Varying sibilant articulation and s-retraction in Manchester English

All paths lead to [ʃ]

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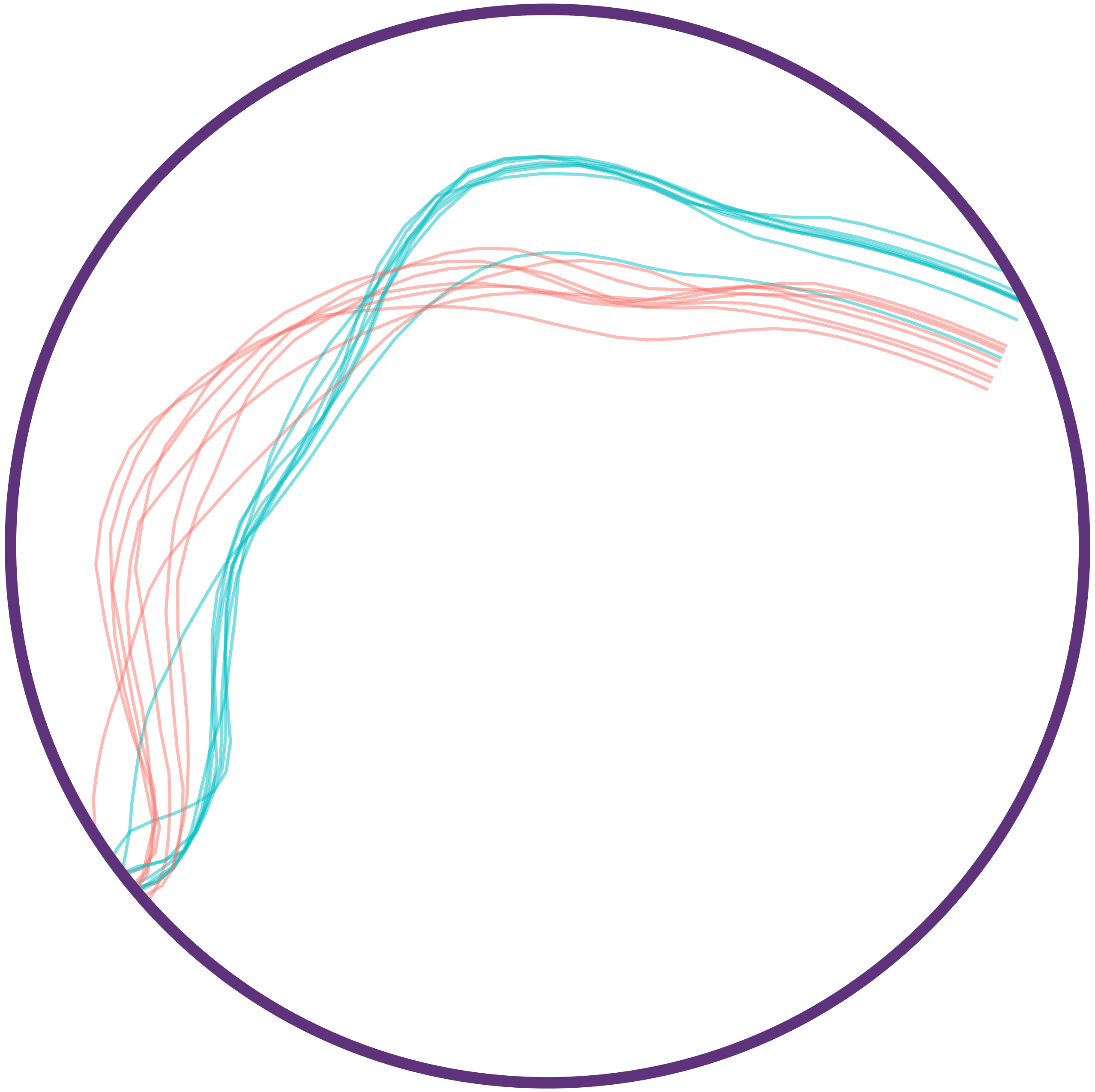
This talk

The acoustics and articulation

of *s*-retraction



WHAT IS *S*-RETRACTION?

A process which turns **/s/** into a more **[ʃ]**-like sound

“Retraction” of the place of articulation from **alveolar** to **post-alveolar**

↓ ↓

/stɹ/ e.g. *strewn*

/stj/ e.g. *student*

PREVIOUS STUDIES

- Has recently been subject to a large-scale, cross-dialectal corpus study by Stuart-Smith et al. (2018)
- Attested throughout the **US** (Labov 1984, Shapiro 1995, Phillips 2001, Durian 2007, Mielke et al. 2010, Baker et al. 2011, Gylfadottir 2015, Phillips 2016, Wilbanks 2017)
- As well as **New Zealand** (Lawrence 2000)
- And the **UK** (Altendorf 2003, Bass 2009, Sollgan 2013, Glain 2014, Wilson 2018)
- However, mainly in American English and (as a result) mainly on **/stɹ/**
  - British English has **/stj/**, absent in AmE, which is severely under-studied

Previous studies

- Quite often the focus has been on the sociolinguistic profile of this change
- Relatively less work on the phonetic realisation
  - Some studies have adopted a binary classification (Janda & Joseph 2003, Bass 2009)
  - Rutter (2011) reports that a majority of retracted forms fall within a speaker's normal range for **[ʃ]**, with only limited evidence of intermediate forms
  - But Labov (2001) argues that there are 4 variants differing in how **[ʃ]**-like they are
- Has been characterised as **retraction**, based primarily on acoustic data
  - Notable exceptions are ultrasound studies by Mielke et al. (2010) and Baker et al. (2011)
- However, acoustics doesn't always have a one-to-one mapping with articulation
  - See e.g. Mielke et al. 2016 on **covert articulation** of **/ɹ/**

Phonetic motivations

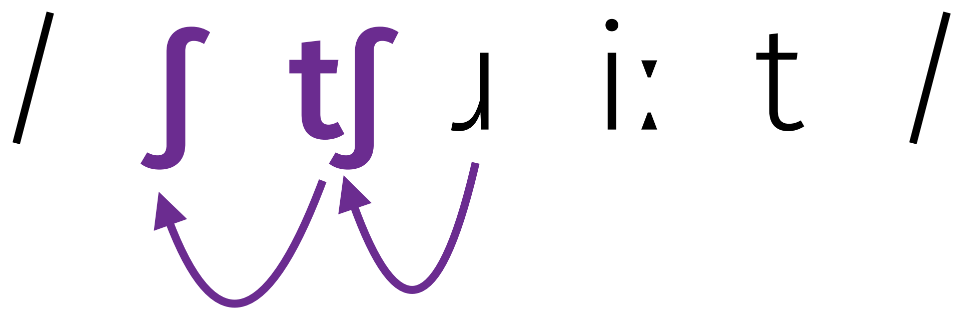
- The rôle of **/ɹ/** has been foregrounded in many studies:
  - Shapiro (1995) claims *s*-retraction is triggered **non-locally** by **/ɹ/** based on the fact that **/s/** doesn't retract in **/st/** clusters, e.g. *steep*

/ ʃ t ɹ iː t /

  - Baker et al. (2011) find that even "non-retractors" show coarticulatory bias towards retraction in clusters containing **/ɹ/**, e.g. **/spɹ/**
  - Relationship between degree of palato-alveolar constriction in retracted **/s/** and bunched **/ɹ/**
  - They also argue that individual differences in this coarticulatory bias provide a solution to the actuation problem
    - see also Stevens & Harrington (2016) for more work on the possible phonetic origins
  - Sollgan (2013) also shows that, in Edinburgh, alveolar realisations of **/ɹ/** rarely co-occur with retracted **/s/**

Phonetic motivations

- However, others have argued that **/ɹ/**'s influence may be more indirect:
  - Lawrence (2000) claims that this is local assimilation with **/ɹ/** causing affrication of **/t/** to **/tʃ/** leading to *s*-retraction

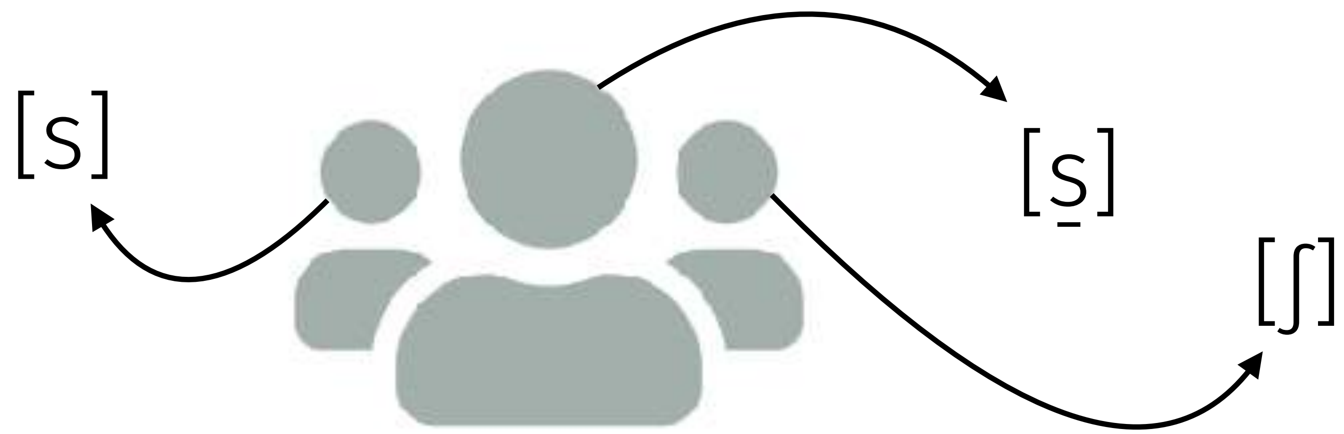


- Pre-**/ɹ/** affrication of **/t/** is a widespread process throughout varieties of English (Cruttenden 2014:189-92; see also Magloughlin 2018 and references therein)
- Children spelling *try* as CHRIE, *dragon* as JRAGIN (O'Neil 2013:222)
  - This could be particularly appropriate for BrE, where **/t/** undergoes a similar process before **/j/** for most speakers.
    - e.g. *tune* /tjʉːn/ > [tʃʉːn]   *stupid* /stjʉːpɪd/ > [ʃtʃʉːpɪd]?
  - Though, for Raleigh English, Magloughlin & Wilbanks (2016) report no correlation between affrication rate and retraction rate

RESEARCH QUESTIONS

1. What is the exact phonetic nature of this process in BrE? Is the surface realisation of **/s/** in these contexts identical to an underlying **/ʃ/**?

1a. Is the magnitude of retraction subject to inter-speaker variation?



2. Which of the two competing accounts of the triggering mechanisms finds the most empirical support in BrE, and what does this mean for the locality of this process and the proposals regarding its actuation?

3. What is the exact articulatory mechanism of s-retraction and how does this map onto the acoustic signal?

Research questions

These research questions will be addressed using complementary methods of data collection:

