

Language acquisition and language universals

From babbling to first words in four languages

Common trends cross language and individual differences

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The aim of this paper is to compare the developmental trajectory of speech production capacities in children acquiring different languages from the babbling period to the emergence of early grammar. The question of phonetic continuity between babbling and the early lexicon was addressed with the following questions: Do children across languages follow universal trends described previously? Are sound patterns used in babbling the same as in first words across languages? How do child patterns compare with ambient language patterns? We collected and imposed a uniform analysis profile on large corpora for four diverse languages: French, Romanian, Dutch and Tunisian Arabic. Fifteen children developing normally in a monolingual environment according to community standards and reports from parents and physicians regarding developmental milestones were observed in their typical daily environment. One hour of spontaneous vocalization data was audio and video recorded every two weeks from 8 through 25 months. 529 hours were recorded and transcribed using International Phonetic Alphabet conventions. Lexical and phonetic characteristics were longitudinally analyzed for each of the four languages. Second, minimally 1,000 dictionary entries from the ambient language employed by the parents of each child participant were analyzed for comparison with the child data for that ambient language. Our consistent data collection methods allow consideration of common trends, individual and cross-linguistic language differences in child and in ambient language databases. Despite individual differences found within and across languages, the majority of children tended to follow the common trends reported in the literature. Our data allowed us also to consider with the question of continuity across babbling, first word, and later word periods. Results indicated that phonetic complexity expands after the lexical spurt. This increase in complexity could be related

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to increasing control over speech articulators as well as increase in cognitive and perceptual capacities for matching language forms. To answer our second question regarding the influence of ambient language input, we compared child frequencies to patterns in the 1,000 word dictionary data for each language. These results indicate that input does not play an obvious role in observed patterns across these languages; children are more like one another across languages than they are like their ambient language in this early period.

Introduction

Emergence of complexity in modern child speech output affords a unique opportunity from the perspective of contemporary ontogeny to view potential correlates of complexity emergence across the deep historical process of language phylogeny. Modern language illustrates a pinnacle achievement of system based complexity. This complex system enables humans to achieve mutually intelligible communication using a symbolic system to code an infinite array of topics. Linguistic communication is further shaded by the nuances of linguistic, cultural and social norms in the 5–6,000 modern languages spoken today. Phonological systems in these widely diverse modern languages and language families illustrate the vast array of choices made by speakers throughout the phylogenetic process in implementation of vocal system capacities for sending and receiving messages. In the deep history of language evolution, speakers in diverse communities implemented distinct and disparate capacities of the production system in service of message transmission. These diverse systems of ambient language phonological regularity were driven by the need to increase the complexity of messages sent and received in the vocal medium as social cultures grew in complexity as well (see d’Errico et al., this volume, for a perspective from archaeological investigations).

In modern infants, early speech output patterns based on maturation of immature physical production systems are intertwined with emergence of sound patterns reflecting phonological distinctions for coding messages. Ambient language differentiation is based on learning processes as well as on implementation of more complex patterns produced by the child in the speech output system. Similar to the phylogenetic process, emergence of ambient language speech production patterns in ontogeny shows movement from simple vocal output systems at the onset of speech like canonical babbling (Kern & Davis, 2009) toward more complexity of movement patterning as infants gain cognitive, motor and perceptual capacities to send and receive increasingly complex messages (see Vihman, 1997, for a review). One primary question arises: when do infants begin to display in output the precise regularities particular to their own ambient language? An additional question

in understanding emergence of complexity concerns the order in which components of vocal output related to ambient language regularities emerge. Order of emergence of these precise phonological regularities unique to each infant's ambient language community is founded on multiple variables. Paramount foundations of learning of ambient language regularities in modern infants include the status of speech motor output systems (e.g., Green et al., 2002; Boliek et al., 1997) as well as perceptual capacities for learning nuanced ambient phonological characteristics from adult ambient language input (e.g., Werker & Curtin, 2005; Saffran & Aslin, 1997). Of considerable importance as well in understanding potential connections of ontogenetic findings to phylogeny is the relationship of cognitive capacities to emergence of systematic phonological knowledge and behavioural capacities. Individual differences in infant developmental trajectories within and across languages provide a critical dimension of inquiry needed for understanding the course of ontogeny comprehensively. To the extent that children's vocal output patterns are more diverse within and across languages than they are consistent, cognitive processes are implicated in understanding the course of phonological development. In contrast, consistent vocal output trends with little individual variation implicates production system constraints in the context of early emergence of perceptual learning capacities (Saffran, Aslin, & Newport, 1996).

Available studies of early periods of ontogeny relative to common vocal output trends and emergence of ambient language learning are prominently centered on the canonical babbling and early single word periods of development. These studies indicate common effects in production patterns as well as some indication of early appearance of output patterns related to input from the ambient language. To understand the interaction of patterns based on production system propensities common to all infants versus the role of early learning from unique environmental regularities in the ambient phonology, it is important to examine diverse languages that produce targets for learning outside the common characteristics suggested as being present in many infants across languages. That is a major goal of this program of study. The larger philosophical goal is to consider the nature of these patterns as the illuminate understanding of the process and the behavioral correlates of emergent complexity in the evolution of the vocal capacity in early speakers.

Early development of speech production capacities in modern infants

Prelinguistic vocalizations of modern infants, in the period before language emerges have been frequently studied. These earliest speech like patterns, termed canonical babbling (Oller, 2000), are perceptually similar to early language based speech output but do not code meanings. These vocalizations show common patterning across languages (Kern & Davis, 2009). A near universal basis for babbling

has been postulated based on available studies. Similarities in sound types (i.e. “b” or “d”), sound combinations (e. g., “ba”, “da”, “ku”) and utterance types (e. g. simple CV or CVCV utterances such as “ba” or “dadi”) preferences across different language communities have been frequently documented.

Consonants most frequently reported are stops (total occlusions, e. g., “p”), and to a lesser extent, nasals (e. g., “m”) and glides (e. g., “w”) (Locke, 1983; Roug, Landberg & Lundberg, 1989; Stoel-Gammon, 1985; Vihman *et al.*, 1985). During the babbling period, children tend also to produce many coronals (tongue tip, e.g., “d”) and labial (lip closure, e. g., “b”) consonants (Locke, 1983) and few dorsals (tongue back, e. g., “k”; Stoel-Gammon, 1985). Vowels from the lower left quadrant of the vowel space (i.e. mid and low front and central vowels; e. g., “ah” or “uh”) are most often observed (Bickley, 1983; Buhr, 1980; Kent & Bauer, 1985; Lieberman, 1980; MacNeilage & Davis, 1990; Stoel-Gammon & Harrington, 1990). Languages exhibit great diversity in consonant and vowel sound types, but coronal place and stop and nasal manner of articulation are present and predominant in a large number of world languages (Ladefoged & Maddieson, 1996). Oral occlusives are more frequent than nasals in child repertoires and in language inventories. Front and central vowels are also prominent in inventories across languages, although vowel diversity is quite broad in languages compared with early child production patterns.

