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Phonological development from babbling to speech: Common tendencies and individual differences

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ABSTRACT
Taking as a point of departure Locke's biological model for the origins of phonological development, this study encompasses analyses of phonetic tendencies, consonant use in babbling and early words, and phonological word-selection patterns. Data from 10 children aged 9 to 16 months are drawn from four lexically defined points covering the period from no word use to a cumulative vocabulary of 50 words. Individual differences are found to prevail from the start in all three domains analyzed, with some increase in uniformity across subjects with increasing knowledge of language. Furthermore, the phonological processes typical of development from age 1 to 3 or 4 years are found to be rooted in the phonetic tendencies of the prelinguistic period.

Studies of child phonology have increasingly focused in recent years on the earliest period of word acquisition – the period of the first "fifty words" (e.g., Ferguson, 1978b; Ferguson & Farwell, 1975; Ingram, 1974; Labov & Labov, 1978; Leonard, Newhoff, & Mesalam, 1980; Menyuk & Menn, 1979; Shibamoto & Olmsted, 1978; Stoel-Gammon & Cooper, 1984; Vihman, 1976), with general agreement as to the importance of individual differences even at this early stage. At the same time, a series of studies have examined the phonetic character of babbling in the period immediately preceding the beginnings of word acquisition (e.g., Cruttenden, 1970; Oller, Wieman, Doyle, & Ross, 1976; Stark, 1980; Vihman, Macken, Miller, Simmons, & Miller, 1985; Woods & Stockman, 1982 as well as some of the studies cited earlier), yielding general agreement to the effect that babbling and early words share a great many characteristics -- so much so, in fact, that often the concurrent babbling and first words of a given child cannot easily be distinguished.

Thus the earlier linguistically oriented theories of phonology acquisition,

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which assumed a sharp discontinuity between babbling and speech, universal constraints on phonological systems, and a relatively "innatist" view of the processes involved (cf. Ferguson & Garnica, 1975) are being replaced by models that assume continuity of development and individual differences. Some of these new models emphasize the perceptuo-motor, "biological" origins of phonological structure in the child's development (Locke, 1983) or the "self-organizing" nature of its emergence (Lindblom, 1985); others emphasize the active, creative role of the child and the interactive origins of phonological structure (Macken & Ferguson, 1983; Menn, 1983). Both types of models require for validation detailed longitudinal analyses of phonological development, taking note of common tendencies as well as of individual differences. The present paper provides a substantial amount of relevant data from ten infants growing up in an English-speaking environment. This is at least a partial response to Locke's call for "a fairly large number of infants . . . followed from late in their pre-meaningful babbling to the phonology of their first 50 to 100 words" (Locke, 1983, p. 81). Although the subject population is small in number and all ten are drawn from the same ambient language, social class, and language socialization patterns (cf. Ochs & Schieffelin, 1985), the study adds appreciably to the stock of published data and leads to several clear-cut conclusions about the significance of common tendencies and individual differences during the ten infants' transition from babbling to early words.

The study examines the development of the infants' speech sound production in relation to the development of their lexicon. It seems more productive to attempt to calibrate development in this way than to rely on an age-based comparison, or even on some overall or cognitive developmental scale. The use of a measure of lexical advance at this early period in the child's language development is similar in aim to the use at a later period of a measure of mean length of utterance as a standard of comparison for syntactic and even general linguistic development (Brown, 1973).

Locke (1983) has proposed a "working model" of the origins of phonological system in the child. He pushes the beginnings of phonology back to what he calls the "pragmatic stage," when certain vocalizations come to be used with communicative intent. This occurs in the second 6 months of life, when variegated babbling ("utterances with differing consonantal or vocalic elements": Oller, 1980) typically begins. In this stage, the child's phonetic repertoire is held to be essentially universal, resulting from biological factors such as the nature of the vocal tract. In the "cognitive stage," which follows, environmental influence in the form of adult-based word use is first in evidence – implying that the child can store and retrieve some relatively stable perceived versions of expressions in the adult language, though the phonological production patterns are fundamentally unchanged from the preceding period of variegated babbling. Only in the "systemic stage" (beginning at age 18 months or so) does the child's phonological development begin to be markedly influenced by the phonetic characteristics of the particular adult language he or she is targeting: that is, only then do the environmental factors and the three developmental "mechanisms" of maintenance, learning, and loss (Locke, 1983, pp. 85–92) begin to play a significant role.

This highly suggestive model of early phonology emphasizes the universal characteristics of the pragmatic and cognitive stages and the language-specific

characteristics of the systemic stage and subsequent development. In the present study, we investigate commonalities and individual differences throughout the period that Locke divides into these stages. Three separate analyses will be presented, each intended to afford a somewhat different perspective on the same data.

First, we undertake an analysis of the **phonetic tendencies** in the combined pool of word and babble vocalizations for each child at each developmental point. By comparing the phonetic profiles so constructed across all the children and over time for each of several parameters, we can establish the degree of commonality for any given phonetic category.

Second, we separate words from babble (to the extent possible) in order to construct **consonant inventories** for each child at each development point. These inventories allow us to investigate the emergence of a portion of the phonological system with reference in particular to the relationship between babbling and words. Though it has been shown that the phonetic tendencies in babble and words are closely related in any one child's vocalizations at any given point in time (Vihman et al., 1985), by comparing these inventories, we can establish common developmental trends as well as individual patterns of preferred segment use in babbling and in words.

Finally, we carry the question of the extent of individual differences in shaping early phonology one step further by constructing "**word selection trees.**" This is a modification of the "phone tree" analysis introduced by Ferguson and Farwell (1975) to investigate both phonological development and the high phonetic variability in this early period. The word-selection tree traces the phonological factor in word choice over time (see Schwartz & Leonard, 1982), based on the shape of the adult word as it is reflected in the child's production. By observing the choices of the various children we can, again, consider the strength of universal constraints as against individual variation.

METHOD

Subjects

Data were collected from ten first-born children acquiring English as their first language, five boys and five girls, over a 7-month period beginning when each child was about 9 months old. The children were audio- and video-recorded in free play with their mothers for half an hour each week in their own homes; once a month, a portion of the weekly session was devoted to administering the Užgiris–Hunt (1975) scales for assessment of cognitive development in infancy. Subjects were located primarily through infant care classes, resulting in a relatively homogeneous, well-educated, middle-class sample of parents. For further detail regarding subjects, see Vihman et al. (1985).

The maternal interview developed by Bates, Benigni, Bretherton, Camaioni, & Volterra (1979) was conducted once a month, focusing the mothers' attention on the issues of language and play, which were of central interest to the project. The mothers also maintained daily logs in which they primarily reported advances in the child's receptive and productive repertoire of words and communicative gestures. During the recorded sessions, mothers were instructed to make available toys or other stimuli that had given rise to word use during the preced-

ing week, so that word use would come as close as possible to representing the child's highest current level of use.

Data preparation

Detailed phonetic transcripts were prepared from the audiotapes of about 60% of the weekly free-play sessions. The phonetic system used was IPA, supplemented by a symbology and a set of diacritic notations developed for use in transcribing child speech (cf. Bush, Edwards, Luckau, Stoel, Macken, & Peterson, 1973) as well as by further symbols and diacritics developed in the course of the project for special use in transcribing the vocalizations of 9- to 16-month-old infants. Four transcribers contributed to the data base, two of them preparing 82% of the transcripts. Transcriber reliability was tested using brief samples from tapes of seven of the babies, selected from the full age range represented in our data. Agreement with regard to place and manner in consonants, syllable shape, and vocalization length in syllables was tallied, yielding 86% agreement on the relevant categories (n = 126 vocalizations and 2,452 possible points of agreement) when the samples prepared by all four transcribers were compared with a standard developed for this analysis by the two main transcribers. Direct comparison of the original sample transcripts made by the two main transcribers showed 82% agreement. If differences between transcribers involving the presence or absence of a glottal consonant ([ʔ] or [h]) are disregarded, reliability reaches 91% across all four transcribers in comparison with the standard, or 88% in a direct comparison of the two main transcribers. Agreement with regard to numbers of vocalizations – or utterances identifiable as distinct units by breath control, timing, and a unified intonation contour – was 97%. (See Vihman et al., 1985, for a full account of the reliability procedure.)

Finally, the videotapes were viewed and re-viewed to detect and confirm contextual cues used to establish word or "nonword" status for each of the child's vocalizations. Vihman et al. (1985) includes a lengthy discussion of the problems encountered in separating words from babble (cf. also Vihman & Miller, 1986); we will not repeat this discussion here, but the basic criteria used in that earlier study applied here as well:

> Before we credited a child with a spontaneous use of a word, we required that he or she produce a phonetic form that was a recognizable attempt at the adult word, given frequent child-reduction rules. . . . In addition, the child had to use the word appropriately, with an apparently intentional meaning that was plausible in terms of the adult meaning or use of the word and commonly occurring child semantic rules. . . . (p. 401)[1]

As in the earlier study, imitations and onomatopoeia (including forms idiosyncratic to a given family) were counted as words, so long as the adult model was used with a consistent conventional meaning. Vocalizations used with consistent communicative function by the child but lacking an adult model, that is, "phonetically consistent forms" (Dore, Franklin, Miller, & Ramer, 1976), "vocables" (Ferguson, 1978b), "proto-words" (Menn, 1978), "quasi-words" (Stoel-Gammon & Cooper, 1984) or "invented words" (Locke, 1983), were not distinguished from babble for the purposes of the present study.

Selection of data points

After making a count of word types used spontaneously at each weekly session for each child, we selected four points that would allow us to compare the children in a developmentally meaningful way rather than on a purely chronological basis. The points chosen were 0 words, 4 words, 15 words, and 25 words (see Table 1). The 4-word point, representing the earliest point at which four or more different words were used spontaneously in a half-hour recording (the "criterion session" of Vihman et al., 1985), was selected because it appeared to mark a change in the children's language use. One, two, or three words might have previously been variably used over a number of weekly sessions, but after the first four-word session, word use per session generally remained stable or increased on a weekly basis (disregarding the Užgiris–Hunt sessions, which were more structured and typically involved a lower level of word use by the child). The fifteen-word point was chosen here to reflect the largest number of different word types used in a single session by a majority of the subjects: seven children reached this point. The last point, 25 words, was selected to reflect maximum word-type use for the five children who developed the largest vocabularies by the end of the project.

Having identified these four lexically based points of comparison, we selected for detailed analysis three sessions each from the months including the four-word and the fifteen-word points (avoiding Užgiris–Hunt sessions wherever possible as well as sessions in which audio or video equipment failures reduced the data available), and a single 25-word session.[2] In addition, for our 0-word point, we selected a session a few weeks earlier than the criterion session. Some children had one or two words from the beginning while for others a very long period of fluctuating 0- to 3-word use occurred. In order to keep the time interval between the 0- and the 4-word points as similar as possible across subjects within the limits of individual variation in rate of lexical advance, we chose an early session at which 0 to 2 words were used, but before which no more than one word had been used. Even so, the interval between the first and second sessions chosen ranges from 6 weeks to 4 months.