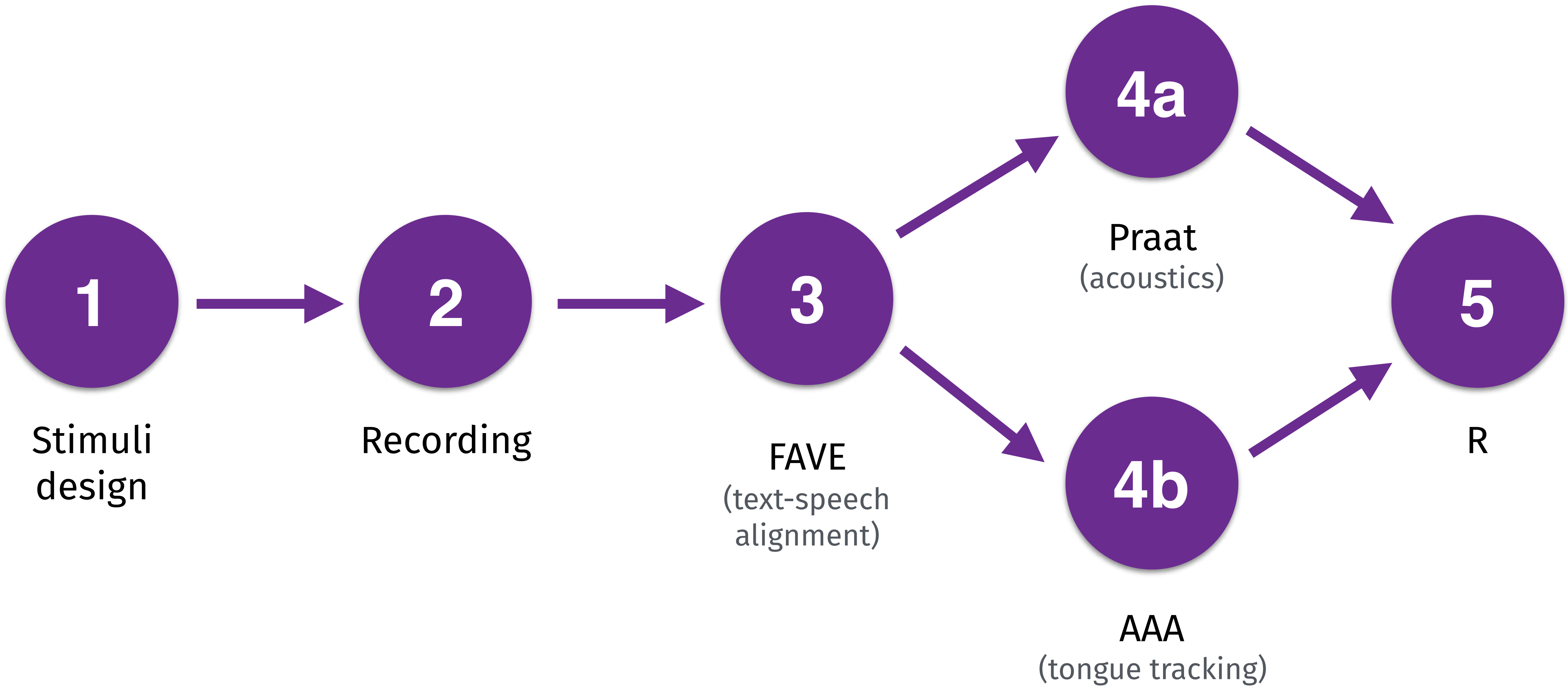
acoustic

and

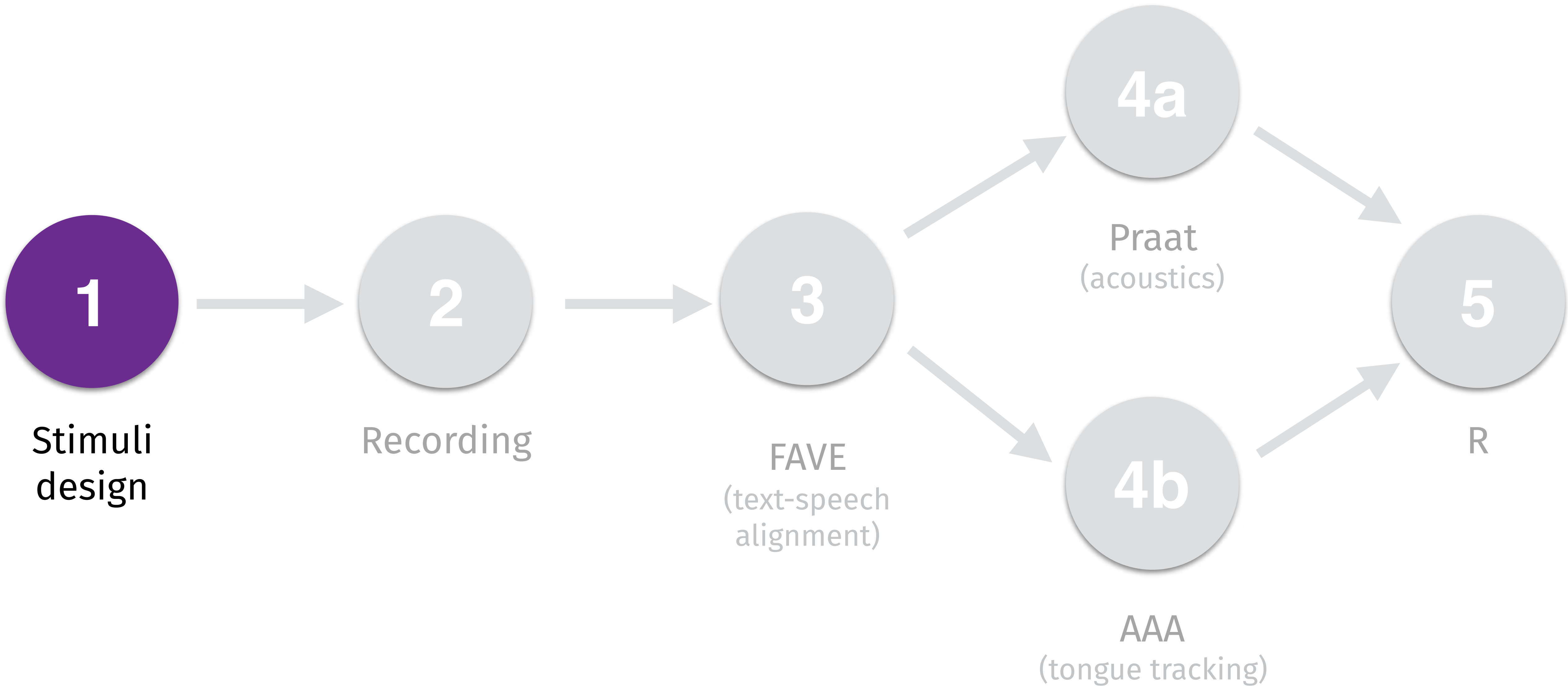
articulatory (UTI)

METHODOLOGY

Workflow


1
Stimuli
design
2
Recording
3
FAVE
(text-speech
alignment)
4a
Praat
(acoustics)
4b
AAA
(tongue tracking)
5
R

Workflow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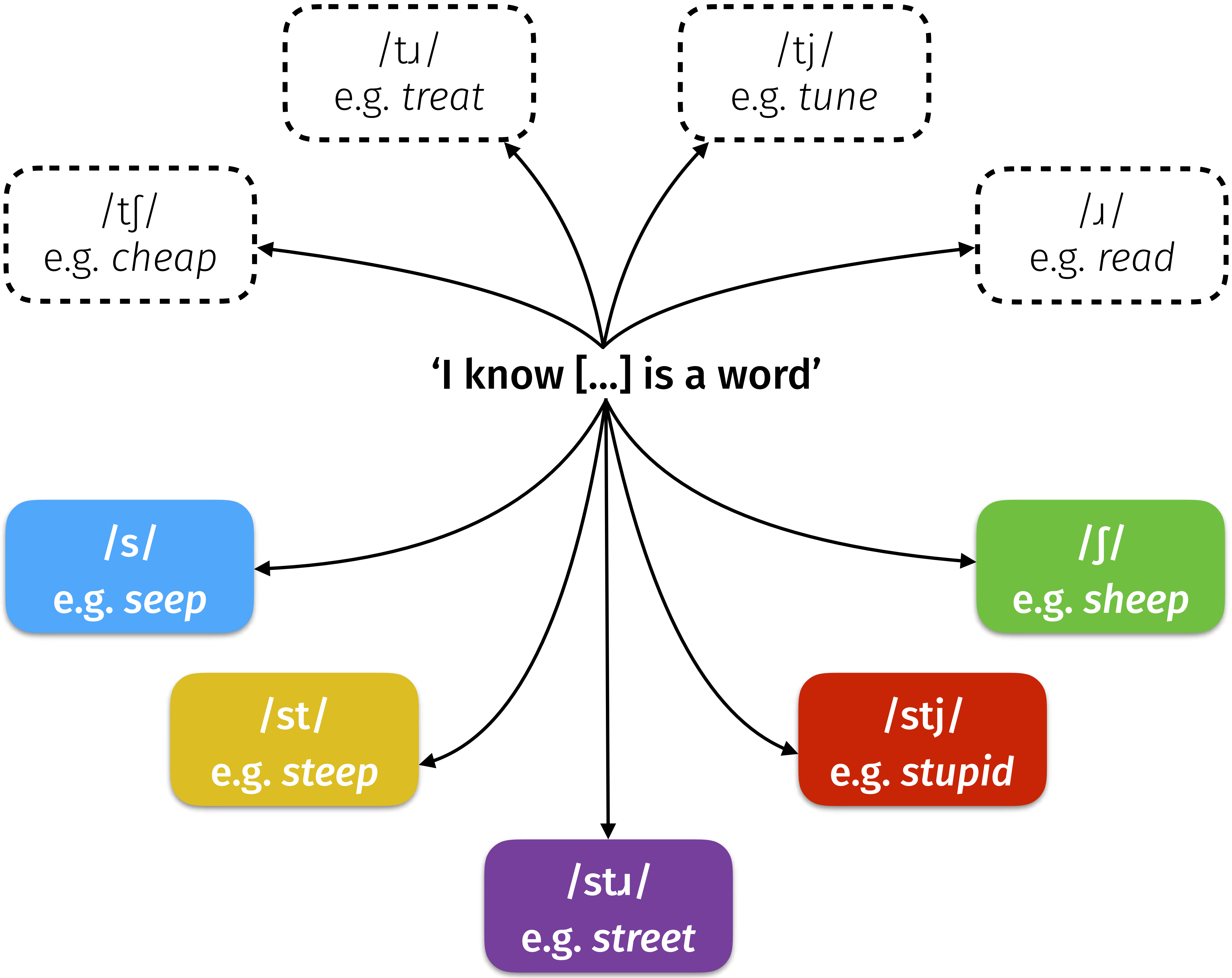
Stimuli

- Various word-initial contexts embedded in a carrier sentence

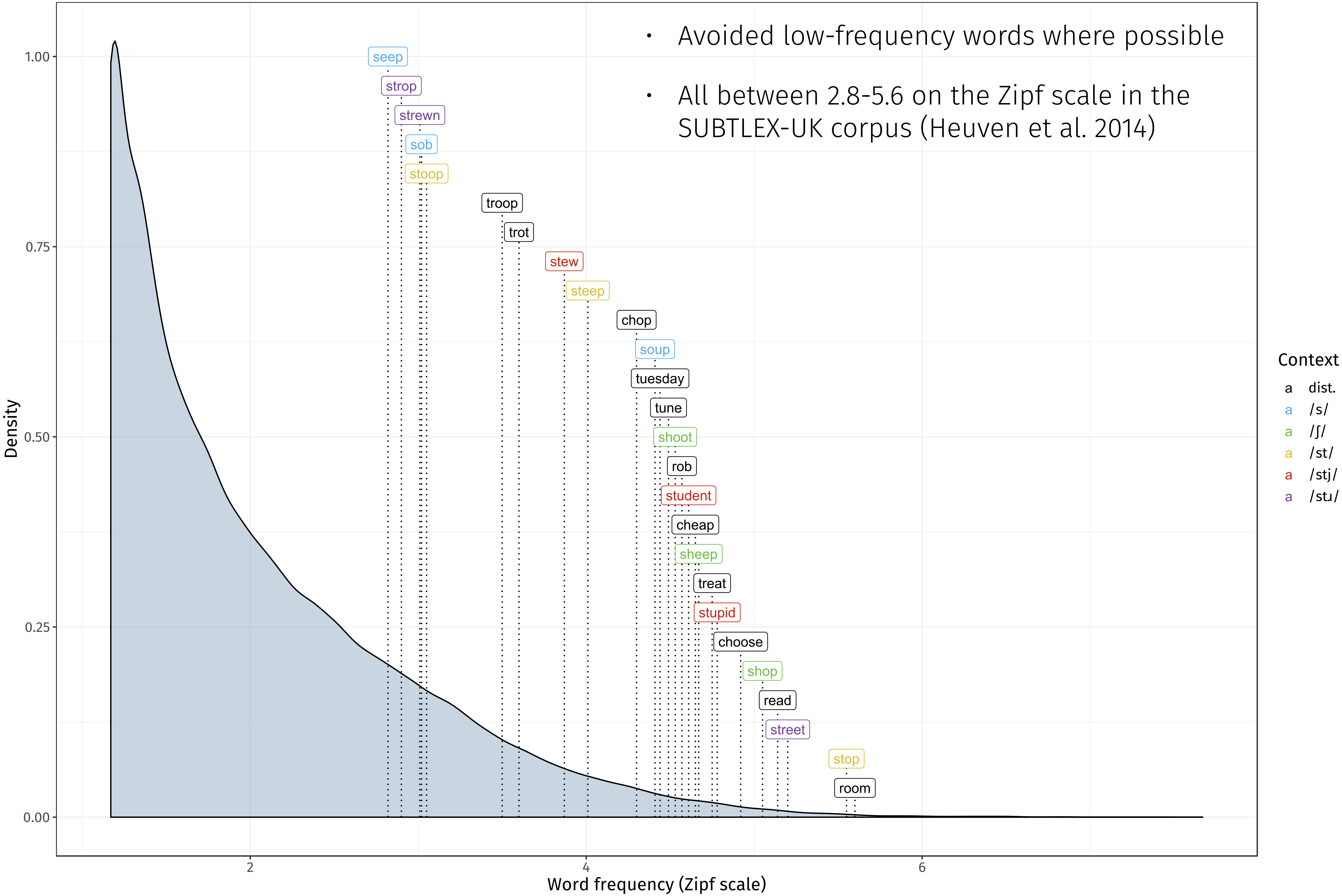


Stimuli

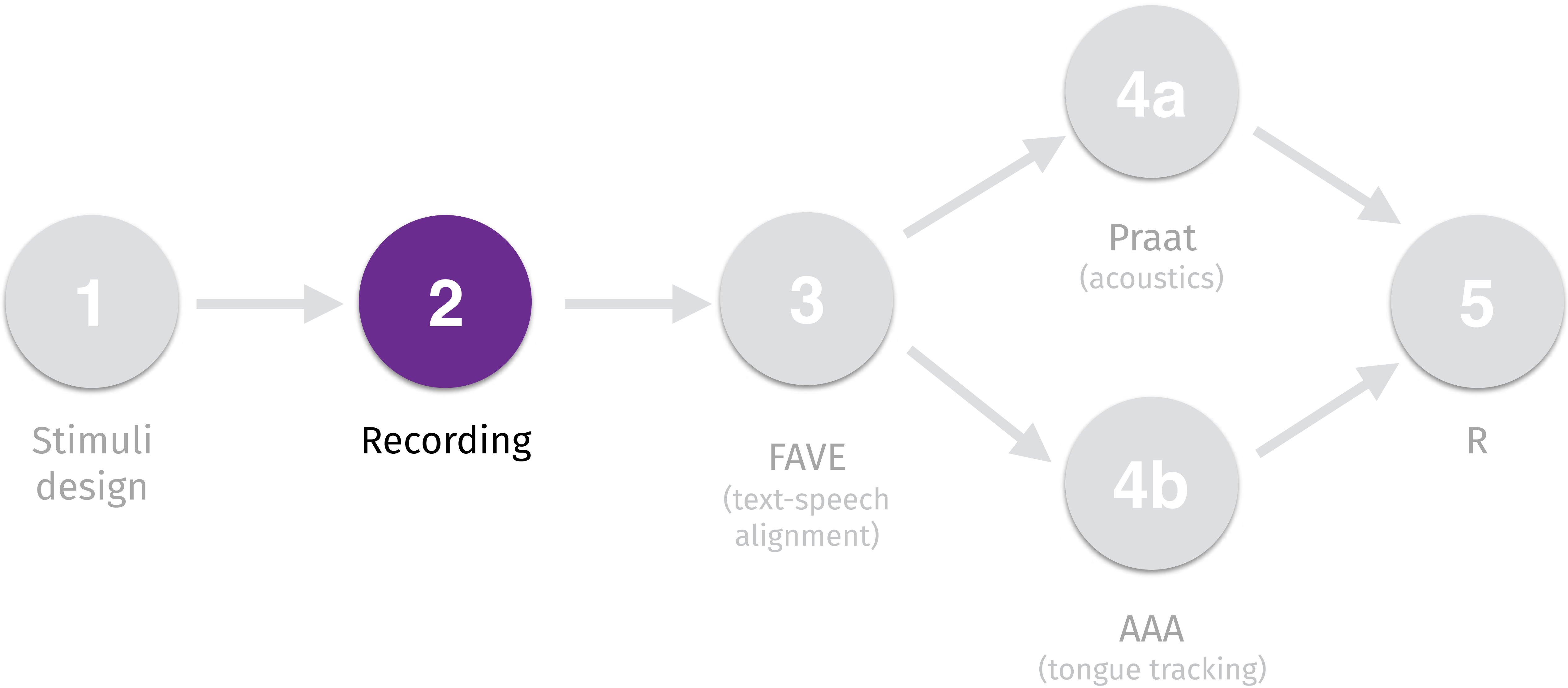
- 5 repetitions per token (130 sentences in total)
- Different randomised order for each speaker
- All monosyllabic (except from *student*, *stupid*)
- Controlled for following vowel
  - **[iː]**, **[ɒ]**, **[ʉː]** (except from **/stj/** tokens, which only occur before **[ʉː]**)

