Realization and representation of plosives in Jutlandic varieties of Danish
Variation in phonetics predicts variation in phonology

Laboratory Phonology 17, 7 July 2020

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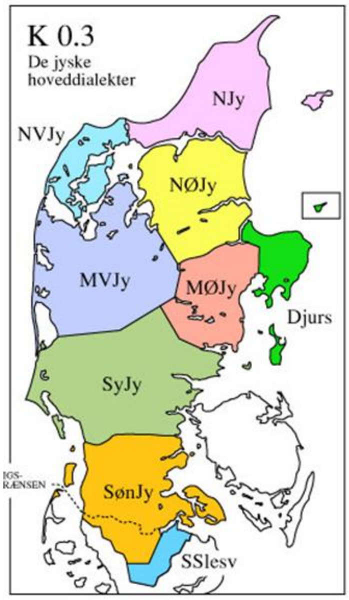
Road map

- Geo-social variation in Denmark
- Corpus of dialect recordings
- Plosive variation in Danish
- Phonetic studies
    - Voice onset time
    - Spectral characteristics / Center of gravity
- Phonological patterns

Geo-social variation in Denmark

- In the past century or so, Denmark has been subject to rapid dialect leveling (e.g. Pedersen 2003; Kristiansen 2003).
- Around the year 1870, more than 90% of the population spoke regional dialects other than the incipient national standard language (Skautrup 1968).
- Around the year 1960, we see withdrawal of non-standard varieties from the public sphere due to educational reform enforcing the standard language, increased urbanization, and a widespread, strong standard language ideology in the general population (Kristiansen 1990; Pedersen 2003).
- Now: Danish is likely one of the linguistically most homogeneous language communities in the world. The use of local dialect features often coexist with standard language use as markers of various social functions (Maegaard & Monka 2019; Scheuer et al. 2019).
- At the end of the 19th century, variation abounded at every major structural level: phonology, morphology, syntax, lexicon.
- This map - made by the Peter Skautrup Centre for Jutlandic Dialect Research - delineates major dialect areas of the Jutland on the basis of isogloss bundles:



- The dialect areas are generally not sharply delimited (Skautrup 1968).
- There is a rich tradition for descriptive dialectology in Denmark (see references in Hovdhaugen et al. 2000).
- Numerous volumes are published, both in the form of monographs describing single dialects, and comparative work. These mostly deal with:
    - Morpho-phonology (Andersen 1958, Jul Nielsen 1968)
    - Lexicon (Dictionary of Insular Danish, Jutlandic Dictionary, Feilberg 1886-1914)
- And less so with
    - Syntax (Veirup 1960, 1964a, 1964b, Pedersen 2019)
    - Phonetics and non-categorical phonology (Ringgaard 1968, Ejstrup 2010)

Corpus of dialect recordings

- A huge corpus of dialect recordings is available, courtesy of dialect research centres at Aarhus University and the University of Copenhagen. The full breadth of recordings is recorded between the 1930s and 2000s, and is very eclectic, covering all age groups and a number of different genres (Goldshtein & Puggaard 2019).
- This map shows the locations covered in the corpus:

- Many recordings from 1971-1976 have been restored directly from the original tapes by the Danish Royal Library. These are freely available online in high quality.
    - Sociolinguistic interviews
    - Correspond to NORM criteria (Chambers & Trudgill 1988):
        - Non-mobile, older, rural, male (except more women than found in some comparable corpora).
    - Informants born around the turn of the century, mean age approx. 77 years.
- This map shows the coverage of restored recordings from 1971-1976:

- Insular recordings have been used for lexicographic research (Gudiksen & Hovmark 2008).
- Recordings from the Jutland peninsula have never been used for scientific study.

- Developments in computational methods for phonetics and statistics since the 1970s makes this an incredible resource for doing corpus linguistics.
- Few recordings are transcribed, and the existing transcriptions are in an outdated format (Pedersen 1973, Andersen 1981).
    - As such, a lot of legwork is still required for any research project making use of the corpus.
- The sheer scope of this corpus, and the rampant variation when it was made, makes it a fantastic testing ground for research in language variation and change.

