PROSODIC CONDITIONING OF THE IMPLEMENTATION OF PHONATION IN OBSTRUENTS

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Phonation in English obstruents

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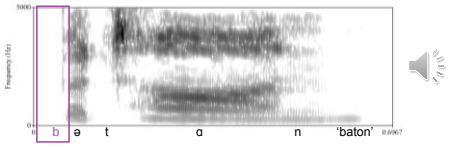
- A curious but well-documented fact about English: post-pausal [+voice] obstruents are largely produced without any phonation in the closure. (Docherty 1992, Lisker & Abramson 1964, 1967, Keating 1984)
- The realization of obstruents in this environment has played a central role in phonological analyses of English (and other Germanic languages) as not "true voicing" languages (Iverson and Salmons 1995; Jessen and Ringen 2002; Beckman, Jessen, and Ringen 2009, 2013; Honeybone 2005; Nicolae and Nevins 2016; Tsuchida et al. 2000)



Phonation in English obstruents

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- But should an analysis mainly rely on post-pausal position? What about other prosodic environments?
- Previous results are limited, but evidence from lab-constructed stimuli indicates that phonation in voiced obstruents is conditioned by prosodic boundaries & preceding sound. E.g.:
  - Rates of intervocalic stop voicing at > 80% (Flege & Brown,1982; Keating, 1984; Westbury,1979)
  - Final stops usually show partial voicing (Br. English, Docherty 1992)
  - Fricatives less voiced when adjacent to voiceless stops as compared to voiced stops (Docherty 1992, Haggard 1978, Smith 1997, also German: Möbius 2004)
- In many environments, then, at least partial phonation is produced for [+voice] obstruents in English.

Phonation in English obstruents

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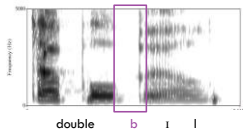
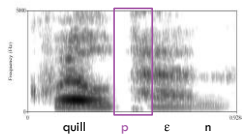
- If phonation can be partial or non-existent for [+voice] obstruents, how do English speakers keep [+voice] and [-voice] obstruents distinct?
  - Other cues can be manipulated, of course: voice onset time (VOT), F0, F1 onset frequency, etc. (Hanson 2009; Lisker 1986; Lisker and Abramson 1967; Zlatin 1979)
  - Voiceless obstruents can have 'edge phonation' (Lisker & Abramson 1964)
  - Most often at left edge when preceded by vowel (Docherty 1992, Pirello et al. 1997)
- If examined on a larger scale, do we find systematic distinctions in phonation in various prosodic positions?





Implementation of voicing in English

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- This study examines ~22,000 stops and fricatives in a corpus of read speech to establish how phonation is realized in both voiced and voiceless obstruents in American English.
  - Conditioning factors: phrase position, word position, and preceding segment.
- Two measures considered:
  - Whether obstruents are (fully) phonated, partially phonated, or unphonated
  - If partially phonated, **where** in the constriction the phonation occurs

Representation of voicing in English

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- Preview of results: Especially for [+voice] obstruents, and to some degree [-voice] obstruents, the realization of phonation is conditioned by position & surrounding sounds.
- I will sketch how gestural notions of voicing specification can capture the gradient implementation of phonation in the voicing contrasts of English.

Methods: Participants

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- Data from 2 previously published studies (N = 37)
  - Bouavichith & Davidson (2013): 13 college students from Midwest, 18-25 years
  - Davidson & Erker (2014): 24 college students in New York, 18-25 years
    - Most from mid-Atlantic and New England, also some from the Midwest (Chicago, Michigan, Minnesota), and one each from Georgia, Texas, and New Mexico

Methods: Materials

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- Short stories read by participants
  - Materials were designed for another purpose, so the target obstruents were culled from wherever they occurred in the text.
- Voiced obstruents: /b d g/, /v ð z ʒ/, /dʒ /
- Voiceless obstruents: /p t k/, /f θ s ʃ/, /tʃ/
- Some sounds discarded, e.g.,
  - /ð/ in function words (there, this, the, etc.)
  - /d, v/ in *and* & *of*
  - Sibilants adjacent to sibilants (this shop)
  - Coronal stops adjacent to coronal stops (allowed to)
  - Stops before stops that were unreleased (big boat)

