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From babbling towards the sound systems of English and French: a longitudinal two-case study*

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ABSTRACT

The utterances of one French and one American infant at 0;5, 0;8, 0;11, and 1;2 were transcribed and acoustically analysed for syllable duration and vowel formant values. Both general and language-specific effects emerged in the longitudinal study. Initial similarities in the consonantal repertoires of both infants, increasing control in producing target F_1 and F_2 values, and developmental changes in babbling characteristics over time seem to reflect universal patterns. Yet the babbling of the infants differed in ways that appear to be due to differences in their language environments. Shifts in the infants' sound repertoires reflected phoneme frequencies in the adult languages. The English-learning infant produced more closed syllables, which is characteristic of English, than the French-learning infant. The French-learning infant tended to produce more regularly-timed nonfinal syllables and showed significantly more final-syllable lengthening (both characteristic of French) than the English-learning infant.

INTRODUCTION

The study of very young children's acquisition of the sound patterns of their native language has focused, in particular, on whether or not there is

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continuity between babbling and early speech and on the roles of the linguistic environment and of general developmental processes in the child's early productions. Current research has produced much evidence in support of continuity between babbling and early speech and has suggested the importance of physiological maturation to the child's growing sound repertoire. However, empirical investigations of language-specific influences have had somewhat mixed outcomes, perhaps, in part, because of differences in the types of language-specific influences that were investigated (e.g. segmental versus prosodic) or in the techniques used (e.g. phonetic transcription vs. acoustic analysis). Therefore, in our present investigation of continuity and language specificity, we both phonetically transcribed and acoustically analysed a number of prosodic and segmental characteristics in the babbling development of an English-learning and a French-learning infant at four points between the ages of 0;5 and 1;2.

The best-known claim about the discontinuity between babbling and early speech comes from Jakobson (1968: 25). He suggested that 'the phonemic poverty of the first linguistic stages', as compared with 'the phonetic abundance of babbling', is indicative of a fundamental distinction between the two stages, and that the babbling period is therefore unrelated to the acquisition of language. He even proposed that infants pass through a silent period during the transition from babbling to speech, in which the child produces no sounds whatsoever.

This claim of discontinuity between babbling and early speech has not been supported by recent studies (Menyuk, 1971; Oller, Wieman, Doyle & Ross, 1976; Ferguson, 1978; Menyuk & Menn, 1979; Stark, 1980; Kent & Bauer, 1985; Vihman, Macken, Miller, Simmons & Miller, 1985). For example, Vihman *et al.* (1985) examined the babbling and early word productions of nine children from 0;9 to 1;4 and found that babbling continued to occur after the onset of first words, without evidence of a silent period, and that the phonetic properties of babbled utterances both influenced and were influenced by word productions. Babbling increased in complexity following the acquisition of words, and some sounds appeared in babble only after words containing those sounds were learned. In addition, an infant's 'babble repertoire' was reflected in his or her later words.

The evidence that supports the role of physiological maturation in children's early vocal productions comes largely from studies that look at the developmental stages of babbling or at patterns in children's early segmental inventories. Oller (1980) and Stark (1980) defined several developmental stages of speechlike sound making within the babbling period that reveal babbling to be a logical and organized precursor to adult-like speech.

The first stage identified by both Oller and Stark begins at birth and lasts a month to six weeks. During this period, termed the 'phonation' or 'reflective vocalization' stage, infants produce cry and fussing sounds as well as some partially resonant and a few fully resonant vocalizations. At the next stage, called the 'goo' or 'cooing' stage, roughly between 0;2 and 0;4, increasing vocal control gives rise to the infants' production of sounds that are typically heard as 'coos' by adults. At about 0;4 infants enter the 'expansion' or 'vocal play' stage, during which they produce a wide variety of vocalizations including squeals, growls and nasal murmurs. Towards the end of this period, they produce sounds that begin to approximate a number of adult consonants and vowels. Next, at about 0;6 or 0;7, infants begin a period of 'canonical' or 'reduplicated' babbling, in which they produce strings of identical consonant- and vowel-like elements, e.g. 'bababa'. The timing of these elements is much closer to that of adult speech than before. At the next stage, 'variegated' or 'non-reduplicative' babbling, which begins at about 0;10 or 0;11, infants are able to produce strings of syllables that contain a variety of consonantal and vocalic types, e.g. 'adega', as well as a greater variety of syllable types. This last stage immediately precedes the infant's early word productions. Each stage generally reflects the onset and increasing incidence of a new type of vocalization, but the infant does not abandon earlier types of vocalization. Thus, a child who is capable of variegated babbling may still produce utterances of the reduplicative type, just as a child who has begun to produce words also continues to produce babbled utterances.

Others have found additional evidence in support of the roles of continuity and maturational processes through the examination of infants' acquisition of phone types. Thus, Locke (1983) reviews the evidence for universal patterns in children's acquisition of speech sounds and argues in favour of anatomical and physiological maturation as the common source of these patterns.

Evidence for maturational processes has also emerged in studies of the acoustic properties of children's babbling and early speech. Buhr (1980) measured the vowel formant frequencies of the transcribed utterances of an American infant from 16 to 64 weeks of age and plotted the results on an F_1/F_2 plane. In describing the longitudinal development of the child's vowel space, Buhr attributes the early appearance of the sounds [i], [e], and [ɛ] to the early development of the control of jaw position. The sound [u], on the other hand, requires control of three elements: jaw position, which appears early on, longitudinal tongue movement, which arises early on in connection with swallowing, and lip rounding, which is also associated with sucking behaviour. According to Buhr, the late emergence of [u] is due either to the difficulty of co-ordinating the three types of oral movement, or to the fact that voluntary control of lip rounding emerges considerably after its involuntary use in sucking. Finally, the development of neuromuscular ability in the lips, jaw, and front tongue is known to precede the physical descent of the larynx and rear tongue. Thus, Buhr attributes the emergence of the acute axis of the vowel triangle, which includes front vowels such as

[i], before the emergence of the grave axis, which includes the low back vowels such as [ɑ], to this difference in physiological development.

Other acoustic studies also chart basic developmental progress towards more adult-like productions. Bond, Petrosino & Dean (1982) measured the first and second formant frequencies of the speechlike productions of an infant from 1;5 to 2;2 and plotted the results on an F_1/F_2 plane. Their data suggest a refinement of the vowel space over time toward more adult-like formant frequency patterns, which presumably reflect the development of increased articulatory proficiency with age. Mack & Lieberman (1985) measured the babbling and words of an infant from 46–149 weeks for vowel length and consonant closure. They found that specific segments of babble increased greatly in duration during the course of development, demonstrating the child's growing ability to approximate to the longer adult-like norms.

But even though current research provides support for the ideas that there is continuity between babbling and speech and that maturation plays a role in the development of children's vocal productions, these factors do not preclude the possibility that the specific language environment may begin to influence vocalizations during infancy. The reports on language-specific influences have been mixed, however. A number of studies suggest an influence of the characteristics of the native language on the child's prelinguistic utterances, whereas others have failed to uncover language differences. One of the earliest suggestions for language-specific influences comes from Brown (1958: 199), who hypothesized that babbling 'drifts in the direction of the speech an infant hears', until the infant has mastered the adult phonology of the parents' language.

Some perceptual evidence appears to support Brown's notion of 'babbling drift.' Dinger & Blom (1973) asked 50 Dutch and 50 American women to listen to 90-sec recordings of Dutch and American infants taken at 33, 43, 53, 62, and 70 weeks (approximately 0;8, 0;10, 1;0, 1;2, and 1;4), and to identify whether the babbling was Dutch or American. The women correctly identified the language background of the infants significantly often for ages 1;0, 1;2, and 1;4 suggesting that after 1;0, language identification was possible. However, Dinger & Blom acknowledged that some words may have been included in the babbling samples, so that it is not clear on what basis the listeners made their judgements. Boysson-Bardies and her colleagues (Boysson-Bardies, Sagart & Durand, 1984) also found that French adult listeners were able to distinguish at better than chance levels the babbling of French infants from the babblings of Chinese and Arab infants at 0;6 and 0;8, though they were no longer able to do so when listening to the babbling of 10-month-old infants (see also Weir, 1966). The stimuli consisted of 15-sec samples of babbling from a number of different children from each of the language backgrounds. Unlike the productions at 0;6 and 0;8, which had clearer melodic patterns, the stimuli from the productions of the 10-month-olds were all highly articulated reduplicative babbles, and were thus poorer in intonation contour.

