It has been argued that IDS has functions which may benefit the listener, particularly in language development [9]. Generally, IDS has been proposed to serve three main purposes, which are of affective, attentional and didactic nature [5, 10, 11, 14, 15, 16]. Accordingly, IDS might draw and sustain infants' attention [5, 11, 14, 15]; it might express positive vocal affect [11, 10, 15, 16]; and, it may support infants' language learning process [9, 10, 12]. The present study focused on the didactic aspect by attending to the acoustic properties of IDS that have been proposed to contribute to speech clarity [13, 21, 28].

### The role of articulatory stretched vowel space in IDS

It has been shown that infant-directed speech contains acoustically exaggerated properties that have been reported to be correlated with speech intelligibility in IDS [9, 10, 12, 13]. In particular, expanded vowel space (as measured by  $F_1/F_2$  space) has been shown to represent very reliable measurements of overall clarity in speech, which has been regarded to help infants to focus on acoustically crucial information [17, 18, 19]. This exaggerated vowel space is termed a 'hyperarticulated' speech style.

Hyperarticulated speech is considered to enable more accurate phonetic units to be more easily perceived as being acoustically distinct [10, 12, 20]. However, there have not been many investigations that have empirically tested whether actual perception of speech in language learners is affected by the extension of vowel space. Liu et al. [13], for example, reported an association between the qualitative speech effort by mothers and infants' performance on phonetic speech perception. The extent of vowel space area, which was produced in speech by mothers, was correlated with infants' phonetic discrimination abilities. However, this correlational study only provided circumstantial and not direct evidence linking linguistic discrimination and hyperarticulation [13].

As a more direct test, we wished to find out whether the acoustical modifications used in IDS are uniquely didactic and distinguishable from other forms of clear (but not necessarily hyperarticulated) speech. The present study was therefore aimed at comparing vowel space in IDS with vowel space of read speech, which has been used in previous research to produce clear speech as well [21, 22, 23].

Reading tasks have been used in experimental studies for various purposes such as to elicit a hypoarticulated speaking manner (e.g. participants read sentences whilst completing distractor tasks) or to produce a hyperarticulatory speech style [21, 24]. The resulting outcome of cautiously regulated read speech produced under ideal conditions has been shown to include the acoustic features of clear speech such as higher mean pitch, larger pitch range, decreased speech rate [24, 25], articulatory stretched vowel space [22] and elongated and recurring pauses [22, 26].

We investigate whether the vowel space produced in IDS is similar to that elicited in read speech. Although previous research has compared read speech with naturally elicited speech, it has focused on the comparison of acoustic features of casual and clear speech produced in two task types: a spot-a-difference task and reading task [24]. It was found that pitch median, pitch range and reduced speech rate were all larger for read speech than in natural interactions across the clear and casual speech styles [24]. Although these observations seem to be similar to those found previously in IDS, that study only examined ADS and not IDS. Moreover, clear speech in the naturalistic speaking condition was artificially elicited by means of a vocoder and while that study only measured formant range, the present study will focus on naturally elicited IDS and measure the midpoint of the first and second formant, and comparing conditions within speakers. The present study therefore is the first to compare the acoustic characteristic of vowel space of clear read speech and of spontaneous clear speech that is produced in naturalistic interactions with a communicative purpose for the same set of speakers.

### Methods

#### Participants

Fourteen mothers (20-45 years) were recruited through Brunel University. All mothers and their infants (12-20 months) were White British and from the West London area. There were no reported language or speech disorders in the participants.

## Design

This study used a within-subjects design in which the target vowels /a:/, /i:/ and /e/ were produced in both the mother-infant interaction condition and the reading condition. The dependent variable was the acoustic measure of vowel space (indexed by mean vowel space plotted using  $F1$  and  $F2$  values of each of the three corner vowels, /a:/, /i:/, /e/), in the target words in which one of the three target vowels was present.

## Materials

For the purpose of eliciting the target vowels /a:/, /i:/ and /e/, the words 'car', 'green' and 'red' were chosen as specific target words, which contain each of the target vowels respectively. The elicitation of these target vowels from the mothers in the interaction condition was facilitated by using 19 picture cards that depicted pictures of everyday objects with their names on them (e.g. cat, shoes, door).

A collection of 27 sentences with a syntactically simple organization was designed and included the aforementioned target words for the reading condition. The sentences carried meaningful weight, e.g. 'green tea can improve your health/ stop signs are red'. A digital voice recorder Edirol R-09HR by Roland (sampling rate: 44,100 Hz) was used to record speech production in both conditions. Each interaction was recorded as a mono 16-bit wavfile.

