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## INTRODUCTION

- Children do not always progress abruptly from incorrect, neutralized productions to readily perceivable and transcribable phonological categories.
- Children may go through a stage of ‘covert’ contrast.
- *Covert contrast*: A subphonemic difference between two sounds that is not perceptible to adults (e.g., Macken & Barton, 1980).
- Covert contrast for stops and fricatives has been reported in the literature, but there is little work on affricates and consonant clusters.
- Furthermore, there is limited work on covert contrast for languages other than English.

## PURPOSE OF THIS STUDY

- To look for covert contrast in word-initial stop-/s/ clusters and the affricate /ts/ in Greek.

## METHOD

### [Participants]

- 18 monolingual Greek-speaking children (five 2-year-olds, seven 3-year-olds, three 4-year-olds, and three 5-year-olds)
- Typically-developing
- Selected from a larger sample of 60 2-to-5-year-olds
- Selected because they produced correct /s/ in singleton targets, but reduced stop-/s/ clusters and the affricate /ts/ to [s]
- Cluster reduction to [s] in stop-/s/ sequences was a common error pattern (Syrika et al., 2007).
- 15 native Greek-speaking adults were also recorded in the same task.

### [Task and Procedure]

- Word-repetition task
- A picture and a digitized recording of the stimulus were presented simultaneously.
- The children were instructed to repeat the word that they heard.
- Children’s repetitions were digitally recorded.

### [Stimuli]

- 2-or 3-syllable real words with word-initial /s/, /ps/, /ts/, and /ks/ before each of the vowels /a/, /e/, /i/, /o/
- All words were stressed on the first syllable.

### [Analysis]

- Children’s productions were transcribed by a Greek native speaker/phonetician.
- For the productions of the 18 children analyzed, we paired productions of [s] in cluster reductions to correct /s/ targets in the same vocalic context.
- For example, [sa] in target /psari/ (fish) was paired with the same child’s correct production of /sa/ in target /savra/ (lizard).
- We examined the duration of the fricative [s] for both cluster reductions and correct productions of singleton /s/.
- We performed a spectral moments analysis to compare the fricative internal dynamics of productions of reduced [s] in stop-/s/ sequences to productions of correct singleton /s/.

/s/	Sample words	/ps/	Sample words	/ts/	Sample words	/ks/	Sample Words
sa	/savra/ (lizard) /saʎa/ (spit)	psa	/psari/ (fish)	tsa	/tsada/ (bag) /tsai/ (tea)	ksa	/ksaðerfos/ (male cousin)
se	/sela/ (saddle) /serni/ (He/she/it is dragging)	pse	/pselni/ (he/she is chanting)	tse	/tsepi/ (pocket)	kse	/ksenos/ (stranger, foreigner)
si	/sinefo/ (cloud) /siðero/ (iron)	psi	/psixa/ (white part of bread)	tsi	/tsisa/ (baby word for peeing) /tsibla/ (sticky eye discharge)	ksi	/ksilo/ (stick)
so	/soma/ (body) /soða/ (soda water)	psa	/psona/ (groceries)	tso	/tsofli/ (egg shell)	kso	/ksoplato/ (backless dress)



### [Measurement Criteria]

#### Duration Analysis

- *Fricative onset*: the onset of the aperiodic high-frequency noise characteristic of voiceless fricatives
- *Fricative offset*: the first vocal pulse following a clearly periodic downswing of a wave cycle
- For adults, *fricative onset in stop-/s/ sequences*: upward swing of first zero crossing following the stop burst