On the other hand, a number of other studies failed to find support for adults' ability to identify perceptually the linguistic background of the child from babbled productions (e.g. Atkinson, MacWhinney & Stoel, 1970; Olney & Scholnick, 1976; Thevenin, Eilers, Oller & Lavoie, 1985). Thus, Thevenin *et al.* (1985) examined the ability of adult monolingual speakers of English and bilingual speakers of English and Spanish to discriminate the babbling of English-learning from Spanish-learning infants at 0;7 to 0;10 and at 0;11 to 1;2. The stimuli consisted of eight utterances each of 1- to 3-sec stretches of canonical babbling from 14 infant subjects (seven English- and seven Spanish-learning children). Adult listeners were not able to make correct language background identifications for the infants at either 0;7 to 0;10 or at 0;11 to 1;2, although they did show certain consistent patterns of response to particular infants and utterances.

One possible explanation for the discrepancy between the Thevenin *et al.* (1985) study and that of Boysson-Bardies *et al.* (1984) is that adults' ability to judge the linguistic background of a child may depend on the prosodic characteristics of the babbling, and thus may require long samples with pronounced melodic contour. It may also be that speech development, like the development of the child's phonological system, shows evidence of regression (Menn, 1971). Thus, children may in fact produce intonation contours that mirror those of the language of their environment at an early age and then apparently cease to produce such patterns consistently as they turn their attention to the production of more segmentally complex utterances. It is, then, perhaps not surprising that the French judges in the Boysson-Bardies *et al.* (1984) experiment were unable to identify the language background of the 10-month-old children, although they had done so for the younger children, because the prosodic cues were apparently poorer in the productions of the 10-month-olds.

More recently, however, studies of the acoustic and phonetic properties of infants' babbling from specific language backgrounds have provided evidence in support of the babbling drift hypothesis. Boysson-Bardies, Halle, Sagart & Durand (1989) found that the distribution of vowel formant frequencies of five 10-month-old infants each from French, English, Cantonese, and Arabic backgrounds reflected the different formant-frequency pattern distributions of adult vowels in the target languages, a result that demonstrates the early influence of the language environment on vowel production in infant babbling.

Similarly, Boysson-Bardies (1989) reports evidence of babbling drift in a cross-linguistic study involving infants from French, American, Japanese, and Swedish backgrounds. Five children from each linguistic community were recorded in six sessions, starting at 0;10, when they could only babble, and continuing until the 25-word stage. In this study, transcriptions of the consonantal repertoires of the infants showed evidence both of universal developmental processes and of language-specific influence from about 1;10 on. Thus, stops represent, by and large, the largest proportion of consonants for infants from all language backgrounds, presumably because they are easier to produce than other consonants. However, from the session at 0;10 onwards there was a clear stop frequency difference between the French infants, on the one hand, and the American and Swedish infants, on the other. The latter groups regularly produced a higher mean percentage of stops than did the French. This difference is consistent with the higher frequency of stop consonants in the target-words attempted by the American infants and in those attempted by the Swedish infants when compared to the frequency of stop consonants in the target words attempted by the French infants.

Most studies examining the effect of the linguistic environment have generally taken a cross-sectional rather than longitudinal approach. On the other hand, most of the previous research investigating the role of maturational factors in speech development has focused on a single language longitudinally. Even in the rare cases where a study of the effect of the linguistic environment was longitudinal, as in the case of Boysson-Bardies (1989), the data were usually only phonetically transcribed and not acoustically analysed. If we are to determine the time course of maturational and language-specific factors on speech development, we need to make longitudinal cross-linguistic comparisons. Furthermore, acoustic analyses may reveal effects that are not apparent in perceptual or transcription studies. In an acoustic analysis of voice onset time (VOT), Macken & Barton (1980) found that some children, who were heard by adults to be using initial voiced stops for voiceless targets, were actually producing longer VOTs for their voiceless targets than for their voiced ones. The difference between the two types of stops was, however, inaudible to the unaided ear. Therefore, the present study examined the role of maturational and language-specific effects longitudinally by comparing both the transcriptions and the acoustic analyses of the vocal productions of a French-learning and an American English-learning infant at 0;5, 0;8, 0;11, and 1;2. A case study approach to this problem is appropriate as a means of generating specific hypotheses about the speech development of French- and English-learning infants that can later be tested on a larger sample of subjects from each language background.

French and American English infants were chosen for comparison because of specific known segmental, syllabic, and prosodic differences between French and English. A comparison of the sound inventories of the two languages reveals that English has diphthongs, which are not found in French, more fricatives and affricates than French, and one more nasal consonant than French (/ŋ/), while French, on the other hand, has nasal vowel phonemes, which are not found in English (Delattre, 1965). Syllabically, the two languages also differ in the most common syllable structures and the typical word lengths (in numbers of syllables). English contains more closed syllables and more monosyllabic words than French (Delattre, 1965). Finally, in terms of prosody, French and English differ in fundamental frequency (F_0) contours and durational patterns. For the present study, we focused on acoustic measures of durational pattern differences between the adult languages. French and English are classified respectively as syllable-timed and stress-timed languages (e.g. Pike, 1945, but cf. Wenk & Wioland, 1982). French, the syllable-timed language, has a rhythmic structure characterized by non-final syllables generally equal in length, or ISOSYLLABICITY, and by regular breath-group-final lengthening. English, the stress-timed language, has phrase-final lengthening, but this interacts with lengthening due to lexical stress, and therefore does not show the relative non-final isosyllabicity of French.

Therefore, if the language environment influences infant babbling, we should expect to see greater isosyllabicity, more phrase-final lengthening, and perhaps more polysyllabic utterances in the babbling of the French infant, whereas we should see more monosyllabic productions and more utterances with closed syllables in the babbling of the American infant. Furthermore, if the infants' productions are affected by the segmental inventories of their linguistic environments, their productions should, over the course of time, reflect that influence in the proportions of specific vowel and consonant types. Thus, language-specific effects were assessed through the examination of segmental features, syllable type, and timing, both in terms of the transcriptions of the utterances (consonant and vowel inventories) and in terms of their acoustic properties as well (the F_1 and F_2 formant frequency values of the vowels and durational measures of the syllables).

General effects, or language-independent similarities in the developmental patterns of the two infants, should be revealed through the study of syllable types and segmental features. The babbling sequences produced by both infants over time should evolve in keeping with the stages described by Stark (1980) and Oller (1980). If physiological constraints are the main determinants of the types of sounds that very young infants produce, the vocal repertoires of the two infants should be more similar to one another at earlier stages rather than at later stages, when other determinants (from the surrounding language) have also come into play. Finally, over time, both infants should improve in their ability to produce the target formant frequency values of their vowels and thus show less variability in those measurements.

METHOD

Subjects

The babbling of a male American English-learning infant (E-CR) and that of a female French infant (F-YC) were recorded in their homes by their parents on a weekly basis from 0;5 to 1;5. Both infants were second children, each with a single sibling of the same sex at least four years older. The American infant, recorded in a household in Providence, RI, heard regionally typical American English and the French infant, recorded in Paris, heard Parisian French.

Materials

E-CR was recorded using a Panasonic cassette tape recorder with a Realistic supercardioid 33992A microphone. F-YC's utterances were recorded using a Panasonic RQ 3145 cassette tape recorder with a high quality cardioid microphone.

Procedure

Data collection. Individual recording sessions lasted approximately 10–20 min. The parents were instructed to choose a time for recording when the infant was likely to be alert and unlikely to cry (e.g. in the morning after eating). The parents were to hold the microphone at about 20 cm from the baby, avoiding external noise, and to say the date at the beginning of each recording to identify individual sessions. The parents could either elicit babbling by talking and gesturing (making sure to stop talking while the baby vocalized) or record spontaneous babbling as it occurred. A comment sheet was filled out for each tape, including date, time, and situation (e.g. 'in bath' or 'watching sister'), and the parents were asked to indicate whether babbling was spontaneous or elicited by a specific person.

Utterance sampling. The utterances used in this analysis were taken from four separate months of recordings beginning when the children turned 0;5, 0;8, 0;11 and 1;2. These ages were chosen to capture four of the stages of infant vocalization that were described earlier: vocal play, reduplicative babbling, variegated babbling, and the period of the onset of the child's first words (Oller, 1980; Stark, 1980). Only utterances containing V, CV, VC and CVC syllables with vocalic durations greater than 100 ms were selected for analysis. No other productions typical of the vocal play period (i.e. squeals, growls, etc.), emotive sounds (i.e. crying, laughing, etc.) or vegetative noises were used.

