Emergence of Phonotactic Complexity in Early Phonological Development

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"…….. complementary frameworks can yield complementary insights ."

(Fentress, 1992, p.1537)

GOAL

- Illustrate how the Texas Speech Production (TSP) database has been used to consider emergence of phonotactic properties in early speech acquisition.

THE TSP DATABASE: PARTICIPANTS

- Longitudinal corpora, typically developing children
- Monolingual English language environment in Texas
- Collected monthly between7-36 months of age
- Background Testing:
  - Hearing: Play audiometry, 25db at 500, 1, 2, and 4K Hz.
  - Cognitive Development: The *Battelle Developmental Screening Inventory* (Newborg et al, 1984)
  - Vocabulary Development: *MacArthur Communicative Development Inventory (CDI)* (Fenson et al, 1993).

The TSP database: Data Collection

- Hour free play: child, primary caregiver, research assistant.
- Toys provided + child allowed play with her toys.
- Wireless microphone systems clipped to clothing; transmitter in a fanny pack.

Goal of the TSP project

Test movement-based phonetic perspective on early phonological acquisition.

Frame-Content Perspective

Generate robust explanatory phonetic principles

Vocal patterns in acquisition

Consideration of the processes underlying modern speaker's

acquisition of the most complex human action and knowledge systems available in nature.

Patterns in modern languages

Examine evidence for non-arbitrary explanatory prinicples for considering patterns apparent in languages

Patterns in putative vocalizations of earlier speakers

Consider potential window into the historical process whereby

early hominids began use of the auditory - vocal channel

to effect communication

Biological-Functional Approaches to Phonological Acquisition

Acquisition of mature *behavioral patterns* and *underlying knowledge* accomplished by interactions of biological and social components of a complex system across acquisition

Knowledge Patterns : Child internalizes neural/cognitive competencies rooted in manipulations in the external world

Behavioral Patterns : Child assembles functionally adaptive behavioral patterns to respond to local contexts and exploit intrinsic dynamics of the production and perception systems.

Phonological outcomes result from multiple interactions between heterogeneous aspects of a complex system

Frame-Content Perspective

MacNeilage & Davis 1990, 1993

Focus:

Serial ordering tendencies in operation of the vocal apparatus

Principle:

Rhythmic mandibular oscillation

Accompanied by phonation

Aspect of the infant's movement system available for the initial approximation of the serial organization of adult speech by the onset of babbling:

Frame-Content Perspective

Unit

Early Acquisition:

Frame: oscillation of the mandible

Depression-mouth opening for vowels

Elevation-mouth closing for consonants

Later Acquisition:

Content: Ambient language segmental movement patterns that can be produced in serially organized language output

Behavioral patterns based on production and perception are the foundation for emerging knowledge base.

FRAME-CONTENT PREDICTIONS

Strong associations between close and open phases in mandibular oscillation cycles

- Without independent movements of other articulators
- Will result in within and across syllable regularities:

Within Syllable CV Co-occurrence Hypothesis

Labial (lip) consonants with central vowels
Coronal (tongue tip) consonants with front vowels
Dorsal (tongue body) consonants with back vowels

Across Syllable Variegation Hypothesis

Consonants: Dominance of manner over place
Vowels: Dominance of height over front-back

PHONOTACTIC PROPERTIES RELATED TO SERIAL REGULARITIES IN CHILD OUTPUT

I. Consonant Assimilation

II. Consonant Clusters

CONSONANT ASSIMILATION: METHODS

KIM & DAVIS (IN PREP)

Participants

- 10 children from the TSP database
- Across the period of12 to 36 months of age

Data Analysis

- 1467 assimilated word forms (i.e. 1,058 CVC and 409 C VCV; 7% of the entire corpus)

- 20,522 words in the corpus
  - 17,775 CVC forms
  - 2,747 CVCV forms

- Entire time period and four time periods in six month i ntervals (12-18; 18-24; 24-30; 30-36mos.)