Background: Variation in plosives

- Standard Danish har a voiceless unaspirated ~ aspirated contrast in plosives, and voicing does not play a role in Danish phonology (e.g. Grønnum 2005).
- Variation in /t/ realization in the Jutland peninsula is overt, but not dealt with in the literature.
    - Standard Danish has a highly affricated variant, often transcribed as [t^s] (e.g. Grønnum 1998).
    - Some varieties use a ‘dry t’, with no assibilation.
    - Often attributed to Northern Jutland, but Brink & Lund (1975) claim that non-assibilated /t/ is the norm throughout the Jutland peninsula.
- Pilot study (Puggaard 2018) found that neither Brink & Lund nor the received knowledge match reality.
    - ‘Dry t’ is found in large parts of Jutland, but assibilation is also found in some traditional dialects.
    - The distinction is not categorical.
    - VOT and burst characteristics are correlated, but not perfectly so.
- Eleanor Chodroff & colleagues (Chodroff & Wilson 2017, 2018; Chodroff et al. 2019) found covariation in VOT and burst characteristics (centre of gravity) across laryngeal settings and place of articulation, such that
    - /b ~ p/ covary for speakers, varieties, languages
    - /p ~ t ~ k/ covary for speakers, varieties, languages
    - etc.
- So although the well-known, overt variation is found in /t/, similar patterns are likely to be found for other plosives as well.
    - It is not surprising if variation in /t/ is more easily noticed. Coronal burst characteristics are more salient than other places of articulation (Winitz et al. 1972), so presence/absence of assibilation is more likely to be noticed here!

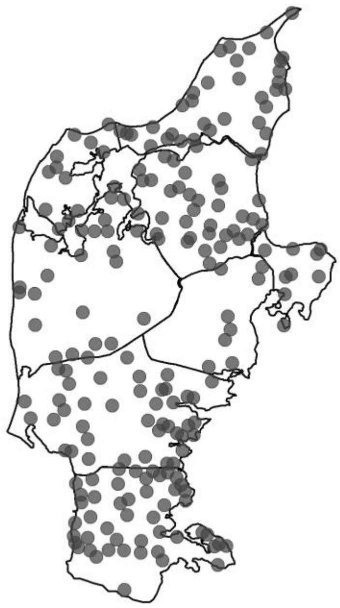
Hypotheses and key assumptions

- The received knowledge about /t/-variation in Jutland - that there is no assibilation in the northern part of the peninsula - does not give the whole picture.
- /t/ is not alone in showing regional variation.
- A growing body of literature in usage-based phonology suggests that underlying representations are emergent from the pool of synchronic variation (see e.g. Pierrehumbert 2016).
- If we buy this assumption, we should expect patterns of “free variation” in simple onset will to some extent correlate with allophonic patterns and phonological developments in other contexts.

Methods

Data for this study

- This map shows the locations of recordings used for the current study:



- 213 recordings were used in the study
    - All recordings from Jutland of sufficient quality were used.
    - Although: only one recording per location.
- 70-100 plosives were segmented for each recording using Praat (Boersma & Weenink 2018).
    - First 50 fortis stops, varying number of lenis stops.
    - VOT extracted.
        - Positive VOT only; see e.g. Stuart-Smith et al. 2015, Chodroff & Wilson 2017 for motivation of this choice)
    - Mean COG throughout release extracted for fortis stops /p t k/.
        - Excluded if VOT >10ms, or mean COG >500Hz.

- Number of phonemes included in each study are given in the following table:

Phoneme	VOT study	COG study
/b/	2,212	–
/d/	2,369	–
/g/	2,273	–
/p/	1,386	1,128
/t/	5,169	5,037
/k/	4,095	3,866

- Phonetic environmental effects and speaker information that might influence VOT/COG were noted:
    - (following) vowel height: high, mid, low (e.g. Fischer-Jørgensen 1980, but cf. Mortensen & Tøndering 2013)
    - (following) vowel backness: back, non-back (Gósy 2001)
    - (following) vowel rounding: +/- (Fischer-Jørgensen 1972; Heegård subm.)
    - Palatal release: +/-
    - Stress: +/- (Lisker & Abramson 1967)
    - Place of articulation/laryngeal setting: /b, d, g, p, t, k/ (Strevens 1960; Lisker & Abramson 1964; Dorman et al. 1977; Cho & Ladefoged 1999)
    - Informant gender (Swartz 1992; Stevens 1998; Stuart-Smith 2007; Torre & Barlow 2009)

