ADAPTATION TO LANGUAGE: EVIDENCE FROM BABBLING AND FIRST WORDS IN FOUR LANGUAGES

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Differences among languages offer a way of studying the process of infant adaptation from broad initial capacities to language-specific phonetic production. We designed analyses of the distribution of consonantal place and manner categories in French, English, Japanese, and Swedish to determine (1) whether systematic differences can be found in the babbling and first words of infants from different language backgrounds, and, if so, (2) whether these differences are related to the phonetic structure of the language spoken in the environment. Five infants from each linguistic environment were recorded under similar conditions from babbling only to the production of 25 words in a session. Although all of the infants generally made greater use of labials, dentals, and stops than of other classes of sounds, a clear phonetic selection could already be discerned in babbling, leading to statistically significant differences among the groups. This selection can be seen to arise from phonetic patterns of the ambient language. Comparison of the babbling and infant word repertoires reveals differences reflecting the motoric consequences of sequencing constraints.*

INTRODUCTION

1. Comparison of different languages makes it possible to investigate the epigenetic processes involved in the attainment of what may be the most complex of human action patterns: the production of speech. It can be assumed that there exists a capacity for language which is common to members of all speech communities. But different languages require that this capacity be shaped into different patterns—patterns that may be quite precisely defined by analysis of the adult language in question. Crosslinguistic study of the course of evolution toward these patterns can yield considerable insight into the nature of species-wide phonetic capacities, both by establishing commonalities in the progress of normally-developing infants and by determining the modifications and the time course involved in achieving particular adult-language goals.

Work in the area of speech acquisition over the past several years has led to a profound change in our views about the nature of infants' early vocal action capacities. The earlier view, based on the theories of Jakobson (1941/68), held that prespeech infants produce all of the sounds of the world's languages. Jakobson maintained, however, that with the advent of word production children revert to a highly restricted sound-production capacity, dedicated to the unfolding of a universal sequence of segmental contrasts. This view has now been replaced by one that emphasizes the CONSTRAINTS on prespeech ca-

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pacities, as well as their essential relevance to the form of the first words (Locke 1983, Vihman et al. 1985).

This more recent view has sometimes been taken to mean that production of the child's first words requires no language-specific motor capacities (Locke 1983). Earlier work attempting to show language-specific influences within the first year through adult-listener judgments has been criticized on methodological grounds (Thevenin et al. 1985). However, at least two recent studies have demonstrated language-specific production patterns in vowels in the course of the first year, before the appearance of the first words. These studies are based on statistical analysis of the relative distribution of vowel sounds in the adult target language and in the vocalization patterns of infants, as defined by formant frequencies (de Boysson-Bardies et al. 1986, de Boysson-Bardies et al. 1989).

These two studies suggest that vowel production begins to approximate favored values in the adult language even before production of the first words. Can similar effects be shown for consonants? This question is important for two reasons. First, it is often assumed that vowels are easier to produce than consonants; a demonstration of prespeech progress towards adult vowel patterns therefore does not necessarily imply comparable progress towards consonant patterns. Second, the overwhelming majority of speech acquisition studies to date have focussed on consonants. As a result, the theoretical context for the evaluation of any observed pattern of consonant production is better developed than that for vowels. The present study represents an attempt to determine whether language-specific patterns can be observed in babbling and first words in the case of consonants as well as vowels.

The methods to be used here resemble those of the vowel studies mentioned above in that we emphasize the relative distribution of sounds produced in relation to adult-language targets. This focus is deliberate: we view early adult-language effects on infant vocal production as the result of infant SELECTION from a range of possible sound productions, and not as evidence of new sound ACQUISITION. However, the present study differs from the earlier vowel studies in the following respects:

(1) Our analysis of consonantal production, like other such studies of this age group (Stoel-Gammon & Cooper 1984, Vihman et al. 1985, Vihman et al. 1986), is based on auditory analysis of infant vocalizations (i.e. on phonetic transcripts) rather than on acoustic analysis. This difference follows from the relatively greater reliability of consonant transcription for infant vocalizations (Stockman et al. 1981) as compared with vowels, as well as from the absence of a stable context-independent acoustic characterization of (adult) consonant production (Perkell & Klatt 1986).

(2) This study is based on a longitudinal analysis of vocalizations spanning the period from babbling only to early words with concurrent babbling, whereas the vowel studies were restricted to a single time point just preceding the onset of word production. This expanded focus is intended to provide a broader perspective on the process of adaptation to the target language.

(3) In this study phonetic characterizations of infant vocalizations are directly compared with statistical properties of the actual target words attempted by

the children in each group. We took these words to offer the most representative adult-language sample available. Consonantal computations based on samples of media speech (e.g. from newspapers and radio) are less typical of the infant's language environment. Fluent speech includes uncommon words unlikely to be heard or retained by the infant. Furthermore, acoustically less salient function words account for a high proportion of adult production, but infants neglect weak-stress function elements (Gerken et al. 1990, Pye 1983). We assume that selective attention processes underlie the organization of speech production. We therefore based our analyses of adult place and manner categories in each language on the phonetic shape of the adult words serving as targets for one or more infants. The relevant sample included approximately 105–120 words for each group.

One aspect of the acquisition of speech production that has received considerable attention recently is the ubiquity of individual differences in production capacities and propensities, even among children learning the same target language (Ferguson & Farwell 1975, Vihman et al. 1986). These differences might be considered sufficient to cast doubt on the possibility of making meaningful generalizations about whole groups of normally-developing subjects. However, the studies described earlier have shown interpretable crosslinguistic differences in VOWEL patterns in spite of broad individual variability. The question here is whether crosslinguistic differences in early consonant production are also sufficiently robust to be discerned in spite of individual variability among infants exposed to the same language.

Our goal, therefore, is to determine (1) whether systematic differences in the consonant repertoire can be found in the babbling and first words of infants from different language backgrounds, and, if so, (2) whether these differences are related to the phonetic structure of the language spoken in the environment.

METHOD

2.1 SUBJECTS. Twenty normally-developing infants—5 French, 5 American, 5 Japanese, and 5 Swedish—participated in the investigation; each group comprised three boys and two girls, except the Americans, who were three girls and two boys. All the subjects were from middle-class families, and all but two (both French) were first-born children.

2.2. RECORDING PROCEDURE AND DATA COLLECTION. The infants were audio- and video-recorded twice a month from the age of nine months, when only one child (Swedish) had begun to produce identifiable words, until they had each produced at least twenty-five words in a half-hour session. The French, American, and Swedish infants were recorded in their country of origin; the Japanese infants were recorded in the San Francisco area, in monolingual Japanese homes. The infants were all recorded at home in unstructured play sessions with the mother.

Since babbling and first-word productions require reliable audio recording for phonetic transcription, the infants wore an electric condenser microphone hidden in a pocket on the inside of a cloth vest. The microphone was connected

to a high fidelity audio or video tape recorder. All the sessions were videotaped to provide information about situational context, direction of the child's attention, and gestures accompanying vocalizations. Parents were asked to interact with the child in a natural way, but to elicit communicative behavior and any suspected words.

