Tara McAllister, MIT Linguistics
mcallis@mit.edu

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Fricative Neutralization in Strong Position in Child Phonology

1. Introduction

1. In both typical and disordered development, some children show a stage in which fricatives are avoided in syllable onsets but realized faithfully in coda position.
   - This is an example of neutralization in prosodically strong positions that currently is not well-explained.
   - I will describe the distribution of fricatives in a longitudinal study of one child with apraxia of speech.
     - This child strongly avoided prevocalic fricatives and used a rather surprising range of repairs, most notably gliding and glide insertion.
   - I will account for his pattern with reference to an effort-based model of coarticulation, with specific attention to the complications posed by immature speech-motor planning capabilities.

2. Neutralization in strong positions in child phonology
   - Child phonology is noted for a number of processes of positional neutralization that preserve contrast in weak positions while neutralizing in strong positions.
   - Such processes are virtually unattested in adult languages, where positional neutralization targets prosodically weak positions (word-final or foot-medial).
     - This can be viewed as a phonetically natural pattern driven by the strength of perceptual cues in prevocalic versus preconsonantal or prepausal positions (Jun 1995, Smith 2000, Steriade 2001).
   - The perceptually motivated account does not transfer readily to the child pattern of neutralization in strong positions.
   - Some success in accounting for children's "unnatural" processes has been achieved by analyses that invoke specific anatomical and physiological properties of the immature articulatory mechanism (Inkelas & Rose, 2008).

3. Distribution of fricatives in phonological acquisition
   - Fricative manner and coda position are marked and relatively late-emerging.
   - It is thus surprising that some children produce fricative codas before they acquire fricatives in onset position.

- Evidence from studies of babbling in typically developing infants:
    - Fricatives outnumber stops in coda position (Oller, Wieman, Doyle, & Ross, 1976; Kent & Bauer, 1985).
    - Coda fricatives outnumber prevocalic fricatives (Oller & Eilers, 1982; Redford, MacNeilage & Davis, 1997, Gildersleeve-Neuman, Davis & MacNeilage, 2000)
- For older children, the literature reports numerous cases where fricatives were produced accurately in coda and neutralized (to stops, glides, or ∅) in onset
    - Menn, 1971; Edwards, 1996; Dinnsen, 1996; Rvachew & Andrews, 2002; Marshall & Chiat, 2003; Stites, Demuth & Kirk, 2004; Dinnsen & Farris-Trimble, 2008.
- The reverse pattern of fricative acquisition is also attested (Stoel-Gammon, 1998; Rvachew & Andrews, 2002; Stites, Demuth & Kirk, 2004).
- Thus far, literature addressing children's fricative neutralization in strong positions has been largely at the level of description rather than explanation.

2. Case Study Data

4. B, age 4.
    - Severely unintelligible speech consistent with childhood apraxia of speech.
    - IQ and receptive language abilities within normal limits for age.
    - Processes in B's speech that will not be discussed in detail here: Contextual voicing; velar fronting; glide epenthesis in onsetless syllables; cluster simplification; gliding/vocalization of liquids; distorted, variable vowel quality; atypical prosody with excess/equal stress.

5. B had tremendous difficulty producing fricatives in prevocalic position and engaged in a wide and interesting variety of repairs to avoid them.
    - For expository purposes, assume that B's grammar includes a constraint banning prevocalic fricatives.
        - *SV: No fricatives adjacent to a following vowel
    - We will revisit *SV with the goal of arriving at a more explanatory formulation.

6. B was recorded in 1-hour therapy sessions on a roughly weekly basis from ages 3;9 - 4;3.
    - Child utterances (both spontaneous and elicited) from over 15 hours of clinician-child and parent-child interactions were narrowly transcribed.
    - All identifiable words with prevocalic fricative targets were coded by fricative target (/s, ʃ, f, h/), vowel context, and substitution pattern. Total = 813 tokens.

7. B's Stage 1 (Ages 3;9-3;11): Fricative gliding in onset; fricatives as the unique coda consonant.
   - Supraglottal fricative onsets are realized as glides.