Stimuli

- Avoided low-frequency words where possible
- All between 2.8-5.6 on the Zipf scale in the SUBTLEX-UK corpus (Heuven et al. 2014)



Workflow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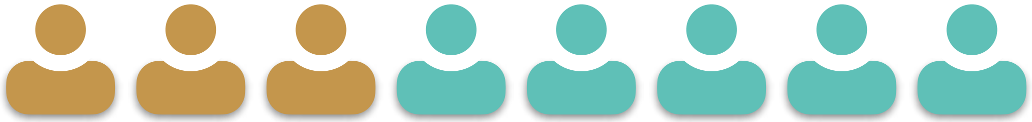
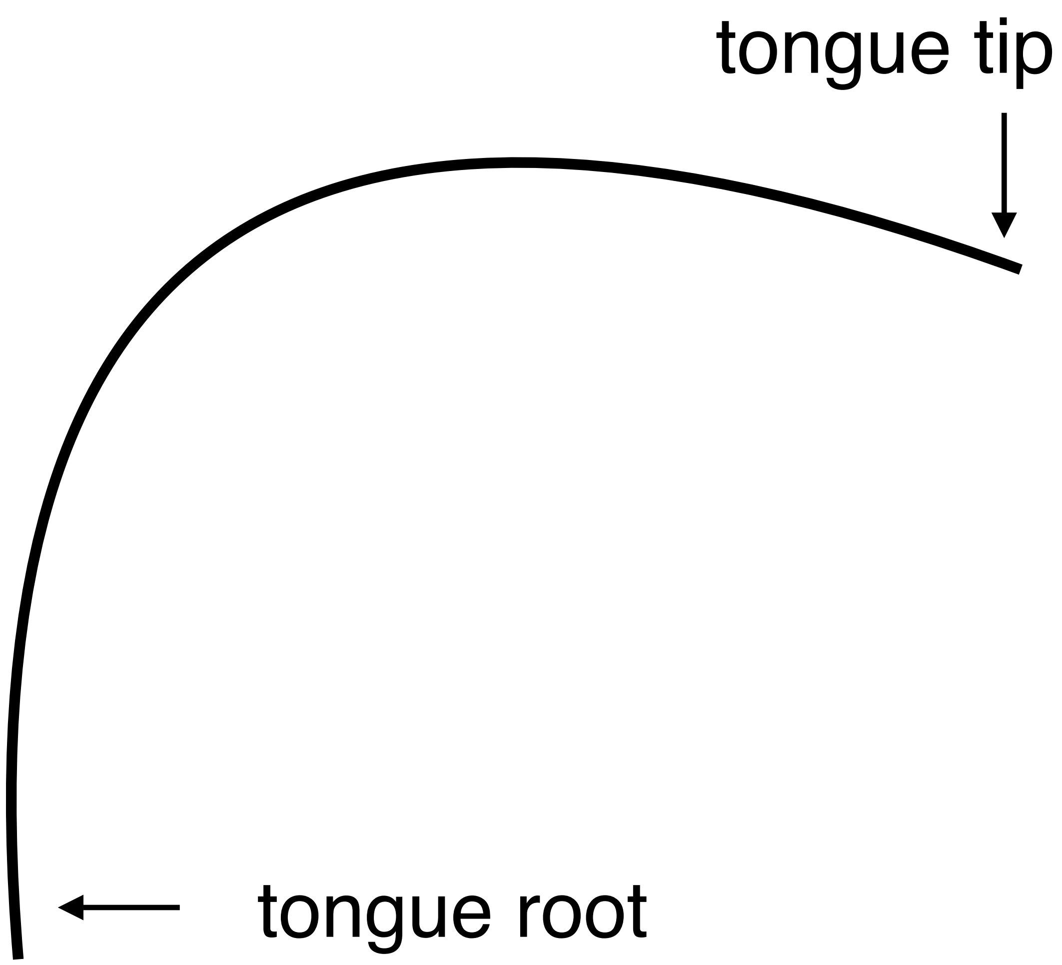
Recording

- Synchronised UTI (60fps) and audio recording (lavalier mic)
- Mid-sagittal view
- Stabilised with headcage
- Currently 8 speakers (3M; 5F) aged 18-26



  - All born (or at least raised from age 4) in Greater Manchester
    - but in some cases parents aren't from Manchester (or even England)



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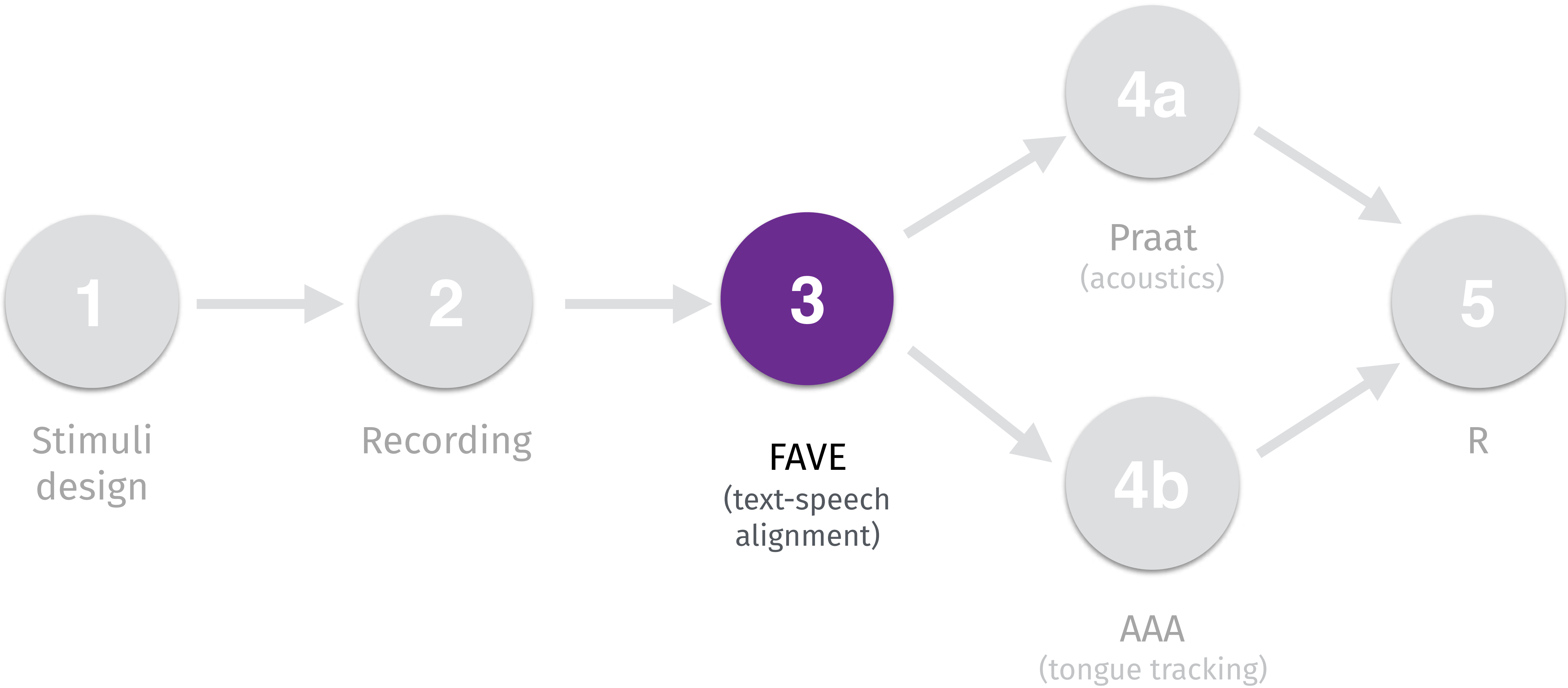
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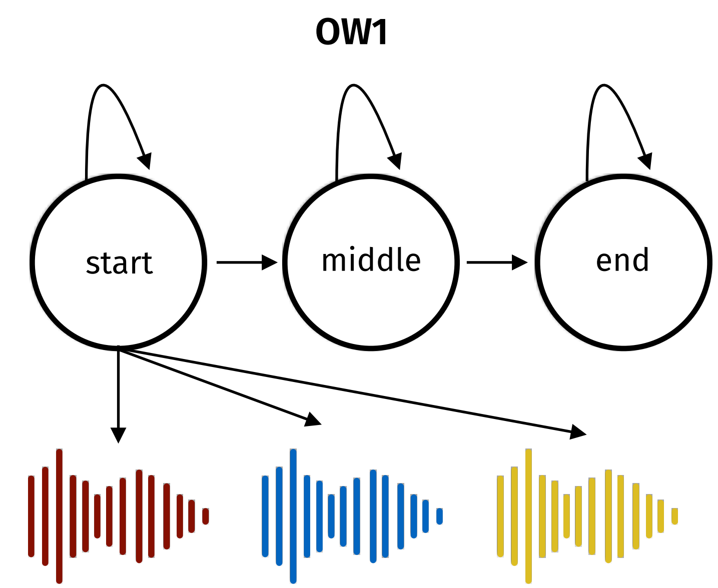
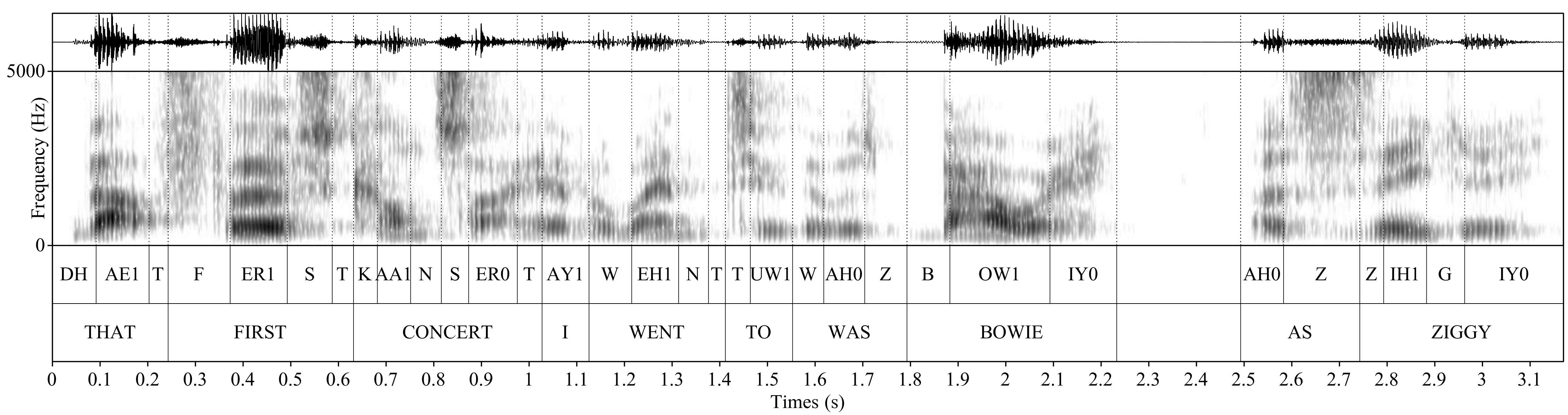
FAVE (Rosenfelder et al. 2011)