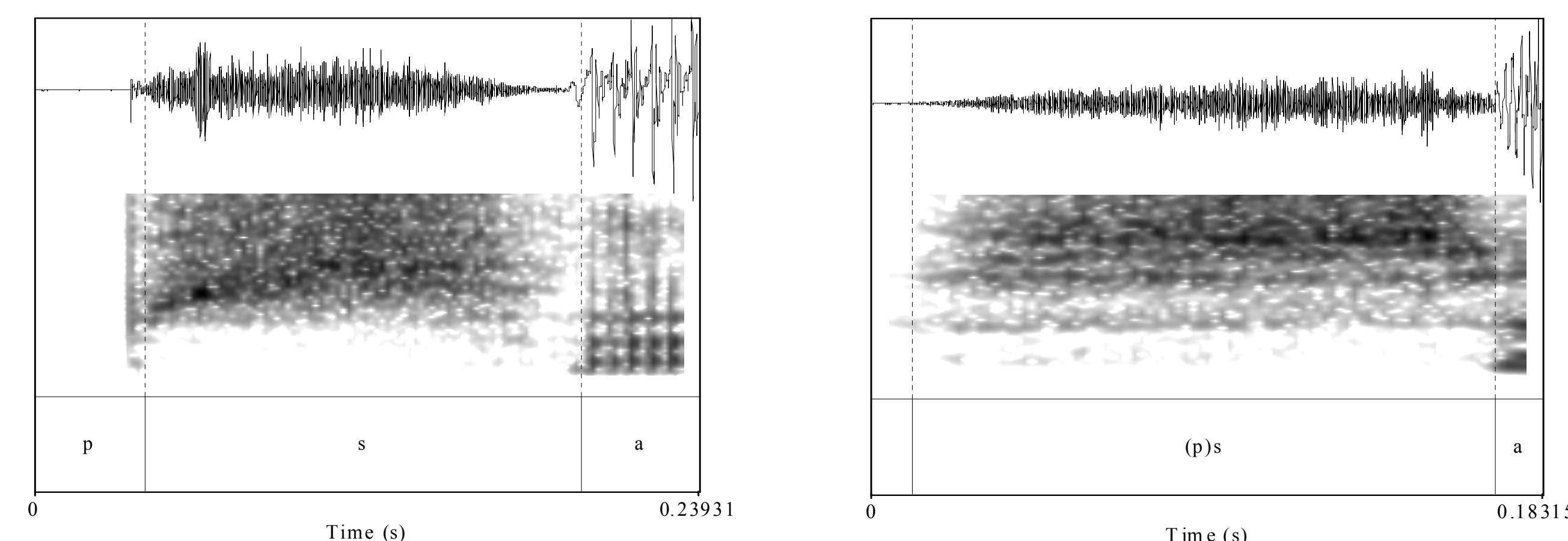


Figure 1: Alignment of fricative noise. For adults, the burst is not included in marking the onset (left), while for children whose initial /p/ is deleted, no burst is present (right).

#### Spectral Moments Analysis

- The fricative was divided into seven equal steps of windows, with each window size being 40 ms.
- We calculated the first four spectral moments in each window.