2.3. WORD IDENTIFICATION. Words or word candidates were counted after each session. To be considered as a possible word, a vocalization had to resemble an adult word plausibly in shape and to be used in a plausible context; identification by the mother was also helpful.

The following aspects of each vocalization were specifically examined: number of segments matching the adult form; prosodic-feature matches with the adult form; imitation of the adult word in context; determinative context, for words with specific meanings such as concrete nouns or action verbs; identification by the mother, by explicit comment or by acceptance of the child word in continuing the conversation; absence of other uses of the phonetic shape of the vocalization outside an appropriate context; and appropriate use in more than one situation. When one or more criteria relevant to both form and content were met, the vocalizations were taken to be words. All other vocalizations are here counted as 'babble'.

2.4. SELECTION OF DATA POINTS. The number of spontaneous word types identified in a session was used to define four lexical milestones for comparison across children: zero words (0 to at most 2 different words), four words, 15 words, and 25 words. For four words and 15 words, another session within the same month was also analyzed. The 25-word session was typically the last.

Table 1 shows some group effects that deserve additional comment. Note first that age of lexical attainment can be deduced from this table for the last three sessions only; the 0-word session was simply chosen to precede the first session in which word use was clearly established. Second, the relatively precocious age range for American subjects at 25 words is an artifact of subject selection, since these children were recorded as part of a larger study (10 subjects) which terminated at 16–17 months (Vihman et al. 1985). Only the five most advanced infants, who had attained the 25-word level by the end of the study, could be included for comparison here.

	0 words	4 words	15 words	25 words
FRENCH:	10	12	15	16–17
ENGLISH:	9–10	11–12	14	16
JAPANESE:	13	14	17–18	19
SWEDISH:	9	11–12	15–16	16–17

TABLE 1. Mean age of subjects in months at the four milestones.

The source of the slower lexical advance of the Japanese group can only be the subject of speculation at this point. On the one hand, it could be related to the more sophisticated and longer target words aimed at by the children,

leading them to more polysyllabic productions when first words appear. On the other hand, Bornstein et al. (1991) and others have reported lower vocal production and later lexical attainment by Japanese infants raised in Japan, as compared with American or French infants; Japanese child-raising traditions that involve less emphasis on verbal interaction than in America and Europe have been invoked by way of explanation.

2.5. TRANSCRIPTIONS AND DATA ANALYSIS. Monthly transcripts were made at each site by a native transcriber, and additional sessions were transcribed once the critical lexical points had been established for the 4- and 15-word levels.

Transcriptions were prepared using the International Phonetic Alphabet. Reliability was first tested within each group and then across languages, to determine crosslinguistic agreement levels and to check for possible language bias. In each case agreement was determined for four categories: consonantal place and manner features, consonant count in pre- and postvocalic position, and vocalization length in syllables. Transcription and reliability procedures and the results for English are detailed in Vihman et al. 1985. Intralanguage agreement ranges from 80% (for French transcribers) to 89% (for Swedish transcribers).

Crosslinguistic reliability was checked for some pairs of languages by having transcribers retranscribe portions of other-language recordings (27 4-word sessions and 4 15-word sessions); percentage of agreement ranges from 81.1 to 85.9.

2.6. QUANTITATIVE MEASURES. Counts were made for each subject at each of the six critical sessions for vowels, consonants, and length in syllables for all vocalizations, babbling and words. Final consonants were also counted separately.

Only true consonants were considered for the present analysis; glides, *h*, and glottal stop were excluded from this study. Consonants were classified according to place and manner categories. For place of articulation, consonants were classified into three categories: (1) labials (including labiodentals), (2) dentals (including alveolars and palatals), and (3) velars (including uvulars). For manner of articulation, five categories were taken into account: stops, affricates, fricatives, nasals, and liquids. Affricates and fricatives were subsequently grouped together to eliminate a category of very low incidence in all four languages (under 4% for affricates).

Intergroup comparisons were planned to test the hypothesis that linguistic background will influence the distribution of place and manner of consonants in infant productions, reflecting the main trends found in target words in each group. Analyses of variance measures by linguistic group (French, English, Japanese, Swedish) and by place (labial, dental, velar), with repeated measures on the last factor, were performed on the overall distribution of consonants, the distribution of consonants in babbling productions only, and the distribution of consonants in words. The same analyses were carried out for manner categories.

LONGITUDINAL TRENDS: DEVELOPMENT OVER THE PERIOD STUDIED

3. Tables 2 and 3 show mean and standard deviation for place and manner for all word points (i.e. milestones chosen for analysis on the basis of word level; both word and babble vocalizations are included) in all four languages.

		0 words	4 words	15 words	25 words
FRENCH:	Labials:	52.4	53.4	55.8	52.4
		(24.93)	(32.84)	(19.17)	(6.91)
	Dentals:	38.7	40.9	30.3	38.8
		(25.71)	(30.35)	(18.2)	(11.39)
	Velars:	8.9	5.7	13.8	8.6
		(9.63)	(7.08)	(13.32)	(9.08)
ENGLISH:	Labials:	55.9	48.0	41.5	39.6
		(22.90)	(23.71)	(17.51)	(9.77)
	Dentals:	31.1	29.1	37.0	40.1
		(26.60)	(25.51)	(20.69)	(10.31)
	Velars:	13.0	22.5	21.4	20.3
		(6.40)	(19.01)	(16.84)	(3.97)
JAPANESE:	Labials:	37.6	30.0	24.4	22.4
		(27.36)	(7.64)	(9.50)	(11.44)
	Dentals:	40.2	46.5	47.0	51.3
		(14.14)	(11.76)	(8.37)	(4.53)
	Velars:	22.2	23.4	28.6	26.3
		(17.15)	(11.57)	(6.79)	(7.97)
SWEDISH:	Labials:	21.1	22.4	20.7	19.5
			(11.6)	(9.06)	(15.04)
	Dentals:	42.4	62.5	51.5	57.5
			(16.6)	(7.93)	(17.8)
	Velars:	36.4	15.1	27.8	22.9
			(17)	(7.4)	(11)

TABLE 2. Consonantal distribution for the four milestones: PLACE (percent and S.D.).

The overall production of consonants shows good stability in mean frequency of distribution for place and manner categories throughout the period studied within each linguistic group. The standard deviations are homogeneous across the four groups and across the six sessions. Developmental effects across the four word points are generally evidenced more by a drop in the standard deviation than through large changes in the mean. Development is thus consistent with the idea of a reduction in individual variability, reinforcing the specific tendencies in each language group. For place categories, intersubject variability in the first sessions is very strong. However, the dramatic drop in standard deviation from the first session to the 25-word session for labials and dentals expresses the main trends found for place distribution. In French and Swedish the mean for labial production is stable throughout the period studied, while there is a consistent decline in labials in English and Japanese (see Figure 1).