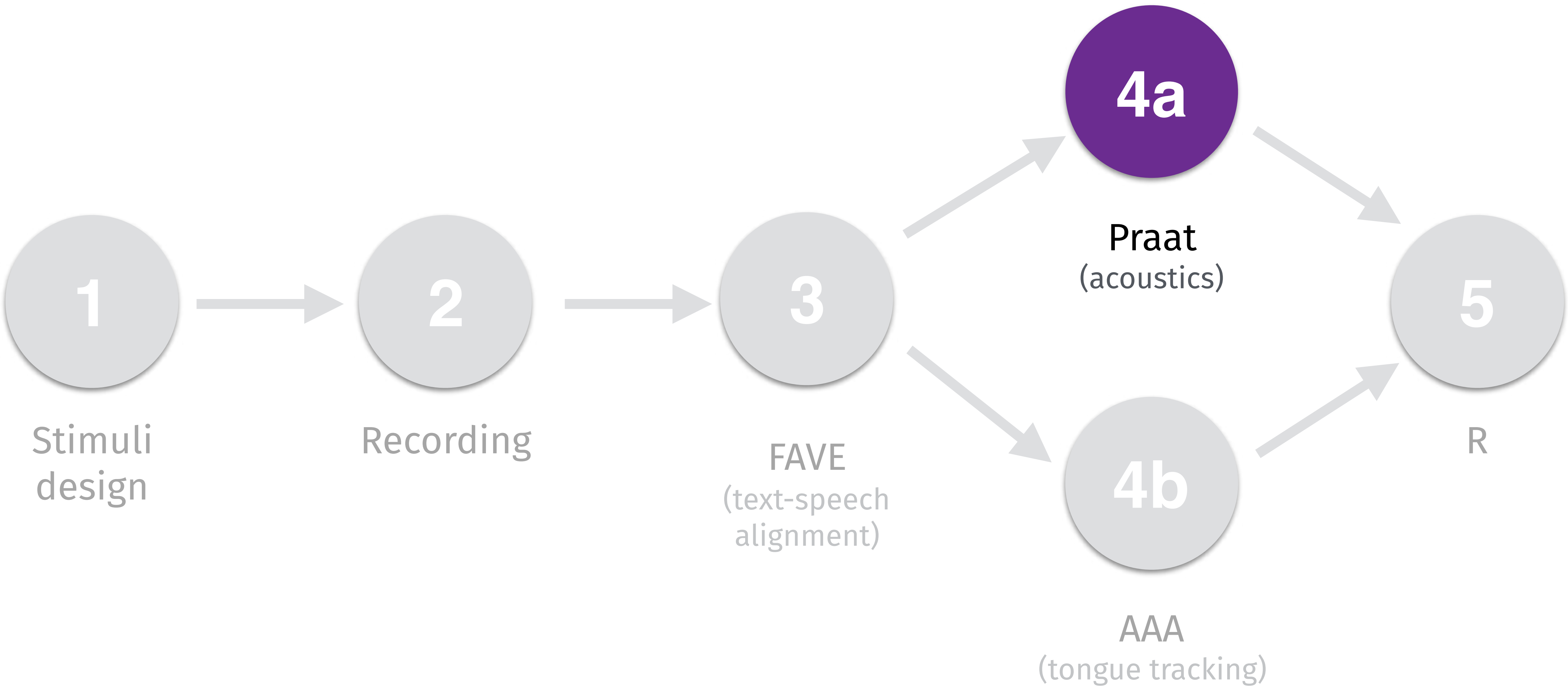
...that first concert I went to was **Bowie** as Ziggy...

word	transcription
	...
BOVINE	B OW1 V AY2 N
BOWIE	**B OW1 IY0**
BOWING	B AW1 IH0 NG
BOWING	B OW1 IH0 NG
BOWL	B OW1 L
	...





Workflow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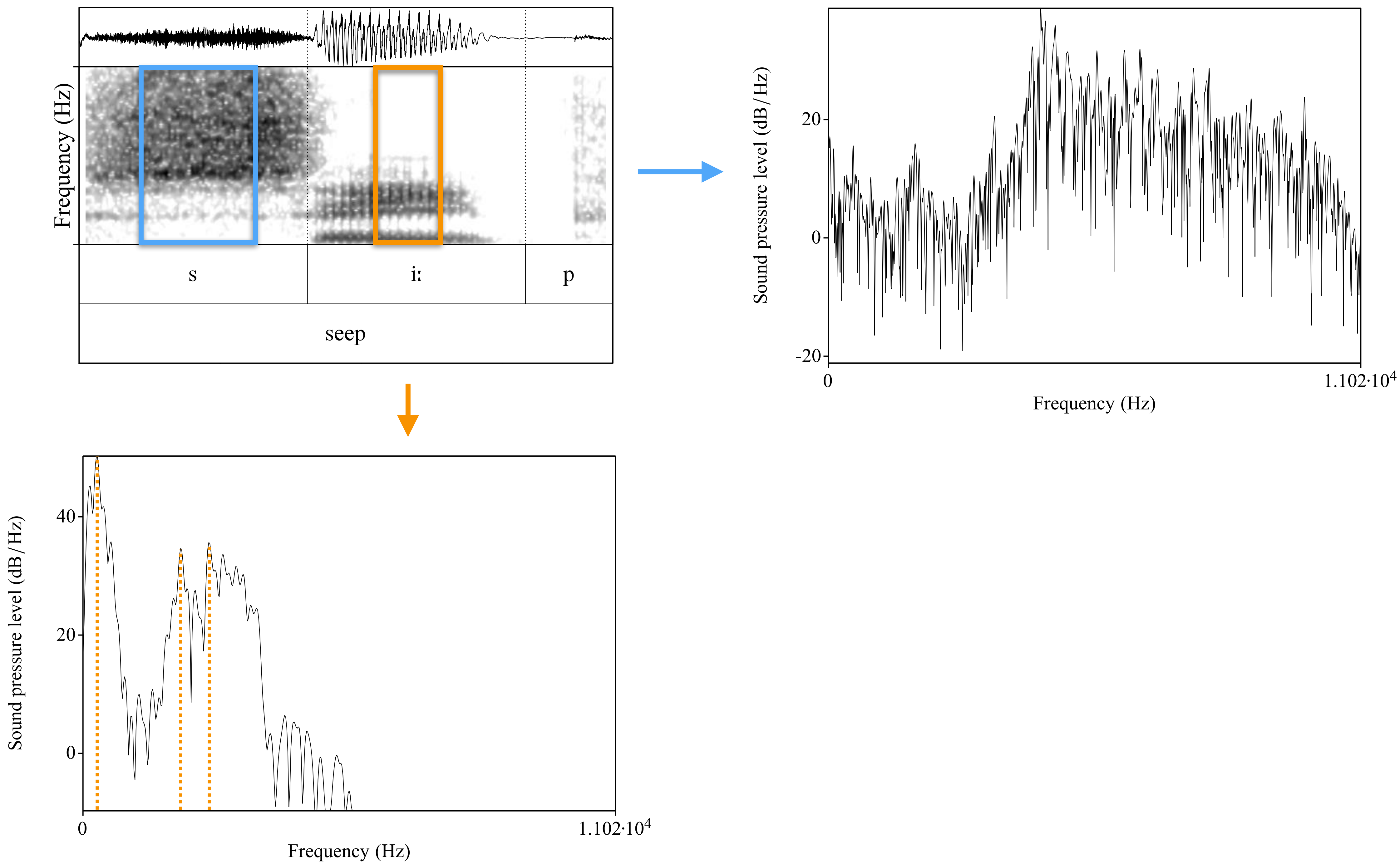
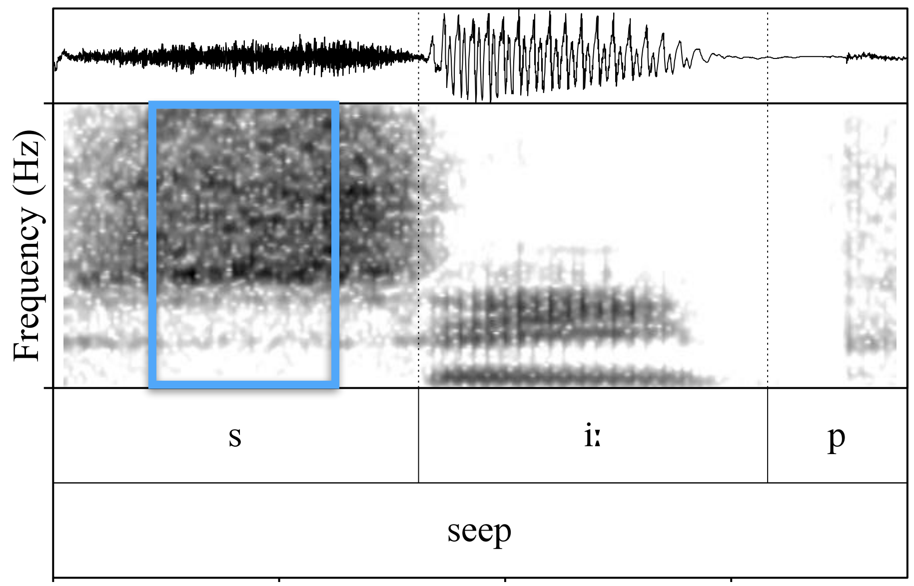
ACOUSTIC DATA ANALYSIS

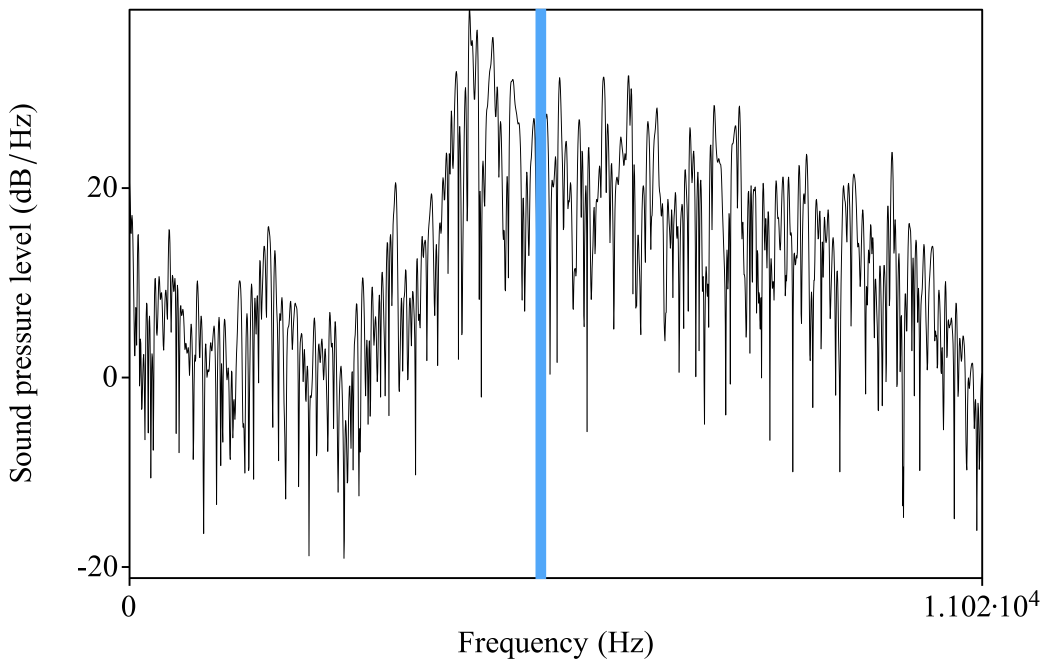
- For each fricative, we extract a “spectral slice” using a Praat script (DiCanio 2017):



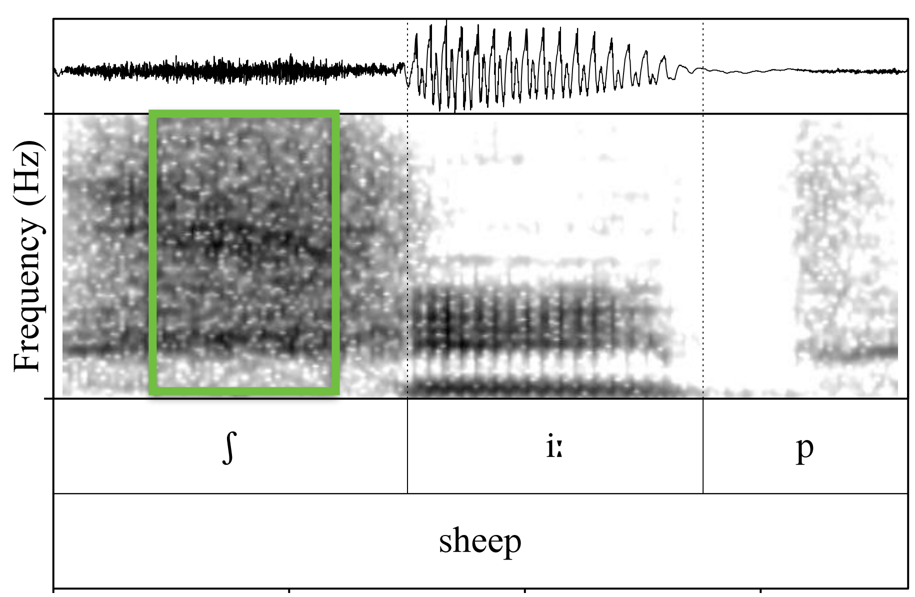
ACOUSTIC DATA ANALYSIS

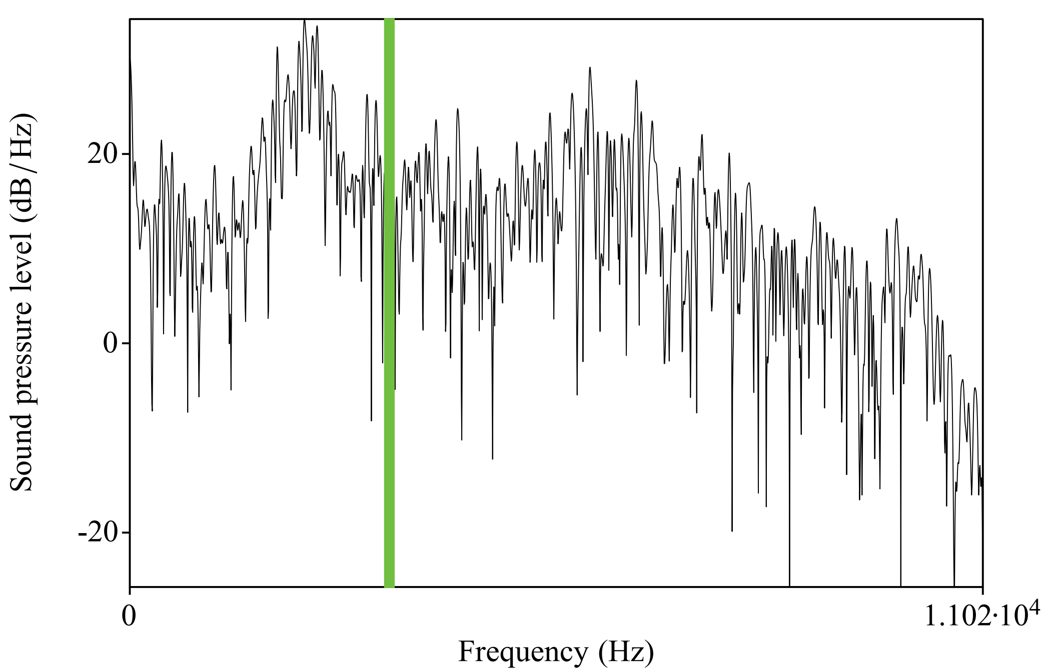
- For each fricative, we extract a "spectral slice" using a Praat script (DiCanio 2017):
  - Then calculate the **centre of gravity** (CoG) - a single-point spectral mean, where higher values are more **/s/**-like, and lower values are more **/ʃ/**-like (Jongman et al. 2000)





