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The Fine-grained Phonetics and Acquisition of Voiced Stops in Greek

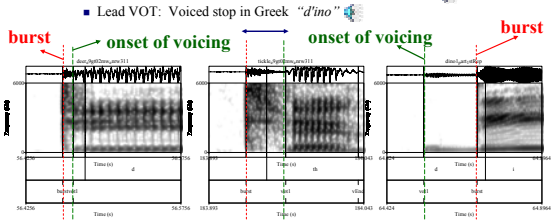
Eun Jong Kong & Mary E Beckman
Department of Linguistics
Ohio State University

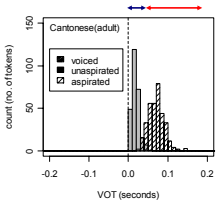
Introduction

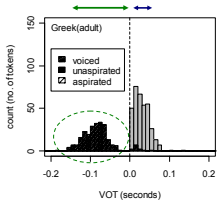
- The universal order in phonological acquisition : phonation-type contrast
  - Jakobson's implicational universal (1941/1968)
    "Voiceless unaspirated stops are produced first, and the mastery of voiced or aspirated stops implies the mastery of voiceless unaspirated ones."

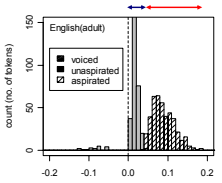
- **unaspirated stops**: produced in babbling at 6-7 months
- **aspirated stops** mastered at about 2 years across languages
- **voiced stops** are not mastered until 4-5 years in French (Allen, 1985), Thai (Gandour et al, 1986), Hindi (Davis, 1995), etc.

- Voice Onset Time (VOT) as a phonetic unit of mastery description
  - the latency of the onset of low-frequency periodicity in the waveform and spectrogram relative to the release of the oral seal as indicated by the transient "burst" noise in the spectrogram. (Lisker & Abramson, 1964)
    - Short lag VOT
      : Voiceless unaspirated stop in English *"deer"* ,in Greek *"t'ixos"*
    - Long lag VOT: Voiceless aspirated stop in English *"tickle"*
    - Lead VOT: Voiced stop in Greek *"d'ino"*







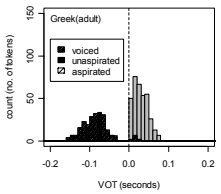


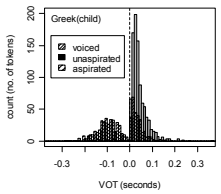
- Cantonese and English:
  - Long Lag VOT vs Short Lag VOT
- Greek:
  - Short Lag VOT vs Lead VOT

<figure 1> VOT values for word-initial lingual stops produced by adults (Kong & Beckman 2006)

- Articulatory difficulty in voiced stops
  - Kewley-Port and Preston (1974) suggested that this apparent universal order of mastery and the associated substitution patterns are due to the relative difficulty of producing different phonation types.
    - ***A voiced stop*** (lead VOT) requires the speaker to leak off some air pressure from the oral cavity in order to maintain vocal fold vibration as sub-glottal pressure builds up.
    - Spanish (Macken & Barton, 1980b): spirantized word-initially
    - French (Allen, 1985; Veneziano & Sinclair, 2000): nasal venting interpreted as voicing continuation from a preceding "inserted" indefinite article.

- Greek-acquiring children's voiced stops
  - Kong & Beckman (2006) found that the very early acquisition of voiced stops in Greek appears to contradict this universal tendency toward late mastery of voiced stops cross-linguistically.
    - Word repetition task elicited by audio and picture prompt.
    - Word initial lingual stops in a variety of vowel contexts.
    - Subjects were about **20 children aged 2 and 3 years** and 3 female adult speakers of each language.





Research Question

- Recall that these Greek children are all much younger than the ages reported for mastery of voiced stops in French, Thai, Hindi, etc
- Why are the Greek children capable of producing the very long voicing lead values characteristic of the Greek voiced stops?
- Does this pattern contradict Kewley-Port & Preston's (1974) account of articulatory difficulty in explaining the acquisition order of phonation-type contrastive categories?