[jɔs]	'swords'
[jaʔ]	'shark'
[wɔdɛʔ]	'forget'

   - Fricative codas are realized faithfully; non-fricative codas are debuccalized or deleted. Note faithful realization of prevocalic stops.

[kaʊs]	'cows'	[daʔ]	'cake'
[mas]	'mouse'	[jʌʔ]	'up'
[babajis]	'strawberries'	[mij]	'mean'

   - Medial fricatives are followed by an epenthetic glottal stop, or even a pause.

[wasʔo]	'waffle'	[bʌʃʔo]	'shovel'
[wesʔas]	'raisins'		

8. As a first approximation, we model B's constraint set as follows:

   - With no violation of *SV, coda fricatives are realized faithfully.

Table 1. Fricatives realized faithfully in coda position (Stage I)

Input: /bʌs/ 'bus'	*SV	FAITH
a. ☞ bʌs		
[…others]		*!

   - Word-medially, various repairs are theoretically available to B. He makes a perceptually minimal change by inserting [ʔ] between fricative and vowel.

Table 2. Glottal stop epenthesis following medial fricatives (Stage I)

Input:/mɛsij/ 'messy'	IDENT-continuant	*SV	IDENT-consonantal	DEP-IO (ʔ)
a. mʌsij		*!		
b.☞ mʌsʔij				*
c. mʌjij			*!	
d. mʌdij	*!			

   - Word-initially, glottal stop epenthesis is not available ($*_\sigma$[Sʔ), and the fricative cannot be preserved.

- Gliding appears as a last-ditch option to save the [+continuant] feature.

Table 3. Fricative gliding in onset position (Stage I)

Input: /so/ ‘sew’	IDENT-continuant	*$_\sigma$[Sʔ	*SV	IDENT-consonantal	DEP-IO (ʔ)
a. soʊ			*!		
b. sʔoʊ		*!			*
c. ☞ joʊ				*	
d. toʊ	*!				

9. B’s Stage 2 (Ages 4;0-4;2): Context-dependent production of fricative onsets.
   - Gliding continues in running speech.

     [jio] ‘seal’ [japĩ] ‘shopping’
     [jak] ‘sock’

   - Fricatives are produced with an epenthetic glide in monitored speech.

     [sjʌ] ‘sun’ [ʃjɛpo] ‘shepherd’
     [sjut] ‘suit’

   - Glottal stop epenthesis continues in word-medial position.

     [pisʔɛs] ‘pieces’ [dojʊʃʔɛs] ‘delicious’
     [sjʊsʔɔ] ‘sister’

Table 4. Glide epenthesis following onset fricatives (Stage II)

Input:/sak/ ‘sock’	IDENT-continuant	*$_\sigma$[Sʔ	*SV	IDENT-consonantal	DEP-IO (glide)	DEP-IO (ʔ)
a. sak			*!			
b. ☞ jak				*		
c. ☞ sjak					*	
d. sʔak		*!				*

- Note that the preference to violate lower-ranked DEP-IO(ʔ) in the intervocalic case remains unchanged.

Table 5. Ongoing glottal stop epenthesis following medial fricatives (Stage II)

Input:/pisəz/ ‘pieces’	IDENT-continuant	$*_\sigma$[Sʔ	*SV	DEP-IO (glide)	IDENT-consonantal	DEP-IO (ʔ)
a. pisɛs			*!			
b.☞ pisʔɛz						*
c. pijɛs					*!	
d. pisjɛz				*!		

10. Stage II continued: Faithful prevocalic fricatives are attested in a limited context.
    - Fricatives are only produced in the context of a [+high] vowel
    - Also limited to highly monitored speech.

      [ʃuw] ‘shoe’ [sʊp] ‘sip’
      [sio] ‘seal’

    - For the moment, we will represent this new possibility by splitting *SV into two positional constraints, $*SV_{[+HIGH]}$ and $*SV_{[-HIGH]}$.