Phonetic transcription. Utterances were divided into separate strings or breath groups, which were defined as an individual syllable or sequence of syllables separated from other utterances by a silent interval of 400 ms or more. Each utterance was transcribed by two phonetically trained listeners, both of whom are fluent in English and French. Utterances for which the transcribers disagreed were retranscribed until agreement was reached.[1]

Acoustic analysis. The utterances were input at half speed and digitized with a Macintosh Plus computer at a sample rate of 10 KHz, using a MacADIOS digitizer and a TTE 411AFS amplifier. The utterances were measured for vocalic F_1 and F_2 frequencies (Hz) at the peak amplitude portion of each vowel. Vowels for which either F_1 or F_2 measurements were indeterminate were dropped from the formant frequency analysis. For F-YC, 15·9% and for E-CR, 15·8% of the vowels overall gave indeterminate measures. Eleven utterances were randomly selected from each infant's productions for remeasurement. For E-CR these utterances contained a total of 41 syllables, and the overall mean discrepancy for F_1 and F_2 measurements was under 15 Hz. For F-YC these utterances contained a total of 69 syllables, and the overall mean discrepancy for F_1 and F_2 measurements was under 20 Hz.

Syllabic durations (ms) were also measured. In multisyllabic utterances, measurements were made by visually inspecting the waveform and by listening to each of the measured portions. A conservative criterion for measurement of vowel-final syllables was adopted: only visibly voiced portions of the final syllable were included. Remeasurement of the durations of the same random sample of E-CR's utterances was within 23 ms on average, while remeasurement of the durations of F-YC's eleven utterances was within 13 ms on average. A total of 881 syllables for the French infant (114, 317, 201, and 249 syllables at 0;5, 0;8, 0;11, and 1;2, respectively) and 701 syllables for the American infant (178, 218, 218 and 87 syllables at 0;5, 0;8, 0;11, and 1;2, respectively) were measured.

RESULTS

The results will be described in terms of segments, syllable structure, and timing, in that order. The transcriptions provide the data for an analysis of consonant and vowel frequencies of occurrence and of the syllable structure.

[1] The two transcribers of the vocalizations used in this analysis are both native speakers of English who are fluently bilingual in French. However, it is possible that when the data for the French infant were considered, the transcriptions of ambiguous sounds, particularly vowels, might have been interpreted in favour of English targets. For example, the vowel sound of 'beet,' when short in duration, might be interpreted as the vowel sound of 'bit,' a frequent sound in English, but one which does not exist in French. Of course, any such bias would lead to conservative estimates of language-specific differences between the infants.

TABLE 1. *List of consonants in order of percentage of occurrence at 0;5, 0;8, 0;11, and 1;2 for E-CR*[a]

0;5		0;8		0;11		1;2	
x	24·4	b	30·4	d	17·0	d	27·4
g	15·9	w	15·9	ʔ	14·8	ʃ	25·8
h	14·8	h	10·9	w	8·2	ʧ	11·3
w	12·7	j	8·9	ʤ	7·7	b	8·1
ʔ	11·7	g	6·5	j	7·7	ʤ	8·1
j	9·5	v	6·5	h	7·1	j	6·5
m	3·2	x	6·5	ʃ	6·6	ð	3·2
l	3·2	l	5·4	b	6·0	w	3·2
f	2·1	ʔ	3·3	l	4·4	f	1·6
p	1·0	d	2·2	t	3·3	h	1·6
v	1·0	ʤ	1·1	g	3·2	s	1·6
		m	1·1	n	2·7	t	1·6
		ð	1·1	ʧ	2·2		
		z	1·1	s	1·6		
				ʒ	1·6		
				ð	1·1		
				v	1·1		
				x	1·1		
				f	0·5		
				m	0·5		
				r	0·5		
				z	0·5		

[a] Percentage base: total number of consonants in syllables analysed at each age: 178, 218, 218 and 87 at 0;5, 0;8, 0;11, and 1;2, respectively.

The acoustic analyses provide the data for formant analyses of the vowels and for the timing characteristics of the children's utterances.

Segmental features

Transcription analysis. The sound systems of English and French will be discussed first in terms of the consonant and vowel frequencies and then in terms of the distribution of consonants according to manner and place of articulation. In order to examine longitudinal patterns of change in segment frequencies, charts of percent distribution of vowels and consonants were created for each infant at each age and then listed in order of percentage of occurrence (see Tables 1–4). The charts were compared to lists of the sounds of French and English in order of percentage of occurrence (see Table 5; Delattre, 1965).

As can be seen from Table 5, English and French share 18 consonants of the 25 listed. Six consonants appear in English but not in French (generally fricatives and affricates and the nasal /ŋ/), and one appears in French but not in English (/ɥ/, a labial-palatal approximant). Of the 21 vowels, 8 are shared by the two languages, 5 occur in English but not French (mostly diphthongs) and 8 occur in French but not English (front rounded and nasal vowels).

Across all ages observed, the infants had 27 segments in common in their productions, and each had an additional eight sounds that the other did not use. Sixteen of the common segments were consonants, thirteen of which appear in both French and English. The English-learning infant produced an additional seven consonants, mostly fricatives and affricates, two of which are only found in English ([ʤ] and [ʧ]), and one ([x]) that is found in neither English nor French. The French infant produced only the shared 16 consonants, three of which occur only in English and not in French. As for the vowels, both infants produced the same 11 vowels, though with different frequencies of occurrence. The eleven vowels included two non-French vowels ([æ] and [ɩ]) and one non-English vowel ([ø]).

Because French and English share many of the same segments, it is not clear whether the infants' productions are similar because of the similar sounds to which they were exposed, or because, as Locke (1983) would argue, certain sound patterns are particularly common in the languages of the world because they reflect the child's and the adult's natural phonetic proclivities. However, an examination of the longitudinal changes in each infant's productions suggests target-language influence.

TABLE 2. *List of vowels in order of percentage of occurrence at 0;5, 0;8, 0;11, and 1;2 for E-CR*[a]

0;5		0;8		0;11		1;2	
ə	38·1	ə	27·9	ə	31·1	ə	36·4
æ	19·0	a	21·4	a	27·4	æ	17·0
u	13·5	u	20·0	ɛ	9·0	a	12·5
ɔ	9·2	æ	11·6	ɩ	8·0	ɩ	9·1
a	8·0	ɛ	7·4	æ	5·7	ɛ	9·1
ɛ	4·3	i	3·3	ɔ	5·2	i	5·7
i	1·8	e	3·3	i	3·8	e	3·4
ɩ	1·8	o	2·8	u	3·8	ɔ	2·3
o	1·8	ɩ	1·9	e	1·9	o	2·3
e	1·2	ɔ	0·5	o	1·9	u	2·3
o	1·2			ø	1·9		

[a] Percentage base: as for Table 1.

Most of the consonants in the American infant's babble repertoire (see Table 1) which showed an increase in relative frequency over time ([d, ð]) or which began to appear at 0;11 ([t, n, r, s, z]) are more frequent in the English language than those which diminished in relative frequency ([b, h, w, j]) or disappeared altogether from the inventory ([g, p, v]). The American infant, CR, also introduced or increased the relative frequency of voiced and unvoiced alveolar and palato-alveolar fricatives and affricates ([ʧ, ʤ, ʃ, s, ʒ])

TABLE 3. *List of consonants in order of percentage of occurrence at 0;5, 0;8, 0;11, and 1;2 for F-YC*[a]

0;5		0;8		0;11		1;2	
l	36·6	d	66·4	d	58·4	d	30·8
d	29·3	l	12·6	j	10·3	b	16·8
h	18·3	m	5·3	w	9·9	j	14·4
g	3·7	h	3·2	b	8·1	m	9·6
ŋ	3·7	j	3·2	l	5·4	n	8·2
m	2·4	n	2·4	ǰ	3·2	p	7·7
b	1·2	b	1·6	ð	2·2	l	5·8
r	1·2	g	1·6	h	1·1	w	3·4
t	1·2	t	1·2	n	1·1	t	1·4
ð	1·2	ð	1·2	m	0·5	g	1·0
v	1·2	w	0·4	t	0·5	h	1·0
		x	0·4				
		ʔ	0·4				

[a] Percentage base: total number of consonants in syllables analysed: 114, 317, 201 and 249 at 0;5, 0;8, 0;11, and 1;2, respectively.

