Less of this, more of that:
Trading Relations in Production of Word-Final Voicing Contrast in American English.

Olga Dmitrieva

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Contrasts are complex

- The realization of phonological categories is acoustically complex:
- Multiple acoustic cues jointly contribute to the perception and categorization of speech sounds.
- How do cues interact in guiding speech perception?
- One type of interaction we know of is *trading relations.*

Trading relations

Perception

- In perception, trading relations between cues are fairly well known and relatively uncontroversial:

  “A change in the value of one cue can be offset by an opposing change in another cue so that phonetic quality is preserved.” Parker et al. (1986), p. 130

  (Summerfield & Haggard, 1077; Best et al., 1981; Repp, 1982; Parker et al., 1986, Hodgson & Miller, 1996; inter alios)

Trading relations

Perception

- For example, Whalen et al. (1990) showed that *onset f0* and *VOT* trade against each other in cuing voicing in initial stops: *ba* vs. *pa*
- Hodgson & Miller (1996) show that *onset F1* and *silence duration* trade in determining the best exemplar of *stay* (as opposed to *say*).
- Similar trading relations were found among cues to *intervocalic voicing* (Parker et al., 1986), *place* (Bailey & Summerfield, 1980), and *manner* of articulation (Doorman et al., 1980).

Trading relations

Production

- Given the abundance of evidence for trading relations in perception, it is natural to expect this property to also be at work in production:

  “it should be possible to offset a ‘weakness’ in one cue by strengthening the value of another”

  Best et al. (1981), p. 192

  - And yet, evidence for trading in production is comparably scarce
    - Fewer studies looked for it?
    - Those that did, did not always find it.

Trading relations

Production

- Dmitrieva et al. (2015) did not find evidence for *within-category* trading relations between *VOT* and *onset f0* in voiced and voiceless initial stops:
  - More ambiguous VOT values were not ‘strengthened’ by more prototypical onset f0 values in production.
- Purnell et al. (2005 a,b) found a trading relation between *glottal pulsing* and *vowel duration* in cuing final obstruent voicing in Wisconsin English:
  - “tokens can be lower in one measure as long as they are higher in the other”.

Trading relations

Production

- Purnell's study examined speakers from the geographic area influenced by substrate languages with final devoicing: German, Polish, Dutch, Yiddish.
- He proposes that the trading relations found in this dialectal area may have a sociolinguistic origin:
    - Immigrant speakers, aware of the voicing distinction in English, used glottal pulsing to signal it.
    - As a more English-like correlate of final voicing - vowel duration - was acquired by the following generations, the two cues entered into a trading relation.

Trading relations

Production

- Can trading relations in production occur in the absence of special conditions, such as language contact?
- Data discussed here represent a Mid-Western variety of General American English, speakers are young and monolingual and arguably free of significant effects of other languages.
- An examination of the acoustic correlates of final voicing suggests a trading relation between the cues, albeit of a different type from that discussed by Purnell.

The present study

Participants

- Twenty native monolingual speakers of English recorded on campus of Purdue University in West Lafayette, Indiana (two discarded from analysis for technical reasons).
- Most of the participants were undergraduate students enrolled at Purdue (age: 18-22 y.o.) born and raised in Indiana in monolingual English-speaking families.
- Most studied Spanish as a 2nd language but did not achieved proficiency beyond basic.
- Although Indiana was originally settled by many immigrants from Germany, German heritage did not feature prominently in the language background of our participants.

The present study

Stimuli

- Real monosyllabic English words differing minimally with respect to the voicing of the final obstruent:
- **Stops**: *cap-cab* (6 minimal pairs per place of articulation)
- **Fricatives**: *fuss-fuzz* (6 minimal pairs, f/v & s/z)
- **Affricates**: *batch-badge* (2 minimal pairs)
- Total: 52 experimental stimuli
- 71 distractors

The present study

Procedure

- Participants were seated in a quiet room.
- Words were presented on the computer screen, one by one, in random order.
- A new word - every 2.5 sec, to control for rate of speech.
- Participants were instructed to pronounce each word as it appears the way they speak normally.
- All words were presented three times to each participant, with optional breaks between blocks (total of 156 recorded stimuli per participant).
- Participants were recorded using a hypercardioid dynamic michrophone (Audio-technica 1000HE) and a Marantz PMD660 recorder.

