The Articulatory Basis of Positional Asymmetries in Phonological Acquisition

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I. A functional solution to the problem of child-specific phonological processes

1. Child-specific phonological processes: Processes that may be commonly attested in the course of typical development, but lack counterparts in adult phonological typology. Examples:
   a. Velar fronting: [doʊ] "go"
   b. Fricative gliding: [joʊ] "sew"
   c. Major place harmony: [gʌk] "duck"
2. In contrast with adult phonologies, numerous child-specific processes (including 1a-c) neutralize phonemic contrast in strong positions while preserving contrast in weak contexts.
   a. Traditionally, strong positions are word- or foot-initial, while weak contexts are non-initial.
      - More accurately, strong versus weak contexts are differentiated by perceptual cue strength, but the traditional definition should suffice for all of the contrasts considered here.
3. These processes are difficult to model without making incorrect predictions for adult typology. A satisfactory model must explain how these processes are suppressed in the transition to maturity.

Table 1. Alternatives for modeling neutralization in strong position

Phonological framework	*Child processes call for:*	*Attested in adults?*
Positional faithfulness (Beckman, 1998)	Constraints enhancing faithfulness to weak positions (IDENT-weak)	No
Positional markedness (Smith, 2000, 2002)	Constraints limiting featural contrasts in strong positions (e.g. *LAB/σ′)	No
Licensing-by-cue (Steriade, 1997, 1999, 2001)	Constraints enforcing enhanced faithfulness to perceptually weak positions	No

4. Hypothesis: All genuine child-specific constraints are rooted in child-specific phonetic factors.
   a. I adopt a phonetically-informed version of phonology, assuming that models of both child and adult grammars are more satisfactory if informed by motoric/aerodynamic/perceptual factors.
   b. From this perspective, if there are areas of divergence in phonetic pressures between immature and mature systems, we predict differences across child and adult phonologies.
   c. These constraints cease to play an active role in the grammar as the child-specific phonetic pressures are eliminated over the course of maturation.
   d. Articulatory differences can be seen to represent the primary motivation for child-specific processes.
5. I will argue that three recalcitrant problems in phonological modeling of child speech receive a satisfactory explanation with reference to child-specific articulatory pressures.

II. Aspects of articulatory maturation contributing to child-specific speech processes

6. Hallmarks of child articulation: Greater variability, <u>slower rate</u>, disrupted rhythm, diminished coordination, <u>decreased precision and flexibility</u>.
   a. Slower rate: Individual words and segments have a longer duration in child speech.
      - Articulator velocity plays a role in calculations of articulatory effort.
      - Here it will be assumed that the constraint *EFFORT ("Minimize articulator velocity") is more heavily weighted in less skilled speakers.
   b. Decreased precision and flexibility: Described in detail in (8).
7. General principles of motor maturation can inform our understanding of child speech development.
   a. In early stages, stability is maximized at the expense of efficiency and precision.
      - Reducing the number of degrees of movement freedom allows the child to hold motor tasks to a manageable level of complexity.
         - e.g. Stiffly extended legs create stability for a child to take his first steps.
      - Stability comes with the cost of "clumsy, stereotyped," and energy-inefficient movement.

   b. Over the course of repetitive practice, there is a process of *diversification*, where modifications are tried out in search of the optimal movement pattern.
      - Number of degrees of movement freedom increases.
      - Movement becomes specialized for a particular goal and responds flexibly to perturbations.
      - Extraneous muscle activation is decreased (overall energy expenditure declines).

8. In speech-motor control, different articulators present differing degrees of motor control difficulty.
   a. Jaw movements are simple, stabilized by a bilaterally hinged joint.
   b. The tongue, a muscular hydrostat, has separate "skeletal, movement, and shaping requirements" and thus presents a unique motor control challenge for the child speaker (Kent, 1992).
   c. The young child thus tends to rely on changes in jaw height to shape the oral cavity.
   d. MacNeilage & Davis (1990) argue that patterns of consonant-vowel cooccurrence in babbling reflect repetitive mandibular oscillation with the tongue held in a fixed position.
   e. Jaw-dominated movement continues throughout early childhood, giving rise to the prevalence of ballistic (imprecise) over controlled gestures (Kent, 1992).

9. Here, the principle of mandibular dominance was expressed as a constraint MOVE-AS-UNIT: "Lingual targets are produced by movements of the tongue-jaw complex."
   a. Tongue-jaw complex: The oral tongue is tensed and moves with the active mandible.
   b. MOVE-AS-UNIT is proposed as a violable constraint:
      - Its effects surface even in children who have demonstrate the capacity for separate tongue and jaw movement (Edwards et al., 1999).
      - Its effects have a systematic, grammatical quality.

