TRANSITIONAL CUES IN FRICATIVE NOISE IN GREEK /S/-STOP AND STOP-/S/ SEQUENCES: CHILDREN VS. ADULTS

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ABSTRACT

Greek is one of the few languages to allow /s/-stop and stop-/s/ sequences at three places of articulation (bilabial, dental, velar) in word-initial position. This study measured the coarticulation of /s/ with the preceding or following stop in native Greek-speaking children's and adults' productions of real words beginning with /sp/, /st/, /sk/, /ps/, /ts/, /ks/, in a variety of vowel contexts. The aim was to determine whether stop place cues are signaled effectively in the spectrum of adjacent /s/ in both types of consonant sequences attested in Greek. FFT spectra were calculated for overlapping 10 ms windows from the beginning to the end of fricative noise and spectral moments were computed in each window. Systematic differences in the fricative spectra as a function of the adjacent stop consonant were observed in the /s/+stop sequence (as in English) and also in the stop+/s/ sequence (where the differences in the portion after the stop burst proper mirrored the patterns at the end of the fricative in the clusters in the other order). Coarticulation was comparable across age groups, although there was greater variability in children's productions.

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INTRODUCTION AND RATIONALE

- Previous work in English has shown that the place of articulation of a stop after an /s/ is signaled by modulation of the noise spectrum for /s/ as the stop closure is made (e.g., Stevens, 1998).
- These transitional cues are reported to resemble the cues for the stops next to vowels, and to proceed upward before /t/, straight before /k/, and downward before /p/. In word-final stop-/s/ clusters the transitions during the beginning part of the frication are reported to be the mirror image of the transitions observed during /s/-stop clusters (e.g., Malécot & Chermak, 1966).
  - ➢ However, considerably less is known about the effect of a stop's release on an /s/ in consonant sequences at syllable onset.
  - ➢ Moreover, limited work has been done in other languages to examine whether such coarticulatory effects are universal or language-specific.
  - ➢ Furthermore, little is known about children's development of consonant-consonant coarticulation.
  - ➢ Greek is an excellent language in which to test these effects, given that it contrasts all three places of stop articulation both before and after /s/ in the same prosodic position.
- This study aimed to examine the coarticulation of /s/ with the preceding or following stop in Greek children's and adults' productions of initial consonant sequences.

METHOD

- Participants:
  - ➢ Forty children (10 children at each of the following ages: 2-, 3-, 4-, and 5-years), and ten young adults (age range: 20-35 years).
  - ➢ All participants were monolingual native speakers of Greek, with normal hearing and speech/language development.
- Stimuli:
  - ➢ Consonant sequences /sp/, /st/, /sk/, /ps/, /ts/, /ks/ placed in word-initial position in familiar real words in the following vowel contexts /a, e, i, o, u/.
  - ➢ All stimuli judged as correct by a Greek native speaker/phonetician (the first author).
- Word repetition task: Participants asked to repeat each word, given auditory prompt.
- Analysis:
  - ➢ Using Praat (Boersma & Weenink, 2001), we generated Fast Fourier Transforms (FFT) for each token, from the beginning to the end of fricative noise, using 10 ms overlapping Hanning windows.
  - ➢ We calculated the spectral center of gravity (centroid) in each window (e.g., Munson, 2004)
  - ➢ The centroid trajectories with different number of analysis windows were then adjusted to have the same number of frames using a smoothing spline method (SS-ANOVA) (e.g., Davidson, 2006).

RESULTS: ADULTS

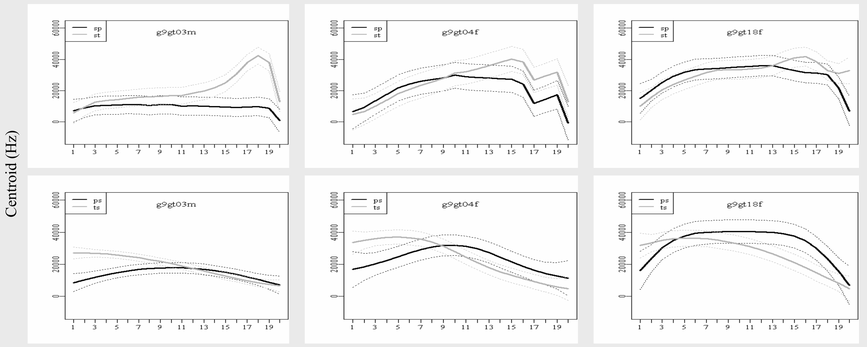

Figure 1. Centroid trajectories of Greek /s/-stop (top) and stop-/s/ sequences (bottom) elicited at word-initial position by 3 Greek adult speakers. The abscissa represents the scaled 20 frames of analysis windows arranged in time sequence, and the ordinate represents the centroid frequencies (first spectral moment). Each solid trajectory line shows the smoothed mean values of the centroid frequencies measured in the /s/-stop and stop-/s/ sequences. The dotted lines below and above the solid line are the 95% confidence intervals.

