

Moving Targets and Unsteady States: Errored productions of sibilant fricatives by young children

Patrick Reidy, *The Ohio State University, Department of Linguistics*



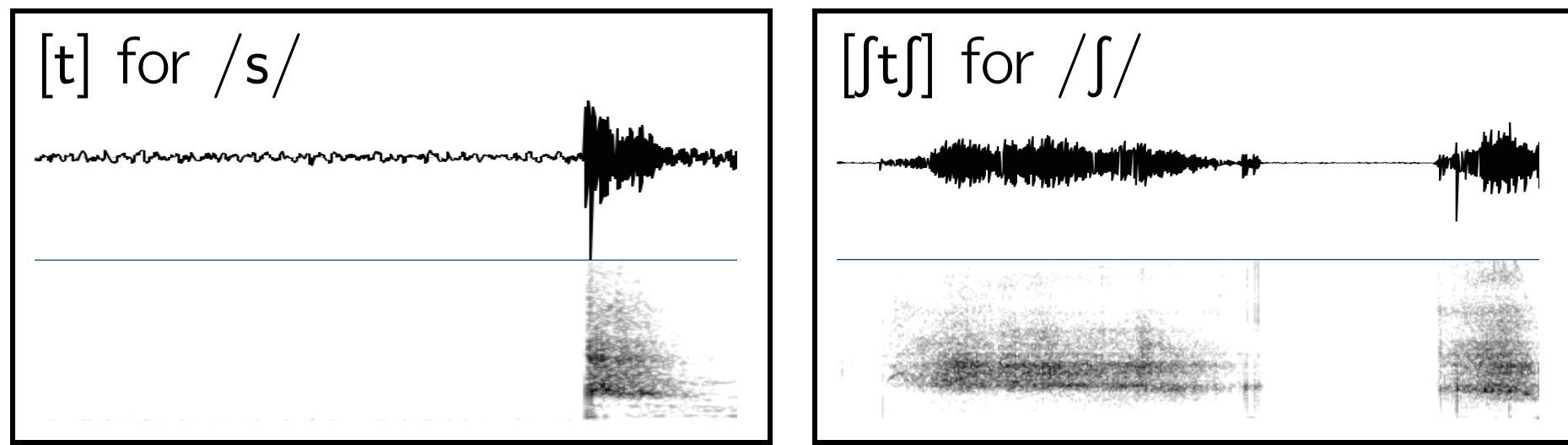
Purpose of Study

- ▷ The production of /s/ or /ʃ/ requires a sustained sibilant turbulence noise source to be generated—a difficult task that a majority of children do not acquire until age 4.
- ▷ The current study investigates the error patterns of young children's /s/ and /ʃ/ productions in order to determine developmental predictors of a child's ability to produce and maintain the target sibilant noise.
- ▷ Acoustic measures for differentiating sibilant errors are also proposed.