		0 words	4 words	15 words	25 words
FRENCH:	Stops:	43.8	62.7	61.7	48.3
		(14.07)	(18.52)	(12.40)	(12.49)
	Fricatives:	7.9	13.5	11.2	12.7
		(2.7)	(13.38)	(4.72)	(10.32)
	Nasals:	36.3	16.5	18.6	27.3
		(14.11)	(9.63)	(7.39)	(2.80)
	Liquids:	11.8	7.3	8.4	11.6
		(7.67)	(14.74)	(7.84)	(11.46)
ENGLISH:	Stops:	64.8	69.3	69.3	67.6
		(16.12)	(15.97)	(10.53)	(11.78)
	Fricatives:	11.8	6.0	11.5	11.8
		(9.43)	(1.92)	(4.45)	(5.55)
	Nasals:	16.8	16.3	13.7	16.0
		(20.82)	(16.33)	(8.78)	(6.91)
	Liquids:	6.5	8.3	5.4	4.6
		(6.90)	(7.36)	(6.38)	(5.03)
JAPANESE:	Stops:	58.7	59.5	67.7	61.3
		(8.54)	(7.77)	(9.83)	(3.88)
	Fricatives:	12.5	11.8	9.5	9.8
		(8.47)	(4.55)	(4.02)	(4.29)
	Nasals:	26.7	23.4	17.1	21.2
		(12.43)	(8.24)	(9.86)	(6.01)
	Liquids:	2.1	5.2	5.5	7.7
		(2.04)	(4.91)	(8.17)	(6.44)
SWEDISH:	Stops:	66.5	79.4	75.0	71.0
		(21.7)	(5.8)	(11)	(11.5)
	Fricatives:	6.5	8.2	4.5	6.8
		(15.2)	(8.6)	(2.7)	(3.3)
	Nasals:	16.6	6.8	13.3	8.1
		(7.8)	(5.2)	(6.2)	(6.12)
	Liquids:	10.3	5.5	7.2	14.1
		(7.2)	(4.5)	(8.5)	(11.9)

TABLE 3. Consonantal distribution for the four milestones: MANNER (percent and S.D.).

The mean for stops is stable throughout the period studied (Figure 2). A drop in standard deviation between the 0-word and 25-word sessions can be seen in those manner categories with frequencies large enough to be evaluated (namely, stops and nasals: see Table 3).

SPECIFIC RESULTS: CONSONANTAL DISTRIBUTION IN THE FOUR GROUPS

4.1. ALL VOCALIZATIONS TAKEN TOGETHER. Table 4 shows the overall results for place and manner categories.

4.1.1. PLACE. The main effect of place is significant: $F(2,32) = 16$, $p < .001$. The interaction between place and groups is also significant: $F(6,32) = 3.33$, $p < .05$. This interaction effect is due mainly to the fact that the groups differ

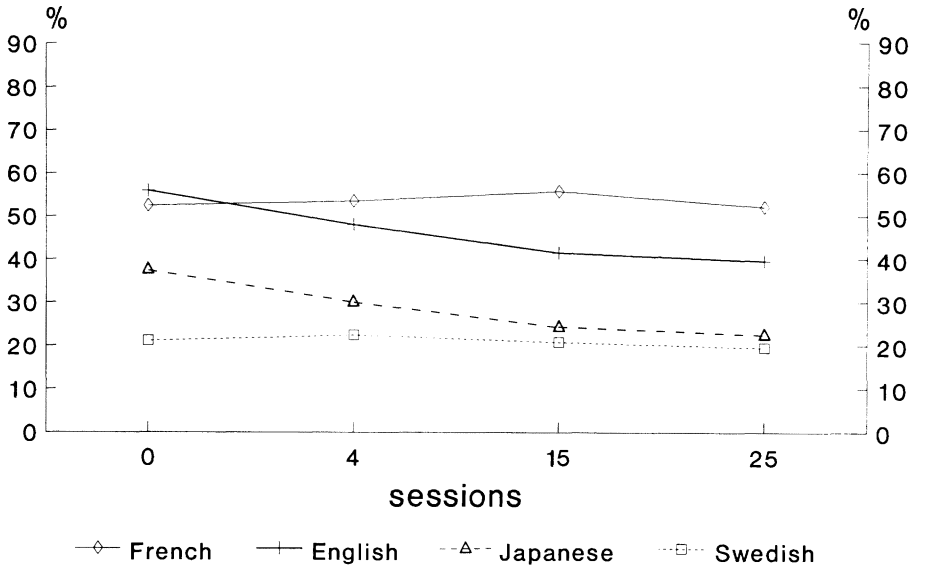

FIGURE 1. Percentage of labials by session (all productions).

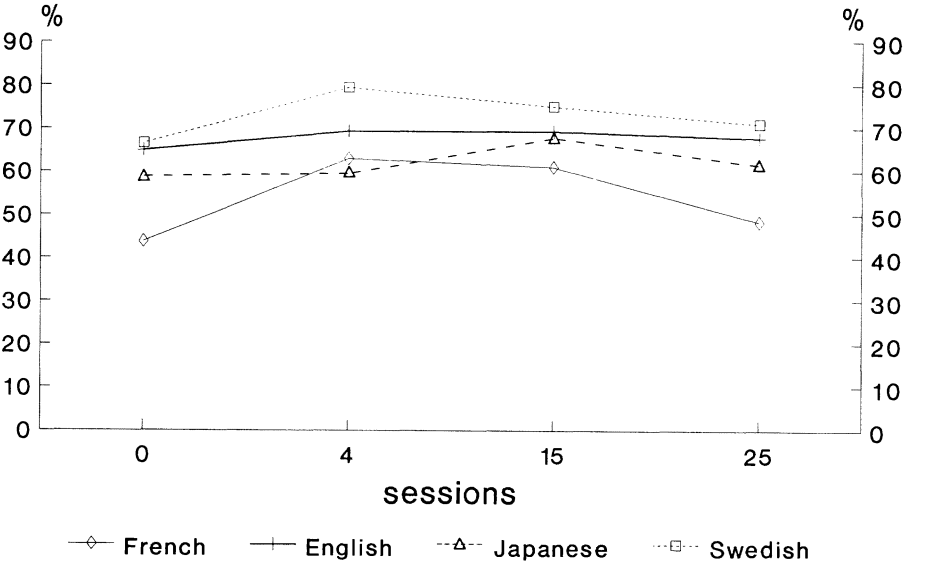

FIGURE 2. Percentage of stops by session (all productions).