Statistical modeling

- Statistical analysis was done in the R environment (R Core Team 2020).
- The data were fitted to generalized additive mixed models (Wood 2017; Sóskuthy 2017; Wieling 2018) using the *bam()* function from the *mgcv* package (Wood 2019).
    - GAMMs are non-linear regression models used for data that varies dynamically across time or space.
    - Often used in linguistics for data that varies dynamically across time rather than following a straight line, such as pitch trajectories (Baayen et al. 2018).
- Speaker/environmental information included as linear predictors.
- Random slopes for individual informants by phonemic stop category.
- Geographical information (latitude, longitude) included as non-linear predictor (smooth term).
    - For the COG model, the influence of VOT on COG was also modeled as a non-linear predictor.
- Full model specifications can be seen in the appendix.

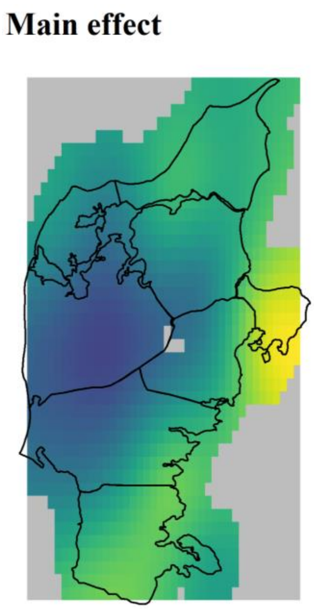
- The visualizations seen below and above were made using the packages *itsadug* (van Rij et al. 2020), *mgcViz* (Fasiolo et al. 2019, 2020), *ggplot2* (Wickham 2016; Wickham et al. 2020), and *mapDK* (Barfort 2015).

Results

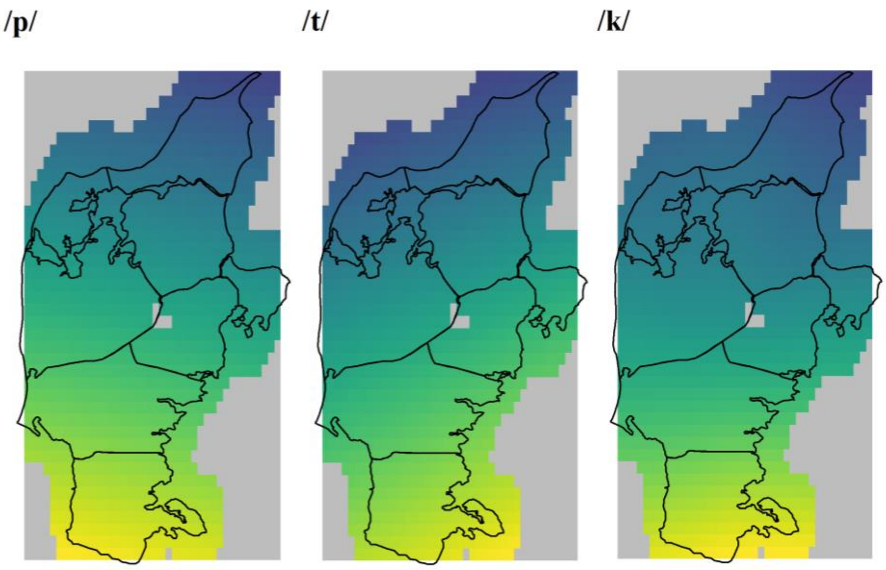
(more details in Appendix)