Table 6. Emerging faithful production of fricatives before [+high] vowels (Stage II)

Input:/ʃuw/ ‘shoe’	IDENT-continuant	$*_\sigma$[Sʔ	$*SV_{[-HIGH]}$	DEP-IO (glide)	IDENT-consonantal	$*SV_{[+HIGH]}$	DEP-IO (ʔ)
a. ☞ ʃuw						*	
b. ☞ juw					*		
c. ☞ ʃjuw				*			

11. B's Stage III (Age 4;2 +): Expanded production of fricative onsets.

- Faithful production replaces glide epenthesis in monitored speech.

[sij]	'see'	[ʃʊdo]	'sugar'
[sʌn]	'sun'		

- Faithful production in word-medial position.

[jʊʃɛs]	'wishes'	[jiso]	'lizard'
[dʊsɛt]	'different'		

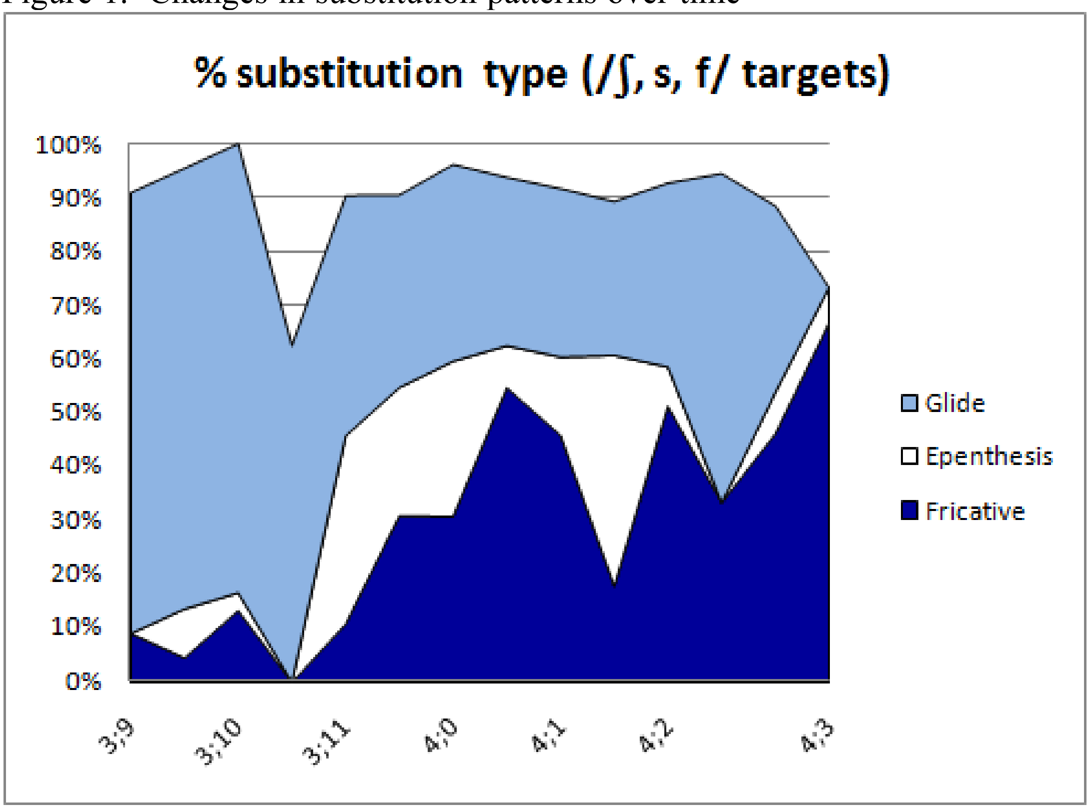
- Gliding continues in running speech and entrenched lexical items.