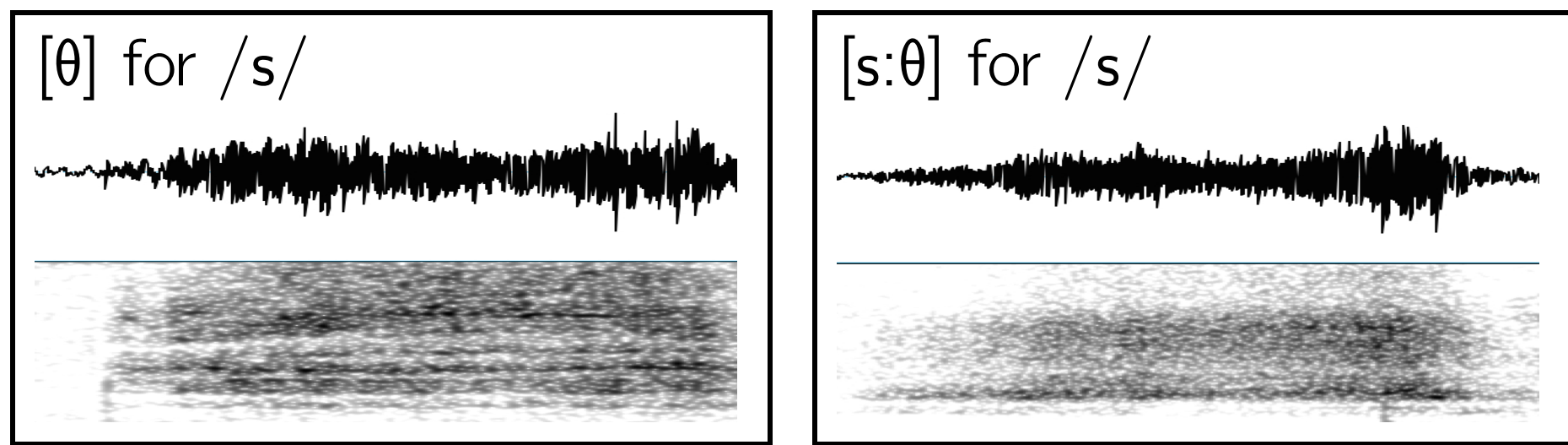
Acoustic Data & Phonetic Transcription

- ▷ 80 native English-acquiring children produced tokens of /s/ and /ʃ/ in word-initial, pre-vocalic position of real words that were elicited during an audio-prompted, picture-naming task (παυδολογος Project).
- ▷ A trained phonetician narrowly transcribed the children's /s/ and /ʃ/ productions. The symbol set allowed atomic WorldBet symbols to be joined with a colon, denoting a sound intermediate between two others; or concatenated, denoting a production whose quality changed over time.
- ▷ Transcriptions were partitioned into correct productions and three types of error: fortition, lenition, and sibilant.

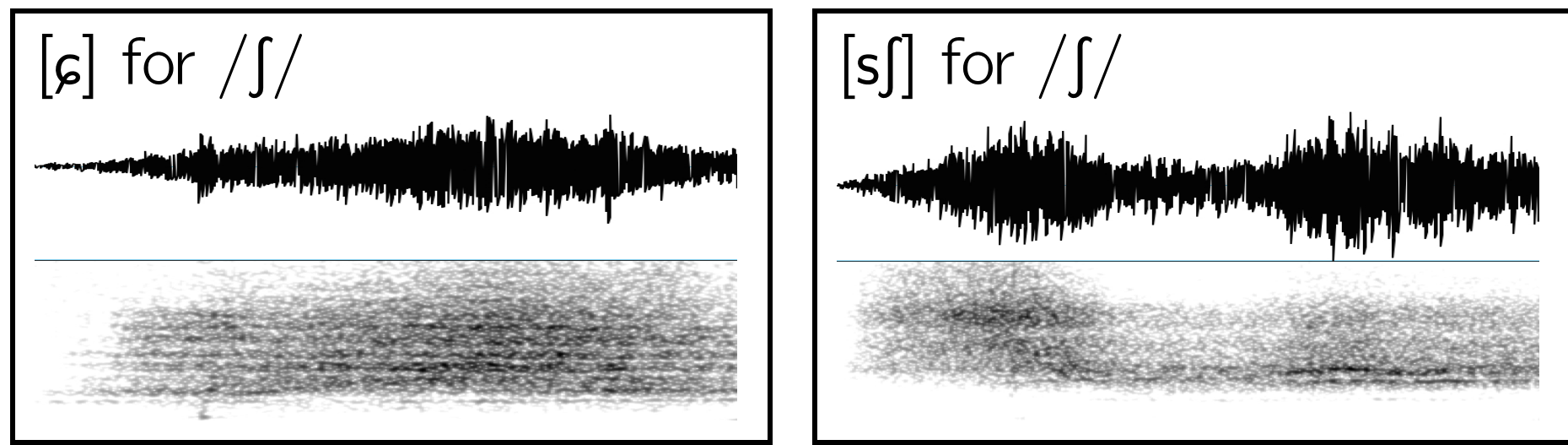
Fortition: Plosive onset or interruption of the turbulence



Lenition: Sustained turbulence, but not sibilance



Sibilant: Incorrect place for target sibilant source



Acknowledgements

- ▷ Work was supported by an Ohio State Graduate School Fellowship & an ASA Raymond H. Stetson Scholarship to the author.
- ▷ Data collection and phonetic transcription was supported by NIDCD grant R01-02932 to Jan Edwards (UW Madison).

