Intervocalic voicing of Danish stops

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Overview

- What do we (think we) know about intervocalic voicing in Danish stops?
- Hypotheses
- Methods
- Results
- Discussion

Danish stops

- Danish has six stop phonemes /b d g p t k/
- Phonetically, in simple onset position,
  - /b d g/ are voiceless unaspirated [p t k]
  - They're sometimes transcribed [b̥ d̥ g̊] (e.g. Grønnum 1998) to indicate that they are voiceless but phonetically *lenis*
  - /p t k/ are voiceless aspirated [p^h t^h k^h]
  - They're sometimes transcribed [[$b̥^h$ $d̥^h$ $g̊^h$]] to indicate that they're also phonetically lenis
  - And /t/ is usually given as [t^s] to indicate strong, salient affrication

Intervocalic stop voicing

- There are few sources on intervocalic stop voicing in Danish, and most of them are brief mentions with no obvious empirical basis
  - Abrahams (1949) and Spore (1965) mention the phenomenon in books that are written in (sigh!) French
  - Fischer-Jørgensen (1954):

> These seem to be the only differences between the two groups of sounds. Both are completely voiceless after a pause and after a voiceless sound, and partly voiced by assimilation after a voiced sound (**B D G** are often completely voiced after a voiced sound).

Intervocalic stop voicing

- Fischer-Jørgensen (1980):

Medially before [ə] and the weak endings ig [ɪ] and ing [eŋ], as well as finally, only one set of stops is found, which is almost always pronounced as (very) weakly voiced [bdg] medially

- Keating et al. (1983):

Danish treats medial stops differently, with spirantization of the [+voice] stops and voicing of the [—voice] stops.

What do we (think we) know?

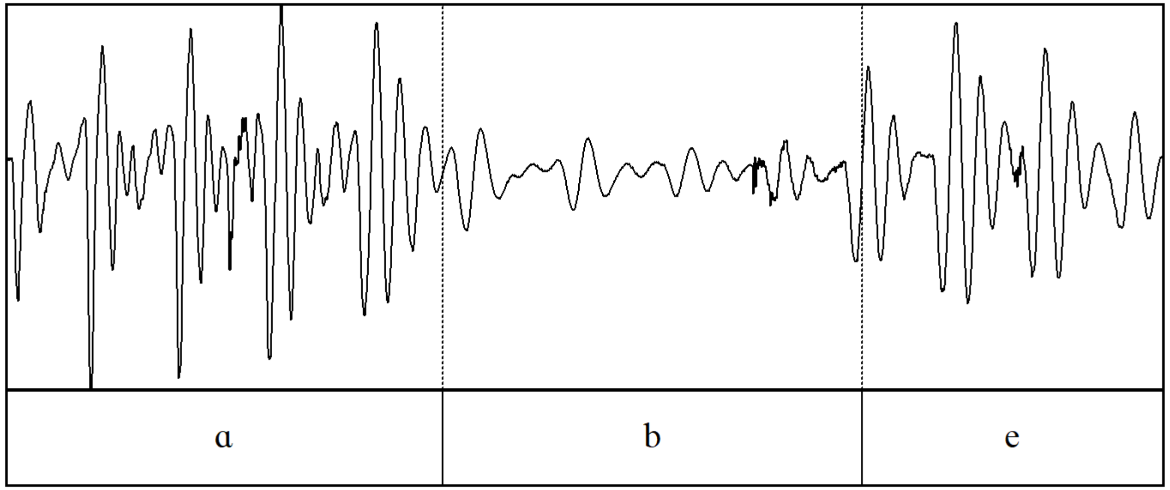
- /b d g/ are often voiced intervocalically
  - Maybe partially?
- Medial stops are voiced intervocalically, probably categorically
  - We understand medial as foot-internal
- /b d g ~ p t k/ differ only in aspiration, not relative muscle activity
  - No fortis-lenis distinction

What do we want to find out?

- RQ1 How often are stops voiced intervocalically?
- RQ2 Are /b d g/ voiced more often than /p t k/?
  - The literature only mentions /b d g/, but if there is no fortis-lenis distinction, there is no a priori reason to assume that closure voicing is more prevalent for /b d g/
  - Voicing is difficult to maintain during closure, and the closure is shortest for /p t k/ (Fischer-Jørgensen 1954, Puggaard et al. 2019).
  - All else being equal, this would suggest more voicing for /p t k/.
- RQ3 Which phonetic and extraphonetic factors influence intervocalic stop voicing?