Because the 50-word stage has been so often used in previous studies, based generally on a cumulative lexicon reported by a diarist parent, we compared the timing of the children's cumulative vocabulary as reported in the mothers' logs with our own "stages" based on word-type use during a given session. These comparisons revealed that the "four-word stage" reliably reflects a cumulative lexicon of about ten words, while use of 15 word-types corresponds to about 30 to 50 words in the mother's log, and 25 word types in a session corresponds to 50 or more words in the cumulative lexicon reported by the mothers (see again Table 1). Recall that we count as word types words that the mothers may not report, such as onomatopoeia (*yum-yum* or *vroom-vroom*) and marginal words (*oops, unh-unh*), whereas the mothers report words related to meals, bedtime, or trips away from the home, for example, which are unlikely to be elicited during a session. Table 3 in Vihman et al. (1985) gives some indication, for each of the nine subjects whose data were included in that study, of the degree of overlap between words identified on our transcripts and words reported by the mothers.

Table 1. *Subjects and data points*[a]

		4 words			15 words			
	0 words	1	2	3	1	2	3	25 words
A	0;11.7 1 [0] (0%) 45	1;2.26 4 [4] (17%) 179	1;3.4[b] 3 [9] (14%) 101	1;3.9 7 [9] (22%) 97	1;4.23 5 [39] (14%) 192	1;5.15 15 [50] (33%) 242	1;5.21 17 [50+] (38%) 202	
C	0;10.19 0 [2] (0%) 71	1;3.0 7 [10] (13%) 114	1;3.14 2 [11] (20%) 84	1;4.0 3 [12] (17%) 118				
D	0;9.17 1 [0] (4%) 220	0;11.5 5 [7] (24%) 117	0;11.12 4 [9] (22%) 210	0;11.26 7 [12] (40%) 117	1;1.29 16 [27] (43%) 147	1;2.6 14 [27] (24%) 212	1;2.20 17 [30] (37%) 154	1;3.24 31 [49] (49%) 239
E	0;10.7 2 [2] (9%) 116	1;1.0 8 [9] (19%) 156	1;1.7[b] 3 [9] (42%) 85	1;1.14 11 [12] (46%) 78	1;1.28 19 [24] (65%) 68	1;2.8 20 [27] (64%) 124	1;2.18 18 [50] (48%) 249	1;3.29 39 [50+] (70%) 165
J	0;10.27 0 [3] (3%) 86	1;2.11 8 [11] (28%) 142	1;2.18 7 [11] (21%) 175	1;2.25 11 [11] (16%) 250				
M	0;8.19 0 [2] (0%) 66	0;10.15 3 [7] (37%) 150	0;10.23 5 [8] (7%) 183	0;11.9 6 [15] (16%) 129	1;0.10 14 [24] (36%) 156	1;0.26[b] 20 [43] (40%) 133	1;1.8 30 [55] (54%) 247	1;2.20 30 [55+] (92%) 419
S	0;10.0 2 [0] (9%) 185	1;0.19 5 [14] (12%) 161	1.0.24 9 [16] (24%) 270	1;1.2[b] 10 [19] (13%) 83	1;2.5 17 [38] (35%) 196	1;2.12 23 [41] (45%) 267	1;2.19 18 [41] (31%) 185	1;3.23 40 [50+] (46%) 303
Su	0;10.23 1 [3] (13%) 136	1;1.8 7 [9] (14%) 124	1;1.22 3 [9] (12%) 89	1;1.29 10 [9] (25%) 208				
T	0;10.8 2 [3] (14%) 186	0;11.7 7 [4] (45%) 262	0;11.27 7 [7] (50%) 101	1;0.3 6 [7] (32%) 232	1;3.2 17 [25] (31%) 239	1;3.10[b] 10 [27] (45%) 143	1;4.0 20 [32] (35%) 228	1;5.29 55 [50+] (63%) 380
Th	0;11.19 0 [4] (2%) 115	1;0.26 8 [11] (26%) 175	1;1.9 5 [13] (25%) 119	1;1.16 10 [14] (30%) 156	1;3.11 10 [24] (34%) 402	1;3.18 16 [24] (26%) 468	1;4.2 13 [31] (36%) 160	

[a]For each subject, we indicate age in years, months, and days (first line); number of spontaneous word types used for each session and, in brackets, the number of words used to date according to maternal report (second line); the proportion of (both imitated and spontaneous) word tokens out of all vocalizations (third line); and total number of vocalizations analyzed (fourth line).

[b]Užgiris–Hunt sessions analyzed.

Table 2. *Classification system used to construct a profile of phonetic tendencies*[a]

	p/b	m	t/d	. . . n vocs	
monosyllables					
	pæ bʊ̥ʔ	mɛʰ	tʰa! dø̥	103	47%
disyllables					
glottal or glide + VCV	ʔəpæʔ ʔʌbœʰ	ʔəmæːʰ	wətʌ jadʌ	36	
CV + glottal or glide + V	pʻeːjɛ bʉːwæ	mæ̃::hæ̃	taːʔjɛ	7	46%
C1VC1V		mɛːmæ̃	tætæ	47	
C1VC2V	pʻatʻeɪ baːdæ		ta̤ʒeʰ teːkæ	12	
polysyllables					
one C		ˈæhɛhɛʔaᵐmæʔ	hɛtatʰœ hɛʔdidiz::	11	
two C			hɛtapa ʔətʻɛkʻi	4	7%
three C		ˈɛᵐmigoᵘwidəbudəbᵇ			
n vocs	25	28	74	220	
% of total	11%	13%	34%		

[a]Examples are from Deborah, 0 word session, age 0;9.17.
[b]This vocalization is taken from a later sample (0;11.12), since no three-consonant ploysyllables occur in the 0-word sample.

Data analysis

Phonetic tendencies. The distribution of vocalizations by number of syllables (one, two, or more) and by consonant use was charted. To simplify somewhat an otherwise unwieldy task, we chose to chart vocalizations by the first true consonant used (i.e., excluding glides, glottal stop and [h]), or in the absence of any true consonant, by the first glide used, if any. Only the first consonant was used because that consonant appeared most likely to represent the child's vocal intentions or plan, given the common occurrence of repeated consonants in multisyllabic vocalizations (documented below; cf. also de Boysson-Bardies, Bacri, Sagart, & Poizat, 1981). The use of final consonants, especially rare in the early stages, seemed to constitute an independent production choice, unrelated to the succession of syllables initiated by the first true consonant use. Thus vocalization-final consonants were tallied separately and did not enter into the general classification of vocalizations according to consonants. Table 2, taken from a single sample (Deborah, 0 words, age 0;9.17), illustrates the categorization used, giving examples of just three true consonant categories, p/b, m, and t/d. The figures given in the column labeled n[umber of] voc[alization]s refer to the whole sample from which these examples are drawn. Since no polysyllabic

strings with three different true consonants occurred in this sample, an example of that category is drawn from a later sample.

Using the data so organized, we charted the distribution of (a) vocalization length in babble and words combined (monosyllables, disyllables, and other polysyllables). Omitting the glottals and the glides, we charted the distribution of true consonants by (b) place of articulation (labial [and labiodental], dental [and alveolar and palatal], velar [and uvular]) and (c) manner of articulation (stop, nasal, fricative, and liquid). The liquids were not included in the analysis of place of articulation, since distribution across the various places is not generally relevant for this manner category.

In addition, we tallied (d) the percentage of vocalizations including at least one true consonant, over all vocalizations used, (e) the percentage of vocalization-final consonants over all vocalizations, (f) the percentage of vocalizations including a consonant cluster in any position, over all vocalizations (including true consonant plus glide as well as non-English affricates, such as [k^x], among the clusters), (g) the percentage of contrasting nonfinal true consonants (C_1 . . . C_2 . . . [C_3 . . .]) in a single vocalization, over all multisyllabic vocalizations (i.e., disyllables and polysyllables), and (h) the percentage of repeated or "reduplicated" consonants over all disyllables.

Consonant inventories. In order to investigate the development of the consonant inventory viewed as an emergent system, we separated words from nonwords, as described earlier. The consonant inventories were further divided into nonfinal (whether vocalization-initial or -medial) and final. Vocalization-medial clusters of obstruent plus liquid were included in the inventories as units, since they were virtually the only clusters of true consonants to occur in vocalization-initial position as well. Finally, we distinguished between marginal occurrence of a segment, in either words or nonwords, in a given session (one to three tokens) and full use (four or more tokens). For our summary tables, we combined the three 4-word sessions and the three 15-word sessions so that a segment was included in the relevant (word or nonword) consonant inventory only if it was used to criterion (four or more uses) in either words or nonwords in any **one** of the three sessions sampled for that point in the child's development.

Word selection trees. For each sample analyzed, we charted the adult words attempted, whether spontaneous or imitated (excluding only onomatopoeia or other words whose adult form is highly variable, e.g., *unh-hunh, mhm, mm,* etc.) against the full set of English consonants to be mastered. We placed words under the first nonfinal consonant of the **adult word** if that consonant occurred in **at least one variant token of the word in the child's production** (e.g., [da$^{\text{ʔ}}$i: ~ tai ~ kai ~ ga:i] *doggy,* Andrew, 1;2.26, counts as a D-word). Differences in degree of aspiration or voicing were disregarded in this classification. Where no initial consonant occurs in the adult word or where the first consonant used by the child matches a later consonant in the adult form, we listed the word under the apparent source consonant, if any (e.g., [$^{\text{ʔ}}$ap ~ hʌp] *up,* Andrew, 1;2.26, listed under P, [$^{\text{ʔ}}$i$^{\text{h}}$k'I$^{\text{ʔ}}$] *(chi)cken,* Deborah, 1;2.20, or [tæI ~ hukæ] *(s)ky,* Deborah, 1;3.29, both listed under K). Words that contain no consonant matching a consonant in the adult word were listed under the closest matching consonant (e.g., [si]

three, Deborah, 1:1.29, listed under THETA, or [əzis] *fish*, Timmy 1;5.29, listed under ESH). Where no consonant appeared in the child's word, it was listed as vowel-initial (e.g., [ʔeᵊ] *(h)air*, Deborah, 1;3.29).

Next, word selection trees were constructed by plotting the consonants "selected" by each subject at each session against the full set of English consonants. Boxed capital letters are used to distinguish these trees from the phone trees of Ferguson and Farwell (1975). As is done in constructing phone trees, we connected the same consonants noted for different sessions by a dotted line if none of the same words were involved or by a solid line if at least one of the words used in the later session had also been used earlier. The number of words "selecting" a given consonant was noted as well.

RESULTS

The analyses to be presented here proceed from (1) an examination of the phonetic tendencies exhibited in the combined corpus of words and babble to (2) a comparison of the separate consonant inventories of words and babble as they evolve across the stages of lexical advance, and finally to (3) a consideration of the word choices made by the different children, against the background of the first two analyses. Thus we will move from a focus on prosodic phenomena (vocalization length, syllabic shape) and consonantal features to the segments in which the features are manifested, and finally to the words that the children are targeting as they marshall their phonetic resources to produce adult-based language.