[jʌn]	'fun'	[jæʔədas]	'Santa Claus'
[jamo]	'summer'		

3. Summary of Fricative Distribution

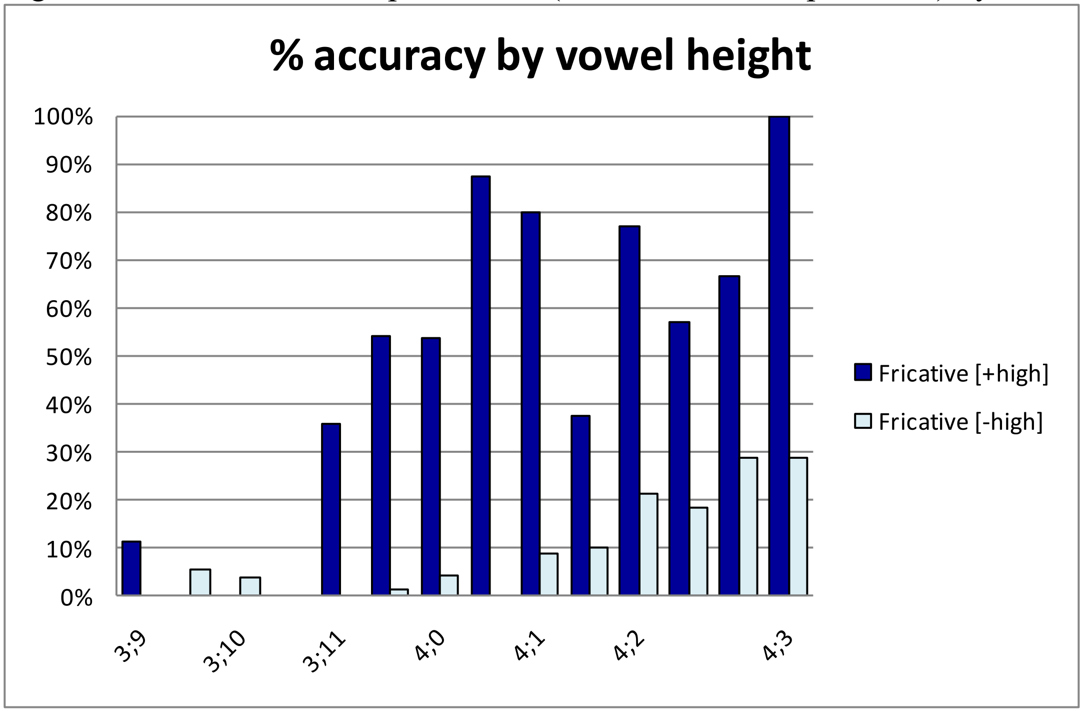
12. Figure 1 summarizes the prevalence of patterns of fricative production (gliding, glide epenthesis, faithful fricative manner) over time.
    - Variability can partly be attributed to collapsed presentation of isolated/imitative tokens and spontaneous speech.

Figure 1. Changes in substitution patterns over time



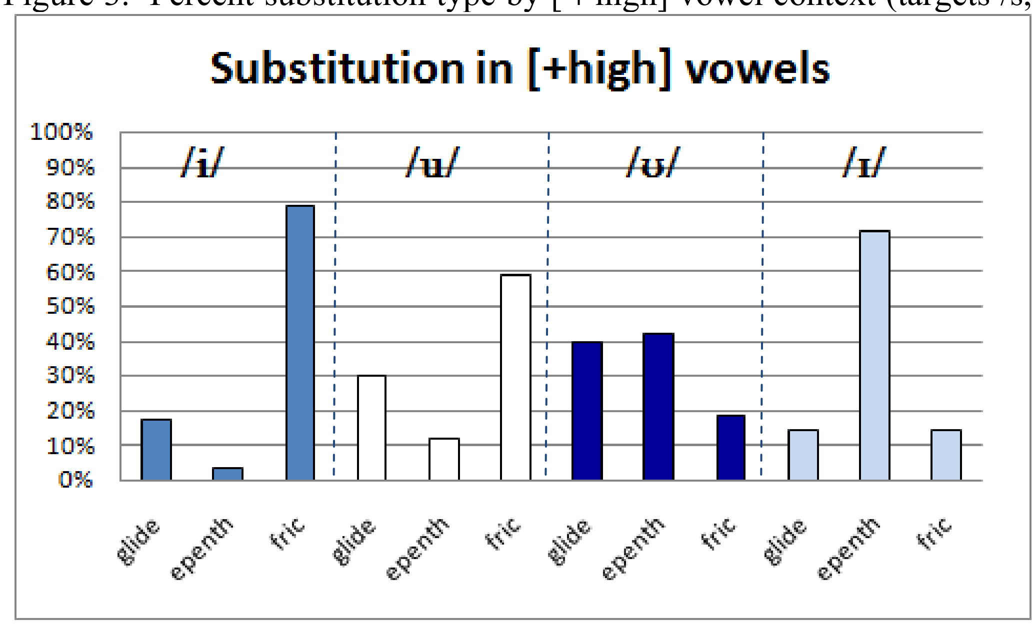
13. Fricative production accuracy varies with following vowel height.
  - Significantly greater accuracy before [+high] vowels.

