Acquisition of stop burst cues in English, Greek, and Japanese

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INTRODUCTION AND RATIONALE

- In English and many other languages, children acquire velar stop consonants later than alveolar stop consonants.
- "Velar fronting" (the substitution of alveolar for velar stops) is a common error pattern in typical phonological development and in phonological disorder.
- Why is this?
  - ➢ One possible explanation is that velar stops are constrained in a gradient way by the tongue position for the following vowel (Wada et al., 1969).
- Importance of a cross-linguistic study:
  - ➢ In some languages (e.g., Greek, Japanese) velar stops are palatalized before front vowels and therefore have a more front position than they do in English.
- Importance of acoustic analysis:
  - ➢ We can use spectral moments analysis to examine the place of articulation for the stop burst.

QUESTIONS OF THIS STUDY

1) Is velar stop production dependent on the following vowel in a gradient way (as opposed to categorical allophony)?
2) Are there cross-language differences in the effect of following vowel context on velar stop production for adults?
3) If yes to 2, then at what age are these cross-language differences observed in child productions?

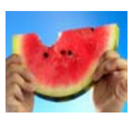
METHOD

Data collection and transcription

- Languages: English, Greek, Japanese
  - All data recorded in each country with a native speaker as the experimenter.
- Participants:
  - ➢ 6 adults, 10 2-year-olds, 10 5-year-olds for each language.
  - ➢ All adults and children typically developing and with normal hearing.
- Stimuli:
  - ➢ Consonants /t/ and /k/ placed in word-initial position in familiar words in the following vowel contexts: /a, e, i, o, u/.
  - ➢ Three word forms for each vowel context
  - ➢ Photographs of each word were accompanied by a digitized recording (spoken by a female native speaker).
- Word repetition task: Participant asked to repeat each word, given visual and auditory prompts.
- Transcription analysis: native speaker transcribed all initial CV's.
- Initial consonant coded as correct or incorrect.

EXAMPLES OF STIMULI

English /kɑfi/



Greek /karpuzi/

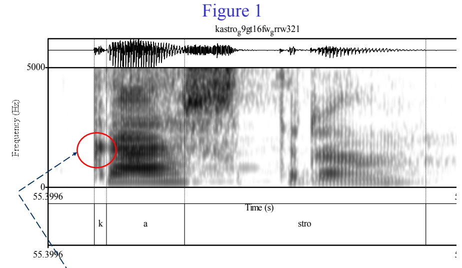
Japanese /kaba/

METHOD

Acoustical analysis

- Only correct productions were used in the acoustic analysis
- Each production was marked for the location of the stop burst
- Spectral slices were generated across a 10-ms Hamming window, centered at the burst, to obtain a frequency distribution of the burst energy (see Fig. 1).
  - ➢ The very small window was used to effectively isolate the front cavity resonances of the burst, and therefore minimize influence of the following vowel
- The highest amplitude frequency (Bark) was calculated for each burst spectrum
  - ➢ This measure was used to estimate the length of the front cavity, and thus the point of constriction during production of the target consonant
  - ➢ Non-linear spectral analysis was used to generate more compact distributions of spectra, and to more accurately model articulation as perceived by the listener (Kewley-Port 1983)

Figure 1



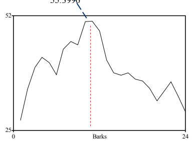


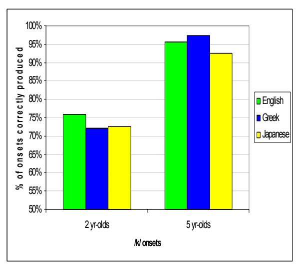
Figure 1. Above: waveform and spectrogram of Greek token /kastro/. Left: spectrum generated from 10-ms window centered on the burst, with arrows marking the highest amplitude frequency.

RESULTS

Transcription analysis

- Figure 2 compares percent correct for /k/ for the 2-year-olds and 5-year-olds in all three languages.

Figure 2



- It can be observed that for all languages, 5-yr-olds produced /k/ more correctly than 2-yr-olds.
- No consistent differences in /k/ accuracy were found across languages for either age group.

Stop burst analysis: English-speaking adults

- Figure 3 shows peak amplitude frequency values for /t/ and /k/ in all five vowel contexts, averaged across the 6 adult English speakers.
- For the /t/ burst, there is no change in peak amplitude frequency as a function of the following vowel.
- For the /k/ burst, differences in peak amplitude frequency are categorical:
  - ➢ A high peak amplitude frequency for /k/ is seen before the front vowels /i/, /e/.
  - ➢ A low peak amplitude frequency for /k/ is seen before the back vowels /a/, /o/, /u/.

Figure 3

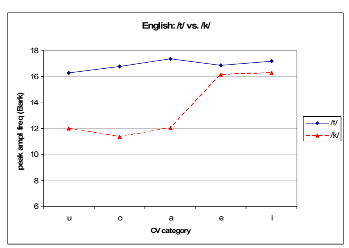


Figure 3. Comparison of peak amplitude frequency of adult-produced /t/ and /k/ spectra in English, measured in Bark (Z), in five vowel contexts.

Stop burst analysis: Adults in three languages

- Figure 4 shows peak amplitude for /k/ in all five vowel contexts for each of the three languages, averaged across the 18 adult native speakers for each language.
- The effect of vowel context on the /k/ stop burst differs in Greek and Japanese, as compared to English.
  - ➢ The effect of vowel context on the /k/ burst is gradient in Greek and Japanese, while it is categorical in English.
  - ➢ The peak amplitude frequency for the /k/ burst is higher before /i/ in Greek and Japanese relative to English.
  - ➢ The peak amplitude frequency for the /k/ burst is lower before /u/ in Greek and Japanese relative to English.