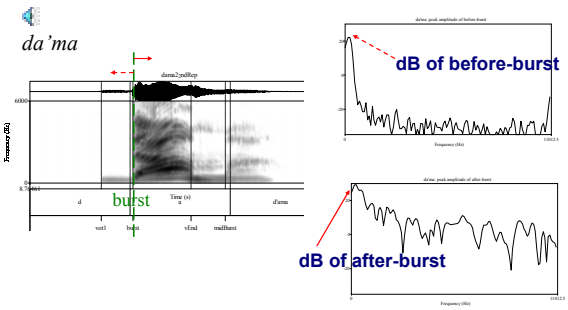
- Could the Greek voiced stops be (at least partially) nasalized?
  - Greek voiced stops have developed relatively recently from clusters of nasal followed by voiceless stop, and many speakers still produce them as clusters or as pre-nasalized stops in at least some prosodic environments (Arvaniti & Joseph 1999).
    - kj'edro , ts'ada
  - Greek children may be taking advantage of this nasal variant of voiced stops in order to side-step the articulatory difficulty of controlling oral cavity pressure in order to maintain vocal fold vibration during closure.

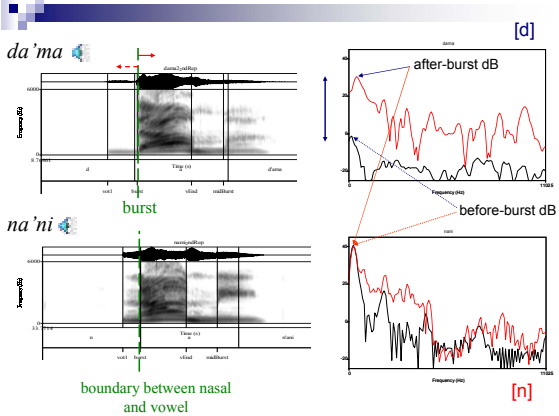
- If the voiced stops are partially nasalized, VOT, a temporal measure, would not capture this nasal characteristic of Greek voiced stops.
  - This calls for another type of acoustic analysis that compares Greek voiced stops with nasals to examine how similar they are in adults' and children's productions.

Analysis : intensity change around the burst

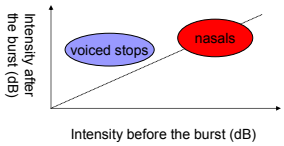
- Burton, Blumstein & Stevens (1992) examined the acoustic differences among oral voiced stops, contrastively pre-nasalized stops, and nasals in Moru.
  - Greater intensity during nasal murmur than during voiced-stop closure.
- The first peak amplitude in nasal murmur does not change before the implosion or after the release (Stevens, 2000)
- Measuring the peak amplitude difference between before the burst and after the burst

- Spectrums of 6ms Hamming window before the burst (top) and 6ms Hamming window after the burst (bottom)





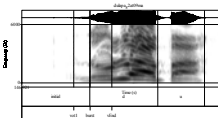
- Prediction: **at the two-dimensional plot of before-/after- burst dB**
  - Little energy difference between after-burst and before-burst in nasals
  - Greater after-burst energy than before-burst in voiced stops
    - **Nasals** to be clustered *along/on the diagonal line* whereas **voiced-stops** to be clustered *off the diagonal line*.
  - Greater before-burst energy in nasals than in voiced stops
    - **Nasals** to be located *at the right side* and **voiced stops** to be located *at the left side* along the before-burst continuum.