10. Properties of MOVE-AS-UNIT:
    a. Lingual control becomes more challenging as the tongue moves further away from its source of stability, the jaw. Thus, a discrete lingual gesture with a high articulatory target incurs a larger violation of MOVE-AS-UNIT than a discrete lingual gesture with a lower target.
    b. Jaw-dominated movement is associated with distinctive patterns of linguopalatal contact.
       - When the jaw has a high position, the tongue body is compressed in an anterior direction.
         - This is evident in studies of adult articulation (the velar loop phenomenon).
         - Because the child's jaw is held higher, this compression is more pronounced.
         - The result is a pattern of *undifferentiated lingual contact*, spanning effectively the entire palate at midline (Gibbon, 1999).
       - Due to the rotational component of mandibular movement, linguopalatal contact tends to be initiated in a posterior region and spread anteriorly.
         - Thus, velar release habitually precedes coronal release in an undifferentiated gesture.

11. On the elimination of MOVE-AS-UNIT effects:
    a. With increasing motor skill, discrete lingual gestures become stable independent of jaw support.
    b. In a skilled speaker, moving requires more energy than moving the tongue. Thus, *EFFORT prohibits movements of the tongue-jaw complex when a discrete lingual gesture would suffice.
    c. To ensure that*EFFORT >> MOVE-AS-UNIT in all mature speakers, the weight of MOVE-AS-UNIT is posited to be an index of the stability advantage for tongue-jaw over lingual movement.
       - As this advantage drops near zero over the course of development, the weight of MOVE-AS-UNIT becomes vanishingly small.

12. How do child-specific articulatory limitations translate into patterns of neutralization in strong position? The positional nature of children's processes will be shown to reflect asymmetries in the force and duration of gestures across syllable-initial and syllable-final contexts.

III. A case study of Move-as-Unit effects: Velar fronting

13. Velar fronting typically applies preferentially in word-initial and pretonic contexts while preserving contrast in coda position (Chiat, 1983; Stoel-Gammon, 1996; Bills & Golston, 2002; Morisette, Dinnsen, & Gierut, 2003; Inkelas & Rose, 2003, 2008).

14. Velar fronting case study:
    a. Subject: B, age 4, diagnosed with Childhood Apraxia of Speech.
    b. Words containing prevocalic velar targets were collected from the transcribed record of B's biweekly therapy sessions between 3;9 and 4;4. Total N = 1,696.
    c. Targets were coded for developmental stage, prosodic context (initial, medial pretonic, medial posttonic), vowel context (back, nonback), voicing, and presence of other velar targets.
    d. B's productions were coded into four major categories

Table 2. Output categories in velar production analysis

Category		*Example*		*Score*
Faithful velar place		[okej]	"okay"	1
Fronted place		[dat]	"cut"	0
Glottal replacement		[mʌʔĩ]	"making"	0
Segmented production	Preglottalized	[mʌʔkij]	"monkey"	0
	Postglottalized	[dakʔoʊ]	"tiger"	

16. Results were analyzed using logistic regression, dependent variable = faithful velar place. Four factors were significant ($p < .000$): developmental stage, prosodic context, voicing, and presence of other velars.

17. Main effect of prosodic context: Medial posttonic > Initial, Medial pretonic (Fig. 1).
    Qualitative observations:
    a. Word-final targets (not included in regression) were more accurate than medial posttonic velars.
    b. Accurate production emerged in medial pretonic context before initial context.

18. Main effect of voicing: Voiced > Voiceless (Fig. 2). In Stage 4/4, accurate voiced targets contrasted systematically with segmented voiceless targets:
    a. [kʔip] "keep" [kʔandoʊ] "candle"
    b. [gam] "gum" [gabaʃ] "garbage"

19. Across non-final positions, velar place with segmented (pre- or post-glottalized) manner emerged before fully faithful velar production.