Methods: Materials

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- Forced-aligned textgrids were created, but all obstruent boundaries were adjusted by hand
- Stops that were not produced with closure (e.g. spirantized, glottalized) or fricatives produced as approximants were not included
- Punctuation in the reading passage (. / , / ? / !) used to determine presence of pause boundaries
  - 87% matched up w/insertion of 'sp' in forced alignment
- Stories converted to Carnegie Mellon (CMU) transcriptions to track surrounding phonemes

Methods: Voicing classification

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- Praat's *fraction of locally unvoiced frames* in Voice Report (VR) used to determine how to classify phonation in the obstruent constriction
  - Phonated: >90% of interval identified as voiced by VR
  - Partially phonated: Between 10-90% voiced
  - Unphonated: <10% voiced
  - Three-way contrast used in phrase-medial position: not possible to determine where stops begin in phrase-initial or final position (if unreleased finally)
- **Voicing shape**: Where in the interval does phonation occur? Will return to this below.

Results: Phrase position

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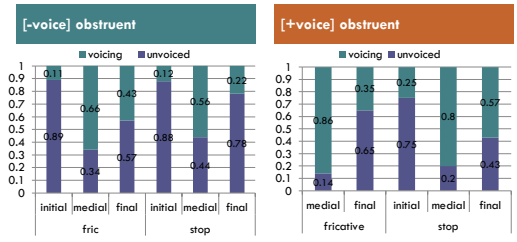

- Patterns are similar, but > presence of phonation for [+voice] phrase-medial obs
- Phrase-initial [+vc] stops largely unphonated (75%), but greater for [-vc] (88%)
  - [-voice] initial phonation mostly due to 2 sentences where comma ≠ pause

Results: Word position

(all tokens are *phrase-medial position*)

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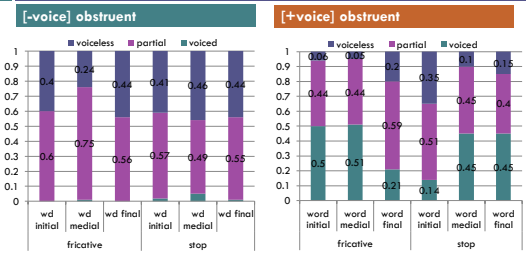

- More overall voicelessness for [-voice] & more full phonation for [+voice]
- Substantial amount of partial phonation for [-voice] phrase-medial obstruents
- Significant ⇧ in partial phonation for medial [-voice] fricatives (relative to other [-voice])
- For [+voice], significant ⇧ in unphonated word-initial stops

Results: Preceding Segment [-voice]

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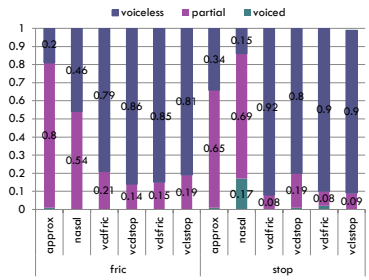
- For fricatives, most partial phonation due to preceding approximant (incl. vowels)
- For stops, approx & nasals lead to most phonation
- Stops & frics preceded by obstruents are mostly unphonated.



Results: Preceding Segment [+voice]

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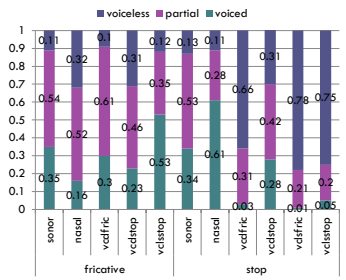
- Preceding sonorants condition most partial & full phonation
- Nasals increase full phonation in stops, not fricatives (same pattern as [-voice])
- Preceding obstruent, regardless of underlying voicing specification, tends to increase unphonated stops
  - Low N for some categories leads to unexpected results (e.g. vcls stop before fric)



Summary: Categorical voicing measure

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- No phonation overall: notably increased for [-voice]
  - All phrase positions: [-voice] = 65%, [+voice] = 43%
  - Phrase medial only: [-voice] = 40%, [+voice] = 15%
- Phrase position
  - Both [±voice]: most voicelessness in initial > final > medial position
  - Rates of phonation for phrase-initial [+voice] stops are similar to previous reports
- Word position
  - Few effects for [-voice], except increase in proportion of partial phonation for medial fricatives
  - For [+voice], initial stops have significantly less phonation
    - Perhaps a segmentation-enhancing strategy, if listeners expect less phonation word-initially

