

# A PHONETIC AND ACOUSTIC STUDY OF BABBLING IN AN ITALIAN CHILD

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## ABSTRACT

This single case study focuses on the phonetic aspect of early speech development, namely babbling and early words, and presents a perceptive as well as an acoustic analysis. Results show that, while generic progress may be found in the increasing prevalence of the number of CV syllables within the global repertory of utterances, the aspects that better reveal the influence of the target language include the frequency of occurrence of vowel and consonant types, in combination with an expansion and refining of phonotactic possibilities.

## 1. INTRODUCTION

At present, one of the most confirmed and influential theories referring to babbling is the *Frame, then Content* theory, put forward by P. MacNeilage and B. Davis in a number of papers (cf. for instance [1]). Briefly, this theory states that infants come to acquire the articulatory control manifested in babbling from a motor-based oral function, phylo- and onto-genetically derived from the nutritional activity. The acoustic effects generated from the regularity of the rhythmic alternation between the open and close phase of jaw movements are perceived by the adults as syllables. At first, this syllable is a pure frame, i.e. a dynamic prototype of the adult syllable, and its content is constituted by a limited number of different CV combinations, since the variety is constrained by the presence of a biomechanical link between jaw and other articulators. Content elements begin to acquire relative independence as the child, moving towards target language, increases the control over speech articulators in speech movement sequences. Many authors, and in particular R.D. Kent and M.M. Vihman, consider the syllable of babbling as the point of contact between biology and phonology and the best common reference for describing infant utterances with acoustic, physiological and perceptual methods. According to Kent [2], the syllable takes on an important role in the rhythmic organization of behavior, the positioning of prosodic phenomena, the coordination of articulatory gestures, and the achievement of phonotactic knowledge. According to Vihman [4], an analysis of syllabic production makes it possible to study the role of biological constraints on pre-linguistic utterances, the influence of the target language and the individual creativity in the construction of syllabic patterns.

## 2. METHOD

Davide, a full-term born male infant, attended this study. His parents are middle-class, and the language spoken is standard Italian. He was recorded with an AIWA tape recorder, mod. TP-

850 and a Sony microphone, mod. ECM-T7, every two weeks from the 8<sup>th</sup> month onwards, during play situations in the presence of his mother. The recordings, lasting 45 minutes each, were made at home in a noise-free environment. Only the analysis of the 4 recordings relative to the ages of 9;09 and 9;28 (months and days) for the 10<sup>th</sup> month, 11; 21 for the 12<sup>th</sup> month, 13;07 for the 14<sup>th</sup> month and 15;16 for the 16<sup>th</sup> month are presented here. According to the MacArthur questionnaire [4], at 9;09 he produced 4 words and at 13;01 produced 31 words.

Phonetic transcriptions of the recorded material was performed by an experienced phonetician, using the symbols and diacritics provided in [6], besides those of the IPA (1993). On these bases, it was possible to discriminate babbling and any words from vegetative and reflexive sounds as well as from sounds belonging to the *vocal play* stage. The selected occurrences were acquired at 20 kHz sampling frequency with the CSL 4300 package and examined for compliance with the acoustic criteria proposed by Oller [6]. Only vowels produced with modal voice (i.e. neither laryngalized, strongly nasalized, desonorized, nor in falsetto) and preceded by "true" consonants (no glottal stops) were analyzed. This revision resulted in the elimination of 108/353 potential babbling utterances. Isolated CV syllables were accepted. Two successive syllables were considered to refer to different utterances if separated by more than 500 ms. In the presence of vocalic modulations, the number and type of occurring vowels was specified, keeping in mind the possibility for a vowel to have very long transitions (up to 120 ms). Before executing the acoustic analysis, a new phonetic transcription was performed by the first author on the babbling occurrences, exploiting the spectrographic information and the sound feedback facilities of the CSL 4300 package, and making recourse to an interactive phonetic symbol guide [7]. The validity of this transcription was checked by providing another transcriber (the second author) with the same facilities. The agreement score for the main symbols (diacritics excluded) on 25 % of the whole corpus, was quite high (98,3%). Further, the first vowels which received the same classification by all the three transcribers were stored as reference for the classification of subsequent phonetic material.