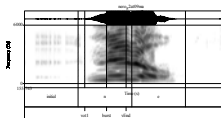
Data:

- adults:
  - Wordlist read by one female speaker
    - The list was created to produce word-initial voiced stops and word initial nasals.
      : *g'afa, d'ama, n'ani* ...
  - Repeated 5 times
- children (2 and 3 year olds):
  - Picture naming task (or voice-elicited by the researcher)
    - Originally administered in Greek to test the articulatory ability for Paidologos project in 2006.
      : *du'lapa* (wardrobe), *ne'ro* (water), bala (ball), *ga'rizi* (sound of donkey) …

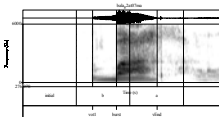
g2at09ma_dulapa



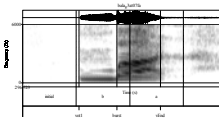
g2at09ma_nero



g2at07ma_bala

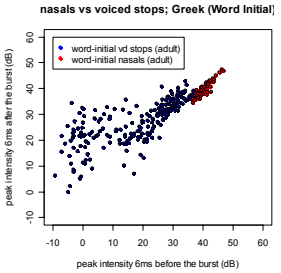


g3at07fa_bala



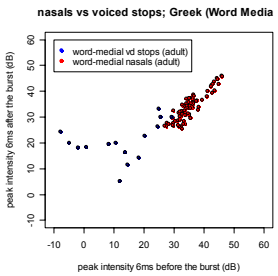
Result: adult voiced stops and nasals

- ***Word-initially***, voiced stops were effectively distinguished from nasals by this acoustic measure.
  - Higher dB overall in nasals than in voiced stops.
  - Higher dB after burst than before burst in voiced stops.



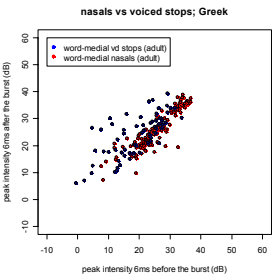
Result: adult voiced stops and nasals

- ***Word-medially***, the tendency was less obvious, probably because of the small number of tokens examined.
  - Higher dB overall in nasals than in voiced stops.
  - Higher dB after burst than before burst in voiced stops.



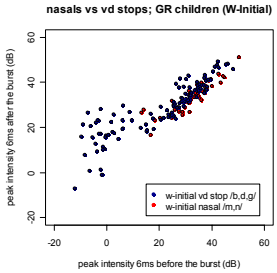
Result: adult voiced stops and nasals

- Supplemented by the word-repetition data set
  - Collected for Paidologos pilot 2004.
- ***Word-medially***, voiced stops are completely overlapped with nasals on the basis of this burst intensity analysis.



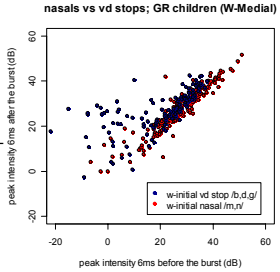
Result: child voiced stops and nasals

- ***Word-initially***, voiced stops largely overlap with nasals.
  - The cluster of voiced stops whose before- and after-burst dB is above 20dB tends to overlap with nasals.



Result: child voiced stops and nasals

- ***Word-medially***, voiced stops largely overlap with nasals:
  - There is more overlap in word-medial position than in word-initial position.



Result: summary

- Voiced stops produced by adults patterned distinctively from nasals *word-initially*, whereas they showed overlap *word-medially*.
- Voiced stops produced by children overlap with nasals both *word-initially* and *word-medially*.
- Greek voiced stops were acoustically similar to nasals in children's productions, indicating that nasality during the closure is one strategy that children use to ensure voicing during closure.

Discussion and Conclusion

- If the Greek voicing contrast is described in terms of VOT, then Greek has a simple two-way phonation-type contrast between short lag (for voiceless stops) and voicing lead (for voiced stops).
- However, a closer examination of the acoustics of the voiced stops in Greek suggests that more is involved than control of VOT, and that the voiced stop closure acoustically resembles nasal murmur in children's production.

- The Greek children seem to use nasalization to vent air pressure during closure, making for earlier mastery of voicing lead than in other languages such as French, Thai and Hindi.
- This cross language difference suggests a more nuanced interpretation of Jakobson's developmental universal concerning the acquisition of phonation-type contrasts:
  - Voiced stops are late if the phonetics of the language precludes a strategy such as nasalization during closure to overcome their difficult aerodynamic requirements.

- **Acknowledgement**
  - This work was supported by NIDCD grant 02932 to Jan Edwards and Mary Beckman.
  - We thank the speakers who let us record them.

Thank you for your attention!