

PLOSIVE REDUCTION AT THE GROUP LEVEL AND IN THE INDIVIDUAL SPEAKER

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ABSTRACT

This study presents results of phonetic factors on the reduction of plosives in spontaneously spoken Danish. Using mixed-effect logistic regression with speaker as random effect factor, it is shown that reduction of /d/ is distinct from reduction of /b/ and /g/. Speaker tendency for reduction relative to the group average is shown to be consistent across place of articulation for /b/ and /g/ for the majority of speakers sampled.

Keywords: plosive reduction, Danish

1. INTRODUCTION

The reduction of plosives is a well-studied phenomenon in laboratory speech and increasingly in spontaneous speech. But it is relatively understudied in contemporary Danish spontaneous speech. This paper presents the results of an investigation of the variation in the manifestation of the phonemes /b/, /d/ and /g/ in word internal position in spontaneous speech by using the DanPASS corpus [5]. Language internal factors known to affect plosive reduction in other languages [2, 4] are included in order to investigate their effect in Danish. The main question is whether the reduction of plosives can be seen as the result of a general process of reduction or as separate processes pertaining to the manifestation of each phoneme. In other words, is plosive reduction in Danish like spirantization in Spanish where all plosives are reduced to fricatives in particular segmental environments, albeit to different degrees [3]? Or has reduction become phonologized separately for one or more of the three plosives such that the situation is similar to that in varieties of English which show near-categorical flapping of coronals in intervocalic position [6]?

In addition to studying plosive reduction in Danish by looking at the aggregate behavior of a group of individuals, the present study also investigates the behavior of individual speakers

across the three phonemes. This is done to further study the extent to which reduction of each plosive should be viewed as a separate process, like flapping of coronals in American English, or as a general process of plosive reduction, like spirantization in Peninsular Spanish. Can we expect a speaker to be more or less prone to reduction in general, and therefore assume that if he or she has a relatively high tendency for reducing coronals compared to other speakers, he or she should also have a relatively high tendency to reduce labial and dorsal plosives in comparison with a group average? For plosives at different places of articulation that can be seen to be reduced in a similar way in the same phonetic contexts, it is hypothesized that individuals will show the same tendency for reduction relative to the group mean irrespective of place of articulation, which will support the interpretation of the process as a general phenomenon that applies to both or all three plosives. The probability for reduction may still vary between phonemes, but a speaker's tendency for reduction relative to the group average should be the same.

To investigate plosive reduction in groups and in individual speakers, multiple logistic regression with mixed-effects was used. Phonetic factors were incorporated as fixed effects in the regression models, and individual speakers were included as a random effect factor in the modelling of reduction for each of the three plosives /b d g/. The use of speaker as a random factor allows for control of heterogeneity in speaker behavior [1], but here they will also be examined in order to further understand the behavior of individuals.

2. DESIGN OF THE STUDY

The study is based on quantitative analyses of the transcriptions of the dialogues included in the DanPASS Corpus [5].

2.1. Description of the corpus

The dialogues in the DanPASS Corpus consist of 6 hours and 55 minutes of running speech. 22 adult speakers participated in a version of the HCRC Map Task adapted to Danish. The phonetic transcriptions of the recordings form the basis of the present study. All words were transcribed by two phonetically trained transcribers and all disagreements were resolved in conference with the project leader who also subsequently proofread the entire corpus. Relatively fine degrees of differences in constriction have been distinguished in the transcriptions, but voicing of plosives has not been noted. Therefore the present study of reduction only concerns degree of constriction.

2.2. The data

Since previous work [7] has shown that reduction of /p t k/ is very rare in spontaneously spoken Danish, only the non-aspirated stops /b d g/ were included in the statistical analysis. In addition, initial inspection of the results revealed that reduction is much more likely in word internal position than in word marginal position, cf. table 1 below.

Table 1: Proportion of reduced tokens as a function of position in the word.

| Phoneme | Position in the word | Proportion reduced | Total n |
|---------|----------------------|--------------------|---------|
| /b/ | Marginal | 4% | 830 |
| | Internal | 10% | 896 |
| /d/ | Marginal | 11% | 1482 |
| | Internal | 26% | 7308 |
| /g/ | Marginal | 11% | 2758 |
| | Internal | 49% | 1538 |

Therefore the quantitative analysis of the influence of the phonetic factors presented here was restricted to the subset of word internal tokens, since this is where reduction is most prevalent for all three plosives.

