THE INFLUENCE OF TARGET-LANGUAGES ON VOCALIC SPACE IN TEN-MONTH-OLD INFANTS

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We have hypothesized that incipient linguistic differenciation in babbling children could be first reflected in vowel production. Twenty ten-month old infants from Paris French, London English, Hong-Kong Cantonese and Algiers Arabic backgrounds were recorded in the cities of origin. 1047 non-nasalized vowels extracted from syllables containing at least one consonant were spectrally analyzed. Formant frequencies were plotted on F1-F2 charts by infant and by language group. Statistical analyses provide evidence of an early differenciation in vowel production between infants from different language backgrounds.

The hypothesis that prelinguistic productions are unrelated to any specific language is supported by similarities found in the statistical distribution of consonants in the productions of infants from different linguistic backgrounds. We postulate that articulatory gestures for vowel production could offer the first indication of linguistic differentiation in prelinguistic infants.

The development of vowel space has been shown to be a gradual process. However, at 10 months, children's vowel spaces have reached a relatively large extension (1) (2) and there is a relative stabilisation of the anatomical configuration of the vocal tract around 38-40 weeks . We thus decided to investigate whether language-specific effects on vowels could be shown to exist in the babbling of 10-month old infants. We investigated the vowels of ten-month old infants from French, English, Algerian and Cantonese linguistic backgrounds.

The two positions about babbling in relations to language background entail different predictions:

1. If the babbling forms depend mainly upon biological mechanisms and maturational processes, there should be no systematic differences between infants and the distribution of vowel formant frequencies should be independent of the language of the environment.

2. On the contrary, if by 10 months infants have already begun to be influenced in their productions by the language of their environment, we may expect to find systematic differences between children as a function of the differences existing between the corresponding adult languages in the domain of vowel production.

Vowel production in the adult languages

Frequency counts of vowels in running speech (3-4-5) show English and Cantonese to be sharply contrasted in the frequency of occurence of certain vowel sounds. Specifically the following feature ratios are markedly higher for English than for Cantonese: front/back, high/low, unrounded/rounded. In each case French stands between English and Cantonese. In terms of the distribution of vowel formant frequencies in running speech these preferences entail the following:

- Cantonese prefers high F1's and low F2's (compact vowels).
- English shows the reverse preference and favors low F1's and high F2's (diffuse vowels).
- On both the F1 and F2 dimensions, French stands between English and Cantonese.

No acoustic description or phoneme frequency count is available for Algiers Arabic. Given the general information on Maghreb Arabic we may conjecture that Algiers Arabic may favor more central values of F1 and F2, possibly with a bias, due to pharyngealization, toward higher central values for F1 and lower central values for F2.

If similar preferences are found in the babbling of infants that will support the claim of an early influence of target languages on babbling.

Recording Procedures

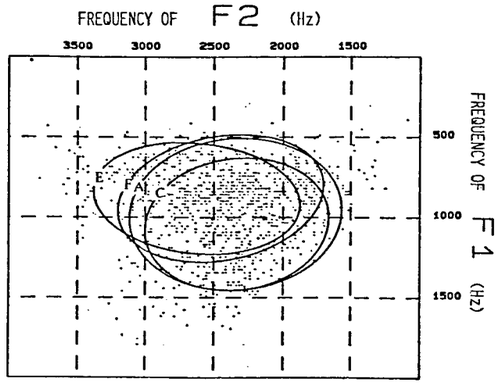
Five ten-month old infants were separately tape-recorded during a single one-hour ses-

sion in each of the following cities: Paris, London, Algiers and Hongkong. Children were paired for age and sex across language groups.

