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Emergent complexity in early vocal acquisition: Cross linguistic comparisons of canonical babbling

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Phonetic complexity, as evidenced in speech production patterns, is based on congruence of production system, perceptual, and cognitive capacities in adult speakers. Pre-linguistic vocalization patterns in human infants afford the opportunity to consider first stages in emergence of this complex system. The production system forms a primary site for considering determinates of early output complexity, as the respiratory, phonatory, and articulatory subsystems of infant humans support the types of vocal forms observed in early stages as well as those maintained in phonological systems of languages. The role of perceptual input from the environment in earliest stages of infant learning of ambient language phonological regularities is a second locus of emergent complexity. Young infants must both attend to and reproduce regularities to master the full range of phonological forms in their language. Cross linguistic comparison of babbling in infants acquiring typologically different languages including Dutch, Romanian, Turkish, Tunisian Arabic and French are described to consider production system based regularities and early perceptually based learning supporting emergence of ambient language phonological complexity.

1. Theoretical background

1. 1. Common trends in babbling

Canonical babbling marks a seminal step into production of syllable like output in infants. Canonical babbling is defined as rhythmic alternations between consonant and vowel-like properties, giving a percept of rhythmic speech that simulates adult output without conveying meaning (Davis & MacNeilage, 1995; Oller, 2000). These rhythmic alternations between consonants and vowels are maintained in adult speakers and form the foundation for complexity in languages (Maddieson, 1984). Longitudinal investigations of the transition from canonical babbling to speech have shown continuity between phonetic forms in infant pre-linguistic vocalizations and earliest speech forms (Oller, 1980; Stark, 1980; Stoel-Gammon & Cooper, 1984; Vihman, Ferguson & Elbert, 1986). This continuity supports the importance of considering canonical babbling as a crucial first step in the young child's journey toward mastery of ambient language phonology.

Strong similarities in sound and utterance type preferences in canonical babbling across different language communities have been documented, suggesting a universal basis for babbling (Locke, 1983). For consonants, stop, nasal and glide manner of articulation are most frequently reported (Locke, 1983; Robb & Bleihle, 1994; Roug, Landberg & Lundberg, 1989; Stoel-Gammon, 1985; Vihman, Macken, Miller, Simmons, & Miller,

1985). Infants tend to produce consonants at the coronal and labial consonant place of articulation (Locke, 1983) and few dorsals are noted (Stoel-Gammon, 1985). Vowels from the lower left quadrant of the vowel space (i.e. mid and low front and central vowels) are most often observed (Bickly, 1983; Buhr, 1980; Davis & MacNeilage, 1990; Kent & Bauer, 1985; Lieberman, 1980; Stoel-Gammon & Harrington, 1990).

The phenomenon of serial ordering is one of the most distinctive properties of speech production in languages (Maddieson, 1984). In a typical utterance, consonants and vowels do not appear in isolation but are produced serially. Within-syllable patterns for contiguous consonants and vowels provide a site for considering emergence of complexity in utterance structures, as rhythmic consonant and vowel syllables emerge typically at around 8-9 months; in previous stages infant vocalizations do not exhibit rhythmic syllable-like properties (see Oller, 2000, for a review). Three preferred within-syllable co-occurrence patterns have been reported in studies of serial properties; coronal (tongue tip closure) consonants with front vowels (e.g. “di”), dorsal (tongue back closure) consonants with back vowels (e.g. “ku”), and labial (lip closure) consonants with central vowels (e.g. “ba”). These widely observed serial patterns are predicted by the Frame Content hypothesis (MacNeilage & Davis, 1990). The Frame Content hypothesis proposes that the tongue does not move independently from the jaw within syllables, but remains in the same position for the consonant closure and the open or vowel portions of rhythmic cycles. Within syllable consonant vowel characteristics are based on these rhythmic jaw close open close cycles without independent movement of articulators independent of the jaw. In studies of 6 English-learning infants during babbling (Davis & MacNeilage, 1995) and 10 infants during the single word period (Davis, MacNeilage & Matyear, 2002), all three predicted co-occurrences of the Frame Content perspective were found at above chance levels; other potential co-occurrences did not occur above chance. Evidence for these serial patterns have also been found in analyses of 5 French, 5 Swedish and 5 Japanese infants from the Stanford Child Language database (Davis & MacNeilage, 2000), 2 Brazilian-Portuguese learning children (Teixiera & Davis, 2002), 7 infants acquiring Quichua (Gildersleeve-Neuman & Davis, 1998) and 7 Korean-learning infants (Lee, 2003).

Some counterexamples to these CV co-occurrence trends have been reported (Boysson-Bardies, 1993; Oller & Steffans, 1993; Tyler & Langsdale, 1996; Vihman, 1992). However, most differences in outcome may result from methodological differences. A labial central association in initial syllables was shown by Boysson-Bardies (1993) for French, Swedish and Yoruba infants but not for English: the English-speaking infants in her study preferred the labial front association. However, Boysson-Bardies analyzed the first and second syllables of utterances separately resulting in very small databases for statistical analysis. Oller and Steffans (1993) evaluated their results against the expected frequencies of consonants. They did not include expected frequencies of vowels, complicating comparison of results. The three predicted co-occurrences were observable in Tyler and Langsdale’s (1996) data if the small numbers of observations in the three age groups studied were pooled. An alveolar front association was not found in 3 English-speaking and 2 Swedish-speaking subjects by Vihman (1992). However, she counted /ae/ as a central vowel, also complicating the interpretation of her results relative to the predicted CV co-occurrences.