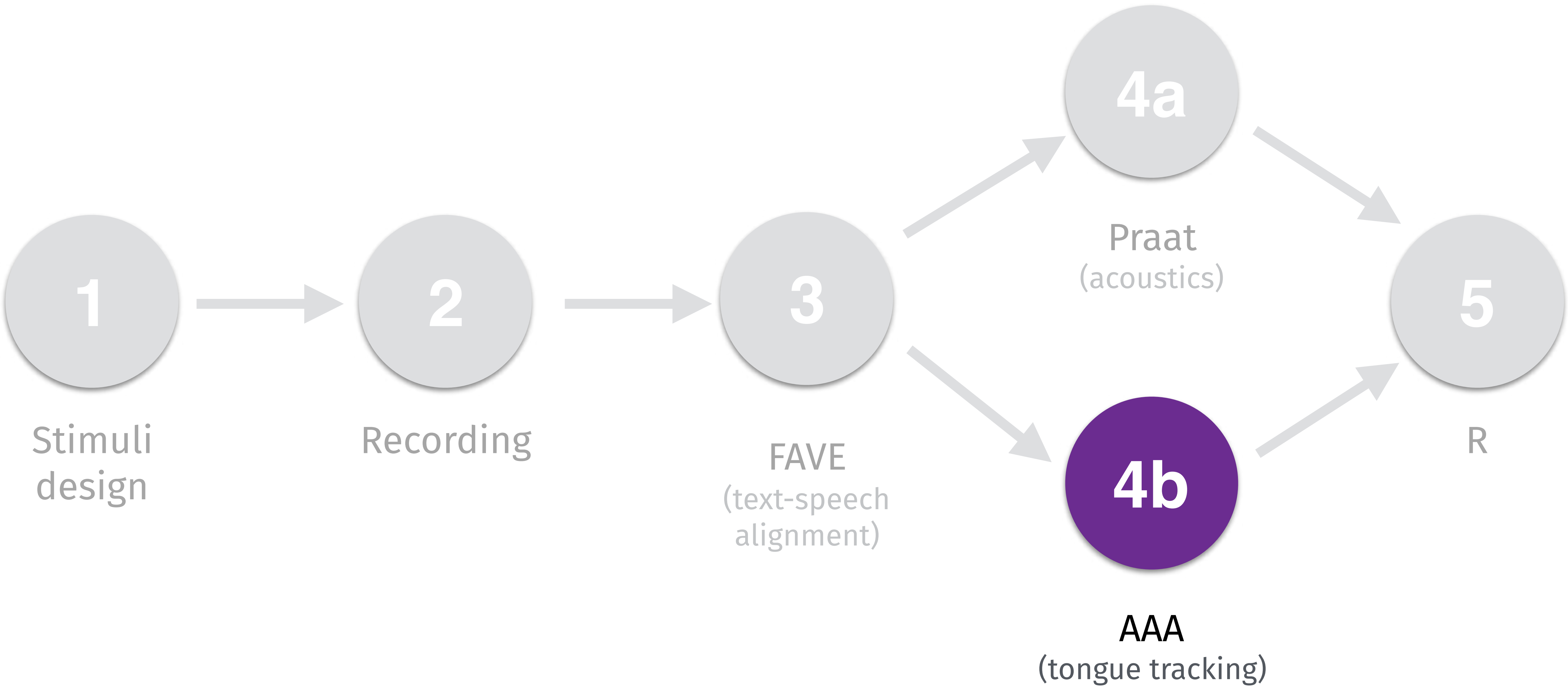
/s/ CoG: 5358Hz





/ʃ/ CoG: 3307Hz

Workflow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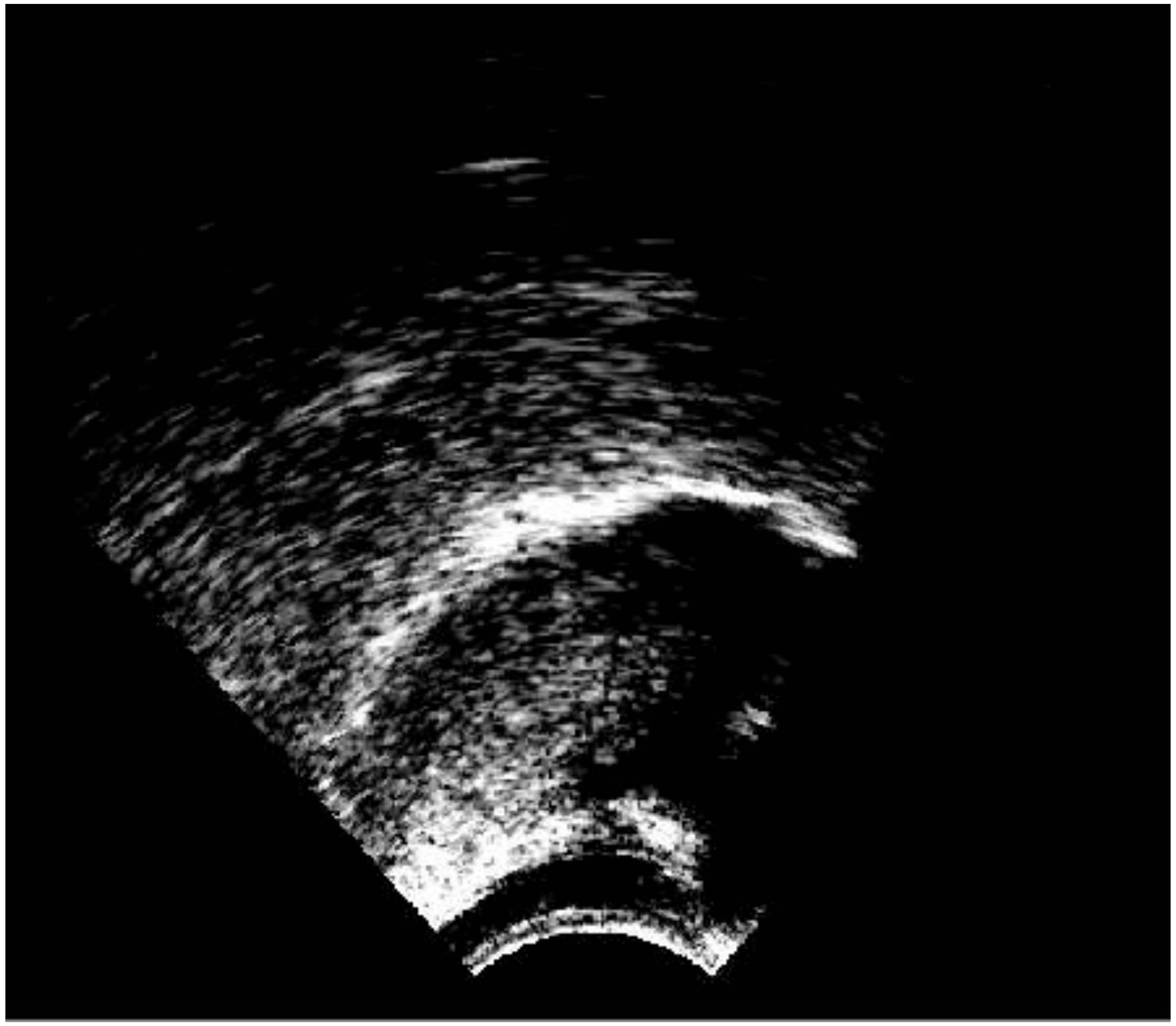
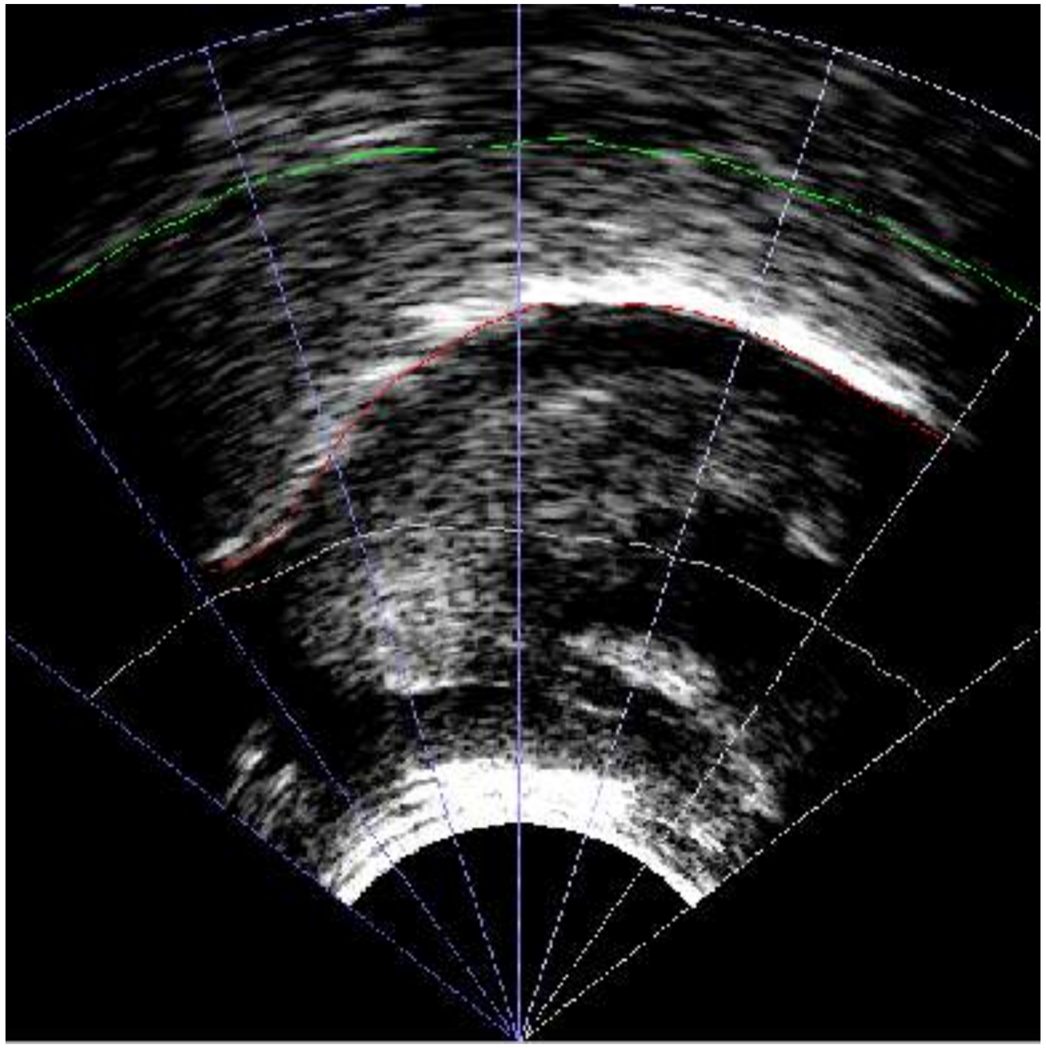
Articulatory data analysis

- Tongue splines tracked and exported using AAA (Articulate Instruments Ltd. 2011)

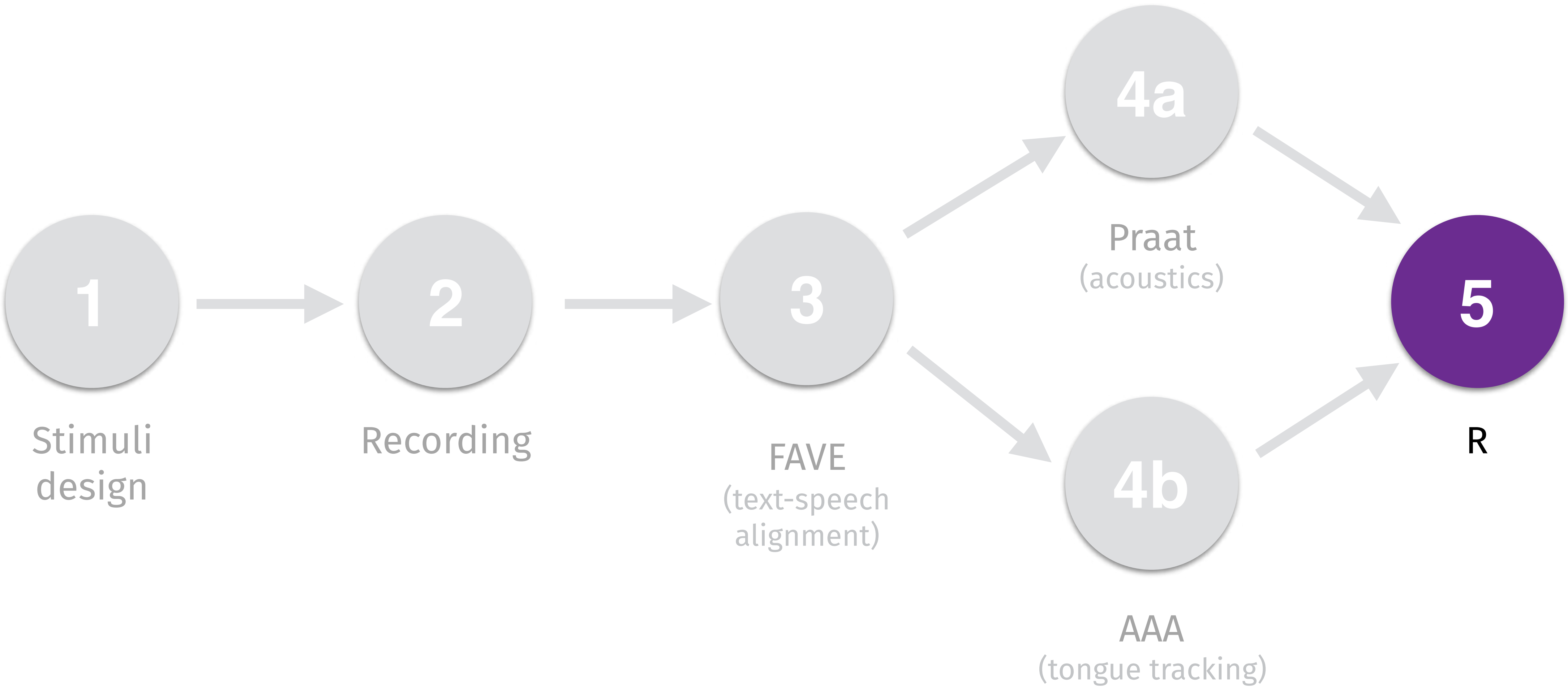


(example clip of ultrasound footage from AAA)