## RESULTS: DURATION ANALYSIS

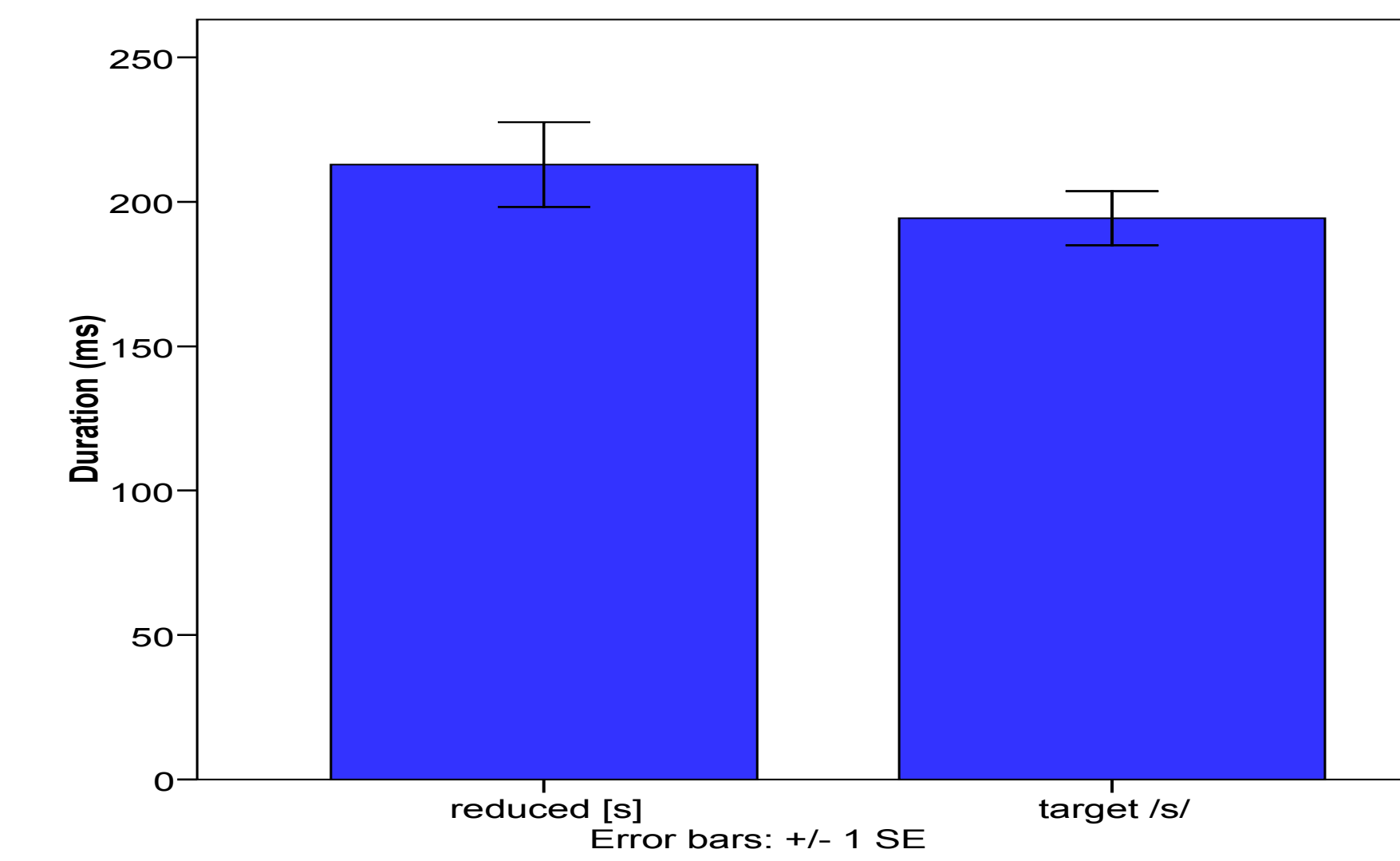


Figure 2: Average duration (in ms) of reduced [s] vs. target /s/

- Duration of [s] for the cluster reductions tended to be longer than for the target /s/ productions.
- The [s] durations for the cluster reductions were much more variable than for target /s/ productions.
- Range of values for [s] durations:
  - [s] cluster reductions: 233 ms (124 to 358 ms)
  - Correct /s/ singletons: 151 ms (133 to 283 ms)

## RESULTS: SPECTRAL MOMENTS ANALYSIS

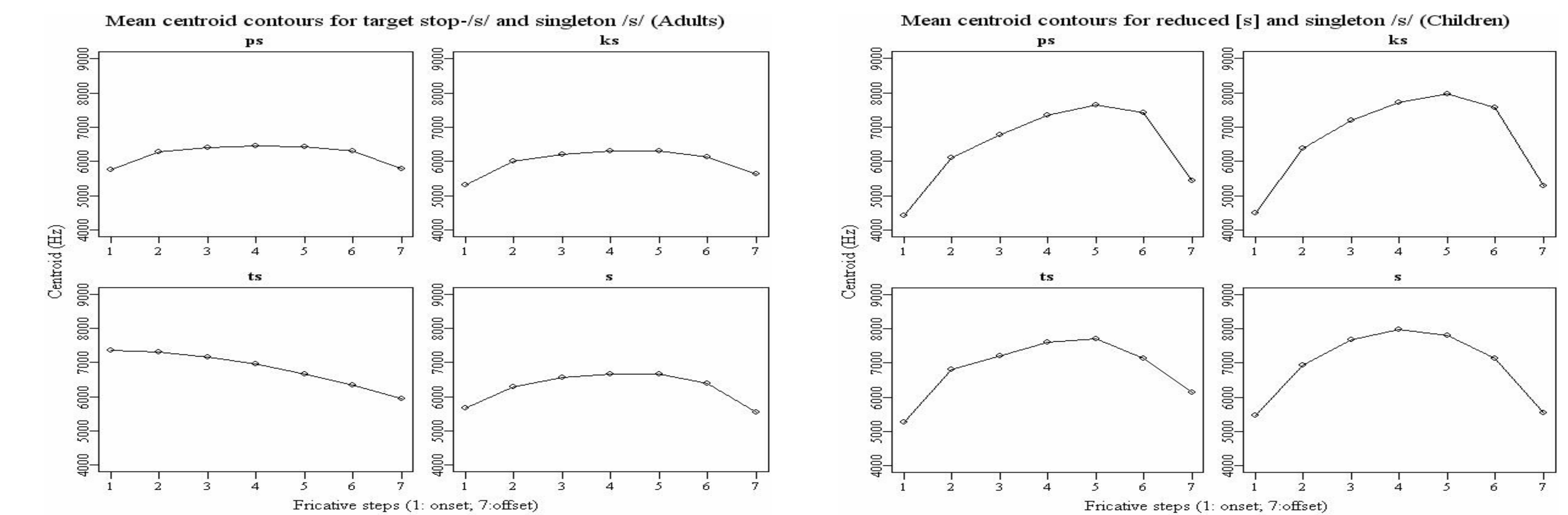


Figure 3: Mean centroid (first spectral moment) contours averaged across adults (left) and children (right).

### Adults:

- The centroid (first spectral moment) contours for the two clusters /ps/ and /ks/ look remarkably similar to that of the singleton /s/.
- The different pattern in the centroid contour for /ts/ is most likely due to its phonological status as an affricate.

### Children:

- By contrast to the adults’, the centroid contours of all three target stop-/s/ sequences are similar to each other and different from that of singleton /s/.
- The peak centroid frequencies are later for the target stop-/s/ sequences as compared to singleton /s/, suggesting that there is a trace of the “deleted” stop consonant.

## CONCLUSION & DISCUSSION

- Covert contrast was observed for Greek-speaking children who were perceived to neutralize stop-/s/ sequences to singleton [s], suggesting the need to supplement transcription with acoustic analysis.
- The later peak centroid values for the target stop-/s/ sequences suggest that there may be some underlying stop consonant gesture that is not perceptible.
- Future research will focus on a finer-grained analysis of the acoustic data, including an examination of individual subject data and the addition of an amplitude measure to provide a better articulatory interpretation of the above findings.
- Moreover, we plan to examine adult naïve listeners’ perception of these reduced stop-/s/ sequences and singleton /s/.

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