Vocalization patterns across syllables are also of importance to considering emergence of vocal complexity. In languages, most words contain varied consonants and vowels across syllables; phonological reduplication, or repetition of the same syllable, is infrequent (Maddieson, 1984). In contrast, two types of canonical babbling in pre-linguistic infants have been described: reduplicated and variegated. Reduplicated or repeated syllables (e.g. “baba”) account for half or more of all vocal patterns in babbling and more than half of early word forms (Davis *et al*., 2002). In variegated forms, infants change vowels and/or consonants in two successive syllables (e.g. “babi” or “bada”). Several studies have shown concurrent use of both reduplication and variegation during babbling (Mitchell & Kent, 1990; Smith, Brown-Sweeney & Stoel-Gammon, 1989). In variegated babbling, more manner than place changes for consonants (Davis & MacNeilage, 1995, Davis *et al*., 2002) and more height than front-back changes for vowels have been shown during babbling and first words (Bickley, 1983; Davis & MacNeilage, 1995, Davis *et al*., 2002). The preference for manner changes for consonants and height changes for vowels is consistent with the Frame Content hypothesis (MacNeilage & Davis, 1990). As patterns are based on rhythmic jaw oscillations without independent tongue movement, predominance of manner and height changes over place and front-back changes are predicted when successive syllables show different levels of jaw closure.

1. 2. Early Ambient Language Effects

Infants exhibit abilities to learn rapidly from language input regularities as early as 8-10 months, based on responses in experimental lab settings (e.g. Saffran, Aslin, & Newport, 1996; Werker & Lalonde, 1988). It has also been proposed that learning from ambient language input may influence and shape vocalization preferences in the late babbling and/or first word periods. Appearance of ambient language influences in production repertoires has been examined for utterance and syllable structures (Boysson-Bardies, 1993; Kopkalli-Yavuz & Topbaç, 2000), vowel and consonant repertoires and distribution (Boysson-Bardies, Hallé, Sagart & Durand, 1989 and 1992) as well as CV co-occurrence preferences (e.g. Lee, 2003).

Some studies of early appearance of ambient language regularities have focused on adult capacities for perception of differences in children from different language environments. Thevenin, Eilers, Oller & Lavoie (1985) failed to find support for adults’ ability to discriminate the babbling of 7 to 14 month old English and Spanish-learning infants. However, stimuli consisted of short 1 to 3 sec stretches of canonical babbling. Boysson-Bardies, Sagart & Durand (1984) presented naïve adults with sequences of early babbling of French, Arabic & Cantonese infants. Participants were asked to identify babbling of French infants. Listeners were correct in judging 70% of the tokens, suggesting that babbling in the pre-linguistic period may exhibit perceptually apparent ambient language characteristics. Adults were able to correctly identify language differences at 6 and 8 months, but not babbling of 10 month olds. According to Boysson-Bardies *et al.* (1984), this result could be explained by stimuli differences: stimuli from 10 month olds showed “less consistency” in intonation contours. Despite discrepancies in results, where adults were less accurate listening to older infants, these perceptual studies

suggest a potential role of prosodic cues in adult listeners' abilities to judge language background of young infants.

Other studies targeting acoustic and phonetic properties of infants' babbling output have provided some support for early ambient language learning. Boysson-Bardies, Hallé, Sagart & Durand (1989) compared vocalizations of French, English, Cantonese and Algerian 10 month olds. Based on computation of "mean vowels" (i. e. mean F1 and F2), they proposed that the acoustic vowel distribution was significantly different for the 4 language groups. There was also "close similarity" between infant and adult vowels in each of the four linguistic communities. Boysson-Bardies, Hallé, Sagart & Durand (1992) also suggested an early influence of the language environment on consonants in the four languages. They found significant differences in the distribution of place and manner of articulation across the four languages. Stop consonants represented the largest proportion for all infants. From 10 months, French infants produced fewer stops than American and Swedish infants, however. Levitt & Utman (1992) compared one French and one English-learning infant. English shows higher frequencies of fricatives, affricates and nasals than French; approximants are more frequent in French than in English. Each infant's consonant inventory moved toward their own ambient language in composition and frequency; both infants showed a closest match to the ambient frequencies at 5 months. The French child also favored front low vowels and the English child preferred mid central vowels, consistent with frequencies in their ambient language. The study reported on a very small sample of data for the two children, however, complicating generalization of results on timing of early ambient language learning. In general, available studies are limited in the size of the databases and number of participants, so conclusions must be considered as needing further confirmation

Strongly consistent trends in production patterns as well as preliminary indications about the timing of learning from ambient language input are apparent. However, empirical investigations of early ambient language learning do not provide strong evidence due to methodological issues (e.g. adult perceptual studies versus infant production patterns, amount of data analyzed, age of observation, number of participants, longitudinal vs. cross-sectional data collection and use of perception based phonetic transcription vs. acoustic analysis). To evaluate the emergence of early learning from the ambient language more fully, the issue must be considered in the context of common production patterns seen across languages. Larger cohorts of children in varied language environments illustrating diverse ambient language targets are necessary. Consistent data collection and analysis procedures are also essential to comprehensively evaluate this question.

2. Predictions

In this work, a uniform analysis profile on large corpora for five different languages is imposed, with the goal of understand timing of emergence and precise characteristics of ambient language learning in the context of reports on common production trends.

Predictions based on common trends will be tested as follows:

There will be a significantly higher proportion of:

- stop, nasal and glide consonant manner of articulation,
- coronal and labial consonant place of articulation,

- mid and low front and central vowels.

Within syllable consonant vowel co-occurrences will show a significant tendency for:

- labial consonants and central vowels,
- coronal consonants and front vowels,
- dorsal consonants and back vowels.

