Universal Intrasyllabic Patterns in Early Acquisition

Barbara L. Davis† and Peter F. MacNeilage‡
† The University of Texas at Austin, Austin, TX
E-mail: babs@mail.utexas.edu, macneilage@mail.utexas.edu

ABSTRACT

Universal phonetic patterns can be observed in babbling and early speech when infants produce rhythmic vocalizations that show structural similarities as well as differences from mature speakers. The Frame/Content perspective [1] illuminates underlying principles motivating intrasyllabic, consonant and vowel patterns observed in these early speech-like vocal sequences. According to this perspective, lack of articulator movements independent of the mandible in vocal sequences result in intrasyllabic co-occurrences of labial consonants with central vowels, coronal consonants with front vowels, and dorsal consonants with back vowels. As complexity emerges in consonant clusters, vocal sequences retain regularities of patterning predicted by the Frame/Content perspective. In addition, these patterns appear to be resilient in the face of auditory perceptual deficit. Although syllable use is low in infants with hearing impairment, when syllables are produced they follow the patterns found in hearing infants and predicted by the Frame/Content perspective. (143)

1. INTRODUCTION

The syllable is a universal structure found in all modern languages. The most frequent syllable type across languages is the consonant-vowel (CV) sequence, either in isolation or in a series of CV alternations [2]. The Frame/Content perspective proposes that the rhythmic close and open alternation of the mandible, resulting in the the CV structure, is a basic behavior of the production system whereby mandibular elevation results in the percept of a consonant and relative depression of the mandible enables resonance properties related to the percept of a vowel. This CV percept is proposed as being an emergent property of the biomechanical characteristics of the speech production mechanism functioning in the time domain. These consonant-vowel alternations, based on rhythmic mandibular oscillation, have been asserted to have historical roots in chewing, sucking, and licking behaviors. These ingestive cyclicities could have been co-opted for an oral communication system when accompanied by phonation [3]. This conceptualization provides a potential link between the CV pattern in modern languages and precursor behaviors, thus enabling a potential for a deep historical level of explanation for the most basic structures found in modern languages.

Acquisition of speech production skill has been a frequent paradigm used for exploration of regularities in phonetic patterning in languages. The value of exploration of the earliest phases of speech acquisition lies in the potential for understanding the most complex system of serial action accomplished by the body when it is in its formative, and potentially most simple, phases of expression. These early rhythmic vocal sequences can be seen as exploitation of the most basic characteristics of the production mechanism by an immature organism in order to accomplish serial action. Comparative methodologies focusing on similarities and differences between infant vocal patterns and language patterns can reveal potentially universal phonetic structures that have been retained in patterning even as the pressure for message complexity increases in mature speakers. In this regard, the comparison of pre-linguistic vocal patterns, when there is no message transmission involved, with earliest message-related patterns in early words, can also potentially help to understand the ways in which vocal patterns available to the infant in babbling are shaped by the need to accomplish intelligible communication in the first word period and beyond.

General Characteristics of Early Infant Vocalizations

Outlining the facts of acquisition is an important first step to consideration of their importance in understanding the origins of intrasyllabic patterns. Although consonants and vowels are probably not controlled as separate entities in babbling (7-12 months) or first words (12-18 months), most data exploring these stages have come from phonetic transcription studies using these categories. These studies have shown strong similarities in sound preferences across different communities, suggesting a universal basis for babbling and earliest stages of speech production. Consonantal phones most frequently reported are stops [b], [d], nasals [m], [n], glides [j], [w], and [h]. While coronal (tongue tip) consonants tend to predominate in babbling, labial (lip) consonants are more frequent in first words. Dorsal (tongue body) consonants (i.e. [g]) are relatively infrequent. Mid and low front and central vowel qualities are reported in both transcription and acoustical studies. Most frequent syllable types are CV, (i.e. “ba”), and CVCV (i.e. “baba”). In the time domain, the infant’s development of both babbling and early speech patterns is characterized as operating within an overall rhythmic envelope consisting of mouth close-open movements with resultant alternations between non-resonant and resonant acoustic output.

2. DATA

What types of data are available to describe the course of phonetic acquisition in this period? Our research program over the past twenty years has centered on longitudinal

ISBN 1-876346-48-5

observation of serial vocal patterns from the onset of canonical babbling [4] and across the period of single word productions [5] in infants in an English language environment as well as across a variety of languages [6]. We have observed naturally occurring vocal behaviors and accumulated very large corpora on each individual infant for comparative computer analysis of serial vocal patterning. Our emphasis has been on describing intrasyllabic and intersyllabic regularities as well as word level positional patterns of vowel and consonant qualities. We have centered our research program on evaluating central tendencies in infant vocal development to test predictions of the Frame/Content perspective. From this research program we have proposed a set of putative phonetic universal patterns that we have termed a "motor core" for speech production [7]. These "motor core" tendencies form the basis for our proposals of universals in acquisition as well as for comparative analysis with mature language patterns to see which patterns are retained in languages and which are resolved in favor of greater complexity in the course of developing more complex message transmission.

