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Japanese and French infants' vocalizations at the onset of first words: A comparison of phonetic and prosodic cues in disyllabic productions

P.A. Hallé

Introduction

During the last decade, the claim of a continuity between prespeech forms and first words, in opposition to Jakobson's view, has been supported by a number of studies, in particular, by many empirical field research (Kent & Hodge, 1990; Vihman, Macken, Miller Simmon & Miller, 1985). Recently however, this issue has been reopened by Davis and MacNeilage (1990). The status of the prespeech babbling and of the babbling concurrent to early words, is still a controversial issue. On the one hand, cross-linguistic studies covering prespeech have demonstrated its convergence toward adult speech (de Boysson-Bardies, Halle, Sagart & Durand, 1989: Vowels; Halle & de Boysson-Bardies, 1990; Whalen, Levitt & Wang, in press: Intonation; de Boysson-Bardies & Vihman, 1991: Consonants). On the other hand, the recent work by Davis and MacNeilage (1990), a case study of one American child, aged 14-20 months, concludes to large phonetic differences between attempted words and concurrent babbling: The babbling forms often are "pure frames" (in MacNeilage's theory of "frames and content" in MacNeilage & Davis, 1990), reflecting no or little selectivity from the adult phonetic repertoire, whereas emerging speech forms often are 'frames' filled with differentiated 'contents', reflecting a sizeable degree of selectivity from the adult repertoire. Davis and MacNeilage found in their subject a much higher degree of 'mechanical' interaction between vowels and consonants in babbling than in speech: The "articulatory compatibility" factor suggested by Kent and Murray (1982) is presumably weighing more heavily on babbling than on speech forms. Hence, Davis and MacNeilage's research is questionning the issue of continuity between prespeech and speech, as well as the issue of an early selection from the ambient language: In their babbling, the children would exhibit little language adjustment, and rather, produce sounds governed by biological factors, such as ease of production.

In a previous study (Halle & de Boysson-Bardies, 1990), we have demonstrated that prominent prosodic cues (F0 contours and rime durations) in infants' vocalizations exhibited opposite patterns in French and Japanese, by 18 months of age. Those patterns precisely reflected the specificity of French and Japanese adult speech prosody, which exhibit highly contrasted features, either globally or locally (that is, at the lexical level). Taking MacNeilage's notion of babbling forms as pure frames, prosody in babbling forms should be neutral with regard to whatever target language: It should be mainly governed by non-specific interactions between segmentals and prosody. In contrast, prosody in words should exhibit emerging language-specific trends. Our results however, did not support the notion of discrepant tendencies in infants' words and concurrent babbling forms with respect to prosodic cues.

We will now examine our data from the viewpoint of the phonetic composition of infants' vocalizations: Are babbling forms governed by mechanical coarticulation constraints, whatever the target language, while only words exhibit some degree of language adjustment, as would suggest the Davis & MacNeilage's study ? On the contrary, are both babbling and words reflecting the phonetic composition of the target languages ? Finally, how do interact, if at all, segmental and prosodic levels of organization ?

After a short presentation of our cross-language study of prosody in French and Japanese infants' disyllables, we will present the phonetic analyses relative to the same material.

Data collection and sampling

The French and Japanese data were collected as part of the Cross-linguistic Project on Infant Vocalizations (de Boysson-Bardies, Vihman, Durand, Roug-Hellichius & Landberg, 1991). Five children from each language group were audio- and video-recorded in bi-weekly 30 minute sessions, from about 10 months until the '25-word session', when they produced at least 25 different word-types in a session. 'Target words' in each language group are the adult words attempted at least once by at least one infant in the group, regardless of the session. In this paper, we report only on the 25-word session. The vocalizations were transcribed into IPA by native speakers and then cross-checked. The agreement between transcribers was about 87%. The main transcription problems were: Voiced versus unvoiced, and [a] versus [ɑ]. Disyllabic vocalizations, which account for 43% of the vocalizations in French and 45% in Japanese were selected for instrumental analyses: Aside from their large occurrence in the data, disyllables were chosen because they allow a clearcut quantitative description in terms of F0 contour and duration patterns. We found 66 disyllabic target word-types in French, and 104 in Japanese.

For each infant, all the disyllabic utterances produced during the 25-word session were retained provided they met the following requirements: F0 could be estimated, no abrupt discontinuity occurred in F0 contour (items with a falsetto or creacky voice portion were discarded), the vocalization was neither shouted or cried. Two infants, one in each group, produced less than 15 items meeting these requirements and were not considered further. For other children, the number of disyllables retained ranged from 35 to 138 (mean 86): A total of 315 disyllables for French, of 370 disyllables for Japanese infants.

F0 contours and rime durations

Adult forms

French and Japanese languages were of particular interest for a comparative study because their global prosodic features are well contrasted. The most typical intonation

contour in French is the rising continuation contour (Delattre, 1961; Rossi, 1980). Final lengthening in French, on the last syllable of prosodic groups or in words, is well established: Ratios of syllable durations of about 1.7 are usually observed in adult speech (Wenk & Wiolland, 1982). In contrast, the usual continuation intonation is normally falling or flat in Japanese. Final lengthening occurs only with question intonation and is not observed to accompany the continuation intonation (Nishinuma, 1979; Hoequist, 1983). Local prosodic features are contrasted as well: Pitch contour and durations are not lexically constrained in French, whereas 'word tones' and contrasts of segmental quantity are in Japanese. If the intonation and timing patterns of the ambient language influence infants' vocalizations, we expect to find similar differences between French and Japanese children.

Analysis of prosody in children's disyllables

F0 was extracted from the digitized speech signal and checked with the help of narrow band spectrograms: Incorrect and spurious F0 values were removed. F0 contours were then smoothed by fitting natural cubic spline functions to the raw values: F0 raw values were grouped over 50 ms wide intervals, and piecewise cubic interpolation was performed between group centers. The following parameters were computed from the smoothed contours: F0 onset value and mean value, and F0 excursion. F0 excursion was the ratio of the 'signed' F0 range to the F0 onset value. Falling contours were given a negative F0 range, rising contours a positive one. We thus established a continuity from largely falling contours to largely rising contours (large F0 excursion in absolute value, but negative versus positive sign), encompassing 'flat' contours, which simply have small F0 excursions in absolute value.

In order to characterize the temporal balance in disyllables, we have chosen to analyse rime rather than syllable durations because we take the durations of initial consonants to be irrelevant to prosody in either French or Japanese (they may be relevant in other languages, e.g. Swedish). Given the difficulty to locate rime or syllable boundaries in utterances when voiced throughout, we limited ourselves to disyllable types where syllable-initial consonants were not voiced: For the measurement of rime durations, 109 out of 315 disyllables were retained for the French infants (35%), and for the Japanese, 189 out of 370 (51%).

Global results

Mean values of the parameters describing F0 contours, computed for each infant and averaged within each language group are summarized in Table 1. For the F0 excursion parameter, the difference between the French and the Japanese groups is highly significant ($t(6)=4.56$, $p<0.005$). French infants all produced a majority of rising F0 contours (73%), while Japanese produced a majority of falling contours (74%). Histograms of the F0 excursion parameter in Figure 1 illustrate this difference.