2.3. Phonetic factors included in the study

Based on previous studies of plosive reduction the following factors were included:

- *Stress.* Tokens were coded as either stressed or unstressed on the basis of the transcriptions. Tokens that were either unequivocally located in onset or coda position were assigned the stress of the syllable they belonged to. Intervocalic tokens were assigned the stress of the preceding syllable if the following vowel

was a [ə] or [e], and the stress of the following syllable if this syllable contained a full vowel.

- *Articulation rate.* Local articulation rate measured as realized syllables pr. second was used to investigate the role of speech tempo in plosive reduction. The articulation rate was measured for the prosodic phrase in which each token occurred (for details on the delimitation of prosodic phrases in the DanPASS corpus see [5]).
- *Segmental environment.* To test the possible effect of neighboring segments, the segmental context of each token was extracted from the corpus and coded as either intervocalic, VxV, interconsonantal, CxC, prevocalic CxV, and postvocalic, VxC.

These phonetic factors were entered as fixed effects in a mixed-effects logistic regression model that included speaker as a random effect factor. This model was fit to each of the three subsets of the data for plosive reduction.

3. RESULTS

As already shown in table 1 the probability for reduction differs between the three plosives. Furthermore, the type of reduction also differs across the three places of articulation as shown in table 2 below.

Table 2: The proportion of reduced and deleted tokens for word internal /b d g/ in the DanPASS Dialogues.

| Phoneme | Variant | Proportion | n |
|---------|---------|------------|------|
| /b/ | [b] | 90% | 809 |
| | Reduced | 8% | 73 |
| | Deleted | 2% | 14 |
| /d/ | [d] | 74% | 5076 |
| | Reduced | 4% | 617 |
| | Deleted | 22% | 1615 |
| /g/ | [g] | 51% | 771 |
| | Reduced | 45% | 712 |
| | Deleted | 4% | 55 |

3.1. Plosive reduction at the group level

3.1.1. Differences between place of articulation

Table 2 not only shows that reduction is less common for /b/ than for /d/ and /g/, but also that deletion is the most common type of reduction for coronals, although they are occasionally realized as taps. For labials, reduction to [β] is more common than deletion, and for /g/ reduction to [ɣ] or [x] is also the prevalent form of reduction rather than outright deletion. These differences suggest that

reduction of coronals may be a different process than the reduction of labials and dorsals in Danish.

3.1.2. Stress and plosive reduction

Stress emerges as a significant factor for all three plosives and reduction is always more likely in unstressed syllables than in stressed syllables. The table below summarizes the estimates and *p*-values for each of the three plosives.

Table 3: Model coefficients for stress for each of the three places of articulation.

| Phoneme | Stress | Estimate | <i>p</i> |
|---------|------------|----------|----------|
| /b/ | Unstressed | 2.33 | <0.001 |
| /d/ | Unstressed | 3.89 | <0.001 |
| /g/ | Unstressed | 0.47 | 0.01 |

This pattern suggests that stress is an inhibitory factor in plosive reduction across all three places of articulation, although the effect is larger for /b/ and /d/ than it is for /g/.

3.1.3. Local articulation rate and plosive reduction

Speech rate cannot be seen to have any influence on the reduction of /b/, probably because the reduction of /b/ is quite rare in the corpus. The table below summarizes the effect of local articulation rate. Note that all estimates are positive, i.e. the probability for reduction always increases with articulation rate.

Table 4: Model coefficients for local articulation rate for each of the three places of articulation.

| Phoneme | Estimate | <i>p</i> |
|---------|----------|----------|
| /b/ | - | - |
| /d/ | 0.19 | <0.001 |
| /g/ | 0.24 | <0.001 |

The estimates for local articulation rate are rather small compared to those for stress given in table 2 above. This indicates that local articulation rate is a marginal factor in plosive reduction in spontaneously spoken Danish.

3.1.4. Segmental context and plosive reduction

The effect of segmental context on plosive reduction shows interesting differences between the three places of articulation. Table 5 gives the estimates for segmental context when postvocalic position was the reference level, since postvocalic context generally inhibits reduction. The indication for significance thus shows whether the probability for plosive reduction is different from the probability for plosive reduction in a postvocalic

context. For each phoneme, then, the segmental context with the highest statistically significant estimate can be interpreted as the segmental context in which plosive reduction is most likely, all other things being equal.

Table 5: Model coefficients for segmental context for each of the three places of articulation.

| Phoneme | Estimates | | |
|---------|-------------------|---------------|-------------|
| | Inter-consonantal | Inter-vocalic | Pre-vocalic |
| /b/ | 0.77151 | 1.25145* | -0.04142 |
| /d/ | 0.84385*** | -0.14764 | -1.22594*** |
| /g/ | -0.10684 | 1.58768*** | 0.26176 |

Reference level = 'postvocalic', i.e. VxC, for all three models.
* *p* < 0.05, ** *p* < 0.01, *** *p* < 0.001

Reduction of /b/ is most common in intervocalic position. The pattern for /d/ is different. Here, reduction is most likely in interconsonantal contexts. Taken together with the finding that /d/ is deleted more often than it is tapped suggests that /d/ reduction is best described as consonant cluster simplification. The pattern for /g/ is similar to that found for /b/ with intervocalic context again being the environment that has the highest estimate in the model.