Figure 4

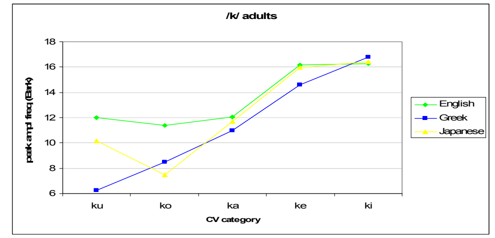
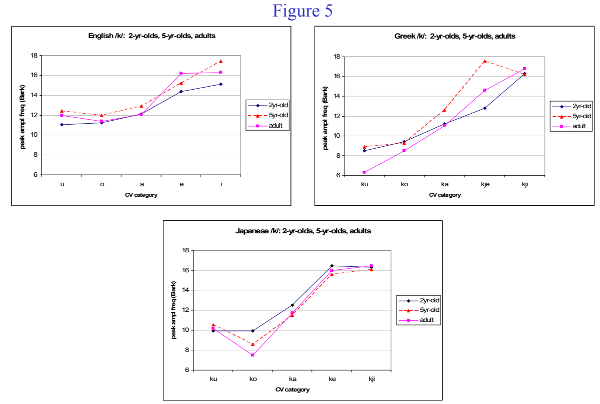


Figure 4. Comparison of peak amplitude frequency of all adult subjects for Greek [k], Japanese [k] and English [kʰ] in the five cardinal vowel contexts.

Figure 5



Stop burst analysis: Children in three languages

- Figure 5 shows peak amplitude frequency for /k/ in all five contexts, for adults, 5-year-olds, and 2-year-olds, with separate plots for each language.
- Language-specific patterns are observed for both 2-year-olds and 5-year-olds in all three languages.
  - ➢ In English, even the 2-year-olds show a categorical effect of vowel context on peak amplitude frequency for the /k/ burst.
  - ➢ In Greek and Japanese, even the 2-year-olds show a gradient effect of vowel context on peak amplitude frequency for the /k/ burst.
  - ➢ In Greek and Japanese, children of both age groups produced a smaller range of constriction points than did Greek and Japanese adult speakers:
    - less extreme points before back vowel /u/ (/o/ for Japanese) and front vowel /i/
    - relatively flatter slopes ranging across all vowel environments

Stop burst analysis: Averaged spectra

- Figures 6 and 7 show the average spectra of bursts for two vowel contexts (/u/ and /i/) across all adult speakers (Fig. 6) and 2-yr-old speakers (Fig. 7) within a language, with the dotted lines denoting the variation around the mean.
  - ➢ The data from the 2-yr-olds reflect overall adult-like patterns, varying similarly in peak amplitude frequency across language and vowel contexts.
  - ➢ However, spectral shape differs with respect to kurtosis (compactness) of these amplitude peaks: 2-yr-olds produced velar stops of lower compactness.

Figure 6

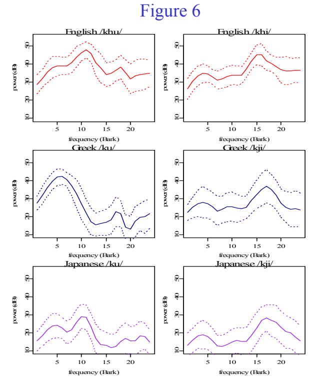


Figure 6. Average spectra of all adult subjects for Greek [k], Japanese [k] and English [kʰ] before /u/ and /i/.

Figure 7

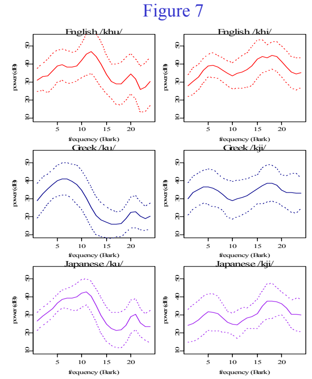


Figure 7. Average spectra of all 2-yr-old subjects for Greek [k], Japanese [k] and English [kʰ] before /u/ and /i/.

DISCUSSION AND CONCLUSION

- In Greek and Japanese, vowel context has a greater influence on the place of articulation of dorsal obstruents, as compared with English:
  - ➢ /k/ before /u/ is more back; /k/ before /i/ is more front
  - ➢ The effect appears to be more gradient in Greek and Japanese than in English.
- These same language-specific effects of vowel context were observed in the correct productions for children as young as 2 years
  - ➢ This suggests that the later production of velar relative to alveolar stop in children in many languages is not a function of the motor complexity of decoupling C and V gestures.
  - ➢ This explanation would have predicted a stronger vowel effect on /k/ production for children.
- Accuracy results for /k/ were similar for the two groups of children across the three languages.
  - ➢ A more detailed analysis of error patterns across vowel contexts is necessary in order to reveal any possible language-specific differences.
- Future directions
  - ➢ Analyze other spectral moments of /k/ bursts, such as kurtosis
  - ➢ Look at differences in CV formant transitions
  - ➢ Compare across different posture types (e.g., more fine-grained /k/ vs. /t/ comparisons)

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the παιδολογος project
cross-language investigation of phonological development