Across syllables, there will be a significant tendency for:

- co-occurrence of both reduplication and variegation,
- manner over place changes for consonants in variegated syllables,
- height over front-back changes for vowels in variegated syllables.

3. Method

3. 1. Participants

Twenty infants (4 infants per language) were observed in their normal daily environment. Infants were described as developing typically according to community standards and reports from parents and physicians regarding developmental milestones. All infants were monolingual learners of Turkish, French, Romanian, Dutch and Tunisian Arabic respectively. These languages represent diverse language families: French and Romanian are Romance languages, Dutch is a West-Germanic language, Turkish is a Ural-Altaic language and Tunisian belongs to the Arabic language family. Table 1 summarizes descriptive data for participants.

3. 2. Data Collection

One hour of spontaneous vocalization data was audio and video recorded every two weeks from 8 through 25 months in the infants' homes. Parents were told to follow their normal types of activities with their child. No extra materials were introduced into the environment, so that samples reflected the infants' typical vocalizations in familiar surroundings.

3. 3. Data Analysis

Spontaneous vocalization samples during canonical babbling were analyzed. 'Canonical babbling' was defined as beginning with the onset of rhythmic speech-like syllables based on parent report. Data was collected until each child was chronologically 12 months of age.

165 hours of spontaneous data were phonetically transcribed using the International Phonetic Alphabet with broad phonetic transcription conventions. All singleton consonants and vowels as well as perceptually rhythmic syllable-like vocalizations were transcribed. Tokens considered as single utterance strings were separated by 1 second of silence, noise or adult speech. Transcribed data were entered into Logical International Phonetic Programs (LIPP, Oller & Delgado, 1990) for analysis of patterns.

Table1. Participants and Data Analyzed.

Language	Language Family	Number of participants	Number of one hour sessions
French	Romance	4	32
Romanian	Romance	4	33
Tunisian	Arabic	4	27
Turkish	Ural-Altaic	4	34
Dutch	West-Germanic	4	39
Total		20	165

A variety of phonetic characteristics were considered. Consonants were grouped according to 1) manner of articulation: oral and nasal *stops*, oral and glottal *fricatives*, glides, and *other* (i.e. trills, taps and affricates) and 2) place of articulation: *labial* (bilabial, labiodental, labiopalatal and labiovelar), *coronal* (dental, alveolar, postalveolar and palatal), *dorsal* (velar and uvular) and *guttural* (pharyngeal and glottal). 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) *front/back*: front, central and back, and 2) *height*: high, mid and low. An *other* category included all segments that could not be perceptually recognized by transcribers as specific consonants or vowels (i.e. UC - undefined consonant, UV - undefined vowel). For all sounds occurring in perceptually rhythmic syllable contexts, within syllable consonant vowel (CV) co-occurrence patterns were analysed. For this analysis, consonants were grouped into 3 categories according to consonant place of articulation: labial, coronal and dorsal. Vowels were grouped into front, central and back dimensions. For across syllable patterns, utterance strings were considered reduplicated if all consonant and vowel types were identical. Variegated strings were designated by changes in consonant place or manner, vowel height or front-back, or both.

4. Results

4.1. Utterance structures

Table 2 displays frequency of occurrence for utterances, segments and the C/V ratio. Number of utterances for all languages was 38,719 ranging from 3,409 (Turkish) to 10,623 (Dutch). Overall number of segments totalled 168,145. In all languages, number of vowels exceeded consonants as illustrated by the C/V ratio. Overall, 57,472 consonants were analysed. Number of consonants ranged from 6,771 (Turkish) to 16,760 (Tunisian) across languages. Percentages (occurring greater than 5%; i.e. >5%) and totals of consonants in each language are given in Appendix A. 69,007 vowels, including those occurring > 5% were transcribed (See Appendix B for percentages and totals of vowels occurring >5%).

Table 2. Frequency of Occurrence of Segments and Utterances.

	Utterances	Consonants	Vowels	C/V ratio	Other	Total segments
French	10,085	9,462	12,196	0.78	320	32,063
Romanian	8,280	9,512	11,807	0.80	19	29,618
Tunisian	6,322	16,760	19,145	0.88	82	42,309
Turkish	3,409	6,771	8,201	0.83	1,595	19,967
Dutch	10,623	14,967	17,658	0.85	940	44,188
Total	38,719	57,472	69,007	0.83	2,956	168,145

4. 2. Consonant characteristics

Manner of articulation: Some similarities were apparent as well as some striking differences across languages relative to manner of articulation. Figure 1 displays results for manner of articulation for all consonants in the corpus. Oral stops were most frequent (43.5%). Four languages of five exhibited this trend: oral stops accounted for 51.5% in French, 51% in Romanian, 42.5% in Dutch and 57.5% in Turkish. Tunisian infants produced only 29.5% stops. A high percentage of glottal fricatives is observed in Tunisian (31.5%) and Dutch (25.5%). In Tunisian, the glottal fricative [h] represented the largest consonant type (31.5%), almost equal to the number of stops (29.5%). The glottal fricative [h] represented 25.5% of occurrences for Dutch infants. When glottal fricatives were not counted, glides (15%) and nasals (12%) were the second most frequent manner of articulation for all languages. French infants produced twice the group average for nasals. Dutch and Tunisian infants produced far fewer nasals. Finally, in all languages children produced more orals and nasals and glides than other manner of articulation (Z-test, $p \leq 10^{-6}$). This result confirms our first hypotheses concerning a significantly higher proportion of stop, nasal and glide consonant manner of articulation.