Table 1. Parameters describing F0 contours: Mean values for each infant.

	infant	nb. of items	Onset (Hz)	Mean (Hz)	Excursion (%)
(French)	Marie	95	292	316	+20%
	Laurent	64	342	356	+10%
	Charles	93	344	410	+32%
	Carole	63	317	335	+22%
	Average		324	356	+21%
(Japanese)	Taro	35	286	270	-3%
	Haruo	99	337	347	-25%
	Emi	98	344	319	-28%
	Kazuko	138	383	389	-5%
	Average		337	331	-15%

Table 2. Duration patterns: Mean values for each infant.

	infants	nb. of items	Rime r1 (ms)	Rime r2 (ms)	r2/r1
(French)	Marie	31	171	229	1.52
	Laurent	13	196	227	1.23
	Charles	35	216	320	1.58
	Carole	30	173	243	1.47
	Average	27	189	255	1.45
(Japanese)	Taro	24	148	137	0.92
	Haruo	55	202	320	1.68
	Emi	38	164	128	0.83
	Kazuko	72	267	237	1.00
	Average	47	195	205	1.15

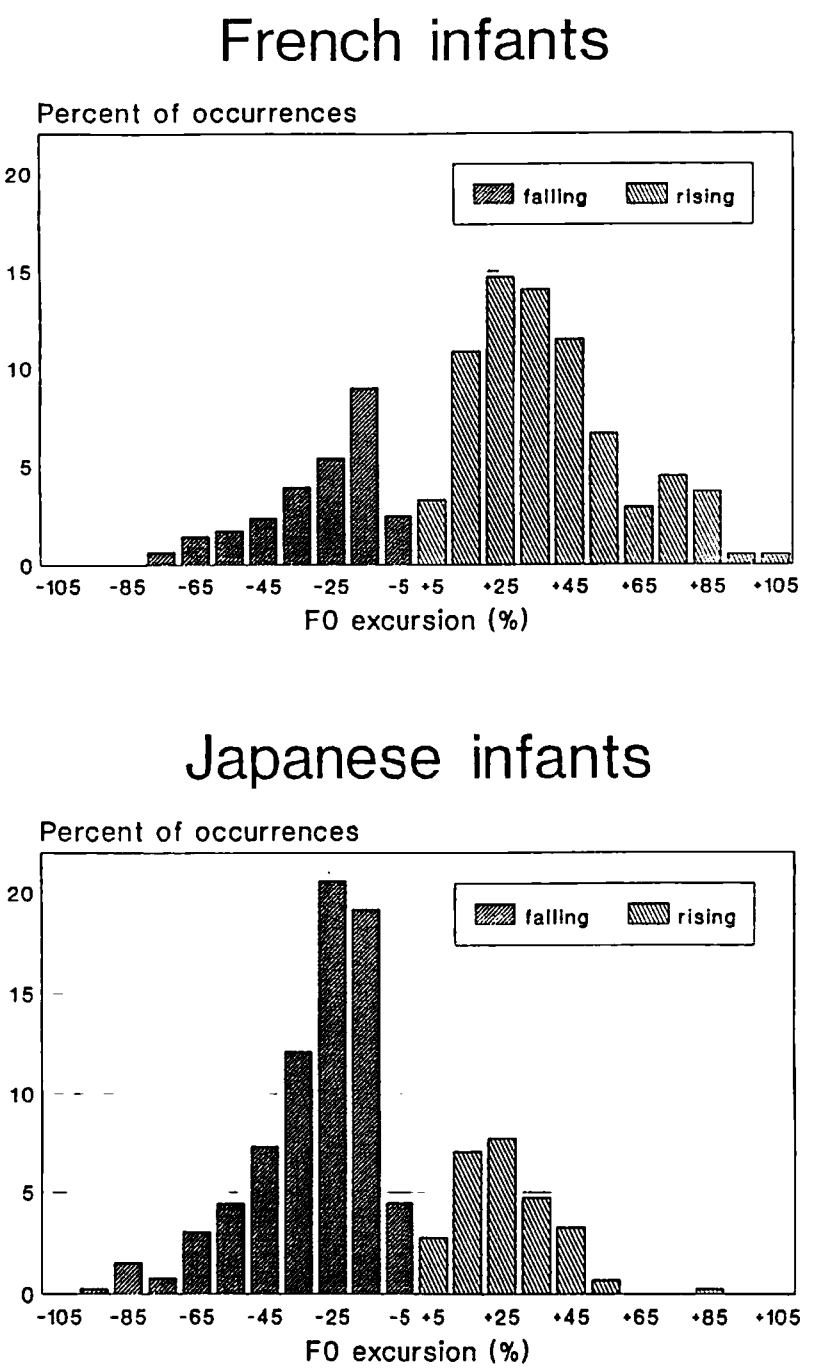
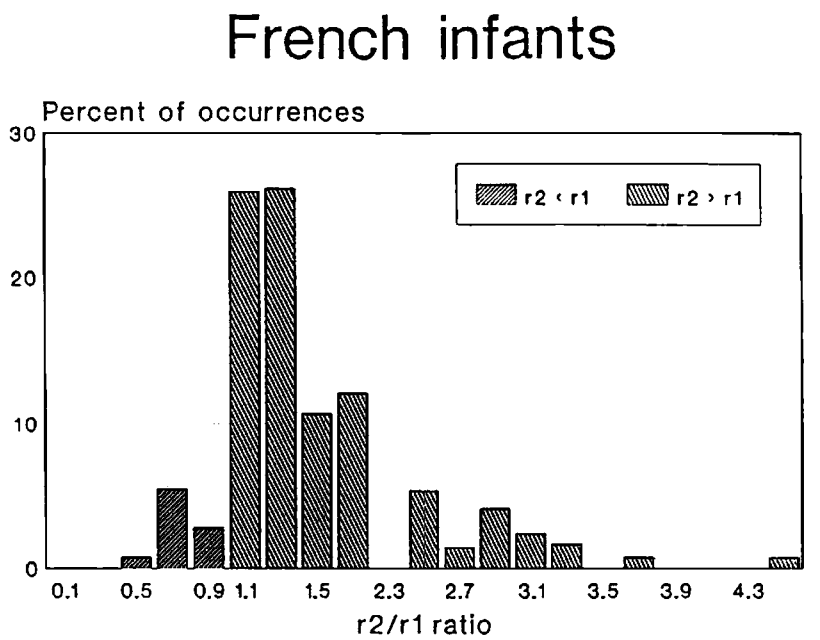