TABLE 4. *List of vowels in order of percentage of occurrence at 0;5, 0;8, 0;11, and 1;2 for F-YC*[a]

0;5		0;8		0;11		1;2	
æ	44·2	a	39·6	æ	40·5	a	33·5
a	26·5	æ	27·7	i	14·1	æ	24·6
ə	19·5	ə	17·3	ə	11·2	ə	19·8
ɛ	2·7	ɛ	4·5	a	10·7	u	8·9
e	1·8	ɵ	3·0	ɛ	7·8	ɵ	5·6
u	1·8	u	2·4	e	4·4	ɩ	2·0
ɵ	1·8	ɩ	2·1	u	3·4	i	1·6
i	0·9	o	2·1	ɩ	3·0	ɛ	1·6
ɩ	0·9	i	1·2	ɵ	3·0	e	0·8
		ɔ	0·3	o	2·0	ɔ	0·8
						o	0·8

[a] Percentage base: as for Table 3.

at 0;11. It is possible that CR developed the neuromuscular ability to produce these sounds at about this time, resulting in an increase in their production. The only non-English sound in CR's inventory is [x], which showed a gradual decrease over time and disappeared entirely by 1;2. There are only two consonants in English (/ŋ/ and /θ/) that CR did not produce.

CR's vowel productions (see Table 2) show a similar effect. He displayed a preference for [ə], [æ], and [a] at all months, and percentages for each remained relatively stable over time, consistent with their high frequency of occurrence in English. The sound [e] was relatively infrequent in his babble repertoire longitudinally, and is also infrequent in English. Dramatic

TABLE 5. *Lists of consonants and vowels in order of percentage of occurrence in English and French (Delattre, 1965)*[a]

English				French			
consonants		vowels		consonants		vowels	
t	12·7	ə	24·1	r	15·0	e	19·3
n	11·4	ɪ̲	15·1	l	10·6	a	16·7
r	8·3	æ̲	9·9	t	9·7	i	12·4
l	7·6	i	8·9	s	8·8	ə	7·6
s	7·4	a	7·3	p	8·0	ɑ̲̃	7·6
d	6·1	ɛ	7·2	d	7·2	ɛ	6·7
z	4·9	u	5·9	k	6·4	u	6·4
m	4·7	a̲i̲	5·7	m	6·0	ɔ	5·1
ð̲	4·6	o	5·2	n	5·2	y̲	4·7
k	4·3	e	4·1	v	4·5	ɔ̲̃	3·8
w	3·7	a̲u̲	2·3	j	3·2	o	2·6
b	3·4	ɔ	2·1	ʒ	3·0	ɛ̲̃	2·4
h̲	3·3	ʊ̲	2·1	f	2·6	œ̲	1·8
v	3·2	o̲i̲	0·2	z	2·3	ø	1·7
f	2·8			w	2·3	œ̲̃	1·0
p	2·3			b	2·3	ɑ̲	0·1
ŋ̲	2·2			g	1·1		
j	2·0			ʃ	0·9		
g	1·6			ɥ̲	0·8		
θ̲	0·9						
ʃ	0·8						
ʤ̲	0·8						
ʧ̲	0·6						
ʒ	0·2						

[a] Percentage base for vowels: total number of vowels in the sample for the relevant language. Percentage base for consonants: total number of consonants in the sample for the relevant language. Sounds not shared by the two languages are indicated by underlining.

increases in the relative frequency of [ɩ] and [ɛ] at 0;11 and, at 1;2, increases in the frequency of [i] and decreases in [ɔ] and [u] are also consistent with the relative frequency of occurrence of these sounds in English.

Similar language-specific patterns are also apparent in the repertoire of the French infant, YC. YC showed a definite preference after 0;8 for the sound [d], which has a relatively high frequency of occurrence in French (see Table 3), but this sound is also frequent in English and occurred often in CR's productions as well. Nonetheless, in general, most consonants which showed increased frequency of occurrence longitudinally ([b, m, n, j]) or appeared in the inventory at 1;2 ([p]) occur more frequently in French than the consonant which decreased in frequency ([g]). In addition, YC initially produced a number of non-French sounds in her inventory, but these sounds diminished greatly in frequency by 1;2 ([h]), disappeared gradually over time ([ð]), or appeared only at 0;5 or 0;8 without recurrence ([ŋ, ʔ, r, x]). She did not display the increased production of alveolar fricatives and palato-alveolar fricatives and affricates shown by CR at 0;11, although [ʤ] and the palatal glide [j] did appear in her inventory at about this time. However, affricates do not exist in French, and [ʤ] did not reappear in YC's speech sample at 1;2.

In general, YC produced the same vowels as CR, in terms of the transcriptions assigned them. Her preference for low front vowels ([a] and [æ]) was stable at each of the four months sampled. However, the mid central vowel consistently favoured by CR ([ə]), which is the most frequent vowel in English (see Table 5), remained in third place for YC, and is the fourth most frequent vowel in French. The French sounds /y/ and /œ/ and the French nasal vowels did not occur in YC's productions. It is possible that these sounds failed to emerge, and that the children's vowel inventories were similar, because of physiological constraints on vowel production, such as inability to produce the necessary voluntary lip-rounding or the appropriate lowering of the velum. Patterns of change in relative frequency of occurrence for vowel sounds are not as clear for YC as they are for CR, with the exception of an increase in the production of [u] over time, a decrease in [o], and the stable frequency of [a] and [ə], all of which correspond with the relative distributional frequency of each sound in the Delattre data.

Overall, these longitudinal patterns of production, for both infants, particularly in the case of consonants, seem to suggest the possibility of transition into the adult language. Indeed, when we calculate the percentage of the total consonantal inventory at 0;5, 0;8, 0;11, and 1;2 that the children share, we see that it starts at 35% at 0;5, increases to 69% at 0;8 and then diminishes to 50% at 0;11 and 35% again at 1;2. This gradual decrease from a high of 69% overlap at 0;8 and each child's increased production of the consonant sounds in the ambient language suggest language-specific developmental effects.

Some further support for language-specific patterns emerges if we consider the children's consonant productions at each age in terms of manner (Fig. 1) and their vowel productions in terms of vowel height and frontness (Fig. 2). Each figure also contains the data for the appropriate adult language from Table 5 collapsed into the same categories.

As can be seen from Fig. 1, English uses fricatives, affricates and nasals more than French, whereas approximants are more frequent in French. Surprisingly, both infants showed perhaps their closest match to the frequency distributions of the manner categories of their native language in their vocal productions at 0;5 (Fig. 1). Both infants also showed a strong preference for producing stops at 0;8 and 0;11, though more so in the case of the French infant YC. At 1;2, the infants appeared to be heading back towards a pattern that closely matches that of their native language, except that the French infant, YC, produced very few fricatives, and the American

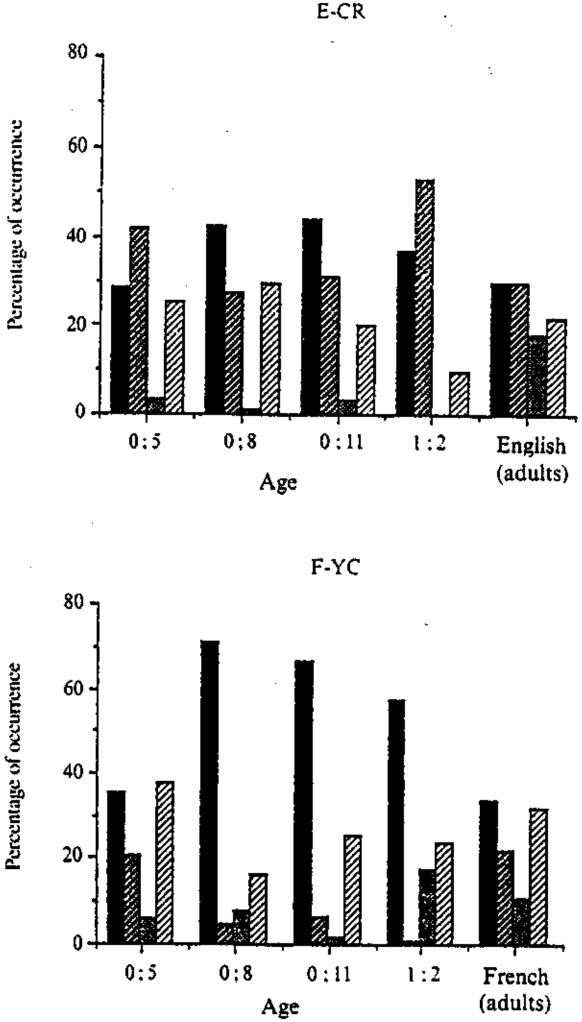

Fig. 1. Distribution of the consonant productions of the American (E-CR) and the French (F-YC) infant by manner class and age (excluding [ʔ] and [h]). ■, Stop; ▨, fric/affric; ▩, nasal; ▨, approx.

infant, CR, produced somewhat more fricatives and affricates than stops (as he did at 0;5) and very few nasals. The results for CR at 1;2 months are based on the smallest number of syllables (87), and should perhaps be regarded with caution.