The present study

Measurements

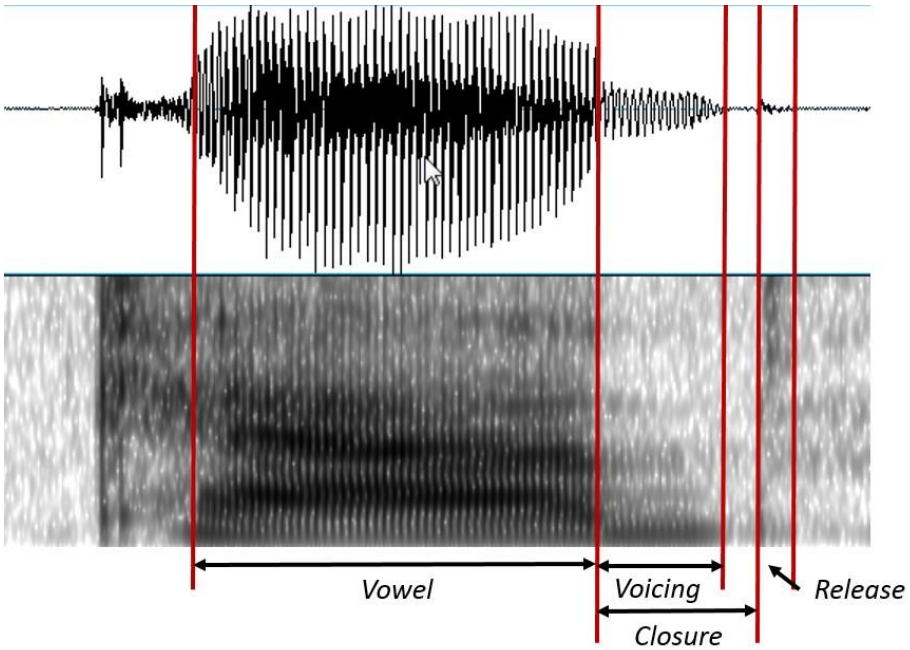
- Voicing distinction in English is ‘surprisingly’ complex:
- Numerous, often context dependent, acoustic correlates are involved.
- The most intuitive one – laryngeal voicing or *glottal pulsing* – is neither necessary nor sufficient to signal the distinction.
- Among other, often more perceptually powerful correlates, are
  - Preceding vowel duration
  - Duration of consonantal closure/constriction
  - Strength of the release
  - *f0*, F1 of the preceding and following vowels