Phonetic tendencies

Table 3 presents the proportional distribution of (a) vocalization length, (b) consonant place, and (c) consonant manner,[3] as well as (d) the incidence of vocalizations including a true consonant over all vocalizations, (e) the incidence of vocalization-final consonants over all vocalizations, (f) the incidence of vocalizations including a consonant cluster over all vocalizations, (g) the incidence of contrasting consonants in multisyllabic strings, and (h) the incidence of reduplicated-consonant sequences (C_1VC_1V) in disyllabic strings.[4] In connection with the figures of Table 3(b), (c), and (d), it should be borne in mind that only the first (nonfinal) true consonant in a string, if any, was used to characterize each vocalization (recall Table 2).

Inspection of the figures on Table 3 reveals at once that a large amount of diversity is present in the distribution of several categories, even at the earliest stage, when the children might be expected to exhibit common tendencies, the "universal" patterns resulting from biological constraints.[5] In order to gain a clearer picture of the developmental trends in the data, we have restated the variability of each phonetic category (as roughly expressed in the standard deviation) in terms of **degree** and **direction** of change across stages (Table 4). Thus, for example, there is a 16-percentage point decrease in the standard deviation for labials from the 4- to the 15-word stage (indicated by an asterisk [*]) and a 12-point decrease for the dentals (indicated by a plus [+]).

It is striking to note that only one out of ten changes in level of variability that

Table 3. *Distribution of phonetic categories (in percentages)*

a. Vocalization length

(1) Monosyllables

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	61	46	47	33	66	49	47	62	49	49	51	9.7
4	48	45	52	59	82	60	74	48	55	83	61	14.2
15	59	44	42	59	71	45	70				56	12.2
25	49	55	56	51	70						56	8.2

(2) Disyllables

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	31	27	46	35	19	35	42	26	40	34	34	8.1
4	35	31	25	31	14	27	13	32	27	11	25	9.0
15	31	40	40	30	19	37	24				32	8.1
25	45	37	31	48	21						36	10.9

(3) Polysyllables

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	9	28	7	32	14	17	11	13	12	17	16	8.1
4	17	24	23	10	4	13	13	20	17	6	15	6.8
15	10	16	18	11	9	18	6				13	4.8
25	6	8	13	1	9						7	4.4

b. Consonant place

(1) Labials

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	62	86	36	67	29	12	27	9	65	47	44	25.6
4	56	85	36	66	25	24	37	34	27	23	41	20.9
15	44	49	44	43	36	46	41				43	4.1
25	29	45	44	46	41						41	7.0

(2) Dentals

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	25	0	54	7	62	70	45	80	33	50	43	26.2
4	5	13	25	18	67	57	34	53	61	59	39	22.8
15	15	45	32	36	47	38	29				35	10.8
25	44	39	39	36	49						41	5.1

(3) Velars

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	13	14	9	26	9	18	27	11	1	3	13	8.6
4	41	2	39	16	8	19	29	13	12	19	20	12.8
15	47	7	24	21	17	16	31				23	12.8
25	27	16	17	18	10						18	6.1

c. Consonant manner

(1) Stops

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	81	47	75	83	63	71	64	87	80	17	66	22.5
4	89	70	71	52	83	70	82	72	60	51	70	12.8
15	83	59	66	71	77	82	82				73	9.4
25	68	58	65	84	65						68	9.7

(2) Nasals

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	3	47	22	10	2	0	27	2	17	67	20	22.2
4	2	29	16	45	3	19	18	17	11	17	18	12.4
15	7	34	8	21	7	13	7				13	10.8
25	21	35	6	15	18						19	10.6

Table 3. (*cont.*)

(3) Fricatives

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	13	0	3	0	20	26	9	9	3	17	10	8.6
4	8	0	6	3	2	9	8	7	27	31	10	10.4
15	8	7	25	7	5	3	11				9	7.3
25	10	7	29	1	9						11	10.5

(4) Liquids

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	2	7	1	7	15	3	0	2	0	0	4	4.8
4	1	1	6	0	13	2	1	4	2	0	3	4.0
15	2	1	1	1	11	1	0				2	3.8
25	1	0	0	0	9						2	3.9

d. True consonants

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	46	13	68	44	44	75	24	53	55	42	46	18.4
4	68	70	33	57	43	35	39	68	40	22	48	17.0
15	72	70	65	60	55	54	39				59	11.3
25	79	66	56	92	61						71	14.4

e. Final consonants

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	9	1	1	3	11	13	0	5	8	13	6	5.1
4	0	17	5	7	11	5	6	8	10	16	9	5.2
15	1	10	4	23	12	10	7				10	7.0
25	25	2	1	23	33						17	14.5

f. Consonant clusters

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	5	0	1	6	3	8	0	0	2	6	3	3.0
4	3	3	6	5	5	4	2	9	9	2	5	2.6
15	3	5	11	8	6	11	4				7	3.2
25	7	2	5	1	7						4	2.8

g. Contrasting consonants

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	1	0	13	23	16	20	0	3	7	19	10	9.0
4	6	5	17	13	13	6	4	13	17	23	12	6.3
15	16	24	33	25	16	12	6				19	9.1
25	29	15	11	17	12						17	7.2

h. Reduplicated consonants

Stage	T	E	D	M	S	Th	A	J	Su	C	Mean	SD
0	9	5	36	4	47	28	11	64	7	21	23	20.3
4	18	45	12	23	17	8	8	36	6	23	20	13.0
15	21	43	24	31	24	19	6				24	11.3
25	30	38	15	15	20						24	10.1

Table 4. *Changes in variability of phonetic categories across stages*

Stage	0–4 words	4–15 words	15–25 words
Phonetic category			
(a) Vocalization length			
Monosyllables	–	–	–
Disyllables	–	–	–
Polysyllables	–	–	–
(b) Consonant place			
Labials	[× (↓)]	* (↓)	–
Dentals	–	+ (↓)	× (↓)
Velars	–	–	× (↓)
(c) Consonant manner			
Stops	[+ (↓)]	–	–
Nasals	[+ (↓)]	–	–
Fricatives	–	–	–
Liquids	–	–	–
(d) True consonants	–	× (↓)	–
(e) Final consonants	–	–	× (↑)
(f) Consonant clusters	–	–	–
(g) Contrasting consonants (all polysyllables)	–	–	–
(h) Reduplicated consonants (disyllables)	× (↓)	–	–

Note: – = 0–4 point difference between stages; × = 5–8 point difference between stages; + = 9–12 point difference between stages; * = 13–16 point difference between stages; ↑ = increase in level of variance; ↓ = decrease in level of variance. Changes marked off in brackets ([ ]) do not obtain for standard deviations based on the five most advanced subjects only (see text).

amount to a 5-point difference or more involve an **increase in variability.** The remaining changes show a decrease in variability, or **increasing uniformity.** It should be borne in mind that the number of subjects is smaller at the last two stages. However, when means and standard deviation are derived for the five most advanced subjects only, the same general pattern holds: there are 14 changes, 10 of them involving increasing uniformity. (The categories that fail to show the indicated change when sample size for the earlier stages is reduced are bracketed on Table 4.) Though in principle the potential for variability decreases with a decrease in number of subjects, the pattern of increasing uniformity as the only consistent change over time does not itself appear to be an artifact of the change in number of subjects. Thus, insofar as uniformity at the earliest stages analyzed here may represent universal constraints, these constraints may be assumed to be in general harmony with the structural requirements or constraints of the environmental language as well, as in only one category (final consonants) does early cross-subject agreement give way to greater variability as language is learned.

The increase in uniformity in the data at later points we take to reflect the effect of learning the same language – or perhaps of learning any language at all. If our subjects are becoming more like one another in their use of phonetic categories in babbling and words as a result of their increasing exposure to and attention to English in particular, then it should be possible to distinguish between the babbling and early words of children from different language backgrounds, without necessarily knowing which vocalizations are words or which languages are involved. In fact de Boysson-Bardies, Sagart, & Bacri (1981) reported findings of just this kind. Their subject, aged 1;6–1;8, was still largely unintelligible, but phonetic analysis revealed that his "late babbling" was closer to the phonetic repertoire of French than to that of English or Thai. Experimental efforts to identify a "drift" toward the phonology of a particular language at an earlier age, using adult judges, have not generally been successful (see Atkinson MacWhinney, & Stoel, 1968; de Boysson-Bardies, Sagart, & Durand, 1984; Oller & Eilers, 1982; Thevenin, Eilers, Oller & LaVoie, 1985; and the discussion in Locke, 1983). This suggests that, to the extent that our sample of 10 children is sufficiently large to be representative, a comparable analysis of the babbling of French, Chinese, and Eskimo children, say, should reveal roughly the same distribution of phonetic categories at the zero- and four-word points, but might well show increasing differentiation from our results at later points.

Some categories are of relatively low incidence across subjects for the entire period investigated (polysyllables, velars, nasals, fricatives, liquids, final consonants, consonant clusters, contrasting and reduplicated consonants). In order to bring these data into clearer focus, let us somewhat arbitrarily define 25% use as a "significant" level. That is, we can consider a category essentially "not used" to any significant extent only if **no one subject** makes use of the category in 25% or more of his or her vocalizations at any one stage. Under this criterion, we find, first, that neither liquids nor consonant clusters play an important part in the phonetic repertoire of any of the children in the course of the transition period. Second, in four of the categories – velars, nasals, fricatives, and reduplicated consonants – we find significant use by one or more children at every stage, with a notable persistence in use of particular categories by certain children over time (cf. velars for Timmy and Andrew, reduplicated consonants and nasals for Emily). Third, the category of polysyllables shows a significant level of use by two of the children at the zero-word point only. Finally, in the categories of contrasting and final consonants, we see the emergence of significant levels of use only at the 15- and 25-word points, respectively. Every one of these nine low-use categories has been reported to vary in early phonology acquisition (cf., e.g., Ferguson & Farwell, 1975; Ferguson, 1978a; Ingram, Christensen, Veach, & Webster, 1980; Leonard et al., 1980; Schwartz, Leonard, Wilcox & Folger, 1980; and Greenlee, 1974).