Children tend to favor open (CV, e.g., “da”) as opposed to closed (CVC, e.g., “cot”) syllable types (Kent & Bauer, 1985; Locke, 1983; Oller & Eilers, 1982; Stoel-Gammon, 1985; Vihman, 1992). These common infant preferences, found in babbling and first words, are retained in some languages. Syllable types show the open syllable as the only universal syllable type in languages (Maddieson, 1984).

Speech sounds in vocal utterances are not produced alone but as a series of alternations of consonants and vowels. This phenomenon of serial ordering is one of the most distinctive properties of speech production. MacNeilage and Davis (1993, 2000) have tested a model termed the “Frame-Content Theory” to characterize the serial organization of vocalizations in babbling (Davis & MacNeilage, 1995), first words (Davis, MacNeilage, & Matyear 2002), and languages (MacNeilage, Davis, Kinney, & Matyear, 2000).

In the Frame-Content Theory, biomechanical based predictions have been made regarding both intrasyllabic and intersyllabic regularities in vocal output. Intrasyllabic consonant-vowel alternations form the basis for syllables in spoken language. In pre-linguistic canonical babbling, they are proposed as being based on rhythmic close-open mandibular oscillations accompanied by phonation. These rhythmic mandibular oscillations (termed “frames”) comprise the production system based unit within which speech-like behaviors first emerge. As children gain control over the independent coordination of articulators (including

tongue, velum, and lips) within utterances, individual speech sound movements (i. e., “content”) are gradually differentiated to become separate entities in production and perception.

In babbling and first words, “frame dominance”, without independent control of other active articulators, produces predictions for patterns within spoken utterances. Three preferred intrasyllabic co-occurrence patterns emerge from this hypothesis. These co-occurrences are for coronal (tongue tip closure) consonants to occur with front vowels (e.g. “di”), dorsal (tongue back closure) consonants to occur with back vowels (e. g. “ku”), and labial (lip closure) consonants to occur with central vowels (e.g. “ba”). In each of these intrasyllabic sequences, the tongue does not move independently of the jaw within the syllable, but stays in the same position for the open portion (vowel) of the syllable as the jaw opens as it was for the consonant closure portion.

Recent studies have tested predicted serial patterns within utterances in the babbling and early speech period in English and a variety of other languages. In an English language environment studies of 6 children during babbling (Davis & MacNeilage, 1995) and 10 children in first words (Davis, MacNeilage & Matyear, 2002), confirmed predicted patterns at above chance levels using chi square analysis. Predicted intersyllabic and intrasyllabic trends have also been found in analyses of 5 French children, 5 Swedish children and 5 Japanese children from the Stanford Child Language Database (Davis & MacNeilage, 2000), one Brazilian-Portuguese learning child (Teixiera & Davis, 2002), 7 children acquiring Quichua (Gildersleeve-Neumann & Davis, 1998) and 7 Korean children (Lee, Davis & MacNeilage, 2007). While these patterns have not been confirmed universally in these studies, they are present in every language and account for the predominant trends in serial output organization when the corpora are large enough to test predictions.

The very strong persistence of some child patterns in languages as well as their presence at the onset of speech-like vocalizations in infants indicates that they reflect fundamental properties of the speech production system. When patterns are retained in languages, they do not merely represent an aspect of the acquisition process disappearing with maturity of the vocal apparatus. Both the common patterns and the language specific variants observed should have significant implications for understanding of the phylogeny of speech production complexity supporting modern language message transmission. It is possible, for example, that patterns common to all or most languages were present in the first spoken language, as they represent fundamental properties of operation of the production system. In contrast, language specific patterns are perhaps more likely to have emerged later in the phylogenetic process as individual languages diversified to increase the size of their respective message sets.

Perceptual influences on early speech production preferences

In addition to the strong presence of near universal trends at the onset of speech like production output, input from the ambient language plays a role in children's very early perception as early as 8–10 months (e. g., Werker & Tees, 2005). Input from the ambient language has been proposed as shaping children's production preferences at some point in the late babbling and first word periods. This potential for ambient language influence has been examined for utterance and syllable structures (de Boysson-Bardies, 1993; Kopkalli-Yavuz & Topbas, 2000), vowel and consonant repertoires (de Boysson-Bardies, Hallé, Sagart & Durand, 1989; 1984; Lee, Davis & MacNeilage, 2008) and distribution as well as CV co-occurrence preferences (e.g. Lee, Davis & MacNeilage, 2007).

In one representative study, de Boysson-Bardies, Sagart & Durand (1984) presented naïve adults with sequences of early babbling of French, Arabic & Cantonese children. Participants were asked to identify the babbling of French infants. Listeners were correct in judging 70% of tokens, suggesting that babbling in the pre-linguistic period may show language specific intonation characteristics. De Boysson-Bardies, Hallé, Sagart & Durand (1989) also compared vocal sounds of French, English, Cantonese and Algerian infants. They proposed that the acoustic vowel distribution was significantly different for the 4 language groups. De Boysson-Bardies, Hallé, Sagart & Durand (1984) showed the same tendency within the infant's consonant repertoires. Their consonant data indicated significant differences in the distribution of place and manner of consonant articulation across the languages analyzed. French infants produced more labials than Japanese or Swedish infants. De Boysson-Bardies (1993) also examined syllable types. She compared Yoruba babbling to French, English, and Swedish babbling. She interpreted her findings as showing that French, English and Swedish children produce between 65% and 75% of CVCV disyllables, whereas Yoruba children produced 62% VCV word types. She attributed this difference to the particular structure of Yoruba, where most words begin with a vowel.

Levitt & Utman (1992) compared reduplication and variegation in babbling in French and American English-learning infants. They found that French infants showed significantly more reduplicated utterances during the babbling period (four or more syllables in length) than their American-English learning infant cohort. This type of result suggests an early effect of the ambient language related to the length of the prosodic word during the pre-linguistic babbling period.

Present research into early periods of speech ontogeny has most often included studies of small numbers of infants. Diverse methodologies have been employed for analysis. To ensure adequately large corpora of data for statistical analysis of patterns as well as to ensure consistent analysis procedures, we have collected and

imposed a uniform analysis profile on large corpora for five diverse languages. Our goal is to understand common trends as well as the timing and characteristics of appearance of language specific influences in the ontogenetic process of phonological acquisition in modern infants. An additional goal is to observe the process past the earliest periods to begin to understand the emergence of ambient language phonological regularities across diverse languages more fully.