The early preference for stops on the part of both infants is consistent with the universal tendency for early consonant productions to be stops (Locke, 1983). Although our French infant produced more stops, consistent with their distribution in adult French, than our American infant, Boysson-Bardies (1989), on the other hand, found that French infants produced fewer stops than American infants. However, her study began with older infants (0;10), followed them through the 25-word stage, and compared the children's distribution of consonants with the consonants in the adult models of the children's target-words rather than the language as a whole. The discrepancy may thus be due to the fact that our two infants were largely prelinguistic, whereas those of Boysson-Bardies had made entry into the linguistic systems of their environments.[2]

In the case of the vowel categories, the infants' productions were divided into seven categories, front high (fh), front mid (fm), front low (fl), mid central (mc), back high (bh), back mid (bm) and back low (bl). As can be seen from Fig. 2, F-YC favoured front vowels, in particular front low, which is consistent with the higher frequency of front as compared to central and back vowels in French. On the other hand, E-CR produced considerably more mid central vowels, which is consistent with their higher frequency in English. Furthermore, over the period of investigation, E-CR showed an increase in front high vowels, which is also consistent with their relatively high frequency in adult English.

The percentage of each infant's consonant and vowel productions in terms of the categories established in Figs 1 and 2 was correlated with the percentage of those categories in the adult languages. Table 6 shows the results of those correlations. Most of the correlations themselves are not significant (except one for F-YC at 0;5 and two for E-CR at 1;2), as would be expected given the fact that the infants' consonantal and vowel repertoires are more limited than the adults' because of developmental constraints. However, it is striking that in 14 out of 16 comparisons ($p < 0.002$, by a binomial distribution test), the French infant's productions correlate more strongly than the American infant's productions with the French consonant and vowel categories, whereas the American infant's productions correlate more strongly than the French infant's productions with the English consonant and vowel categories.

Formant analyses of the vowels. Mean F_1 and F_2 frequencies and standard deviations for all vowels at each age were plotted for both infants (see Fig. 3) and compared with the findings of Boysson-Bardies, Halle, Sagart & Durand

[2] The data at 1;2 may have included some words with the babble, because it was not possible to identify and exclude words on the basis of the parents' written comments during that month. However, we observe that the pattern here, and others described later, in general begin at 0;11 or earlier, and infants were clearly prelinguistic then. Thus, we do not feel that the possible inclusion of some words in the data at 1;2 substantially changes our pattern of results.

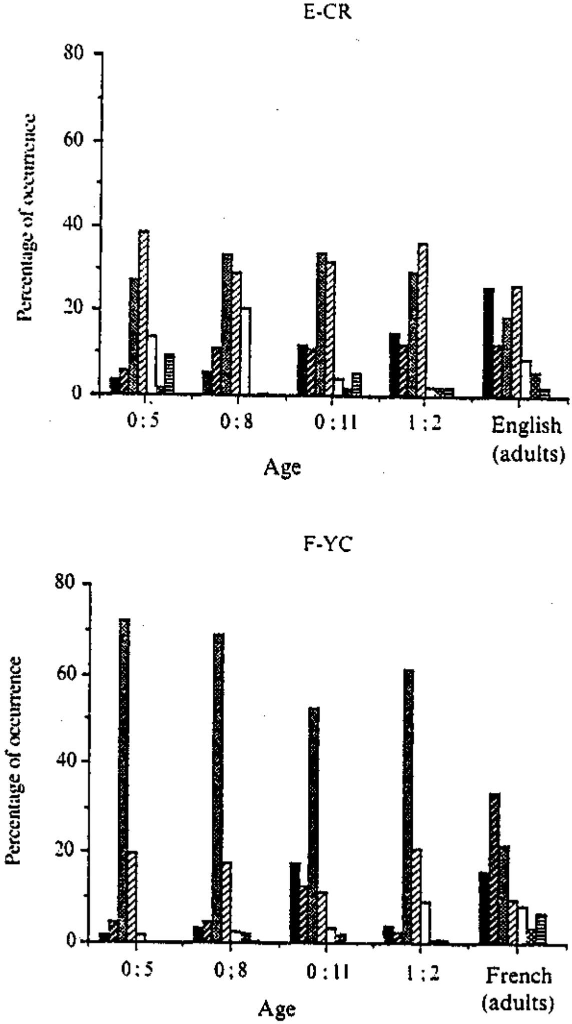

Fig. 2. Distribution of the vowel productions of the American and the French infant by category and age. ▪, Front high; ▨, front mid; ▪, front low; ▨, mid central; □, back high; ▩, back mid; ▤, back low.

(1989) for English and French infants. Of the 178, 218, 218, and 87 syllables analysed at 0;5, 0;8, 0;11, and 1;2, respectively, for E-CR, 26, 38, 33, and 14 syllables gave indeterminate F_1 or F_2 measurements and were excluded from the analyses. Similarly, of the 114, 317, 201, and 249 syllables analysed at 0;5, 0;8, 0;11, and 1;2, respectively, for F-YC, 9, 31, 35 and 65 syllables at each of the four ages gave indeterminate F_1 or F_2 measurements and were excluded from the analyses. Mean F_2 for the English-learning child, E-CR,

TABLE 6. *Correlations between the infant consonant productions and those of English and French in terms of manner categories and between infant vowel productions and those of English and French in terms of vowel height and frontness.*

	French consonants		English consonants	
Age	F-YC	E-CR	E-CR	F-YC
0;5	0·99*	0·56	0·88	0·47
0;8	0·67	0·94	0·81	0·49
0;11	0·81	0·78	0·94	0·52
1;2	0·61	0·34	0·96*	0·23
	French vowels		English vowels	
Age	F-YC	E-CR	E-CR	F-YC
0;5	0·32	−0·03	0·51	0·37
0;8	0·31	0·26	0·53	0·36
0;11	0·50	0·32	0·72	0·50
1;2	0·25	0·31	0·82*	0·39

* $p < 0·05$.

remained relatively stable until 0;11 when it began to increase. Mean F_2 for the French-learning child, F-YC, remained relatively stable until 1;2 when it began to decrease. At 1;2 the mean F_2 for E-CR was higher than that of F-YC. This pattern is consistent with the higher mean F_2 found by Boysson-Bardies *et al.* (1989) in the productions of English-learning infants when compared to those of French-learning infants, although this difference appeared in their data at 0;10.

Mean F_1 remained fairly stable for both children, increasing slightly for the American child over the four months sampled, and decreasing slightly for the French child over the same period. Overall, the mean F_1 was lower for E-CR than for F-YC, but the average values appear to be converging, while in the case of F_2, they seem to begin to diverge. Boysson-Bardies *et al.* found essentially identical measurements for mean F_1 for their sample of English and French infants, so this convergence is perhaps to be expected. Although language-specific differences occurred later in this analysis than in that of Boysson-Bardies *et al.*, they nonetheless appear to suggest the influence of the language environment on the acoustic properties of vowels for both infants.[3]

[3] The mean formant frequencies for English in Boysson-Bardies *et al.* (1989) were calculated for British English. We are assuming that the values for American English would bear essentially the same relationship to the other languages as did British English, although the actual means might differ.

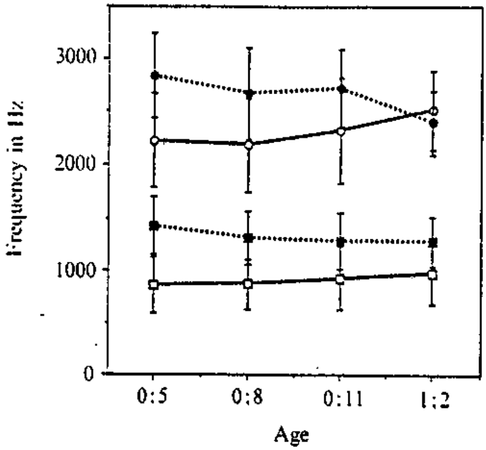

Fig. 3. Mean F_1 and F_2 and standard deviations for the American and the French infant by age. —□—, F_1 (E-CR); —○—, F_2 (E-CR); ---■---, F_1 (F-YC); ---●---, F_2 (F-YC).