Acoustic analyses.
The tapes were transcribed into narrow IPA transcription by one transcriber. These transcriptions were then simplified by reducing the number of vowel symbols to nine. The frequency of occurrence of each wide vowel class in the babbling productions of each child were then established. Acoustic analyses were run on non-nasalized vowels from canonical or variegated babbling (6). For each babbling utterance, one token of each of the different vowel symbols was analysed such that the same repartition of vowels in the acoustic analyses as found in the wide transcriptions was maintained.
The audio signal was analogically low-pass filtered at 4.5 KHz, then sampled at a rate of 10 KHz. After visually displaying the resulting signal, a relatively steady-state portion of 30 msec. was selected for each vowel to be analyzed. F1 and F2 were estimated from 20Hz resolution short-time spectra cepstrally smoothed by means of the "True Envelope" method (7).The first and second formants were plotted at the corresponding frequencies on F1xF2 formant charts.

Results and statistical analysis.
The overall ranges of formant variation for all children are approximately 400-1800 Hz for F1 and 1250-3800 Hz for F2.
All vowels by all twenty subjects are plotted in the formant chart in fig.1. The ellipses enclose 75% of the vowels in each of the four language groups.

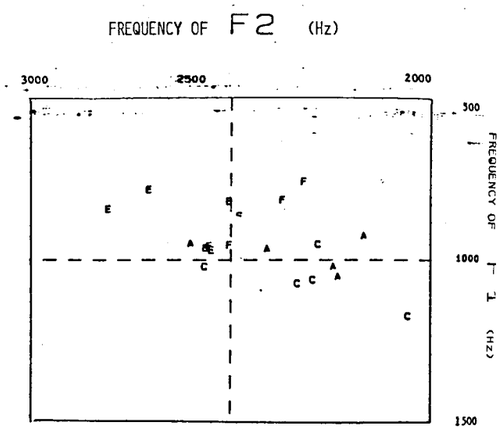
Fig.1.



F1-F2 plot of all vowels by all infants. Ellipses enclose 75% of the vowels in the French (F), English (E), Cantonese (C) and Algerian (A) groups.

Taken together for each child, mean F1 and mean F2 define a "mean vowel" which lies at the center of the area of the formant chart occupied by the vowel productions of a child. The "mean vowels" of each child are shown in fig. 2.

Fig. 2



Plot of mean F1 and F2 frequencies in Hz by subjects. Mean vowels of French, English, Cantonese and Algerian infants are marked F,E,C,and A.

The mean vowels of five infants - 2 French, 2 English and 1 Algerian - are very close together, with formant frequencies close to F1 = .95 KHz and F2 = 2.55 KHz. With the rest of the children, the "mean vowels" occupy different sectors of the formant chart as a function of language background.
Mean formant frequencies and standard deviations by language group are listed in Table I

Table I

	French	English	Cantonese	Algerian
F1	878 (239)	876 (207)	1047 (241)	976 (282)
F2	2456 (439)	2628 (452)	2343 (381)	2341 (459)

An overall analysis of variance (ANOVA) was run on these data with Language as factor and mean F1 and mean F2 as observations. The effect of language environment was found to be significant for F1: $F = 6.651$ $(3,16)$ $p<.01$, and for F2 as well: $F = 4.728$ $(3,16)$ $p<.05$.

A second set of analyses was performed based on estimated distances between vowel sets. If we assume that the vowel sets of infants all belong to a single population, in other words, that there are no significant differences between infants from different language backgrounds (hypothesis H0), we can then characterize that population by a covariance matrix computed on all the data, and characterize the distance between the vowel sets of any two infants by means of Mahalannobis distances:

$$d_{kl,lj}^2 = \Delta\Sigma_a^{-1}\Delta^T$$

where k and l are indexes for the languages, i and j indexes for infants within a given language, and Δ is the vector of differences between F1 means (i=1 to 2). Average intra-language distances are computed according to:

$$(1) \qquad D_k = \left(\sum_{i=1}^{4}\sum_{j=i+1}^{5} n_{ki}n_{kj}\, d_{ki,kj}^2\right)/\left(\sum_{i=1}^{4}\sum_{j=i+1}^{5} n_{ki}n_{kj}\right)$$

where n_{ki} is the degree of freedom of the corresponding vowel sets and Dk the average intra-language distance within the kth language. Similarly, the averaged inter-language distance between the kth and lth languages is given by:

$$(2) \qquad D_{k,l} = \left(\sum_{i=1}^{5}\sum_{j=1}^{5} n_{ki}n_{lj}\, d_{ki,lj}^2\right)/\left(\sum_{i=1}^{5}\sum_{j=1}^{5} n_{ki}n_{lj}\right)$$