Method

Participants

Fifteen children (nine boys and six girls) selected from four different ambient language environments participated. French (three boys and one girl), Romanian (two boys and one girl), Dutch (two boys and two girls) and Tunisian Arabic (two boys and two girls) participants were included. The languages studied belong to typologically diverse language families: French and Romanian are Romance languages, Dutch is a Germanic language and Tunisian belongs to the Arabic language family.

All children were members of middle to upper class families who were providing monolingual input to their children. Child participants were selected through informal search in each language community. Mothers were expected to participate in the interaction and elicitation of spontaneous language with their children every two weeks across a period of 17 months. Children with siblings as well as only children participated in the study. All participants were reported as being normally developing according to medical and educational reports from parents and caregivers based on community standards. Children were enrolled in the project by the age of eight months when their parents reported that canonical babbling was established. They were followed until the age of 25 months.

Data collection

One focus of the study was analysis of continuity between the phonetic characteristics of speech sounds and sound sequences in babbling with changes across the period of development of the early lexicon to 25 months of age. Data collection started at eight months, the period in which all the children were reported to have started producing canonical babbling. It was terminated at 25 months when all participants (except two Romanian children) were producing a large number of diverse lexical items. Data collected across the entire period was divided into three parts: the *babbling* period between eight months and the acquisition of the first words (around 12 months), the *early word* period between the first word and the

point where the child had acquired a language production of 50 words, and the *later word* period after the acquisition of the first 50 words.

During this data collection time frame of 17 months, one hour of spontaneous language data was recorded every two weeks in the normal home environment of the children. Each infant's vocal output was audio and video recorded.

Mothers participated in interaction during the recordings without any external instruction except to interact with their children as they normally would in daily care routines and in play. In total, 128 hours of babbling were collected; at least six hours per child. For the early word period, 269 hours of recordings were collected, with at least 11 hours per child. In the later word period, 132 hours of data were collected. Two Romanian children did not reach the 50 word level by the age of 25 months. No later word data is available for those two children. Table 1 shows the division of data collection relative to number of one hour sessions.

Table 1 Number of Sessions during Babbling, Early Word and Later Word Periods

Child	Number of sessions by period		
	Babbling	Early words	Later words
French 1	8	19	14
French 2	7	14	10
French 3	9	23	4
French 4	8	19	14
French Total	32	75	42
Romanian 1	8	16	–
Romanian 2	8	21	6
Romanian 3	10	23	–
Romanian Total	26	60	6
Dutch 1	10	18	5
Dutch 2	8	11	17
Dutch 3	10	12	16
Dutch 4	10	15	19
Dutch Total	38	56	57
Tunisian 1	6	15	6
Tunisian 2	10	19	7
Tunisian 3	7	22	8
Tunisian 4	9	22	6
Tunisian Total	32	78	27
Total	128	269	132

Language dictionaries

To compare the spontaneous vocalizations and word based data of the children with the ambient language of their environment, 1,000 entries from the language communities employed by the parents of each infant were collected from dictionaries available on computer. Dictionaries for French, Dutch, Romanian, and Tunisian were employed.

Data transcription

After collection, the child data was phonetically transcribed using the International Phonetic Alphabet (IPA). At the onset of the study, transcribers were trained in infant transcription. Broad phonetic transcriptions were used, supplemented by some diacritics (mainly for palatalized, pharyngealized, nasalized sounds and duration of sounds). Tokens considered as single utterance strings were bounded by one second of silence, noise or adult speech.

Transcribed sounds were perceptually divided into consonants and vowels by transcribers. Consonants were grouped according to 1) place of articulation: *labial* (bilabial, labiodental, labio-palatal and labio-velar), *coronal* (dental, alveolar, post-alveolar and palatal), *dorsal* (velar and uvular) and *guttural* (pharyngeal and glottal) and 2) manner of articulation as oral stops, fricatives, liquids, nasals, glides and “other” (i.e. trills, taps and affricates). Glides were considered as consonants as they share the consonantal property of accompanying the mouth-closing phase of babbling. Vowels were grouped according to 1) height: *high* (high and lowered-high), *mid* (higher-mid, mid and lower-mid) and *low* (raised-low and low) 2) *front/back*: front, central and back. An “other” category included all non-transcribable segments (UC, UV, US) that were not perceptually accessible to transcribers.

All transcribed data were entered for computer analysis using software designed for analysis of infant speech data, particularly the Logical International Phonetic Programs (LIPP, Oller and Delgado, 1990). LIPP is a database program designed to count data that has been phonetically transcribed using IPA symbols.

Data analysis

Six domains were examined for each participant: 1. Frequencies of consonant and vowel sounds, 2. Consonant manner of articulation, 3. Consonant place of articulation, 4. Vowel types, 5. Manner versus place change for consonants in CVCV sequences, 6. Height versus front-back change for vowels in CVCV sequences. To evaluate these structural sound pattern changes across periods several types of analysis were completed.

Means of early appearing sounds or structures were compared to the means of later appearing ones across the three periods in each of the four languages. T-tests were used to assess whether the means of the two groups of sounds or structures were statistically different across the three periods. Alpha level was set at .05. As number of participants in each language was small, with three to four participants, a qualitative analysis of individual child scores was included to understand individual differences within language groups.

A second analysis focussed on cross-language differences. Mean, standard deviation and interval of confidence were calculated for early appearing sounds or structures in each language. In the case of a standard deviation higher than 15 in a language group, the child furthest from the mean was excluded from analysis in order to work with a more homogeneous group. Interval of confidence allows the building of a confidence space for each language. The confidence spaces were then compared in a pair wise comparison. In the case of an overlap between two confidence spaces, the languages concerned were considered as exhibiting the same behaviour. In the case of no overlap, the languages were considered as presenting statistically significant differences.

The goal of a third analysis was to observe changes across the three developmental periods of *babbling*, *early words*, and *later words*. T-tests were used to verify whether the changes observed in sound patterns analyzed from 1) the *babbling* to the *early word* period and 2) the *early word* period to the *later word* period were significantly different from one another in each of the four languages. As it was the case for the first type of analysis, alpha level was set at .05 and a more qualitative analysis of individual children's scores was also conducted.

Results

Consonant and vowel frequencies

Consonants and vowel types transcribed for all participants across the four language groups are enumerated in Table 2. Table 2 shows that in the *babbling* period, children produced more vowels (60,378) than consonants (51,269). A Wilcoxon signed ranks test indicates that this difference is significant ($p=.009$). In the *early word* period, children produced an approximately equivalent frequency of vowels (21,952) and consonants (20,726). A Wilcoxon signed ranks test shows no significant difference ($p=.427$) between the two sound types. In the *later word* period, children produced more consonants (79,058) than vowels (72,646). Although they produced more consonants, a Wilcoxon signed ranks test showed that the difference was not significant ($p=.279$).