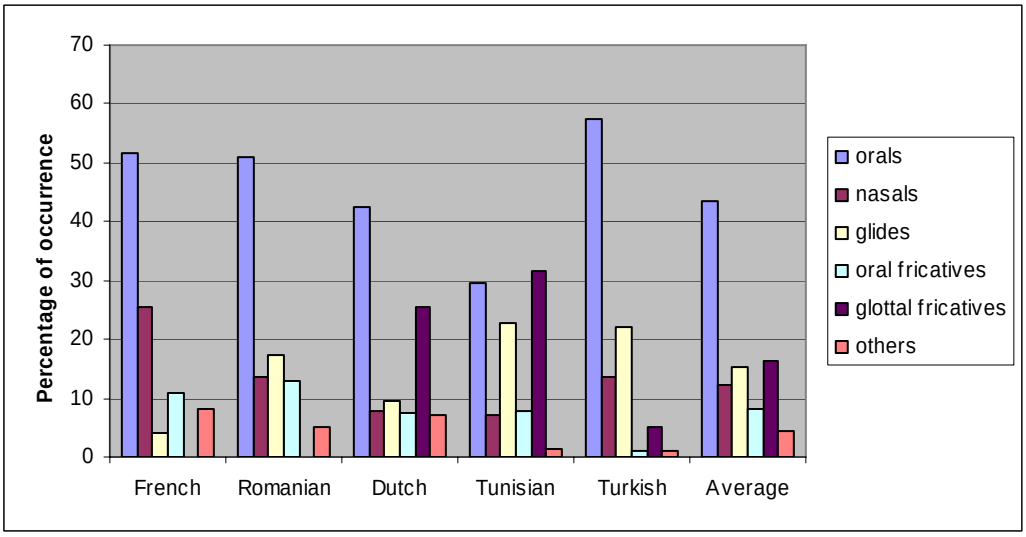

Figure 1. Consonant Manner of Articulation.

Place of articulation: Figure 2 displays place of articulation results for all consonants in the corpus. Coronals were the most frequent at 47%. However in French,

labials (47%) were most frequent; in particular, the labial nasal [m] was frequently produced (21.5%). Tunisian infants produced more glottals, with a high frequency of the glottal fricative [h] as noted above for manner of articulation. The second most frequent Tunisian place category was coronals. Across all languages, there were more glottals than dorsal, due to Tunisian and Dutch. Our second hypotheses is confirmed, as the proportion of labials and coronals is significantly different (more frequent) than the proportion of dorsals and glottals in each of the 5 languages (Z-test, $p \leq 10^{-6}$).

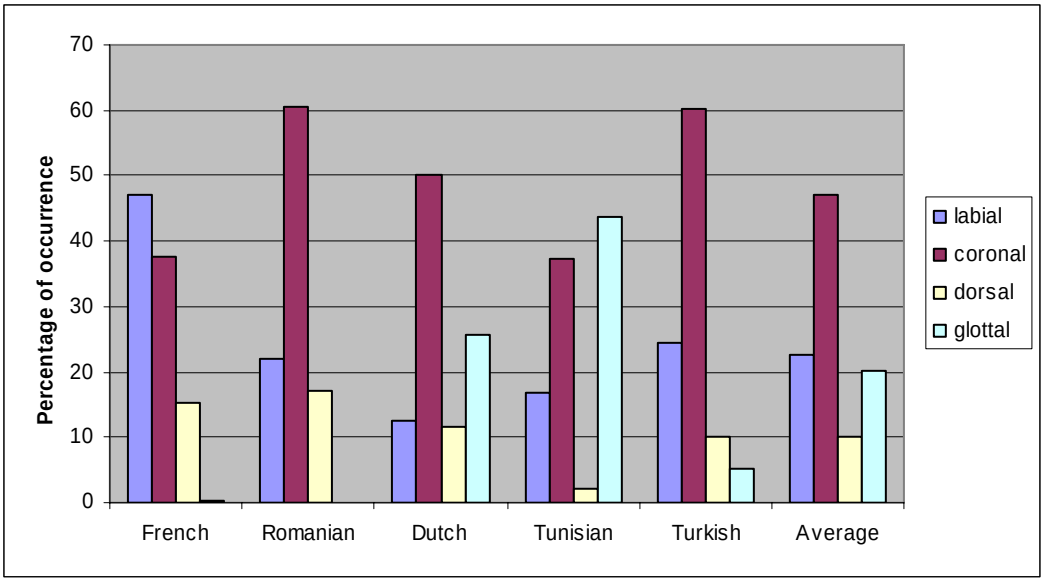

Figure 2. Consonant place of articulation.

4. 3. Vowel Characteristics

Vowel frequencies ranged from 8,201 to 19,145. Two or three vowels accounted for 50% of all types. Only the mid low vowel [a] occurred with a frequency of >5% in all 5 languages.

Vowels in the lower left quadrant of the vowel space were separated and compared with other vowel types (Figure 3). Overall, mid and low front and central vowels were most frequent. Combining the five languages, the lower left quadrant category yielded 66% of all vowels**.** This analysis confirms our third hypotheses that children will produce more vowels from lower left quadrant than other vowel types. In each language, the difference between the two groups is statistically significant in showing a predominance of the vowels from the lower left quadrant (Z-test, $p \leq 10^{-6}$).

In French, the low central vowel [a] and mid- front rounded vowel [□] represented approximately 60%; 3 other vowels occurred >5%. In Tunisian, the two most frequent vowels were [Θ] and [e]; only [a] occurred at > 5%. Dutch infants exhibited a high percentage of both central vowels [↔] and [a]; 3 others at > 5%. In Turkish [↔] occurred more than 29%: 5 other vowels at more than 5%: [□], [Θ], [a], [∝], [u], [̀] and [∅]. Romanians produced [a] most frequently (29.5%); five other vowels occurred at frequencies > 5%.