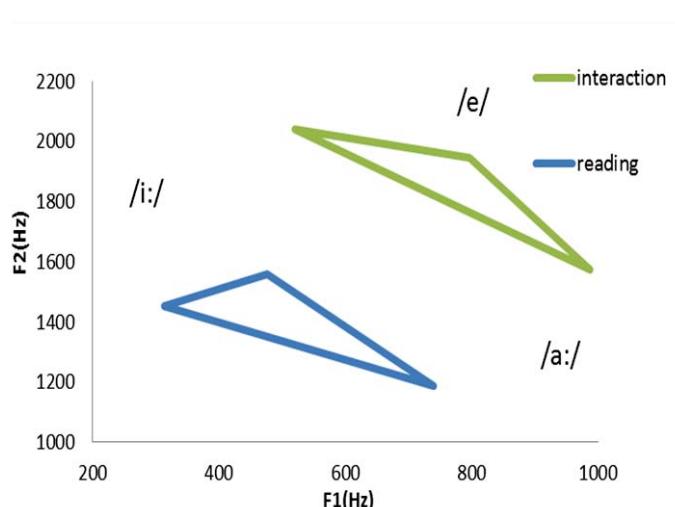
## Procedure

In each half an hour audio-recorded interaction, mothers were instructed to show their infants the 19 picture cards with everyday objects on them and to try to engage their infants in a dialogue. After this part, mothers were asked to read out aloud in a clear voice the short list of sentences and then finally to complete a short online questionnaire on their demographic and linguistic backgrounds. All interactions were recorded in a quiet room in participants' homes to ensure a naturalistic communication between mothers and infants.

## Results

A repeated-measures ANOVA was executed to analyse the acoustic measures of vowel triangle area. Data from three participants were not included in the data analysis due to the absence of sufficient instances for one of the corner vowels.

As the Mauchly's test statistic was not significant ( $p>0.05$ ), the univariate tests were used. For mean  $F1$  values, the interaction condition and reading condition differed significantly from each other ( $F(1, 10) = 85.62 p<0.05$ , partial eta squared = .895). Similarly for mean  $F2$  values, the two conditions were significantly different ( $F (1, 10) = 13.86, p<0.05$ , partial eta squared = .581). The means for both formants were larger in the mother-infant interaction condition than in the reading condition. It can therefore be said that mothers' vowel articulation differed significantly in speech to their infants as compared to the reading task.



**Figure 1:** Exaggeration of the three target vowels in the infant-directed speech condition and its absence in the reading condition as indicated by differences in  $F1$  and  $F2$ .

A comparison of vowel space between the interaction condition and reading condition was conducted with a paired sampled  $t$  test that revealed a significantly larger vowel space for the interaction condition than the reading condition ( $t=1.92, df=10; p<0.05$ ) (Figure 1). Thus, this result shows that mothers' articulatory vowel space in speech to infants is significantly more expanded than their vowel space expressed when reading sentences.

## Discussion

In summary, results indicate that vowel space in speech to infants is significantly more expanded than vowel space in read speech. Although this study focused on the elicitation of clear speech only, this result is to some degree similar to a previous study in which women were observed to show the inclination to produce more extended vowel range in casual speech than men [24].

The present result confirms the previous research suggesting that the acoustic modifications in IDS are uniquely didactic [9,10]. The fact that vowel space was reduced in the reading condition compared to IDS suggests that the hyperarticulation found in IDS may be uniquely didactic. As such, it could be suggested that IDS requires more acoustic exaggeration than in read speech due to the natural linguistic needs of the listener as a language learner that is the infant [10]. Measures of pitch, intensity, pitch and intensity range, and speech rate will be further analysed to determine whether vowel space expansion as compared to other acoustic changes (e.g. pitch) is more uniquely didactic oriented.

The current study has confirmed the views of other researchers suggesting that IDS is a uniquely didactically-oriented speech style. This result is in line with Kuhl's Native Language Magnet Theory (enhanced), which suggests that extended vowel space in IDS serves to overemphasise crucial phonetic contrasts through which infants' speech perception skills might be assisted [13, 27, 28].

Of course, the linguistic benefit of IDS can only be presumed at this moment and additional research is required to test more directly, for example, whether the linguistic benefit perceived by infants in IDS is similar to that perceived by foreigners in speech to foreign-sounding foreigners [10, 29]. Presently, speech samples that were collected in this study for read speech and spontaneous speech are being used in speech perception tasks to establish whether IDS actually helps infants to learn words.