Table 2. Consonant and Vowel Frequency of Occurrence by Period

	Consonant and Vowel Frequencies by Period					
	Babbling		Early words		Later words	
Child	Cons	Vowels	Cons	Vowels	Cons	Vowels
French 1	3276	684	1043	1257	7078	7870
French 2	2003	2176	1149	1274	5477	5910
French 3	1464	4073	1934	3005	1725	1912
French 4	3213	4073	948	1131	10026	9545
French Total	9956	11006	5074	6667	24306	25,237
Romanian 1	1558	2026	2813	2265	–	–
Romanian 2	3115	4259	297	260	3804	4001
Romanian 3	2999	3654	1176	1192	–	–
Romanian Total	7672	9939	4286	3717	3804	4001
Dutch 1	5726	7284	2251	2054	1931	1902
Dutch 2	2870	2972	768	565	5442	4018
Dutch 3	1704	2418	1024	1077	10,636	9019
Dutch 4	4419	4885	635	554	17,517	13987
Dutch Total	14,719	17,557	4678	4250	35,526	28,926
Tunisian 1	2625	2995	1254	1028	1197	1033
Tunisian 2	5660	6597	1148	1367	4286	4252
Tunisian 3	4321	4804	2071	2421	8205	7217
Tunisian 4	6316	7480	2215	2502	1734	1798
Tunisian Total	18,922	21,876	6688	7318	15,422	14,300
Total	51,269	60,378	20,726	21,952	79,058	72,464

Consonant manner of articulation

The frequency of stops (oral and nasal) and glides were compared to fricatives, liquids and others (affricates, trill and taps) in the four languages individually, across the four languages and across the three time periods. The consonants have been grouped as function of their order of appearance: the stops and glides being in most cases described as “early appearing” sounds in children’s productions whereas fricatives, liquids and other types of consonants are considered as “later appearing” sounds. Figure 1 presents mean percentage of stops and glides and confidence intervals for French, Romanian, Dutch and Tunisian languages in *babbling* (8 to 12;15 months), *early word* (from the first words to the 50 word-mark) and *later word* (from the 50 word-mark to 25 months) periods. Finally, the mean percentages of

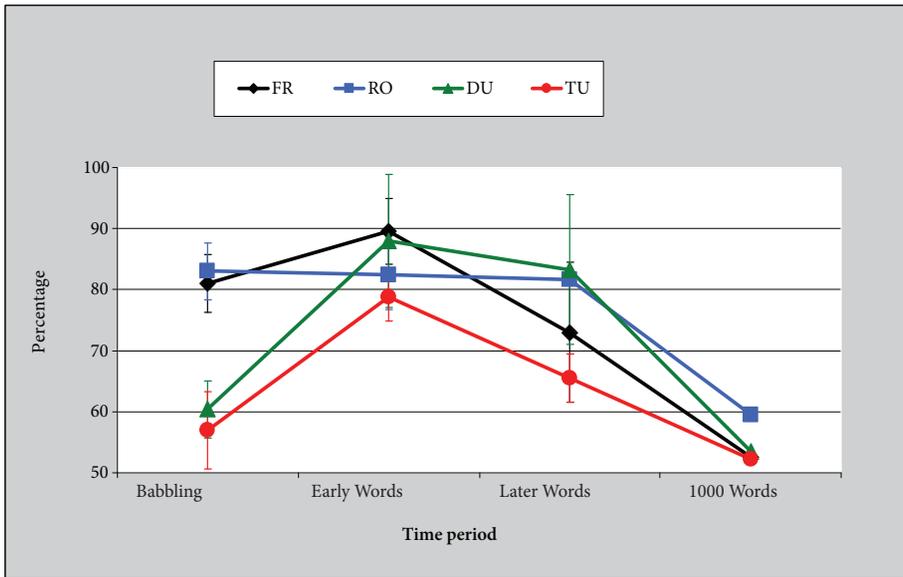


Figure 1. Mean percentage of stops and glides (vs. fricatives, liquids and others) according to language group and developmental period

both categories are given for the 1,000 words which represent the ambient language based on analyses of dictionaries on computer for each language studied.

Participants followed the preferred trends described in previous studies: in all four languages percentage of stops and glides was higher than 50%, indicating a strong preference for early appearing sounds. The differences in frequencies between early and later appearing sounds were statistically significant in all four languages across all three periods. This finding was characteristic of all children except one Tunisian child who used as many early as later appearing sounds in *babbling* and one Romanian child who showed the same pattern during the *early word* period.

Despite these strong general trends, some cross-language differences emerged. During the *babbling* period, the languages were grouped into pairs: Romanian children were like French children in producing more than 80% of stops and glides. Dutch and Tunisian children produced only around 60% of these two manners of articulation. One explanation for these differences might be sought in ambient language input differences. If there were differences in input, these results would indicate early ambient language learning. However, this explanation is not valid relative to Dutch and Tunisian language frequencies. Dutch and Tunisian language analyses did not show lower frequencies of stops and glides than Romanian or French in either sound type (i.e., what sounds occurred) nor in tokens

(i.e., how many times the sounds occurred). Moreover, in the French and Tunisian 1,000 word dictionary analysis, the frequency of stops and glides was not different from the frequency of other manners of articulation whereas in Romanian and Dutch stops and glides were more frequent. The only difference between the two pairs of languages where the children showed diverse patterns is in the number of glottal fricatives. Glottal fricatives are much more frequent in the Dutch and Tunisian languages than in the French or Romanian languages. In the *early word* period, one difference remained: French children used statistically more stops and glides than Tunisian children (89.6% vs. 78.8%). Finally at the *later word* period, Tunisian participants used statistically fewer stops and glides than Dutch children (65.5% vs. 83.3%).

Figure 1 allows also observation of the developmental trajectory from the *babbling* to the *later word* periods. Frequency of stops and glides increased from *babbling* to *early word* periods in three out of four languages and then decreased from the *early word* to the *later word* period. In Romanian, stop and glide manner of articulation decreased significantly from *babbling* to *early words*. As only two Romanian children of three reached the 50 word-mark level, nothing more can be concluded. Most of the children followed this developmental trajectory with an increase of stops and glides followed by a decrease. Only one Romanian child used less stops and glides in the *early word* period than in the *babbling* period, three children used more stops and glides in the *later word* than in the *early word* period (one French, one Romanian and one Dutch) and two produced the same manner patterns in the early and later word periods (one Dutch and one Tunisian).