RESULTS: CHILDREN

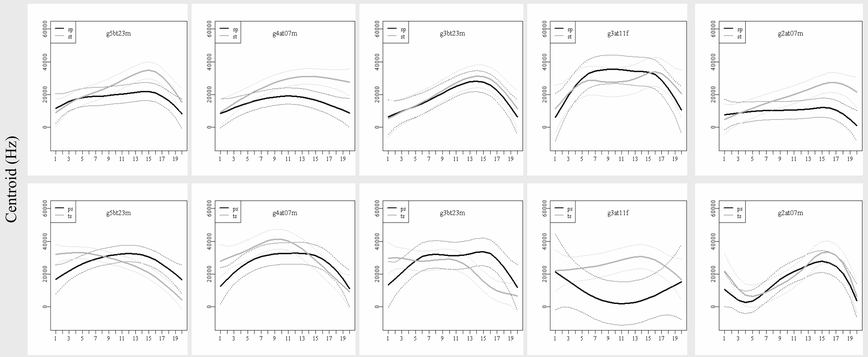

Figure 2. Centroid trajectories of Greek /s/-stop (top) and stop-/s/ sequences (bottom) elicited at word-initial position by Greek child speakers. The abscissa represents the scaled 20 frames of analysis windows arranged in time sequence, and the ordinate represents the centroid frequencies (first spectral moment). Each solid trajectory line shows the smoothed mean values of the centroid frequencies measured in the /s/-stop and stop-/s/ sequences. The dotted lines below and above the solid line are the 95% confidence intervals.

- Only /s/ clusters with /p/ and /t/ were analyzed. Centroids for /k/ showed no clear pattern (see Discussion).
- There was a significant effect of place:
  - ➢ There was a significant difference in centroids for /s/-stop sequences at the end of the trajectory.
  - ➢ There was a significant difference in centroids for stop-/s/ sequences at the beginning of the trajectory.
- There was a relatively consistent pattern among adults and children, such that higher centroids were produced for /s/ in the context of bilabials as opposed to that of dentals.
  - ➢ However, the direction of the transition varied considerably among the younger children, particularly for the stop-/s/ sequences.

DISCUSSION AND CONCLUSION

- Different places of articulation for the adjacent stop influence the spectra of /s/ in different ways, and are an important cue for speech perception.
- These effects are similar for /s/-stop and stop-/s/ sequences in word-initial position:
  - ➢ The centroid trajectories associated with labial stops are lower in frequency than those associated with dental stops.
  - ➢ Initial /s/-stop sequences (/sp/ and /st/) are significantly different at offset of frication.
  - ➢ Initial stop-/s/ sequences (/ps/ and /ts/) are significantly different at onset of frication.
  - ➢ The centroid trajectories of /s/-stop and stop-/s/ sequences are mirror images of each other.
  - ➢ These patterns are strikingly similar to those that have been reported for English.
- Children and adults show a similar pattern in centroid trajectories, though there is variability among child speakers.
- However, it is not until the age of about 3;5 (years; months) that Greek children begin to show contrastive use of coarticulatory stop place cues in the fricative noise of /s/-stop and stop-/s/ sequences.
- Centroids for /k/ showed no distinct pattern. This is most likely related to the bimodal peaks that characterize velar spectra on a linear scale.
  - ➢ We plan to use a psychoacoustic analysis to better characterize the transitions observed in /sk/ and /ks/ clusters.

FUTURE DIRECTIONS

- In future studies, we plan to perform an auditory-based analysis to quantify the effect of velar place of articulation on the adjacent fricative spectra.
- We also plan to examine children's coarticulation patterns in incorrect productions for target /s/-stop and stop-/s/ sequences, such as reductions to [s], as well as [s]-stop, and stop-[s] substitutions.
- Moreover, we will examine whether naïve adult listeners can predict the preceding or following place of articulation of the stop on the sole basis of acoustic information contained in the fricative [s] segment. These analyses are currently under way.

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