VOT

- All linear predictors significant at $p<.001$ level.
    - *Except gender*, which has no significant effect on VOT.
- The literature suggests an interaction between backness ~ place of articulation (Fischer-Jørgensen 1972), and rounding ~ place of articulation (Gósy 2001).
    - No such effect was found.
- In both laryngeal settings, evidence was found for /b, p/ being shorter than /d, t/ - but not /d, t/ being shorter than /g, k/.
    - i.e., labials < coronals, but coronals ≈ velars
- Strong main effect of geography, and specific geographical effects for /p, t, k/ but not /b, d, g/. These effects are mapped here:



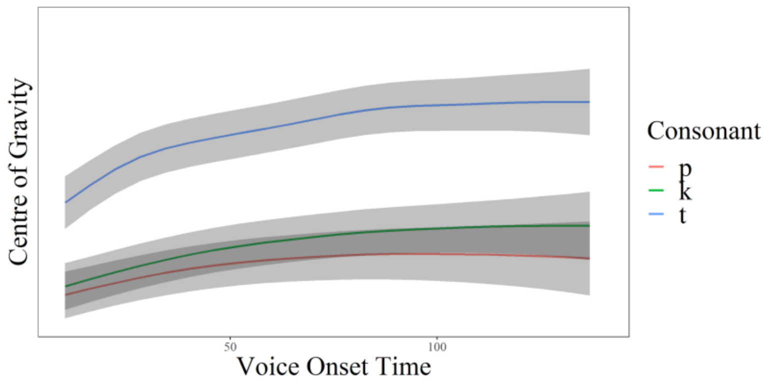
- Dark blue = low fitted VOT values; bright yellow = high fitted VOT values.
- The main effect is a pattern that can be generally attributed to all stops, showing
    - Very low VOT in the centre/west of the peninsula;
    - Somewhat higher VOT in the far north;
    - Higher yet VOT in the south/east;
    - Very high VOT in the eastern area (Djursland).



- Specific geographical effects for /p, t, k/ are all very similar. These must be interpreted in conjunction with the main effect, and show
  - Very high VOT in the south;
  - Very low VOT in the north;
  - Fully gradient patterns in between.

COG

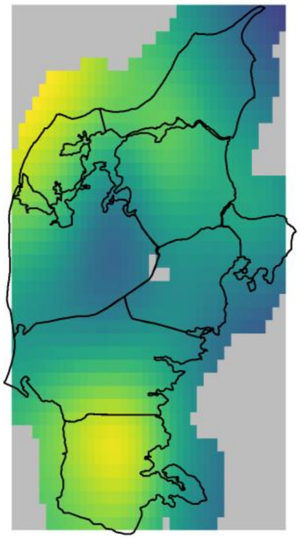
- All linear predictors significant at p<.001 level.
- Strong main effect of geography, but no specific geographical effects for /p, t, k/.
- Significant non-linear relationship between VOT and COG.
  - Strong main effect.
  - Only phoneme-specific effect is for /t/.
- These effects are visualized here:



- This figure shows the COG-VOT relationship.
  - COG for /p, k/ increases as VOT increases, although this effect mostly plateaus for tokens above 50ms VOT.

- The same is true for /t/, although the effect here is more pronounced between 10-30ms VOT, continues until ~80ms VOT, and then plateaus for longer tokens.

Main effect, COG



- We have established that VOT is a useful predictor for COG, so this map must be read in conjunction with the VOT maps above. Bright yellow = high COG values *relative to VOT in the same area*, etc. With that in mind, the map shows
    - Very high relative COG values in the north-west, and in the south.
    - Very low relative COG values in the centre of the peninsula and in the far north-east.

Phonological patterns

Hypotheses

- Given what we now know about the distribution of phonetic variation, and our assumption that this will correlate with phonological patterns, we can form some hypotheses.
- We focus here on lenition, mostly in the form of (probabilistic) spirantization.
    - Often found in weak prosodic positions like coda and unstressed onset.
- On a general note: Since occlusions are generally tighter for fortis plosives /p, t, k/, lenis plosives /b, d, g/ are expected to more readily spirantize through gestural weakening.

VOT:

- If low, the laryngeal distinction is probably (partially) maintained through prevoicing, which may be phonological.
    - We have not measured prevoicing, but this indeed seems to be the case.