PREDICTIONS: ASSIMILATION PATTERNS IN CHILDREN

- Prediction 1. Preference for forms that are available to th e production system

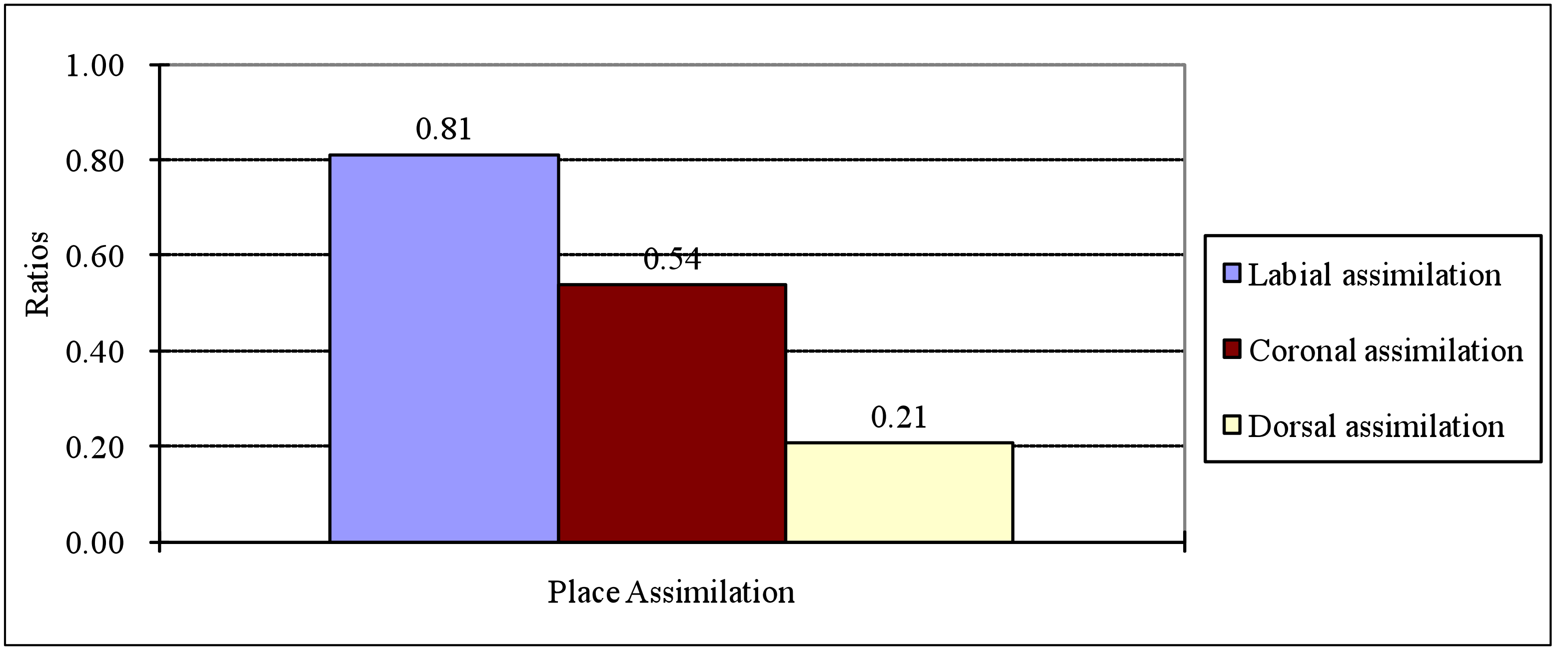
- Prediction 2. Intervening vowel context effects

- Prediction 3. Word level effects (i.e. CVC and CVCV)