Vowel Front-Back Patterns:

Intrasyllabic regularities in CV patterning form a first site for proposal of universal organizational principles in the acquisition period. Based on the Frame/Content perspective, intrasyllabic patterning is accomplished by rhythmic mandibular oscillation, accompanied by phonation, with little movement of other articulators such as the tongue, lips, or velum. These rhythmic mandibular movements are proposed as being based on biomechanical characteristics of the production system resulting in the percept of CV syllable structure. Specific predictions include labial closure accompanied by a central vowel, coronal closure accompanied by a front vowel, and dorsal closure accompanied by a back vowel. Tests of the production system based proposals of the Frame/Content perspective have been confirmed almost universally in English infants during babbling and first words as well as in a number of acquisition studies in languages as diverse as Equadorian-Quichua [8], Swedish, French, Japanese Italian, Brazilian-Portuguese, and Korean (See Davis and MacNeilage [9] for a review of these studies). Consonants with lower frequency of occurrence (i.e. fricatives, liquids, and affricates) produced by four infants in English have also been investigated [10]. Co-occurrence patterns similar to those found for stops, nasals, and glides were apparent, emphasizing the generality of this intrasyllabic pattern regardless of consonant manner. A review of these patterns in 10 diverse languages [7] indicates that these predicted intrasyllabic patterns are largely present, with few exceptions. This type of finding indicates that intrasyllabic regularities related to consonant-vowel associations in the front-back dimension are a basic and near universal feature in acquisition as well as in languages, indicating that this regularity can be considered a fundamental characteristic of the speech production mechanism rather than a transitory phenomena displayed in immature infants and resolved with development in adult speakers.

Vowel Height Patterns:

The vowel height dimension has been explored in the English-speaking infant database [11]. Results of this analysis were consistent with findings for consonant vowel associations in the vowel front-back dimension. Coronal and dorsal consonants, where the tongue is engaged in the closure portion, favored high vowels generally as predicted by a hypothesis of minimal movement within syllables by articulators other than the jaw. For coronals, higher than chance values were found for all three front vowel categories (i.e. low, 1.05, mid, 1.22, and high, 1.31). Lower than chance values were found for all central and back vowel categories. Dorsals showed above chance values for associations with both high and mid-back vowels (not enough low vowels were present for analysis). Dorsals were preferentially associated with high and mid front vowels as well, perhaps due to allophonic variation. As predicted, labial consonants tended to favor low central vowels and there was an inverse correlation with vowel height and strong avoidance of high-front vowels. This intrasyllabic patterning was predicted by the prominence of mandibular oscillations in the absence of independent movement of other articulators proposed in the Frame/Content hypothesis. In contrast, results for language patterns based on analysis of 10 languages available from dictionaries on computer showed diversification from predicted patterns of the Frame/Content perspective, likely related to need for increase in message transmission as well as development of articulator independence for tongue height changes within syllables. This height diversification in languages is in contrast to the maintenance of CV co-occurrence patterns in the front back dimension found in languages [7].

Consonant Cluster Patterns:

The concept of frame dominance has implications for consonant cluster development. Most segmental sequences within syllables are sequences composed of a consonant and a following vowel. For example, Maddieson [2] reported that about two-thirds of the languages in a sample of 30 languages had either no consonant clusters or a negligible number of them. When infants are required to produce consonant clusters in their language, what is the course of their development? We predicted that early consonant clusters would be primarily homorganic, tending to involve only one major place of articulation – labial, coronal or dorsal, rather then heterorganic.

We [12] analyzed 1,952 two-element consonant clusters in four English-learning infants between 7 months and 3 years of age. About 4/5ths of the clusters produced were homorganic (1581 versus 371). There were many more homorganic clusters in both babbling (436 versus 57) and words (1145 to 314). All but one infant (who had more heterorganic clusters in babbling) had more homorganic clusters in both babbling and words. There were more homorganic clusters in initial position (803 versus 239),

medial position (364 versus 52) and final position (414 to 80). Four manners of articulation were produced in initial position in clusters observed (stops, nasals, fricatives and glides), and five (also glides) in final position. In all 20 possible combinations of manner of articulation, there were more homorganic than heterorganic clusters.