    - If /b, d, g/ spirantize, voicing is expected to be retained, giving [v, ð̥, ɣ].
- If high, we have no reason to suspect phonological voicing.
    - So if /b, d, g/ spirantize, we expect [f, s, x].

COG
- If high, /p, t, k/ have very salient place cues during release.
    - These resemble fricatives at same place of articulation.
    - This increases likelihood of reanalysis as fricatives through cue reranking, or just dropping occlusion in certain environments.
- If low, /p, t, k/ should be less likely to spirantize.

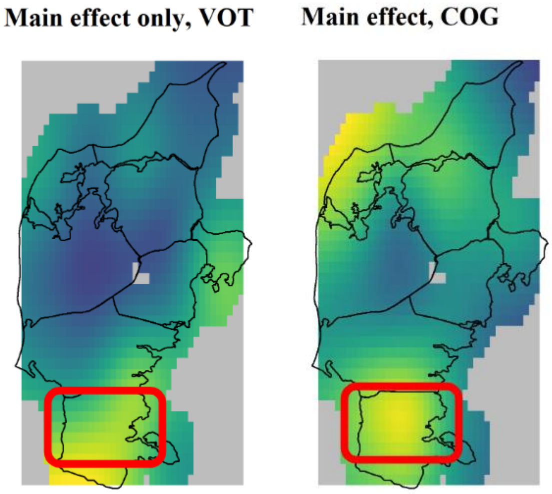
This table provides an overview of our predictions:

	VOT	COG
low	/b d g/ → [v ð̥ ɣ]	/p t k/ stable
high	/b d g/ → [f s x]	/p t k/ → [f s x]

- The high-low dichotomy is of course a simplification, but a useful one.
- This gives four logical possibilities:
    - We explore reduction patterns in the speech of four representative speakers, supplemented by findings from the dialectological literature.
    - We will occasionally refer to maps produced by *Jysk Ordbog* (JO).

Toftlund

- Toftlund is in an area with high VOT and high COG.



Reduction patterns

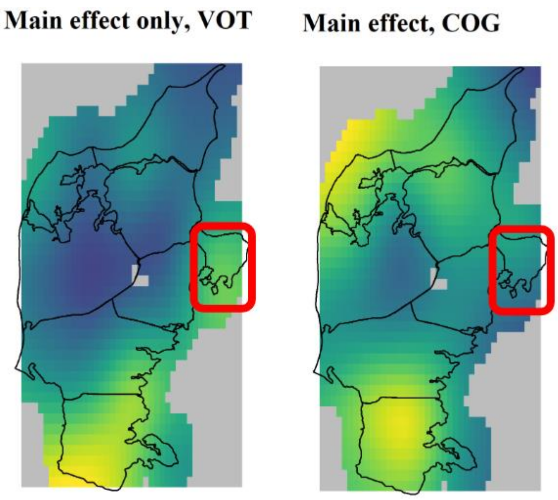
- Categorically: /g, k/ → [x]   / _# (JO: K4.2):
  - Same pattern also found in onset as non-categorical reduction phenomenon:
    - (1) /kalt/ → [xalt] ‘called’
  - Voicing can be found intervocalically:
    - (2) /vi#gik/ → [viɣix] ‘we went’
    - (3) /egɛn/ → [eɣɛn] ‘again’
- Categorically: /b/ → [f]   / _# (JO: K4.3):
    - (4) /ski:b/ → /ski:f/ ‘ships
  - But /p/ → [p]   / _#
  - We have few examples of /b/ → [v] in onset:
    - Generally not categorical; in some instances possibly lexical.
    - (5) /na:bo/ → [na:vo] ‘neighbor’
    - (6) /bygət/ → [vygə] ‘built’

Upshot

- Laryngeal neutralization in velars.
- /b/ generally remains voiceless when spirantized.
- This is in line with our hypotheses.