- Prediction 4. Decrease in movement capacity constraints over time

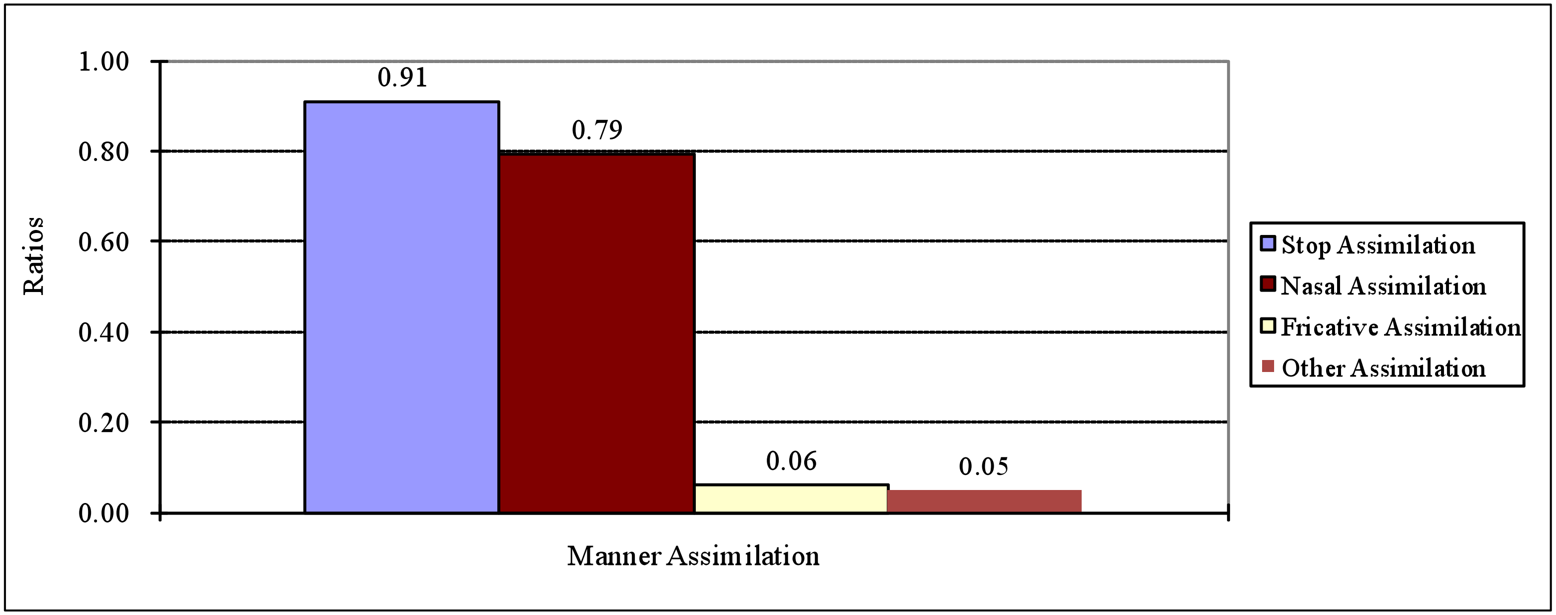
PLACE RESULTS

- Labial > Coronal > Dorsal assimilation
- Same trend in any consonant sequence in targets



Manner Results

- Stop ≥ Nasal > Fricative assimilation
- Same trend in any consonant sequences in targets (except nasal-s top sequence)



P 1 Preferences: Discussion
Labial > Coronal > Dorsal

- Movement-based hierarchy
  - Labials are the most available for children
    - involve mandibular movement only – the basic frame (MacNeilage & Davis, 1990)
  - Dorsals are the least available (Locke, 1983)
    - involve the back of the tongue
  - L > C > D frequencies in early words (Davis, et al., 2002) while input languages have more coronals than labials (Maddieson, 1984).

P1 Preferences: Discussion
Stop ≥ Nasal > Fricative

- Movement-based hierarchy
  - Stops and Nasals are more available
    - involve release from complete closure of the oral trac t during mandibular close-open oscillation (Davis, et al., 2 002)
  - Fricatives involve fine adjustments of varied degrees of c losure
  - Nasal assimilation more frequent in NS-OS targets
  - The velum remains in the same status from the beginning throughout entire utterances (Matyear, et al., 1997)

P2 Vowel Context Effects

- Two of the three expected CV co-occurrence patterns were o bserved at above chance levels (i.e. above 1.0).
- Coronals with Front Vowels Dorsals with Back vowels.

Consonant Assimilation	Vowel: Front	Central	Back
Coronal	1.04	1.06	0.69
Labial	1.02	0.93	1.15
Dorsal	0.77	0.95	1.85

(χ^2 =20.79, $p < .001$)

P2 Vowel Contexts Effect in CVC

- Only dorsal-back pattern at above-change level

Consonant Assimilation	Front	Central	Back
Coronal	0.94	1.17	0.71
Labial	1.20	0.59	1.49
Dorsal	0.36	1.68	1.07

(Vowel)

($\chi^2 = 43.90$, $p < .001$)

P2 Vowel Context Effects in CVCV

- All three predicted associations occurred at a bove chance levels.

Consonant Assimilation	Vowel: Front	Central	Back
Coronal	1.34	0.83	0.61
Labial	0.59	1.51	0.34
Dorsal	1.04	0.59	2.38

($\chi^2 = 50.55$, $p < .001$)

P2 Discussion: VOWEL CONTEXT EFFECTS

Intervening Vowel Effects on Linguals

- Vowel context effects: lack of independent movements of articulators during the transition from the consonant to the vowel.