Figure 1. Velar accuracy by prosodic context

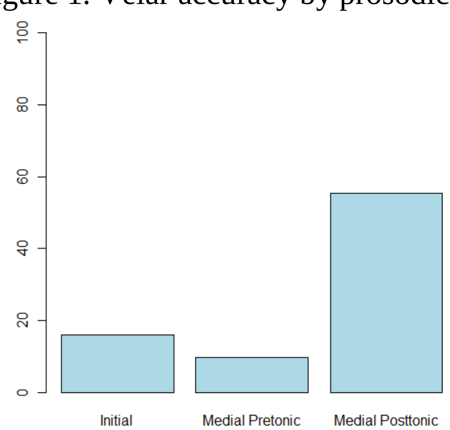
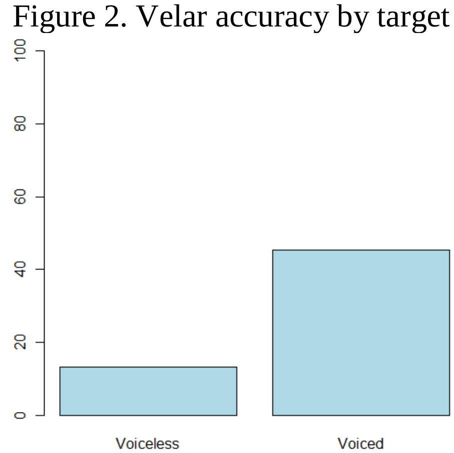


Figure 2. Velar accuracy by target voicing



20. All contexts seen to facilitate velar place are associated with a relatively low level of intraoral pressure.
    a. Consonants in word-initial and pretonic positions are associated with elevated intraoral pressure (Malécot, 1955; Ladefoged, 1967; Ladefoged & Loeb, 2002).
    b. Voiceless stops have higher intraoral pressure than voiced stops (Ladefoged & Maddieson,1996).
    c. Preglottalization prevents accumulation of air pressure in the oral cavity (Clements & Osu, 2002).

21. Elevated intraoral pressure necessitates more forceful closure to avoid spirantization. Tighter closures have been documented in word-initial relative to word-final contexts (e.g. Keating & Fougéron, 1997) and in voiceless relative to voiced contexts (e.g. Mooshammer et al., 2006, 2007).

22. Recall that the difficulty associated with discrete lingual gestures increases as the tongue moves further from the stable base provided by the jaw.
    a. The magnitude of the MOVE-AS-UNIT violation for a lingual gesture is scaled to articulatory target height, which can be calculated from positional and laryngeal factors influencing intraoral pressure.

Table 3. Proposed metric for calculating MOVE-AS-UNIT violations from intraoral pressure

Context	Example	Oral Place	Pretonic	Voiceless	Initial	Glottalized	Sum
Initial pretonic voiceless	[kiŋ], *king*	+2	+1	+1	+.5		4.5
Pretonic voiceless	[bukaj], *bouquet*	+2	+1	+1			4
Initial pretonic voiced	[gam], gum	+2	+1		+.5		3.5
Pretonic voiced	[əgɛn], *again*	+2	+1				3
Posttonic voiceless	[maki], *monkey*	+2		+1		-.5	2.5
Posttonic voiced	[dɔgi], *doggie*	+2					2
Final	[dak], *duck*	+2				-1	1

23. MOVE-AS-UNIT is not violated when the tongue plays a passive role in a jaw-dominated gesture. This results in undifferentiated lingual contact, violating faith constraints DEP-Place and HAVE-ONE-PLACE.

Table 4. Word-initial velars are fronted (high-weighted MOVE-AS-UNIT, B's Stage 2)

/kʌp/, "cup"	MAX-Place (3)	MOVE-AS-UNIT (2)	DEP-Place (2)	HAVE-ONE-PLACE (1)	**SUM**
a. ☞ cʌp	0	0	1	1	**3**
b. kʌp	0	4.5	0	0	**9**
c. tʌp	1	4.5	1	0	**14**

Table 5. Word-final velars are realized faithfully (high-weighted MOVE-AS-UNIT, B's Stage 2)

/dʌk/, "duck"	MAX-Place (3)	MOVE-AS-UNIT (2)	DEP-Place (2)	HAVE-ONE-PLACE (1)	**SUM**
a. dʌc	0	0	1	1	**3**
b. ☞ dʌk	0	1	0	0	**2**
c. dʌt	1	1	1	0	**7**

24. Over the course of development, the decreasing weight of MOVE-AS-UNIT allows velar place to emerge in contexts with increasingly higher articulatory targets.