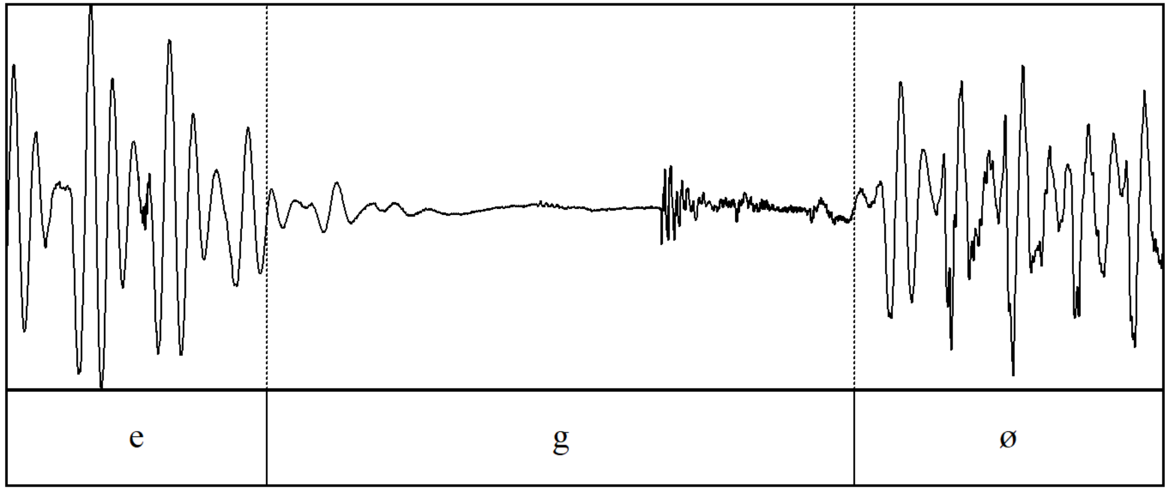
How do we test it?

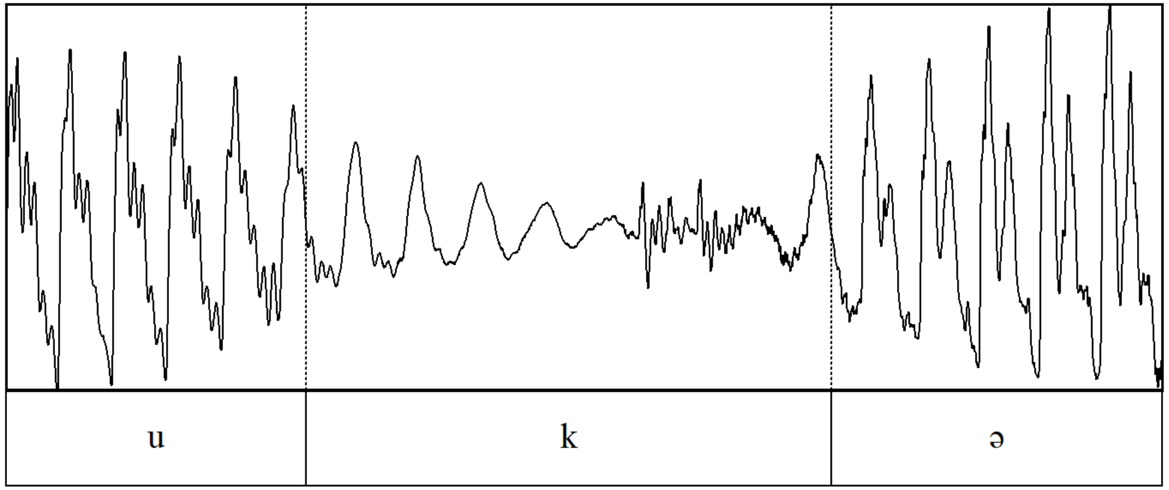
- Using the DanPASS corpus (Grønnum 2009, 2016)
  - 171 minutes of spontaneous monologues recorded in 1996
- We used a Praat script to isolate intervocalic stops (by Dirk Jan Vet)
  - Intervocalic: flanked by either vowels or glides
- Each stopped marked as *either fully voiced or not* based on visual inspection
  - This is admittedly a huge simplification! There's a lot of potential variation between a [b] and a [p]