Boysson-Bardies *et al.* (1989) have argued that from about 0;10, infants have sufficient articulatory control to produce vocal tract positions that result in sound productions that reflect the ambient language. We explored the possibility of such an influence by examining the formant frequency patterns for ten vowels produced by the two infants. Mean and standard deviation of F_1 and F_2 for the ten vowel sounds were plotted for each infant at each age (see Figures 4 and 5). In the adult languages, F_1 generally varies inversely with vowel height, whereas F_2 is generally higher for front vowels and lower for back vowels. F_1 can thus often be correlated with correct jaw control (or tongue height), whereas F_2 usually corresponds to tongue fronting (but cf. Ladefoged (1975) for some qualifications on inferring tongue position from F_2 for back vowels).

Given the appropriate patterning of F_1 in Fig. 4, and in particular the low variance in F_1 at the first three ages, E-CR may have developed better jaw control first. The increased variance in F_1 at 1;2 for CR appears to be associated with a reduction in variance in F_2, which suggests that he may have begun mastering the articulatory patterns for F_2 at that time. On the other hand, given the regular patterning of F_2 in Fig. 5 from 0;11 months on, YC may have mastered tongue fronting first. This would be reasonable, given the importance of tongue fronting in French (Delattre, 1965). Furthermore, there is a notable reduction in the variance in F_1 and/or F_2 in YC's productions from 0;11 to 1;2 in the four vowels that are most frequent in French (/e, a, i, ə/).

In order to test whether F-YC produced less variable F_2s and E-CR less variable F_1s, we conducted an analysis of variance on the log transforms of

E-CR

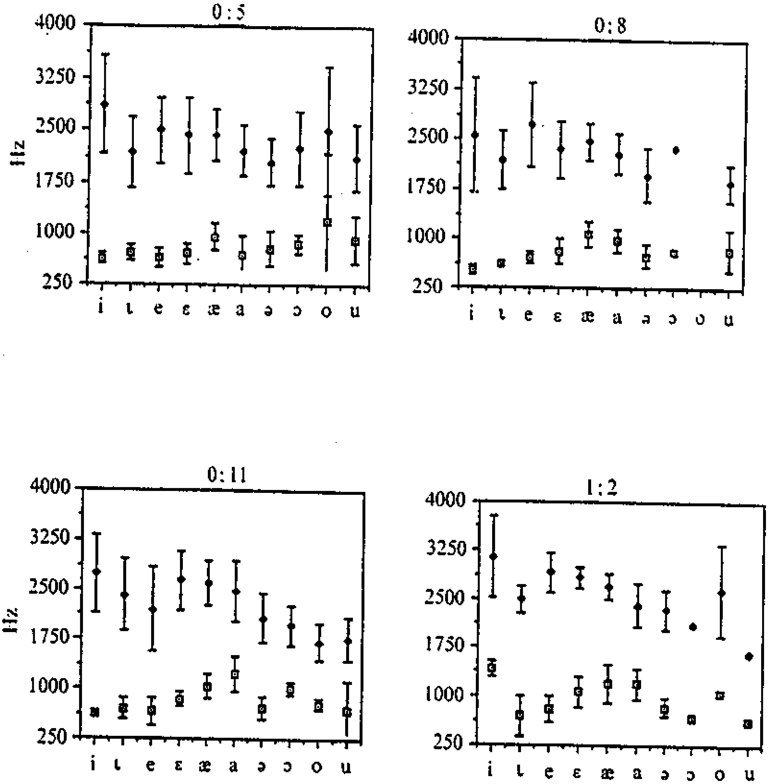

Fig. 4. Mean F_1 and F_2 and standard deviations for 10 vowels for the American infant by age. ⊡, F_1; ◆, F_2.

the standard errors of the mean for each vowel's F_1 and F_2 measurements at each time period. The analysis contained one between-factor (infant language source), with each of the ten vowels treated as subjects, and two within-factors (time period and formant number). There was a significant effect of formant number [$F(1, 18) = 27.525$, $p = 0.0001$] with F_1 means overall less variable than F_2 means. There was also a significant interaction of formant number by language source [$F(1, 18) = 9.099$, $p = 0.0074$] which showed that F_1 measures for E-CR were less variable than those for F-YC, whereas F_2 measures for F-YC were less variable than those for E-CR. There were no other significant effects or interactions.

Thus, the analyses of the formant patterns suggest that both infants

F-YC

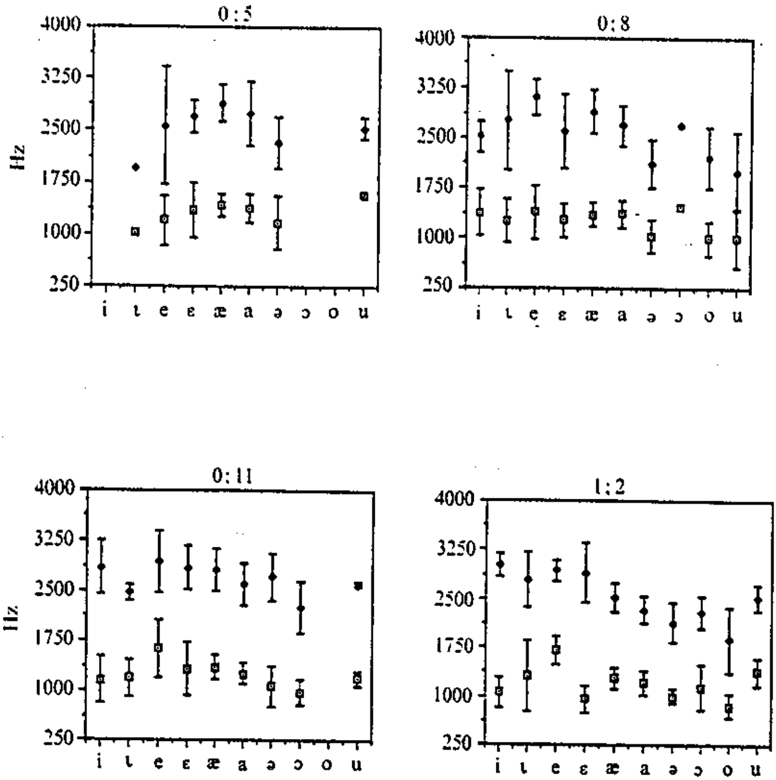

Fig. 5. Mean F_1 and F_2 and standard deviations for 10 vowels for the French infant by age. ⊡, F_1; ◆, F_2.

appeared to develop more adult-like vowel formant frequency patterns over time, presumably as a result of their increasing articulatory control in producing vowels. There is also some evidence for the influence of language-specific articulatory effects in the pattern of variability for F_1 and F_2, which reflects the particular ways in which each infant began to demonstrate increasing articulatory control.

Syllable characteristics

All of the two-syllable or longer utterances that contained at least two consonant- and vowel-like segments (e.g. CVCV or VCVC) were tallied for each infant at each age. Fig. 6 provides some support for the stages of Stark

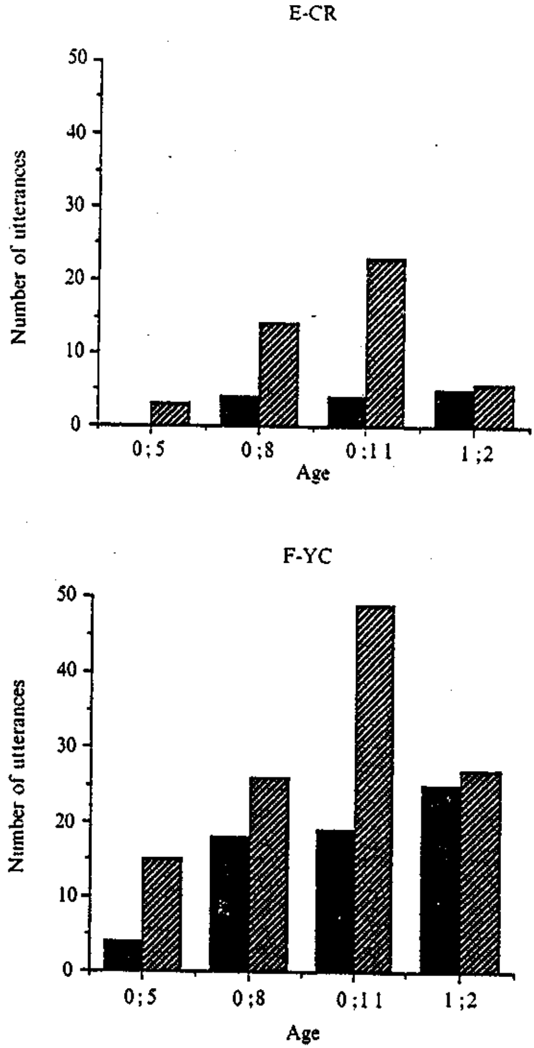

Fig. 6. Number of reduplicated and variegated utterances produced by the American and the French infants by age. ■, Reduplicated; ▨, variegated.