	PLACE			
	FRENCH	ENGLISH	JAPANESE	SWEDISH
Labials:	53.8	45.9	29.6	20.3
	(14.4)	(13.5)	(8.6)	(1.81)
Dentals:	36.7	33.9	46.3	54.0
	(15)	(16.3)	(3.5)	(8.55)
Velars:	9.5	20.2	24.0	25.8
	(8.1)	(10.3)	(9.9)	(8.99)
	MANNER			
	FRENCH	ENGLISH	JAPANESE	SWEDISH
Stops:	56.9	68.3	61.2	72.7
	(9.9)	(9.1)	(2.4)	(10.5)
Fricatives:	11.7	9.9	11.0	7.7
	(5)	(4.1)	(2.9)	(3.3)
Nasals:	22.3	15.4	22.0	12.0
	(5.9)	(11.3)	(5.6)	(4.6)
Liquids:	9.2	6.4	5.8	7.5
	(9.1)	(6)	(4.6)	(6.1)

TABLE 4. Overall distribution in place and manner (percent and S.D.).

significantly in the distribution of labials: $F(3,16) = 5.32$, $p < .05$. There is no overall significant difference for the other place categories. Pairwise comparison between language groups shows that French infants' labial production differs significantly from Japanese infants' labial production—$F(1,8) = 10.37$, $p < .02$—and from Swedish infants' labial production: $F(1,8) = 3.25$, $p < .02$. French infants' velar production also differs from that of Swedish infants—$F(1,8) = 5.44$, $p < .05$—and Japanese infants: $F(1,8) = 6.14$, $p < .05$.

There is no significant difference between French and English in the distribution of the place categories. English shows only a tendency to differ in place category distribution from Japanese—$F(1,8) = 5.13$, $p < .06$—and from Swedish for labials, $F(1,8) = 5.11$, $p < .06$.

4.1.2. MANNER. Analysis of variance by groups and by manner categories shows a main effect of the manner factor: $F(3,48) = 232.6$, $p < .001$. The interaction between manner categories and language groups is significant: $F(9,48) = 2.14$, $p < .05$. There are no significant differences for the other categories. Pairwise comparison between languages shows that Swedish infants' production differs from French for stops, $F(1,8) = 6.02$, $p < .05$, and for nasals, $F(1,8) = 9.31$, $p < .01$, and also from Japanese for nasals: $F(1,8) = 9.62$, $p < .02$. The American infants do not differ significantly from the other groups.

4.2. BABBLING PRODUCTIONS. Analyses of babbling productions show that there is a significant interaction between language groups and the distribution of place categories—$F(6,32) = 4.67$, $p < .005$—and manner categories: $F(9,48) = 3.31$, $p < .005$.

4.2.1. PLACE. Table 5 shows the distribution of place for both babbling and words. The French and American groups do not differ for place categories in

babbling production, but in the percentage of labials produced French differs from Japanese—$F(1,8) = 16.30$, $p < .005$—and from Swedish: $F(1,8) = 18.79$, $p < .005$. English differs from Swedish, $F(1,8) = 7.87$, $p < .05$, and from Japanese: $F(1,8) = 5.32$, $p = .05$.

		BABBLING	WORDS
FRENCH:	Labials:	49.4	58.1
		(11.5)	(13.1)
	Dentals:	39.7	31.2
		(12.9)	(16.8)
	Velars:	10.9	10.7
		(8.1)	(12.7)
ENGLISH:	Labials:	42.4	48.0
		(15.2)	(11.8)
	Dentals:	36.3	35.0
		(14.1)	(16.1)
	Velars:	21.2	16.9
		(9.9)	(12.3)
JAPANESE:	Labials:	25.4	30.2
		(6.6)	(12.7)
	Dentals:	47.1	50.4
		(9.0)	(3.9)
	Velars:	27.5	19.4
		(11.7)	(10.3)
SWEDISH:	Labials:	18.2	27.9
		(10.4)	(16.6)
	Dentals:	56.7	47.6
		(5.7)	(18.6)
	Velars:	25.0	24.4
		(10.9)	(6.5)

TABLE 5. Distribution in babbling and words: PLACE (percent and S.D.).

The difference between Swedish and French in dental production is significant: $F(1,8) = 7.91$, $p < .01$. In Japanese and Swedish dentals are more numerous than labials from the first session onwards. The high percentage of dentals in Swedish can be traced to the high percentage of dental stops (83%), while Japanese dentals are often nasals (33%). Japanese velar production is significantly higher than French: $F(1,8) = 6.73$, $p < .05$. No other pairwise comparisons show a significant difference.

4.2.2. MANNER. Table 6 shows the distribution of manner categories for both babbling and words. The French group differs from all the other groups in the production of stops in babbling: French vs. English, $F(1,8) = 6.84$, $p < .05$; French vs. Japanese, $F(1,8) = 19.95$, $p < .001$; and French vs. Swedish, $F(1,8) = 15.75$, $p < .005$. The English, Japanese, and Swedish groups do not differ significantly from each other in stop production. The Swedish infants produce fewer nasals than either the French infants, $F(1,8) = 11.95$, $p < .01$, or the Japanese infants: $F(1,8) = 6.38$, $p < .05$.

		Babbling	Words
French:	Stops:	50.7	61.5
		(7.8)	(15.8)
	Fricatives:	16.3	6.8
		(6.9)	(7.5)
	Nasals:	23.3	21.5
		(7.2)	(7.2)
	Liquids:	9.7	10.2
		(8.9)	(9.2)
English:	Stops:	66.8	75.4
		(10.4)	(6)
	Fricatives:	11.6	7.3
		(4.3)	(4)
	Nasals:	14.7	13.5
		(11.7)	(8.7)
	Liquids:	6.7	3.7
		(7.2)	(3.2)
Japanese:	Stops:	69.5	57.5
		(4.9)	(5.3)
	Fricatives:	10.1	10.3
		(1.9)	(6.6)
	Nasals:	16.2	27.0
		(2.4)	(13.5)
	Liquids:	4.2	5.0
		(2.9)	(9.1)
Swedish:	Stops:	69.8	77.9
		(7.2)	(9.8)
	Fricatives:	10.1	3.3
		(3.5)	(2.9)
	Nasals:	8.8	14.2
		(6)	(8.3)
	Liquids:	11.3	4.6
		(10.9)	(4.1)

Table 6. Distribution in babbling and words: manner (percent and S.D.).

4.3. Word production. For word production, the interaction of language group by place is significant: $F(6,32) = 3.10$, $p < .02$. As was the case with babbling, infant words differ for labial production: $F(3,16) = 5.56$, $p < .01$. In the infants' words, French differs significantly from Japanese and Swedish in the percentage of labials, and from Swedish alone in the percentage of dentals. The American infants tend to differ from the Japanese and Swedish infants, but the difference does not reach significance.

The interaction between linguistic groups and manner categories is significant: $F(9,48) = 2.88$, $p < .05$. The groups differ on stop production: $F(3,16) = 4.95$, $p < .01$; there is no systematic difference in the other manner categories.

4.4. Comparison of babbling and infant words. The distribution for place of articulation in words is similar to the distribution in babbling. There are no

significant differences here among French, American, Japanese, and Swedish infants; the increase in labial production found in words for all four groups of infants fails to reach significance.