The present study

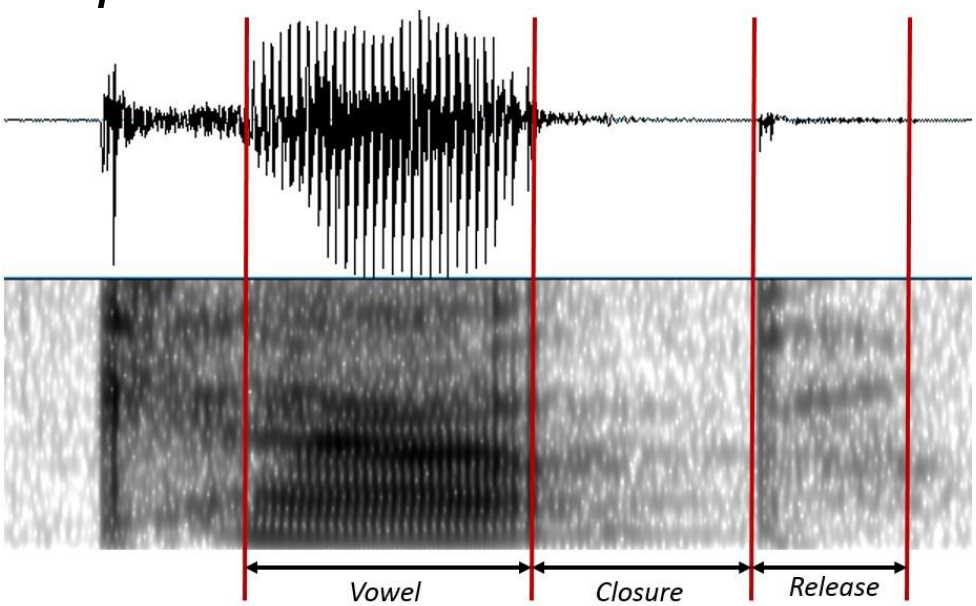
Measurements

Focus on durational correlates:

cab



cap



The present study

Analysis

- The four durational measurements were analyzed in a series of Repeated Measures ANOVAs:
- Independent factors: Voicing and Segment Type (stops vs. fricatives vs. affricates).
- For the Segment Type factor, the omnibus analysis was followed by pairwise comparisons with a Bonferroni adjustment.

The present study

Predictions

- Why is final voicing suitable for testing the trading relations hypothesis?
- Various cues to voicing are not equally available to all types of segments in English:
- Final fricatives are particularly susceptible to the loss of *laryngeal voicing*
    - Possibly a universal feature, related to the aerodynamic incompatibility between voicing and frication (Ohala, 1983).
- Final stops in English are frequently *unreleased*, eliminating the release (and closure) duration as voicing cues.