(1980) and Oller (1980) in terms of the onset of reduplicative babbling (for CR) and the period during which variegated babbling becomes more frequent (for both infants). Thus, the American infant produced reduplicative or canonical babbling at 0;8 but not before. Both Stark and Oller suggest that such babbling should begin between 0;6 and 0;7, so CR's performance is consistent with this stage in their developmental schemes. On the other hand, the French infant actually produced some reduplicative utterances in the samples at 0;5, but also showed a great increase in production of such babbles between 0;5 and 0;8. The speech samples of both children yielded a fairly level number of reduplicative babbles from 0;8 on, with F-YC producing a consistently higher number.

Stark and Oller predict that variegated babbling should begin between 0;10 and 0;11 months. Both infants produced variegated babbles before the 11-month sample, but they both showed the greatest number of variegated babbles at 0;11. The fact that both reduplicative (in the case of YC) and variegated babbling (in the cases of both infants) appeared earlier than expected is consistent with the report of Smith, Brown-Sweeney & Stoel-Gammon (1989), who also found that both reduplicative and variegated productions co-occurred in the babbling of the ten American infants that they studied at four month intervals from 0;6 to 1;6. (See also Mitchell & Kent, 1990, for similar observations.)

We conducted an analysis of variance on the number of reduplicated and variegated babbles with one between-factor (infant language source) and one within-factor (babbling-type – reduplicated or variegated), treating each of the four time periods as subjects. There was a significant effect of infant language source [$F(1, 6) = 7{\cdot}670$, $p = 0{\cdot}0324$], reflecting the higher incidence of multisyllabic babbling in the French infant's speech. There was also a significant effect of babbling type [$F(1, 6) = 10{\cdot}826$, $p = 0{\cdot}0176$], since there were more variegated than reduplicated utterances overall. There was no infant language source by babbling type interaction. Thus, although the French infant produced more multisyllabic babbles, the pattern of variegated and reduplicative babbling was essentially the same for both children.

The transcription data were also used to determine the number of open and closed syllables produced by both infants at each age. The percentage of closed syllables in the productions of the American infant dramatically increased at 0;11, while percentages for the French infant remained low and relatively stable (see Fig. 7). A χ^2 test on the frequency distributions of open and closed syllables was significant in the case of E-CR (χ^2 (3) = 33·648, $p = 0{\cdot}0001$) but not in the case of F-YC (χ^2 (3) = 5·983, $p = 0{\cdot}1124$). This discrepancy is consistent with the greater frequency of closed syllables in English than in French (Delattre, 1965) and suggests that by 0;11 CR had begun to produce a distribution of syllable types that is characteristic of his English language environment.

Finally, the number of syllables per utterance for all utterances containing at least one consonant or consonant-like segment was plotted for each infant at each of the four ages. If the children's productions of monosyllabic versus polysyllabic utterances were influenced by the ambient language, then we would expect a greater incidence of polysyllabic utterances produced by the French child and a greater incidence of monosyllabic utterances produced by

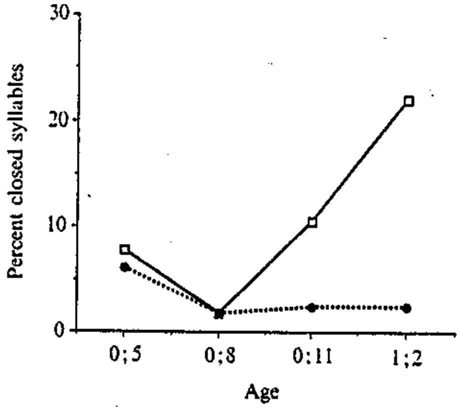

Fig. 7. Percentage of closed syllables produced by the American and the French infant by age. —□—, E-CR; ---●---, F-YC.

the American child. Chi-squared tests of the frequency distributions of the monosyllabic and polysyllabic utterances of the two children at 0;5 and 1;2 were not significant (χ^2 (1) = 0·4, p = 0·5251 and χ^2 (1) = 0·1, p = 0·7815, respectively), although they were significant at 0;8 (χ^2 (1) = 31·5, p = 0·0001) and at 0;11 χ^2 (1) = 12·8, p = 0·0003). However, as can be seen in Fig. 8, at 0;8 it was actually the American child who produced more polysyllabic utterances, while the French child produced more monosyllabic utterances. At 0;11 the pattern was somewhat more as predicted, in that the French infant produced considerably more polysyllabic than monosyllabic utterances, although the American infant did not produce more monosyllabic than polysyllabic utterances at that time. Since other researchers have found an effect of adult-language utterance lengths on child productions (Boysson-Bardies, 1989) in examining the productions of children beginning at 0;10 and following them until the 25-word stage, it is possible that utterance length effects emerge later in children's productions.

Timing

In terms of rhythmic or timing constraints, French shows greater isosyllabicity than English, or a tendency for non-final syllables to be more or less equal in length. Furthermore, syllable lengthening is also more consistent in French, because it is always breath-group final and is not confounded with lengthening due to lexical stress, as in English. To determine the relative isosyllabicity of syllable duration for the French infant as compared with that of the American infant, the means of all non-final syllables in the first, second, or third position of an utterance, at each of the four ages, were calculated for both F-YC and E-CR. Means for F-YC were generally less

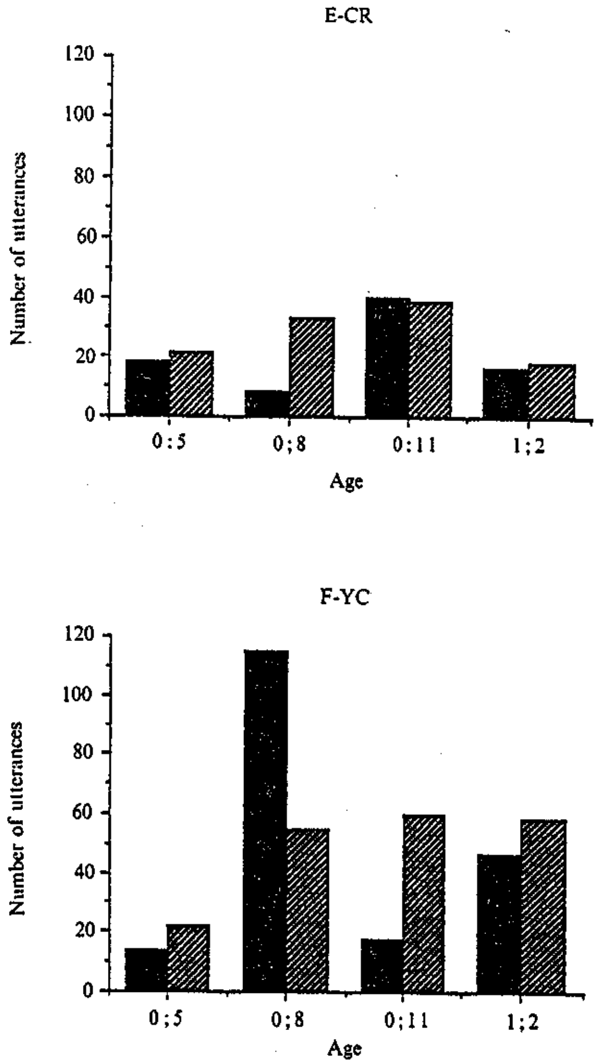

Fig. 8. Number of monosyllabic and polysyllabic utterances produced by the American and the French infant by age. ■, Single syllables; ▨, two or more syllables.

variable across utterance position than those for E-CR (see Fig. 9). The difference between the longest average syllable length and the shortest was 62·3, 23·6, 48·7, and 131 ms at 0;5, 0;8, 0;11, and 1;2 respectively, for the French infant, whereas for the American infant, this difference was 103·3, 155·8, 80·3 and 144·4 ms at 0;5, 0;8, 0;11, and 1;2. These differences just failed to reach significance, ($t(3) = 2{\cdot}1$, $p = 0{\cdot}0659$, one-tailed). The tendency

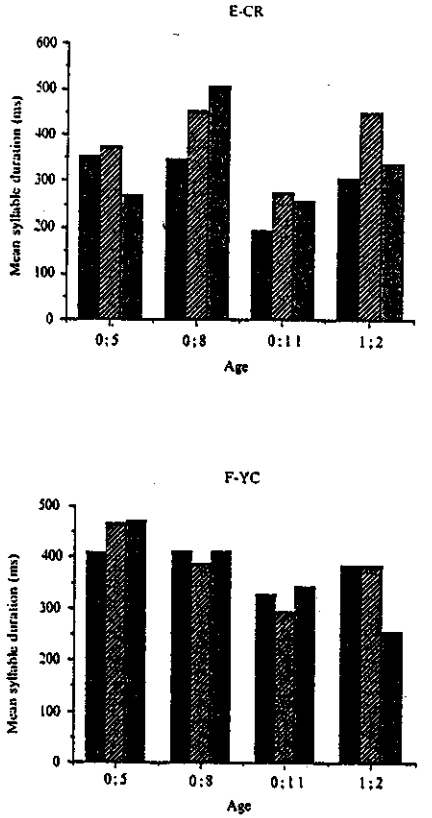

Fig. 9. Mean syllable duration in ms for syllables in the first, second, or third position in the utterances produced by the American and the French infant by age. ■, First position, ▨, second position; ▩, third position.

for the French infant to produce more regularly-timed non-final syllables appears nonetheless to be a strong one, because at every age, the French infant produced non-final syllables that were on average closer in duration to one another than did the American infant. Konopczynski (1986), who examined the duration of syllables in the babbling productions of four French children aged 0;8 to 2;0, also found evidence for isosyllabicity.

