Child-Specific Patterns of Positional Neutralization: Articulatory vs. Perceptual Influences

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I. The problem of child-specific patterns of positional neutralization

1. This talk will discuss child phonological patterns that preferentially neutralize phonemic contrast in prosodically strong contexts ("**neutralization in strong position**").

Table 1. Positional velar fronting: neutralization in initial/pretonic but not final/posttonic position

Word-Initial		*Word-Final*		*Medial Pretonic*		*Medial Posttonic*	
[dabus]	"caboose"	[dajæk]	"kayak"	[bidas]	"because"	[dʊki]	"cookie"
[dətaʊ]	"guitar"	[bʌg]	"bug"	[ədɛn]	"again"	[dagoʊ]	"tiger"

Other examples: Fricative/affricate stopping (Dinnsen, 1996, 1998; Edwards, 1996; Marshall & Chiat, 2003); liquid gliding (Smit, 1993; Inkelas & Rose, 2008); cluster reduction (Lléo and Prinz, 1996; Levelt, Schiller & Levelt, 2000).

2. Overall prevalence of child processes of strong neutralization is not known.

   However, sufficiently widespread that preference to preserve contrast in weak contexts has been described as a general property of child phonology (Dinnsen & Farris-Trimble, 2008).

3. Comparable patterns are not attested in adult phonological typology.
   a. Adult grammars show preferential neutralization in prosodically weak contexts.
   b. Proposed phonetic basis: Neutralization occurs in a context of lower perceptual salience (Steriade, 1997, 1999, 2001).

4. Child processes are difficult to model without incorrect predictions for adult typology (Table 2). A satisfactory model must explain how they are suppressed over maturation.

Table 2. 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 contexts	No

5. Proposal: Both child and adult patterns of positional neutralization have a phonetic basis.
   a. However, child and adult speakers face different low-level phonetic pressures.
   b. Differences across child and adult phonologies are then predicted by a phonetically-based model of phonology (Hayes, Kirchner, & Steriade, 2004).
   c. Child-specific constraints become inactive as child-specific phonetic pressures are eliminated over the course of normal maturation.

6. Two possible directions of analysis:
   a. Child-specific perceptual sensitivities cause different positions to be marked as prominent in child phonology (Dinnsen & Farris-Trimble, 2008).
   b. Child-specific articulatory factors can cause neutralization. These factors are sensitive to differences in articulatory force in strong versus weak prosodic contexts (Inkelas & Rose, 2003, 2008).

7. Here, evidence from a single case study will support an articulatory account.
   a. Part I: Nonword discrimination task shows perceptual advantage for strong position.
   b. Part II: Longitudinal study of velar fronting shows articulatory conditioning factors.

8. Case study data drawn from B, a 4-year-old boy acquiring American English.
   a. Severe speech delay and hallmarks of speech-motor planning difficulty.
   b. Recorded longitudinally in biweekly sessions between 3;7 and 4;4.
   c. Processes of neutralization in strong position: velar fronting, fricative gliding.

II. Do child-specific perceptual sensitivities drive neutralization in strong position?

9. Adults perceive contrast more accurately in initial/prevocalic position than in final/postvocalic position (Fujimura, Macchi, & Streeter, 1978; Ohala, 1990; Redford & Diehl, 1999).

10. Dinnsen & Farris-Trimble (2008): Young children exhibit the opposite perceptual bias.
    b. They posit that children perceive contrast more accurately in non-initial position.
    c. Related to hypothesis that infants pay special attention to ends of words to support word segmentation (Slobin, 1973; Echols & Newport, 1992; Aslin et al., 1996).

11. D&F-T propose prominence-assigning constraints FINALPROM, INITIALPROM:
    a. FINALPROM: “The final constituent of a syllable, foot, or prosodic word must be prominent.”
    b. In child grammar, FINALPROM >> INITIALPROM.
    c. Over maturation, sensitivity to initial position increases and ranking is reversed.