Consonant inventories

Table 5 presents the inventory of consonants used in babble and in words by each of the children at the two points when three sessions were included in the analysis, the 4-word point and, for all but three children, the 15-word point. Each inventory is based on analysis of all three sessions; in order to be included,

Table 5. *Consonant inventories*[a]

Consonant class	4 words		15 words	
	Babble	Words	Babble	Words
1	p t k ʔ	p k ʔ	p t k ʔ	p t k ʔ
2	b d g	b g	b d g	b d g
3	h	h	h	h
4	β v			
5	n			m n
6	j w		*l j	j
		[42%]		[37%]
		Timmy		
	m ʃ	**p s dz k**		**p z l**
1	p t ʔ	p t ʔ	p t k ʔ	p t k ʔ
2	b d	b	b d g	b d g
3	h		f h	
4			v z	
5	m	m	m n	m n
6	j w		l j w	
		[36%]		[59%]
		Emily		
			s ʃ	
1	p t k ʔ	t ʔ	p t tʃ k kˣʔ	p t ʔ
2	b d g	b	b d g*	b
3	h	h	f s ç ʃ x h	s ç ʃ h
4	ð*		v γ*	
5	m n	m	m ŋ	m
6	l j w		w j	j w
		[29%]		[35%]
		Deborah		
	p	**β̌**	**p k**	**p t k ŋ**
1	p t k ʔ	p k ʔ	p t k ʔ	p t tʃ k ʔ
2	b g	b	d g	b d dʒ
3	h		ɸ h	ɸ h
4				
5	m n	m n	m n	n
6	j w	β̌	w	β̌ w
		[20%]		[43%]
		Molly		
	p t l k	**t**	**p x**	**p s**
1	t ʔ	t ʔ	p t k ʔ	p t k ʔ
2	b d g	d	b d g	b d g
3	h	h	h	
4				
5			n	m
6	l j		β̌ l r j w	β̌ r j w
		[10%]		[37%]
		Sean		

Table 5 (*cont.*)

Consonant class	4 words		15 words	
	Babble	Words	Babble	Words
	m		**p n k ŋ**	**p m k**
1	p t k ʔ	t ʔ	p t k ʔ	b t k q ʔ
2	b d g	d	b d g	b d g
3	s h	h	h	h
4				
5	m n		m n ŋ*	m n
6	r j w	w	β̆ l j w	β j w
		[27%]		[32%]
		Thomas		
				p
1	p t k ʔ	p t k ʔ	t k ʔ	p t k ʔ
2	b d g	b	b d g	b d
3	h	h	s h	h
4				
5	m̆		m	n
6	β̆ l j w		j w	w
		[22%]		[42%]
		Andrew		
	p m			
1	p t k ʔ	p t q ʔ		
2	b d g	b d		
3	h			
4	v	*		
5	m n	m n		
6	l j w	w		
		[22%]		
		Jonah		
1	p t tʃ k ʔ	p t k ʔ		
2	b d	b d		
3	s ʃ h	h		
4	z ʒ	z ʒ		
5	m n			
6	j w	j		
		[17%]		
		Susie		
	ʃ	s		
1	t k ʔ	k ʔ		
2	b d g			
3	ʃ h			
4	β z ʒ			
5				
6	j			
		[17%]		
		Camille		

however, a segment had to be used four or more times in at least one session. Final consonants, charted separately in boldface, were tallied in the same way. The mean percentage of words over all vocalizations is noted in each case under the inventory of consonants used in words so that opportunity for use can be taken into account.

Not surprisingly, an increase in the number of consonants used in words from the 4- to the 15-word stage is evident for all seven of the children with relevant data. An increase also occurs in the inventory of consonants used in babbling for three of the children, while the size of the inventory remains essentially unchanged for the other four.

The individual differences suggested by the high variability already noted along certain segmental parameters (e.g., use of velars, nasals, fricatives, liquids, and final consonants) are in evidence here as well. For example, Emily lacks velars entirely at the 4-word stage, in both babble and words (except word-finally), while Sean lacks nasals. On the other hand, Susie and Camille each use three or four sibilants at this point, and four children use [l] in babble, though none do so in words as yet. A bilabial trill, marginal in adult English, is used to criterion in babble by Andrew and in both babble and words by Molly. Four children use no final consonants at this stage. The remaining six children use from one to four different consonants in final position in babbling, but only Emily uses as many as four different final consonants to criterion in words. Three of the other children use one final consonant each in words; the remainder use none.

At the 15-word point, Deborah still shows no consistent use of velars in words, though they occur in her babble at 4 and at 15 words. On the other hand, Molly, who used nasals in both babble and words at the earlier point, now uses only [n] in words. Sean, Timmy, and Thomas use no fricatives in words or babble, while Deborah has seven fricative segments in babble and three in words. No other child has more than a single voiced/voiceless pair of fricatives in words or babble. Sean is the only child to use a nonfinal liquid in words as well as in babble. Only Timmy now lacks final consonants entirely; the final consonant inventory is about the same in words (1.7 per child, on average) as in babble (1.4 per child). The single most common final consonant is [p] (used by all but one child), but [s], [z], [x], and [ŋ] are used finally by children who fail to use them in other positions in the same vocalization type (babble or word).[6]

Comparing the word and babble inventories, at the 4-word point (when word tokens make up between 10 and 42% of all vocalizations for a given child) eight out of ten children use one or more voiced stops that do not occur in words; by 15 words this is true of only three out of seven children. The segment most com-

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[a]Order of listing: Final consonants (in boldface); voiceless stops (1); voiced stops (2); voiceless fricatives (3); voiced fricatives (4); nasals (5); glides, liquids, bilabial trill [β̞] (6). (* = used in medial position only.) Mean percent of words over all vocalizations for the three sessions is bracketed.

monly found in babble but not in words is [g]. On the other hand, even at 4 words, four of the children use consonants in words that do not consistently appear in their babble: out of seven such segments, two are labials. At fifteen words, five out of seven children use segments in words that do not occur in babble; four out of nine such segments are labials.

Looking more specifically for non-final segments found in words but not in babble at the 4-word point, we find just one instance: [β̆] (Molly). At the 15-word point Molly's [β] (used in *vroom*) is still confined to the word inventory. The converse situation, in which segments found in babble are not yet established in words at the 4-word point, is much more common. Of 47 such segments found in the inventories of the seven children, over half occur in words by the 15-word point (25 segments).

Thus we have found, first, that the consonant inventories for babble have not yet begun to diminish by the 15-word point, when children have cumulative vocabularies of 30 to 50 words. Second, we find in the consonant inventories the kind of variation we would expect, given the variability in segmental features found in the analysis of phonetic tendencies. In addition, we see some tendency for voiced stops to be associated with babble, especially at the 4-word point, whereas labials – which emerged as a uniform "phonetic tendency" category at the 15-word point (see Table 4) – are associated with words already at the 4-word point. This confirms a tendency already noted in Vihman et al., 1985 (cf. also Locke, 1983). Finally, of the rare segments that occur in words but not in babble at the earlier point, none have become established in babble as well by the 15-word point. In the reverse and more expected situation, in which segments are used early in babbling but not yet in words, there is about an even chance of those segments being established in words by the 15-word point. Thus our data are compatible with the view that there is continuous interaction and interinfluence between the emerging early words and contemporaneous babble, although the analyses presented here are not sufficiently fine-grained temporally to demonstrate such an interaction (see the close analysis of emerging first words and contemporaneous babble in the "playpen monologues" of one child at age 15 to 16 months: Elbers & Ton, 1985).

Word choices

Though overall word shape, prosody, and vowel pattern must also play a role in word choice (cf. Waterson, 1971; Vihman, 1981; Stoel-Gammon & Cooper, 1984), we are here making the simplifying assumption that words are generally targeted for their consonants (for some evidence that this is more often the case, cf. Shibamoto & Olmsted, 1978). The adult consonants that appear to be targeted in choice of words to produce (whether spontaneously or in imitation) are shown in Figures 1–5 for the five children who reached the 25-word point, along with an indication of the number of different word types represented by each consonant. Here we perceive more clearly the pattern of individual differences in phonological development broadly suggested by the analysis of phonetic tendencies and partially revealed by the inventorying of established consonant use.

Emily follows an orderly course. She begins with a B-word (*bye-bye*), an M-word (*mama*), an H-word (*hello*), and a vowel-initial word (*uh-oh*). In the course of the four-word sessions, she adds both P- (*Snoopy, up, piggy, puppy*) and B-words (*baby, ball, beads, big, bird*) as well as one word each with T (*tick-tock*) and D (*daddy*) and one M-word in addition to *mama* (*monster*). By the third session, she has added two K-words (*oink, Oscar*). At 15 words, she expands her repertoire along lines already laid down, with added labial words (F: *frog, fish,* and V: *love you*) as well as N-words (*no, night-night*). The only attempts at sibilant words are *bunnies:* (ʔiz::bizəbiz] and *fish* [si]. At the 25-word point, more velar words appear, as well as one S-word (the letter *C*) and several W-words (*water, watch this*).

Similarly systematic development based on words using small sets of phonetically related segments can be seen in Molly's chart. Beginning at the 4-word point with the three most common stops, B, D, and K (*baby; dog; cracker, kitty, cat*), as well as nasals (*moo, mommy, no*), she expands her repertoire at 15 words only by adding the corresponding voiced or voiceless stop (P: *pretty, peek, pig, oops;* T: *toot-toot, teeth, TV, tick-tock;* G: *good-girl*), four H-words (*horse, hi, ho-ho* and *hot*), and a single word each with F (*four*), THETA (*three,* pronounced [hi], [fi] or [pi]), W (*one*), and R (*rockie,* with initial vowel or h).[7] At the 25-word point, only the affricates T.ESH (*cheese*) and D.EZH (*Jenny,* pronounced with [t]) are added, leaving the sibilants and liquids as yet largely untried.

Timmy's course is restrained at first, but marked by notable expansion in the later stages. Beginning with three obstruents, B (*ball, bell, block, bump*), T (*kitty*), and ETH ([*what's*] *that*), he switches to the velars (*car, kitty, quack, girl*) and M (*mama*) at the 4-word point, adding only to his inventory of B-words (*box, button*). In the course of the three 15-word sessions, he fills in some P-words (*please, Humpty*), resumes sparing use of dental stops (*toot-toot; drums, daddy*), and also adds fricative words (*Ruth, flower, flies, fish*), two N-words (*nose, Nana*), an L-word (*light*), and two glide-words (*whoo, yeah*). At the 25-word point, he broadens his inventory further with S-words (*spoon, yes*), an affricate-word (*cheese*), an ENG-word (*ring*), and 2 H-words (*hi, hoo-hoo*).

Deborah and Sean display a rather different kind of development. In Deborah's case, we find a broad array of consonants used from the beginning (when several imitations occurred: *bye-bye,* produced as [dada], *two-three, daddy, okay,* and *mama,* alongside a spontaneous use of *uh-oh*). Only H is added during the 4-word sessions (*hi*), but at 15 words, Deborah begins to make use of words with interdentals (*three, this,* both produced with sibilants) and sibilants (*Sesame Street, shoe, scratchy, Judy*) and also glides (*row-row; what's this?; yummy*). One N-word is also added (*no*). At 25 words, we find consolidation of existing patterns, with no further expansion, though the labiodentals and L remain unexplored.