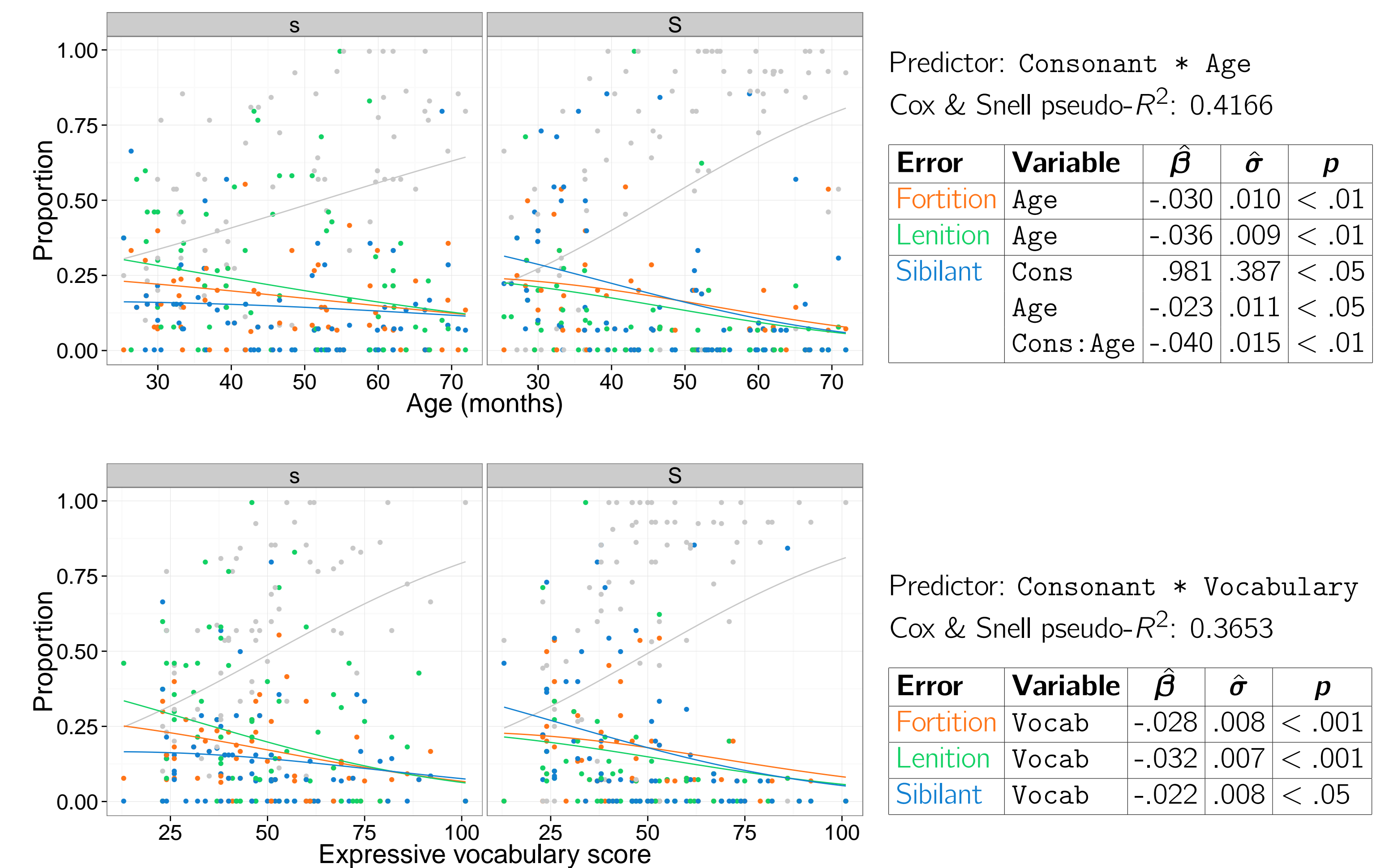
Developmental Predictors of Error Types

Background & Hypotheses

- ▷ Haelsig & Madison (1986) found that children produced *stopping* errors most frequently between 3 and 3.5 years; *fronting* occurred only between 3 and 4.5 years, and was less frequent than stopping; and *affrication* almost never occurred. By contrast, Li, Edwards & Beckman (2009) observed a preponderance of *fronting* errors in 2- and 3-year-olds' productions of /s/ and /ʃ/, as well as more *affrication* than *stopping* errors.
- ▷ Knowledge of a phonological category comprises generalizations over the articulatory motor patterns that must be executed during speech production, as well as over the representations of lexical items that are themselves generalized from somatosensory patterns. So, developmental error patterns in young children's /s/ and /ʃ/ productions may reflect either *age*-related refinements in motor control or higher-order generalization as vocabulary expands.
- ▶ **Hypothesis 1:** All errors should decrease as age or vocabulary size increases.
- ▷ Depending on the target consonant, fronting errors will correspond to either *lenition* (e.g., [θ] for /s/) or *sibilant* (e.g., [s] for /ʃ/) errors in the current classification.
- ▶ **Hypothesis 2:** Lenition and sibilant errors should show consonant-specific reduction patterns across either developmental factor.

Dirichlet regression of error proportions

- ▷ The effects of age and expressive vocabulary size (EVT-II) were investigated with Dirichlet regression, a multinomial generalization of beta regression.



Discussion

- ▷ The effects of Age and Vocabulary were significant and negative for the fortition, lenition, and sibilant errors, supporting Hypothesis 1 that errors decrease with increasing development.
- ▷ The Age-model had greater pseudo- R^2 than the Vocabulary-model, suggesting that age is a better predictor of the development of articulatory control for producing sibilants.
- ▷ The effect of Consonant and the Consonant:Age interaction were significant for sibilant errors, but neither the effect of Consonant nor its interaction with either developmental factor was significant for the other error types. Thus, Hypothesis 2 was not fully supported.