12. I will focus on an empirical test of Dinnsen & Farris-Trimble’s analysis.

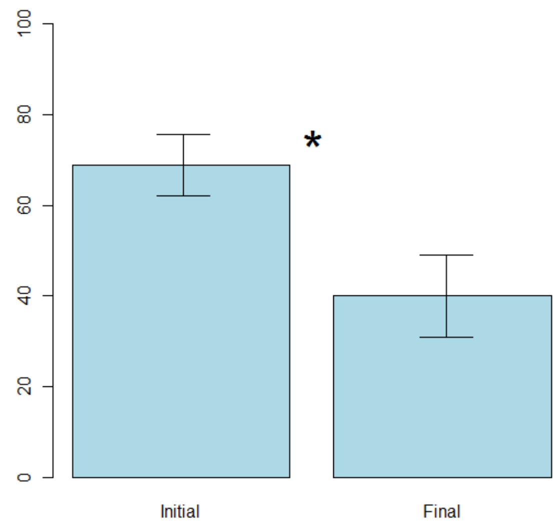
13. B was engaged in a nonword discrimination task featuring pairs of phonetically controlled nonwords in a carrier phrase context (“I can say ___”).
    a. 23 identical nonword pairs
    b. 24 pairs differing by a single phoneme in word-initial position (e.g. *tuv*—*kuv*) or word-final position (e.g. *vud*—*vug*).
    c. Digitized stimuli were played in random order; B responded *same* or *different*.
    d. Complete stimulus set presented twice over three sessions.

14. Accuracy results were fitted to a 5-factor logistic model.
    a. Dependent variable: Accuracy in detecting contrast when present.
    b. Independent variables: Session number, initial vs. final position, identity of target contrast, voicing of target contrast, presence of potential harmonizing contrast.

15. Results of logistic regression using likelihood ratio test on residual deviance statistic:

    b. Significant predictors of discrimination accuracy: Session ($p < .000$), position in syllable ($p = .002$), phonemic contrast ($p < .000$).
    c. Session: B's accuracy was significantly greater in the third testing session.
    d. <u>Position (Fig. 1): Accuracy was significantly greater for initial relative to final contrasts.</u>
    e. Contrast: B detected a contrast he produced in error with significantly lower accuracy than two contrasts he produced correctly.

Fig. 1. Initial vs final discrimination accuracy



16. B's positional bias in perception was consistent with a typical adult pattern (Fujimura, Macchi, & Streeter, 1978; Redford & Diehl, 1999), contra Dinnsen & Farris-Trimble.

17. For this child, neutralization in strong position cannot be attributed to a perceptual cause.

    An articulatory account will instead be pursued.

III. Do properties of child articulation drive neutralization in strong position?

18. It is well-documented that child articulation differs from adult articulation.

    a. Tongue has more anterior position and larger size relative to vocal tract (Crelin, 1987).
    b. Speech gestures are slower, more variable, less precise. *More detail to follow.*

19. Inkelas & Rose (2003, 2008) invoked child-specific articulatory properties to account for positional velar fronting (PVF), an example of strong neutralization.

20. Velar fronting to coronal place is common in typically developing children up to 3 years old (Grunwell, 1981), as well as in disorders.

    - Preferential application in word-initial and pretonic contexts is well-documented (Ingram, 1974; Chiat, 1983; Stoel-Gammon, 1996; Bills & Golston, 2002; Morisette, Dinnsen, & Gierut, 2003; Inkelas & Rose, 2003, 2008).

21. Inkelas & Rose: PVF occurs when child's articulatory limitations interact with articulatory strengthening in prosodically strong contexts.

    a. Child perceives that adults use enhanced gestures in strong contexts; tries to imitate.
    b. Influenced by articulatory limitations:
        - Large, anteriorly positioned tongue
        - Diminished motor control
    c. Linguopalatal contact for the enhanced gesture tends to extend into coronal region.

22. I&R maintain that the phonetically-motivated process is then phonologized. Evidence:

    a. Not all children exhibit PVF.
    b. PVF was eliminated abruptly/categorically from speech of their case study subject.

23. I endorse Inkelas & Rose's hypothesis that neutralization in strong position is driven by prosodically conditioned asymmetries in gestural force.

    However, case study will show the need for more than a simple strong/weak dichotomy.

    - Greater accuracy word-finally than in medial posttonic position.
    - Earlier emergence of velar place in medial pretonic relative to word-initial position.
    - Segmental conditioning effects.