The formant analysis on vowels was performed after that the concurrent displays of the waveform envelope, F0 tracing, amplitude contour, and a 586 Hz bandwidth FFT sonogram, enabled the individuation of the most stable part of the vowel (i.e. where F1 and F2 are possibly flat, clearly discernible and separated from each other). An LPC analysis (14 poles) was then applied to this selected portion, and the averaged values were automatically extracted for F1 and F2. The reliability of the LPC analysis was tested on the first 100 cases against a

manual interpolation of the harmonic envelope (50 Hz bandwidth). The results of a t-test did not reveal any significant difference between the two series of measurements (p for F1=0.348; p for F2=1.000), thus preference was given to the automatic LPC measures, except for the clearly wrong cases. The inter-subject agreement was checked with a t-test, by comparing the values resulting from the set of measurements made by the first author and that performed by an expert phonetician on 10% of the corpus. Again, differences were not statistically significant (difference for F1= 12.8 Hz, p=0.216; difference for F2=79.3 Hz, p=0.180).

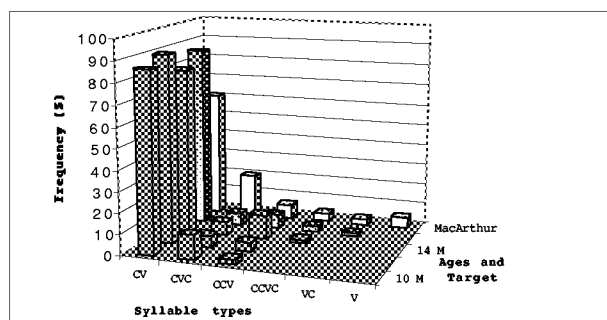
### 3. RESULTS

Table 1 shows statistics describing some quantitative characteristics of the analyzed corpus.

Variables	No. babbling and words utterances / No. total vocalizations	No. analyzed syllables (No. syll. in words)	No. analyzed syllables in mono- / pluri-syllables
Months			
10th	not available	93	35-58
12th	98/294 (33%)	91 (1)	27-64
14th	81/182 (44%)	60 (9)	38-22
16th	122/163(74 %)	115 (51)	31-84

**Table 1.** Counts of babbling utterances and words over total vocalizations (expressed also as percentages), counts of the analyzed syllables (those belonging to words are enclosed between parenthesis) and counts of the syllables belonging to either monosyllables or plurisyllables.

The syllables identified and analyzed are 359. The first column of table 1 reveals a progressive increase of the babbling utterances and words over the total counts of vocalizations, with the syllables' words progressively increasing their proportion within the total of the analyzed syllables (2<sup>nd</sup> col.).



**Figure 1.** Frequency (in percentage) of syllable types produced by Davide at the ages of 10, 12, 14 and 16 months and by [4]. V-type syllables were not included in the count for Davide.

Figure 1 illustrates the occurrence frequency percentage for each syllable type in babbling production. The 358 syllables pronounced by Davide are compared to the frequency of syllable types in a selection (consisting of 440 syllable tokens) performed by the present authors, of the target words attested by parents as present in the vocabulary of at less 3 out of 315

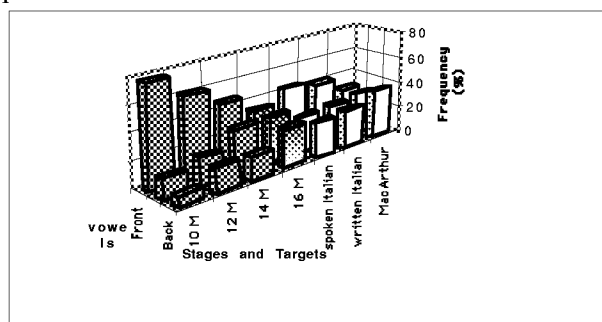
children (i.e. the whole population, appendix B of [4]). The most frequent and stable syllable type is the CV type (80-90%), which is also the most frequent within the target lexicon (70%). With the increase in age of the child, it was possible to note an expansion of his repertory of syllable types, which increased in number and complexity towards that of adult language.