Sean begins with a far more restricted inventory than Deborah at 0 words, but at 4 words adds labials (*ball, boo, block; flower*), velars (*car, all gone*), and interdentals (*thankyou, this, that,* all produced with [d]). Unexpectedly, *book* is produced as a K-word at this point ([kuk]). At 15 words, we find a repertoire that seems to be expanding on all fronts, with sibilants, nasals, and liquids added to the existing types. Sean's R-words include *(f)rog, horse, red, there,* and *rocker,*

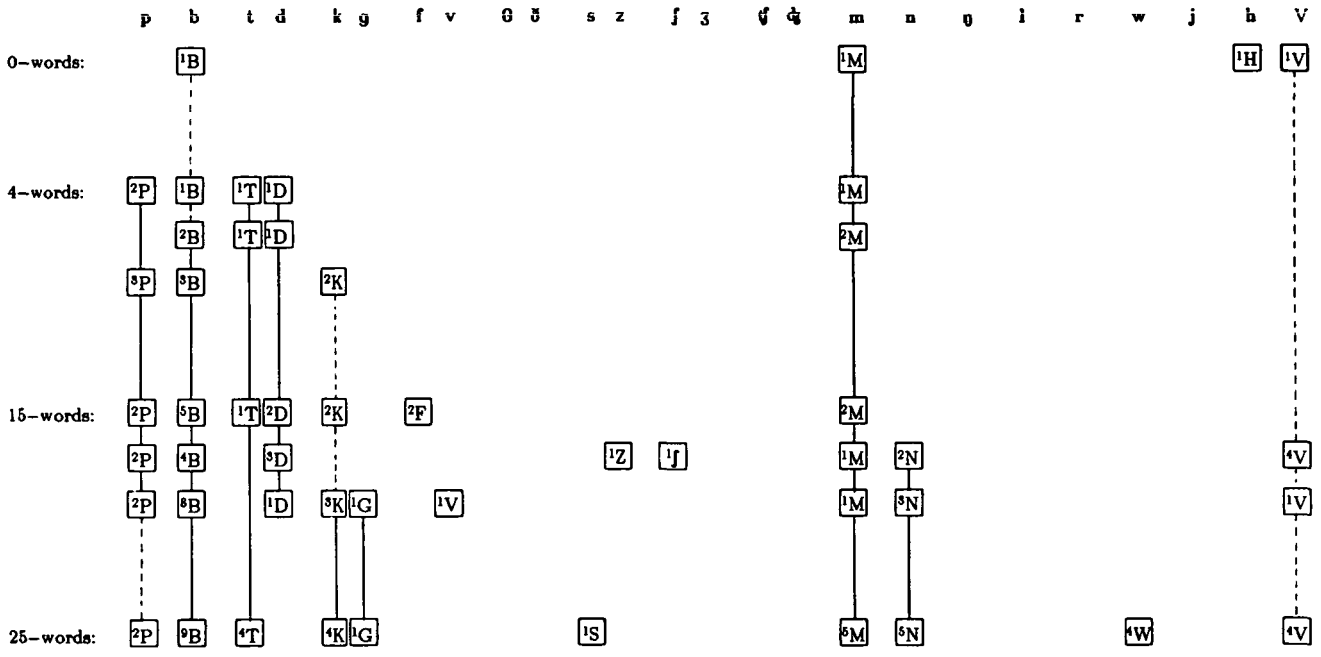

Figure 1. Word-selection trees: Emily. (Superscripts indicate number of words selected.)

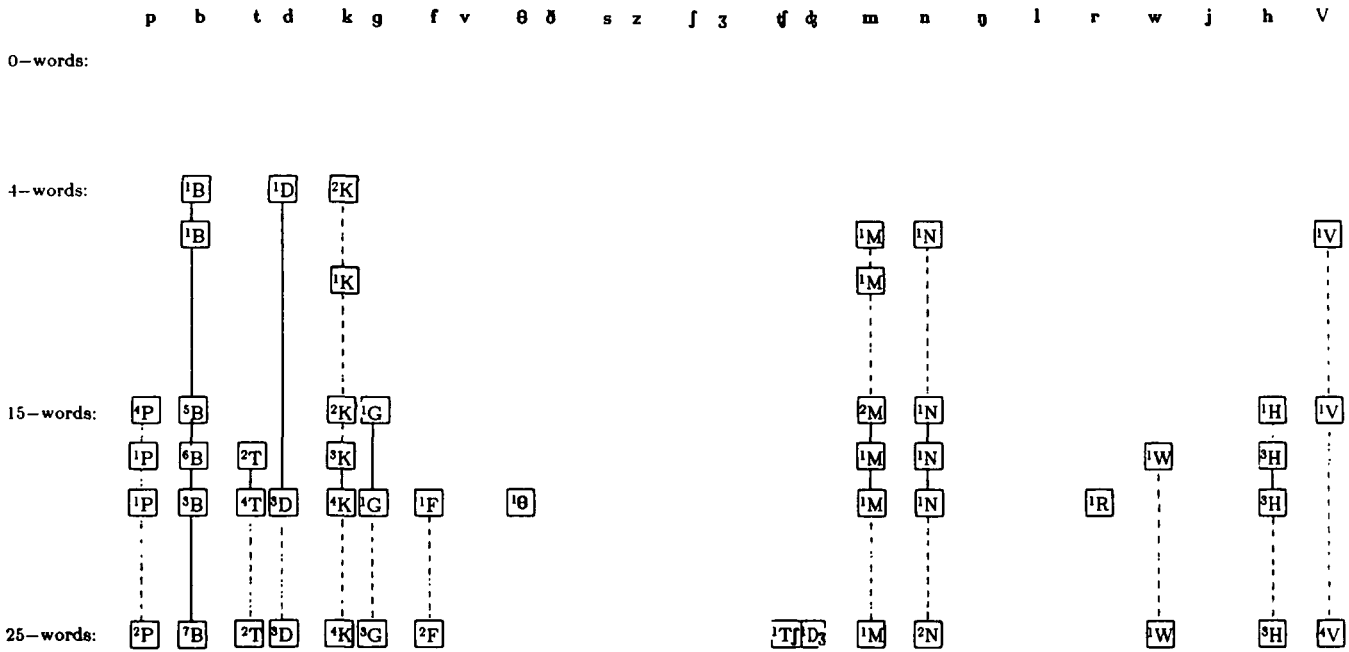

Figure 2. *Word-selection trees: Molly.* (Superscripts indicate number of words selected.)

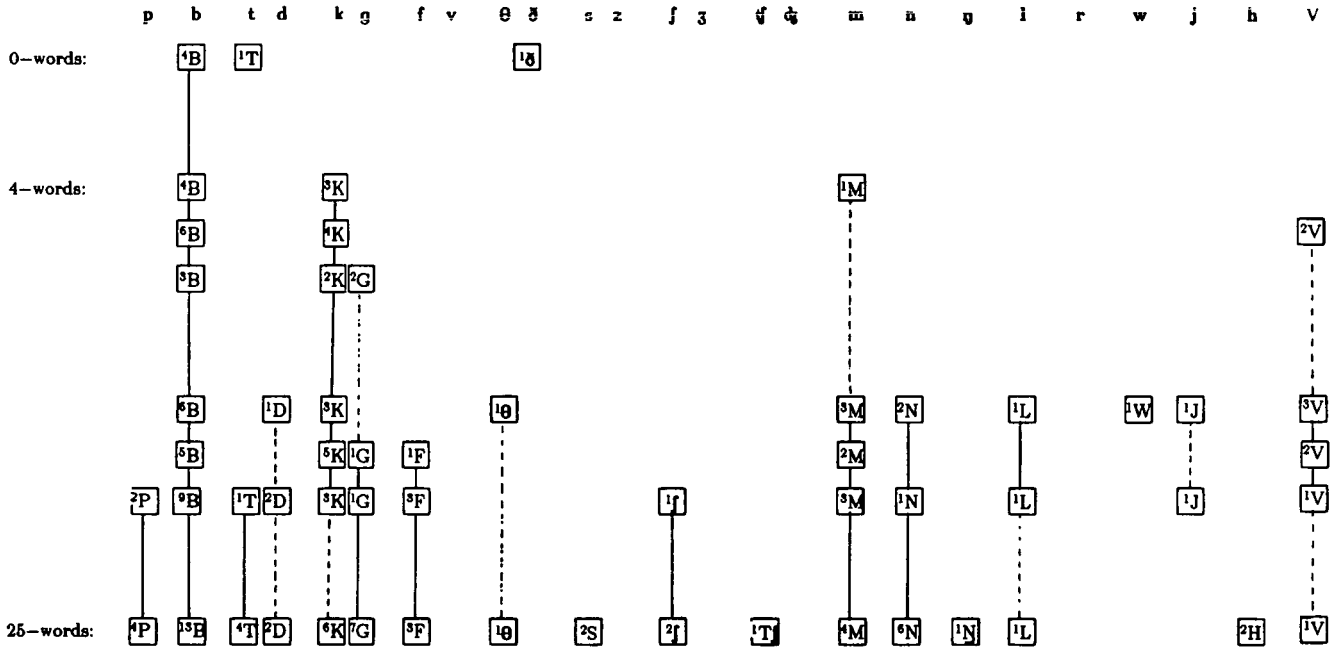

Figure 3. Word-selection trees: Timmy. (Superscripts indicate number of words selected.)

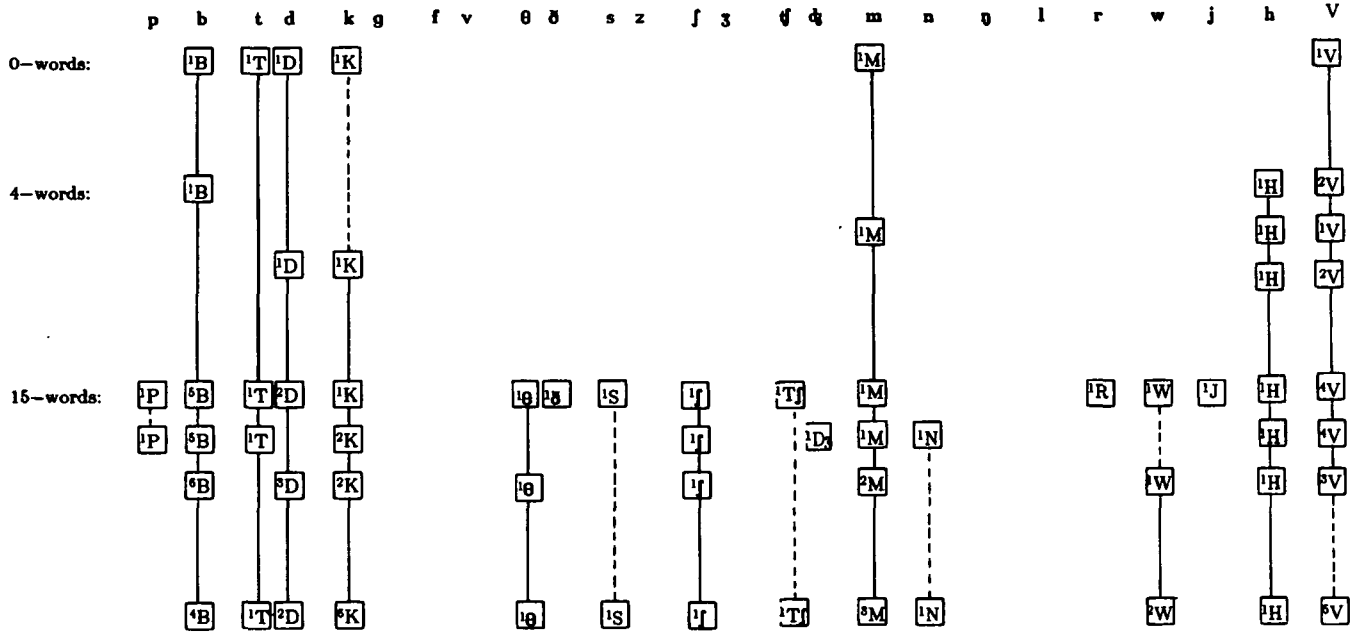

Figure 4. Word-selection trees: Deborah. (Superscripts indicate number of words selected.)