Figure 2. Percent accurate production (within-class, no epenthesis) by vowel context



14. Within [+high] vowels, tense vowels /i, u/ were most often produced accurately, while lax vowels /ɪ, ʊ/ were more frequently realized with glide epenthesis.

Figure 3. Percent substitution type by [+high] vowel context (targets /s, ʃ, f/)



4. An Investigation of Phonetic Factors

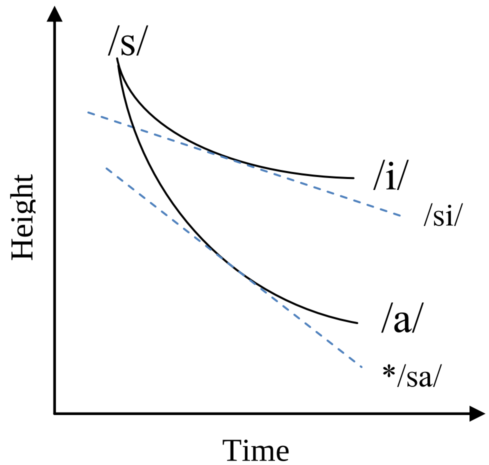
15. We are now in a position to examine the factors that might underlie B's fricative distribution.
    - Recall that *SV is a problematic constraint: It is unattested in adults, and it goes against expectations from the relative strength of perceptual cues.
    - However, *SV is attested in the speech of other children besides B.
    - I will assume *SV is phonetically grounded and reflects limitations specific to young children's articulation (cf. Hayes 1999, Inkelas & Rose 2008).
        - These limitations are overcome rather quickly in typical maturation, which explains the absence of *SV effects in adult speech.

16. I will propose that B's fricative distribution reflects the interaction of two articulatory factors:
    - Effort-minimizing constraints that limit rapid articulatory transitions. These are universal and motivate coarticulation in adult speech.
    - Motor planning limitations affecting precisely timed coordination of articulators. These are specific to very young or apraxic speakers.

17. Coarticulation is, in part, a strategy to reduce effort through avoidance of rapid articulatory transitions.
    - We can model coarticulation using a weighted constraint *EFFORT, "minimize articulator velocity" (Flemming, 2001, 2008).
    - The need to avoid rapid transitions may be particularly strong in children, who show a greater degree of coarticulation than adults (Nittrouer, Studdert-Kennedy, & McGowan,1989; Goodell & Studdert-Kennedy, 1991).

18. B's preference for fricatives before [+high] segments suggests an effort-minimization strategy. Consider the distance between articulatory targets, holding time constant for the moment.
    - Among English speech sounds, coronal consonants are produced with the highest jaw position (Keating, Lindblom, Lubker, & Kreiman, 1994).
    - Jaw position is even higher for coronal fricatives than stops (Lindblom, 1983; Geumann, Kroos, & Tillman, 1999; Mooshammer, Hoole, & Geumann, 2006).
    - The transition from a coronal fricative to a [-high] vowel requires a significantly larger jaw excursion than the transition to a [+high] vowel.
    - Tangent lines in Figure 4 show that the greater articulatory excursion translates to greater velocity and thus greater effort.