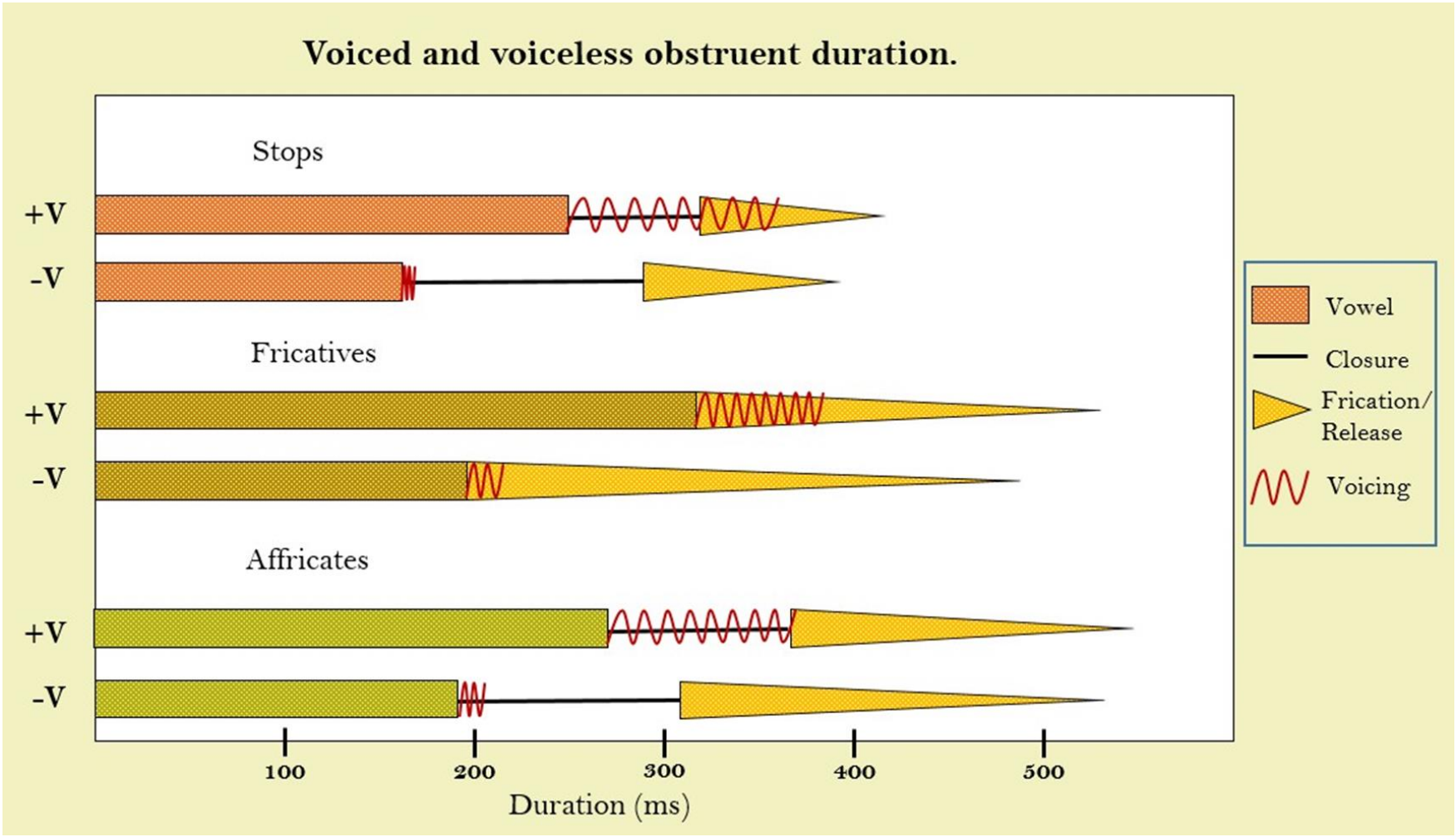
The present study

Predictions

- **Fricatives** will demonstrate a diminished contrast in the *glottal pulsing* correlate, which may be compensated by an enhanced contrast in other correlates (e.g. *vowel duration, frication duration*).
- Voiced and voiceless **stops** will not be differentiated by the *release duration.*
- Other voicing correlates in unreleased stops (e.g. *vowel duration*) may be emphasized to compensate for the loss of release.

Results

Overall durational patterns



Results

Percent voiced closure/frication

- **A significant effect of Voicing** (p<0.001):

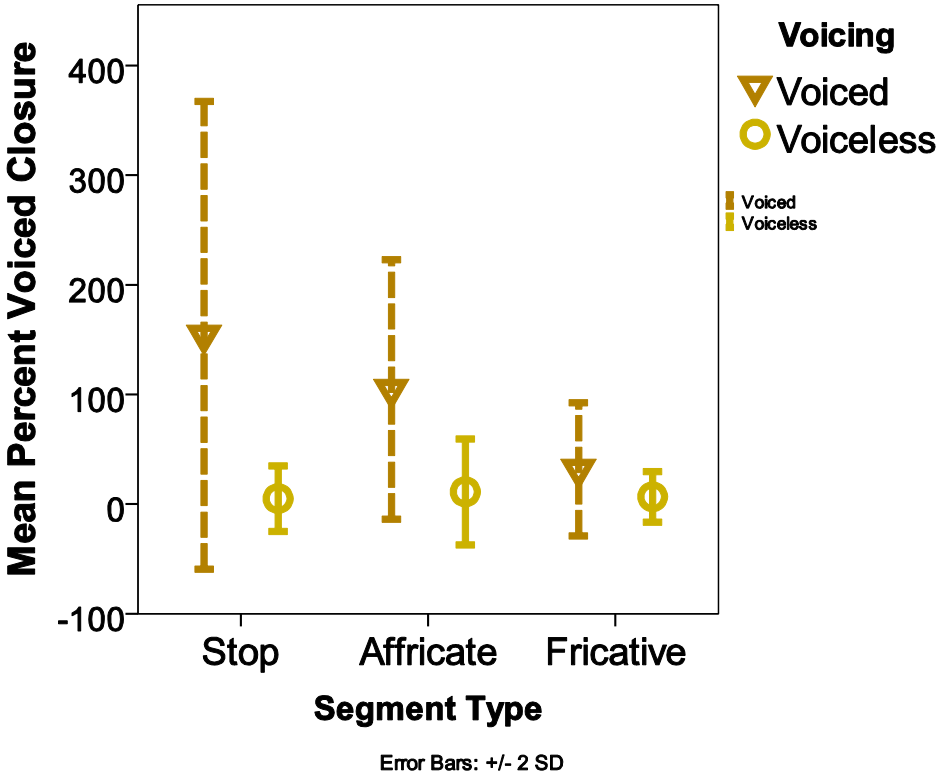
Voiced > voiceless

- **A significant effect of Segment type** (p<0.001):

Stop > Affricate > Fricative

- **A significant Voicing X Segment type interaction** (p<0.001):

Difference between voiced and voiceless sounds is greatest for stops, smallest for fricatives.