Consonant place of articulation

Consonant sounds were grouped by place of articulation and by frequency in children's productions: consequently, labials were grouped with coronals as early sound types and dorsals with gutturals as later sound types. Figure 2 presents mean percentage of labials and coronals and confidence intervals for the four languages and the three time periods.

In all four languages, a large majority of children preferred to use labial and coronal consonants over dorsal and guttural consonants across the entire period of observation. All children exhibited this trend during the *early word* and the *later word* periods. Only during *babbling* were some inter-individual differences observed. Two Tunisian children used more dorsal and guttural consonants and two other children (one Dutch and one Tunisian) used as many labials and coronals as other places of articulation.

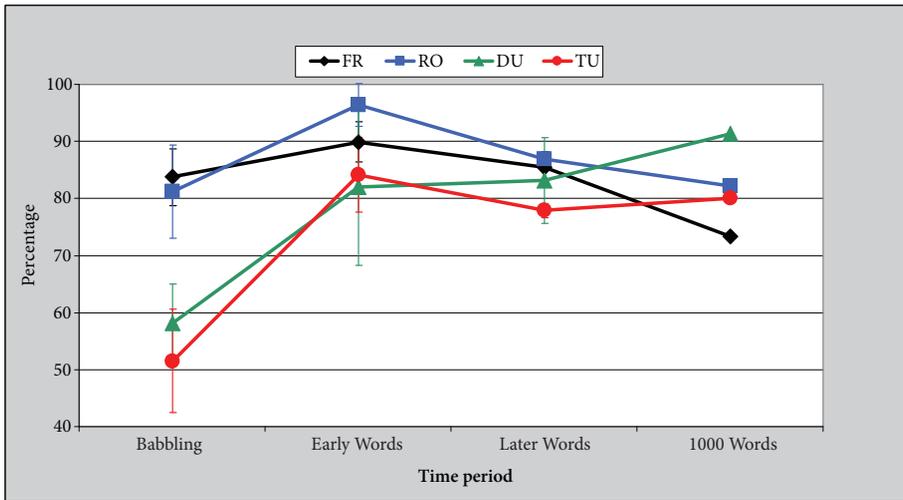


Figure 2. Mean percentage of labials and coronals (vs. dorsals and gutturals) according to language and time period

For cross language comparisons, only 14 children were analyzed during the *babbling* period. The standard deviation in Dutch for mean of labials and coronals was higher than 15 exhibiting an important heterogeneity in Dutch children's productions. Consequently the child who was the furthest from the mean was excluded from analysis. As for manner of articulation, the languages were grouped into pairs: French and Romanian (83.7% and 81.2%) produced statistically more labials and coronals than Dutch and Tunisian (58.1% and 51.5%). This outcome could be related to the previous results for manner of articulation. There are more glottal fricatives in the Dutch and Tunisian languages and these fricatives are pronounced in the back of the vocal tract. During the *early word* period, no cross language differences were observed whereas during the *later word* period only French children (85.5%) continued to be different from Tunisian children (77.9%) in use of place of articulation properties.

Consideration of changes from one period to another one also showed some differences. First, frequency of labials and coronals increased significantly in all four languages from the *babbling* to *first word* periods. Only two children behaved differently. One Dutch child produced equivalent frequencies of labials and coronals in both periods. One French child used fewer labials and coronals in the *early word* than in the *babbling* period. Second, frequency of labials and coronals decreased in three out of four languages from *first word* period to *later word* period. For the Romanian children, not enough data were available to evaluate the *later word* period; only one out of three children had data for that period. The decrease

of labials and coronals in comparison to glottals and gutturals was a preferred trend for 10/13 children. Two Dutch children choose the reverse trend and in one Tunisian child, there was no significant change.

Vowel types

Vowels were grouped as belonging to the lower left part of the vocalic space (LLQ) compared to the “other” types of vowels. LLQ vowels are described as being most frequent in early production inventories across a number of studies of this period. For LLQ, the mid and low front vowels as well as the mid and low central vowels were included. Figure 3 shows the results.

In babbling, children in all four languages produced significantly more vowels from the LLQ of the vocalic space. All children except one followed this trend. In *babbling*, one Romanian child was not considered, as the standard deviation for the Romanian group was over 15. This comparison revealed one statistically significant difference: Tunisian children produced more vowels from the LLQ than the other three languages (90.25%). This result cannot be explained by the influence of ambient language: Tunisian is the only language in which the 1,000 words dictionary data are composed of more “other” vowels than vowels from the left inferior part of vocalic space (52% (1,113) vs. 48% (1,021)).

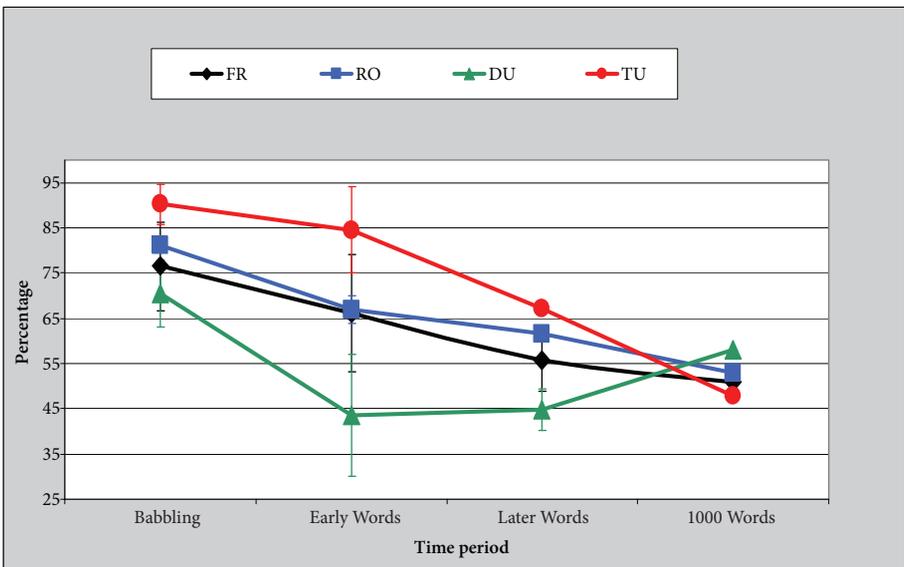


Figure 3. Mean percentage of vowels belonging to the left inferior part of vocalic space (LLQ) vs. “other” vowels according to language and time period

In the *early word* period, French, Romanian and Tunisian children preferred to produce vowels from the LLQ, consistent with *babbling* patterns. Nine of ten children adhered to this preference. In Dutch, only one child showed the LLQ preference, two preferred “other” vowel types and one produced an equal frequency of LLQ vowels and “other” vowels. In cross-language comparisons in the *early word* period, three children (one French, one Romanian and one Tunisian) were not taken into account for analysis as the standard deviation was over 15 in the three language groups. These comparisons revealed a more frequent use of early appearing sounds in Tunisian children as opposed to Romanian and Dutch children (84.5% vs. 67% and 43.5%)

Finally at the *later word* period, as during *early word* period, Dutch children were the only participants not to exhibit a preference for LLQ vowels (45%) as compared to “other” later occurring vowel types. The ambient language learning explanation is not cogent, as the Dutch 1,000 word dictionary analysis showed significantly more early appearing LLQ sounds (1,553 out of 2,690). Three of four French children, the one Romanian child, and all four Tunisian children produced significantly more LLQ early appearing vowels. In contrast, three of four Dutch children preferred “other” later appearing vowels and one produced equal frequencies of the two categories.

