ARTICULATORY ORGANIZATION OF EARLY WORDS: FROM SYLLABLE TO PHONEME

Elizabeth W. Goodell† and Michael Studdert-Kennedy‡

University of Connecticut and Haskins Laboratories, †Trinity College, Hartford, CT, ‡Yale University, New Haven, CT

ABSTRACT

Evidence that children's initial units of phonological contrast are words or short formulaic phrases rather than phonemes or features invites the hypothesis that the initial domain of articulatory (or gestural) organization may also be larger than the phoneme. The present study investigates the development of intrasyllabic gestural overlap in fricative-vowel syllables between the ages of 22 and 32 months. Results indicate that children at both ages display more gestural overlap than adults.

1. INTRODUCTION

Studies of early phonological development have typically taken abstract linguistic units (phonemes, features) as underived, phonological primitives, and have implicitly, or explicitly, attributed a functional role to these units in the perceptual representation and articulatory organization of a child's early words. However, recent studies have found evidence for a continuous line of development from prelinguistic mouthings through babble to early words [1], encouraging the notions that: (1) the units of linguistic contrast in a child's early speech are not phonemes and features, but words, or formulaic phrases, consisting of one or a few syllables [2]; (2) the initial units of articulatory organization are gestural routines extending over a word or phrase [3, 7]; (3) phonemes and their featural descriptors emerge from syllables by gradual differentiation of consonantal and vocalic oral gestures [3, 6]. Results consistent with this account have come from a study of fricative-vowel coproduction (or gestural overlap) in young children and adults, in which 3-year-old children uttering fricative-vowel syllables displayed significantly more gestural overlap between fricative and vowel than older children and adults [4]. The present 10-month longitudinal study extends the preceding investigation to younger ages: 22 and 32 months.

2. METHOD

The subjects were six girls (mean age=22 months, mean MLU=1.36, at beginning of study) and six adult females. The test utterances were designed to investigate fricative-vowel coproduction in CVCV contexts, similar to previous studies [cf. 4, 5]. The utterance types were three nonsense disyllables: ['sɑsɑ], ['sisi], and ['susu]. The vowels, [ɑ, i, u], were chosen because they occupy extreme points in the vowel space so that if the vowels of fricative-vowel syllables were anticipated in the fricatives, differences in the lingual front-back dimension, as indicated by estimates of the fricative second formant (F2), should be apparent.

The children's data were collected in the first and tenth months during half hour sessions with the experimenter in the child's home. As many utterances as possible were elicited through games with stuffed animals. Out of a total of 234 child utterances, the resulting number of acceptable utterances of each type for each child ranged from 2 to 20, with a mean of 6.5. Nine utterances from the children's data were excluded due to background noise or lack of formant structure in V1. The adults produced 6 utterances of each type in random order. No adult responses were excluded.

All tokens were digitized at a 20-kHz sampling rate on a VAX 780 computer, and a waveform editing and display system was used to measure the duration of the first fricative and vowel. Five locations for estimating formant frequencies were then chosen: (a) the midpoint of the initial fricative (1/2 fric), (b) the onset of voicing for the first vowel, (c) the midpoint between (a) and (b) (3/4 fric), (d) the midpoint of the first vowel (1/2 vowl) and (e) the midpoint between (b) and (d) (1/4 vowl). Estimates of the center frequencies of the second formants were made at these five locations from Discrete Fourier Transform spectra, computed with a 25.6 msec. Hamming window and a 3.2 msec. slide between windows. F2 estimates could not be made at both points in the fricative of every token: 54% of the adult tokens permitted F2 estimates at 1/2 fric, 77% at 3/4 fric; 76% of the children's data permitted estimates at 1/2 fric, 85% at 3/4 fric. Estimates of the center frequencies for the first formants were made at the last three points. All vocalic formant estimates were made by finding the highest amplitude harmonic in the region of a given formant at a given location and computing the weighted mean of this harmonic and the harmonics immediately above and below it.