The distribution of manner categories for words is parallel to the babbling distribution for French, English, and Swedish. However, there is less difference among language groups in the word distribution than in the babbling distribution.

There is a systematic increase in stop production in words for French, English, and Swedish (around 10%), but the difference fails to reach significance in any group. Swedish infants produce significantly fewer fricatives in words than the other language groups: $F(1,8) = 11.09$, $p < .02$. A tendency to produce fewer fricatives in words is also found for French infants. For Japanese there is a significant difference between babbling production and words due to a significant decrease in stops in infant words: ($t(4) = 3.28$, $p = .03$). The intergroup differences found in the percentage of nasals in babbling are reduced in words.

Distribution of consonants in the adult reference sample

5. The distribution of place and manner categories in the phonetic shape of the adult target words shows clearcut differences among the four language groups (see Table 7 and Figure 3).

	Place					
	Labials		Dentals		Velars	
	(a)	(b)	(a)	(b)	(a)	(b)
French:	54.3	60.0	33.6	26.2	12.1	13.7
English:	34.1	49.0	43.0	34.0	22.8	17.0
Japanese:	27.8	41.3	55.2	38.6	17.0	20.1
Swedish:	33.5	40.8	39.5	36.6	27.0	22.5

	Manner							
	Stops		Fricatives		Nasals		Liquids	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
French:	48.1	60.8	11.2	11.6	21.7	19.7	19.0	7.8
English:	55.4	63.6	12.1	12.0	15.1	12.0	17.4	12.3
Japanese:	45.0	63.3	19.1	10.7	31.1	25.0	4.8	1.0
Swedish:	57.9	64.7	9.9	12.0	17.0	13.2	15.2	10.0

Table 7. Target words: consonantal distribution (percent). (a) = overall; (b) = initial.

5.1. Place. The distribution of consonants according to place categories in the target words of the four linguistic groups is significantly different: chi-square (6df) = 22.65 $p < .01$. However, the difference in the distribution of initial consonants shows only a tendency towards significance: chi-square (6df) = 11.36,10 $p > .05$. The four languages differ mainly in the percentage of labials in the target words. The percentage of labials is higher in initial position than overall for all four groups. This difference reaches significance for English and Japanese target words; but initial labials are far more numerous in French than they are in English, Japanese, or Swedish, which share a closely similar distribution of place categories in initial position.

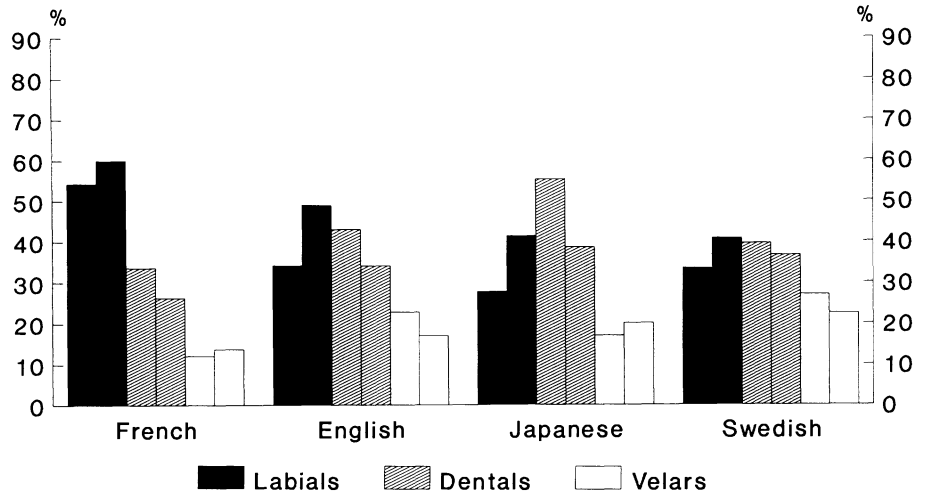

FIGURE 3. Distribution of place categories in French, English, Japanese, and Swedish target words.
1st column: all consonants in target words.
2nd column: initial consonants in target words.

5.2. MANNER. There is an overall significant difference in the distribution of consonants according to manner categories in the target words of the four linguistic groups: chi-square (9 df) = 21.81 $p < .01$. Japanese target words are significantly different from the target words of the other groups in the manner categories.

The distribution of manner categories at the onset of target words in the four language groups differs markedly from the overall distribution of consonants (see Figure 4). Stops are favored in initial position. However, there is only a

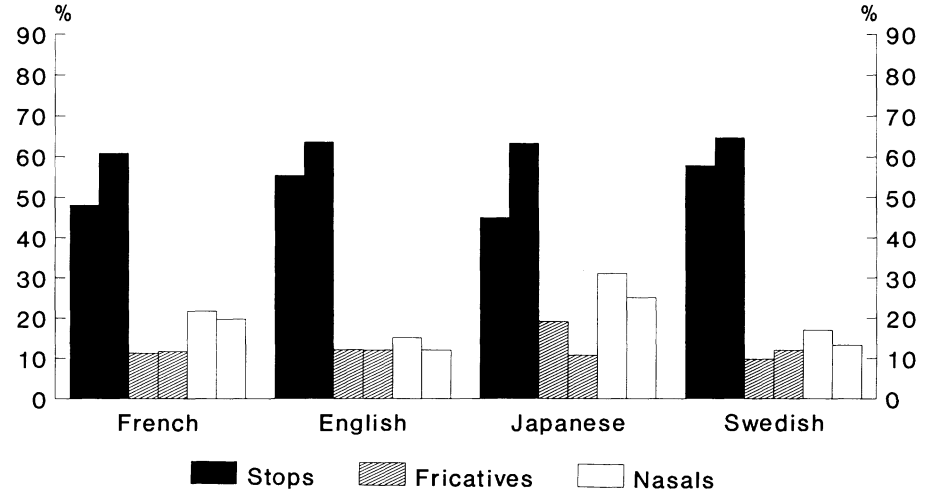

FIGURE 4. Distribution of manner categories in French, English, Japanese, and Swedish target words.
1st column: all consonants in target words.
2nd column: initial consonants in target words.

tendency toward a significant difference in initial consonant distribution across the four groups.

Swedish and English target words show a higher percentage of stops overall than do French and Japanese words, but the percentage of initial stops is very similar in Swedish, English, and Japanese.

Comparison of infant productions with the adult reference sample

6. If there is an effect of linguistic environment on infant phonetic productions, the differences found in the distribution of consonants for place and manner categories ought to be predictable from the distribution of place and manner categories in target words.

We have calculated the distribution of target-word consonants both overall and in initial position (see Table 7). Interesting differences in the rankings can be derived from these two counts. In general, however, the predictions are borne out by the analyses of the children's productions.

