A Child-specific Compensatory Mechanism in the Acquisition of English /s/: Children's Deviant Forms Are Not Always Grammar-driven

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• Impressionistic transcription-based studies
  - Various substitutions and distortions found in children’s outputs during language development

• Acoustic studies
  - Covert contrast: despite acoustic differences, fails to make phonological distinction audible to adult listener
- Mismatch between children’s intention and adults’ perception during language acquisition
• What are their phonological goals?
I. Two previous approaches

• Listener-oriented approaches
  - what the adult hears is not different from what the child produces.
1. Two previous approaches

- **Traditional generative approach:** developmental grammars are typologically existing adult grammars (e.g. Gnanadesikan 1995)
  - Difficult to explain child-specific phonological processes that occur in syllable onset position
  - Fails to consider any biological and anatomical differences between children and adults
I. Two previous approaches

- **Child-specific grammar approach:** the existence of *child-specific grammars* derived from child motoric constraints (e.g. McAllister Byun 2011)

  - Difficult to provide explanations for the existence of covert contrast
  
  - Difficult to account for existence of covert contrast
2. Goals & Hypotheses

- Hypothesis: children use the adult target grammar as their phonological goals for /s/ when outputs are not on the target.
- Child specific compensatory strategies in articulatory challenging contexts should provide evidence.
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- Gender-specific patterns found in adult speech production (Diehl et al., 1996; Fant 1975; Haley et al., 2010; Hillenbrand et al., 1995; Jongman et al., 2000; Simpson, 2009)

- Gender-specific patterns also found in child speech production despite little anatomical differences (Fox & Nissen, 2005; Mugitani & Hiroya, 2012)

- **Updated hypothesis:** Children’s phonological goal is *gender-specific target /s/*
3. Coarticulation effects

- Shape and degree of constriction
- Sufficient amount of high velocity airflow
- Location of the constriction in relation to the front teeth

No change in varying V context in adults

Stevens 1998 p. 380
3. Coarticulation effects

- **Tongue-tip articulation highly dependent on vertical movement of jaw** (Gick et al., 2010; Stone & Vatikiotis-Bateson, 1995; Vatikiotis-Bateson & Ostry, 1999).

- **Adults:** Tongue tip/blade gestures can compensate for jaw and tongue body lowering gestures (Iskarous et al., 2011; Shadle et al., 2006).

- **Children:** Development of subparts of tongue show different growth patterns (Cheng et al. 2007).
  - Both front and body of tongue movements dependent
3. Coarticulation effects

- Coarticulation matters (vowel effects)
  - Children are aware of their articulatory limitations and context effects
  - Effortful speech production in more challenging environments (i.e. compensatory mechanism)
4. Current study

- Comparison of two corpora
  - Word-initial [sV] productions from 79 children ages 2 to 5 (Edwards & Beckman, 2008)
  - Word-initial [sV] productions from 13 adults (Clayards in progress)

- Analytical tool
  - Statistical analyses using mixed-effects regression models, Acoustic analyses using Praat (Boersma & Weenink, 2014)
4.1 Predictors:

- **Individual predictors**
  - Age and Gender

- **Contextual predictors**
  - Normalized F1 and F2

- **Aerodynamic predictor**
  - Relative intensity of turbulence

Gick et al., 2013
4.2 Quantification: clear /s/

- Quantification of spectral distribution of target /s/ (or clear /s/) compared with non-target /s/
  - **Higher Center of Gravity (CoG):** average energy located in higher frequencies
  - **Lower Standard Deviation (SD):** energy concentrated in a small band
  - **Lower Skewness:** distribution left-tailed
4.2 Quantification: clear /s/

- CoG = 7590 Hz
- SD = 2915
- Skewness = 0.544

- CoG = 9037 Hz
- SD = 2015
- Skewness = 0.011

★ Clearly produced=target-like /s/
4.3 Result: Gender

Figure 1. Female speakers produce acoustically clearer /s/

- CoG
  \((\beta=-1.297, t=-6.37, p < .0001)\)

- Skewness
  \((\beta=0.75, t=-3.77, p=0.0002)\)
4.4 Result: F2

Figure 2. Front vowels (low F2) result in acoustically clear /s/

- Front B: $\beta=226$, $t=2.94$, $p=0.003$
- Front F: $\beta=-60.29$, $t=-2.46$, $p=0.014$
- Front M: $\beta=-0.28$, $t=-2.13$, $p=0.033$
4.5 Summary

- F1 does not affect the spectral distribution of /s/ due to adults’ skillful lingual gestures.

- Greater F2 (i.e. front vowels) is associated with acoustically clear /s/.

- Female speakers produce acoustically clearer /s/ than male speakers.

- Intensity of /s/ (not discussed) does not matter (but it is important in children’s production of /s/).
5. Children

Figure 3. Acoustically clear /s/ is judged as ‘correct’ /s/

- Correct /s/: Higher CoG, lower SD, lower skewness and louder intensity
- Correct /s/: similar to female adult /s/ compared to male adult /s/.
5.1 Result: Age

Figure 4. Older children produce clearer /s/

(β = 622, t=1.96, p=0.05)  
(β = -216, t=-2.04, p=0.041)
5.2 Result: Age & Gender

Figure 5. Older children show gender-specific patterns

- For CoG: \( \beta = -1.795, t = -3.02, p = 0.0025 \)
- For SD: \( \beta = -0.395, t = -1.96, p = 0.05 \)
- For skewness: \( \beta = -0.189, t = -3.2, p = 0.0014 \)
5.2 Result: Age & Gender

Figure 6. Older children show gender-specific patterns

- No gender specific anatomical differences found in the front cavity (Lieberman et al., 2001; Vorperian et al., 2009; 2011)
5.3 Result: Intensity

Figure 7. /s/ with higher intensity is more target-like

- Unlike adults, intensity matters for CoG and SD.

- CoG
  \( (\beta = 530, t=4.04, p <.0001) \)

- SD
  \( (\beta = -484, t=-7.06, p <.0001) \)
5.4 Result: Vowel height (F1)

Figure 8. Low vowels result in more target-like /s/

Why is /s/ more target-like in low-vowel context?
6. Questions

• Why is /s/ more target-like in low vowel contexts in children’s production?
  ➡ Possibly due to a compensatory mechanism

• Why is /s/ more target-like in low vowel contexts in children’s production?
  ➡ The compensatory mechanism may be related to effortful intensity manipulation
7. Effortful noise production

\[ ps = kU^3A^{-2.5} \] (Stevens, 1998, p.103).

- **A**: The size of the constriction area
- **\( U \)**: Volume airflow
- More opening (i.e., low vowel) during /s/ production decreases sound power of noise

★ If intensity is louder in low vowel contexts children must have manipulated airflow.
7. Effortful noise production

• Gesturally, more airflow is produced with wider glottal opening and stiffer vocal folds (Kent 2004).

→ This should affect periodicity in vowel production
7.1 Harmonics-to-Noise Ratio

Figure 10. Low vowels are noisier than high vowels

- Supports proposal that children do effortful noise production in low vowel contexts
8. Summary

- Both adults and children are influenced by vowel context but not in the same way (i.e. vowel backness vs. vowel height)

- Older children produce target-like /s/ and show gender-specific patterns

- Higher intensity results in acoustically clearer /s/
9. Conclusion

- Children do not seem to have child-specific phonological goals while acquiring English /s/

- What is child-specific is their compensatory mechanism used to achieve the adult target grammar

- We found evidence that children have gender-specific targets
Thank you!