Figure 1. Histograms of the F0 excursion



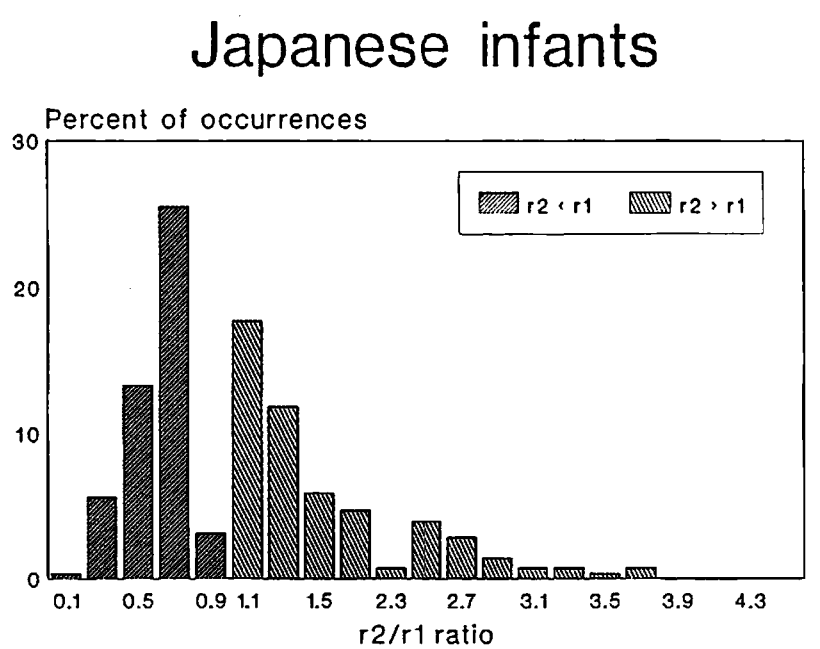


Figure 2. Histograms of the r2/r1 ratio

For the items retained for the measurement of rime durations, we computed the durations of the first and the second rime, and the ratio of the second to the first rime durations (r1/r2 ratio). Results are summarized in Table 2. The first rime duration is not significantly different between French and Japanese groups ($t(6)=0.22$, $p>0.3$). French infants' vocalizations all show a substantial increment of duration on the last syllable rime. Final lengthening is not observed in three out of four Japanese children. The French group is more homogeneous than the Japanese, as can be seen from the r2/r1 ratio (SD 0.15 versus 0.39). The heterogeneity within the Japanese group is due to Haruo, the only Japanese child who produced longer second rimes. The r2/r1 ratio tends to be larger for French children, and the difference is highly significant if Haruo's data are excluded from the Japanese group ($t(5)=5.42$, $p<0.003$). Histograms of the r2/r1 ratio in Figure 2 illustrate this difference.

Japanese children: attempted words versus babbling

In Japanese adult speech, lexically constrained word tones and vocalic quantities affect the prosodic variables. Hence, we can compare infant and adult forms from this 'lexical' perspective. We used the set of 104 disyllabic target word-types as the Japanese adult reference: Only 2% had a complex rise-fall lexical pitch contour in Standard Japanese, 36% had a rising contour, and 62% a falling contour. Hence a clear majority of falling contours. Estimating rime durations from the number of moras contributing to the rime in the adult glosses of target words, we found that 72% of the target disyllables had both rimes short, 11% had both rimes long, 11% had the first long and the second short, and only 6% had the first short and the second long. These figures indicate that Japanese target disyllables are balanced in rime durations as a rule, with a strong trend to have a short second rime.

About 63% of the disyllables produced by the Japanese children at the 25-word session were identified as attempts to adult words. Tables 3 or 4 present separately the prosodic patterns in babbling and in attempted words. Table 3 shows the observed F0 contours in infants' disyllables. The proportion of falling contours is equally high in words and babbling (73% versus 74%), even higher than in target words (62%). However, this proportion is significantly lower in attempted words whose adult form has a rising contour (57%), as shown by a Chi-square test: $X^2(2)=19.94$, $p<0.001$. This is an indication that acquisition of word tone is on the way. Table 4 shows the observed r2/r1 ratios in infants' disyllables: They are not significantly different in words and babbling (1.17 versus 1.13), and globally reflect the trend of target disyllables to be balanced in rime durations. These ratios are somehow inflated since Haruo's data are also included, but still, they remain close to one, regardless of the adult model in attempted words, excepted for the few items whose adult form has a short-long pattern of rime duration (mean r2/r1 of about 2).

Table 3. Observed F0 contours according to the type of vocalization: Attempted Words or Babbling (four infants pooled: N=370 items). The percentages shown are the percentages of contours observed as rising within vocalization type.

OBSERVED F0 CONTOURS	VOCALIZATION TYPE: *Attempted words* — Adult form rising	Adult form falling	TOTAL	*Babbling*
rising	39 (43.3%)	24 (16.8%)	**63 (27.0%)**	**35 (25.5%)**
falling	51	119	**170**	**98**
TOTAL	90	143	233	137

Table 4. Observed r2/r1 ratios according to the type of vocalization: Attempted Words or Babbling (four infants pooled: N=370 items).

OBSERVED R2/R1 RATIO	VOCALIZATION TYPE: *Attempted words* — Adult form pattern: Long-Short	Balanced	Short-Long	TOTAL	*Babbling*
r2/r1	1.15	1.10	2.00	**1.17**	**1.13**
nb. items	16	92	8	116	73

Table 5. Proportions of terminal glottal stops in disyllables.

(French)	Charles	Laurent	Carole	Marie	Total
nb. items	35	13	30	31	109
glottal stops	0 (0%)	0 (0%)	1 (3%)	2(6%)	3 (3%)
(Japanese)	Taro	Haruo	Kazuko	Emi	Total
nb. items	24	55	72	38	189
glottal stops	8 (33%)	3 (5%)	26 (36%)	8 (21%)	45 (24%)

Discussion

The global properties of French versus Japanese intonation and duration patterns are present in the vocalizations of children by about 18 months of age. Indeed, the most striking difference between the two language groups lies in the F0 excursion variable, which clearly shows that French children produce a large majority of rising contours while Japanese children show the opposite tendency. In the case of Japanese children, falling or rather flat F0 contours reflect not only global intonation, but also lexical intonation, that is, pitch accent on words.

As for final lengthening, the French children's data are in close agreement with previous studies: Konopczynski (1986) found an average final lengthening ratio of 1.6 in four children between 16 and 24 months. We find an average ratio of 1.5. In the Japanese group, final lengthening seems to be exceptional. It is observed only in one child, Haruo. However, we suspect here some interaction with the segmental level of organization: Table 5 shows that French children are rarely found to produce a terminal glottal stop while Japanese children exhibit the opposite tendency, *excepted for Haruo*. The use of a terminal glottal stop is also attested in adult speech (Kinda-Ichi & Maes, 1978). We may surmise that it is a device used in Japanese to inhibit final lengthening, a perhaps universal tendency (Robb & Saxman, 1990).

According to the Japanese data, we do not find trends different in babbling than in words, although words tend to some degree of correctness with respect to lexical word tone.

To summarize, our results show that, toward the end of the transition from babbling to early words, even disyllables are strikingly congruent with adult prosody, although one would expect them to be poor in prosodic cues, given their brevity. French and Japanese children clearly differ with respect to F0 contours and rime durations, and closely reflect the specific trends in French and Japanese adult speech. No difference is found, with that respect, between attempted words and concurrent babbling in either language group.

We will turn now to analyses of the phonetic composition of the children's data. We still have to consider the hypothesis that the interaction between segmental and prosodic levels of organization can explain the prosodic patterns that we found. Therefore, care will be taken to examine this interaction: Specifically, we will examine the influence of vowel intrinsic F0 and intrinsic duration on the F0 contours and on the balance of rime durations in disyllables.

Phonetic composition

In one of the first outcomes of the Cross-linguistic Project on Infant Vocalizations,

de Boysson-Bardies et al. (1991) reported on the distributions of consonants found in English, French, Japanese, and Swedish infants' babbling and early words, from about 10 months until the 25-word session. They concluded to language-specific differences in either babbling or words.

Davis and MacNeilage's study (1990) focused on vowels and consonant-vowel interactions. They found that CV interactions in babbling forms and in the first syllable of disyllables can be anticipated "on sheer mechanical grounds". This result is challenging the previous findings of an early language adjustment. Hence, our reexamination of French and Japanese data in the 25-word session, from a phonetic perspective. In the next sections, we examine the distribution of consonants, of vowels, and CV interactions. Finally, we examine vowel sequences and their possible interaction with the F0 contours and the patterns of rime durations in disyllables.