<fr**a be**ˈgynˀdelsen>

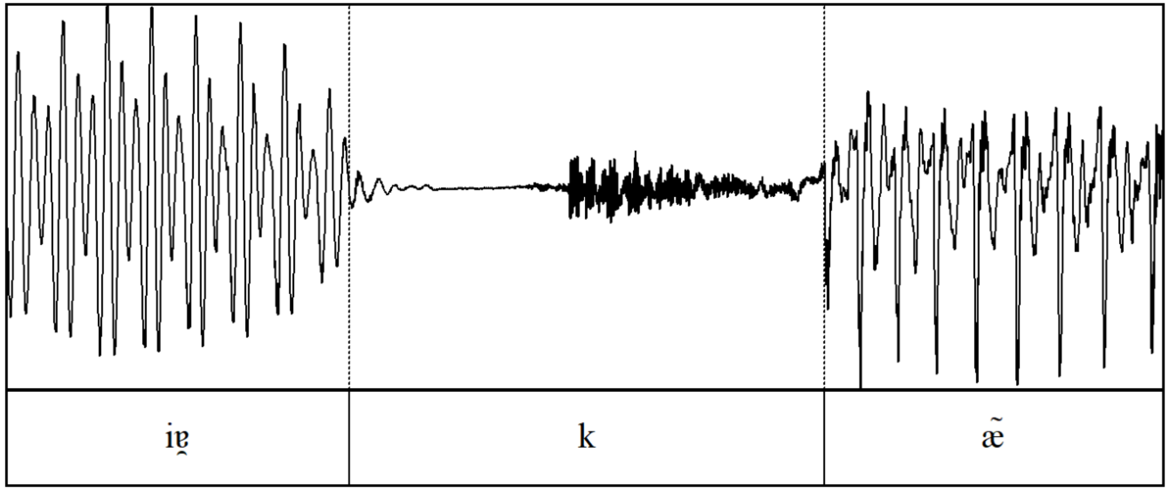
<fra b**e**ˈ**gy**nˀdelsen>





<d**u ka**n>

<ˈ**firka**nˀt>



How do we test it?

- This gives a total of 3,744 intervocalic stops

Phoneme	Number
/b/	189
/d/	1,278
/g/	752
/p/	327
/t/	431
/k/	767

Potential predictors

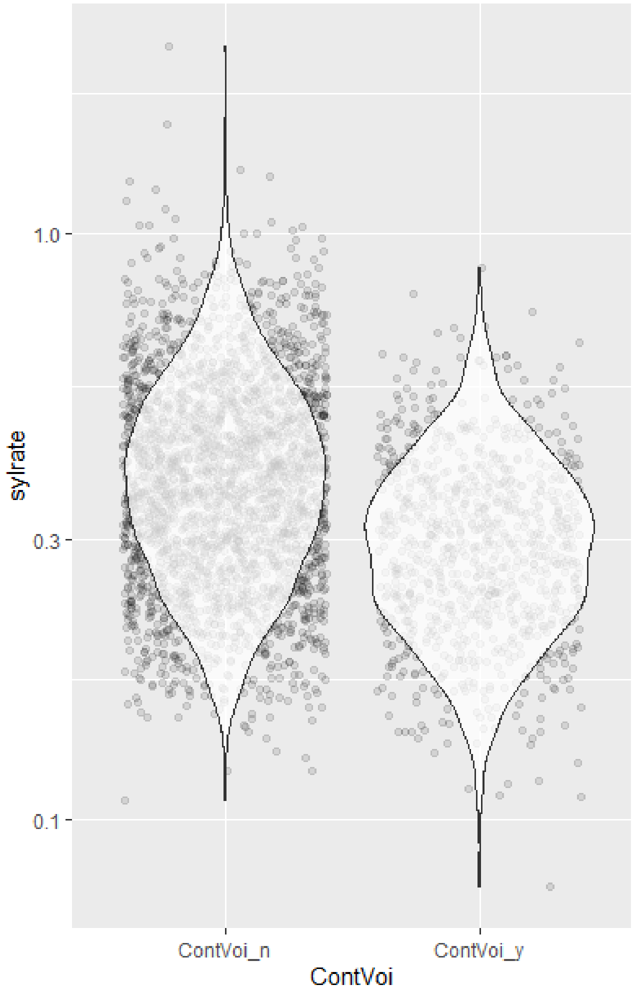
Variable	Predicted likelihood of voicing	Notes
Phonological laryngeal setting	**”unaspirated” > ”aspirated”**	
Place of articulation	**bilabial > alveolar > velar**	**strongest effect for velar stops**
Stress	unstressed > stressed	
Preceding stress	stressed > unstressed	
Adjacent stød	decreased	strongest effect preceding the stop
Adjacent approximant	decreased	
Adjacent high vowel	decreased	strongest effect preceding the stop
Adjacent central vowel	increased	
Morphological boundary	**internal > inflectional > derivational > compound > word**	
Word class type	closed > open	
Local lexical frequency	increases with frequency	
Local speech rate	**increases with speech rate**	
Lexical item	random	
Task	random	
Gender	men > women	
Age	decreases with age	
Individual speaker	random	