Table 2 lists the percentage of occurrence of the 10 most frequent vowels along the 4 stages of Davide, together with 2 statistics referring to standard Italian [8, 9] and a statistic referring to the above mentioned lexical selection from [4].

10th	12th	14th	16th	Ital. [16]	[17]	[15]
e 23.3	e 18.7	a 26.7	a 22.6	a 26.9	28.7	31.7
ɪ 17.2	ɛ 11.0	ɪ 13.3	ɪ 10.4	ɪ 21.0	15.7	11.2
i 8.6	ɪ 8.8	e 11.7	ɑ 9.6	e 20.0	23.3	14.6
ɛ 8.6	ø 8.8	æ 10.0	o 7.0	o 18.9	21.7	24.7
ø 8.6	ə 7.7	ɪ 5.0	ɪ 6.1	ɛ 4.3	3.6	5.4
ɪ 5.4	a 6.6	u 5.0	u 4.3	u 5.2	4.5	6.7
y 4.3	ɪ 5.5	y 5.0	æ 4.3	ɔ 2.5	2.1	5.6
ə 3.2	ʌ 4.4	ʊ 5.0	e 3.5			
æ 3.2	æ 4.4	o 3.3	ɛ 3.5			
ʏ 3.2	o 3.3	ʉ 3.3	ø 3.5			
	u 3.3		ʉ 3.5			
oth. 15.5	oth. 18.5	oth. 22.1	oth. 18.2			

**Table 2.** List of the most frequent vowels (%). As to standard Italian, 3 statistics are reported: [8, 9, 4].

While during the first stage all the vowels are non-low and frontals, in the 12<sup>th</sup> month the /a/ appears and the two final stages are more and more similar to the adult frequencies, mainly in the preference accorded to the lowest vocalic types (/a, ɑ, æ/; see. the 31.7% for the /a/ in [4]). The prevalence in the vowel system of the anterior set and the absence of the whole posterior and rounded set is also a characteristic of the vowel development of the child studied by Buhr [10]. His explanation addresses biomechanical reasons, as the anterior vowels may be produced by the jaw movement only, whereas complexity of the movements hampers the articulation of the posterior/rounded vowels.



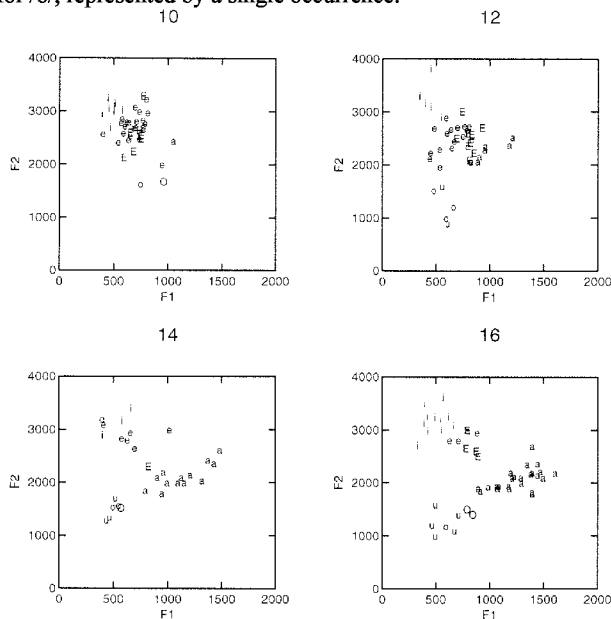
**Figure 2.** Frequency occurrence percentages of vowels in Davide's productions and in [8, 9, 4], classified along the longitudinal articulatory axis.

As to importance of articulatory considerations, Kent and Miolo [2] highlight the role of the tongue, a very complex organ, in the vowel development. As the high vowels /i/ and /ɪ/ are not common in babbling in general, their initial prevalence in

Davide may be due to an idiosyncratic factor. In fact, the above mentioned authors admit both the strength of the individual variability and the articulatory feasibility of these vowels in the ages here considered.