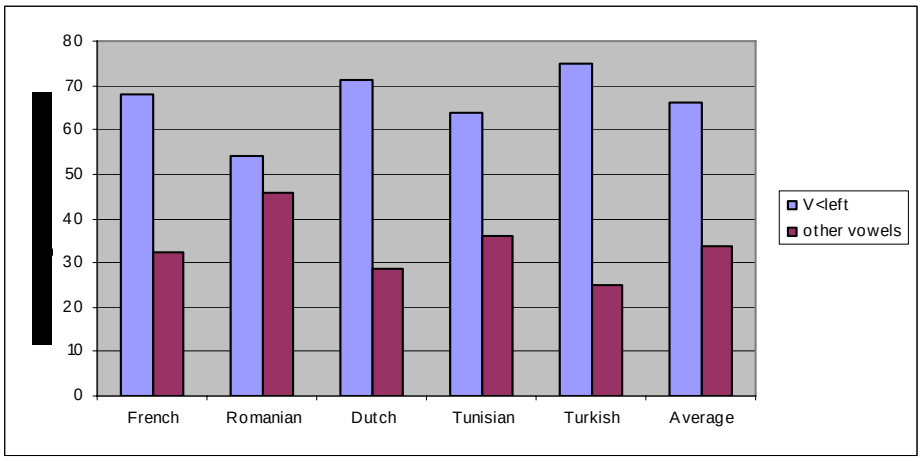

Figure 3. Vowels from the lower left quadrant versus other vowel types.

Group and language trends for vowels were apparent for both vowel height and front-back dimensions. Figure 4 displays the distribution of vowels by front-back dimensions for each language and overall. As shown in figure 4, the three types of vowels are not homogeneously distributed in the different languages: Front vowels are higher frequency in French and Tunisian (Z-test, $p \leq 10^{-6}$) ; central vowels are higher frequency in all languages except in Tunisian (Z-test, $p \leq 10^{-6}$), back vowels were the least represented category in all 5 languages (Z-test, $p \leq 10^{-6}$).

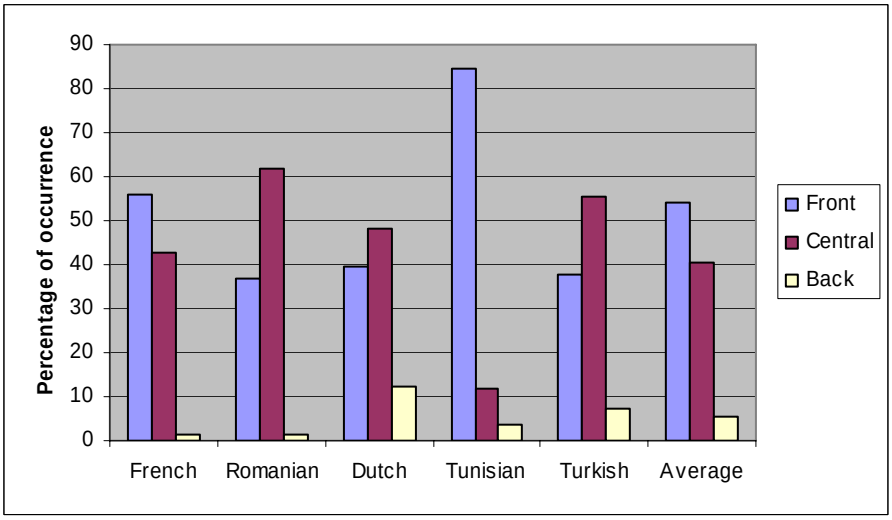

Figure 4. Vowel front back dimension.

Figure 5 displays the percentage of vowels in the height dimension for the 5 languages. Again, the three categories don't exhibit a homogeneous distribution. Mid vowels are significantly higher in frequency in French (Z-test, $p \leq 10^{-6}$), Dutch (Z-test, $p \leq 10^{-6}$) and Turkish (Z-test, $p \leq 0.001$) ; low vowels are higher frequency in Tunisian (Z-test, $p \leq 10^{-6}$) whereas high vowels are low in frequency (Z-test, $p \leq 10^{-6}$ in French, Dutch, Tunisian; Z-test, $p \leq 0.001$ in Turkish) except in Romanian.

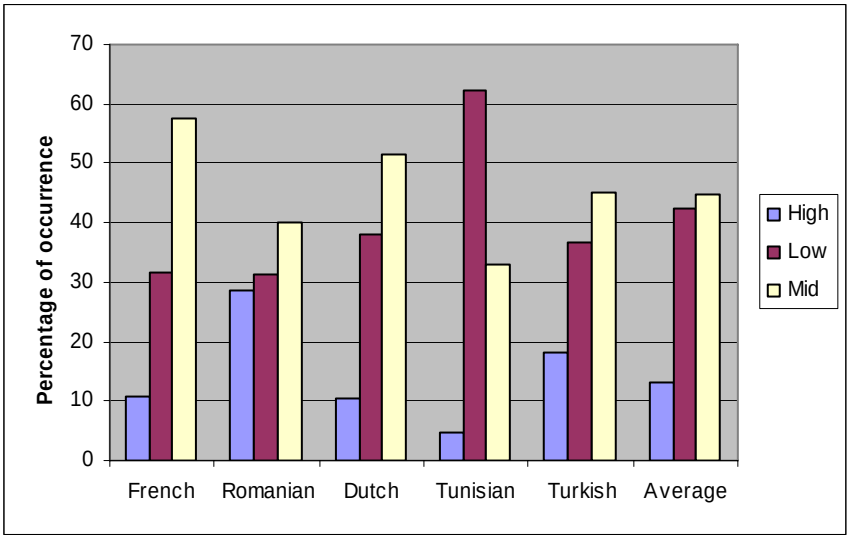

Figure 5. Vowel height dimension.