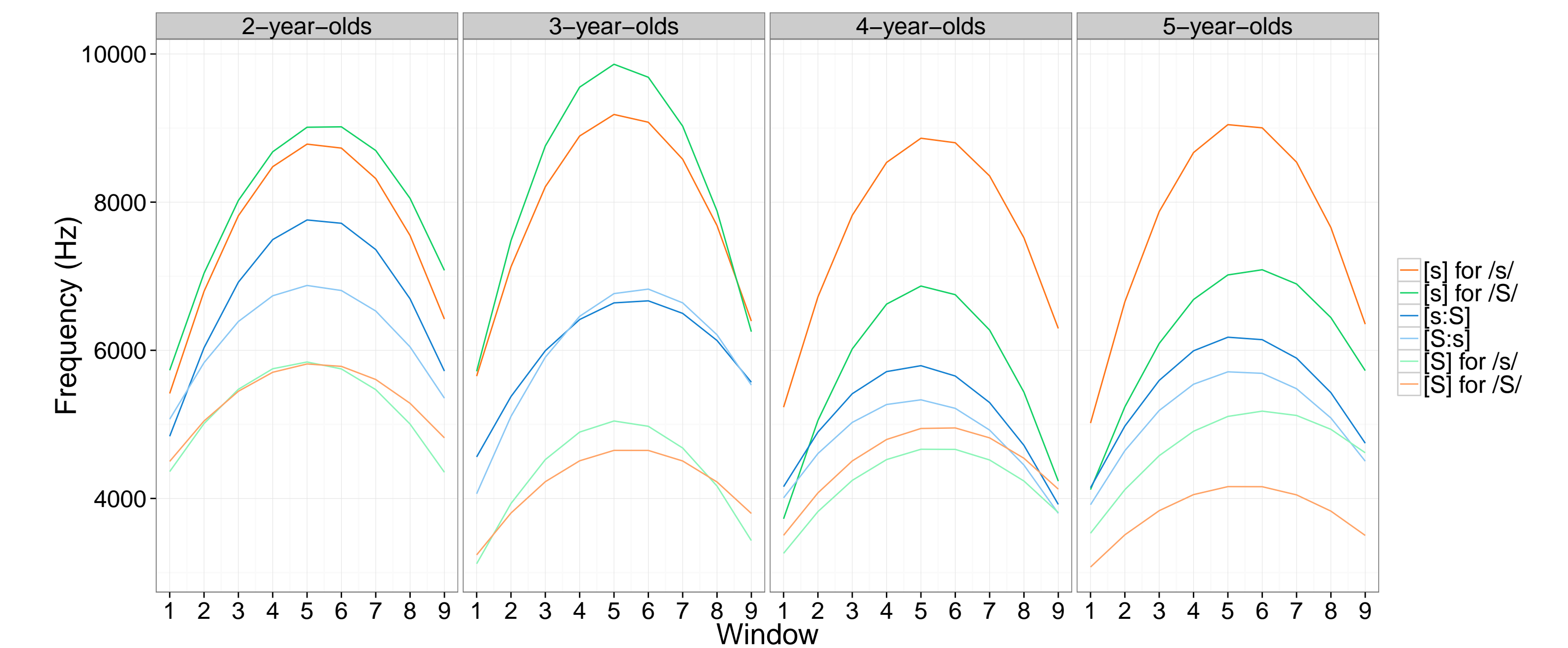
Acoustic Analyses

Background & Hypotheses

- ▷ Phonetic transcription can be a blunt tool for analyzing children's speech. For example, Schellinger *et al.* (2008) found that [s] for /θ/ and [θ] for /s/ substitutions were perceptually differentiable from correct [s] and [θ] productions, respectively.
- ▷ The spectral properties of children's correct [s] and [ʃ] productions are not constant across the duration of frication. In particular, the peak frequency of either sibilant follows a convex-downward curve through frequency-space, such that the trajectory for [s] is distinguished from [ʃ] by a higher maximum frequency and greater curvature (Reidy, 2014).
- ▶ **Hypothesis 3:** The substitution and intermediate sibilant errors will exhibit acoustic differences from correct [s] and [ʃ], such that moving from [s] to [ʃ] in the sibilant continuum will coincide with a decrease in peak-Hz trajectory peak frequency and curvature.
- ▶ **Hypothesis 4:** The fortition and lenition errors will exhibit acoustic differences, such that there are abrupt rises and falls in the RMS amplitude contour at the edges of closures and at the transitions between non- sibilant and sibilant intervals.
→ Work is in progress to develop a quantitative measure to evaluate the qualitative observation of such abrupt transitions in the RMS amplitude.