IV. Velar fronting case study data

24. Velar fronting case study:

    a. 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 = 2,408.
    b. Four major categories were represented in B's productions

Table 3. Output categories in velar production

<table>
<tr><th colspan="2">Category</th><th>Example</th><th>Percent of Tokens</th><th>Correct?</th></tr>
<tr><td colspan="2">Faithful velar place</td><td>[dagoʊ] “tiger”</td><td>41%</td><td>1</td></tr>
<tr><td colspan="2">Fronted place</td><td>[dat] “cut”</td><td>34%</td><td>0</td></tr>
<tr><td rowspan="3">Segmented production*</td><td>Preglottalized</td><td>[mʌʔkij] “monkey”</td><td rowspan="3">9%</td><td rowspan="3">0</td></tr>
<tr><td rowspan="2">Postglottalized</td><td>[dʊkʔan] “chicken”</td></tr>
<tr><td>[kʔʌp] “cup"</td></tr>
<tr><td colspan="2">Glottal replacement</td><td>[mʌʔĩ] “making”</td><td>6%</td><td>0</td></tr>
</table>

*Segmented production had a specific association with velar place. It was not observed in connection with coronal targets.

25. Targets were coded for a range of potential conditioning factors:

    a. **Developmental stage** (four approximate stages based on shifts in production)
    b. **Prosodic context** (strong = initial/medial pretonic, weak = final/medial posttonic)
    c. **Voicing** (voiced target, voiceless target)
        - Strong process of context-sensitive voicing entailed that transcribed voicing would be almost entirely redundant with prosodic context.
        - Possibility of a covert voicing contrast (Macken & Barton, 1976).
    d. **Vowel context** (back, nonback)
    e. **Harmony context** (other velar present vs absent in surface form)

28. Results were fitted to a five-predictor logistic model (DV = velar production accuracy).

    a. Partial significance of each factor was determined using the chi-square statistic.
    b. All five main terms were significant predictors of variance ($p < .001$).

29. Two findings will be bypassed for the moment.
    a. Main effect of vowel context (Back > Nonback): Consistent with previous research (Nicolaidis et al., 2003). Measuring of formants to confirm vowel quality is still ongoing.
    b. Main effect of harmony context (Other velar present > absent): Consistent with previous research (Chiat, 1983). Requires articulatory model of consonant harmony.

30. Main effect of prosodic context: Weak > Strong (Fig. 2).
    a. Consistent with previous literature.
    b. Post-hoc pairwise comparisons (Fig. 3): Final > all others. Medial posttonic > initial, medial pretonic. Initial vs medial pretonic not significant after Bonferroni correction.

Figure 2. Accuracy: Strong vs weak context

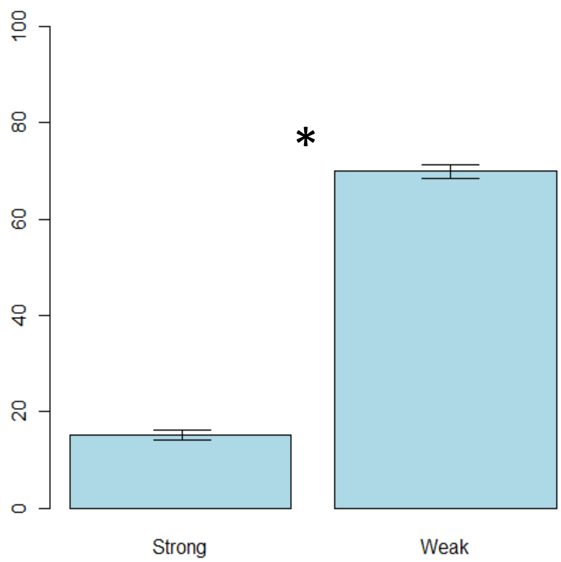
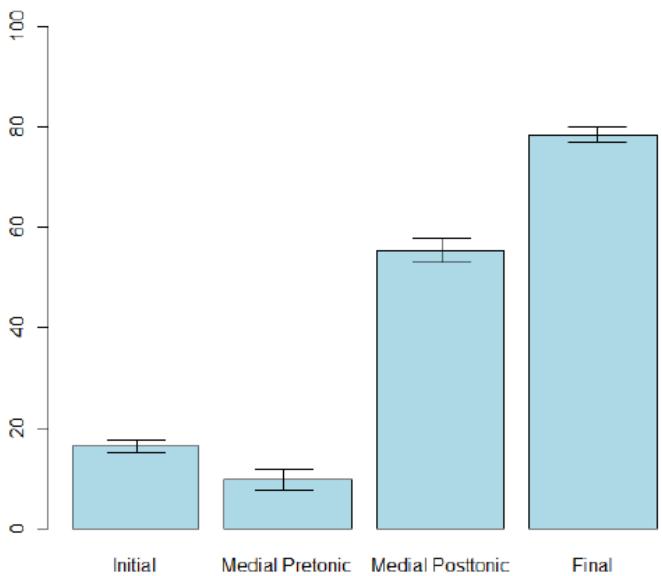