Table 6. Word-initial voiced velars are realized faithfully (low-weighted MOVE-AS-UNIT, B's Stage 4)

/gat/, "got"	MAX-Place (4)	DEP-Place (2.5)	DEP-[ʔ] (2.25)	HAVE-ONE-PLACE (2)	IDENT-Voice (1.5)	MOVE-AS-UNIT (1)	**SUM**
a. ɟat	0	1	0	1	0	0	**4.5**
b. ☞ gat	0	0	0	0	0	3.5	**3.5**
c. dat	1	1	0	0	0	3.5	**10**
d. kʔat	0	0	1	0	1	2	**5.75**

Table 7. Word-initial voiceless velars are postglottalized (low-weighted MOVE-AS-UNIT, B's Stage 4)

/kʌp/, "cup"	MAX-Place (4)	DEP-Place (2.5)	DEP-[ʔ] (2.25)	HAVE-ONE-PLACE (2)	IDENT-Voice (1.5)	MOVE-AS-UNIT (1)	**SUM**
a. cʌp	0	1	0	1	0	0	**4.5**
b. gʌp	0	0	0	0	1	3.5	**5**
c. kʌp	0	0	0	0	0	4.5	**4.5**
d. tʌp	1	1	0	0	0	4.5	**11**
e. ☞ kʔʌp	0	0	1	0	0	2	**4.25**

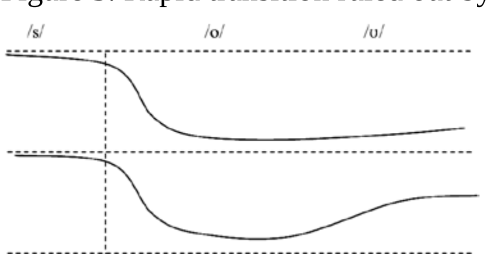
IV. *EFFORT and MOVE-AS-UNIT effects in fricative acquisition

25. An unexplained asymmetry: Some children acquire fricatives in word-final before word-initial contexts.
    a. Fricatives occur preferentially in coda position in babbling (e.g. Oller & Eilers, 1982; Redford, MacNeilage & Davis, 1997).
    b. In older children, prevocalic fricatives may be neutralized with stops or glides while coda fricatives are preserved (e.g. Edwards, 1996; Marshall & Chiat, 2003; Dinnsen & Farris-Trimble, 2008).

26. Asymmetric acquisition of fricatives in case study subject B
    a. Earliest recorded stage (ages 3;9-3;11), all speech contexts:
        - Onset fricatives are replaced with glides.
          [jɔs] 'swords' [jaʔ] 'shark' [wɔdɛʔ] 'forget'
        - Coda fricatives are realized faithfully, with epenthetic glottal stop word-medially.
          [mas] 'mouse' [babajis] 'strawberries' [bʌʃʔo] 'shovel'
    b. Intermediate stage (ages 4;0-4;2), monitored speech only:
        - Onset fricatives are realized faithfully before some [+high] vowels:
          [sij] 'see' [sio] 'seal' [ʃuw] 'shoe'
        - An epenthetic glide separates an onset fricative from a nonhigh vowel.
          [sjʌ] 'sun' [sjak] 'sock' [ʃjɛpo] 'shepherd'
    c. Logistic regression confirmed that transcribed vowel height was a significant predictor of fricative accuracy (p < .000). When scalar-level F1 height was added as a factor for a subset of tokens (~200 tokens collected between 3;10 and 3;11), the contribution was marginally significant, *p* = .07.

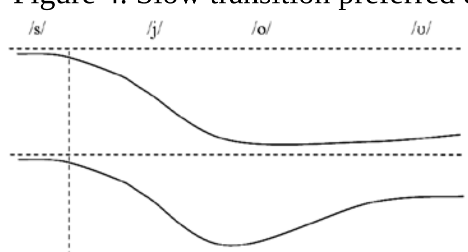
27. Factors conditioning B's prevocalic fricative production are posited to reflect the action of *EFFORT, "Minimize articulator velocity."
    a. With time held constant, a smaller articulatory distance is preferred, hence the advantage for high vowels (small transition) over nonhigh vowels (large transition, seen in Fig. 3).
    b. *EFFORT violations can also be limited by extending the duration of the articulatory transition. Glide epenthesis is reinterpreted as the perceptual result of an elongated fricative-vowel transition (Fig. 4).
    c. Gliding (Fig. 5) also reflects an elongated transition, with more extensive coarticulatory undershoot.
    d. No glide percept emerges in slowed adult speech: A coarticulated fricative-vowel transition in adult speech involves anticipatory jaw-lowering, with the tongue held high to sustain frication (Mooshammer et al., 2006). For high-weighted MOVE-AS-UNIT, this candidate (Fig. 6) loses to the form with simultaneous tongue and jaw lowering (Figure 4).
    e. B also appears to produce all coronal fricatives with a relatively high tongue body, with spectral analysis revealing considerable overlap between alveolar and postalveolar fricatives.