If the vowels are classified according to the back-to-front axis (Figure 2), a linear tendency emerges towards the frequencies of the target adult language, as testified by the agreement between the percentages of the 16<sup>th</sup> month and those of [4]. From the initial virtual sticking to front articulations, a more balanced use of the whole back-to-front articulatory space is finally reached.

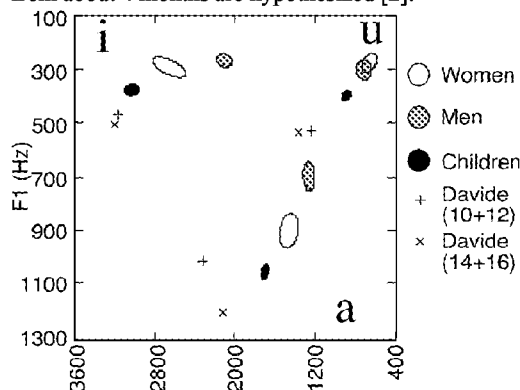
The acoustic analyses of the vowels may render the picture clearer, as shown in Figure 3. Vowels classified as occurrences of the seven vowels of standard Italian are plotted in the acoustic space (Hz) defined by the F1 and F2 coordinates (any potential allophones were excluded). In the first stage, the front vowels are confused in a crowded space comprised between 500-1000 Hz for F1 and 2000-3000 Hz for F2. When Davide was in his 12<sup>th</sup> month, the previously absent vowels, /a/ and the back set, appeared on the right and lower apices of a just emerging vocalic triangle. In the 14<sup>th</sup> month, the vocalic triangle lengthens its sides and begins to distinguish the cardinal vowels /a, i, u/. When the final stage of the 16<sup>th</sup> month was reached, Davide had almost completed his evolution towards the adult model: the areas of existence are well distinguishable for all vowels, except for /o/, represented by a single occurrence.



**Figure 3.** Plots of the vowels belonging to standard Italian produced by Davide in each of the four stages (E=/ε/; O=/ɔ/).

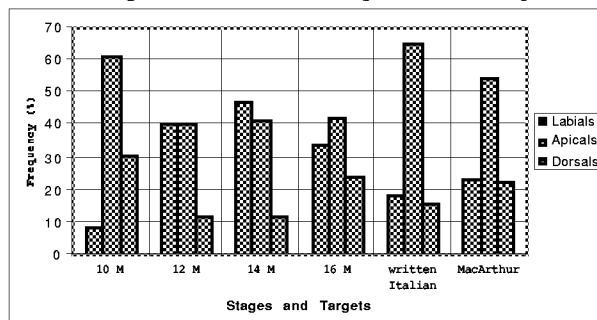
In figure 4, a comparison is proposed between the mean values of the cardinal vowels /a, i, u/ produced by Davide in the 2 main stages (the 10<sup>th</sup> month with the 12<sup>th</sup> month, and the 14<sup>th</sup> month with the 16<sup>th</sup> month), and the centroid of existence for the vowels of the subjects of [11]. These subjects are a representative sample of Italian adult male and female speakers of northern Italian, and children from the first three classes of primary school. The vowels produced by Davide are in lines with the centroids, and the position of the /a/ in the final stage

may be explained as a realignment. These data are better interpretable if a similarity in the shape of the vocal tract and a linear factor active in the proportional growth of the vocal tract from about 4 months are hypothesized [2].



**Figure 4.** Areas of existence for the cardinal vowels produced by the subjects of [11] (centroids) and Davide (mean values).

Early vowel acquisition patterns are also important in terms of understanding how correct consonant production is acquired.



**Figure 5.** Frequency occurrence percentages of labial, apical and dorsal consonants in Davide's productions and in [9] and a selection from [5].