One interpretation of the observed distribution of infant cluster types was that it is primarily due to a tendency to simulate the influence of clusters in the adult language. There are no initial clusters in English beginning with a nasal. Nevertheless, in babbling, the first consonant in initial cluster was a nasal 68 times. In babbling this was the third most frequent cluster that involved a nasal. In contrast, in speech there was no instance of nasals beginning clusters, suggesting that the lack of occurrence of this cluster form in English has been subject to perceptual learning in infants by the onset of word use.

Despite this indication that the form of adult clusters exerted some influence, this influence seems to be relatively small. A comparison of initial and final cluster patterns in infants and in the language illustrates this relatively low level of influence. Medial clusters are not considered because the adult picture is so much more complicated than for initial and final clusters. Using the tripartite articulatory place classification of labial, coronal, dorsal, more than 2/3rds of two-element initial clusters with only upper articulatory constrictions in the English language are heterorganic (24 versus 9). But only one infant produced more heterorganic than homorganic stops in babbling (though only four more). None of the infants produced more heterorganic clusters in speech. In addition, analysis of two element final clusters in English shows slightly more homorganic two-element final clusters than heterorganic clusters (41 to 37). However, these four infants produced an average of over 3 times as many homorganic two-element final clusters as heterorganic clusters in final clusters in babbling. In words, they produced almost twice as many.

Another way to consider the relation between early clusters and language clusters is to consider the relative frequencies of individual cluster types. Cluster frequencies in 3 samples of English [12] indicate that 6 initial two-element clusters (with 2 upper articulatory constrictions) occurred in the top 10 in frequency in all counts. They were, in order of decreasing frequency; [pr, st, tr, fr, kw], and [pl]. The 6 most frequent initial two-element clusters in the first words of the infants, in order of decreasing frequency, were [bw, pw, gw, kw, sn], and [st]. Only [st] and [kw] occurred in both infants and languages, suggesting an absence of a close frequency-based production of infant clusters related to language clusters. In addition, the top two infant clusters, [bw] and [pw], do not occur in the English language providing further evidence of a lack of close mapping between infants and available frequency distributions in the language. In final clusters in adult speech, 6 two-element final clusters always occurred in the top 10 in frequency. They were [nt, nd, st, rd, ld], and [kt]. The corresponding list in final position of infants' first words was [ts, st, ks] [ng], and [dz]. Again, only two cluster types occur on both lists, [nt], and [st]. Thus while homorganic clusters are favored by both infants and in the language, the lack of agreement on all but two clusters in these two data bases suggests a lack of close frequency-based mapping of infant clusters relative to clusters available auditorily to the infant in the language she hears.

Our prediction that infants would have more homorganic than heterorganic clusters should logically apply to infants in any language environment. The correctness of this prediction, and the detailed nature of this tendency if it is indeed universal will be revealed by further studies of cluster acquisition in different language environments. When infants and languages share a preference, it may indicate movement patterns that are so basic that they have been relatively available to speakers throughout the history of language.

Hearing Impaired Infant Patterns:

A different perspective can be obtained on the importance of these intrasyllabic properties by investigation of infants identified with hearing impairment. These children allow evaluation of the relative contribution of auditory perceptual deficits and intrinsic production characteristics to early vocal output patterns. This issue was evaluated in three infants identified at birth with hearing loss and followed longitudinally for 20 months beginning at about 7 months hearing age (i.e. time post-hearing instrument fitting [13]. After fitting with hearing aids, two infants showed moderate aided thresholds (50-80 db) and one a mild level of hearing impairment (30-50 db). The three infants showed a number of patterns usually found in profoundly hearing impaired children and attributed to perceptual deficit: low volubility, high frequency of singleton consonants and vowels relative to syllable frequency, and use of labial nasal consonants and neutral vowels. In the vocal syllables that were produced by the infants, intrasyllabic patterns showed a strong preference for the CV syllable form (over VC forms), and a tendency towards co-occurrence of labial consonants with central vowels in syllables. In the infant whose aided hearing was in the mild range, coronal consonants co-occurred with front vowels preferentially. These intrasyllabic patterns were similar to those found in hearing infants in the same developmental period. They presumably reflect intrinsic production system properties, as these hearing impaired infants did not clearly have the auditory access, even with hearing aids, to derive them from perceptual input.