Figure 3. Rapid transition ruled out by *EFFORT



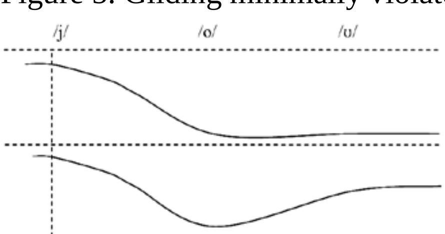
*Violations: *EFFORT (4)*

Figure 4. Slow transition preferred despite glide percept



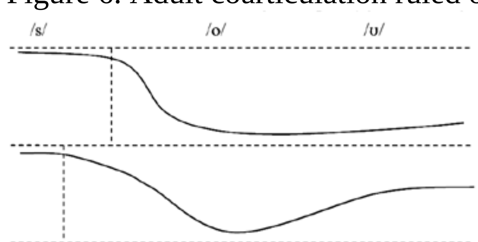
*Violations: *EFFORT (2), DEP-Glide (1)*

Figure 5. Gliding minimally violates *EFFORT



*Violations: *EFFORT (1), IDENT-Consonantal (1)*

Figure 6. Adult coarticulation ruled out by MOVE-UNIT



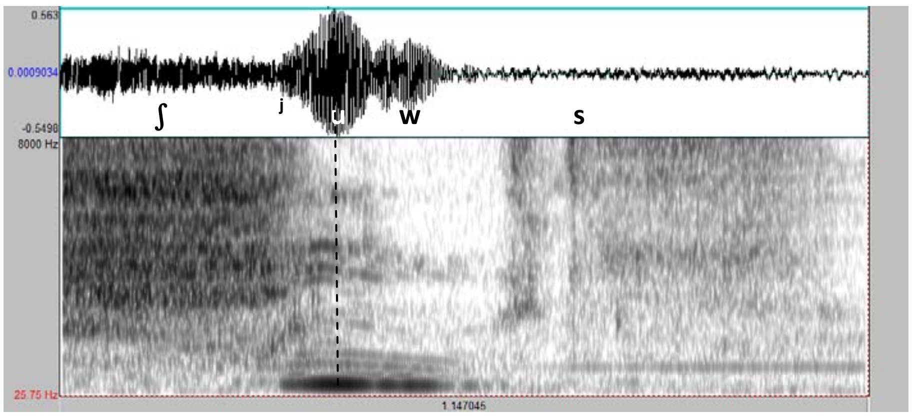
*Violations: *EFFORT (2), MOVE-AS-UNIT (1)*

Table 8. *EFFORT and MOVE-AS-UNIT cause gliding candidate to be preferred (B's Stage 1)

/soʊ/, *sew*	MOVE-AS-UNIT (3)	IDENT-cons (1.5)	*EFFORT (1)	DEP-glide (1)	**SUM**
a. soʊ (Fig. 3)	0	0	4	0	**4**
b. sjo (Fig. 4)	0	0	2	1	**3**
c. ☞ joʊ (Fig. 5)	0	1	1	0	**2.5**
d. s̠oʊ (Fig. 6)	1	0	2	0	**5**

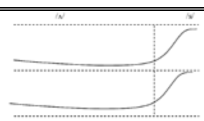
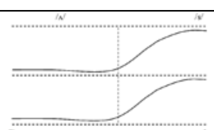
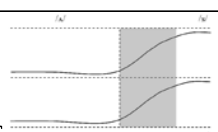
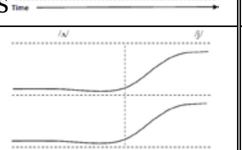
28. Over time, decreasing weight of *EFFORT allows glide epenthesis and faithful fricatives to emerge.
29. Modeling fricative acquisition with *EFFORT suggests that the onset-coda asymmetry reflects a vowel-fricative transition that is either (1) smaller or (2) slower than the fricative-vowel transition.
    Hypothesis 1: Ruled out. Narrow articulatory target permits minimal positional variation (Fougéron, 1999).
    Hypothesis 2: Supported. Figure 7 depicts VC > CV in what looks like phrase-final lengthening. Given B's prosodic disruptions, though, lengthening was observed at the level of individual words/syllables.

Figure 7. Vowel-fricative transitions are slower than fricative-vowel transitions, even phrase-medially.



