Acquisition of consonant clusters by Greek-speaking children: The case of initial /s/-stop and stop-/s/ sequences

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Introduction
- What is a consonant cluster?
  - δρόμος ['DRomos] 'road', ψάχνω ['psaXno] 'look for'.
  - Most clusters (e.g. ['DR'], ['st'], ['xT']) are represented with two letters.
  - ['ps'] and ['ks'] are represented with one letter in spelling ψ and ξ.
  - The affricate ['ts'] is represented with two letters τσ.
- Why are they interesting?
  - Common in many languages.
  - Their acquisition is protracted.
  - Problematic for children with disorders, second language learners.

Overview of Talk
- Literature review
- Research questions
- Methodology
- Results:
  - Accuracy analysis
  - Error analysis
  - Duration analysis
- Summary and conclusions

Trends of typical consonant cluster development in English
1. Singletons produced before clusters.
2. Word-final consonant clusters generally appear in inventories earlier than word-initial clusters.
3. Two-element consonant clusters are generally produced and mastered earlier than three-element clusters.

Trends (continued)
6. Young children typically delete one element of a consonant cluster.
7. Other error patterns include:
   - substitution
   - coalescence
   - metathesis
   - epenthesis

Trends (continued)
Consonant clusters in Greek

- Greek has a rich system of consonant clusters in word-initial and word-medial position.
  - ['x só:st] ‘yesterday’
  - ['sik.ja:xt:ro] ‘scarecrow’
  - ['psa:ri] ‘fish’


Stop + /s/ clusters versus affricate /ts/:

- /ts/ is traditionally analyzed as an affricate in Greek.
- /ps/ and /ks/ are traditionally analyzed as clusters.
- There is also acoustic evidence to support this interpretation for adults (Fourakis et al. 2003).


Focus of the study

<table>
<thead>
<tr>
<th>/s/ + stop sequences</th>
<th>Example</th>
<th>stop + /s/ sequences</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>/sp/</td>
<td>['spiti]</td>
<td>/ps/</td>
<td>['psa:ri]</td>
</tr>
<tr>
<td>/st/</td>
<td>['stasi]</td>
<td>/ts/</td>
<td>['tsada]</td>
</tr>
<tr>
<td>/sk/</td>
<td>['skilos]</td>
<td>/ks/</td>
<td>['ksilo]</td>
</tr>
</tbody>
</table>


Acquisition of consonant clusters in Greek

- There is very little work on the acquisition of consonant clusters in Greek.
- Pan-Hellenic Association of Logopedics (1995) found that:
  - /s/ + stop clusters are acquired before stop + /s/ clusters.
  - stop + /s/ clusters are acquired before /ts/.
- However, that study did not control for stress, position in the word and vowel context.
- There is no information on error patterns.


Research Questions

- What is the time course of acquisition of /s/-stop and stop-/s/ sequences?
- What errors are typical in Greek children’s acquisition of these sequences?
- Do children treat /ts/ differently from /ps/ and /ks/?


Participants

- 100 typically developing Greek-acquiring children between the ages of 2;0 and 6;0 and 20 adults.
- From Northern Greece (Thessaloniki).
- Passed a hearing screening.
- Children had age-appropriate speech and language development, based on parent and teacher report.
### Child Participant Information

<table>
<thead>
<tr>
<th>Age groups</th>
<th>N</th>
<th>Mean Age (in months)</th>
<th>Age Range</th>
<th>Non-verbal IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-year-olds</td>
<td>15</td>
<td>29.784</td>
<td>24,3-35,3</td>
<td>NA</td>
</tr>
<tr>
<td>3-year-olds</td>
<td>15</td>
<td>42.913</td>
<td>38.56-47.83</td>
<td>116,714*</td>
</tr>
<tr>
<td>4-year-olds</td>
<td>15</td>
<td>55.624</td>
<td>48.8-59.63</td>
<td>107,0667</td>
</tr>
<tr>
<td>5-year-olds</td>
<td>15</td>
<td>66.108</td>
<td>60.93-71.93</td>
<td>106,2667</td>
</tr>
</tbody>
</table>

* Calculated only using the 7 children over age 3.6.

### Stimuli

- Target C or CC placed in word-initial position in:
  - Two or three-syllable words with word-initial stress
  - Familiar to the children
  - Pictureable
- Each target C or CC paired with all possible vowel combinations of /i, e, a, o, u/.

### Example of stimuli

/assets/example_of_stimuli.png

- /sk/

### Methods: Accuracy and error analyses

- Native-speaker transcription using Praat waveform editor
- Initial consonant and cluster were labeled
  - Correct
  - Incorrect
- If incorrect, phonetic transcription of perceived error
  - Substitution (e.g. [tava] for /'savə/)
  - Deletion (e.g. [piti] for /'spiti)
  - Distortion (e.g. distorted /s/ in /'stoma/)

### Results: Accuracy of singleton or cluster

- Accuracy increases with age.
- Singletons before clusters.
- Trend for /s/-stop clusters before stop-/s/ clusters.
Results: Accuracy of /s/ in clusters and affricate

- /s/ in clusters more accurate in /s/-stop than in /stop-s/ clusters (2-year-olds only).
- /s/ more accurate in /ps/ and /ks/ compared to /ts/.
- /ts/ patterns differently than /ps/ and /ks/.

Results: Accuracy of stop in clusters and affricate

- Stop more accurate in /s/-stop than in stop-s/ clusters and /ts/ (2- and 3-year-olds).

Methods: Error analysis for stop-/s/ clusters and /ts/

- We grouped the errors into different categories by manner.

Correct                Error

- StopFric substitution (e.g. [kaeul] for /'kæul/)
- FricStop substitution (e.g. [kjæerfæs] for /'kjæerfæs/)
- Affricate substitution (e.g. [kaebærfoes] for /'kaebærfoes/)
- Stop substitution (e.g. [Nepi] for /'Nepi/)
- Fricative substitution (e.g. [læc] for /'læc/)
- Other (e.g. [tsele] for /'tsele/)

Results: Error analysis by manner

- Most frequent substitution for /s/ is a stop.
- Most frequent substitution for /ps/ and /ks/ is a fricative or other stop-fricative sequence.

Methods: Duration analysis

- /s/ duration was measured in word-initial position in /s/, stop-/s/, and /ts/ tokens that were transcribed as correct.
- Durations were measured for productions of 10 of the 3-year-olds, 10 5-year-olds, and 10 adults.
Methods: Duration analysis

Methods: Measuring the onset of /s/

Methods: Aligning the end of /s/

Results: Duration analysis

Summary and conclusions

Summary (continued)
Conclusions

- Results show the importance of cross-linguistic work on acquisition.
  - Cluster reduction in English and Greek.
- Results from acquisition can be useful to our understanding of the adult phonological system.
  - Status of /ts/ versus /ps/ and /ks/ in Greek.