3. RESULTS

3.1 Gestural Overlap in the Fricative

Figure 1a, b, c displays the mean estimated formant paths for adults, 32-month-olds, and 22-month-olds respectively. In Figure 1a (adults) the F2 measurements at 1/2 fric are virtually the same before all three vowels. At 3/4 fric a front back distinction begins to appear with differences of about 300 Hz between F2 values before [i] and the back vowels. Finally, at 1/2 vowl a vowel space has emerged in which [u] has clearly higher F2 values than [ɑ] [cf. 5].

For the 32-month-olds (Figure 1b), substantial anticipatory gestural overlap is apparent in the formant values at 1/2 fric and 3/4 fric with differences of roughly 200 to 500 Hz between the values preceding the different vowels. The front and back vowel formant paths continue to diverge, but at 1/2 vowl the F2 estimates are only slightly higher for [u] than for [ɑ], indicating that the children are relying largely on tongue height to distinguish the vowels (see F1 values).

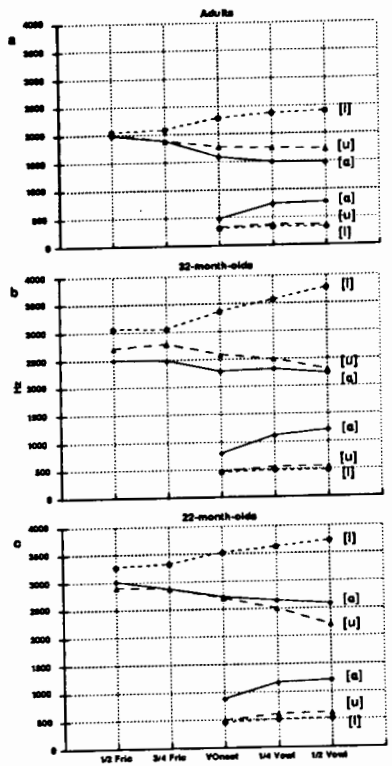

Figure 1a, b, and c. [əV] formant paths for children and adults.

Finally, the 22-month-olds (Figure 1c) display much the same degree of gestural overlap as their older selves in the front-back dimension, as evidenced by the different formant values for [ɑ, u] vs [i] at both 1/2 fric and 3/4 fric. However, unlike their older selves, they do not differentiate the fricatives before [u] and [ɑ], and the final values of F2 at 1/2 vowl for [u] and [ɑ] reverse the pattern observed in the adults. Both the

latter effects arise from an overall higher formant path for [sɑ] at the younger age. (See below under Gestural Overlap in the Vowel).

As an index of gestural overlap permitting comparison across groups, self-normalization ratios were formed: the fricative F2 values for [i] were placed over the fricative F2 values for [u] and [ɑ] at the 1/2 fric and 3/4 fric measurement points. This ratio is an index of the degree of gestural anticipation: if the value is 1, there is no difference between fricative formant measurements before the two vowels, indicating no anticipation of the following vowel. The farther the value from 1, the greater the anticipation of the vowel.

Table 1 lists the mean ratios for adults and children at 1/2 fric and 3/4 fric points. At 1/2 fric F2 values are significantly different before [i] than before both [ɑ] and [u] for the 22-month-olds, before [i] than before [ɑ] but, due to a single deviant, not before [u] for the 32-month-olds. There are no effects of vowel for the adults at this point. At 3/4 fric F2 values are significantly different before [i] than before both [ɑ] and [u] for all except the 32-month-olds before [u] (again due to a single deviant subject).

Table 1. Amount of gestural anticipation at two points in the fricative, indexed by mean ratios of fricative F2 values before [i] to fricative F2 values before [u] and [ɑ]. An index significantly greater than 1.00 indicates a significant degree of gestural anticipation. * p < .025, one-tailed t-test.