## References

- [1] Ferguson, C.A.: Baby talk in six languages. *American Anthropologist* **66** (1964), 103-114
- [2] Snow, C.E.: Beginning from baby talk: twenty years of research on input in interaction. Cambridge University Press, New York, 1994
- [3] Stern, D.N., Spieker, S., Barnett, R.K., & Mackain, K.: The prosody of maternal speech: infant age and context related changes. *Journal of Child Language* **10** (1983), 1-15
- [4] Fernald, A., & Simon, T.: Expanded intonation contours in mothers' speech to newborns. *Developmental Psychology* **20** (1984), 104-113
- [5] Grieser, D.L., & Kuhl, P.K.: Maternal speech to infants in a tonal language: support for universal prosodic features in motherese. *Developmental Psychology* **24** (1988), 14-20
- [6] Fernald, A., Taeschner, T., Hirsh-Pasek, K. & Jusczyk, P.W.: A cross language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of Child Language* **16** (1989), 477-501
- [7] Kitamura C., Thanavishuth C., Burnham D. & Luksaneeyanawin S.: Universality and specificity in infant-directed speech: Pitch modifications as a function of infant age and sex in a tonal and non-tonal language. *Infant Behaviour* **24** (2001), 372-392
- [8] Xu, N. & Burnham, D.: Tone Hyperarticulation and Intonation in Cantonese Infant Directed Speech. In: Proceedings of Speech Prosody, Chicago, May 10-14 (2010), 1-4
- [9] Kuhl, P.K., Andruski, J.E., Chistovich, I.A., Chistovich, L.A., Kozhevnikova, E.V., Ryskina, V.L., Stolyarova, E.I., Sundberg, U. & Lacerda, F.: Cross-language analysis of phonetic units in language addressed to infants. *Science* **277** (1997), 684-686
- [10] Uther, M., Knoll, M.A. & Burnham, D.: Do you speak E-NG-L-I-SH? A comparison of foreigner-and infant-directed speech. *Speech Communication* **49** (2007), 2-7
- [11] Werker J. F. & McLeod P.: Infant preference for both male and female infant directed talk: A developmental study of attentional and affective responsiveness. *Canadian Journal of Experimental Psychology* **43** (1989), 230-246
- [12] Burnham, D., Kitamura, C. & Vollmer-Conna, U.: What's new, Pussycat? On talking to babies and animals. *Science* **296** (2003), 1435
- [13] Liu, H.M., Kuhl, P.K. & Tsao, F.M.: An association between mothers' speech clarity and infants' speech discrimination skills. *Developmental Science* **6** (2003), F1-F10
- [14] Cooper R. P., & Aslin R. N.: Developmental differences in infant attention to the spectral properties of infant-directed speech. *Child Development* **65** (1994), 1663-1677
- [15] Cooper R. P., Abraham J., Berman S. & Staska M.: Baby talk in six languages. *Infant Behaviour Development* **20** (1997), 477-488
- [16] Fernald A., & Kuhl P. K.: Acoustic determinants of infant preference for motherese speech. *Infant Behaviour Development* **10** (1987), 279-293
- [17] Bradlow, A.R., Torretta, G.M. & Pisoni, D.B.: Intelligibility of normal speech I: Global and fine-grained acoustic-phonetic talker characteristics. *Speech Communication* **20** (1996), 255-272
- [18] Turner, G.S., 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* **38** (1995), 1001-1013
- [19] Weismer, G., Jeng, J.-Y., Laures, J.S., Kent, R.D. & Kent, J.F.: Acoustic and intelligibility characteristics of sentence production in neurogenic speech disorders. *Folia Phonetica et Logopaedica* **35** (2001), 1-18
- [20] Lindblom, B.: Explaining phonetic variation: a sketch of H & H theory. Kluwer Academic Publishers, Dordrecht, Netherlands, 1990
- [21] Kain, A., Amano-Kusumoto, A. & Hosom, J.P.: Hybridizing conversational and clear speech to determine the degree of contribution of acoustic features to intelligibility. *Journal of the Acoustical Society of America* **124** (2008), 2308-2319
- [22] Picheny, M.A., Durlach, N. I. & Braida, L.D.: Speaking clearly for the hard of hearing I: Intelligibility differences between clear and conversational speech. *Journal of Speech and Hearing Research* **28** (1985), 96-103
- [23] Harnsberger, J.D., Wright, R. & Pisoni, D.B.: A new method for eliciting three speaking styles in the

laboratory. *Speech communication* **50** (2008), 323-336

- [24] Hazan, V. & Baker, R.: Does reading clearly produce the same acoustic-phonetic modifications as spontaneous speech in a clear speaking style? In: *Proceedings of DiSS-LPSS Joint Workshop Tokyo*, September 25-26 (2010), 7-10
- [25] Bradlow, A.R., Kraus, N. & Hyes, E.: Speaking Clearly for Children With Learning Disabilities. *Journal of Speech, Language, and Hearing Research* **46** (2003), 80-97
- [26] Liu, S., & Zeng, F.: Temporal properties in clear speech perception. *Journal of the Acoustical Society of America* **120** (2006), 424-432
- [27] Kuhl, P.K.: A new view of language acquisition. *Proceedings of the National Academy of Science* **97** (2000), 11850-11857
- [28] Kuhl, P.K.: Early language acquisition: cracking the speech code. *Nature Reviews Neuroscience* **5** (2004), 831-843
- [29] Kangatharan, J., Uther, M. & Gobet, F.: The effect of physical appearance and accent on the elicitation of vowel hyperarticulation by British English native speakers in speech to foreigners. Poster presented at the 164th Meeting of the Acoustical Society of America, Kansas, Missouri 22-26 October 2012