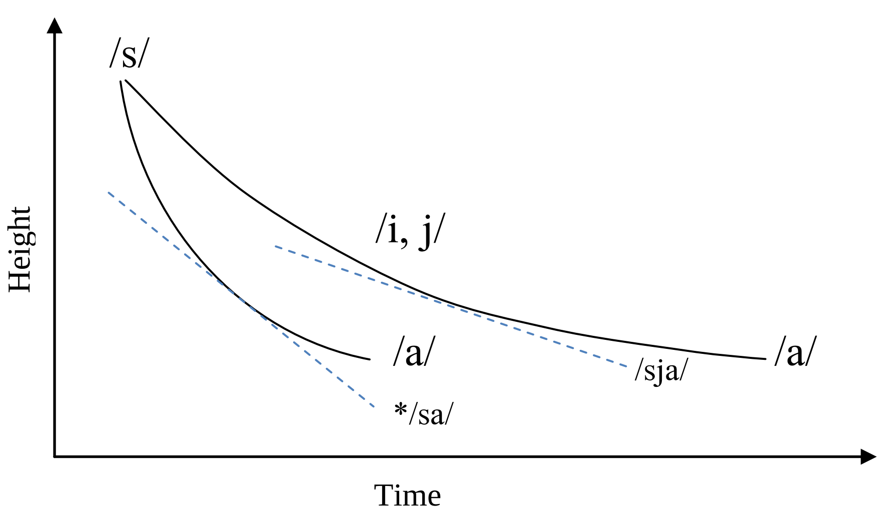
Figure 4. Comparison of articulatory distances, /si/ versus /sa/



- This suggests that we can replace the positional constraints *SV$_{[+\text{HIGH}]}$, *SV$_{[-\text{HIGH}]}$ with a weighted constraint like *EFFORT.
    - In the [-high] case, the cost of violating *EFFORT outweighs the cost of unfaithful fricative production. For [+high], violating *EFFORT is less costly than the faithfulness violation.

19. Since effort reflects the velocity of transitions, we need to consider the time as well as the distance involved in an articulatory transition.
    - A larger transition can be made with an equal degree of effort by elongating the transition in the temporal domain.
    - B exploits this possibility in his process of glide epenthesis.
        - With a slow transition through an intermediate configuration (perceived as /j/), he can hit the fricative target without fatally violating *EFFORT.
        - Note that under this analysis, glide epenthesis no longer needs to be treated as the phonological insertion of a glide target.
            - Reinterpret DEP-IO(glide) accordingly.

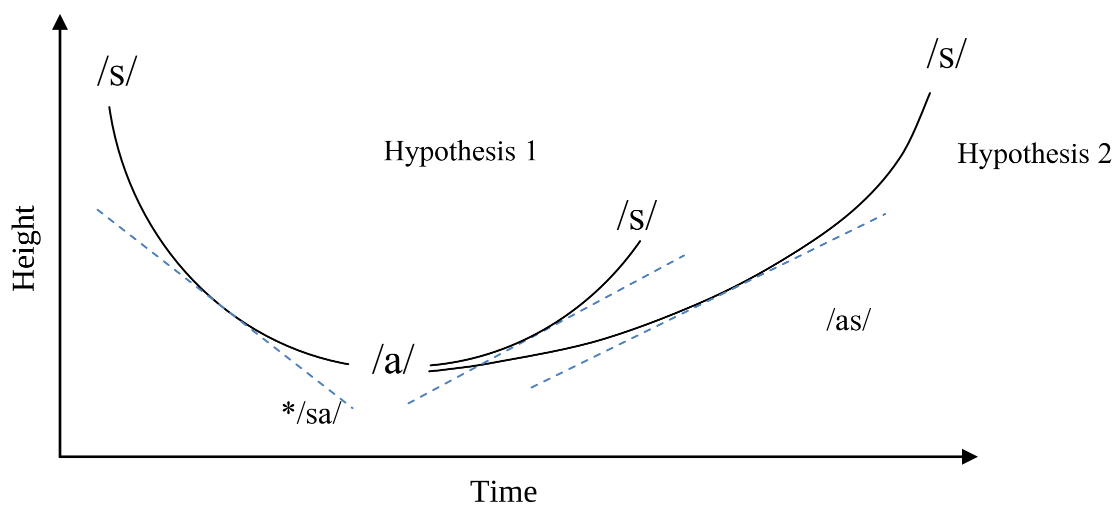
Figure 5. Comparison of transition duration, /sa/ versus /sja/



20. In the case where the prevocalic fricative is sacrificed altogether, we see a more extreme version of coarticulation.
    - In addition to elongation of the transition, there is undershoot of the fricative target (to the point where frication is not generated at all).
    - Sacrificing the fricative makes sense from the standpoint of effort, since it is costly to achieve and maintain a precise degree of aperture.