The data at face value

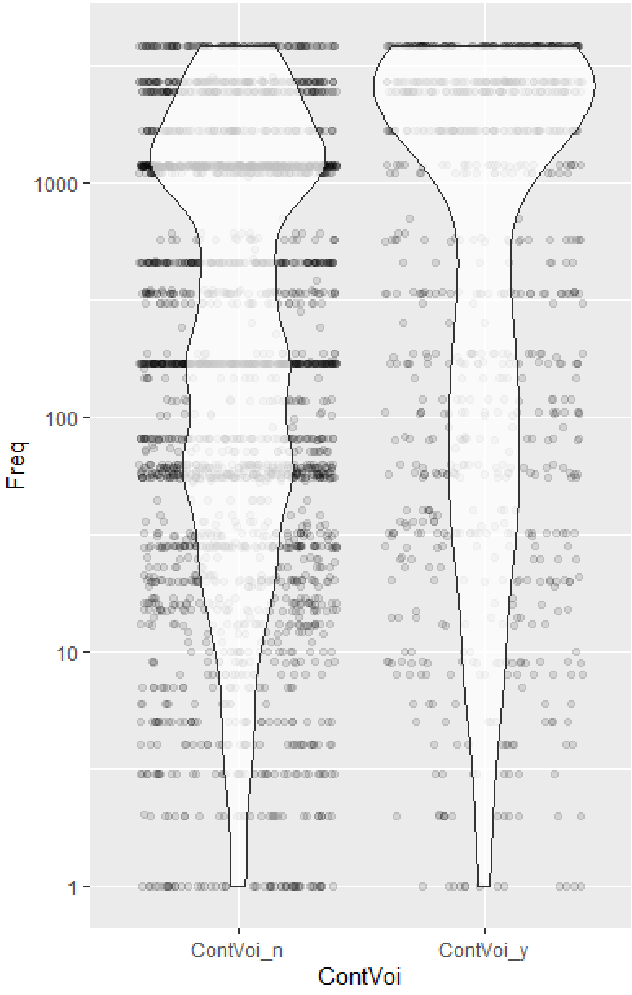
Variable	Correlation	Direction
Phonological laryngeal setting	√	**"unaspirated" (38%) > "aspirated" (5%)**
Place of articulation	💩	**alveolar (36%) > bilabial (17%) > velar (15%)**
Stress	√	absent (26%) > present (21%)
Preceding stress	☹	absent (25%) > present (23%)
Stød	√	absent (26%) > present (17%)
Preceding stød	√	**absent (25%) > present (6%)**
Preceding approximant	√	absent (26%) > present (17%)
High vowel	💩	present (30%) > absent (22%)
Preceding high vowel	☹	absent (25%) > present (22%)
Central vowel	√	present (44%) > absent (22%)
Preceding central vowel	💩	absent (26%) > present (22%)
Morphological boundary	💩	**inflectional (69%) > derivational (39%) > internal (36%) > word (25%) > compound (10%)**
Word class type	√	closed (31%) > open (19%)
Gender	√	male (26%) > female (21%)

