Categorical and Gradient Variability in Intervocalic Stops

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Speech Variability

• Speech is rampantly variable: segments, syllables, entire words get reduced or deleted (but not always) (cf. many papers by Ernestus et al., Pluymaekers et al. 2005, Johnson 2004, Greenberg 1997)

• Despite all this, we usually understand it all fine!

• How much variability comes from phonology, from systematic phonetic sources, from random variation?
Example of a “voiceless” stop

• "She's very artistic about things" (list reading)
• sentence "tic abou…"
Main interest: flaps in comparison to other intervocalic stops

A clear flap: "treaty"

A reduced one: "status"
Flapping in Amer. English

• /t, d/ are traditionally said to become [ɾ] if intervocalic before unstressed syllables: butter, bottle, treaty, ladder, capitalist, …

• This seems to be pretty categorical, although not 100% (Patterson & Connine 2001)

• But there are claims that flapping is not a categorical phonological rule, but phonetic, gradient variability (Fukaya & Byrd 2005)
Phonetics and phonology in flapping

• "The underlying motivation for the phenomenon is a prosodic one that does not pick out a single place of articulation for a symbolic alternation" (Fukaya & Byrd 2005)

• They argue that general prosodic patterns lead to short articulations, which are perceived as a categorically different sound.
Our questions

• Does a categorical phonological rule apply to /t/ and /d/ (and not to /p, k, b, g/)?

• Is some phonetic variability systematic, and conditioned by word frequency, stress and segmental environment, speech style, etc.?

• How common is reduction?
Methods

• Intervocalic, pre-unstressed /p, t, k, b, d, g/
• 6 segmental environments and 2 stress environments:

Sample stimulus words by stop and stress

<table>
<thead>
<tr>
<th>Post-stress</th>
<th>Inter-unstress.</th>
<th>Post-stress</th>
<th>Inter-unstress.</th>
</tr>
</thead>
<tbody>
<tr>
<td>/p/</td>
<td>appetite</td>
<td>precipice</td>
<td>/b/ inhibit</td>
</tr>
<tr>
<td>/t/</td>
<td>status</td>
<td>limited</td>
<td>/d/ credit</td>
</tr>
<tr>
<td>/k/</td>
<td>recognize</td>
<td>applicable</td>
<td>/g/ magazine</td>
</tr>
</tbody>
</table>

Sample stimulus words by segmental environment

Before schwa
Before syllabic /l/
Before /ər/
Before full vowel /i/
After /r/
Phrasal (Across word boundary)

status
cattle
butter
pretty
forty
write a letter

10 items/condition where possible
Subjects & Procedure

22 speakers recorded (7 analyzed so far)

3 speech styles recorded

• open conversation, with friend or family, by phone (in sound booth)
• story reading (targets embedded in stories)
• isolated word list reading
Measurements

- Cons. duration
- Cessation of voicing?
- Whether F2, F3 are visible throughout closure
- Whether a burst is present
- Ratio of minimum intensity to average peak intensity of surrounding vowels

Additional durations not reported here
Results: frequency of reduction

Clearly articulated stops would have bursts, and /p, k/ would be voiceless.

(For all measures except cons. dur., up is more approximant-like, down more stop-like.)
Frequency of reduction: formants

Clearly articulated stops wouldn't have formants.

- Conclusion: There is a lot of reduction in the data, in all speech styles.
Effects of stress environment

- All items are before unstressed syllables, but they can be either post-stress (e.g. 'city') or between unstressed (e.g. 'humanity')

- Result: inter-unstressed environment might be more reduced, but not significantly or consistently
Effects of speech style: deletions

- In 86 out of 4726 stop tokens, the stop is so deleted we can't find any trace of it to measure.