Phone counts

All the subsequent analyses are based on the phonetic transcription of the French and Japanese children's disyllables in the 25-word session. We limited ourselves to the disyllables retained for F0 contour analysis. For sake of clarity, we pooled children by language group, but examine separately babbling forms and attempted words. Infants' vocalizations are compared primarily to the target disyllabic word-types in each language, with occasional reference to phonetic counts in the adult French and Japanese languages in general (our sources are: Tubach & Boe (1990) for French; Sawaki (1980), reanalysed by Halle in this volume, for Japanese). Given the main uncertainties in phonetic transcriptions, vowels have been grouped into six categories: High Front and High Central, Mid Front, Mid Central (mainly the schwa), Low (from [æ] to [ɑ]), Mid Back, and High Back. For sake of simplicity, we denote these categories by 'i', 'e', 'schwa', 'a', 'o', and 'u'. Consonants have been grouped by place and manner of articulation: Labials, Dentals, Palatals, and Velars for place; Plosives, Affricates, Fricatives, Nasals, Liquids, and Semi-vowels for manner. 'Palatal' actually refers to a range of places of articulation from alveo-palatal to palatal, 'Velar' stands for places of articulation from velar to laryngeal.

A computer software was specially implemented to type in phonetic transcriptions, to perform syllabification, and various kinds of counts, whether contextually constrained or not.

Consonants

Figure 3 shows the distributions of consonant place categories in babbling, attempted words, target words and language at large, in French and in Japanese. Target words and language at large have congruent distributions only in C2 position (initial consonant of second syllable), not in C1 position (initial consonant of second syllable). Two robust differences are found between Japanese and French adult speech: More labi-

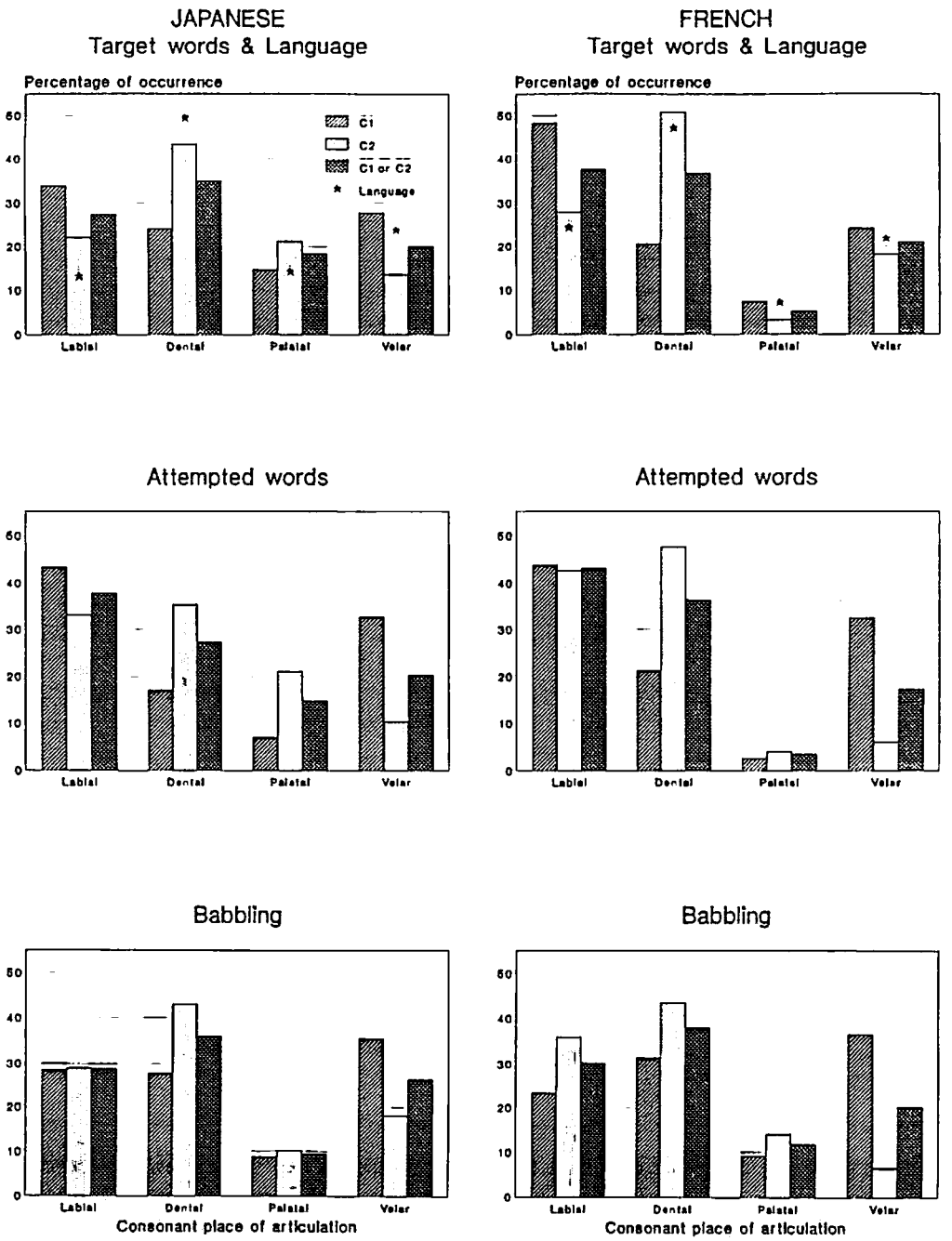


Figure 3. Distribution of consonants (place of articulation) in adult speech and in infants' vocalizations: positions C1, C2, or both

als in French, more palatals in Japanese. As for manner of articulation, the only robust difference is that affricates are unknown in French. The robust differences in place of articulation are also found in infants' words, especially in C2 position for labials (43% in French vs 33% in Japanese) and palatals (4% in French vs 21% in Japanese). A difference specific to target words (not found between the two languages in general) is that French has more dentals in C2 position (51% vs 43%): It is also found in attempted words (47% vs 35%). In the babbling, these salient differences all tend to faint away: French babbling still has more labials in C2 position (36% vs 29%), but has now more palatals than Japanese in either C2 or C1 positions, and more dentals only in C1 position. Likewise, the sole robust difference in manner of articulation disappears in the babbling: French and Japanese babbling both have very few affricates. In short, we find that French and Japanese infants have similar distributions of consonant-types in their babbling, still far from the distributions in adult speech. In attempted words however, the main differences have emerged.

These counts somewhat differ from those reported in de Boysson-Bardies et al. (1991): They also found more labials in French and more 'dentals' in Japanese (they grouped dentals and palatals into a single 'dental' category); but they found this pattern not only in attempted words but also in babbling (although less clearly). To summarize, counts of consonants by manner or place do not reveal large differences between Japanese and French in either target words, attempted words, or babbling, but insofar as differences are even smaller between babbling forms, these results tend to support the notion of less selectivity in babbling forms.