Figure 3. Accuracy: Subdivided by position

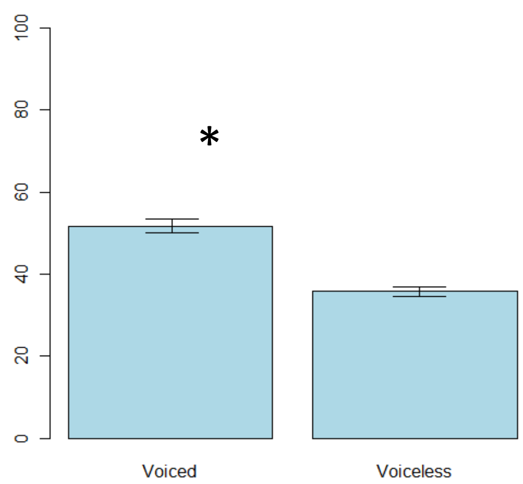


31. Main effect of voicing: Voiced > Voiceless (Fig. 4).
    a. Starting at age 4;2, accurate voiced targets contrasted systematically with segmented voiceless targets in B's output (Table 4).
    b. Runs counter to cross-linguistic adult preference for voiceless over voiced velars (Ohala, 2010).

Table 4. Voiced-voiceless contrast

Age	*Voiced Target*		*Voiceless Target*	
4;2	[bʌgoʊ]	"bagel"	[makʔi]	"monkey"
	[dagoʊ]	"tiger"	[haʔki]	"hockey"
4;4	[gam]	"gum"	[kʔip]	"keep"
	[gabaʃ]	"garbage"	[kʔandoʊ]	"candle"

Figure 4. Velar accuracy by target voicing



32. Case study results pose three challenges:

    a. How does the phonology represent a distinction within a category (strong or weak)?
    b. Why are voiced velars more accurate than voiceless velars?
    c. Why does "segmented production" precede fully faithful velar production?

33. Unifying analysis: Fronting is driven by a directly phonetic constraint (cf. Flemming, 2001, 2008) encoding gradient differences in the height of the articulatory target.

34. Strong versus weak context

    a. Consonant strengthening at the edge of the prosodic word domain is well-documented (Fougeron & Keating, 1997)
    b. Foot-initial strengthening is less well-studied but fully plausible.

35. Voiced versus voiceless target:

    a. Voiceless plosives have greater airflow (Isshiki & Ringel, 1964) due to lack of impedance from vocal folds (McGlone & Shipp, 1972).
    b. To offset greater intraoral pressure, voiceless plosives have higher target/greater gestural force than voiced plosives (Wakumoto et al., 1998; Mooshammer et al., 2007).

36. Segmented forms (accompanying glottal closure)

    a. Closed glottis valves pressure below the level of the oral constriction.
    b. Belong to the class of "non-explosive" consonants (Clements & Osu, 2002).
    c. Low intraoral pressure enables lighter articulatory contact.

V. A constraint encoding gradient differences in articulatory force

37. Proposed constraint is termed MOVE-AS-UNIT: "Lingual targets are produced by movements of the tongue-jaw complex."

38. Three parts to the analysis:

    a. Child speakers' reliance on jaw-controlled movements.
    b. How jaw-controlled movement drives fronting.
    c. Sensitivity of MOVE-AS-UNIT to gradient differences in articulatory force.

39. Early in development, anatomically coupled tongue and jaw tend to move as a single unit.

    a. Tongue is motorically complex; imposes simultaneous "skeletal, movement, and shaping requirements" (Kent, 1992).
    b. Moving the jaw, a bilaterally hinged joint, is motorically simple.
    c. In early stages, tongue movement may be parasitic on jaw movement (MacNeilage & Davis, 1990).
        - Discrete functional regions of tongue do not function separately.
        - Tongue is stiffened and raises and lowers as a single unit with the jaw.

40. Jaw-controlled movement is linked to an undifferentiated pattern of linguopalatal contact.
    a. Undifferentiated lingual gestures: Midsagittal linguopalatal contact extends from alveolar to palatal/velar regions (Gibbon, 1999).
    b. Attributed to inability to control discrete functional regions of the tongue.