- Coronal and dorsal assimilation: Intersyllabic constraints on tongue movement from C to V (and V to C).

Why not labial-vowel effects?

- The tongue is not required for the consonant adjacent to the vowel (Davis, et al.,2002)

Independent tongue movements (content) within syllables emerge with maturation and learning. Coronals and labials more free to vary in CVCs.

More pressure from language input to match diverse CVCV targets.

P3 Word Level Effects

CVC

- Vowel effects weak

	Front	Central	Back
Coronal	0.94	1.17	0.71
Labial	1.20	0.59	1.49
Dorsal	0.36	1.68	1.07

($\chi^2 = 43.90$, $p < .001$)

- Regressive assimilation
  (e.g. /tʌt/ for '*cut*')

CVCV

- Vowel effects strong

	Front	Central	Back
Coronal	1.34	0.83	0.61
Labial	0.59	1.51	0.34
Dorsal	1.04	0.59	2.38

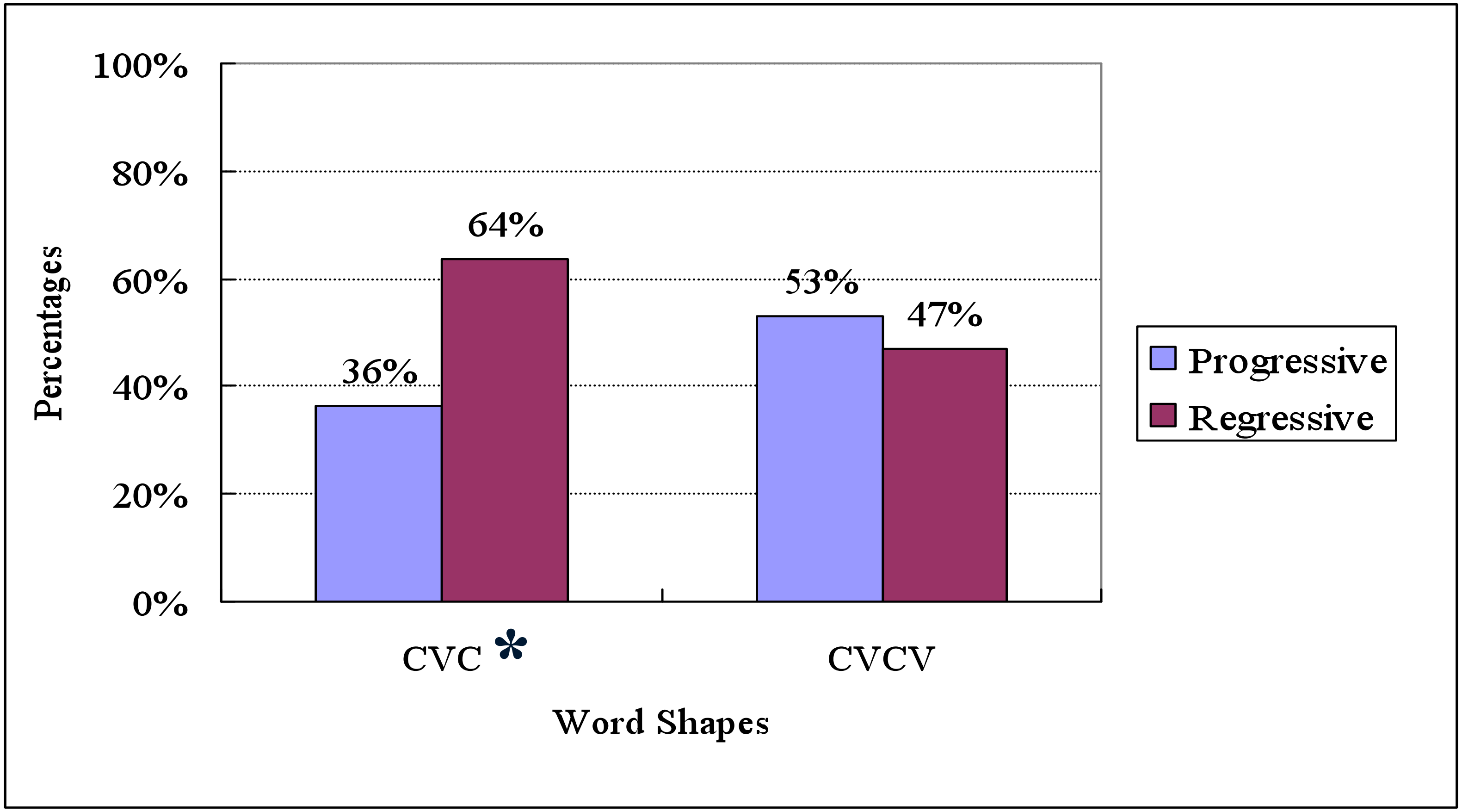
($\chi^2 = 50.55$, $p < .001$)