6.1. Place. The distribution of labials, based on either the overall or the initial-position distribution, would yield the same predicted rankings: French > English > Swedish = Japanese. And indeed the French infants produce a higher percentage of labials than the American infants, who in turn produce more labials than the Swedish or the Japanese infants (Table 4). The ranking obtained for infant production matches very closely that obtained from initial-position distribution in target words (see Figure 5).

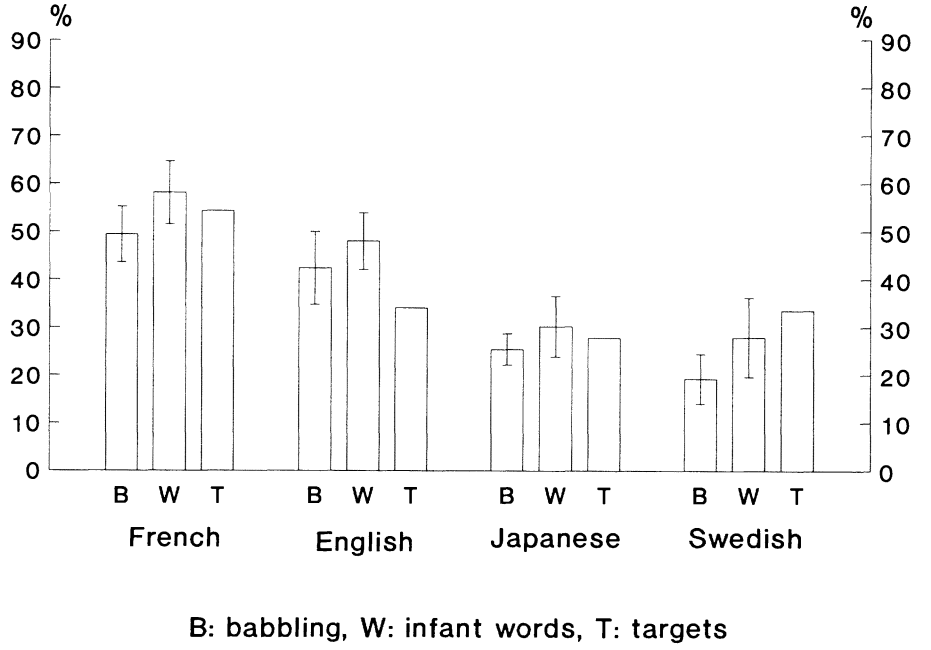

Figure 5. Distribution of labials in babbling, infant words, and target words.

In the case of dentals there is a discrepancy for the English and Swedish data between the ranking obtained from the overall distribution and the ranking based on initial position. In either case, however, the Japanese infants would be expected to produce more dentals and the French fewer. What we find is a two-way distinction, with higher production of dentals by the Swedish and Japanese infants and lower production by the French and American infants. The lower production by the French infants is as predicted, but the English data yield a lower proportion of dentals than would have been expected (see Figure 6).

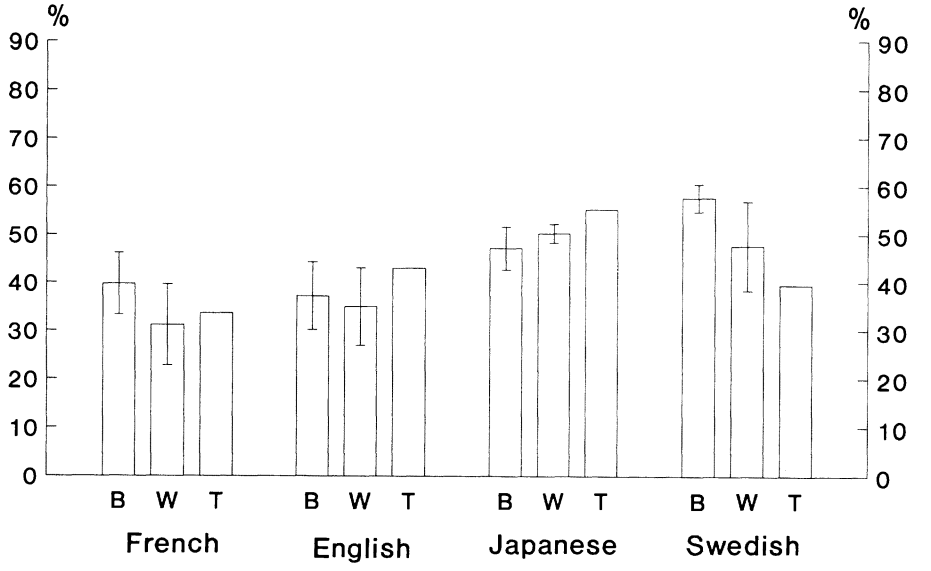

FIGURE 6. Distribution of dentals in babbling, infant words, and target words.

For velars, both overall and initial-position rankings predict Swedish > English = Japanese > French. We find that French infants produce a lower percentage of velars, as expected, while the other three groups show a closely similar distribution.

Except for the lower percentage of dentals in American infant production, the distribution of infant consonant production according to place is predicted by the distribution of initial consonants in target words, and it also fits with the ranking based on overall distribution in target words.

6.2. MANNER. The manner distribution in infant productions agrees with the expected pattern according to the distribution of manner categories in target words. The ranking for overall and initial-position distribution for manner is close.

For stops, the main prediction is that French and Japanese infants should produce fewer stops than the other infants (Swedish > English > Japanese > French). The percentage of stops is indeed higher in the Swedish and English data than in the Japanese and French data (see Figure 7 and Table 4), although, as mentioned above, the difference between Japanese on the one hand and Swedish and English on the other does not reach significance.

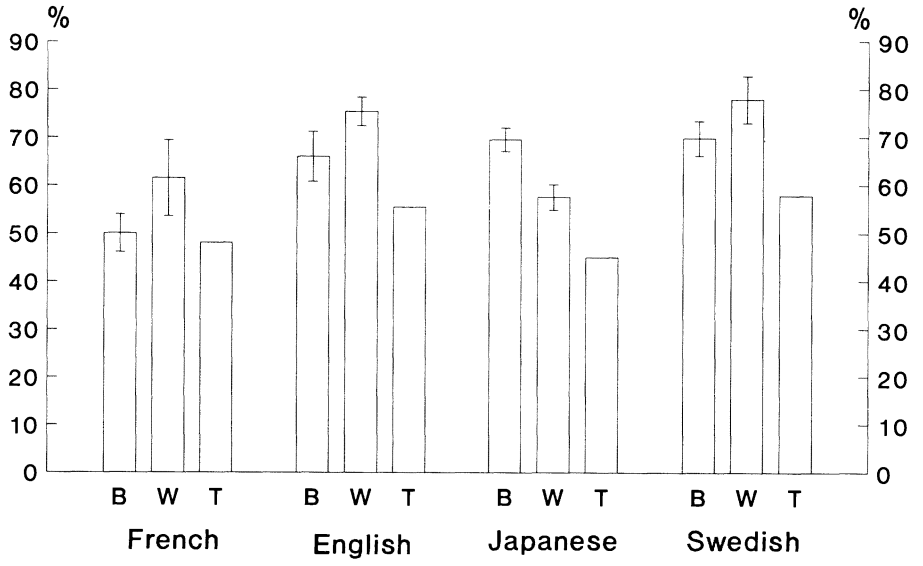

FIGURE 7. Distribution of stops in babbling, infant words, and target words.