Figure 5 illustrates a comparison between Davide's frequencies and the frequencies attested for Italian, based on the classification of the active articulators, resulting in three classes: **labials** (bilabials and labiodentals), **apicals** (dentals, alveolars, postalveolars, retroflexes), and **dorsals** (palatals, velars, uvulars, pharyngeals). For the productions of Davide and for the words listed in the selection from [5] only the initials of the CV and CVC syllables were selected. Though the initial stage reveals a low frequency of labials and a great frequency of dorsals, in the subsequent stages there is a quite good approximation to target language (see the frequencies of [15], between parenthesis in the following sentence). When Davide was in the 16<sup>th</sup> month, the frequencies were the following: 34.0 (23.2) for labials, 40.8 (58.9) for apicals, and 25.2 (17.8) for dorsals.

Data referring to vowel and consonant occurrence frequency, though useful, cannot provide information regarding co-occurrence frequencies, and then preferred syllable types. The intra-syllabic hypothesis of MacNeilage and Davis's theory makes precise predictions regarding the co-occurrences of vowels and consonants within the syllable: front vowels tend to occur after apex consonants; central vowels tend to occur after

labial consonants; back vowels tend to occur after dorsal consonants. Table 3 describes the relationship between the observed and expected frequencies for each cell. The expected value is 1.0. Classification of vowels along the front-back axis is made in accordance with the IPA (1993) table. Data are divided up into two groups (the first 2 and the last 2 stages). The six associations predicted by the *Frames, then content* theory are highlighted in bold character. Four out of six associations exceed the casual probability level, whereas for the unpredicted cases, this level is exceeded by 4 out of 12. The predicted association that do not occur refer to dorsal consonants with back vowels. The  $\chi^2$  statistical test was applied to each single column of this table (6), to assess whether the frequency of occurrence of the determined combinations would give a significantly different result (\*p- .05) from the occurrence frequency of the expected ones. The expected frequencies for each vowel class were derived from the overall frequency for a specific vowel within each of the two samples.

D.	L	D	V	D.	L	D	V
10+12				14+16			
n. 173				n.161			
F	0.760	<b>1.121</b>	0.969	F	0.476	<b>1.407</b>	1.204
C	<b>1.549</b>	0.710	1.112	C	<b>1.322</b>	0.781	0.816
B	1.498	0.772	<b>0.999</b>	B	1.278	0.743	<b>0.969</b>
p< .05					*	*	

**Table 3.** Ratio of the observed-to-expected co-occurrence frequencies for labial (L), apical (A) and dorsal (D) consonants with the front (F), central (C) and back (B) vowels.

The only two significant associations were those regarding the co-occurrence of labial consonants and central vowels, and also apical consonants and front vowels in the 14<sup>th</sup> + 16<sup>th</sup>-month age group. It should be noted that in [2], the only association that was predicted but not statistically confirmed was precisely that existing between velar consonant and posterior vowels. To ascertain the relative influence of either babbling or words on the results of the last 2 stages, two separate  $\chi^2$  analysis were performed. As for words, though a greater observed-to-expected ratio was observed for the three predicted associations than for the unpredicted ones, none of these reached the significance level. As for babbling, the patterns of association at each of the three articulatory positions were all significant, but the A-F association was the only one predicted by the theory, the others being L-B and D-C.

#### 4. CONCLUSION

In this study the authors aimed to combine the auditory assessment method with the precision offered by the instrumental measurement of acoustic characteristics. While generic progress may be determined in the increasing prevalence of the number of CV syllables over vocalizations, the aspects that better reveal the influence of the target language include the frequency of vowel types, especially if their classification refers to front-back dimension, in combination with an expansion and refining of phonotactic possibilities. Further, acoustic and articulatory evidence reveals an initial tendency for more control of height dimension than front/back. The presence of significant

associations between labial consonants and central vowels, as well as between apical consonants and front vowels only in data referring to the later period (14<sup>th</sup> + 16<sup>th</sup> months) may mean that the child develops from a babbling phase characterized by the overwhelming prevalence of front articulations, to a phase characterized by the presence of first words. In this phase the predicted patterns of association occur, perhaps owing to the presence of the same patterns in the target lexicon. This phase is best identified by the association between labial consonants and central vowels (i.e. the 'easier articulations'), and in fact labials increase their incidence (43.8%) in the first words with respect to concurrent babbling (31.86%), as found also by [13].

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