Vowels

Figure 4 shows the distribution of the six vowel categories in babbling, attempted words, target words, and language at large. Separate counts in V1 and V2 positions (first and second syllable) are also given, excepted for the languages at large. In Japanese, the language in general (Sawaki's data) and the target words have very similar distributions. In French, there are large discrepancies between the language at large (Tubach & Boe's data) and target words. First, Tubach & Boe have merged [ə] into [œ], which belongs to the Mid Front category. We have tried to correct this problem by estimating the proportion of schwas from other sources (Delattre, 1965; Haton & Lamotte, 1971; Wioland, 1972): p([ə]) is approximately 0.3 * p(Mid_Front). Hence the corrected counts in Fig. 4. Yet, the frequency of Mid Front vowels still seems to be under-estimated in French target words. Conversely, the frequency of Mid Back vowels seems to be over-estimated. This is probably due to the particular subset of target words familiar to French children. However, there are three robust differences between French and Japanese that resist to the discrepancy between French target words and French language in general: Japanese adult speech has more 'i' and 'u', and less 'e' than French. If we only consider target words, distributions in V1 vs V2 position are much more similar in Japanese than in French (rank correlation coefficients 0.866 against 0.648). In French, there is a dramatic

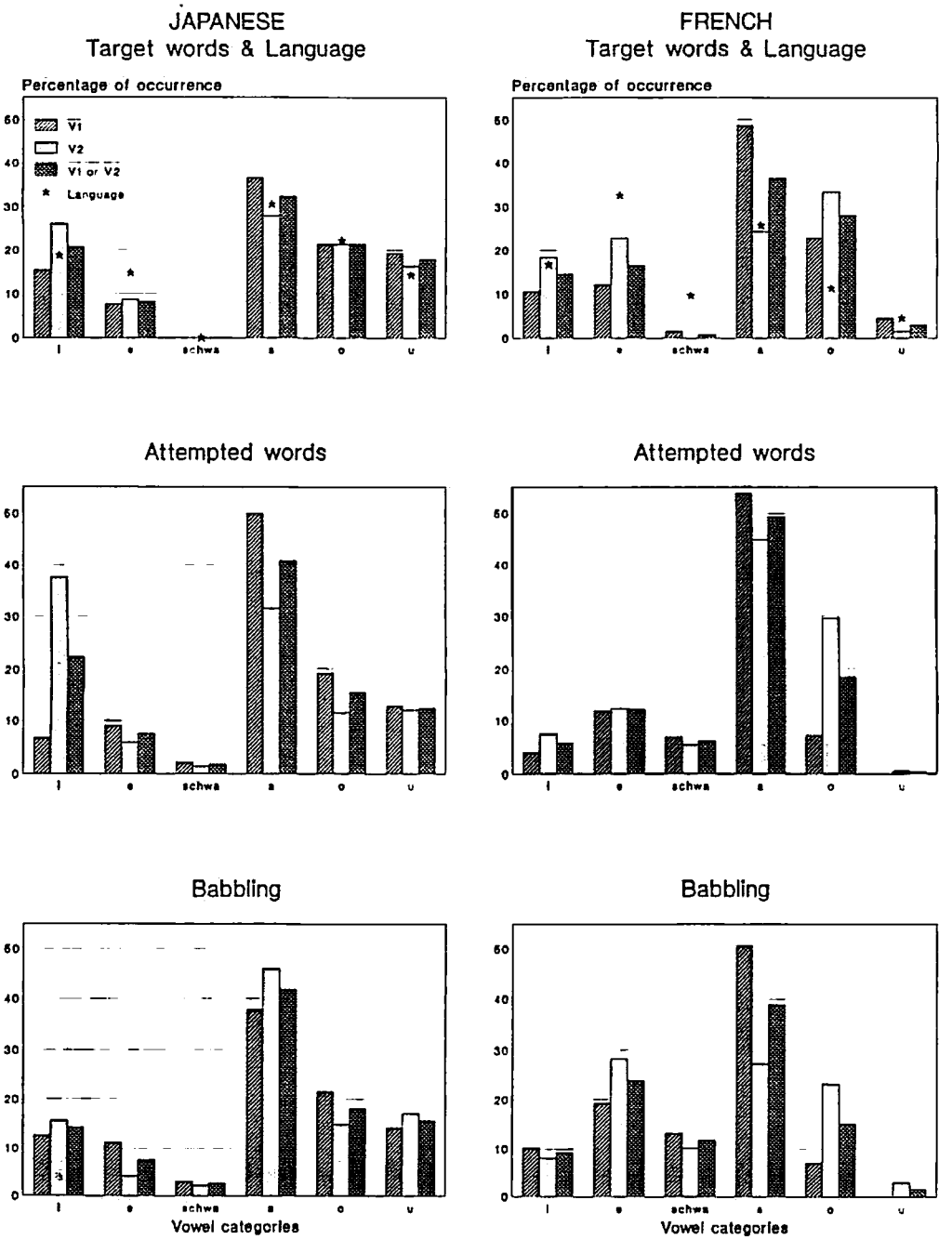


Figure 4. Distribution of vowels in adult speech and in infants' vocalizations: positions V1, V2, or both

decrease of 'a', a sizeable increase of 'e' and 'o' in V2 position. The proportion of schwas is very marginal in target words: Only one instance in French, "dedans" ([dədā], "inside"). The congruence of vocalizations with target words is striking in both languages, as illustrated in Fig. 4. If we take rank correlation coefficients as a measure of similarity between the distributions of vowels, target words are very close to either attempted words or babbling (correlations 0.928 or 0.915 in Japanese, 0.877 or 0.796 in French). According to this kind of measurement however, the status of babbling forms as opposed to words is mixed: In French, target words are closer to babbling than to words in V2 position (0.778 vs 0.724) but not V1 position (0.853 vs 0.917): In Japanese, target words are closer to babbling than to words in *V1* position (0.963 vs 0.912) but not in *V2* position (0.775 vs 0.874). Globally, the distributions of vowels in French and Japanese attempted words are closer to each other than in babbling (correlations 0.816 vs 0.673). In detail, the results are also mixed. Focusing on the three main robust differences between French and Japanese adult speech, we find that they are present in either babbling or words. Japanese infants produce more 'u' and more 'i', less 'e' than French. However, these trends are clearest in words for 'i' in V2 position, and in babbling in both V1 and V2 positions. The dramatic decrease of 'a' in V2 position specific to French target words, is more apparent in babbling than in words. Another trend, which does not appear in target words, is that French children produce more schwas than Japanese, especially in their babbling.

To summarize these results on vowels, we find that babbling forms and attempted words equally reflect the specificities of adult speech. Clearly, they do not support the notion of a lesser selectivity in babbling forms.

Consonant-Vowel preferred associations

We put a special emphasis on the question of CV preferred associations. First, language-specific CV associations in adult speech may be left unnoticed in sheer counts of consonants or vowels, and yet be of paramount importance in the language adjustments made by the children. Second, their 'mechanical' versus arbitrary nature (possibly specific to language groups or to individuals) directly addresses the issue of continuity and language adjustment recently reopened by Davis and MacNeilage. From their reasoning, we infer that 'mechanical' associations must occur in babbling forms --whatever the target language-- more often than in attempted words. One might add: If such associations are also present in adult speech, there is no reason why they should not appear in words as well as in babbling. Conversely, associations that are not consistently found in babbling forms, but do occur in attempted words and in the target language are not likely to belong to the 'mechanical' type of association.