4. 4. Within syllable CV Co-occurrences

The predicted within syllable CV co-occurrence trends tested were: labial consonants with central vowels, coronal consonants with front vowels, and dorsal consonants with back vowels. This test was based on the Frame Content prediction (MacNeilage & Davis, 1990) that consonants and vowels within syllables will be articulatorily contiguous rather than showing tongue movement between consonant and vowel portions of the close open syllable alternation. Predicted labial central vowel co-occurrences, occurred in 3/5 languages. Dutch and Romanian infants did not show the preferred association between labial consonants and central vowels. The predicted coronal front vowel association occurred in 3/5 language groups. Dutch and Tunisian Arabic infants did not show this predicted association. Predicted associations between dorsal and back vowels were found in 3/4 languages where there were enough syllables for evaluation; Romanian infants did not produce enough syllables for chi square analysis. Dutch infants did not show the expected dorsal back association. In general, 4/5 language groups showed the predicted associations; Dutch infants did not.

Overall, there was a tendency for the 20 infants to prefer the three predicted CV co-occurrence patterns over non-predicted patterns. For individual infants, 36 of 60 of the 3 predicted associations were above chance, only 52 of 117 non-predicted cells were above chance. Three infants did not produce some types of syllables, so those cells contained no observations. The overall distribution of above and below chance values of predicted and non-predicted cells was 4.27 ($df = 1$: $p < .05$).

Table 3. Ratio of Observed to Expected Occurrences of Labial, Coronal and Dorsal Consonants with Front, Central and Back Vowels. (Predicted values are in boldface.)

Language	Vowels	Consonants		
French		Coronal	Labial	Dorsal
	Front	**1.11**	.84	.98
	Central	1.09	**1.13**	1.6
	Back	.62	1.15	**1.63**
Tunisian	Front	**1.00**	1.02	.89
	Central	.96	**1.10**	.96
	Back	1.07	.74	**1.76**
Romanian	Front	**1.15**	.68	1.94
	Central	.97	**.99**	1.10
	Back	.26	3.72	--
Turkish	Front	**1.07**	.92	.71
	Central	1.02	**1.08**	.52
	Back	1.69	.85	**3.72**
Dutch	Front	**.93**	.64	1.75
	Central	1.16	**.87**	.54
	Back	.90	2.15	**.37**

4. 5. Across Syllable Reduplication and Variegation

Analysis of CVCV sequences for these 5 languages confirms tendencies toward co-occurrence of reduplication and variegation. Reduplicated and variegated utterances co-occurred in all languages. French and Tunisian infants produced significantly more variegation than reduplication (Z-test, $p \leq 10^{-6}$), Dutch and Romanian infants showed the reverse trend (Z-test, $p \leq 10^{-6}$) whereas Turkish infants used as many variegated as duplicated babbling (see Figure 6).

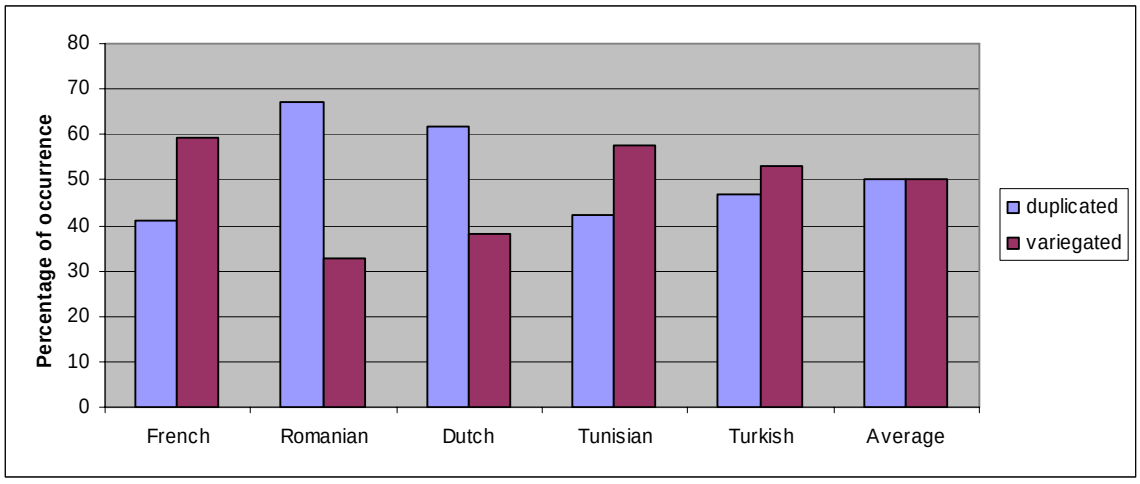

Figure 6. Reduplicated and variegated babbling.

When syllables were variegated across utterances, these 20 infants tended to follow common tendencies described previously. Consonant manner changes predominated over place changes in 4 languages (Figure 7) as predicted by the Frame Content hypothesis: Romanian and Tunisian (Z-test, $p \leq 10^{-6}$), Dutch and Turkish (Z-test, $p \leq 0.001$). For French infants the relative frequencies were almost equal. Vowel changes in variegated babbling showed height changes predominating over back/front changes for the infants in 4 language groups: French and Turkish (Z-test, $p \leq 10^{-6}$), Romanian (Z-test, $p \leq 0.001$) and Tunisian (Z-test, $p \leq 0.01$). In Dutch, the difference between the two categories was not statistically significant (Figure 8).