Ørsted

- Ørsted is in an area with high VOT and low COG:



Reduction patterns

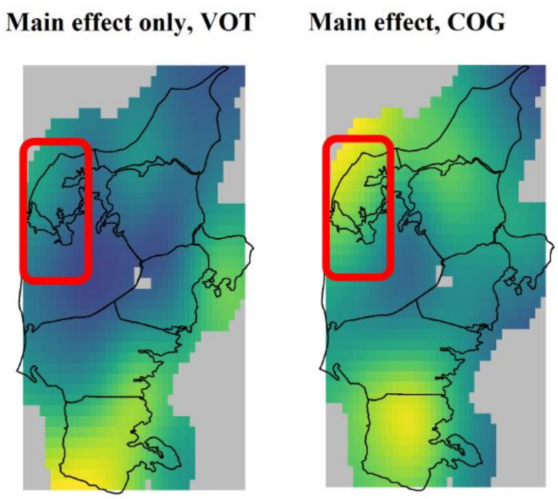
- Of the four "logical possibilities" this is the most phonetically ambiguous - and also the most phonologically ambiguous.
- /k/ very occasionally spirantizes, but fortis plosives are generally stable.
- /b/ → [f] / _ # is frequently found:
  - (7) /tabt/ → [taft] 'lost'
  - (8) /dy:b/ → [dy:f] 'deep'
- However, /d/ → /ð̞/ / #_ appears to be categorical in function words and unstressed syllables:
  - (9) /dɛn/ → [ð̞ɛn] 'the'
  - /g/ is generally stable, but nearby dialects display frequent /g/ → [ɣ].

Upshot

- No laryngeal neutralization.
- Fortis plosives and /g/ are rather stable.
- /d/ categorically weakens to a glide in some positions.
- /b/ often spirantizes in coda, remains voiceless.
- Partially in line with our hypotheses.
  - But the behavior of /d/ is unexpected.

No

- No is in an area with low VOT and high COG:



Reduction patterns

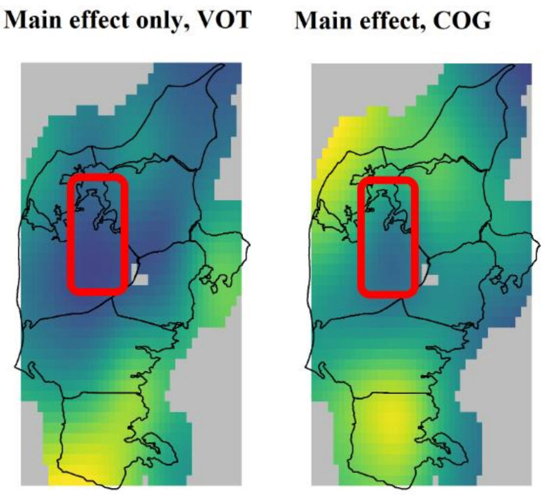
- Stop → fricative frequent both in onset and coda; here we focus on onset.
- /g/ → [ʝ ~ j]   / _V[+high], often lexicalized in function words:
  - (10) /gik/ → [ʝik] 'went'
  - /g/ → [ɣ]   / _V[-high] is a very frequent reduction pattern, but seemingly not lexicalized:
    - (11) /go/ → [ɣo] 'walk'
- /k/ → [x ~ χ] is also very frequent:
  - (but never lexicalized)
    - (12) /kɒm/ → [xm̩] 'came'
    - (13) /dʁɑk/ → [dʁɑχ] 'drank'
- /p/ → [f]   / _# is found, albeit infrequently:
  - (14) /kɒp/ → [kɒf] 'cup'
- /d/ → [ð̞]   / #_ lexicalized in some function words:
  - (15) /dɛn/ → /ð̞ɛn/ 'that'

Upshot

- No laryngeal neutralization.
- /k/ very frequently spirantizes to [x ~ χ]; /p/ seen spirantizing to [f].
- /b d g/ retain voicing when spirantizing.
- This is in line with our hypotheses.

Junget

- Junget is in area with low VOT and low COG.