<table>
<thead>
<tr>
<th>Number of tokens</th>
<th>Conversation</th>
<th>Story reading</th>
<th>List reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>deleted</td>
<td>48</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>not deleted</td>
<td>508</td>
<td>833</td>
<td>3299</td>
</tr>
</tbody>
</table>

- Complete deletions are rare (because we can label even highly reduced flaps), but significantly more likely in more casual speech.
Effects of speech style: reduction

• More casual speech is significantly more reduced than careful speech on 3 measures.

• For some measures, there is less style effect for /t, d/, because of ceiling effects.
Results: Word frequency

- Frequencies from Celex and British Nat'l Corpus
- High frequency words not more reduced
- Patterson & Connine (2005): freq. effect on whether /t/ flaps

(should be negative)

(should be positive)
Effects of phoneme

• /t/ behaves like a voiced stop (similar to /d/)
• /t, d/ are more approximant-like than /b, g/

• /t, d/ are similar to each other
Is there phonology?

- Since /t/ behaves like a voiced stop, there must at least be a phonological process applying to /t/ (cf. Zue & Laferriere 1979).

- Patterson & Connine (2005) show it affects /t/ in almost all cases: close to categorical.

- Our results show phonology puts /t/ in a different range from /p, k/: also categorical.

- Effects of phoneme are far larger than any other systematic effect in the experiment: categorical, phonological effects may be larger than gradient phonetic ones.
Does phonology affect /d/ too?

• Results show /d/ does not differ from /t/: they are similarly approximant-like on a wide range of measures. /d/ and /t/ both differ from /b/ and /g/.

➢ Therefore, the same (or a similar) phonological process probably applies to /d/, too.

➢ It does not apply to any of /p, k, b, g/.
Is this articulatorily based?

• It could just be that the tongue tip can move faster than other articulators, leading to faster gestures and/or gestural overlap, and this is a purely phonetic effect.

• But other languages, and even British English, don't have flapping!

• The phonological aspect could certainly be derived from the articulatory facts, but has to be phonologized: an abstract process.
So is phonology everything?

- No! There is considerable gradient phonetic variability as well.
- Systematic variability: more reduction in casual speech, some patterns depending on segmental environment.
- Substantial random variability as well.
- We find no word frequency effect, while Patterson and Connine (2001) do. Frequency may affect whether one applies a categorical phonological rule, but not how much gradient phonetic reduction occurs.
Conclusions: summary

• Intervocalic stops in American English demonstrate a categorical, phonological, abstract effect on /t, d/ (flapping), as well as both systematic and random phonetic variability.

• Casual speech is more reduced than formal. Stress environment and word frequency have (thus far) limited, if any, effects.

• Both categorical phonology and gradient phonetics are necessary to account for how speech sounds are produced.
A flap example

• Lest you think reduction only happens in casual, connected speech: "capitalist"

Isolated word list reading, in sound booth.
What we're not asking

• Most past literature on flaps (Kahn 1976, Patterson & Connine 2005) focuses on whether /t, d/ flap in some environment. We're looking only at flapping environments, to see what happens among flaps.

• Past literature also compares /t, d/ to look for (in)complete neutralization. We compare /t, d/, but not with the purpose of finding differences that tiny.
A surprising acoustic cue: F4

- Primarily around /r/’s
- F4 is hardly used for anything, except retroflexes
- But this is timed to the flap, and occurs even for highly reduced tokens
Effects of segmental environment

• Examined in word list reading, post-stress conditions only (full factorial design)

• Phoneme and segmental environment interact for most measures, but inconsistently

• Two interesting patterns:
  - Stops appear to reduce less or differently before /i/ than elsewhere (because /i/ is peripheral?)
  - /b, g/ appear to reduce less before [l] than elsewhere, while /t, d/ do not (shared pl. artic.)
Effects of segmental environment

- Pre-i less reduced than pre-schwa for 4/6 measures
- Pre-l vs. pre-schwa only interacts significantly with phoneme for this measure
Examples

• What does this say?  

• "Do you have time to talk to me for a little while?"

Do you have time…

Complete word "have" deleted