Measurement Point	*i/u*	*i/ɑ*
1/2 Fricative		
22-month-olds	1.15*	1.12*
32-month-olds	1.15	1.24*
Adults	1.00	1.04
3/4 Fricative		
22-month-olds	1.19*	1.21*
32-month-olds	1.13	1.24*
Adults	1.12*	1.13*

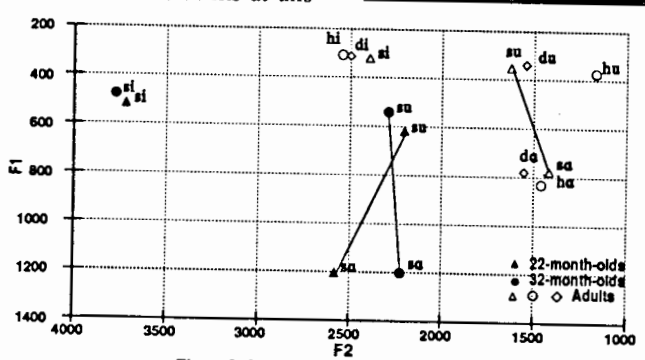

Figure 2. Group vowel plots for selected tokens.

3.2 Gestural Overlap in the Vowel

As noted above, the relative positions of [u] and [ɑ] at 1/2 vowl differ for the three groups. These differences are displayed in Figure 2. Notice that in the adults, F2 is higher for [u] than for [ɑ] by about 250 Hz, in accord with [5], perhaps indicating a more forward constriction location for [u] than [ɑ]. For the 32-month-olds, F2s for [u] and [ɑ] are higher for [u] than for [ɑ] by about 70 Hz, while for the 22-month-olds F2 is higher for [ɑ] than for [u] by about 350 Hz, the reverse of the adults. Lines connecting tokens in Figure 2 illustrate the u-ɑ group differences.

We may now ask concerning the adults: Is the relatively higher F2 for [u] due to overlap of the vocalic gesture with the gestures of the surrounding alveolar sibilants? To answer this question, more data were collected from the adult subjects. In addition to repeating the original fricative stimulus items ['sisi], ['sasa], and ['susu] 6 times each, subjects also produced 6 repetitions each of ['didi], ['dɑdɑ], ['dudu], ['hihi], ['hɑhɑ], and ['huhu]. The means for the first vowels in these contexts are also given in Figure 2. Orthogonal comparisons reveal that [du] and [su] do not significantly differ from each other, [F=1.409, p >.2415], but do differ significantly from [hu], [F=39.712, p <.0001]. Apparently then [u] is articulated further forward if bracketed by alveolar stops or fricatives than if bracketed by the articulatorily neutral [h], while the position for [ɑ] stays the same in both contexts. This result is consistent with the proposal in [5] that overlap of C and V gestures in adults is facilitated if C and V tongue heights are compatible, but are blocked if they are not.

We were not able to collect more data for acoustic analysis from the children. However, the children's original utterances were transcribed independently by two colleagues. It was discovered that many of the 22-month-olds' tokens for [ɑ] were somewhat fronted and raised, e.g. ['seysɑ] instead of ['sɑsɑ]. Evidently the 22-month-olds were not able to block gestural overlap of the low vowel [ɑ] preceding and following [s], as were the adults and, to a fair extent, the 32-month-olds.

3.3 Durations

Children's utterances are often longer than adults'. The mean durations for fricative 1, vowel 1, and syllable 1 were therefore compared, by analysis of variance. There were no significant interactions with, or effects of, age. Accordingly, none of the differences among groups reported above can be attributed to differences in rate of speaking.

4. DISCUSSION

Consistent with the results of [4] for older children, the present study found a significant tendency for 22- and 32-month-old children to anticipate the front-back location of the vowel earlier in the fricative of a fricative-vowel syllable than adults. Two observations suggest that this result does not reflect "planned" coarticulation: (1) the greater difference at 32 months between fricative F2s for [u] and [ɑ] at 1/2 fric than between F2s for [u] and [ɑ] themselves at 1/2 vowl; (2) the tendency at 22 months to front and raise the low back vowel [ɑ] in the context of preceding and following [s]. These results suggest not "planned" coarticulation, but an inability easily to differentiate and control a rapid sequence of diverse tongue gestures. This interpretation is consistent with the hypothesis that consonants and vowels emerge as stable units of articulatory control in children's speech by differentiation of the closing and opening gestures of the canonical syllable [cf. 7]. Such an account obviates the necessity for positing phonemes, or their featural descriptors, as underived, phonological primitives.

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