The data at face value

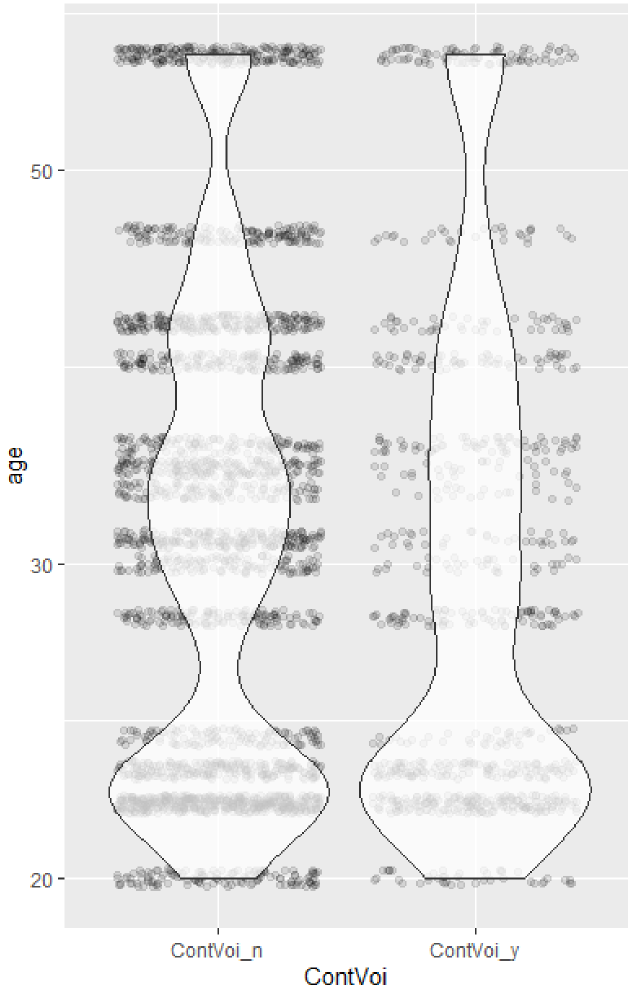
Speech rate



Lexical frequency



Age



Statistics

- Because of the large number of (mostly binary) categorical predictors, we tried our hand at multiple correspondence analysis
  - Which is a form of principal component analysis
  - We did not end up using this, because our predictors were much less correlated than we thought
- In the end, we use logistic mixed effects regression with categorical predictors coded as orthogonal contrasts

Statistics

- We selected the most parsimonious model by
  - Trying out a number of random effects structures
  - Using the R function `multcomp::mixed` to test which individual predictors significantly improved model fit
- The final model looks like this:

```
lme4::glmer(voicing ~ phonological category + place + stress +
            preceding stress + stød + preceding stød +
            morphological boundary + log(frequency) +
            log(speech rate) + log(age) +
            (vowel centrality | speaker),
            family = binomial(link="logit"),
            control=glmerControl(optimizer="bobyqa"))
```

Statistical results

Variable	Estimate	SE	z	p		
(intercept)	-1.96	1.68	-1.17	0.243		
***Phonological laryngeal setting*, -"asp." +"unasp."**	**2.69**	**0.16**	**16.93**	**<.001**	***	√
***Place of articulation*, -alveolar, bilabial +velar**	**-1.24**	**0.14**	**-9.04**	**<.001**	***	√
***Place of articulation*, -bilabial, +alveolar**	**0.00**	**0.19**	**0.02**	**0.982**		(√)
Stress	-0.72	0.14	-5.16	<.001	***	√
Preceding stress	0.75	0.13	5.87	<.001	***	√
Stød	0.78	0.17	4.66	0.003	***	💩
Preceding stød	**-1.94**	**0.43**	**-4.49**	**<.001**	***	√
***Morphological boundary*, +internal**	**1.27**	**0.43**	**2.96**	**0.003**	**	√
***Morphological boundary*, -word**	**-1.00**	**0.21**	**-4.72**	**0.001**	***	√
***Morphological boundary*, -internal, +inflectional**	**1.99**	**0.53**	**3.80**	**0.001**	***	💩
***Morphological boundary*, -derivational, +compound**	**0.39**	**0.34**	**1.15**	**0.249**		☹
Local lexical frequency (log)	0.15	0.03	4.84	<.001	***	√
Local speech rate (log)	**-2.34**	**0.16**	**-14.84**	**<.001**	***	√
Age (log)	-1.00	0.49	-2.05	0.041	*	√

Discussion: RQ3

- As expected, a large number of phonetic and extraphonetic factors influence voicing
  - Phonological laryngeal setting, place of articulation, adjacent stress, adjacent stød, morphological boundary, speech rate, lexical frequency, age
- You can’t necessarily trust correlation at face value!
  - Some correlations disappear or even reverse when controlling for other factors
  - Ex. 1: At face value, alveolars seemed to be voiced at a much higher rate than other POAs. This effect disappears when lexical frequency is taken into account.
  - Ex.2: At face value, men seem to have more voiced stops than women. This effect disappears when the speaker is modeled as a random effect.

Discussion RQ1+RQ2

- In the spontaneous speech of the DanPASS corpus, around 25% of intervocalic stops are voiced throughout
- ~40% of /b d g/ are voiced, 5% of /p t k/ are voiced
  - ~40% is surprisingly low for /b d g/, given the literature
  - The discrepancy between the two sets suggests a difference beyond just aspirated release
  - Westbury (1983) suggests that post-vocalic voicing should continue “automatically” for 60ms during a bilabial closure unless actively inhibited

➢ *This suggests a phonological mechanism that actively inhibits voicing for all Danish stops – but more so for /p t k/!*

  ➢ Perhaps we should reconsider whether Danish stops have a fortis/lenis distinction?

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Tak for jeres opmærksomhed!

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