30. But why not enable faithful fricative production by extending the CV transition as well?
    a. Elongation of VC but not CV portions is a general property of final lengthening (Beckman et al., 1991).
    b. High-weighted IDENT(Timing) prevents lengthening outside of a designated domain (π-domain), which is necessarily adjacent to a final boundary.
    c. Unlike CV transitions, B's extended VC transitions were not transcribed with a glide. This reflects a pervasive process of preaspiration as well as the intrinsically lesser perceptibility of VC transitions.

Table 9. Final lengthening minimizes violation of *EFFORT and permits postvocalic fricatives (B's Stage 1)

/ʌs/, *us*	MOVE-UNIT (3)	IDENT-cons (1.5)	*EFFORT (1)	DEP-j (1)	DEP-h (.5)	**SUM**
	3	1.5	1	1	.5	
a. ʌs 	0	0	4	0	0	**4**
b. $ʌ^{j}s$ 	0	0	1	.5	0	**1.5**
c.☞ $ʌ^{h}s$ 	0	0	1	0	.5	**1.25**
d. ʌj 	0	1	.5	0	0	**2**

V. Processing and articulatory factors in consonant harmony

31. Child consonant harmony most canonically involves long-distance assimilation for major place feature, a phenomenon not attested in adult processes of long-distance consonant assimilation.

32. Generalizations over English child consonant harmony (Pater & Werle, 2001, 2003):
    a. Preferred regressive direction of assimilation. Despite superficial similarity to regressive bias in local assimilation, the perceptual asymmetry motivating that bias does not apply in the CH case.

    [gʌk] "duck" > [kʌk] "cut"

    b. Preferred trigger of harmony is velar; preferred target is coronal. Labials can appear either as trigger with coronals or target with velars, but labial participation in CH is less robust than other places.

    [gɔg] "dog" > [gɪg] "pig" / [pap] "top"

33. Place asymmetries are typically encoded as scales of markedness within constraints driving assimilation. However, new evidence from speech errors suggests a perceptual origin.
    a. Pouplier and colleagues have demonstrated that a large proportion of seemingly categorical speech errors involve coproduction of a target gesture and an intrusive error gesture.
    b. Pouplier & Goldstein (2005) demonstrated that a velar intrusion in a coronal target was perceived as errorful, but intrusive coronal gestures during velar targets were not detected.
    c. This asymmetry is motivated by differences in duration: slow velar gesture tends to overlap rapid coronal gesture (Fig. 8). The duration of the labial gesture is intermediate between coronal and velar.

34. Hypothesis: Like speech errors, child harmony involves coproduction of target and intrusive gestures. Place of articulation asymmetries, at least for coronal and velar place, are driven by perception.

35. Experiment: Acoustic analysis of minimally differing syllables with and without consonant harmony.
    a. Subject: J, 2;11-year-old boy with consistent regressive harmony to a velar trigger.
    b. Stimuli: Repeated utterances of nonwords *duggen* and *guggle*, both consistently transcribed with initial [g] in J's output.
    c. Results: *Duggen* and *guggle* sets were associated with significantly different F2 at vowel onset (p = .03). Direction of difference ($F2_{dug} > F2_{gug}$) was the same as for control children with perceptually distinct /d/ and /g/. Slopes of calculated locus equations also fell in the predicted direction (/g/ > /d/).

Figure 8. Simultaneous coronal and velar gestures are perceived as velar

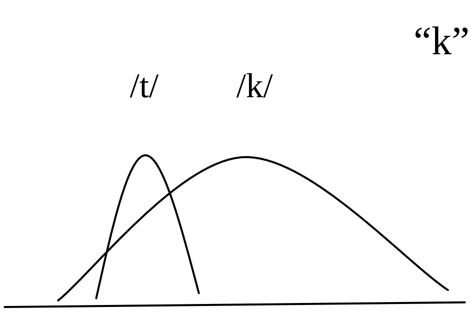
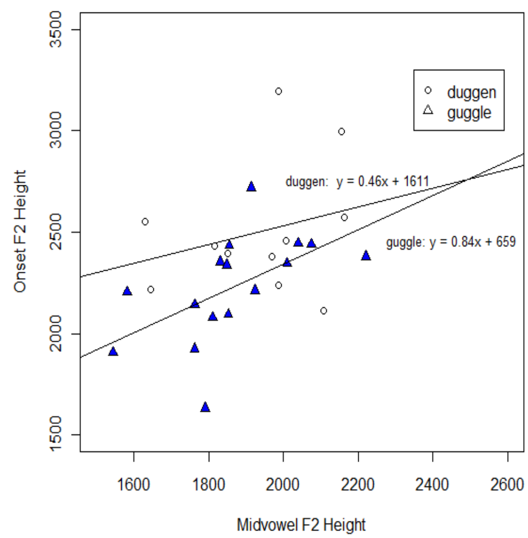