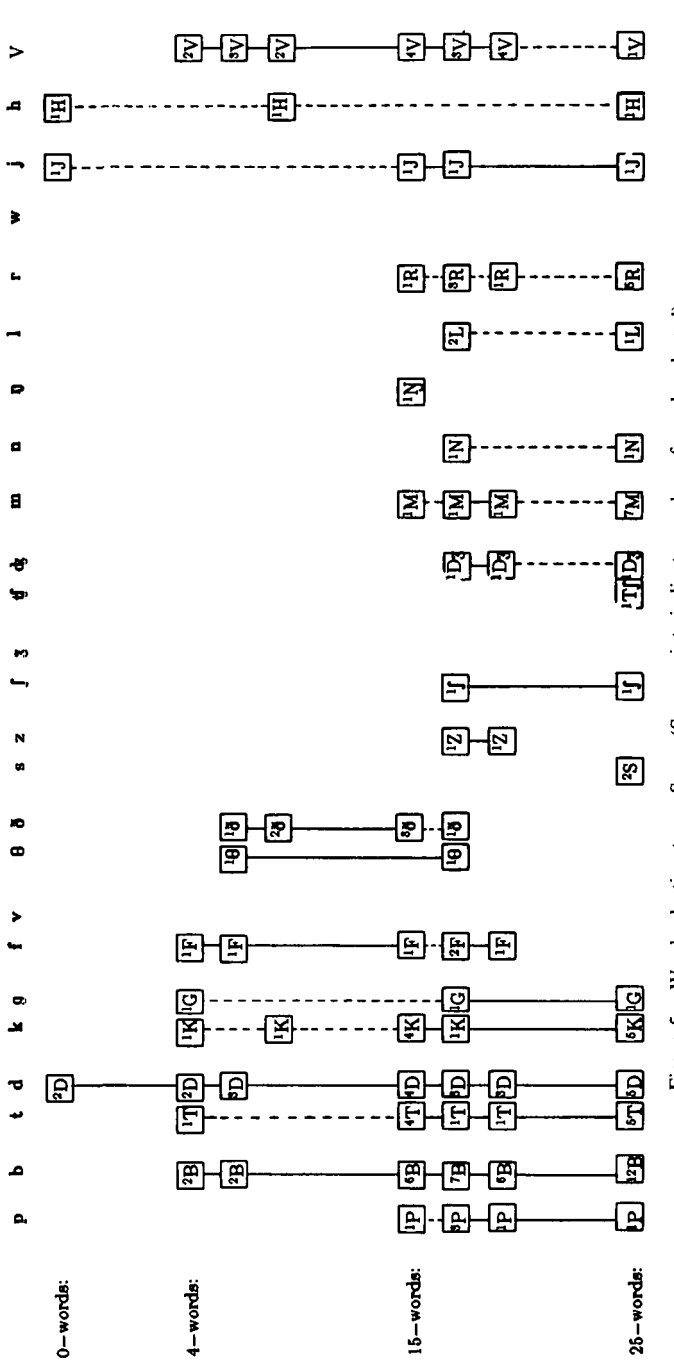

Figure 5. Word-selection trees: Sean. (Superscripts indicate number of words selected).

Table 6. *Number of subjects selecting words with each consonant over time*

Stage	0 words	4 words	15 words	25 words
P	1/10	4/10	7/7	4/5
B	5/10	9/10	7/7	5/5
T	1/10	5/10	7/7	5/5
D	3/10	9/10	7/7	4/5
K	1/10	9/10	7/7	5/5
G	—	4/10	5/7	4/5
F	—	1/10	6/7	2/5
V	—	—	2/7	—
THETA	—	1/10	4/7	2/5
ETH	—	6/10	4/7	—
S	—	2/10	3/7	4/5
Z	—	1/10	3/7	—
ESH	—	1/10	5/7	3/5
EZH	—	—	—	—
T.ESH	—	1/10	2/7	4/5
D.EZH	—	1/10	3/7	2/5
M	2/10	7/10	7/7	5/5
N	—	5/10	7/7	5/5
Ŋ	—	—	1/7	1/5
L	—	1/10	2/7	2/5
R	—	2/10	4/7	1/5
W	—	1/10	5/7	3/5
J	3/10	4/10	4/7	1/5
H	2/10	6/10	4/7	4/5
NO C	1/10	10/10	7/7	5/5

while *turtle* and *yellow* are L-words. At 25 words, there are virtually no consonants left to explore, but Sean's phonetic preferences may be discerned through the numbers of words in the different categories: 5 for each of the dental segments and [k], 12 B-words, 7 M-words, and 5 R-words (adding *Burt, farmhouse, rainbow, rock,* and *rose,* though *rainbow* and *rose* are produced with [w] not [r]).

We see here the children's selection of a gradually expanding range of phonetic word types. For some children, progress is relatively cautious and systematic, with "collections" of words all of a single type or two, while for other children expansion appears to go in all directions at once. (Compare also the persistent use of certain generally low-incidence phonetic categories by some children [Emily, Timmy, Andrew], versus shifting patterns of use over time by other children.) The overall picture of consonants "selected" is an orderly one, however, with regular increases in use between the first two stages (see Table 6; the drop in use for several segments at the 25-word point is probably due to the fact that only one session was sampled here, for each of only 5 children).

Words containing the labial and dental stops and nasals as well as K are clearly the most popular choice, with some selection already at the earliest stage and targeted use by all the children by the 15-word point. ETH, though not actually produced by any of the children, is attempted by over half at the 4-word point – presumably due to its constant salient use in deictics by the adults; H is the only other segment to be so widely targeted. The last remaining stop, G, F and the voiceless sibilants and affricate, and the glides and R all show progress to the point of use by half or more of the children by the 15- or 25-word point. L is selected by one child only at the 4-word point and by two children thereafter. The voiced affricate is targeted by one child at the 4-word point and by three children at the 15-word point. V is targeted by two children at the 15-word point only and word-final ŋ is targeted by one child at the 15-word point (Sean, *singing*) and by another at the 25-word point (Timmy, *ring*). The segment EZH, which occurs (usually intervocalically) in a restricted set of words, none of them likely to be addressed often to 1-year-olds, is the only segment never to be targeted at all.

Thus the place and manner of articulation categories that showed the highest means across all four time points on Table 3 (stops and nasals, labials and dentals) are also the categories according to which the children select their earliest words. The segments according to which words are least often selected include L, V, and THETA, all segments that typically prove difficult for children to produce in the early stages of phonological acquisition. Segments that are of high frequency in English are attempted even if they are difficult for children: these include the velars, the affricates, R, and especially ETH. In the expansion of word choice to include the less accessible segments, we see the pull of the adult language – but with different child strategies (cautious or systematic vs. bold or scattered) in response to the same adult language structure.[8]

Finally, Table 7 presents a schematic comparison of the word selection patterns of our subjects at the 15-word point and word-initial consonant use at a comparable point (when the active vocabulary has reached 50 words) for 19 children learning English (from Ferguson & Farwell, 1975; Shibamoto & Olmsted, 1978; Leonard et al., 1980; and Stoel-Gammon & Cooper, 1984; data from all but the last source are conveniently charted together in Grunwell, 1981, Table 1; cf. also Ferguson, 1986). For the three children whose data were presented in Ferguson & Farwell (1975), it was possible to carry out a word-selection analysis like that presented earlier, since the target words were included with the phones the children used. Thus such target consonants as THETA, ETH, and R were recorded, despite the fact that the corresponding segments were not actually produced. For the remaining children, only segments actually produced were charted, since the published studies do not indicate which words were represented by a given phone.

Despite the differences in method of analysis, the data for word selection by the 7 children in our study correspond quite closely with the data on segment use by the 19 additional children. For half the segments (12/24), the level of use we found corresponds exactly to that reported for the other children. That is, all the children attempted B- and M-words or produced [b] and [m]; over half, but not all, attempted G-, ESH-, W-, and H-words or produced [g], [ʃ], [w], and [h]; at

Table 7. *Comparison of word selection at 15-word-point (7 Stanford subjects) and initial consonant production by 19 other English-speaking children with 50-word vocabularies*

	Stanford	Others[a]		Stanford	Others[a]
p	×	+	ʃ	+	+
b	×	×	ʒ	0	0
t	×	+	tʃ	−	−
d	×	+	dʒ	−	−
k	×	+	m	×	×
g	+	+	n	×	+
f	+	−	ŋ	−	−
v	−	0	l	−	−
θ	+	−	r	+	−
ð	+	−	w	+	+
s	−	−	j	+	−
z	−	−	h	+	+

[a]Data derived from Ferguson & Farwell (1975), Shibamoto & Olmsted (1978), Leonard et al. (1980), and Stoel-Gammon & Cooper (1984).
Note: × = all children in study; + = over half but not all children in study; − = more than one but less than half children in study; 0 = none of the children.

Table 8. *Comparison of highly variable phonetic categories in babbling and early words with phonological processes used at age 2*

Phonetic categories	Mean % use over time & Ss	Corresponding processes[a]
Reduplicated consonants	23%	Reduplication
Nasals	19%	—
Velars	17%	Velar fronting
Contrasting consonants	15%	Consonant harmony
Polysyllables	13%	Weak syllable deletion
Final consonants	11%	Final consonant deletion
Fricatives	10%	Stopping
Consonant clusters	5%	Cluster reduction
Liquids	3%	Gliding
—		Context-sensitive voicing

[a]Based on Grunwell (1981), Table 3 (p. 175).

least one but less than half the children attempted words with S, Z, T.ESH, D.EZH, and L or produced those segments; and none of the children attempted a word with EZH, though one of Stoel-Gammon's subjects produced two words in which [z] and [ʒ] were sometimes used. Of the remaining segments, none differ

by more than one level of use. For example, P, T, D, K, and N were attempted by all the children in our study and were produced by over half the children in the remaining studies (Ferguson & Farwell's K used [d] only for ETH-words).

This rough comparison simply serves to corroborate our impression that the seven children in our study who acquired a vocabulary of close to 50 words (children for whom detailed data are available on the origins of phonetic preferences in the babbling period) are indeed representative of children learning English generally, insofar as the phonological profile of their early lexicon is concerned.

Phonetic preferences and phonological processes

The result that stands out most clearly from our data, we believe, is the degree to which the children differ in their incipient phonological behavior from the first data point examined here. In each of the areas investigated – phonetic tendencies, consonant inventory, and word selection – the prevalence of individual variation was the strongest lesson to be learned. We mentioned earlier that the phonetic categories of low incidence (9 out of 15 parameters analyzed) are those that vary in early phonological learning and thus those to which early phonological processes apply for some children.[9] It seems plausible that the source of those processes are production difficulties foreshadowed in the low frequency of occurrence of the phonetic segments in question in the babbling period, a distributional story eloquently told by our longitudinal analysis of the children's phonetic trends.