Final syllable lengthening in the present study was examined in terms of mean syllable length for final and non-final syllables in reduplicative strings, and in terms of the number of reduplicative strings which showed final syllable lengthening. Reduplicative babbling was used in order to eliminate differences in syllable lengths due to the effects of segments of intrinsically different lengths. Final syllables for both infants were found to be longer than non-final syllables at 0;11 and 1;2 (see Fig. 10).

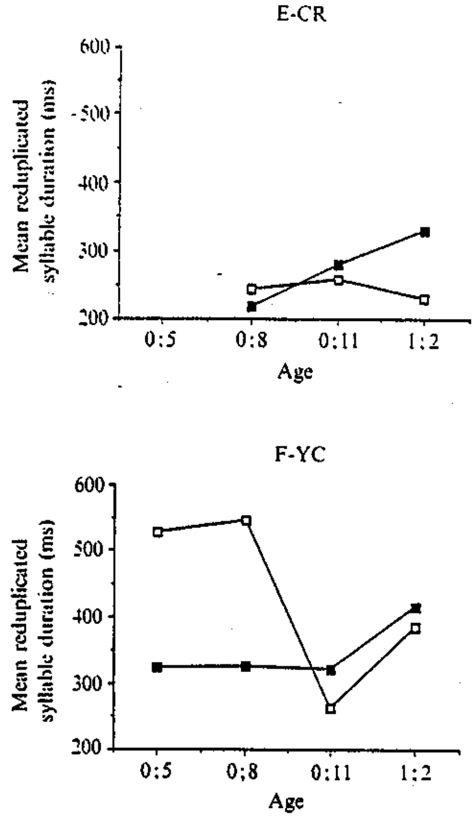

Fig. 10. Mean syllable duration in ms of final vs. non-final syllables of the reduplicated utterances produced by the American and the French infant by age. —■—, Final; —□—, non-final.

However, when the percentage of reduplicative tokens which have longer final than penultimate syllables is plotted for each infant at each age, the French infant showed a gradual increase in the percentage of utterances with final syllable lengthening, while the American infant showed a drop at 1;2 (see Fig. 11). The difference in the number of utterances with final-syllable lengthening for the two children at each of the four ages was significant ($t(3) = 2{\cdot}377$, $p = 0{\cdot}049$, one-tailed). Regular final syllable lengthening is a more striking characteristic of the French language, where the final syllable is the only one lengthened, than English, where syllables that bear stress, as well as those that are final, can be lengthened. These data on final syllable lengthening are consistent with Konopczynski's (1986) finding of final syllable lengthening in the variegated and reduplicative babbling of French children between the ages of 0;8 and 2;0 and with Oller & Smith's (1977)

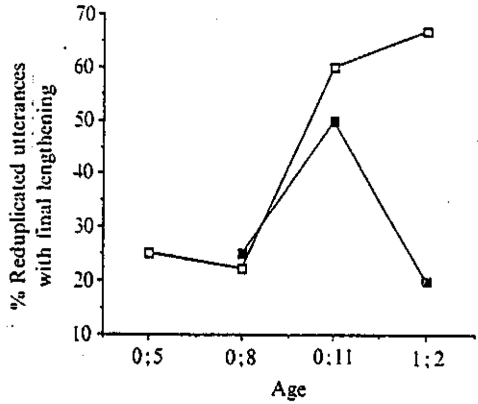

Fig. 11. Percentage of reduplicated utterances with final syllable lengthening produced by the American and the French infant by age. —■—, E-CR; —□—, F-YC.

finding of little final syllable lengthening in the reduplicative babbling of six American infants aged 0;8 to 1;0. However, as is evident from Fig. 6, the American infant produced very few reduplicative utterances overall, so that the present results, while consistent with previous research, must be interpreted with caution.

DISCUSSION

Analyses of the babbling of the two infants in the study showed clear evidence both of similar developmental patterns, presumably due to universal developmental processes in the two infants, and of the prelinguistic influence of the adult language environment.

Evidence of general developmental effects is apparent in both the acoustic analyses and in the examination of segmental inventories. Both infants appeared to produce target F_1 and F_2 with less variability as they got older, suggesting increased articulatory control. Both infants produced 16 of the 23 consonant-like sounds and all 11 vowel sounds which compose the total corpus, and they generally favoured stop consonants over other types. These findings are consistent with Locke's (1983) hypothesis of universal phonological development. Finally, the analysis of the multisyllabic babbling of both children provided some evidence in support of the developmental stages of babbling as described by both Stark (1980) and Oller (1980), although the presence of reduplicative and variegated babbling prior to their predicted onsets is consistent with the findings of Smith *et al.* (1989) and Mitchell & Kent (1990).

The evidence of language-specific effects is also clear, although in most cases these effects appear in longitudinal analyses at the 0;11 sample or later for both infants. Each infant's phonetic inventory began to resemble that of the adult language both in composition and frequency, so that over the course of time, the two infants' phonetic inventories, in particular their consonantal inventories, diverged. Vihman, Ferguson & Elbert (1986) found that the phonetic tendencies of 10 American infants aged 0;9 to 1;4 tended to converge over the period studied. Both the Vihman *et al.* finding of increased similarity for infants learning the same language and the divergence found in the present analysis for infants learning two different languages suggest the influence of the language environment on the infant productions.

Measurements of the acoustic properties of the vowels also revealed some language-specific effects. Mean F_1 for all syllables for both infants appeared to converge over time, whereas mean F_2 for the American infant displayed an increase of about 200 Hz at 1;2, corresponding with a drop of about 300 Hz in mean F_2 for the French infant at that time, so that mean F_2 is higher for CR than for YC at 1;2. These F_1 and F_2 patterns are consistent with the results of a similar analysis to Boysson-Bardies *et al.* (1989), who found that mean F_1 measurements were essentially the same for English-learning and French-learning infants, whereas mean F_2 measurements were higher for the former group. Furthermore, the patterns found for F_1 and F_2 in the infant groups reflected similar F_1/F_2 relationships in the data from the adult languages. Although this pattern was evident for the babbling of ten-month-old infants in the Boysson-Bardies *et al.* study, it only emerged in the 1;2 samples in our data.

In terms of syllable characteristics, the American infant produced a larger percentage of closed syllables than the French at 0;11 and 1;2, and showed a dramatic increase longitudinally in the percentage of closed syllables produced, while percentages of closed syllables for the French infant remained stable over time. Because English has more closed syllables than French, this result suggests the influence of English on CR's babbling.

Analyses of timing patterns in the babbling of the two infants revealed evidence of the characteristic isosyllabicity of French for YC at all ages: when the durations of nonfinal syllables were averaged for each position in the utterance at each age, mean syllable duration tended to be less variable for the French infant than for the American infant. In addition, although both infants showed some final syllable lengthening at 0;11 and 1;2, a larger percentage of the French infant's reduplicative utterances showed final syllable lengthening, suggesting a more pronounced influence of the French rhythmic pattern on YC's babbling.

In general, our results agree with recent findings (Vihman *et al.* 1986; Boysson-Bardies, 1989; Boysson-Bardies *et al.* 1989) of language-specific influences on the segmental characteristics of babbling towards the end of the first year. However, some of the timing differences that emerged in this study, particularly the suggestion of an early development of isosyllabicity in the babbling of the French infant, suggest that the language environment may affect the prosody of babbling even earlier than its segmental characteristics (see also Whalen, Levitt & Wang, 1991). Clearly the prosody of infant babbling warrants further cross-linguistic research.

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