Reduction patterns

- /g/ → [j ~ ʝ]   / _$V_{[+high]}$ and /g/ → [ɣ ~ ʁ]   / _$V_{[-high]}$ frequent but not categorical:
  - (16) /gi/ → [ʝi] 'give'
  - (17) /goːˀr/ → [ʁoː] 'farm'
  - /g/ → [j ~ ʝ]   / _$V_{[+high]}$ is categorical in nearby areas.
- /k/ → /x/, frequent but not categorical:
  - (18) /komə/ → [xomə] 'comes'
- /b/ → [v]   / #_r found in /hʌlstəbroʊ/ → [hʌlstəvʁoʊ] (city name).
  - This may be lexical.
- /d/ → [n]   / N#_ and /g/ → [ŋ]   / N#_
  - (19) /n#dɛngɒŋ/ → [nɛ̃ŋːɒ̃] 'then'

Upshot

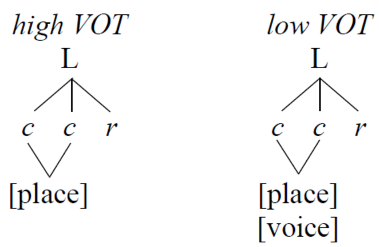
- No laryngeal neutralization.
- Spirantization of fortis plosives limited to /k/.
  - Although frequent here.
- /g/ - and to some extent /b/ - often alternate with voiced fricatives.
- /d, g/ merge with adjacent nasals.
  - This would argue for phonological voicing.
  - Voicing is conducive to nasalization; voicelessness is not.
- Mostly in line with our hypotheses.
  - We did *not* predict spirantization of fortis plosives, which is also relatively suppressed here.

Phonological representation

- Low ~ high VOT = presence ~ absence of phonological voicing in /b, d, g/.
    - This feature is relatively stable in lenition processes.
- Low ~ high COG = absence ~ presence of place features during release of /p, t, k/.
    - This is difficult to capture at a segmental level, but can help account for relative stability (or instability) of plosives.
    - A possible solution may be found with the quantized, subsegmental framework of Q-theory (e.g. Shih & Inkelas 2014, 2019a, 2019b; Inkelas & Shih 2016, 2017).
        - Here are some tentative examples of what this could look like, where L stands for lenis plosive, F stands for fortis plosive, *c* stands for closure, and *r* stands for release (following Grijzenhout et al. 2020):

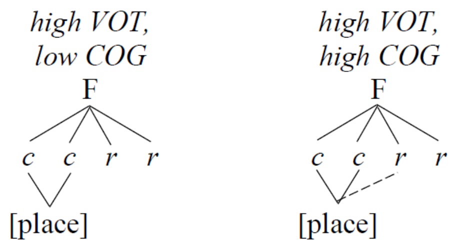
We have not measured COG for the lenis plosives, and do not suspect that it plays a role, so there are only two variants.

- High VOT dialects, and low VOT dialects.
- In both cases, lenis stops consist of three subsegments; two marked as *closure*, and one marked as *release*.
- High VOT dialects can maintain their laryngeal distinction with positive voicing lag alone. For low VOT dialects, this distinction is more fragile, and we suggest that it is (partially) maintained with prevoicing, which is represented on the closure subsegments.

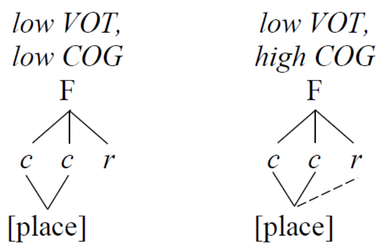


Using our simplified high-low dichotomy four VOT and COG, fortis plosives come in four varieties.

- When VOT is high, there are four subsegments; two marked as *closure*, and two marked as release.
- If COG is low, only the *closures* are specified for place.
- If COG is high, place spreads from the *closures* to at least the first *release*.



- When VOT is low, there are only three subsegments, as with the lenis plosives; two marked as *closure*, and one marked as *release*.
- If COG is low, the representation is the same as for lenis plosives in high VOT dialects.
    - In these varieties, the laryngeal distinction is phonologically maintained with voicing.
- If COG is high, place features spread from the *closures* to the *release*.



Summary

- On the basis of a large corpus of interview data, we found non-linear patterns of variation in the realization of plosives.
    - This variation is not limited to /t/, but applies to all fortis plosives.
- The phonetic variation in fortis plosives predicts phonological patterns for all plosives.
    - These suggest differences in phonological representation in the varieties.
    - This is supported by patterns of lenition seen in the data.