Growth curve analysis of peak-Hz trajectories in sibilant errors

- ▷ Correct productions and sibilant errors were grouped into six categories, approximating an /s—/ʃ/ continuum: [s], [s] substitution, [s:ʃ], [ʃ:s], [ʃ] substitution, [ʃ].
- ▷ For a given sibilant production, nine 20-ms windows were spaced evenly across its duration, and the spectrum of each window was estimated with a multitaper spectrum.
- ▷ Peak frequency was measured (between 1 and 18 kHz); the resulting sequence of measurements is called a *peak-Hz trajectory*.
- ▷ Peak-Hz trajectories were analyzed by age group as the dependent variable in a quadratic growth curve analysis with random intercepts by subject.



Discussion

- ▷ A monotonic decreasing trend in the maximum frequency and curvature of the sibilant errors' peak-Hz trajectories was observed only for the 5-year-olds; the three other age groups exhibited trends that deviated slightly from this trend. Thus, Hypothesis 3 was only partially supported.
- ▷ 2-year-olds: substituted [s] had greater maximum frequency than correct [s], while substituted and correct [ʃ] had nearly identical maxima.
- ▷ 3-year-olds: substituted [s] had greater maximum frequency and curvature than correct [s]; [s:ʃ] had greater curvature than both [ʃ:s] and substituted [ʃ].