Rate conditioned variability in Western Andalusian Spanish aspiration

Benjamin Parrell

Department of Linguistics, University of Southern California

Supported by NIH & the Del Amo Foundation
Many dialects of Spanish, including Western Andalusian Spanish (WAS), show aspiration of /s/ in coda position:

- /kasta/ → [kahta] ("caste")

This has generally been seen as a reduction in the oral constriction gesture for /s/ while maintaining the glottal spreading gesture for voicelessness (e.g. Romero 1995).
WAS, uniquely among Spanish dialects, shows postaspiration of voiceless stops in /s/ + stop sequences (Torreira 2007a).

/kasta/ → [katʰa]

Production of /s/ is variable, ranging from full voiceless [h] to breathy voice at the end of the preceding vowel to no aspiration of any sort before stop closure.

/kasta/ → [kahta], [k̥ta] [katʰa]
Background: /s/ aspiration

pre-closure aspiration (/s/) = 54 ms
post-closure aspiration (VOT) = 26 ms

Parrell, ASA 2009, Portland
Background: /s/ aspiration

pre-closure aspiration (/s/) = 0 ms
post-closure aspiration (VOT) = 56 ms
Past analysis of WAS aspiration has been couched in Articulatory Phonology.

The primitive unit of speech is the *articulatory gesture* (Browman & Goldstein 1989):
- gestures are dynamic constriction actions of the vocal organs (lips, tongue, etc).
- Speech is composed of constellations of (possibly overlapping) gestures.

Intergestural timing can be modeled using coupled oscillators (Goldstein et al. 2006):
- In-phase coupling: synchronous onset of production
- Anti-phase coupling: sequential onset of production
Past Analyses

- For productions of /s/ + stop with preaspiration (e.g. [kahta]), the onset of oral closure gesture for the stop is sequential to the onset of the glottal spreading gesture for /s/
  - Anti-phase relationship

- Aspirated stops analyzed as arising from a change in coupling, from anti-phase to in-phase, between the two gestures (Torreira 2007a, 2007b).
Proposed Gestural Organization

\[ \text{[kahta]} \]
- Tongue Tip
- Glottis: wide
- Acoustic Signal: preaspiration, closure, VOT

\[ \text{[kath\text{\textipa{a}}]} \]
- Tongue Tip
- Glottis: wide
- Acoustic Signal: closure, VOT

Parrell, ASA 2009, Portland
New Hypothesis

- Anti-phase coupling mode is less stable than in-phase
  - Increasing rate can induce a change in coupling from anti-phase to in-phase mode for motor movement (Kelso 1984)
  - This has also been shown for speech (e.g. Oliveira & Martin 2005, de Jong et al. 2002)

- Hypothesis: Increasing rate will cause a shift from anti-phase [ht] sequence to in-phase [th].
4 specific predictions follow from the gestural rephasing hypothesis:

1) subjects will shift from productions with preaspiration and short VOT (anti-phase) to no preaspiration and long VOT (in-phase) as rate increases

2) subjects will never switch in the reverse direction

3) decreases in preaspiration duration will be accompanied by increases in VOT (both consequence of single glottal spreading gesture)

4) variability in production will be greatest during the phase transition, and greater before the phase switch than after (Kelso 1984, Court et al. 2002)
Methods: Stimuli

/s/ + voiceless stop sequences

- 3 boundary conditions:
  - word-internally (pastándola)
  - determiner boundary (las tácitas)
  - word boundary (cantas tapa)
- 3 stops (/p/, /t/, /k/)
- 2 prosodic conditions:
  - /s/+stop sequence in pretonic position (pastándola)
  - /s/+stop sequence in postonic position (una casta)

Data presented here taken only from word-
internal, pretonic /st/ sequences (pastándola,
“grazing-it”)
Methods: Subjects, Procedure

Subjects: 20 college-age WAS speakers from Sevilla and Cádiz provinces

Procedure:
- Each stimulus presented independently on a computer monitor
- Subject pronounced stimulus synchronously with an auditory metronome
- Rate controlled in 7 increasingly faster steps of 4 repetitions each
  - 1100 – 500 ms, 100 ms steps
- 4 trials for each stimulus
Methods: Analysis

