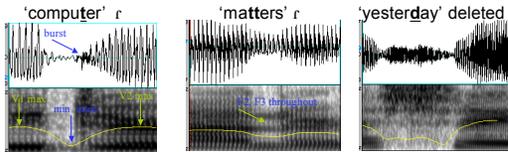


I. Introduction

There is tremendous variability in how sounds are realized in connected speech, and many variants sound natural to listeners. Flaps in English can be reduced to an approximant or deleted:



- How often are flaps reduced?
- Is flap reduction influenced by segmental environment, stress environment, and/or formality of speech style?
- Do flaps differ from other stops in how they are reduced? Do flaps derived from /t/ vs. /d/ differ?
- Does a categorical phonological rule apply to /t, d/ in flapping environment, or is flapping phonetically variable reduction?
- Much past research focuses on whether /t, d/ become flaps (Kahn 1976, Patterson & Connine 2001). This project examines further reduction in environments where they should flap.

II. Methods

- 22 native English speakers were recorded, data from 1 is reported.
- 3 speech styles: casual conversation, story reading, word list reading.
- Words containing /p, t, k, b, d, g/ in six segmental environments and two stress environments were used for the reading conditions. 10 items per condition for list reading where possible, 2 items for story.

Sample stimulus words by stop and stress

Stop	Post-stress	Inter-unstressed
/t/	status	limited
/d/	credit	prejudice
/p/	appetite	precipice
/b/	inhibit	halibut
/k/	recognize	applicable
/g/	magazine	esophagus

Sample stimulus words by segmental environment

Before schwa	status
Before syllabic /l/	cattle
Before /ə/	butter
Before full vowel /i/	pretty
After /t/	forty
Phrasal (Across word boundary, before schwa)	write a letter

- Measurements: ratio of minimum intensity (21 msec window) during consonant to average peak intensity of preceding and following vowel; presence/absence of burst; approximate formant strength during consonant (none, weak, clear); presence of voicelessness during consonant; duration measures.

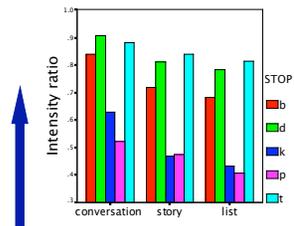


Fig. 1: Comparison of speech styles, by stop. Ratio of minimum intensity of stop to averaged maximum intensity of preceding and following vowel.

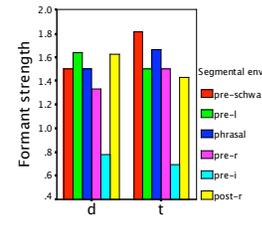


Fig. 2: Effect of segmental environment on formant strength (0=F2 and F3 cease during stop, 1=weak F2 and F3, 2=strong F2 and F3 throughout stop).

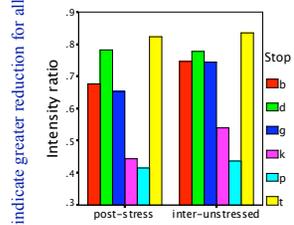


Fig. 3: Effect of stop and stress environment on intensity ratio.

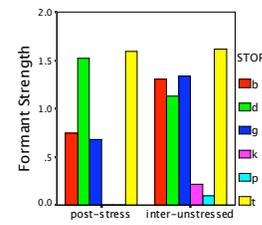


Fig. 4: Effect of stop and stress environment on formant strength.

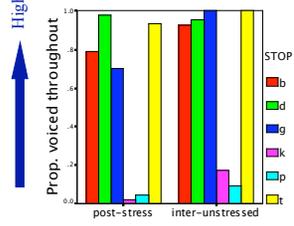


Fig. 5: Effect of stop and stress environment on whether voicing continues throughout the stop.

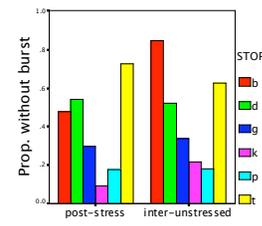


Fig. 6: Effect of stop and stress environment on presence/absence of a visible burst.