- **Fricatives** show a comparatively *diminished* contrast in the *glottal pulsing* correlate.

Results

Vowel duration

- **A significant effect of Voicing** (p<0.001):

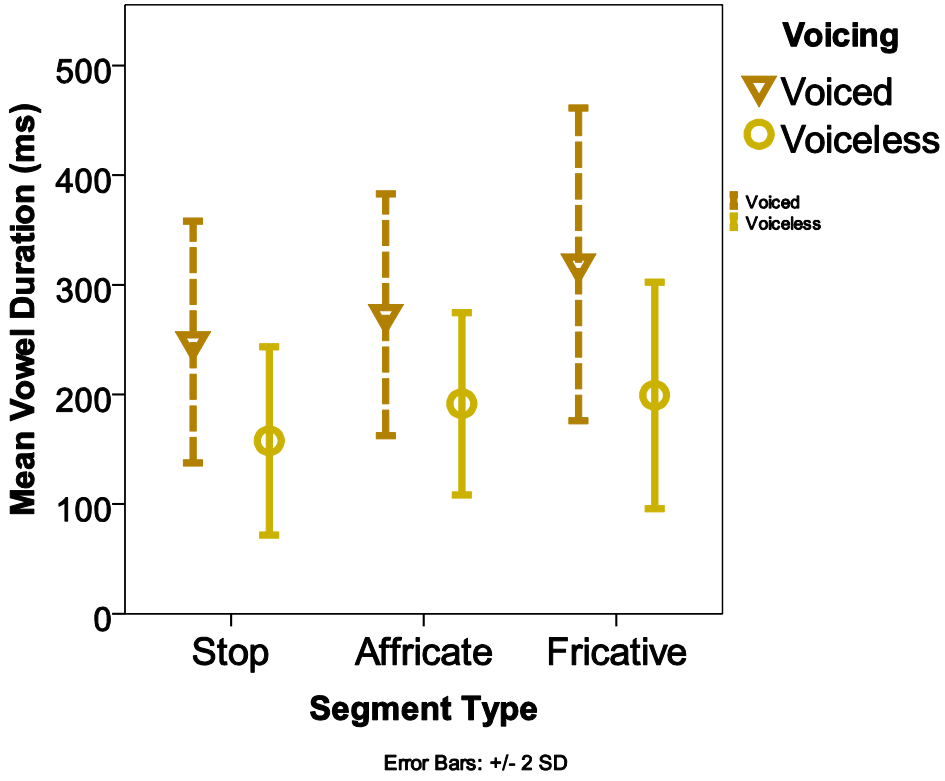
Voiced > voiceless

- **A significant effect of Segment type** (p<0.001):

Fricative > Stop > Affricate

- **A significant Voicing X Segment type interaction** (p<0.001):

Difference between voiced and voiceless is greatest for fricatives (ratio of 1.6), smallest for affricates (ratio of 1.4).



- **Fricatives** show a comparatively *enhanced* contrast in the *vowel duration* correlate.

Results

Closure/frication duration

- **A significant effect of Voicing** (p<0.001):