4. CONCLUSIONS

In summary, studies of intrasyllabic tendencies during the babbling and single word periods suggest potential universal properties in early vocal acquisition. Consonant place closures are articulatorily compatible with vowels in both the height and front-back dimensions in infants, supportive of a proposal of movement economy in serial actions of the production system in acquisition. These patterns, predicted by the Frame/Content perspective are

ISBN 1-876346-48-5 © 2003 UAB

based on rhythmic mandibular oscillation with little independent movement of other articulators within syllables. They are also found in patterns observed in early cluster acquisition. Infants analyzed in an English language environment show a propensity for use of homorganic over heterorganic sequences in clusters between 7 months and 3 years of age, illustrating predominance of articulatory compatibility in another aspect of serial sequencing. In young hearing impaired infants, when syllables are produced at frequencies that allow analysis of intrasyllabic patterns, predicted regularities relative to labial central and coronal front CV relationships are found as well, indicating the strength of production system influences on syllabic patterns, even in the case of less than intact auditory sensory access.

These strong intrasyllabic patterns, predicted by the Frame/Content perspective seem to be largely retained in languages as well, indicating a very fundamental putatively universal property related to the biomechanics of the production system rather than a facet of acquisition that is resolved with maturity of the production mechanism. Similarities are found in CV patterning in the vowel front-back dimension between infants and languages. In addition, homorganic consonant clusters are favored by both infants and to some degree in the English language (i.e. word final position). Patterns of clusters in languages should be explored for relative frequency of homorganic and heterorganic clusters relative to this question. In the vowel height dimension, infants show the patterns predicted by Frame/Content of higher proportions of high vowels with coronals and dorsals where the tongue is already moving to make a closure at the roof of the mouth and lower vowels with labials where the tongue is not engaged during the consonant closure portion. Taken together, the intrasyllabic similarities in the front-back dimension between infants and languages along with the diversification in the height dimension in languages relative to infants indicate that languages may have more generally exploited the manner (jaw height) dimension for diversification over the front-back (tongue movement) dimension.

A biomechanically motivated account based on rhythmic operation of the mandible; the Frame/Content perspective, is proposed as an underlying principle driving the strong consistency in intrasyllabic patterns observed across a variety of languages during acquisition. These biomechanical patterns based on operation of the production system appear to be frequently retained in languages, enhancing characterization of their status as very fundamental within the production system and extremely basic to producing serial vocal action.

5. REFERENCES

[1] P.F. MacNeilage and B.L. Davis, Acquisition of speech production: Frames, then content. In Jeannerod, M. (ed.) *Attention and Performance XIII; Motor Representation and Control*, Hillsdale, N.J.: LEA, 452-468, 1990.

[2] I. Maddieson, *Patterns of sounds.* Cambridge: Cambridge University Press, 1984.

[3] P.F. MacNeilage and B.L. Davis, Origin of the Internal Structure of Words. *Science*. 288, 527-531, 2000.

[4] B.L. Davis and P.F. MacNeilage, The articulatory basis of babbling. *Journal of Speech and Hearing Research*, 38, 1199-1211, 1995.

[5] B.L. Davis, P.F. MacNeilage P.F. and C.L. Matyear, Acquisition of serial complexity in speech production: A Comparison of Phonetic and Phonological Approaches to First Word Production, *Phonetica*, 59: 75-104, 2002.

[6] P.F. MacNeilage, B.L. Davis, C.M. Matyear, and A. Kinney, Origin of Speech Output Complexity in Infants and in Languages. *Psychological Science* . 10 (5) 459-460, 2000.

[7] MacNeilage, B.L. Davis, A. Kinney and C.M. Matyear,. The motor core of speech: A comparison of serial organization patterns in infants and languages. Invited submission to Special Millenium Issue. *Child Development.* 71 (1), 153-163, 2000.

[8] C.E. Gildersleeve-Neumann, Production vs ambient language influences on speech development in Quichua The University of Texas at Austin, Austin, Texas, unpublished Ph.D. dissertation, 2000.

[9] B.L. Davis and P.F. MacNeilage, The Internal Structure of the Syllable: An Ontogenetic Perspective on Origins in B. Malle, Ed., pp. 99-117, *The Rise of Language out of Pre-language*. Benjamin, 2002.

[10] C.E. Gildersleeve-Neumann, C.E., B.L. Davis, B.L. and P.F. MacNeilage, Contingencies governing production of for fricatives, affricates and liquids in babbling. Applied Psycholinguistics. 21-341-363, 2000.

[11] B.L. Davis, Vowel height relations between consonants and vowels in babbling, Texas Linguistics Society Conference, Austin, TX, March 2003.

[12] K.J. Jakielski, B.L. Davis, and P.F. MacNeilage, Acquisition of consonant clusters in babbling and speech, submitted, 2003.

[13] B.L. Davis, H. McCaffrey, D. Von Hapsburg, and A. Warner-Czyz, Perceptual influences on Motor Control: Infants with varied Hearing Levels, submitted, 2003.