Figure 9. Covert /d/-/g/ contrast (Subject J)



36. This covert contrast provides preliminary support for proposal that child CH involves gestural coproduction rather than true substitution.
    a. However, the articulatory motivation Pouplier proposes for intrusive speech errors (oscillator entrainment) does not translate to cases of assimilation between onset and tautosyllabic coda.

37. Diverging from the purely articulatory analyses in Sections III and IV, we look to psycholinguistic processing factors to provide the motivation for CH.

a. Evidence from speech errors and adult phonologies indicates that there is pressure to avoid similar but non-identical targets in close proximity.
b. In a spreading-activation model (e.g. Dell, 1986), targets that share more features are activated to a similar extent, increasing the likelihood of making the wrong selection.
c. This model predicts the regressive directional bias. There is active competition between current and future targets, but past targets are suppressed, posing relatively little competition for a later target.

38. This pressure has been encoded in the phonological framework of agreement by correspondence (Hansson, 2001; Rose & Walker, 2004).
   a. Correspondence is enforced by a hierarchy of CORR-C⇔C constraints whose weight is determined by the degree of similarity between segments. Segments in correspondence are subject to IDENT-CORR constraints militating for featural agreement. Preferred directionality is encoded with a directional constraint, IDENT-C_RC_L.
   b. However, the Dell model and the agreement by correspondence framework identify a single well-formed segment as the output, incompatible with the finding of covert contrast.

39. Proposal: The forms that compete for activation are articulatory gestures rather than segments. When two gestures are activated to a similar degree, simultaneous coproduction.
   a. Input-output faithfulness constraints also have a gestural definition. The ranking MAX-gesture >> DEP-gest reflects a bias to insert rather than delete content, seen in speech errors (Pouplier, 2008).
   b. The most harmonic solution for C_1VC_2 features an intrusive C_2 gesture during C_1 (Table 12).
      - Intrusion is favored even if the word-final consonant has coronal place; the coronal-velar asymmetry reflects the minimal perceptibility of coronal intrusion during a velar target.
      - Progressive harmony can be modeled with a higher weight for the general constraint IDENT-CC, but this ranking features intrusive gestures at both edges of the word (total gestural identity).

Table 10. Regressive assimilation between a coronal and a velar features covert contrast (perceived as [gʌk])

/dʌk/, "duck"	CORR-T↔K (3)	MAX- Gesture (2.5)	IDENT-C_RC_L (2)	IDENT-CC (.5)	DEP- Gesture (.5)	HAVE-ONE-PLACE (.5)	**SUM**
a. $d_xʌk_y$	3	0	0	0	0	0	**3**
b. $d_xʌk_x$	0	0	1	2	0	0	**3**
c. $d_xʌt_x$	0	1	0	0	1	0	**3**
d. $g_xʌk_x$	0	1	0	0	1	0	**3**
e. ☞ $ɟ_xʌk_x$	0	0	0	1	1	1	**1.5**
f. $ɟ_xʌc_x$	0	0	0	0	2	2	**2**

Table 11. Progressive harmony requires total identity (intrusive gestures at both edges)

/kʌt/, "cut"	CORR-T↔K (3)	IDENT-C_RC_L (3)	MAX-Gesture (2.5)	IDENT-CC (1.5)	DEP- Gesture (.5)	HAVE-ONE-PLACE (.5)	**SUM**
a. $k_xʌt_y$	1	0	0	0	0	0	**3**
b. $k_xʌt_x$	0	1	0	2	0	0	**6**
c. $k_xʌk_x$	0	0	1	0	1	0	**3**
d. $t_xʌt_x$	0	0	1	0	1	0	**3**
e. $c_xʌt_x$	0	0	0	1	1	1	**2.5**
f. ☞ $c_xʌc_x$	0	0	0	0	2	2	**2**

40. This model also predicts less robust application of labial place harmony.
   a. We saw that more similar segments face stronger pressure to enter into correspondence.
   b. Adopting an articulatory standard of similarity: T↔K, which share a single articulatory structure, are more similar than P↔K/T.