Table II summarizes the results under the H0 hypothesis. Clearly, infants differ more between different languages than within any single language. This precludes H0 and in itself warrants the conclusion that infants' vowels in babbling differ according to language background.

Table II
Intra-language and inter-language distances under H0

	French	English	Cantonese	Algerian
French	0.31	0.83	0.86	0.83
English		0.38	2.00	1.99
Cantonese			0.45	0.86
Algerian				0.42

The mean intra-language distance is 0.392; the mean inter-language distance is 1.231.

We also tested the hypothesis H1 according to which several populations -possibly one per language- are to be considered. The kth language is characterized by the covariance matrix Σ_k. Intra-language distances are

$$d_{kl,kj}^2 = \Delta\Sigma_k^{-1}\Delta^T,$$

while inter-language distances are obtained by averaging two different covariance matrices, e.g.:

$$d_{kl,lj}^2 = \Delta\Sigma_{k,l}^{-1}\Delta^T, \text{ where } \Sigma_{k,l} = (n_k\Sigma_k + n_l\Sigma_l)/(n_k+n_l),$$

and n_k is the degree of freedom of the entire vowel set of the kth language.

Averaged intra- and inter-language distances are computed as in (1) and (2). Table III summarizes the results obtained under H1: these results are still consistent with the claim of an early influence of linguistic environment.

Table III
Intra-language and inter-language distances under H1.

	French	English	Cantonese	Algerian
French	0.29	0.47	1.00	0.51
English		0.46	1.36	0.80
Cantonese			0.60	0.46
Algerian				0.40

Mean intra-language distance is 0.440 and mean inter-language distance is 0.767.

Specific influence of target languages.
English group.
F1 values for English infants are generally low (mean is 876 Hz, lower than with the Cantonese and Algerian groups) and little dispersed. Individual English children depart only slightly from this general tendency. This illustrates the preference of English children for diffuse vowels as predicted.
Cantonese group.
Mean F1 in Cantonese children is higher than in any other group and mean F2 is lower than in any other group. The preferred formant frequencies of Cantonese infants are those characterizing compact vowels.
French group
As expected,mean F2 is higher than with Cantonese infants and lower than with English infants. Mean F1 (878 Hz) is also lower than mean F1 with the Cantonese and Algerian groups but identical with that of English children.
Algerian group
The distribution of formant frequencies is indeed characterized by a preference for central frequencies: the mean formant values of F1: 976 Hz and F2: 2346 Hz, although the vowel space of Algerian infants as a whole is not noticeably less spread out than that of the other groups.

Conclusion
Our acoustic study of formant frequencies in vowel productions by 10-month olds has shown that certain characteristics of the target-languages are reflected in the productions of babbling.
When speaking about production most investigators frequently refer to constraints on performance only. However in production as well as in perception the programs involved require underlying representations. With respect to production, the preference of babbling children for vowels situated in an

acoustic space that is consistent with the vowel space of the corresponding adult language indicates that target-language oriented articulatory procedures begin to be available. In an earlier study (8) we claimed that setting articulatory limits to tongue and lip movements in vowel production in babbling could be the first step towards acquiring the vowel system of a target language. This implies that the notion of "representation for production" must be considered for 10-month olds.
According to Locke (9) language acquisition begins "when a child moves away from what would continue to be his pattern and closer to the ambient one". In the present article we have shown that the buildup of target language-oriented articulatory skills is already under way at the end of the first year.

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