- Progressive assimilation
  (e.g. /tidi/ for 'kitty')

P3 Word Level Effects

Direction of Assimilation

- Progressive < Regressive in CVC



P3 Discussion: Word Level Effects

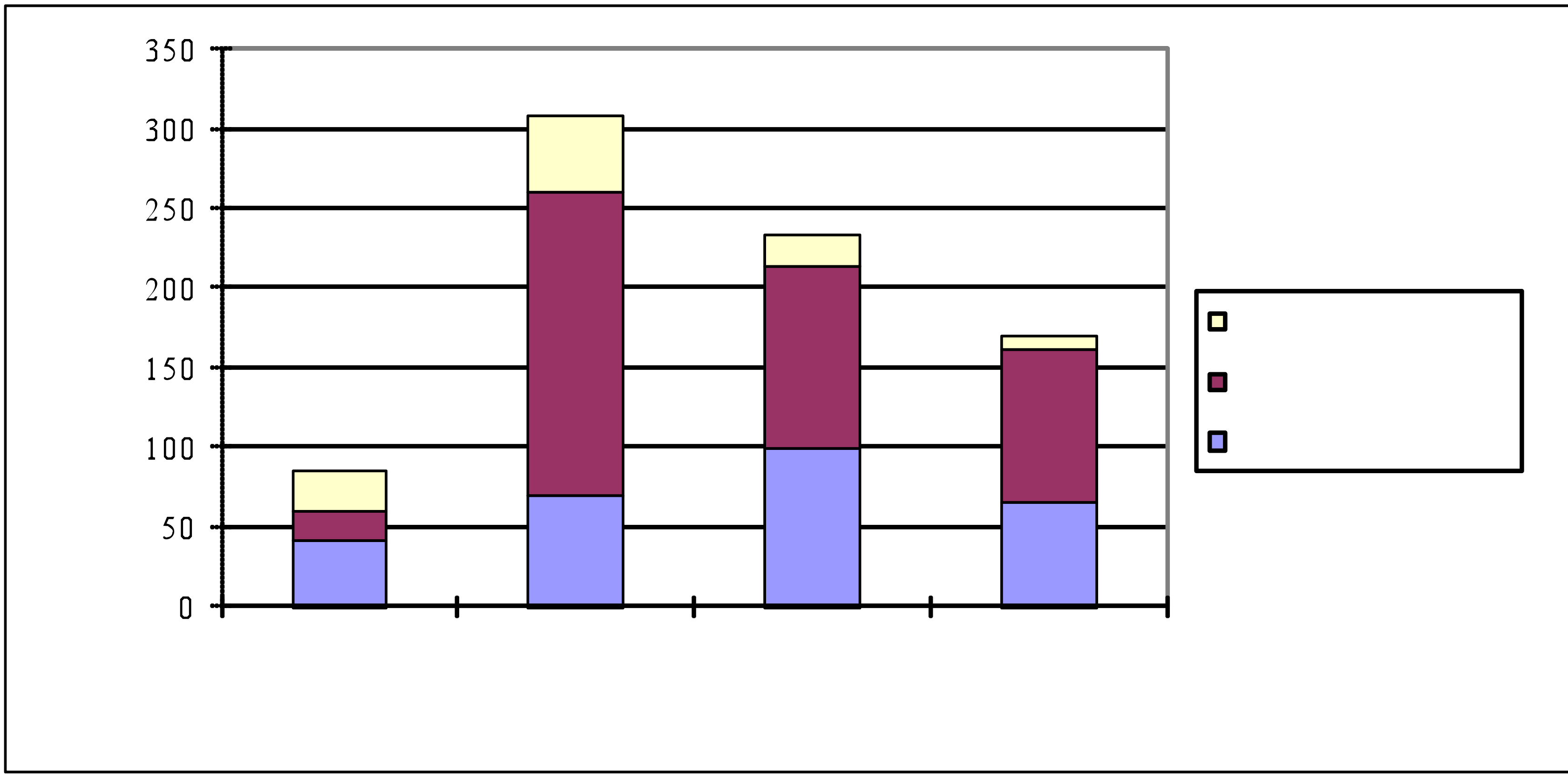
- Strong vowel effects in CVCV
- Regressive assimilation in CVC

  - Movement motivation
    - Intrasyllabic constraints strong in CVCV while more active tongue movement is involved in the final consonant in CVC (Redford, et al, 1997).