For sake of clarity, we group consonants by place of articulation ('Bilabial', 'Dentals', 'Palatals', and 'Velars': Four categories) and retain the same six vowel categories as in the previous section. For each language and speech-type (language in general,

target words, attempted words, and babbling), two Tables are presented. The first Table (a) shows the percentages of vowels encountered after each consonant category: these percentages are *within consonant category* to allow comparisons of vowel distributions in the four consonant categories, regardless of the frequency of occurrence of the consonant categories themselves. The second Table (b) presents 'affinity scores': Assuming a frequency f_i of the consonant category i, a frequency f_j of the vowel category j, and a frequency f_{ij} of the CV sequences made up by the corresponding consonants and vowels, $f_{ij}/(f_i*f_j)$ is the affinity score of these CV sequences. A value close to 1 indicates a frequency of occurrence close to the expected frequency in a Chi-square model of distribution (where the frequency of a given CV is the product of the frequencies of C and V). A value larger than 1 indicates a preferred association, that is, more frequent than expected.

Tables 6.1 to 9.1 present the French data, Tables 6.2 to 9.2 the Japanese data. Firstly, target words and language in general exhibit similar consonant-vowel preferred associations.

In Japanese:
- Labials primarily call for 'a' in target words and in the language in general, secondarily for 'i' and 'e' in target words but not in the language.
- Dentals strongly call for 'e', and, to a lesser extent, to 'o' and 'u', in either language or target words.
- Palatals have an extremely marked affinity for 'i' in either language or target words.
- Velars have different affinities in the language in general and in target words: In the language, they strongly call only for 'a' while in target words, they primarily call for 'o' and 'u', secondarily for 'e'.

In French:
- Labials primarily call for 'a', as in Japanese, but also for 'u' in either target words or language. They secondarily call for 'e' in target words only.
- Dentals call for 'i' in either language or target words. This is much unlike Japanese. In target words but not in the language in general, dentals also call for 'o'. This seems to be due to the frequency of word-types like "ballon" ([balo], "balloon") or "gâteau" ([gatō], "cooky") in target words. The affinity score computed for the dental-schwa asociation is obviously inflated ([ə] occurs only once) and we cannot take it into account.
- Palatals show a strong affinity for 'e' and 'o' in either target words or the language in general.
- Velars have a strong affinity for 'o' and a secondary affinity for 'i' in either target words or language. Target words differ from the language at large by a very strong affinity for 'u' (the [u]s are rare in French target words, but occur only after labials or after velars).

French and Japanese adult speech share common preferred associations in target words. The main ones are:

Tables 6 to 9. Vowel distributions per consonant place of articulation (a) and CV 'affinity scores' (b), for French and Japanese language in general (6.1, 6.2), adult glosses of target words (7.1, 7.2), attempted words (8.1, 8.2), and babbling (9.1, 9.2).

a) Vowel distributions (percentages within consonant category)

6.1 French language (N = 124,043)

	i	e	a	o	u
labial	14.5	32.3	35.1	10.0	8.1
dental	19.1	46.2	22.6	8.7	3.4
palatal	5.2	59.6	14.8	17.0	3.3
velar	17.7	40.5	20.8	16.9	4.1

6.2 Japanese language (N = 5,267)

	i	e	a	o	u
labial	7.6	4.5	65.7	16.5	5.6
dental	2.9	25.7	23.6	28.1	19.6
palatal	56.6	0	7.9	18.4	17.3
velar	9.2	7.6	46.7	21.6	12.0

7.1 French: Target words (N = 115)

	i	e	ə	a	o	u
labial	11.6	18.6	0	53.5	11.6	4.6
dental	19.1	16.7	2.4	23.8	38.1	0
palatal	0	33.3	0	33.3	33.3	0
velar	16.7	12.5	0	25.0	37.5	8.3

7.2 Japanese: Target words (N = 187)

	i	e	ə	a	o	u
labial	21.6	9.8	0	43.1	13.7	11.8
dental	10.8	12.3	0	29.2	29.2	18.5
palatal	44.1	0	0	29.4	11.8	14.7
velar	10.8	10.8	0	18.9	32.4	27.0

8.1 French: Attempted words (N = 351)

	i	e	ə	a	o	u
labial	9.3	13.3	5.3	52.7	16.7	2.7
dental	4.9	13.8	8.1	33.5	39.0	1.6
palatal	5.9	29.4	11.8	17.7	35.3	0
velar	1.6	3.3	4.9	54.1	36.1	0

8.2 Japanese: Attempted words (N = 419)

	i	e	ə	a	o	u
labial	13.9	6.3	1.3	55.7	10.8	12.0
dental	17.9	21.4	0.9	30.4	17.9	11.6
palatal	60.9	0	4.7	14.1	1.6	18.8
velar	25.9	1.2	0	31.8	24.7	16.5

9.1 French: Babbling (N = 168)

	i	e	ə	a	o	u
labial	7.8	27.4	13.7	33.3	11.8	5.9
dental	8.1	25.8	16.1	29.0	21.0	0
palatal	27.3	13.6	4.6	22.7	31.8	0
velar	9.1	24.2	6.1	51.5	9.1	0

9.2 Japanese: Babbling (N = 245)

	i	e	ə	a	o	u
labial	7.1	1.4	1.4	54.3	8.6	27.1
dental	20.7	10.3	0	41.4	18.4	9.2
palatal	20.8	8.3	4.2	58.3	4.2	4.2
velar	12.5	12.5	3.1	21.9	29.7	20.3

b) Consonant-Vowel 'affinities' (underlined: significant affinity; italicized: non reliable figure based on too few items)

6.1 French language

	i	e	a	o	u
labial	0.88	0.75	1.42	0.89	1.72
dental	1.16	1.08	0.91	0.77	0.73
palatal	0.32	1.39	0.60	1.52	0.70
velar	1.07	0.94	0.84	1.50	0.88

6.2 Japanese language

	i	e	a	o	u
labial	0.59	0.30	2.02	0.70	0.36
dental	0.23	1.70	0.73	1.19	1.25
palatal	4.39	0	0.24	0.78	1.09
velar	0.72	0.52	1.52	0.91	0.76

7.1 French: Target words

	i	e	ə	a	o	u
labial	0.79	1.07	*0*	1.50	0.42	1.34
dental	1.25	0.96	*2.74*	0.67	1.37	0
palatal	0	1.92	o	0.93	1.20	0
velar	1.13	0.72	*0*	0.70	1.35	2.4

7.2 Japanese: Target words

	i	e	ə	a	o	u
labial	1.09	1.08	*0*	1.39	0.61	0.67
dental	0.54	1.35	*0*	0.94	1.30	1.05
palatal	2.23	0	*0*	0.95	0.52	0.83
velar	0.55	1.19	*0*	0.61	1.44	1.53

8.1 French infants: Attempted words

	i	e	ə	a	o	u
labial	1.49	1.06	0.81	1.19	0.58	1.56
dental	0.78	1.10	1.24	0.74	1.36	0.95
palatal	0.94	2.35	1.80	0.40	1.23	*0*
velar	0.26	0.26	0.75	1.23	1.25	*0*

8.2 Japanese infants: Attempted words

	i	e	ə	a	o	u
labial	0.57	0.76	*0.88*	1.48	0.76	0.87
dental	0.73	2.57	*0.62*	0.81	1.27	0.84
palatal	2.48	0	*3.27*	0.37	0.11	1.35
velar	1.05	0.14	*0*	0.84	1.75	1.19

9.1 French infants: Babbling

	i	e	ə	a	o	u
labial	0.73	1.12	1.15	0.98	0.68	3.29
dental	0.75	1.06	1.35	0.86	1.21	*0*
palatal	2.55	0.56	0.38	0.67	1.84	*0*
velar	0.85	0.99	0.51	1.52	0.53	*0*

9.2 Japanese infants: Babbling

	i	e	ə	a	o	u
labial	0.49	0.17	*0.88*	1.30	0.50	1.62
dental	1.41	1.27	*0*	0.99	1.07	0.55
palatal	1.42	1.02	*2.55*	1.40	0.24	0.25
velar	0.85	1.53	*1.91*	0.53	1.73	1.21

- labial + 'a'.
- dental + 'o'.
- velar + 'o', velar + 'u', and (weakly), velar + non-Low Front.