(with palate trace, tongue tracking and fan lines)

Workflow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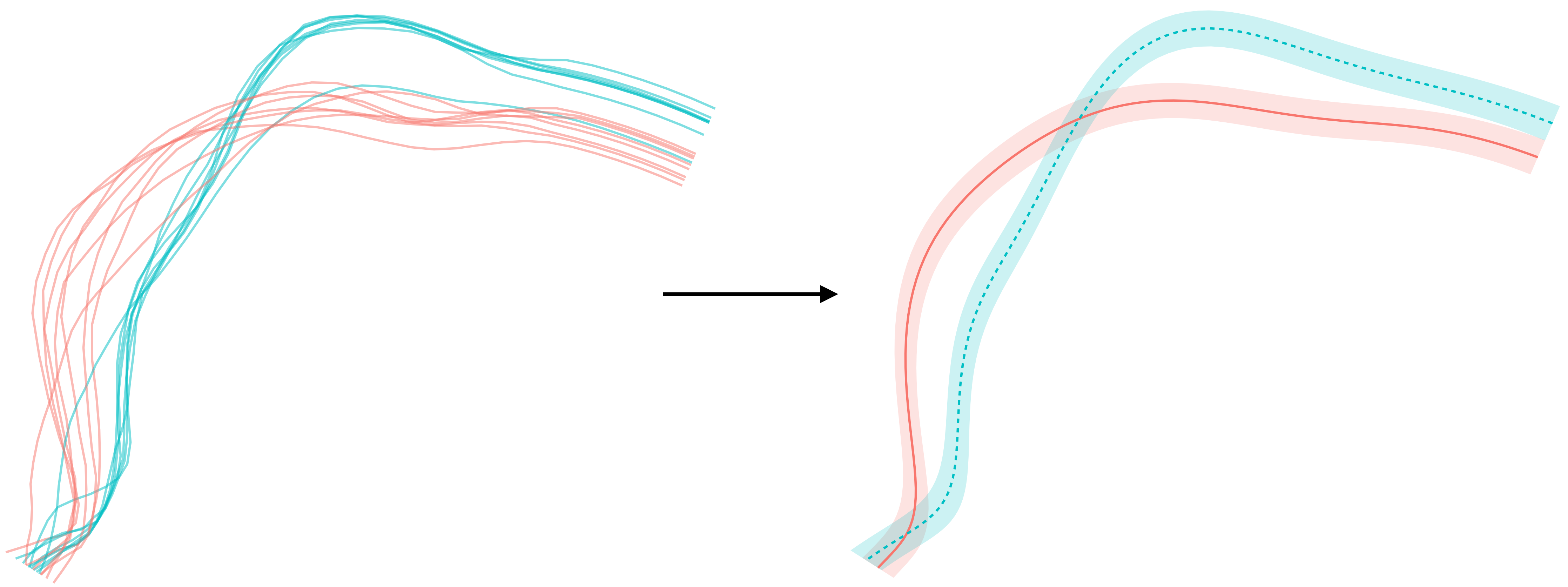
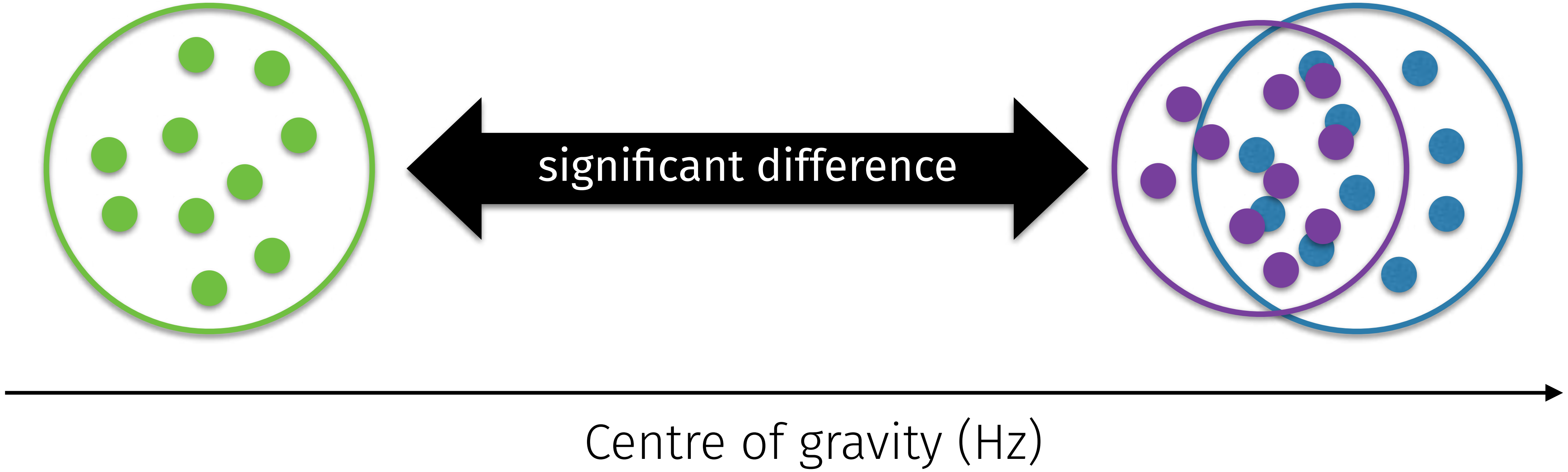
Statistical methods

- **Ultrasound**
  - Modelled with *GAMMs* (*generalised additive mixed models*) using `rticulate` and `tidymv` packages (Coretta 2017, 2018)
  - Ideal for modelling non-linear effects in dynamic (time/space) data (see Sóskuthy 2017 and references therein)



Statistical methods

- **Acoustics**
  - *Mixed-effects linear regression* for CoG measures with `lme4` package (Bates et al. 2015)
  - Used to make pairwise comparisons between contexts
    - determine whether differences (in this case in CoG) are **statistically significant** between environments
    - bimodality can be used to diagnose categoricity v. gradience (e.g. Bermúdez-Otero & Trousdale 2012)



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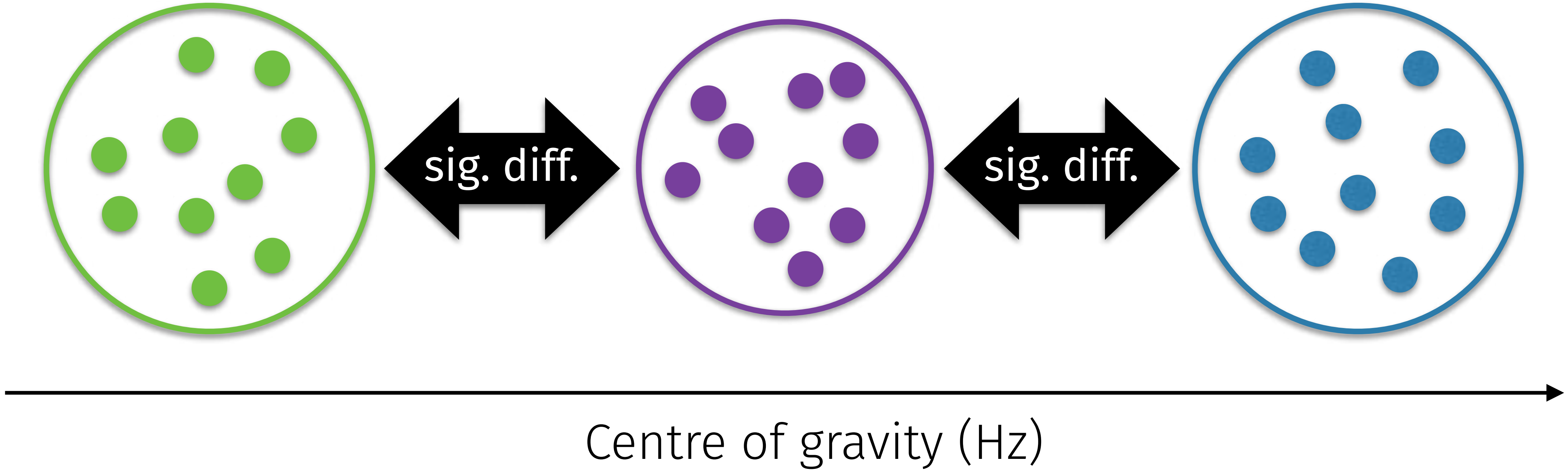

STATISTICAL METHODS

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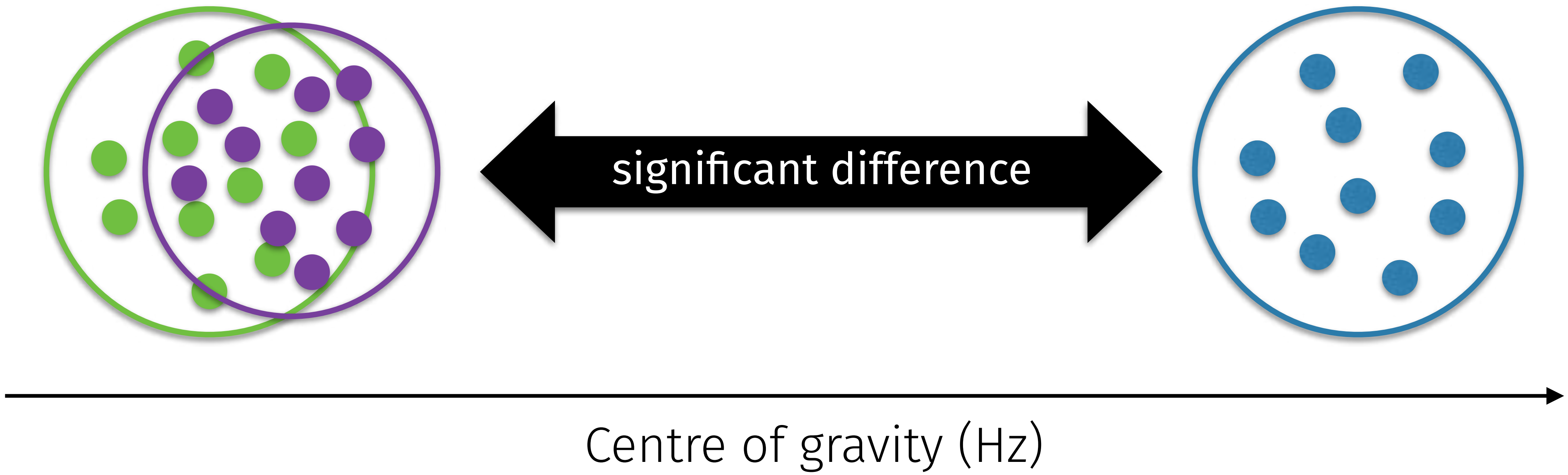
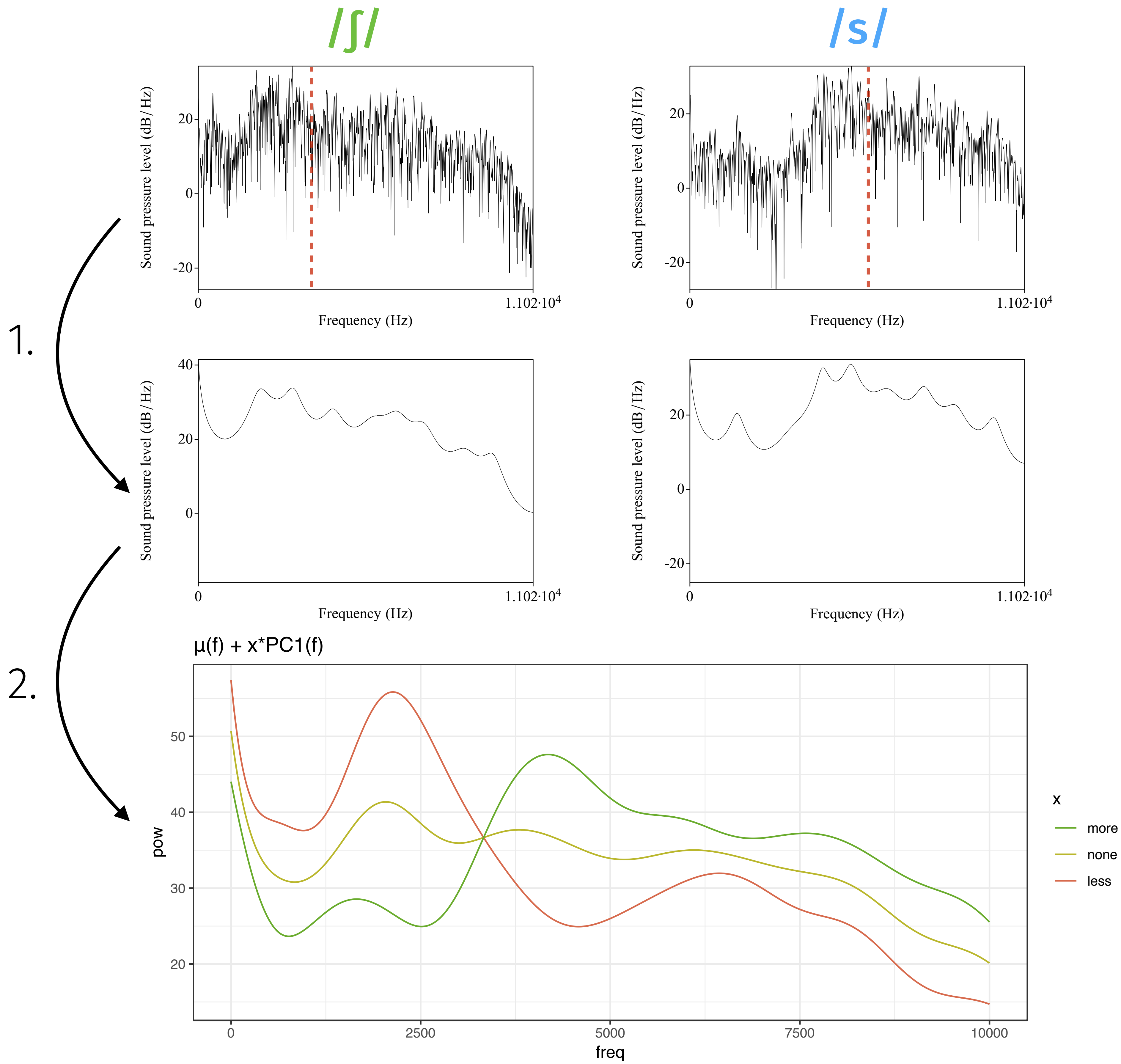