A significant decrease in percentages for early appearing LLQ vowels was shown in all four languages across the three periods. Twelve of 15 children showed a decrease in LLQ early occurring vowel types. Only three out of 15 increased their use of LLQ early appearing sounds (one Romanian, one Dutch and one French child). The *later word* period analysis revealed a more heterogeneous use of the vowel space. Dutch children changed to production of more LLQ early appearing vowels during the *later word* period than the *early word* period. In contrast, Tunisian and French children showed continuing decreases in frequency of LLQ early appearing vowels. Nothing could definitively be concluded about Romanian: only one child’s data was available. However, despite these cross language differences, 9/13 children exhibited a decrease in LLQ early appearing vowels from *early word* to *late word* periods. Only two children exhibited an increase in LLQ vowel use and two children exhibited equivalent use of LLQ and “other” vowel types across the three periods analyzed.

Height vs. Front-back changes in CVCV sequences

Variegated babbling in CVCV sequences was analyzed. For vowels, changes in vowel height were compared to changes in the front-back dimension in two successive syllables. According to a large number of studies, children prefer to change the open close dimension of their mouth (producing a vowel height change) than move their tongue into the front-back dimension (producing a vowel front-back

change) across utterances. This prediction emerges from the Frame/Content perspective (MacNeilage & Davis, 1990), where jaw movements are proposed as accounting for across utterance vowel quality changes more than tongue movements independent of the jaw in early utterances. The results are presented in Figure 4.

During the *babbling* period, in all languages except Dutch, children preferred vowel height changes in successive CV syllables significantly more frequently than front/back changes as predicted by the Frame-Content Theory. In Dutch vowel height changes were predominant but the difference with front/back changes was not significant. However, if evaluated individually, only 5/15 children produced significantly more height than front/back vowel changes. The other children followed the same trend but the difference between height and front/back changes was not statistically significant. Cross language comparisons revealed the following differences: Tunisian children produced more vowel height changes than Romanian (73.9% vs. 63.9%). Romanian children then produced more than French (53.4%) and Dutch children (55%). This result could be considered in the context of the highest ratio of height changes to back/front changes in the Tunisian 1,000 dictionary analysis compared to the other languages (62% height changes vs. 38% back/front changes). However, as this trend is also the most preferred trend in children across these four languages, nothing definitive can be concluded about a possible influence of ambient language.

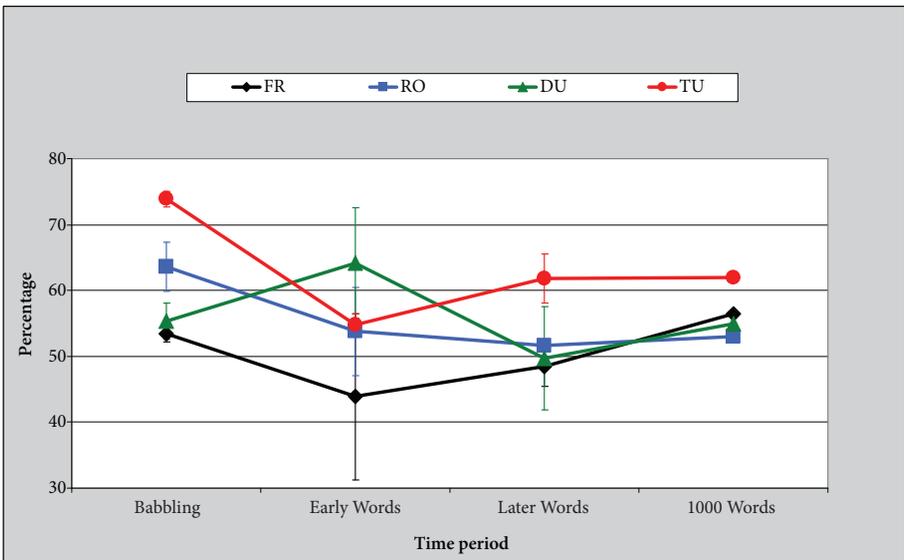


Figure 4. Mean percentage of height changes (vs. front-back changes) according to language and time period

In the *early word* period there was an equal distribution of types of vowel changes in all languages except French. In French, the frequency of front/back changes was statistically higher than height changes (56% vs. 44%). However 10/11 children produced more height changes even if the difference was not statistically significant. One Dutch child had no data of this type in the *early word* period. Only one French child produced more vowel front/back than height changes with a statistically significant difference and one Dutch child exhibited the reverse trend. Contrary to *babbling*, no difference between languages was significant in the *early word* period.

In the *later word* period, French children did not exhibit any preference whereas, in Dutch and Tunisian, vowel height changes were predominant. The only Dutch child with data in this period produced more height changes. 6/13 children (two children had no data) did not exhibit a preference, whereas, 5/13 preferred vowel height changes and only two preferred vowel front-back changes. The only cross language difference to emerge concerned the Tunisian children which, as was already the case in *babbling*, produced more height changes than all other three languages (61.8%).

Longitudinally, from the *babbling* to *early word* periods, a significant decrease of height changes was observed in French and Tunisian and in the one Romanian child (no data were available for two out of three Romanian children). A large majority of children (8/9) revealed the same significant decrease. In Dutch the frequency of height changes increased from *babbling* to *early words* but this was true only in two children out of four (one had no data for early words period and one stayed the same). From the *early word* to the *later word* periods, French and Tunisian children continued to exhibit the same trajectory: a significant increase in height changes. In Dutch, the opposite trajectory was observed. Nothing can be concluded for Romanian as the only child with data for the three periods remained the same. Individual child profiles showed that 6/12 stayed the same, two produced less height changes and 4/12 produced more height changes.