The main differences between French and Japanese are:
- labial + 'u' in French, not in Japanese.
- dental + 'i', palatal + 'e' in French and the opposite pattern (dental + 'e', palatal + 'i') in Japanese.
- palatal + 'o' in French, not in Japanese.

Let us first examine the preferred associations *common* to French and Japanese target words: The common associations which are thought to be mechanical should be observed in the babbling and in the attempted words as well of both language groups, while those which are not should first appear only in words.

- labial + 'a' is found in the attempted words of both French and Japanese infants (1.19 and 1.48) while it is found in the babbling of Japanese infants (1.3) but not of French infants (0.98). This is questionning the presumably 'mechanical' affinity labial + 'a' found by Davis and MacNeilage. If it was a universal trend in early prespeech productions, it should be observed in the babbling of French infants.
- dental + 'o' is consistently found in either babbling or words of both language groups. This association is generally not regarded as resulting from mechanical coarticulation from the viewpoint of lingual positionning. However, it is already present in babbling forms.
- velar + 'o' or 'u' associations are typically regarded as resulting from mechanical coarticulation. However, they are consistently found only in Japanese infants (more markedly for 'o' than for 'u'). They are found in French infants only in attempted words, and only for 'o' (no instance of velar+[u] is found in French vocalizations). Here again, our data do not support Davis and MacNeilage's predictions. Rather, it seems that French and Japanese children's vocalizations all favour vocalic settings that are more neutral (less contrasted) than in adult speech: In Japanese infants the affinity of velars is weaker for 'u' than for 'o' in babbling (1.21 vs 1.73) or words (1.19 vs 1.75); in French infants the affinity of velars clearly shifts toward 'a' (1.52 in babbling, 1.23 in words), a more central setting than in the expected Back vowels.
- velar + non-Low Front vowels ('i' or 'e') is a weak tendency in adult speech. In infants' vocalizations, it is found only in Japanese: Strongly in babbling for 'e' (1.53), weakly in words for 'i' (1.05). This affinity however, is not supposed to result from mechanical coarticulation.

Let us turn now to the preferred associations that are observed in the target words of only one language. The associations which are thought to be mechanical should be observed in the babbling of both languages, and in the attempted words of only the language which preserves them in adult forms. Those which are not, should not appear in the babbling of either languages, and emerge only in the attempted words of the language

which favours them in adult forms.

- labial + 'u' is consistently found in French attempted words or babbling: affinities of 1.56 or 3.29 (the latter figure, for babbling, may be somehow inflated given the scarce number of [u]s in French babbling: But [u]s all occur in a labial context). This association is not found in Japanese attempted words but is found in Japanese babbling (0.87 vs 1.62, figures grounded on much more tokens than in French). Hence, this result would suggest that "labial + 'u'" belongs to the 'mechanical' category of CV associations.
- dental/palatal + 'i'/'e'. These patterns of associations are of special interest. In Japanese, the typically language-specific pattern "dental + 'e', palatal + 'i'" (complemented by an avoidance of dentals for 'i' and of palatals for 'e') is present in attempted words (2.57 and 2.48), not yet in babbling. In the babbling of Japanese infants, 'i' is equally preferred after dentals and palatals (1.41 and 1.42); 'e' is equally preferred too, though to a lesser degree (1.27 and 1.02). These results suggest that the affinity of dentals or palatals for non-Low Front vowels typically has a mechanical nature: It is still undifferentiated in babbling while already reflecting the highly specific adult pattern in attempted words. In French babbling, we would then expect a marked --and undifferentiated-- affinity of dentals and palatals for non-Low Front vowels, shifting in attempted words toward the pattern "dental + 'i', palatal +'e'" found in French adult speech. This expectation is only parly supported by the data. In the babbling of French infants, dentals weakly call for 'e' (1.08), not for 'i' (0.75); palatals strongly call for 'i' (2.55), not for 'e' (0.56). In attempted words, dentals and palatals only call for 'e' (1.1 and 2.35), not for 'i' (0.78 and 0.94): Indeed, the shift toward the adult pattern "dental + 'i', palatal + 'e'" is apparent, but dentals still associate with 'e' instead of 'i'. Moreover, babbling forms do not exhibit more mechanical preferences than words. Rather, it seems that although there is a shift toward adult preferences, vocalizations still favour more neutral vowel settings ('e' instead of 'i'), as in the case of velars ('o'-'a' instead of 'u'-'o').
- Palatals consistently associate with 'o' in French babbling (1.84) or attempted words (1.23), not in the least in Japanese (O.24 or 0.11). This affinity is clearly language-specific, and would certainly not be regarded as mechanical. However, it is more marked in babbling than in words, thereby not supporting the notion that babbling exhibit little language adjustment compared to attempted words.

To summarize, we find that globally, French and Japanese vocalizations differ with respect to the preferred CV associations almost exactly in the same way as French and Japanese target words, and most of the time, as French and Japanese languages in general. Not surprisingly, attempted words come closer to target words than babbling. "Labial + 'u'" and "palatal + 'o'" are associations specific to French: They are found in both babbling and attempted words in French, not in Japanese. Other language-specific associations appear only in attempted words: "dental + 'e', palatal + 'i'" in Japanese: the opposite pattern in French. The situation for velars is more fuzzy. In adult speech, whether French or Japanese, velars clearly call for 'o' and 'u' (a typically 'mechanical' affinity). In infants' vocalizations, there is a shift toward less extreme vowel settings.

The secondary affinity of velars for non-Low Front vowels also suggests a similar avoidance of extreme vowel settings: Velars show more affinity for 'e' than for 'i' in French and especially Japanese babbling, and a very weak affinity for 'i' in Japanese attempted words.

The notion of a lesser degree of language adjustment in babbling compared to attempted words is not well supported by our results. We did not find in babbling forms an unequivocal predominance of the mechanical coarticulation constraints predicted in the Davis and MacNeilage's study, excepted, to some degree, the affinity of dentals and palatals for non-Low Front vowels. Elsewhere, our results with regard to the 'mechanical issue' are not only mixed, as Vihman found in a recent study (1991) which focused on individual preferences, but also question what mechanical or physiological constraints should be: Labials do not 'naturally' call for 'a', they rather call for 'u'; dentals call for 'o', velars call for 'a'-'o' rather than for 'o'-'u', and also call for Front vowels... First, accounts of 'mechanical' coarticulation constraints may need some elaboration. For example, the affinity of velars for non-Low Back vowels is generally explained by "the facilitating effect of a single back-of-tongue gesture serving for a full syllable" (Vihman, 1991). From a different viewpoint, maintaining the tongue in an elevated back position (far from the rest position) *over a full syllable* seems quite demanding: Is it not 'natural' to let the tongue go back to its rest position ? It seems that there is some confusion in the literature between the expected cooccurrences of consonants and vowels that are governed by such principles as 'ease of production', and the unavoidable CV coarticulation effects in speech, that are governed by such mechanical principles as inertia. Second, as our data tend to show, consonant-vowel interactions fail to explain the phonetic language adjustment already present in babbling forms.