  - Perceptual motivation
    - The absolute final position (CVC_C2) in words is salient for children relative to non-final positions (Albin & Echols, 1996)

P4 Developmental Patterns

- Time periods: 12-18; 18-24; 24-30; 30-36mos.
- Frequency of assimilation was the highest at Time 2, then decr eased.
- Labial & Coronal assimilation persisted.



P4 Developmental Patterns

- Vowel effects were strong at Times 1 and 2 then decreased.
- Persisted longer for CVCV than for CVC.

		Overall			CVC			CVCV		
		Front vowel	Central vowel	Back vowel	Front vowel	Central vowel	Back vowel	Front vowel	Central vowel	Back vowel
12 to 18	Coronal assimilation	1.44	0.77	0.00	2.16	0.80	0.00	1.46	0.66	0.00
	Labial assimilation	0.67	1.16	2.07	0.48	1.06	1.92	0.71	1.19	2.14
	Dorsal assimilation	1.21	0.92	0.00	0.00	1.28	0.00	1.15	0.91	0.00
19 to 24	Coronal assimilation	1.16	1.10	0.48	1.06	1.11	0.52	1.39	0.94	0.47
	Labial assimilation	0.67	1.09	1.34	0.71	0.72	2.43	0.62	1.85	0.29
	Dorsal assimilation	0.83	0.48	2.57	1.27	0.77	1.30	0.61	0.39	2.59
25 to 30	Coronal assimilation	0.96	1.03	1.06	0.86	1.20	1.03	2.05	0.53	0.00
	Labial assimilation	1.18	0.79	0.95	1.34	0.46	1.02	0.51	1.27	0.83
	Dorsal assimilation	0.32	1.89	0.91	0.00	2.68	0.64	1.32	0.69	2.86
31 to 36	Coronal assimilation	0.96	1.23	0.69	0.99	1.30	0.64	0.73	1.11	1.81
	Labial assimilation	1.02	0.71	1.49	1.05	0.57	1.41	0.00	1.61	0.00
	Dorsal assimilation	1.22	0.74	0.73	0.00	2.14	2.82	2.49	0.23	0.00

P4 Discussion: Developmental Patterns

- Vowel effects decreased.
  - CV movement-based constraints decrease over ti me.

- Preference for motorically available forms persists.
  - Children continue to favor labial and coronal for ms available to the movement system from the on set of word use.

  - Acquisition of serial complexity follows a path of overcoming movement constraints to match ambi ent language word complexity guided by perceptu al input from ambient language.

Discussion: Assimilation

- All four study predictions confirmed

- Results support Frame-Content principles

    Movement based principles guiding output patterns in formative period of phonological development

    Children move from highly movement types and movement sequences to ambient language specific levels of complexity

    - Guided by socially mediated perceptual input to meet functional goals within their environment..

TOPIC: INTERSYLLABIC COMPLEXITY CONSONANT CLUSTERS

- Prediction 1: Homorganic versus heterorganic clusters. Cluster constituents will be characterized by lack of place related movements (i.e. homorganic for place).

- Prediction 2: CV co-occurrence constraints in CCV clusters. There will be vowel context effects on CCV clusters

(Jakielski,Davis & MacNeilage, in prep)

CONSONANT CLUSTERS: METHODS

- Participants
  - 5 children from the TSP database
  - From onset of babbling to 36 months of age

- Data Analysis
  - All canonical babbling and word tokens analyzed.
  - 2,334 clusters in babbling and words across study.
    - 782 in babbling
    - 1,552 in words.
  - Data analyzed
    - within 8 time intervals (7-8, 9-12, 13-16, 17-20, 21-24, 25-28, 29-32, 33-36 mos.)
    - CCs in initial, medial, and final positions

P1 Results: clusters in babbling

- Clusters in Initial, Medial, and Final Position: Babbling.