For nasals, the expected ranking (based on both overall and initial position) would be Japanese > French > English = Swedish. We find a two-way distinction: Japanese = French > English = Swedish (see Figure 8).

For fricatives and liquids, the percentages are too small to be informative for group comparison. However, the data do reflect the overall distribution of these categories in the target words—slightly fewer fricatives in Swedish and fewer liquids in Japanese.

DISCUSSION AND CONCLUSION

7. As predicted by the different models of babbling production, a high percentage of both labials and dentals is found in all four languages (Locke 1983, Stoel-Gammon & Cooper 1984). Manner is characterized by a preponderance of stops, which represent more than 50% of all consonants in every session except the first and last sessions for French. But in overall production the percentage of stops in the four groups fits so closely with the percentage of initial stops in the target words of each group that the 'common' tendencies

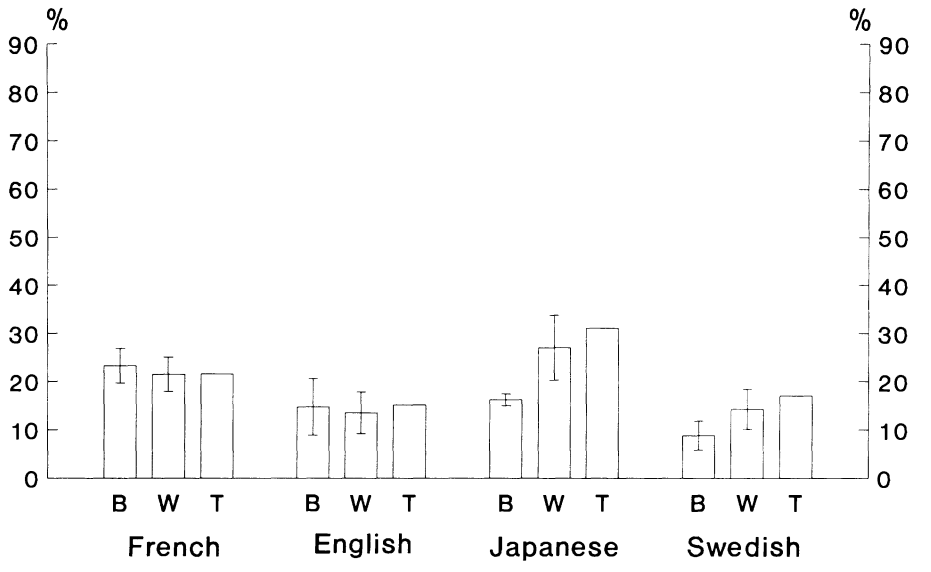

FIGURE 8. Distribution of nasals in babbling, infant words, and target words.

can also be seen as reflecting the structure of the language subsets. Indeed, the target words for the different language groups have the common characteristic of a generally high percentage of stops (45% to 58%) and a still higher percentage at word onset (more than 60% of initial consonants in each group). It is possible to argue that words belonging to the relevant pragmatic environment of infants have in part been selected for their ease of production and/or for perceptual salience (Locke 1983).

Models taking into account the general and specific characteristics of the input maintain that word or utterance onset is one of the most salient points in the speech signal. Some acoustic characteristics, such as the burst of energy of the stop, and some visual characteristics, such as lip closure for labials, may help to form a global organization of perceptually rich forms that is particularly relevant to place and manner categories (Stevens 1972, 1980, Blumstein 1986, Lindblom 1986). Furthermore, in English and Swedish the first syllable of a dissyllable is often stressed, reinforcing the weight of the onset (Cutler & Carter 1987). Consonantal production in the transition stage has already been shown to be sensitive to the position of the consonant in the word, as in child language in general: first consonants are rarely omitted, while deletion of the final consonant is frequent (Vihman 1980, Vihman et al. 1986).

The longitudinal distribution of stops for the four languages shows an interesting developmental trend. The percentage of stops is higher in the 4-, 15-, and 25-word sessions than in the 0-word sessions (though the differences are not significant for all groups and all sessions). A model emphasizing the role

of physiological constraints would predict the contrary, since relatively simple ballistic movements are basic to the production of stops, while fricatives and liquids require more precise articulatory control (Kent 1991). In fact, it is chiefly nasal stops that trade off with oral stops, being somewhat higher in the first (0-word) session than in later sessions for all groups. The percentage of fricatives and liquids remains stable from the 0-word to the 25-word sessions.

There is also an interesting interaction between characteristic adult word length and the impact of word-initial consonant type on infant consonant use. For all four languages the proportion of stops is higher in initial position in target words than it is overall. In English, French, and Swedish this dominance of stops in initial position in target words is reflected in the increased proportion of stops in infant word production as compared with babbling. Note further that in each of these three languages the typical target-word length is one or two syllables (English 59% and 35% respectively, French 30% and 67%, Swedish 44% and 52%; cf. de Boysson-Bardies et al. 1991). In Japanese, by contrast, the overall percentage of stops is markedly lower in words than in babbling (58% vs. 70%). Although the dominance of initial stops in Japanese target words is virtually identical to that in the other languages (63%), the overall frequency of stops is only 45%. Since, in Japanese alone, the characteristic target-word length is two or more syllables (84% of target words), with as many as 17% target words of three or more syllables, it seems likely that it is this preponderance of longer words, together with the relatively smaller proportion of stops in noninitial position, that counterbalances the impact of initial stops on Japanese infant word production.

The high percentage of stops in Swedish was not expected. However, around 8% of the target words begin with a cluster such as /sk/, which infants produce with an initial stop. There are no such clusters in French and Japanese target words, and only 1% (/st/) in English. If target words with an initial cluster /s/ + stop were counted as having a stop consonant in initial position, the percentage of stops produced by Swedish infants would be close to the percentage of initial stops in target words.

Whereas for three groups the percentage of stops is higher in word production than in babbling, quite the reverse is found with fricatives, which show a sharply lower level of use in words in the same three groups. The percentage of fricatives in babbling closely reflects that found in target words—roughly 10% of all consonant production in all four languages. In infant words this percentage is reduced by half in English, French, and Swedish. The control needed to produce fricatives intentionally, under contextual or output constraints, leads to strategies of substitution or avoidance (Kent 1991). This systematic difference between the babbling and first-word repertoires for the distribution of stops and fricatives in three languages prefigures the phonological rules of substitution and deletion reported for the productions of older children.