41. On the non-attestation of major place harmony in adult phonologies
   a. Young child speakers have a strong preference for reduplicated consonant sequences, manifest in reduplicated babbling and wordforms (e.g. [baba] for *bottle*) as well as consonant harmony.
   b. By contrast, adult phonologies actively disprefer reduplicated consonant sequences (cf. OCP effects).

c. If change from child to adult grammar involves only demotion of Corr-CC, we expect the occurrence of reduplicated sequences to fall to chance but not below-chance levels.

42. Biomechanical Repetition Avoidance Hypothesis (Walter, 2007): Reduplicated sequences are dispreferred because they require more articulatory effort than heterorganic sequences.
    a. Anticipatory coarticulation is available in alternating but not repetitive series of gestures.

43. Thus, in adult languages I-O faithfulness and effort-minimization gang up to offset the action of Corr-CC (Table 12).

44. Children with active Move-As-Unit have a limited capacity for anticipatory coarticulation.
    a. This neutralizes the effort advantage for candidates with alternating place (Table 13).
    b. Other factors can thus emerge, notably the processing pressures encoded in the Corr-CC hierarchy.

Table 12. Effort-minimization blocks major place assimilation in adult phonology

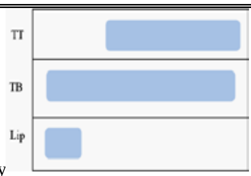
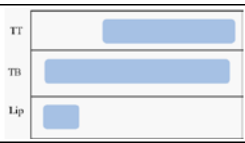
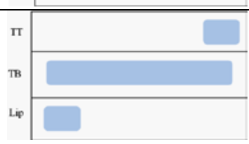
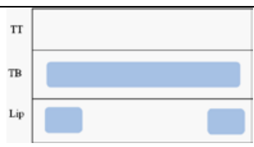
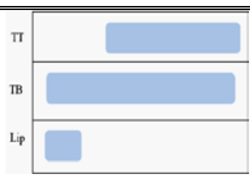
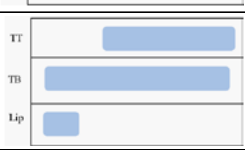
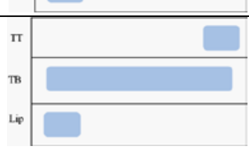
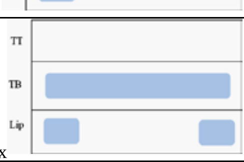
/pat/, "pot"	Ident-Corr (2)	*Effort (2)	Move-As-Unit (.25)	Corr-P↔K (.25)	**SUM**
a. ☞p_xat_y 	0	0	1	1	**.5**
b. p_xat_x 	1	0	0	0	**2**
c. p_xat_y 	0	1	0	1	**2.25**
d. p_xap_x 	0	1	0	0	**2**

Table 13. Move-As-Unit permits emergence of major place correspondence in child speakers

/pat/, "pot"	Ident-Corr (3)	Move-As-Unit (3)	*Effort (2)	Corr-P↔K (1)	**SUM**
a. p_xat_y 	0	1	0	1	**4**
b. p_xat_x 	1	0	0	0	**6**
c. p_xat_y 	0	0	1	1	**3**
d. ☞p_xap_x 	0	0	1	0	**2**

VI. Conclusion

45. Each of the three child-specific processes described here has resisted conventional analyses.
    a. However, they receive a satisfactory explanation through analyses incorporating child-specific articulatory limitations.
    b. In the articulatory analysis, the absence of these processes from adult grammar is unproblematic, since the driving phonetic pressure is eliminated over the course of typical speech-motor maturation.
46. Questions for future consideration:
    a. The data reported here were drawn primarily from case studies of one child with a phonological disorder.
        - It remains unknown to what extent the patterns analyzed here are representative of other children, particularly younger children developing typically.
        - However, the principles invoked in this analysis are posited to be general across speakers with immature speech-motor control.
        - Thus, even if a child exhibits a pattern unlike B's, an analysis with consideration for MOVE-AS-UNIT and *EFFORT is likely to be profitable.
    b. The role of perceptual differences in shaping child-specific patterns remains unclear.
        - The hypothesis that children's processes of strong neutralization reflect a child-specific pattern of enhanced perception of word-final contrasts (Dinnsen & Farris-Trimble, 2008) was not supported in a nonword discrimination task.
        - However, evidence of parallel deficits in production and perception emerged in this study and in previous literature.
        - While this effect might be achieved by allowing markedness constraints to apply over perception as well as production mappings (Pater, 2004), this topic in large part remains to be explored.