FUNCTIONAL PRINCIPAL COMPONENTS ANALYSIS (FPCA)

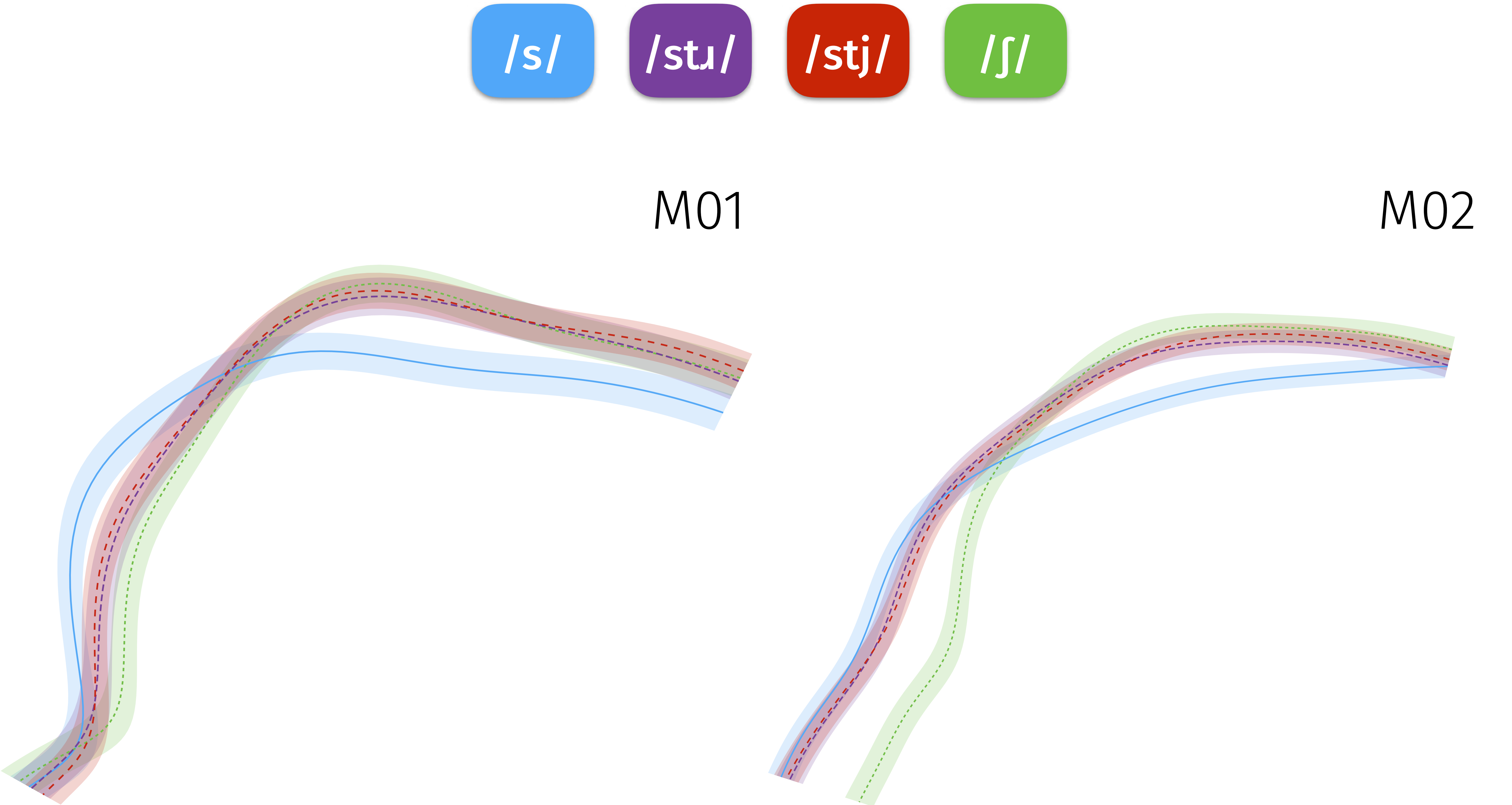
- Single spectral moments (e.g. CoG, skew, kurtosis) often used to distinguish sibilants (Haley et al. 2010:548-9)
- But this is an over-simplification of a complex acoustic signal
- We also analyse the entire curve:
  1. LPC smoothing of spectral slice
  2. Use FPCA to reduce dimensionality and describe curve shapes using two or three principal components (PCs)
     - `fda` package (Ramsay et al. 2013)