21. We also need to account for the asymmetric behavior of prevocalic and postvocalic fricatives. There are two ways fricative-vowel transitions might be more effortful than vowel-fricative transitions.
    - Hypothesis 1. The fricative in the postvocalic case may be a weaker gesture, requiring a smaller degree of articulator displacement.
    - Hypothesis 2. The vowel-fricative transition may be slower than the fricative-vowel transition.

Figure 6. Possible transition asymmetries, /sa/ versus /as/



22. For stops, there is evidence that the strength of articulatory gestures varies with prosodic position (Keating, 2006).
    - Coronal stops appear to be produced with slightly greater constriction in onset than coda, but the size of the effect is quite modest (Keating, 1995).
    - Moreover, the degree of constriction in sibilant production shows very little variation with prosodic position (Fougeron, 1998, 2001).
        - This is attributed to the limited range of articulatory variability tolerated in the production of sibilants.

23. It is not a general finding that CV transitions are more rapid than VC transitions.
    - To the extent that there is evidence on this question in the adult literature, it seems to point in the opposite direction (Hertrich & Ackermann, 1997).
    - However, I will argue that the hypothesized asymmetry emerges from articulatory limitations that are specific to very young or apraxic children.
        - In particular, the asymmetry reflects young speakers' decreased ability to program independent but coordinated movements of tongue and jaw.

24. There is evidence that children gain control of different articulators at different points in development.
    - Children's jaw movements begin to approximate an adult-like pattern significantly earlier than lip or tongue movements (Nittrouer, 1993; Green, Moore & Reilly 2002).
    - The "frame-dominance" theory posits that tongue movements shadow jaw movements until independent control is established (MacNeilage & Davis, 1990).
        - This is evidenced in babbling, where early CV syllables carry a single place of articulation (coronals/front vowels; dorsals/back vowels, etc.).

25. In a fricative-vowel transition in an adult speaker, coarticulation involves lowering of the jaw to anticipate the more open configuration of the vowel, while the tongue remains in a high position to maintain frication (Mooshammer et al., 2006).
    - If tongue and jaw operate as a unit, as soon as the jaw begins to descend, the tongue will simultaneously move away from its constriction, causing frication to cease.
    - Thus, under a certain set of articulatory limitations, the speaker must produce a rapid fricative-vowel transition or sacrifice the fricative.
    - B's substitution of glides mimics the slow, less effortful coarticulated transition without requiring independent tongue and jaw movement.

26. In the case of vowel-to-fricative transitions, the tongue and jaw still need to move together.
    - However, gradual movement of tongue and jaw toward the target height will not cause the vowel to cease being a vowel.

27. Instead, we look for F1 contours suggesting a gradual increase in jaw height throughout the articulation of the vowel.
    - This gradually falling F1 was observed in some of B's postvocalic fricatives.
    - Others were separated from the vowel by a period of aspiration or glottalization (not necessarily apparent to the listener).
        - Articulator reconfiguration may take place during these intervals.
    - Analysis of spectrographic data is ongoing.

28. Why are fricatives but not stops affected?
   - Stop articulation is more stable than fricative articulation in several ways.
     - The stop target allows a wide margin for error (anywhere at or above the height of the palate) vs. the narrow space targeted to produce frication.
     - Contact between the tongue and the palate provides a physical anchor, as well as proprioceptive feedback.
   - This greater stability suggests that stops should precede fricatives in the earliest emergence of lingual gestures independent from the movement of the jaw.

5. Conclusions

- The surprising positional distribution exhibited by B and other children acquiring fricative manner poses a challenge for any framework.
- An investigation of child-specific factors in articulation offers an opportunity to posit phonetic motivation for an otherwise "unnatural" constraint.
- More detailed investigation of child (co-)articulation will be needed to speak in a more concrete manner about the phonetic analysis tentatively invoked here.

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