References

- Connine, C., & Patterson, D. 2001. Variant frequency in flap production. *Phonetica* 58:254-275.
- de Jong, K. 1998. Stress-related variation in the articulation of coda alveolar flaps: Flapping revisited. *Journal of Phonetics*, 26, 283-310.
- Dinnsen, D. 1985. A re-examination of phonological neutralization. *Journal of Linguistics*, 21, 265-279.
- Fukaya, T., & Byrd, D. 2005. An articulatory examination of word-final flapping at phrase edges and intonors. *Journal of the International Phonetic Association*, 35, 45-58.
- Kahn, D. 1976. Syllable-based generalizations in English phonology. *Indiana University Linguistics Club*.
- Mitterer, H., & Ernestus, M. In press. Listeners recover /t/s that speakers reduce: Evidence from /t/-lenition in Dutch. *Journal of Phonetics*.
- Pluymaekers, M., Ernestus, M., & Baayen, R.H. Submitted. Articulatory planning is continuous and sensitive to informational redundancy.
- Port, R. 1977. The influence of tempo on stop closure duration as a cue for voicing and place. *Haskins Laboratories: Status Report on Speech Research SR-51/52, 59-73.*

III. Results

- **Figure 1:** Conversational **speech style** has the most reduction (significant for all four measures; style interacts with stop for two). Conversation does not elicit the full set of conditions, so other analyses examine only wordlist reading.
- **Figure 2:** **Segmental environment** affects reduction inconsistently. Stops before a full vowel /i/ are anomalous: they are unlikely to have clear formants, even though they do remain fully voiced. Thus, stops before /i/ may reduce in a different way than others. These are excluded from other analyses.
- **Figure 3:** **Stress and stop** significantly affect reduction as measured by **intensity ratio** of stop to surrounding vowels, and they also interact. /b, g/ are less reduced than /t, d/ in post-stress environment, but approximately as reduced as /d/ when between unstressed syllables. /t/ is significantly more reduced than /d/.
- **Figures 4 & 5:** Effects on **formant strength** and on proportion with a **voiceless period during the stop** are similar to intensity (except that /t/ and /d/ do not differ on voicelessness). /p, k/ are also slightly reduced between unstressed syllables.
- **Figure 6:** Effects on **presence/absence of a burst** are less clear than other measures. Because some bursts have extremely low amplitude, this may not be a useful measure.

IV. Conclusions

- Reduction of all intervocalic stops is common, as indicated by several acoustic measures. Even /p, k/ in careful wordlist reading can be realized as fully voiced. /b, d, g, t/ often have F2 and F3 continuing throughout the constriction, frequently lack bursts, and have only a small dip in intensity.
- /t, d/ are more reduced than /b, g/ in post-stress environment on most measures, suggesting that there is something categorically different about alveolars. This could be evidence that a categorical phonological rule applies to alveolar intervocalic stops, and/or that tongue tip gestures are more susceptible to reduction (de Jong 1998, Fukaya & Byrd 2005).
- /t/ is more reduced than /d/ on most measures. Surprisingly, this is the opposite direction from an incomplete neutralization effect (Dinnsen 1985). This could reflect frequency. /t/ being at least as reduced as /d/ suggests a categorical phonological rule applies at least to /t/.
- Stress environment seems to affect /b, g/ and /p, k/, but not the alveolars. This indicates a difference in how phonological rules and phonetic reduction apply to alveolars vs. other stops, but it is not clear why /t, d/ are immune to reduction based on stress environment.
- All styles show reduction, but reduction is greater in conversation than reading. However, the effect of speech style is relatively small.

V. Future research

- Large number of speakers to examine the degree of inter-speaker and intra-speaker variability.
- Analysis of word frequency.
- Analysis of intonation and discourse prominence in conversation and story reading (cf. Pluymaekers et al, submitted).
- Perception and processing studies: how do listeners process reduced forms? (cf. Port 1977, Mitterer & Ernestus in press.)