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Appendix: Statistical models

VOT model

Formula: VOT ~ informant gender + palatal release + vowel height +
vowel backness + vowel roundness + phonemic category + stress +
s(informant, by=stop, bs="re") +
s(longitude, latitude) +
s(longitude, latitude, by=stop),
discrete=TRUE, family="scat"

Output:

```
Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  33.6891     0.9361  35.988  < 2e-16 ***
gender=male  -0.4612     0.3276  -1.408    0.159
pal=pal       7.3407     0.5781  12.699  < 2e-16 ***
height=low   -2.3714     0.2354 -10.073  < 2e-16 ***
height=mid   -2.1695     0.2402  -9.033  < 2e-16 ***
back=nbk      2.0239     0.3431   5.899 3.73e-09 ***
rdness=rd     2.3670     0.3101   7.633 2.41e-14 ***
stop=b      -28.0786     0.8519 -32.960  < 2e-16 ***
stop=d      -23.3667     0.8734 -26.754  < 2e-16 ***
stop=g      -23.1501     0.8815 -26.261  < 2e-16 ***
stop=k        9.5132     1.0839   8.777  < 2e-16 ***
stop=t        9.0270     1.1530   7.829 5.21e-15 ***
str=str       2.4861     0.1816  13.688  < 2e-16 ***

Approximate significance of smooth terms:
                     edf Ref.df      F  p-value
s(long,lat)       16.490 19.646  4.228 7.20e-10 ***
s(long,lat):stopp  2.000  2.000  9.276 9.41e-05 ***
s(long,lat):stopb  4.145  5.238  1.198  0.30002
s(long,lat):stopd  2.001  2.002  2.240  0.10650
s(long,lat):stopg  5.178  6.278  1.369  0.22834
s(long,lat):stopk  3.844  3.988  3.994  0.00297 **
s(long,lat):stopt  2.539  2.572 11.319 1.31e-06 ***

Rank: 1492/1494
R-sq.(adj) =   0.66   Deviance explained =   58%
fREML =  30881  Scale est. = 1         n = 17504
```

Notes:

- Multiple likelihood ratio tests run using the *compareML()* function in *itsadug* found this to be the most parsimonious model. It's worth noting that backness*place and roundness*place interactions did not significantly improve the model fit, even though such interactions have previously been shown to influence VOT.

COG model

Formula: COG ~ informant gender + palatal release + vowel height +
vowel backness + vowel roundness + phonemic category + stress +
s(informant, by=stop, bs="re") +
s(vot) + s(vot, by=stop) +
s(longitude, latitude),
discrete=TRUE, family="scat"

Output:

```
Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  1827.68      65.58  27.870  < 2e-16 ***
gender=male  -227.91      54.60  -4.174 3.02e-05 ***
pal=pal       529.27      38.35  13.803  < 2e-16 ***
height=low   -273.26      18.21 -15.008  < 2e-16 ***
height=mid    -90.56      17.42  -5.198 2.06e-07 ***
back=nbk      278.96      25.00  11.158  < 2e-16 ***
round=rd     -283.22      24.08 -11.759  < 2e-16 ***
stop=k        182.37      53.36   3.418 0.000635 ***
stop=t       1321.45      72.02  18.349  < 2e-16 ***
stress=str    104.11      14.05   7.411 1.36e-13 ***

Approximate significance of smooth terms:
                edf Ref.df     F  p-value
s(vot)        2.553  3.457 5.270 0.000579 ***
s(vot):stopp  1.000  1.000 1.634 0.201146
s(vot):stopk  1.000  1.000 3.471 0.062428 .
s(vot):stopt  5.065  6.169 3.482 0.001585 **
s(long,lat)  16.401 17.112 6.116 1.47e-14 ***

Rank: 712/714
R-sq.(adj) =  0.677   Deviance explained = 60.1%
fREML =  17191  Scale est. = 1         n = 10031
```

Notes:

- Multiple likelihood ratio tests run using the *compareML()* function in *itsadug* found this to be the most parsimonious model. It’s worth noting that separate smooths for location by stop phonemic category did not significantly improve the model fit; the same is true for backness*place interaction.