  -4/5 children conformed to this trend in all utterance positions

  -R conformed in final position only.

	Initial		Medial		Final		Totals		Participant Totals
Participant	Hm	He	Hm	He	Hm	He	Hm	He	
C	59	18	45	11	22	0	126	29	155
M	50	3	24	0	33	0	107	3	110
N	14	0	92	3	33	4	139	7	146
P	40	0	10	0	0	0	50	0	50
R	0	3	7	15	7	0	14	18	32
Total	163*	24	178*	29	95*	4	436*	57	493
Context	187		207		99		493		

Hm = homorganic; He = heterorganic. * Indicates significance at the .001 level.

P1 Results: clusters in words

- Clusters in Initial, Medial, and Final Position: Words.

  4/5 infants showed predicted trend in all utterance positions.

  Infant R conformed to this trend in medial and final positions only.

	Initial		Medial		Final		Totals		Participant Totals
Participant	Hm	Ho	Hm	Ho	Hm	Ho	Hm	Ho	
C	590	195	169	20	230	72	989	287	1,276
M	9	0	3	0	27	0	39	0	39
N	29	16	8	3	17	0	54	19	73
P	9	0	0	0	0	0	9	0	9
R	3	4	6	0	45	4	48	8	56
Total	640*	215	186*	23	319*	76	1,145*	314	1,459
Context	855		209		395		1,459		

Hm = homorganic; He = heterorganic. * Indicates significance at the .001 level.

P1 discussion: consonant Clusters

- Over 4 times as many homorganic than heterorganic clusters (1,581 versus 371)
- All five participants produced more homorganic than heterorganic clusters.
- All but one participant (R) produced more homorganic clusters in both babbling and words.
- The percentage of homorganic clusters produced ranged from 72% for R to 100% for P.

Extends the Frame-Content conceptualization: Limited tendency for articulators to make active changes from one consonant in a cluster to the next in any position .

P2 Results: Vowel Context Effects

CCV Babbling

- All three predicted patterns observed.
- Tendency for dorsal-central

	Front	Central	Back
Coronal	1.46*	0.85	0.55
Labial	0.66	1.12*	1.33
Dorsal	0.97	1.00	1.04*

Observed divided by expected values.
*co-occurrence at a level greater than expected.
Chance-level co-occurrence = 1.0.

CCV-Words

Coronal-front and labial-central
No dorsal-back.
Other patterns: dorsal-front, labial-back.

	Front	Central	Back
Coronal	1.06*	0.90	0.93
Labial	0.95	1.08*	1.05*
Dorsal	1.15*	0.77	0.83

Observed divided by the expected values.
* co-occurrence at a level greater than expected.
Chance-level co-occurrence = 1.0.

P2 DISCUSSION: VOWEL CONTEXT EFFECTS

Consonant Clusters in Babbling and Words

- With one exception, the predicted consonant-vowel co-occurrence patterns were observed.
  - Dorsal- back in words not observed. (Approx. 1% of CVs for the 5 children during period).

- Retention of CV co-occurrences, indicating lack of movement from C to V in context of C to C movement patterns

Conclusion

- Movement capacities are a primary motivation for resolutio n of assimilation patterns and cluster acquisition.

- Children use forms most available to their production system to reduce movement complexity required for word targets.

- Reduction in complexity interfaces with increase of function al load in developing phonological system interfaced with m ental lexicon during the first three years of life.

- Perceptual influences guide precision in achieving ambient l anguage complexity.

Theoretical Foundation: Embodiment and Complexity Science

- Interpenetration between organism and environment creates the complex behavioral outcome as well as eventual competence.

  Oyama, 2000

- Intelligent directed behavior may not be viewed as doing or thinking the same thing over and over.

  Clark, 1997

- Child behaviors in acquisition are the product of a “mind in motion” constantly changing itself to fit the whole of its experience based on the actions of the body in relation to input from the environment.

  Port & vanGelder, 1995

Phonotactic Complexity: Future Research

- Broader analyses: including accuracy, deletion, and other error patterns f or CCs and Assimilation.
- Role of Input: Influences of Phonotactic Probability and Syllable Freque ncies
- Lexicon: Frequency of occurrence of individual lexical items and lexical neighborhood effects
- Word and Utterance Level Complexity: Interface of assimilation with syn tactic and morpho-syntactic expansion
- Cross Language Analysis of typologically diverse langauges
- Individual Differences as well as group trends