Manner vs. place changes in CVCV sequences

Consonant manner versus place variegation was analyzed in CVCV sequences. Previous studies have shown a preference for manner changes in young children's productions. This is the type of across utterance change predicted by the Frame Content Theory based on jaw movement without independent movements of other articulators (MacNeilage & Davis, 1990). Consequently, manner changes were considered as the early appearing structures in comparison with place changes. The results are presented in Figure 5.

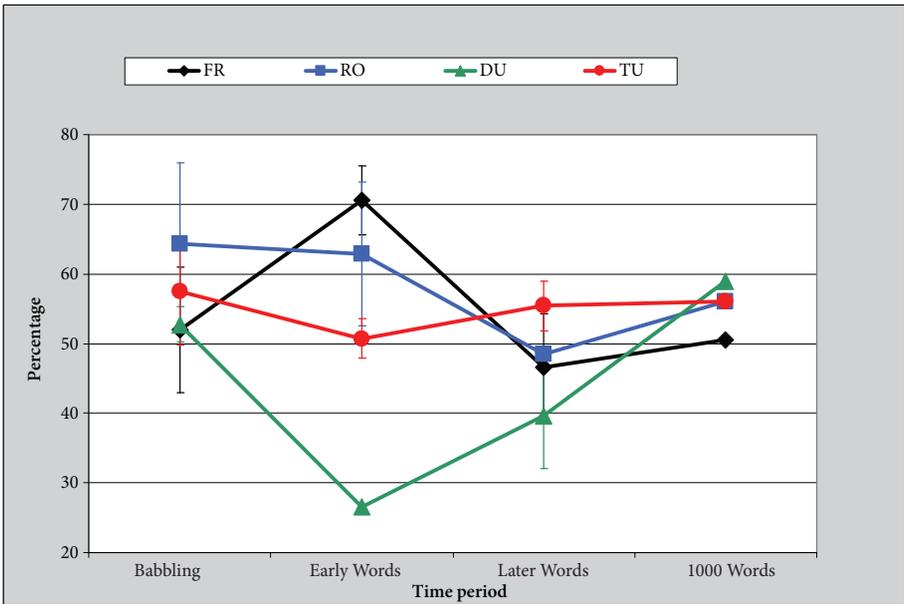


Figure 5. Mean percentage of manner changes (vs. place changes) according to language and time period

As predicted, Romanian and Tunisian children produced significantly more manner than place changes during *babbling* (64.3% and 57.3%). French and Dutch children didn't exhibit any difference between categories. Eleven of 15 children produced as many manner as place changes. Moreover, 10 of the 11 children preferred manner changes even if the difference was not statistically significant. For four children the difference was significant: three used more manner than place changes and one showed the opposite pattern. No significant cross language difference emerged.

In the *early word* period, Romanian, Tunisian and French children produced as many manner as place changes. Eight of 10 children followed this trend. One French child produced significantly more manner than place changes. The only Dutch children with these types of data in the *early word* period produced more place than manner changes. In the cross language analysis, three of four French and two out of three Romanian children were analyzed because of heterogeneity in both groups. The comparison between languages showed a difference between the French and the Tunisian groups: Tunisian children produced more manner changes than the French children. This difference cannot be understood by input frequency. The ambient languages do not present any differences between manner and place changes.

In the *later word* period, differences between groups were particularly important. French and Dutch used more place than manner changes. For the Tunisians, the distribution is inverted with more manner changes. Finally in Romanian, no difference was observed. Despite this heterogeneity across language groups, 7/13 children (no data for two Dutch participants) exhibited the same frequency for both categories. The majority (6/7) produced more manner than place changes even if the difference was not statistically significant. This preference for manner changes is confirmed by two children with more manner than place changes. Only four children used more place changes. Finally the same cross language difference was revealed in these analyses: Tunisian children used statistically more manner changes than French children. The difference between Tunisian and Dutch was not evaluated, as the Dutch group was only composed of one child. Concerning the developmental trajectory from *babbling* to *later word* periods, this domain presented the highest intra and interindividual differences. Manner changes decreased in Tunisian and Dutch. They tended to decrease in Romanian and increased in French. No general trends in use of place and manner variegation across syllables could be ascertained. For three children the percentage decreased, for three it increased and for six it stayed the same. No data was available for three other children. The same heterogeneity emerged from the changes from the *early word* to *later word* periods: French and Romanian (one subject) children used less manner changes whereas Dutch and Tunisian used more during the last period. No real trend could be identified: four children used less manner changes, four used more and two used the same frequency. Two children had no data for the *later word* period and three had no data for the period.

Discussion

The ESF-Eurocores-OMLL (*Origin of Man, Language and Languages*) program provided programmatic support for contemporary multidisciplinary research designed to address the seminal evolutionary perspective proposed by Charles Darwin in the mid 19th century. Diverse research cultures encompassing 'Language and the Brain', 'Language and Archaeology', 'Language and Genetics', 'Language Acquisition and Language Universals', 'Language and Animal Communication', and 'Language Evolution and Computer Modeling' were implemented within the scope of OMLL for asking critical questions about the phylogenetic origins of modern language capacities.

Through the multidisciplinary scholarly inquiries enabled by the OMLL initiative, research paradigms centered on the ontogenetic process of contemporary infants in acquiring mature human speech production capacities have been

considered a relevant contributing perspective. Central questions enabled by examination of ontogeny in human children can be understood in the context of emergence of complexity in service of increase in function, a central tenet of Darwinian evolution. Consideration of the varied parameters of the speech acquisition process enables a short time scale view of the long time scale evolutionary process that can be observed in modern language human capacities.

Issues that we have evaluated in this cross language research program are tailored to consider the emergence of complexity for human speech capacities as they are implemented in service of increasing message complexity in ontogeny. Collection of substantial databases enables statistical analysis of emerging complexity in speech patterning to enhance findings of previous small scale studies that relied on descriptive paradigms. Use of a consistent protocol for data collection and analysis across an extended period of development in diverse language environments enables a broader picture of emergence of speech complexity in early ontogeny than previous studies of single languages or smaller scale studies of pairs of languages. As such, this database can provide a source for considering at a more general level the timing of emergence of complexity in ontogeny.

As well, these comprehensive databases centered in ontogeny enable consideration of aspects of modern languages that are consistent with early emerging patterns versus aspects which reflect diverse types of phonological complexity. As we have noted, aspects of modern languages that are consistent with those observed in ontogeny, such as the use of open syllables across languages, can be seen to reflect extremely basic aspects of operation of the speech production apparatus retained in adult speakers in the face of pressure to implement diverse uses of the production system. As such, they seem to be fruitful areas of inquiry in consideration of patterns characteristic of early speakers in the formative history of communicatively oriented speech production. In turn, the vast panoply of phonological diversity characteristic of modern languages illustrates the ways in which the evolutionary process resulted in diversification of sound patterns as pressures for communicative complexity grew. These diverse phonological systems enable comparative analysis of the timing of learning to reproduce precise ambient language regularities by modern infants. Elements of children's early speech output patterns which match ambient language specific patterns point toward fruitful areas of inquiry for modeling studies in understanding the path to emergence of speech production complexity.