Grunwell (1981) presents a convenient "chronology of phonological processes" (p. 175). Her chronology begins at age 2, when the child is likely to have an active vocabulary of 50 words or more and may thus have begun to go beyond a lexically based organization to create a genuinely phonological system. Grunwell includes nine broad types of process in her chronology (see Table 8). Eight of these processes can be directly related to the low incidence categories in our data and, conversely, seven of our low incidence categories correspond to one or another of the phonological processes Grunwell lists.[10]

The category of **reduplicated consonants** (over all disyllabic vocalizations), unlike the other categories, represents not a phonetic parameter to be achieved in the process of mastering the adult language but rather a primitive property of the phonetic structure of babbling and early words, for some of the children (cf. Ferguson, 1983). It is, if anything, a mark of relative immaturity in the child's phonetic production, since we would expect to find the highest incidence of reduplicated consonants shortly after the emergence of canonical babbling, at 6 to 8 months. It does correspond to a phonological process used at age 2, but this is the only process that, according to Grunwell's chronology, has generally been outgrown by age 2;6.

The next most common low-incidence category, that of **nasals,** is the only one to be involved in no one phonological process widely used in early speech production. Nasals may be assimilated to other manners of articulation as part of consonant harmony (Vihman, 1978), though they are more likely to assimilate fricatives and liquids themselves; and their use is sometimes avoided at first

(Vihman, 1976). But they do not present a problem in early speech. We saw that at least one nasal was an established part of the consonant inventory used by each of the children in words by the 15-word point (though one child, Timmy, used no nasals in babbling at that point), and all seven children were targeting words with both nasals by the 15-word point. That variability in the use of nasals does extend to early word production is suggested by Ervin-Tripp's (1966) revision of Jakobson's predictions regarding the order of acquisition of contrastive segments. Whereas Jakobson (1941/1968) had predicted that "the first consonantal opposition is that of nasal and oral stop" (p. 47 f.), with a stop/fricative opposition only much later, Ervin-Tripp makes the more general prediction that "a stop-continuant (/p/ versus /m/ or /f/) contrast is quite early for all children, the continuant being a fricative *or* nasal" (p. 68; emphasis added).

The well-known difficulty some children experience in producing **velars** is evident in our data (cf. Table 3), where, at the 15-word point, the proportion of vocalizations with velars as the first or only true consonant ranges from 7 to 47%. In Grunwell's chronology the process most commonly applied to velars, fronting, is marked as commonly occurring up to age 2;6, with some use thereafter to about age 3;3. Among our subjects, just one made regular use of this process at age 3 (Vihman, 1984), but three out of seven show some use of velar fronting in their early words.

The relatively low mean incidence of **contrasting consonants** (over all polysyllabic vocalizations) – with a range from 6 to 33% at the 15-word point – seems to be directly related to the common use of consonant harmony, or assimilation of consonants at a distance, in early language use. That is, most of the children do not naturally produce a large number of contrasting consonants in their babbling and early words. Though the consonant harmony process may become established for a given child *after* use of contrasting consonants in some words (cf. Vihman, 1978), it can be assumed that deliberately targeting, or planning to produce, two different places or manners of articulation in a single vocalization (or word) requires some attention, an expenditure of energy that the imposition of some systematic production pattern – such as one involving consonant harmony – will at least partially obviate (cf. Menn, 1983).

The category of **polysyllables** shows a distinct change in mean frequency from the 15- to the 25-word point. Whereas means for the first three stages are roughly the same, all five of the children who reached the 25-word point show lower levels of use of polysyllables at that stage. In the early periods of relatively higher use, polysyllabic strings include reduplicated and variegated babble, "jargon" (sequences of unequally stressed syllables with varied consonants and a unifying intonation contour, in which one or more recognizable words are sometimes embedded), strings of repeated words, including both onomatopoeia ([ʔuhʔuhʔuhʔuh] *woof-woof-woof-woof:* Deborah, 1;2.6) and more standard words ([pepipipipipwipʻi] *piggy-piggy-piggy-pig:* Emily, 1;2.8), and "extended words," in which extra syllables are added to an adult-based word-shape (e.g., [tʻɞ̥tʻəweweɛ̃i] *turtle* [imitated]: Deborah, 1;2.6; for discussion of the extended word phenomenon, see Vihman, 1986). At the 25-word point, then, the lower incidence of polysyllables seems to reflect the children's reduced use of

the looser, more experimental long strings in favor of more controlled attempts at mono- and disyllabic words. (Recall that word tokens make up 64% of all vocalizations at this point, on average across the five children.) This may be seen as a rare instantiation in our data of the reduction of the "wild" or more experimental sound production that Jakobson (1941/1968) saw as characteristic of the babbling period, in favor of a more organized or systematic kind of sound production as language is acquired.

Some longer words are attempted, however (24 out of 326 words used across all sessions analyzed by the seven subjects who reached the 15-word point, or 7%, counting compound words such as *pat-a-cake* and *peanut butter*). For the more common long words – those often heard and probably often attempted as well – the process of weak-syllable deletion is usually applied (cf., e.g., Timmy's [nɛna] for *banana*, Deborah's [sisi] for *Sesame Street*). In the extreme case, all but one or two of several syllables may be missing in the child's rendition; in that case, Nettelbladt's (1983) term "extraction," in which the child seems to "extract" or "choose" only one portion of a model word in the attempted replication, may be more appropriate (e.g., Andrew's [k'ap'a] in imitation of *hippopotamus*). In other cases, "unique reduction devices" (Ferguson, 1978b) may be used, in which the child matches the syllable count of the adult word at the expense of segmental accuracy (cf. Sean's [təvəra:oˀ] for *dinosaur*). According to Grunwell's chronology, weak-syllable deletion continues to be applied with some regularity up to age 3;6 and occasionally for 6 months thereafter.

The low incidence of **final consonants, consonant clusters, fricatives,** and **liquids** is a widely recognized characteristic of both babbling and early words (cf. Oller et al., 1976). For each of these parameters of the adult language there is a characteristic corresponding phonological process applied by children (see Table 8). Grunwell's chronology shows that each of these processes is regularly used by many children until nearly age 3, with less consistent use thereafter.

DISCUSSION

We can now evaluate the extent of common tendencies and individual differences in the phonetic productions of our subjects. In examining the phonetic tendencies presented on Table 3, we found considerable diversity or individual variation from the very beginning of the period studied. Some categories showed relative uniformity, however. The preference for stops is consistently found over all four data points, with stops occurring in over half the children's vocalizations, on average; this also agrees with the three reports on babbling in 11- to 12-month-old American infants compiled by Locke (1983), in which the voiced stops are of high frequency in all three studies and the voiceless stops are also among the 12 most frequent consonants in two of the studies. Our data are thus congruent with the notion that stops are somehow biologically "given," or physiologically basic, in speech production. Note that stops occur in all the world's languages in at least two places of articulation, but more typically in

three or four (Maddieson, 1984: 86% of the 317 languages whose inventories make up the UCLA Phonological Segment Inventory Database [UPSID] distinguish three or four places of articulation; none lack stops). The nasals, on the other hand, were a low-incidence category in our data, with relatively high use by some subjects at each stage but also negligible use (under 10%) by other subjects. Given the presence of at least one nasal, usually two or more, in each of the world's languages (Maddieson, 1984: 95% of the UPSID languages include two or more nasals), one might have expected to find more consistent preference for nasals across all subjects in babbling and early speech.

In addition, the children show a unanimous preference for short vocalizations, especially monosyllables, throughout the period investigated, with low use of polysyllables. Though short vocalizations of this kind are present from the time of emergence of syllables and true consonants (cf. Oller, 1980, p. 99), the use of relatively few long consonant strings in the course of interaction with adults may already reflect the influence of the ambient language. Recall that two children made over 25% use of polysyllables at the earliest time sampled, though none did so thereafter. When alone, most of the children indulge in a greater proportion of long nonword vocalizations, perhaps in play, practice, or exploration of their own capacities (Miller & Vihman, in preparation). The use of more short nonword vocalizations with the mother than when alone suggests accommodation to the mother's presence. In this period, the children are beginning to target a few words to say, generally restricting themselves to one- or two-syllable models. There is also some dialogic use of mono- and disyllabic babble even before the first use of words (Vihman & Miller, 1986). The children may therefore be predominately making use of short nonword vocalizations while interacting with their mothers because those short vocalizations are most like the adult words they are beginning to understand and to target in early word use.

As regards the low incidence categories, we found virtual *nonuse* of the categories of liquids and consonant clusters throughout the period investigated (i.e., no child used either category in 25% or more of the relevant vocalizations). Here again the data are not ideally congruent with patterns of distribution in the world's languages. Liquids are almost as widespread as nasals (Maddieson, 1984: 95.9% of the UPSID languages have at least one liquid, while 96.8% have at least one nasal), and consonant clusters also occur in the vast majority of languages (e.g., 92, or 88%, of the 104 languages sampled in Greenberg, 1978 are reported to have clusters in word-initial position).

It is in the place-of-articulation categories that we see the strongest pattern of increasing uniformity as knowledge of language increases. Labials and dentals become moderately frequent for all the children by the 15-word point, while velars show an increase in variability at the 4-word stage but reach a uniform low level of use at the 25-word point. In adult English, alveolars are much more common across all word positions than labials and velars, though if stops and nasals alone are considered, labials slightly outweigh alveolars in initial position (Mines, Hanson, & Shoup, 1978). The increase in both labials and "dentals" (= dentals, alveolars, and palatals) as word use begins to increase can thus be taken to reflect the influence of the adult language. In addition, the association of

labials with word use may derive from the *visibility* of labial articulation, since this added factor may help the children to achieve controlled production of specific word targets. The fact that no such bias toward labials has been found in the early word-phonology of blind children supports this interpretation (see Mills, in press; Mulford, 1986). Thus the emergence of uniformity in the data for these phonetic categories most likely represents an early step in the learning process, reflecting influence from the environment.

A comment is in order here about the relative frequency of the different places of articulation in infant vocalizations. The dominance of velars in what Oller (1980) calls the "gooing" stage is well documented, though velar production here is not embedded in syllables with adultlike properties as regards timing, resonance, and intensity changes (Oller, 1986). The early velars are perhaps best regarded as proto-consonants; prior to the emergence of canonical syllables, fully adultlike consonant articulations are not consistently produced. Based on data from nine normally developing children reported by Smith & Oller (1981), Locke (1983) surmised that there is a natural tendency for alveolars to succeed velars as the dominant place of articulation at about 6 to 9 months. Furthermore, given Smith's (1982) data on the later babbling of hearing-impaired infants recorded up to age 2;6, Locke concluded that the biological program, if allowed to run its course free of bias from adult language input, would result in the eventual dominance of labials over alveolars, beginning at about 15 months. In Locke's words, "one might suppose . . . that environmental influence begins [for hearing children] *before* the child's internal program has been fully executed and that acquisition in the normal child masks the free and complete expression of the child's biological code" (1983, p. 38).