The percentage of fricatives in the Japanese group does not differ between babbling and word production. Several possible explanations can be suggested: (1) affricates and fricatives are more numerous in Japanese target words than in the target words of the other language groups, and the influence of the

language being learned may counterbalance general tendencies; (2) Japanese infants are older when 15 and 25 words are first produced in a session, and this may weaken the weight of motoric constraints on the articulatory process; or (3) a slightly higher proportion of affricates in the 'fricative/affricate' category could account for the stability of the category.[1] In Japanese motherese, fricatives are often produced as affricates, which express affect. This may entail a special emphasis on affricates.

The percentage of nasals in French infant vocal production is the same overall as in Japanese (although the proportion of nasals is higher in Japanese infant words). A difference could have been expected, given the higher proportion of nasals in Japanese target words (31% against 22% for French; see Table 7). In fact, the frequency of target-word nasals is probably distorted because of the different status of final nasal production in the two adult languages. In Japanese, weak final nasals, conventionally treated as consonants and thus included here in the count of nasal consonants, are very often realized as nasalized vowels in adult speech, while 19% of French words end with nasalized vowels, which are of course excluded from the consonant count. In short, the impact of nasalization as actually experienced by French and Japanese infants may not be very different.

Labials increase by nearly 10% in infant first-word production. This rise, which is found in all four languages, is in part linked to the frequency of initial labials in target words.

Comparison of the babbling repertoire and the infant-word repertoire, independent of lexical level, is very revealing of the motoric consequences that arise from constrained sequencing and concatenation of segments. There is a common articulatory strategy favoring labials and, except for Japanese, stops in word production.

We interpret the main differences between babbling and first-word repertoires as reflecting the constraints of sequencing the articulatory gestures to produce a target word. The motor level has important implications for the shape of first-word productions. The obligatory sequentiality of segments and syllables that is required for word production interacts with coarticulatory tendencies. The use of articulatory gestures and the free production of these gestures need not imply that the segments thus produced are independently manipulable. Consonant and vowel reduplications have been shown to be in an inverse relationship in infant production, reflecting a limited capacity for modification of basic dissyllables (MacNeilage & Davis 1991). The obligatory sequentiality also interacts with infant programming capacities. A limited-resource assumption may account for a tendency to 'return' to more basic adjustments when the infant tries to approximate a complex target (Kent 1991).

The selection of articulatory gestures used in variegated babbling and first words arises in part from phonetic patterns of the ambient language. Target-

[1] A study comparing initial consonant acquisition in English and in Quiché Mayan (Pye et al. 1987) reports frequent use of certain fricatives by the Quiché-learning children, especially /x/. However, the only child in that study who fell within the age range of the present study, and who had a sample of under 25 words, was credited with no fricatives at all.

related discrepancies across the four groups are found in the distribution of consonants according to place and manner categories for both babbling and words, confirming the continuity between babbling repertoire and first-word repertoire. However, the distribution of consonants in first words is more similar across the groups than the distribution of consonants in babbling.[2] As Lindblom observes, 'The number of segments a language uses in the basic or complex categories is predictable from the total size of its inventory. Small vowel or consonant inventories recruit only basic segments' (1988:305). The subset of each language's inventory represented by the target words involves mainly the basic category; the consonants in this subset are not representative of the complete inventories of the different languages. On the one hand, the subset of target words lacks articles, pronouns, and other function words that occur frequently in adult speech. On the other hand, a selection favoring simpler articulatory patterns for words belonging to the everyday environment of infants is suggested by the frequency of initial labials and stops in the target words of all language groups. However, infants do not systematically choose their target words from among the simplest phonetic forms. For example, 18% of target words in Swedish begin with a cluster, 32% of target words in English end with a closed syllable, liquids represent 19% of consonants in target words in French, and polysyllabic words represent 66% of target words in Japanese.[3]

During the period when infants produce variegated babbling, their perceptual capacities are developing. Initial perceptual capacities narrow, and phonetic discrimination becomes more dependent upon the phonemic organization of the language of the environment (Werker & Tees 1984). However, the fact that infants form auditory categories and are sensitive to those aspects of the language which are most relevant to discrimination or categorization in the target language does not mean that these capacities are involved in babbling and in first-word productions. Evidence for selective attention to specific experience at the word level is more relevant. Infants' preference for words of their own language as against words of a different language (Jusczyk 1991) and for samples that preserve words as units (Woodward 1987) suggest that 'something' is coded before ten months that allows recognition of words as units.

Although very little is known about the weight of different cues in speech perception for different languages, it can be assumed that the development of

[2] The individual differences in the children's repertoires do not derive from the mothers' individual phonetic repertoires, so far as we have been able to determine from our analyses of phonetic transcriptions of maternal speech samples (still in progress). In fact, the standard deviation for the intragroup mean distribution of place and manner categories used in the mother's running speech appears to be consistently lower than that in the children's productions.

[3] The fact that infants base their choice of early words partially on phonological factors is now well established (Ferguson & Farwell 1975, Schwartz & Leonard 1982, Vihman et al. 1986). Nevertheless, 'difficult' phonetic targets are not excluded. The presence, in high-frequency, high-interest adult words, of phonetic and phonotactic categories disfavored in babbling and early words will affect infant production. For example, the word *shoe* (French *chaussure*, Japanese *kukku*, Swedish *sko*) was attempted by at least 2 of the 5 children in each group (all 5 in Swedish), despite the fact that it requires a fricative in English and French and begins with a cluster in Swedish (where it is treated as a singleton stop in the children's productions).

perceptual capacities allows the 10-month-old infant to weight specific aspects of input that are important in processing the language spoken in the environment. Indeed, already in the 0-word session we can see language-specific tendencies in consonants—as was demonstrated earlier for vowels (de Boysson-Bardies et al. 1989)—which will evolve into more marked differences with further phonological development.

The production of the first words indicates that the process of building a representation for speech has begun. The proposition that there is a global or unsegmented representation of words seems to account for the first items. For most infants, babbling production continues to coexist with first words for four or five months (Elbers 1982, Vihman & Miller 1988). In our study, as in others, there is a lag of four or five months between the first words and the time when the child's vocabulary increases rapidly, leading in the second part of the second year to a segmental organization of the lexicon and to what has been called the beginning of phonological development, with rule-governed productions (Macken 1979, Vihman & Velleman 1989).

The flexibility of the human capacity for language has to be understood within the framework of a dual dependence on physiological constraints and the experience received through a specific language model. At issue are the forms of the transition from variegated babbling, considered as a first level of speech, and word production, considered as a higher level. The diversity of infant phonetic repertoires suggests that different pathways are available. Each individual infant may 'choose' to favor different components of speech (Macken & Ferguson 1983). The interinfant differences, as well as the similarity between the babbling repertoire and early words, show that infant productions are the complex product of an interaction between articulatory tendencies and the influence of the phonetic structure of the linguistic environment around the time when infants begin to recognize and pay attention to words.

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