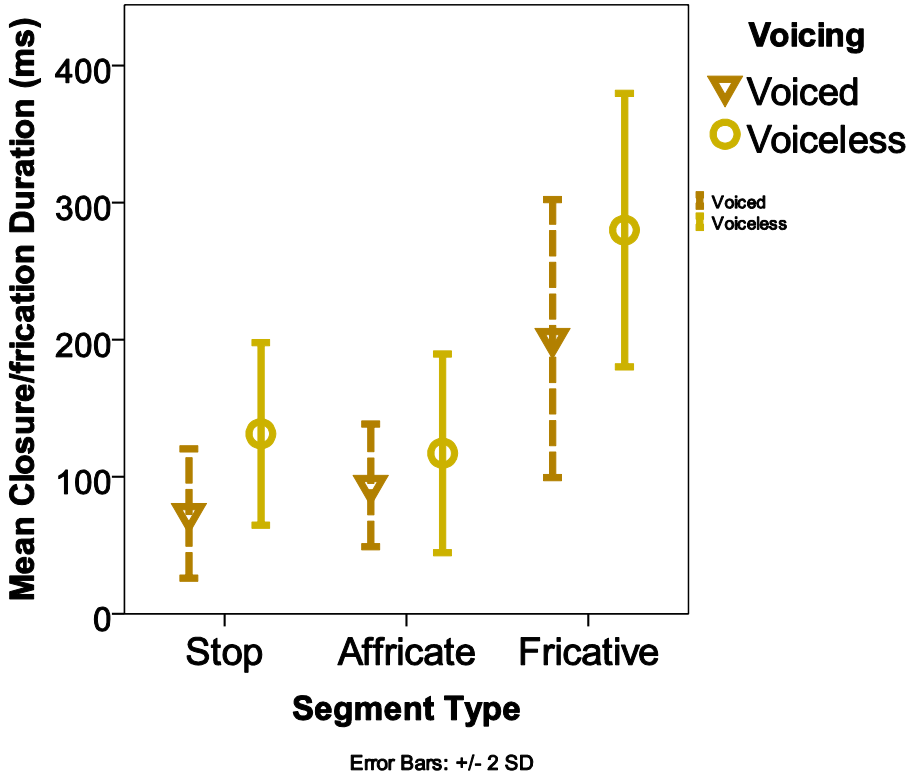
Voiceless > voiced

- **A significant effect of Segment type** (p<0.001):

Fricative > Stop = Affricate

- **A significant Voicing X Segment type interaction** (p<0.001):

Difference between voiced and voiceless is greatest for fricatives, smallest for affricates.



- **Fricatives** show a comparatively *enhanced* contrast in the *frication duration* correlate.

Results

Frication duration

- **A significant effect of Voicing** (p<0.001):

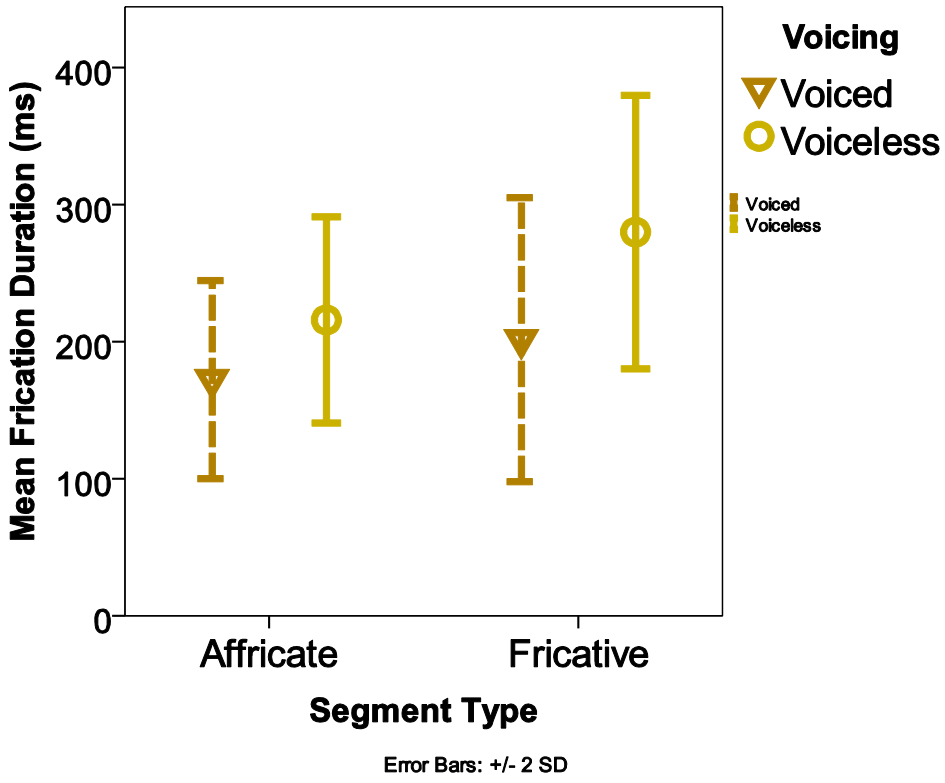
Voiceless > voiced

- **A significant effect of Segment type** (p<0.001):