Our data prompt us to offer a cautionary note. The means for labials and alveolars (Table 3) are scarcely distinct in our data, even at the 0-word stage, when the adult language can as yet have exerted only minimal influence. More important, the large standard deviations for both categories at the first two stages effectively preclude drawing any conclusions about order of dominance. For example, though the mean value for labials is a little over 40% at both the 0- and the 25-word stage, the range at 0-words is 9 to 86% while at 25 words the range is 29 to 46%. Thus our data suggest, first, that there is no clear difference in dominance over time for the labials versus the dentals, though either category alone clearly surpasses the incidence of velars, a general trend noted in all previous studies (cf. Smith & Oller, 1981). Second, we are reminded again to exercise caution in the interpretation of group means, when the standard deviation is large.

The other major category, that of the true consonants, shows moderate means at the early stages but increasingly large means, as well as a lower level of variance, at the 15- and 25-word points. We take increasing use of true consonants to result from a process of attention to the sounds of language and an interest in reproducing them that is first evidenced at the time of emergence of canonical babbling, at about 6 to 9 months. Here again the children can be seen to be developing in the direction of the adult language, where words including true consonants undoubtedly outnumber those lacking such consonants.

Smith and Oller (1981) have shown that the timetable for the emergence of canonical babbling in Down's syndrome infants is surprisingly close to that of normally developing infants. This unexpected result led Smith and Oller tentatively to conclude, with Dodd (1972), that "babbling may not be a largely learned behavior" (p. 50). If the emergence of canonical babbling, marking the beginning of the period of steady growth in use of true consonants (cf. Holmgren, Lindblom, Aurelius, Jalling, & Zetterström, 1986; Koopmans-van Beinum & Van der Stelt, 1986), were entirely maturational, the same timetable could be expected to obtain for deaf infants as well. Recent studies suggest that this is not the case, however. Whereas hearing subjects, despite other differences, agree in producing a high level of canonical babbling by 10 to 12 months, even carefully screened, singly handicapped deaf infants have not been found to reach the canonical stage by 12 months of age (Oller, 1986; Oller et al., 1985). It has been suggested that Down's syndrome children "manifest a 'cumulative deficit' in their development. That is, they tend to appear most normal early in life, and differences become increasingly greater with time" (Smith & Stoel-Gammon, 1983, p. 114). It seems that canonical babbling, and in general the increase in use of true consonants over the transition period, depends on auditory exposure and thus must to some extent reflect learning as well as physiological maturation, but the level of cognitive advance necessary for learning of this kind must also be low enough to allow Down's syndrome children to reach the critical threshold with only minimal delay.

Of the remaining categories, contrasting consonants first show as much as 25% use by some children only in the last two stages while final consonants (the only category to show an increase in variance in the period studied) first come to be used at the 25% level by two out of five children at the 25-word point. Here again the association with increasing language use – and the effect of increasing exposure to English – seems likely. The level of use of contrasting consonants differs across languages. Thus, in Vihman (1978), the three 2-year-old Chinese-speaking children included were found to show a higher proportion of words lacking consonantal contrast in the adult model than the three English-speaking, two Estonian-speaking, three Slavic language-speaking or two Spanish-speaking children. In comparison with our data from children exposed to English, then, we might expect some delay in the first significant level of use of contrasting consonants in the vocalizations of Chinese-speaking children. Similarly, one might predict that infants acquiring a language with restricted use of final consonants would not yet show as much as 25% use of that category at a comparable point in their lexical development.

Of the other two low incidence categories, reduplicated consonants show relatively more uniform use from the 4-word point on, while fricatives show only small changes in variance; for both categories, there is 25% or greater use by some subjects at every stage. Given the structure of English, a higher level of use of fricatives and a lower level of use of reduplicated consonants should be the ultimate effect of increased language learning, but neither of these patterns is in evidence as yet in our data.

By the time they were using 15 different words in a session, then, all of our subjects were generally capable of producing mono- and disyllabic target words,

true consonants including stops and nasals, and both labials and dentals, and some were also beginning to produce final consonants, contrasting consonants, velars, and fricatives. Our data suggest that by this time the children have already been markedly influenced by the language they are exposed to and have begun to modify their own sound productions accordingly. There remain considerable phonetic and phonotactic difficulties for the children to overcome in the course of the next few years.

The period that extends roughly from the time the first 50 words have been acquired to age 3 or 4 is one of accelerated language acquisition, in the course of which systematic phonological processes first come to be applied and then are gradually discarded. We have seen that the common phonological processes used in early language production can be related to the low and variable incidence of the corresponding phonetic parameters in babbling as well as in early words. Maintaining the dichotomy of biology versus environment, we can distinguish between those processes that seem most "natural," or inevitable, given a phonetic gap in the child's repertoire, and those that seem more "cognitive" (i.e., those that must involve more active problem-solving at some level). Thus the processes involving deletion may result from failure to perceive or to store phonetic features that the child's own productions lack (i.e., weak-syllable deletion, final consonant deletion, cluster reduction: cf. Berman, 1977; Dinnsen & Elbert, 1984; Ingram, 1974), and reduplication might result from matching the child's repertoire against the adult target at the level of prosodic structure with little attention to segmental detail. On the other hand, the processes that involve substitutions (velar fronting, stopping, gliding, and consonant harmony, as well as unique reduction devices) seem often to involve a larger element of choice or strategy and to play a role in the child's active organization and systematization of his phonetic output – that is, in the development of a genuine phonological system.

It is clear that children vary in their phonetic preferences and abilities, and undoubtedly in their perceptual capacities as well, though that was not tested here. We do not know the origins of individual phonetic preferences during the babbling period. If we can assume that there were no sharp discrepancies in the input language for our subjects, then we must suppose that, in language as in temperament (cf. Thomas, Chess, Birch, Hertzig, & Korn, 1963), children can simply be expected to differ from the start. From a broader biological perspective, the individual differences evident in our data and hypothesized to hold for all children may constitute a reservoir of genetic variability that offers a means for adjusting to changes in environmental demands and makes possible the range of linguistic and cultural diversity that is such a significant characteristic of the human species (cf. Studdert-Kennedy, 1986).

CONCLUSION

We have taken as our point of departure Locke's biological model, which posits relative uniformity in early vocalizations across all speech communities, in contrast with a learning-based differentiation of later vocalizations determined by the characteristics of the particular language of the environment. Using lexical rather

than chronological points for comparison across subjects, we have considered in some detail the evidence of the development of vocalization patterns in ten subjects during the transition from essentially no words to a cumulative vocabulary, by parental report, of about 50 words. Some common patterns of early vocalization were indeed apparent, such as the predominance of monosyllabic, open-syllable vocalizations and the tendency to early appearance of voiced labial and dental stops and of nasals. But while a certain commonality was present from the beginning, we have also noted striking individual differences and have generally seen change in the direction of greater uniformity as knowledge of language increases. Ultimately, of course, the dichotomy between biology and environmental factors is artificial, as the two necessarily interact in the child's development. Both maturation and learning must be involved, for example, in what may be considered the first step toward language-like vocal production – the emergence of canonical babbling. Both must also play a role in the later shift to uniformly high use of true consonants, which takes place toward the midpoint of the period investigated here.

In addition to differences in particular phonetic preferences, our subjects differed, like those of Ferguson and Farwell (1975), in their general approach to the acquisition of phonology. Where some children proceeded systematically, with a consistent pattern of preferences over time and a tendency to consolidate gains before exploring new territory, others advanced in a less cautious, seemingly more haphazard way. These differences are apparent in the children's differing patterns of growth in consonant inventory as well as in their patterns of word selection.

Finally, we observed that the phonological processes widely found to apply over the time of greatest phonological growth, from 1 to 3 or 4 years, are rooted in the phonetic tendencies of the prelinguistic period. Given a mismatch between child repertoire and adult target, some processes will follow more or less automatically while others involve an element of choice and thus seem to reflect active attempts at systematization and even creative problem-solving.

Locke raises the question, "When does phonology begin?" Like him, we find that the origins of phonology must be traced to the prelinguistic period. However, we have found variability and individual differences to be the hallmark of infant vocalization from the beginning, with differing early consonant inventories and differing word choices based in part on different phonetic preferences, expressed in babbling as well as in words. Insofar as the acquisition of a phonological system implies organization and choice, we again place the origins early, with periods of dynamic change, systematization, organization and reorganization alternating with more stable plateaus at varying points for individual children from the start of lexical and phonological growth.

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NOTES

1. In the present study we accorded word status to a given vocalization only if we felt sufficiently confident that that particular token was being used in a way that could reasonably be related to a specific adult source word. That is, we will not apply here the "extension convention" whereby Vihman et al. (1985) counted as words all vocalizations closely resembling other vocalizations classified in the same session as words on contextual grounds, as, for example, when a child playfully babbles, without referential value, a vocalization that functions as a word elsewhere.
2. Use of lexically based points of comparison meant that only four sessions could be sampled in the case of the three children whose lexical advance was slower (a 0-word point session and three sessions from the month when 4 words were first used).
3. As pointed out in Vihman et al. (1985), the categories within these parameters sum to 100%, so that dominance by any one category means a proportionately lower level of use for the remaining categories. For example, stops dominate the manner parameter throughout the period under study for virtually all the children, so that the three remaining categories, which share less than 50% of the variance, are necessarily at a relatively low level.
4. On Table 3 the subjects are ordered, first, by stage reached, beginning with the five subjects who produced 25 or more words in a single session by the end of the study, followed by those who produced 15 words, and then those who produced less than 15. Within those groups the children are ordered, somewhat arbitrarily, by the mean percent word-token use across the three 4-word sessions.
5. Cf. also Oller, Eilers, Bull, & Carney (1985), whose recordings of 11 subjects showed "large intersession differences" and strong individual differences across subjects already at age 4 to 13 months.
6. Though 7 out of 10 children made use of obstruent + liquid clusters at some point, none did so as much as four times in a single session, so no clusters appear in the inventories on Table 5.
7. The number-words, used repeatedly, as were many of Molly's words (see the type/token figures in Vihman et al., 1985), were part of a counting sequence that began with "one, two, three, four" but soon disintegrated into fragments. The "meaning" of these words for Molly herself – if any – is obscure.
8. We have not analyzed the recorded adult input so as to compare the phonetic categories used by the different mothers, but we would be surprised to find significant differences in input at this level. In fact, Leonard et al. (1980), who followed the early phonological development of identical twins, found individual differences in early consonant usage even with a virtually identical linguistic environment.
9. We use the currently popular term "phonological process" loosely here, to refer to typically observed relationships between adult and child production patterns. We do not mean by our use of the term to ratify related theoretical constructs, including the notions that processes derive from a universal, innate phonological capacity (cf., e.g., Stampe, 1969) and that children's underlying representations are necessarily equivalent to the adults' from the start (Smith, 1973).
10. Voicing was not analyzed as an independent phonetic parameter because of the great difficulty in achieving reliable transcription of voicing by ear.

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