What did we find in this investigation of the process and products of early speech ontogeny across varied languages? We observed strong patterns of continuity between vocal patterns in the *babbling* and *early word* periods of development across the languages studied. As has been found in earlier studies of children in varied language environments, these children in four diverse language groups

exhibited a “motor core” of common production patterns (Locke, 1983; MacNeilage, Davis, Kinney & Matyear, 2000).

Concerning manner of articulation, all children used more stops and glides during the entire three periods covered by the study. Almost all children used more labials and coronals than other places of articulation from *babbling* to *later word* periods. Concerning vowels, all children except one in the *early word* period and one in the *later word* period preferred to produce LLQ vowels. Relative to intersyllabic serial trends across syllables, fewer of the children showed significant use of height changes for vowels and manner changes for vowels predicted by the Frame-Content Theory (MacNeilage & Davis, 1990). While results for these two indices of jaw predominance over independent movements of articulators were not significant in most cases, the trend for both was for a predominance of predicted patterns. This result across languages confirms at a general but not universal level, the importance of understanding production system characteristics underlying observable vocal output patterns. The lack of significant support in later developmental periods can be traced potentially to lexical effects, where children may have favored lexical forms that are produced frequently. To understand this issue more fully, the interface between lexical patterns and phonetic patterns should be examined more fully in this cohort.

Only in the *later word* period, when the children were producing a much larger number of meaningful words, was there an explosion of phonetic diversification signaling emergence of complexity in production system capacities. Emergence of later appearing sounds, including fricative, affricate, and liquid manner of articulation and dorsal and guttural places of articulation was apparent. Expansion of the vowel space to include diverse vowel types not related to the LLQ constraint was also apparent in the *later word* period. This increase in output complexity seems largely related to more control over the speech production system enabling increase in capacities for matching language forms. Increases were not clearly related to precise ambient language patterns of input as they were consistent across languages.

Children in this study were learning different languages with diverse phonetic, phonological and grammatical systems. One more issue at hand in this study was to observe the data in a cross language perspective in order to determine how and when the typological characteristics of a language play a role on the timing and trajectory of speech production pattern acquisition. Only very few cross language differences emerged from this data. Moreover, the differences were not consistent from one stage to another. When looking at place of articulation for instance, there was a statistically significant difference between French and Romanian vs. Dutch and Tunisian in the *babbling* period. In the *early word* period, no difference was seen between languages. Finally, at the *later word* period, only French children behaved differently than Tunisian children. This variability can be explained by a

small number of children per language group and high interindividual differences among these language groups. In addition, we tried to find an explanation for these very inconsistent cross language differences by comparing the frequencies obtained by the children to those of the 1000 word dictionary data for each language which was considered representative of their ambient language input. In most of cases, no clear input related explanation was possible. Overall, there was little evidence of learning to reproduce precise regularities related to sounds and sequences in input from the ambient language environment in these three earliest periods of development.

Research directions

As with many large scale projects addressing difficult issues, we have perhaps generated more questions than definitive answers. However, we have refined our ability to ask higher level questions with this comprehensive large-database and longitudinal approach to understanding the emergence of speech production complexity. Several areas of future research with this corpus should provide fruitful input to understanding the emergence of complexity in this dimension of language capacities more fully. As these analyses are completed, we can come closer to the goal of considering the utility of child speech ontogeny for understanding the process of phylogenetic change that has resulted in modern human language capacities.

Crucially, to achieve the goal of considering phylogeny from the perspective of ontogeny, child to ambient language comparisons should be completed at a more definitive level that was possible in this initial level of data analysis. That project is in progress, supported by more powerful statistical evaluation tools to understand the timing and types of ambient language matches in children both within and across the four languages. An additional level of analysis for language input values in considering emergence of ambient language regularities lies in consideration of phonological properties of child directed speech style in input to children. Child directed speech has been shown to display diversity from adult-directed speech in a number of important dimensions (Fernald & Morikawa (1993; Newport, Gleitman & Gleitman, 1977). Relevant to the phonological input component, a recent analysis of Korean (Lee, Davis & MacNeilage, 2008) has shown statistically significant differences in frequency of child directed speech input values for Korean ambient language features from those found in Korean adult directed speech input. This result suggests that mothers may implement differences from adult phonological regularities to highlight ambient language patterns in speech to their infants in early periods of acquisition. Infant directed speech input should be investigated in these cross language corpora to characterize input values to young children more validly. From another perspective, language to language comparisons of phono-

logical types and frequency of occurrence of those types will provide an additional level of needed information for fully understanding the nature and pressures for emergence of ambient language precision in the phonological dimension.

One major area of diversity from the patterns observed with the present level of macro-analysis in speech patterns of these children in four languages was the level of child individual differences from dominant group patterns. For all of the indices analyzed at all three developmental periods, individual children produced patterns that differed from the dominant group trends found for their own language as well as, in a few cases, dominant trends that were found to be characteristic across the four languages. Clearly, a micro-level of analysis of individual children within and across languages needs to be added to the present macro-analysis represented in this chapter reporting our programmatic progress to date. Child Individual differences and when they begin to appear can help to understand when and how cognitive development may become a driving force in early phonological development (see Vihman & Croft, 2007, for a statement of this position) relative to the production system oriented hypotheses that have been explored here.

Another fruitful area for extension of this research program should include consideration of typologically more diverse languages than the sample represented in this corpus. Languages such as Navajo or Hawaiian represent major cultural and genetic differences that are lacking in these languages. As well, more diverse language families could enable analysis of a wider spectrum of sound and sequence properties. This diversity could help to consider the nature-nurture issue at the heart of understanding the nature of ontogeny of modern language more fully.

The goal of this program of research into ontogeny of early speech production capacities in modern infants was to provide a finely grained level of understanding of the process of acquisition of the phonological component of modern language. Phonology lies at the intersection of complex knowledge and complex behaviour. This aspect of language function should be of seminal interest to gaining insight into the evolutionary process of human language. Of necessity at its onset and in early periods, early evolution of language capacities was embodied in intersection of emerging knowledge based on perceptual access with emerging capacities for planning and producing complex vocal output. This input-knowledge-output continuum would have been in service of communicating needed messages for functioning in an *early* cultural context. In the same way, the input-knowledge-output continuum observable in modern infants from its simplest onset in the first year of life illustrates emergence of a complex system in service of communicating needed messages for function in a *modern* cultural context.

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