Summary: Categorical voicing measure

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- Preceding segment
  - Preceding approximants condition the most phonation; for stops, nasals also enhance phonation
    - Nasal leakage can be used to prolong phonation in stops (esp. for [+voice]) whereas it may conflict with the aerodynamic requirements necessary for frication (Solé 2009)
  - Preceding obstruents tend to decrease phonation regardless of underlying voice specification
    - As the period of obstruction lengthens, the less likely the closure in the second part of the sequence will remain phonated (e.g., Westbury & Keating, 1986)

Voicing shape

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- Though the preceding results give some insight into features that condition the presence of phonation, they provide no insight into *where* in the closure phonation is present in the 'partial phonation' cases.
- Two measures:
  - Categorical: Descriptions of where the phonation occurs
  - Continuous: Closure divided into three equal intervals and proportion of phonation in each interval is measured

Voicing shape: Bleed

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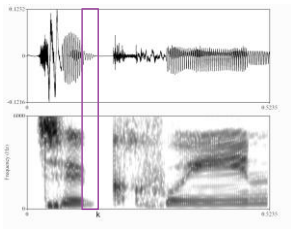
- Phonation that continues from the preceding sonorant and then dissipates before the following stop release or end of frication.



- [k] in 'to Queen'

Voicing shape: Trough

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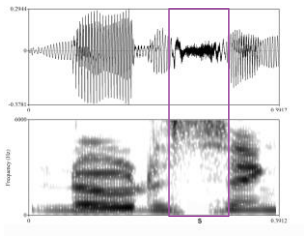
- Phonation continues from the preceding sound, then dies out, and then reappears before the stop release or end of frication.
- [s] in 'noticing'



Voicing shape: Negative VOT

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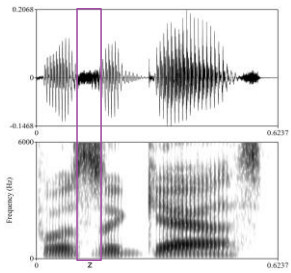
- Named after classic descriptions of negative voice onset time as phonation starting in the middle of the closure or frication period and continuing into the following sound.
- [z] in 'was aghast'



Voicing shape: Hump

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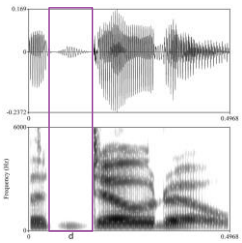
- No phonation at the beginning or end of the closure or frication period, but it is present in the middle of the interval
- [d] in 'adobo'



Voicing shape: Categorical

(all tokens are *phrase-medial position*)

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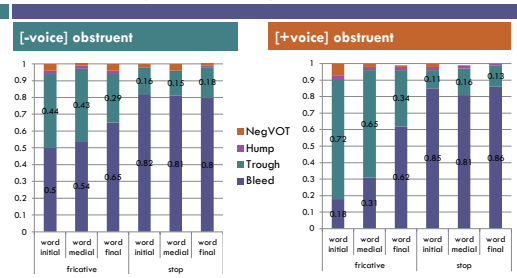

- Fricatives have more trough and stops have more bleed
  - Interaction: final fricatives have ⇧ bleed (esp. [+voice])
- For stops, little difference between [±voice]

Voicing shape: Continuous

(all tokens are *phrase-medial position*)

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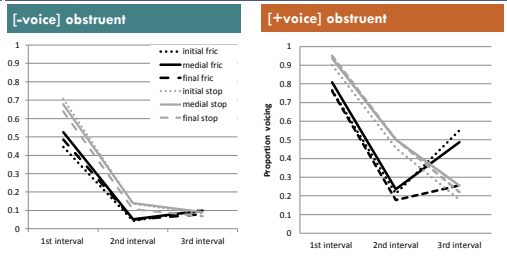

- Left edge phonation present for all obstruents, but to greater degrees in [+voice]
- Less overall phonation for fricatives than for stops
- 'Trough' pattern for fricatives mimicked in continuous measure: edge phonation increases at 3rd interval, esp. for [+voice]