Fricative > Affricate

- **A significant Voicing X Segment type interaction** (p<0.001):

Difference between voiced and voiceless is greater for fricatives than for affricates.



- **Fricatives** show a comparatively *enhanced* contrast in the *frication duration* correlate.

Results

Release duration/presence

- No effect of Voicing on *release duration* in stops
- However, the likelihood of release appears to be voicing-dependent:
- Voiced stops were more frequently unreleased than voiceless ones: $\chi^2(1, N = 2106) = 42.7144, p < .001$

	Unreleased	Released
Voiced	13%	87%
Voiceless	5%	95%

- For voiced stops only, vowels were significantly longer before unreleased than before released ones ($p<0.01$), suggesting compensatory manouvers.

Results

Voicing presence

- Among *voiced* obstruents, fricatives were more likely to completely lack laryngeal voicing.
- Among *voiceless* obstruents, fricatives were more likely to have laryngeal voicing.

	Stops	Fricatives	Affricates
Voiced	93%	**80%**	97%
Voiceless	84%	**58%**	72%

- Control over laryngeal voicing appears to be generally weaker in fricatives.

Summary & Discussion

Fricatives

- Voiced and voiceless **fricatives** are least well distinguished via the *frequency of voicing* and *duration of glottal pulsing* during constriction.
- But they are distinguished better than stops and affricates via *vowel* and *constriction duration*.
- These cues appear to be in a **trading relation**: A greater vowel/constriction duration distinction compensates for a lower laryngeal voicing distinction.
- Another possibility: Fricatives are overall longer segments and have longer vowels preceding them, so a greater amount of lengthening is necessary to trigger a comparable perceptual effect (in accordance with *Weber's law*).

Summary & Discussion

Stops

- **Stops** are well distinguished via all acoustic correlates except *release duration.*
- It is possible that voicing difference not signaled via release duration because release is often absent.
    - In perception, release also seems to matter little for voicing identification (Hillenbrand et al., 1984).
- **Voiced stops** were more likely to be unreleased than voiceless ones.
- But unreleased voiced stops were preceded by longer vowels than released voiced stops.
- In stops, absence of release cue is compensated by an enhanced vowel duration distinction.

Summary & Discussion

Affricates

- Voiced and voiceless affricates were less acoustically distinct in terms of vowel, closure, and frication duration.
- But they arguably have the greatest voicing cue redundancy among English obstruents:
- Affricates are always released: both closure and frication duration are available as cues.
- Laryngeal voicing is not jeopardized because it does not compete with frication.
- It is possible that affricates can afford a lower degree of distinctiveness in individual correlates because of higher cue availability.

Conclusion

- These results suggest that at least on the level of *group means* trading relations may exist in production of phonological contrasts (*cross-category* trading relations).
- Acoustic correlates that are not reliably present or reduced in contractiveness for a group of sounds are compensated for by enhanced contractiveness in other correlates.
- Special conditions, such as language change due to language contact, do not appear to be essential for this type of trading relations to occur.

Conclusion

- It remains to be seen whether trading relations also exist in the present data at the level of *individual tokens* (Purnell et al., 2005) – *category-internal* trading relations.
- Preliminary correlation analyses suggest that at least for some pairings of correlates it is possible:
- For example, similarly to Purnell et al. (2005), in our data glottal pulsing correlates negatively with vowel duration for voiced stops, suggesting that voiced stops lacking in laryngeal voicing are enhanced by longer vowels.
- Interestingly, this type of trading relations implies a certain degree of on-line control on the part of the speaker.

THANK YOU!

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