- Acoustic measurements (from waveform and spectrogram):
  - pre-closure aspiration (/s/)
  - closure duration
  - post-closure aspiration (VOT)
  - total token duration (measure of rate)
- VOT boundary (short vs. long) set by step:
  - 40 ms at step 1, 30 ms at step 7
- Two measurements of rate:
  - step (higher step = faster rate)
  - total duration of token (shorter duration = faster rate)
Example from subject 2 showing three patterns of VOT: consistently long, consistently short, or a switch from short to long.
Results: Predictions 1 & 2

As predicted, subjects switched from short to long VOT (28 trials) but not from long to short (0 trials)

\[\chi^2 = 16.7234, \ p < 0.0001\]
Results: Predictions 1 & 2

- Correlations calculated between VOT and two rate measures across all subjects
  - Three attested patterns calculated separately (LL, SS, SL)
- Past studies on other languages
  - Long VOT stops: VOT decreases as rate increases
  - Short VOT stops: VOT does not vary with rate
- Predictions:
  - LL trials: negative correlation between rate and VOT
  - SS trials: no correlation between rate and VOT
  - SL trials: positive correlation between rate and VOT
Results: Predictions 1 & 2

• Correlation between VOT and step:
  ▫ LL: $r = -0.136774, p < 0.0001$
  ▫ SS: $r = 0.007361, \text{n.s.d.}$
  ▫ SL: $r = 0.3283, p < 0.0001$

• Correlation between VOT and total duration:
  ▫ LL: $r = 0.187525, p < 0.0001$
  ▫ SS: $r = -0.093412, \text{n.s.d.}$
  ▫ SL: $r = -0.2434, p < 0.0001$

• Trials with only long (LL) or short stops (SS) are consistent with cross-linguistic patterns, but trials with a categorical shift in production mode (SL) show the predicted opposite pattern
Results: Prediction 3

• Review of prediction:
  ▫ decreases in preaspiration duration should be accompanied by increases in VOT

• Correlation between preaspiration and VOT:
  ▫ LL: $r = -0.204714$, $p < 0.0001$ (sign test is not significant)
  ▫ SS: $r = -0.078175$, n.s.d.
  ▫ SL: $r = -0.493363$, $p < 0.0001$

• Tokens with long VOT:
  ▫ 1239 total tokens
  ▫ 936 (75%) had no preaspiration
  ▫ 1067 (86%) had less than 15 ms of preaspiration

• Results suggest a categorical trade-off between preaspiration and VOT, predicted if both arise from a single glottal gesture
Results: Prediction 4

- Review of prediction:
  - variability in production will be greatest during the phase transition, and greater before the phase switch than after (Kelso 1984, Court et al. 2002)
- Only used data from SL condition
- Deviation from mean aspiration ratio used as a measure of variability:
  - calculated ratio of VOT / (VOT + preaspiration) for each repetition
  - mean of that ratio calculated at each step
  - absolute value of the deviation from step mean calculated for each repetition
Results: Prediction 4

• For a given subject, steps from all trials were sorted into 3 categories:
  ▫ PRE: before transition
  ▫ SWITCH: during transition
  ▫ POST: after transition

• Onset and offset step of phase transition identified algorithmically
  ▫ Onset: where ratio of VOT / preaspiration = 1:1
  ▫ Offset: where ratio = 2:1

• Repetitions in steps in each of the 3 categories combined across all subjects
Results: Prediction 4

Deviation from mean aspiration ratio for all subjects, sorted by phase group
Results: Prediction 4

- ANOVA test conducted on deviation data
  - revealed significant differences in variance between the three phase groups
  - $M_{\text{PRE}} = 0.1010$, $M_{\text{SWITCH}} = 0.1503$, $M_{\text{POST}} = 0.0560$
  - $F(2,831) = 49.4903$, $p < 0.0001$

- Scheffé post-hoc test:
  - significant differences between all three phase groups ($p < 0.0001$)

- As predicted, variability in production was greatest during the phase transition, and higher before it than after
  - Results are consistent with a switch from an anti-phase to an in-phase coordination
Conclusions

• Post-aspirated voiceless stops in WAS can be explained by a shift in the phasing relationship, from anti- to in-phase, between the glottal abduction gesture for coda /s/ and the oral closure gesture for the voiceless stop.
• Speech can be accurately modeled with coupled-oscillatory dynamics.
• Using this model can help explain otherwise unexplained language variation and change.