Summary of phonetic influences on phonation

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English is a good test case for observing the default aerodynamic conditions for the initiation, prolongation, and cessation of phonation of [+voice] and [-voice] obstruents. Some observations:

1. Phonation carries over from the left edge where possible: after vowels, approximants and nasals
2. Since phonation is not obligatory in English, proportion of phonation decreases substantially by 2nd interval.
   - For [-voice] obstruents, phonation does not recover.
   - Speakers may take advantage of right edge phonation to enhance voicing of [+voice] fricatives.
   - [+voice] stops do not recover in 3rd interval, because speakers need to maintain adequate oral air pressure for the stop burst.

Summary of phonetic influences on phonation

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- When prosodic conditions are more conducive to phonation (phrase- and word-medial position, adjacent to approximants), speakers may use articulatory maneuvers to prolong vocal fold vibration
  - E.g.: Advancing tongue root, relaxing pharyngeal walls, velopharyngeal port venting (Ahn 2016, Bell-Berti 1975; Koenig & Lucero 2008; Proctor et al., 2010; Rothenberg 1968; Solé 2009; Westbury, 1983)
- But the aerodynamic conditions to be enhanced are already evident in the production of [-voice] stops

Representation of voicing in a gestural framework

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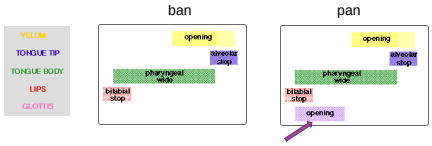
- Articulatory Phonology considers phonation to be the default speech-ready state and does not represent voiced obstruents with a laryngeal adduction gesture (Browman and Goldstein 1986, 1992).
- Is the acoustic evidence consistent with this representation?



Representation of voicing in a gestural framework

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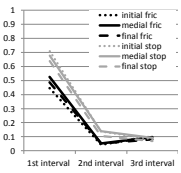
- In contrast, voiceless sounds are represented with a laryngeal opening gesture (based on transillumination, electromyography, photo-electric glottography, and fiberoptic endoscopy, Yoshioka, et al. 1981; Cooper 1991; Löfqvist and Yoshioka 1981; Löfqvist and McGarr 1987).
- Timing of abduction gesture is different by manner
  - Onset of abduction 10-20ms *before* oral constriction for fricatives, 0-15ms *after* constriction for stops (Löfqvist & McGarr 1987)
  - Timing difference may explain why stops have a greater proportion of phonation in the first interval than fricatives do



Representation of voicing in a gestural framework

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- Difference in degrees of phonation for [±voice] is compatible with B&G's hypothesis that English [+voice] stops do not have an adduction gesture.
- When aerodynamic conditions are conducive to phonation—e.g., in intervocalic position or after nasals—[+voice] obstruents tend to have more full voicing.
- When the phonetic environment is not conducive to phonation, such as in utterance-initial position or after obstruents, or at the end of an utterance when airflow is weakest, phonation is less likely to occur.

Representation of voicing in a gestural framework

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- However, other languages have obligatory phonation in obstruent constriction (e.g., Abdelli-Beruh 2004, for French; Burton and Robblee 1997, Samokhina, 2010 for Russian; Keating 1984, for Polish, etc.)
- For these, a laryngeal adduction gesture might be required to ensure phonation under all circumstances.
- More generally, a proper gestural treatment of laryngeal contrasts will require the proposal of either new laryngeal tract variables or applications of existing ones to capture relevant phoneme types, including implosives and ejectives (e.g., Iverson and Salmons 1995; Gallagher 2011)

Conclusion

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- Voiced obstruents: Presence of phonation is determined primarily by aerodynamic conditions of surrounding context.
  - voiced obstruents can be almost always unphonated in some challenging environments
  - environments more conducive to phonation result in fully phonated obstruents (maybe accompanied by active expansion maneuvers)
- Voiceless obstruents: Effects of prosodic factors & adjacent segments are similar, but aerodynamic effects seem tempered by the requirements that are imposed by a laryngeal abduction gesture.
- Current gestural phonology assumptions about representing voice in English are consistent with the acoustics, but will likely need to be expanded to account for cross-linguistic voicing representation.