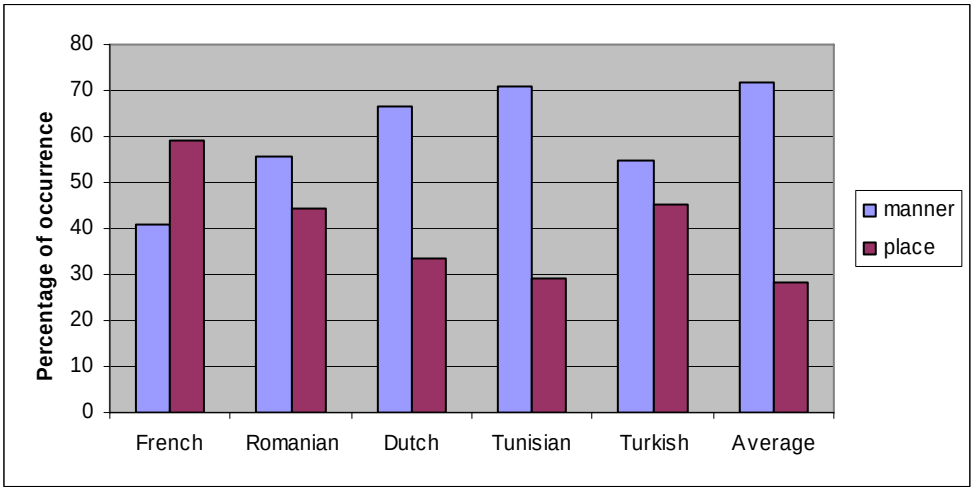

Figure 7. Manner vs. Place changes of consonant articulation in CVCV sequences.

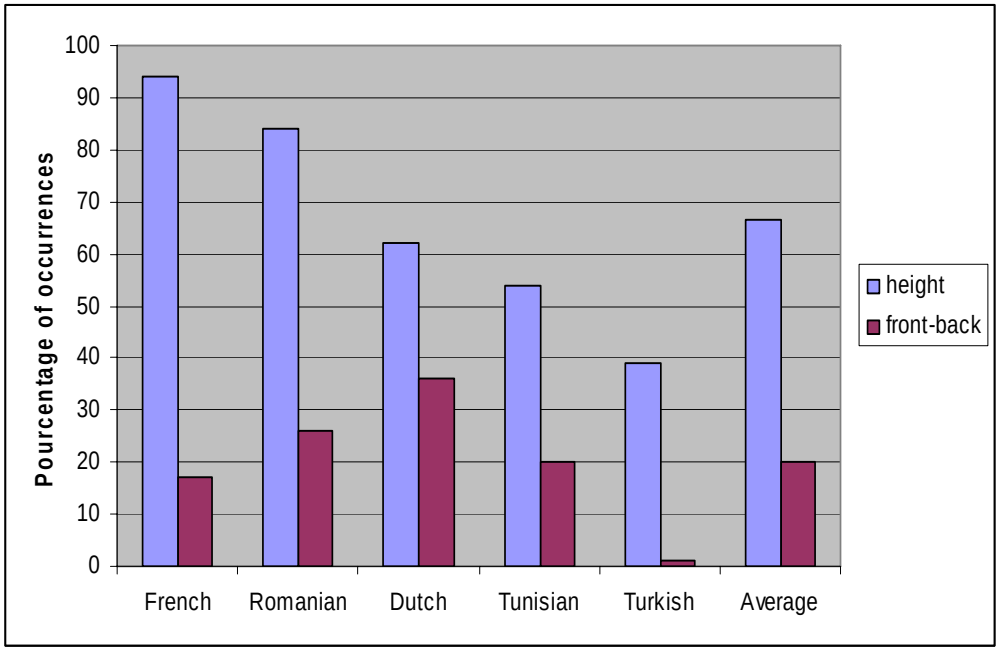

Figure 8. Height vs. Back-Front changes of vowel articulation in CVCV sequences.

5. Discussion and Conclusions

Emergence of complexity, as exhibited in early speech acquisition patterns, necessitates consideration of both universal patterns based on characteristics of the production subsystems common to all infants and early learning from adult speakers in an infants' ambient language community. 'Complexity' in babbling is founded on convergence of multiple physiological sub-systems to enable the first appearance of syllable based speech like output. It is illustrated in interactions within underlying physiological mechanisms and at the level of emergence of the syllable in observable behavioural output. Canonical babbling represents the earliest appearance of language like regularities in infant productions of perceptually rhythmic syllables that simulate adult speech. Patterns in canonical babbling have been shown to be continuous with vocal patterns in the early language-based single word stage. This continuity emphasises the importance of considering speech-like prelinguistic babbling as a first step into language complexity.

Sophisticated early learning capacities have been shown in experimental laboratory paradigms (e. g. Saffran & Aslin, 1997). Observation of spontaneous vocalizations can reveal an infant's ability to exhibit learning of ambient language regularities in naturally occurring output. In this study, we analyzed naturally occurring spontaneous vocalization patterns in canonical babbling for 20 infants in five different language communities to consider the strength of common patterns versus early appearance of language specific tendencies.