41. Proposal: Fronted velars are not true coronals but undifferentiated lingual gestures.
    a. Discrete coronal place is not simpler than discrete velar place in any obvious way.
    b. But jaw-controlled movement resulting in undifferentiated contact *is* simpler than discrete movement of either functional region of the tongue.

42. Height of articulatory target (gestural force) in a given context influences whether discrete lingual or jaw-dominated gesture will be used.
    a. Recall that tongue has "skeletal, movement, and shaping requirements" (Kent, 1992).
    b. When low and close to the mandible, some of the tongue's shaping needs are met passively by contact with the lower teeth.
    c. For a higher target, shaping requirements must be filled by the lingual musculature.
    d. This multiplies the complexity of the motor-control task.
    e. Higher target increases the predisposition to use a jaw-controlled, ballistic gesture.

43. Phonologically encoded: Magnitude of MOVE-AS-UNIT violation is proportional to height of articulatory target.
    Higher target → larger violation → greater likelihood of undifferentiated (fronted) place.

44. Is a phonological constraint really necessary?
    a. Could B's pattern be explained as an extragrammatical phonetic phenomenon?
    b. Note that articulatory force interacts with phonological factor of voicing faithfulness.
    c. When faithful voiced velars were in contrast with segmented voiceless velars, B rarely changed the underlying voicing, although this would obviate glottal epenthesis.
    d. Interaction with IDENT-Voice strongly suggests a phonological process rather than low-level phonetic conditioning.

VI. Implementing the formal analysis

45. Full scale of MOVE-AS-UNIT violations:
    a. No violation is incurred by an undifferentiated gesture.
    b. Lowest violation is for word-final or segmented velars.
    c. A voiceless target receives +1 violation more than a voiceless target.
    d. A target in strong position receives +1 violation more than a target in weak position.
    e. Initial position as a conditioning factor separate from pretonicity: questionable. +.5

Table 5. Scale of MOVE-AS-UNIT violations

Undiff Gest	Final	Pre-/ Post- Glottal	Posttonic Voiced	Posttonic Voiceless	Pretonic Voiced	Initial Voiced	Pretonic Voiceless	Initial Voiceless
0	1	1	2	3	3	3.5	4	4.5

46. Implementation of constraints

a. Harmonic Grammar framework
b. Constraint weights are from B's Stage 3 (4;2-4;4).
c. Undifferentiated gestures are represented with conjoined place [t͡k] or [d͡g].
d. Other constraints: IDENT-PLACE, IDENT-VOICE, DEP-[ʔ]-ONS, DEP-[ʔ], *GLOT-VOICE
e. Three tableaux below depict conditioning by prosodic context and voicing

Table 6. An initial voiceless velar is fronted

/ki/, "key"	*GLOT VOICE	IDENT-PLACE	MOVE-AS-UNIT	IDENT-VOICE	DEP-[ʔ]-ONS	DEP-[ʔ]	SUM
	3	3	2	2	2	1	
a. ki			4.5				**9**
b. gi			3.5	1			**9**
c. kʔi			1		1	1	**5**
d. ☞ t͡ki		1.5					**4.5**

Table 7. A medial posttonic voiceless velar is realized with glottal epenthesis.

/jʌki/, "yucky"	*GLOT VOICE	IDENT-PLACE	MOVE-AS-UNIT	IDENT-VOICE	DEP-[ʔ]-ONS	DEP-[ʔ]	SUM
	3	3	2	2	2	1	
a. jʌki			3				**6**
b. jʌgi			2	1			**6**
c. ☞ jʌʔki			1			1	**3**
d. jʌt͡ki		1.5					**4.5**

Table 8. A medial posttonic voiced velar is realized faithfully.

/beɪgəl/,"bagel"	*GLOT VOICE	IDENT-PLACE	MOVE-AS-UNIT	IDENT-VOICE	DEP-[ʔ]-ONS	DEP-[ʔ]	SUM
	3	3	2	2	2	1	
a. ☞ bʌgoʊ			2				**4**
b. bʌd͡goʊ		1.5					**4.5**
c. bʌʔgoʊ	1		1			1	**5**
d. bʌʔkoʊ			1	1		1	**5**

VII. Conclusions and future directions

47. Phonetically-sensitive constraint MOVE-AS-UNIT makes it possible to model B's output patterns for all prosodic and voicing contexts across all four stages of development.

48. Goal: Analyze other patterns of neutralization in strong position as the consequence of child-specific articulatory limitations that are most prominent in contexts of greatest gestural force.

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