3.1.5. Summary of plosive reduction in spontaneously spoken Danish

Taken together, the results indicate that plosive reduction in word internal position in Danish is not a general process of reduction which applies to all three plosives. In particular, the reduction of coronals can be seen to be different from the reduction of labials and dorsals: /d/ is much more likely to be deleted and this generally occurs in segmental contexts where reduction of /b/ and /g/ is least likely to occur. The reduction of labials and dorsals, however, is quite similar, although reduction of dorsals is much more widespread than reduction of labials cf. tables 1 and 2. This suggests that the reduction of /b/ and /g/ can be interpreted as instantiations of a general process of target undershoot in intervocalic position.

Since the identified patterns were found using speaker as a random effect factor in the modelling of the reduction processes for each of the plosives, the effects of the phonetic factors stress, articulation rate and segmental context can be confidently assumed to apply for all speakers. However, it remains to be seen whether speaker behavior is consistent relative to the average behavior of the group when the tendency for reduction of labials and dorsals is compared for

each speaker. As argued above, a general tendency to reduce both /b/ and /g/ either more or less than the average speaker will support the interpretation that the similarities observed at the group level accurately reflect a mechanism of speech production for the individual speaker.

3.2. Plosive reduction by individual speakers

To investigate speaker tendency for reduction of /b/ and /g/ relative to the average speaker, the random effect coefficients for speakers can be inspected. These are given in table 6.

Table 6: Speaker coefficients for reduction of /b/ and /g/.

| Speaker | Coefficient for /b/ | Coefficient for /g/ |
|---------|---------------------|---------------------|
| 1 | -0.6093 | -0.2540 |
| 2 | 0.2297 | -0.5063 |
| 3 | 0.5056 | 0.0312 |
| 4 | -0.1501 | 0.2772 |
| 6 | 0.6464 | -0.5088 |
| 7 | 0.3904 | 0.3987 |
| 8 | -0.1465 | -0.0477 |
| 9 | 0.1418 | 0.3497 |
| 10 | -0.0104 | -0.3198 |
| 12 | -0.1133 | -0.6374 |
| 13 | -0.4319 | -0.6591 |
| 15 | 0.8501 | 0.2594 |
| 16 | -0.6179 | -0.4945 |
| 17 | 0.5164 | -0.4219 |
| 18 | -0.6882 | -0.0360 |
| 20 | 0.0982 | 0.8973 |
| 21 | -0.2405 | -0.0056 |
| 23 | 0.3505 | 0.7853 |
| 25 | 0.3621 | 0.3191 |
| 27 | -0.3937 | 0.2060 |
| 31 | 0.2350 | 0.1842 |
| 33 | -0.2181 | 0.1727 |

A positive coefficient indicates that the speaker is more likely to reduce a plosive than the group on average and a negative coefficient indicates that the speaker is less likely than the average speaker to reduce the plosive. If reductions of /b/ and /g/ are instantiations of the same process, it is to be expected that any given speaker will tend to have either a positive coefficient or a negative coefficient for both /b/ and /g/.

For the majority of the 22 speakers in the sample, the tendency for reduction relative to the group mean does in fact go in the same direction for /b/ and /g/: eight of the speakers who are less likely to reduce /b/ than the average speaker are also less likely to reduce /g/ than the average speaker. Similarly, eight of the speakers who are more likely to reduce /b/ than the average speaker are also more likely to reduce /g/. Of the remaining

six speakers, half are less likely to reduce /b/ but more likely to reduce /g/, whereas the last three are more likely to reduce /b/ but less likely to reduce /g/.

4. CONCLUSION

The quantitative analyses of patterns of reductions for word internal /b d g/ in Danish spontaneous speech presented here shows that the reduction of /d/ is best viewed as a process of consonant cluster simplification, distinct from the more general process of target undershoot applying to /b/ and /g/. Furthermore, 16 of the 22 speakers in the sample show similar behavior with respect to reduction for /b/ and /g/, supporting an interpretation that reduction of the labial and dorsal plosives are outcomes of the same process. Further work is needed in order to understand the reasons behind the differences observed for the six speakers who show opposing patterns of reduction for /b/ and /g/.

5. REFERENCES

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