To the extent that potentially universal vocalization patterns predominate across languages, infants can be described as manifesting characteristics of the maturing production system common to neotenous humans (Locke, 2006). This data on five diverse languages provides strong evidence for a near universal basis for naturally occurring vocal output patterns during pre-linguistic canonical babbling. Consistencies on any index analyzed across these languages were far more pervasive than differences; infant vocalization patterns looked more like one another and less like the adult speakers in their own ambient language environment.

Overall, the predictions regarding common vocalization tendencies were confirmed. Infants produced more consonant stop and nasal manner of articulation and coronal and labial place of articulation. These consonant tendencies can be characterized as a general pattern of complete closure for consonant manner (i.e. oral and nasal stop manner) and forward articulation with lip or tongue tip for place (i.e. labial and coronal place). A strong preference for vowels in the lower left vowel space emerged, reflecting more jaw opening and forward tongue placement during open portions of rhythmic syllabic output. A perceptual basis for these early patterns is not apparent (see Davis, 2000, for a review of this issue). These patterns for consonants and vowels match trends reported in a variety of previous studies of the babbling and early word periods.

Within and across syllable patterns also showed strong trends toward common patterns in these five languages. Concerning within syllable patterns, the three predicted trends were largely confirmed. Nine out of 14 predicted within syllable associations were confirmed. Not enough syllables were available to evaluate dorsal back associations in Romanian. Three out of 5 coronal front associations were confirmed; Dutch did not show the predicted coronal front association. Three out of 5 labial central associations were

confirmed; Romanian and Dutch infants did not produce these predicted patterns at above chance levels. Three out of 4 dorsal back associations were confirmed; Dutch infants did not produce these predicted patterns above chance and Romanian children did not produce enough syllables for analysis. CV-co-occurrences have previously been observed mainly in studies of infants in an English language environment. The general though not universal confirmation of these early patterns in five additional languages confirms the influence of serial organization tendencies predicted by the Frame Content hypothesis. These patterns indicate predominance of jaw open close over independent tongue movements within syllables as largely characteristic of infant output, regardless of language environment.

In the case of multi-syllabic utterances, the prediction for co-occurrence of reduplication and variegation was confirmed. In variegated utterances, predicted common trends based largely on previous observations of English-learning infants were confirmed as well. For vowels, infants variegated more in the height than the front-back dimension. For consonants, manner exceeded place variegation. Both these tendencies indicate a predominance of jaw close open variegation over tongue movement within utterances. This predominance of manner height variegation patterning is consistent with Frame Content predictions as well, supporting the strong presence of production system based influences. Tongue movement within utterances would be signalled by variegated utterances containing a predominance of consonant place and vowel front-back variegation.

To fully explore the meaning of these common trends as well as observed differences in infant patterning during babbling, analysis of adult values in each ambient language is required. These data indicate relatively few clear exemplars of ambient language learning in the context of strong common tendencies across languages. In Tunisian, glottal fricatives were the most frequent manner/place of articulation pattern. The Tunisian phonemic inventory includes 14 different fricatives and 5 glottal consonants while the other four languages had 2 or less glottal phonemes. Romanian infants preferred to produce “other” vowels as opposed to the vowels in the lower left quadrant of the vowel space. A frequent vowel type in Romanian is the high central vowel. This frequency of occurrence of a vowel type in Romanian infants that is not commonly reported during early acquisition may be related to the occurrence of this high central vowel phoneme in their language input. In addition, the range of variation of individual infants from the group means should be explored to consider the nature and importance of individual differences across infants on these patterns. In Dutch, one infants’ strong use of dorsals skewed the patterns for the language overall. Ongoing analysis of this group of children at later ages could illuminate the timing and nature of emergence of learning of ambient language characteristics.

The present results suggest that common tendencies based on characteristics of the production system predominate during the babbling period. Observable characteristics appear to be based less on learning than on intrinsic self-organizing propensities of the system and how they are revealed in the human infant’s spontaneous vocal output. Kauffman (1995) has called this level of organized output from a complex living organism “order for free.” Early stages of patterned order may thus be viewed as emergent from the characteristics of the production mechanism of young human

speakers. This hypothesis will need to be explored with comparative analysis of children and languages.

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Appendix A. Percentages and Totals of Consonants in Each Language (>5%)

Consonants > 5%	French	%	Tunisian	%	Romanian	%	Turkish	%	Dutch	%
	[m]	21,5	[h]	31,5	[d]	24	[d]	33	[h]	25,5
	[d]	17	[j]	13,5	[j]	12	[j]	17	[d]	15
	[b]	11	[t]	9,5	[t]	9,5	[b]	11,5	[t]	14
	[t]	10,5	[w]	9	[b]	7,5	[g]	8	[k]	7,5
	[g]	5,5	[d]	7,5	[n]	7	[m]	7	[l]	6
			[?]	7,5	[w]	5,5	[n]	8	[j]	5,5
									[n]	5,1
Raw Total		6,206		13,186		6,232		5,558		11,763

Appendix B. Percentages and Totals of Vowels in Each Language (>5%).

Consonants > 5%	French	%	Tunisian	%	Romanian	%	Turkish	%	Dutch	%
	[a]	30	[Θ]	48	[a]	29,5	[↔]	29	[↔]	26,5
	[□]	29	[e]	26	[⁀]	19,5	[Θ]	22	[a]	20
	[E]	7,5	[a]	10,5	[e]	15,5	[a]	14,5	[E]	18
	[□]	7			[E]	12,5	[⁀]	6,5	[⊗]	12,5
	[e]	6			[↔]	11,5	[e]	5,5	[Θ]	5,5
					[i]	7,5	[∝]	5,5		
Raw Total		9,707		16,223		11,357		6,803		14,565