We will now examine whether the possible interactions between the segmental and prosodic levels of organization contribute to the prosodic language adjustments found in French and Japanese children.

Vowel sequences

The existing literature on French or Japanese language at large does not provide data on the frequency of use of vowel sequences. This section is thus limited to the vowel sequences observed in adult glosses of target words, compared to those in children's attempted words and babbling. The degree of aperture of a vowel is strongly correlated to its intrinsic F0 and to its intrinsic duration as well: Low vowels tend to have lower intrinsic F0s and longer intrinsic durations than High vowels. These general trends hold for both adult and infants' speech (Bauer, 1988), for both French and Japanese (Di Cristo, 1976; Nishinuma, 1979). A secondary factor is the Front-Back dimension: [u] has a slightly higher intrinsic F0 than [i]. We will neglect this factor in the following: We distinguish only three categories of vowels, Low, Mid, and High.

Tables 10 to 12 show the distribution of vowel-sequence types in target words, attempted words, and babbling for French (a) and Japanese (b). The 'steepest' sequence types, 'Low-High' and 'High-Low', are highlighted in these Tables, because they presumably have the strongest influence on F0 contours and balance of vowel durations in disyllables.

Japanese target words have more 'flat' sequences (sequences where V1 and V2 belong to the same height category) than French (57.7% vs 43.9%). Within these flat sequences, French favours 'Mid-Mid' and 'Low-Low' sequence types to the expense of 'High-High' sequences which are rare in French target words (4.6%). In Japanese, all flat sequences are equally favoured, with a slight advantage for 'High-High' sequences (21.2%). Considering all the sequences where V2 is higher than V1 (like -a-i), French has more such sequences than Japanese (39.4% vs 26.9%). Considering only 'Low-High' sequences, whose intrinsic F0s are more likely to influence the F0 contours in disyllables, the advantage for French disappears (7.6% vs 11.5%). Sequences where V2 is lower than V1 are equally infrequent in both French and Japanese target words. Considering only 'High-Low' sequences, Japanese has more such sequences than French (6.7% vs 1.5%).

The main trends found in target languages are already present in infants' babbling and words:
- There is a majority of flat sequences in both language groups, with a slight advantage for Japanese, even more apparent in babbling forms.
- Within flat sequences, French babbling or words have very few 'High-High' sequences (3% or 2%) while Japanese has about 16% of 'High-High' sequences in either babbling or words.
- Finally, 'High-Low' sequences are mostly infrequent, especially in Japanese attempted words (0.4%).

The much higher frequency of 'High-High' vowel sequences in Japanese is a robust language-specific difference. It is already present in infants' babbling, as clearly as in words. This result is in good agreement with the main findings of the previous section on Vowels: Japanese globally has more 'i' and 'u' than French. Globally, we do not observe less differentiated vowel sequences in babbling than in words, in either French or Japanese: Again, language adjustment is no more apparent in attempted words than in babbling forms.

The sequences of vowels observed in vocalizations, most often 'flat', should be most often neutral with regard to the prosodic variables of disyllables. When considering even mildly steep sequences 'Mid-Low', 'Low-Mid', 'Mid-High', or 'High-Mid', Japanese children globally produce more 'rising' sequences and less 'falling' sequences than French, especially in attempted words which constitute the large majority of the vocalizations. We could expect then, that non-flat sequences should favour rising F0 contours

Tables 10 to 12. Counts of vowel-sequence types in terms of vowel height: Low (L), Mid (M), or High (H). For target words (10), attempted words (11), and babbling (12), in French (a) or Japanese (b).

10.a French target words (N = 66)

Same Height:	L-L	M-M	H-H	total
	16.7%	22.7%	4.6%	43.9%
V2 Higher:	L-H	L-M	M-H	total
	7.6%	24.2%	7.6%	39.4%
V2 Lower:	M-L	H-M	H-L	total
	6.1%	9.1%	1.5%	16.7%

10.b Japanese target words (N = 104)

Same Height:	L-L	M-M	H-H	total
	19.2%	17.3%	21.2%	57.7%
V2 Higher:	L-H	L-M	M-H	total
	11.5%	5.8%	9.6%	26.9%
V2 Lower:	M-L	H-M	H-L	total
	1.9%	6.7%	6.7%	15.4%

11.a French attempted words (N = 203)

Same Height:	L-L	M-M	H-H	total
	30.0%	23.2%	3.0%	51.2%
V2 Higher:	L-H	L-M	M-H	total
	1.5%	22.2%	3.4%	27.1%
V2 Lower:	M-L	H-M	H-L	total
	12.8%	2.0%	2.0%	16.7%

11.b Japanese attempted words (N = 234)

Same Height:	L-L	M-M	H-H	total
	26.1%	9.8%	16.7%	52.6%
V2 Higher:	L-H	L-M	M-H	total
	17.5%	6.4%	15.4%	39.3%
V2 Lower:	M-L	H-M	H-L	total
	5.1%	2.6%	0.4%	8.1%

12.a French babbling (N = 99)

Same Height:	L-L	M-M	H-H	total
	16.2%	29.3%	2.0%	47.5%
V2 Higher:	L-H	L-M	M-H	total
	8.1%	26.3%	1.0%	35.4%
V2 Lower:	M-L	H-M	H-L	total
	9.1%	6.1%	2.0%	17.2%

12.b Japanese babbling (N = 135)

Same Height:	L-L	M-M	H-H	total
	26.7%	15.6%	15.6%	57.8%
V2 Higher:	L-H	L-M	M-H	total
	9.6%	1.5%	7.4%	18.5%
V2 Lower:	M-L	H-M	H-L	total
	12.6%	4.4%	6.7%	23.7%

and final lengthening in Japanesese disyllables, falling contours and initial lengthening in French. But the reverse prosodic patterns are actually observed. Hence, one cannot object that these observed patterns result from an interaction with the segmental level of organization, at least in terms of vowel sequencing.

General discussion

The main issues addressed in the present study have already been discussed in the different sections. We will then summarize our conclusions very briefly.

First, concerning the results by themselves, we found multiple and converging evidence for a similar degree of language adjustment in babbling and in attempted words. This holds for both prosodic and segmental levels of organization. There is little or no evidence for 'mechanical' coarticulation constraints that would be more pronounced in babbling than in words. Moreover, the mechanical constraints proposed in the literature, e.g. by Davis an MacNeilage (1990) or Vihman (1991) seem to be questionnable.

Second, concerning the appropriate methodology for addressing such issues as continuity between prespeech and speech forms, or such as the beginnings of observable language adjustments, cross-language investigations should not be regarded as only 'helpful' but as mandatory. Locke (1983) proposed that language acquisition begins when a child's sound patterns are redirected from a presumably universal biological path to one that is adjusted to the ambient language. How can we reliably detect these beginnings by observing infant(s) from the same ambient language?

Finally, individual differences should not be ignored, because different strategies of language adjustment may be observed within a single language group (Vihman, Ferguson & Elbert, 1986; Vihman, 1991). In the present study, given the limited number of available data for phonetic analysis, we had to pool infants by langage group, but we plan to examine this important question when more data become available.

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