RESULTS

ARTICULATION

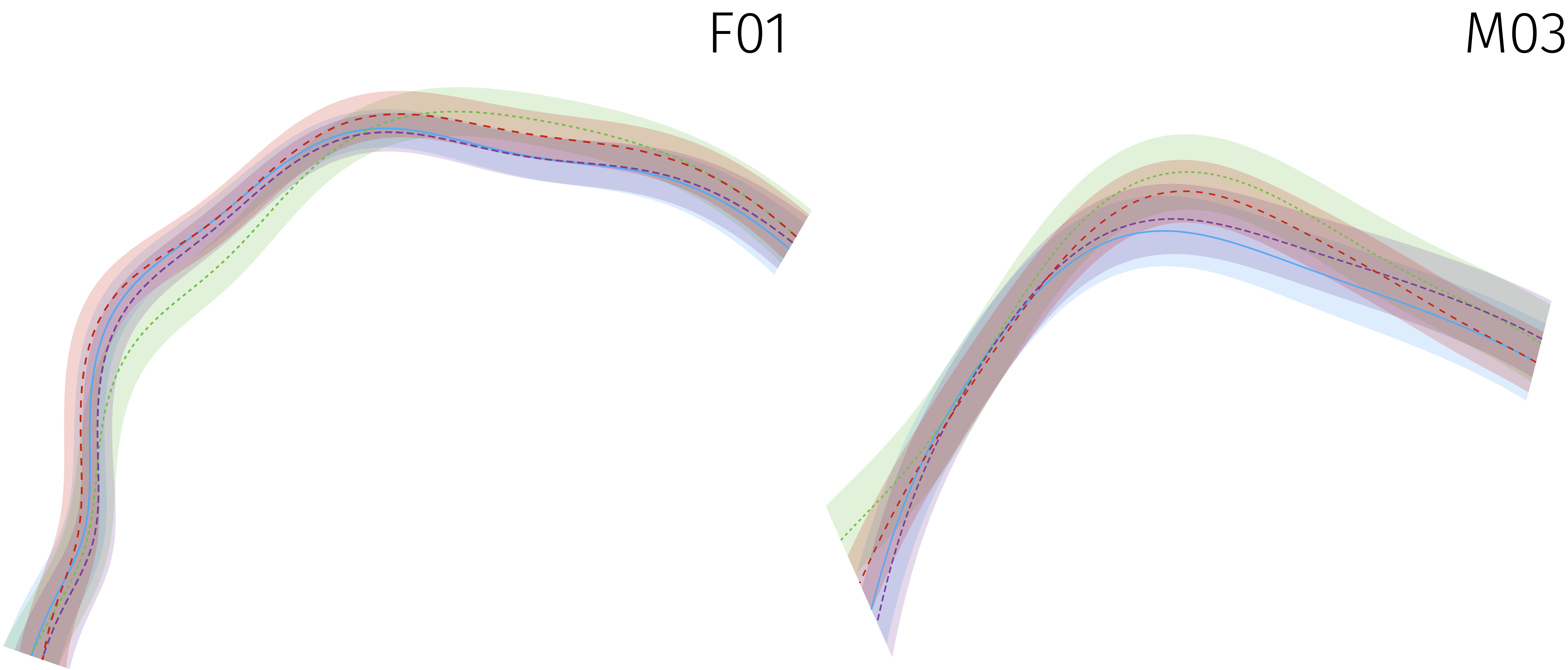
Articulation



Clear bimodality for tongue body: /ʃ/-/stɹ/-/stj/ v. /s/

ARTICULATION

/s/ /stɹ/ /stj/ /ʃ/

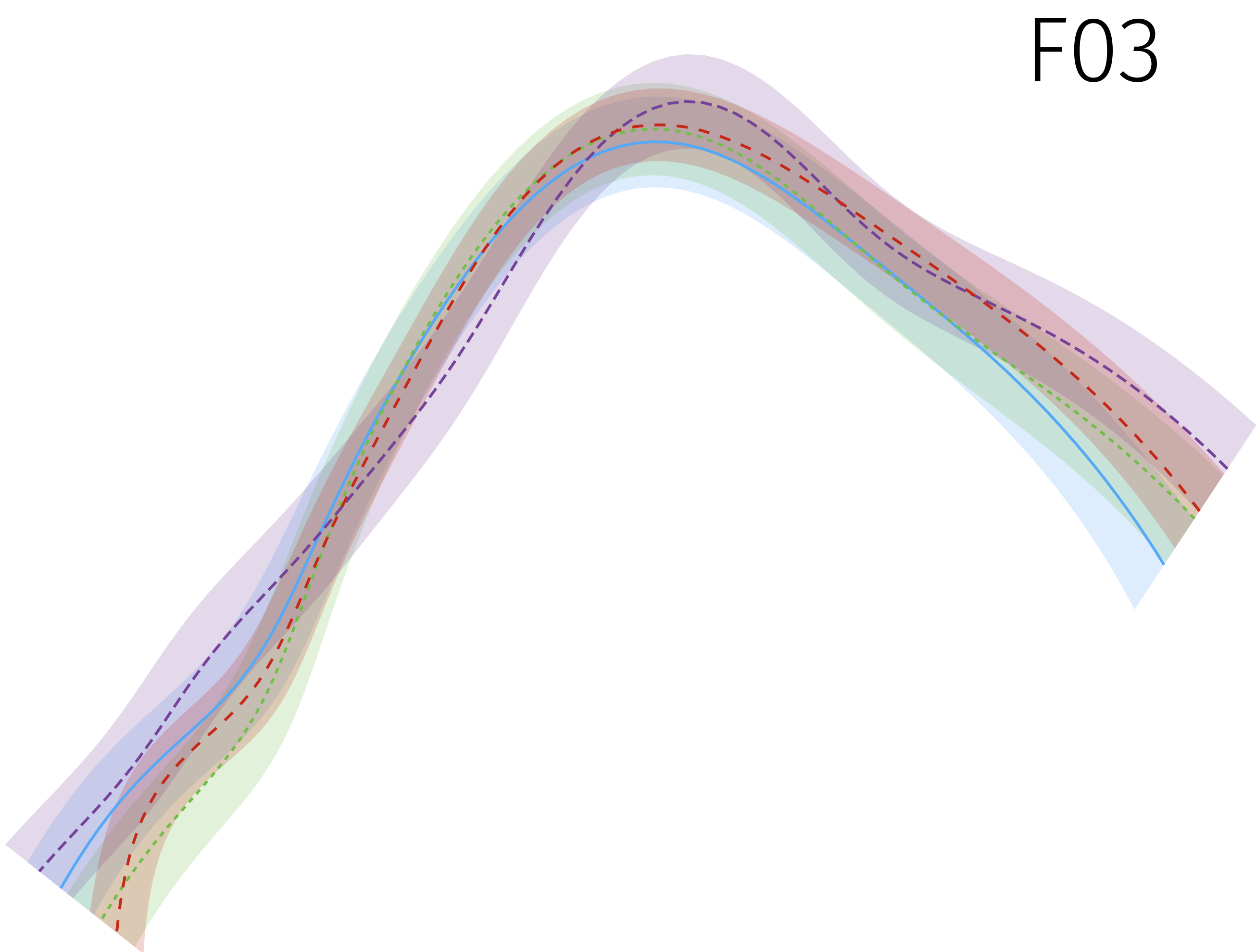


Tongue body for /stj/ largely overlapping with /ʃ/

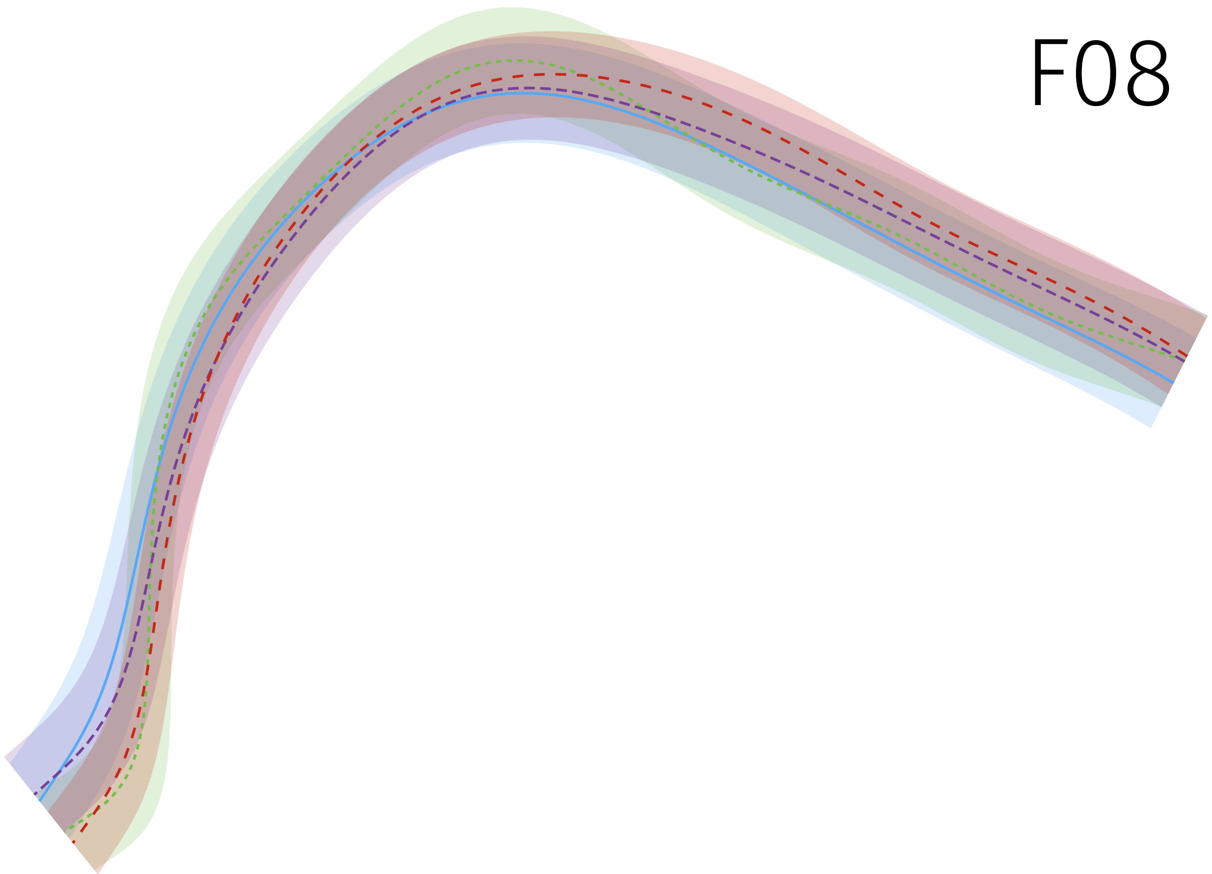
But /stɹ/ much more similar to /s/ than /ʃ/

ARTICULATION

/s/ /stɹ/ /stj/ /ʃ/



(also F06 and F07)

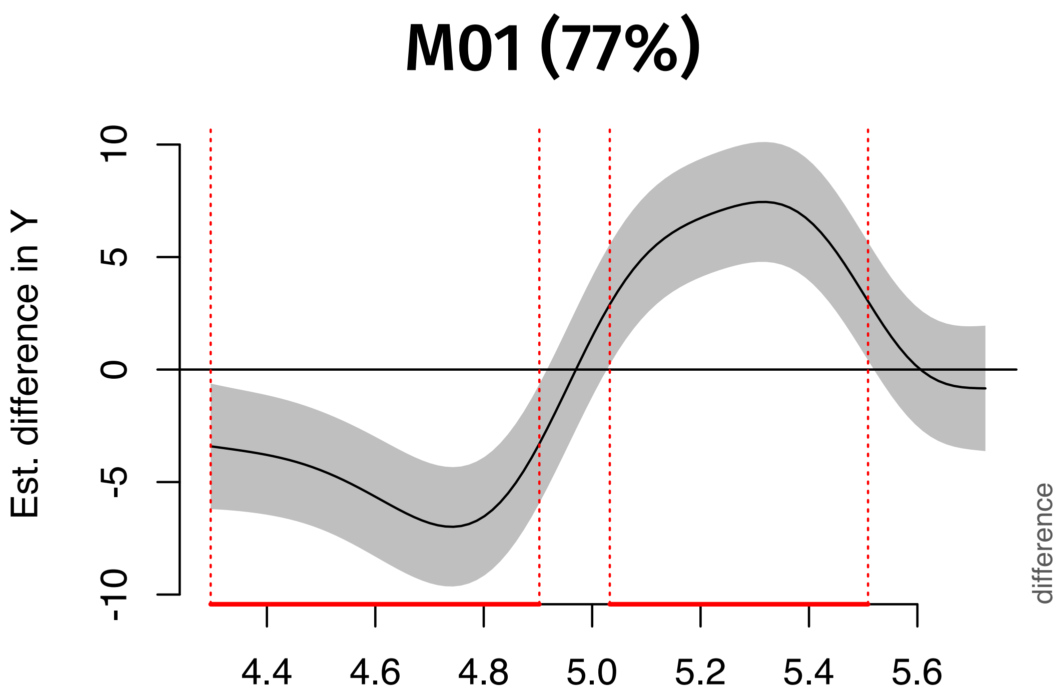


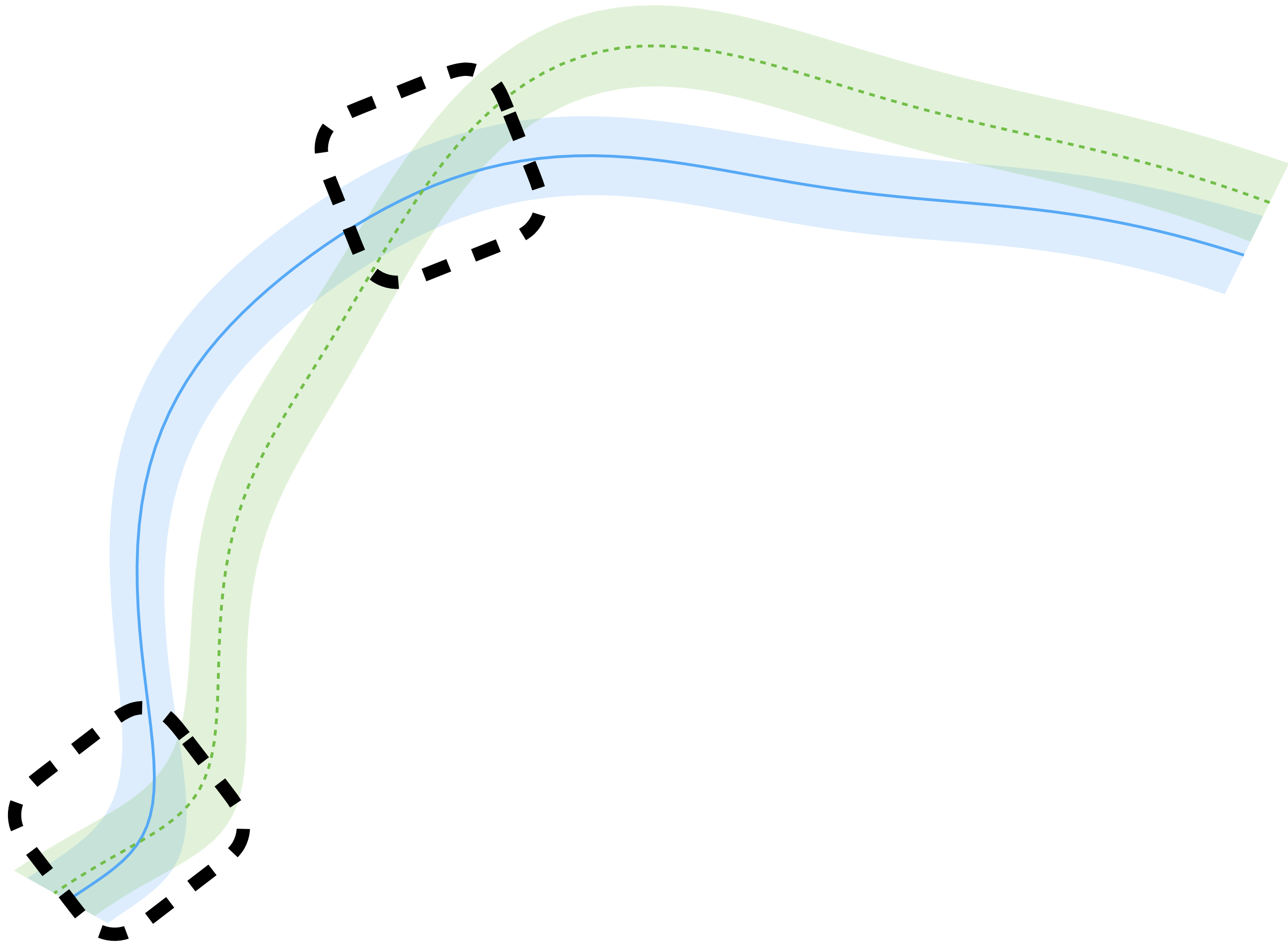
Almost complete overlap between all four contexts, even /s/ and /ʃ/

More differentiation at tongue tip (but confidence intervals also wider)

DIFFERENCE SMOOTHS

- In addition to visual inspection of the splines, difference smooths can be used for pairwise comparisons of /s/ and /ʃ/ tongue shapes
  - Differences between the two curves are highlighted in red (where confidence interval of difference smooth does not contain 0)
  - Broadly speaking, more **red** = more differentiation in tongue shape

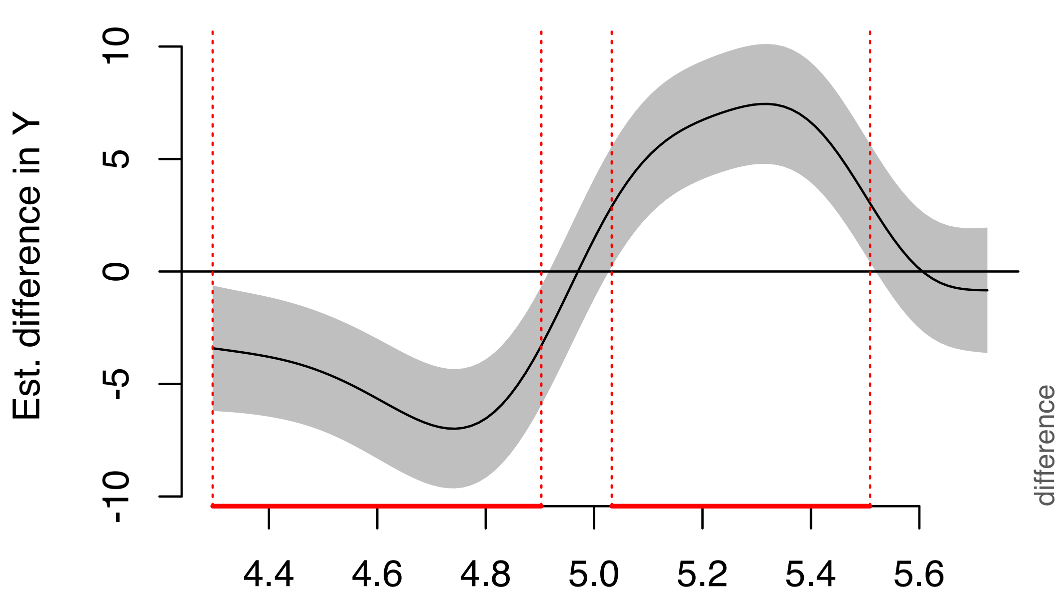




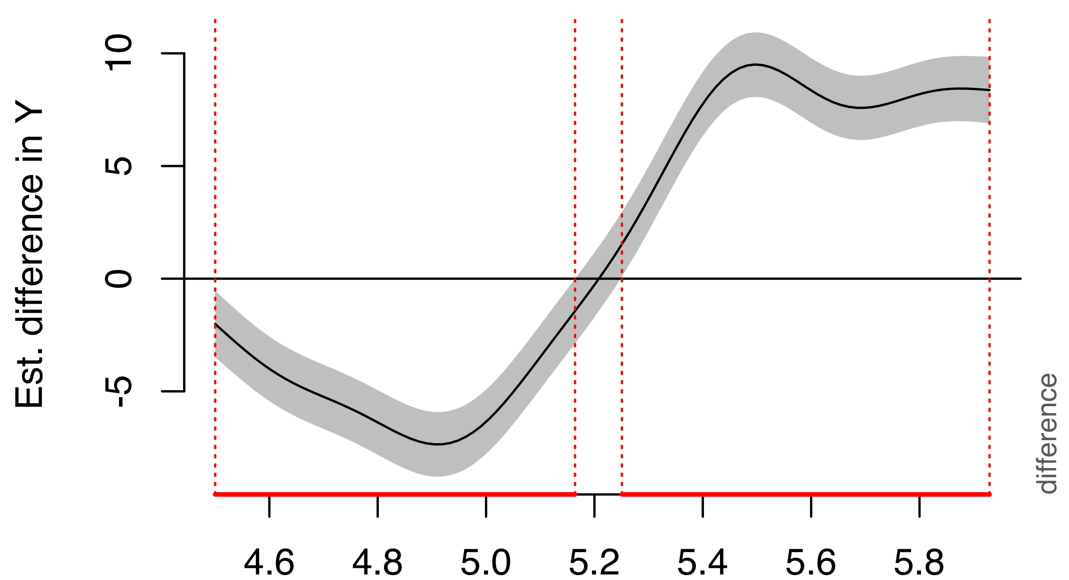
Difference smooths

- In addition to visual inspection of the splines, difference smooths can be used for pairwise comparisons of /s/ and /ʃ/ tongue shapes
  - Differences between the two curves are highlighted in red (where confidence interval of difference smooth does not contain 0)
  - Broadly speaking, more **red** = more differentiation in tongue shape
  - /s/ and /ʃ/ completely different for M01 and M02

M01 (77%)

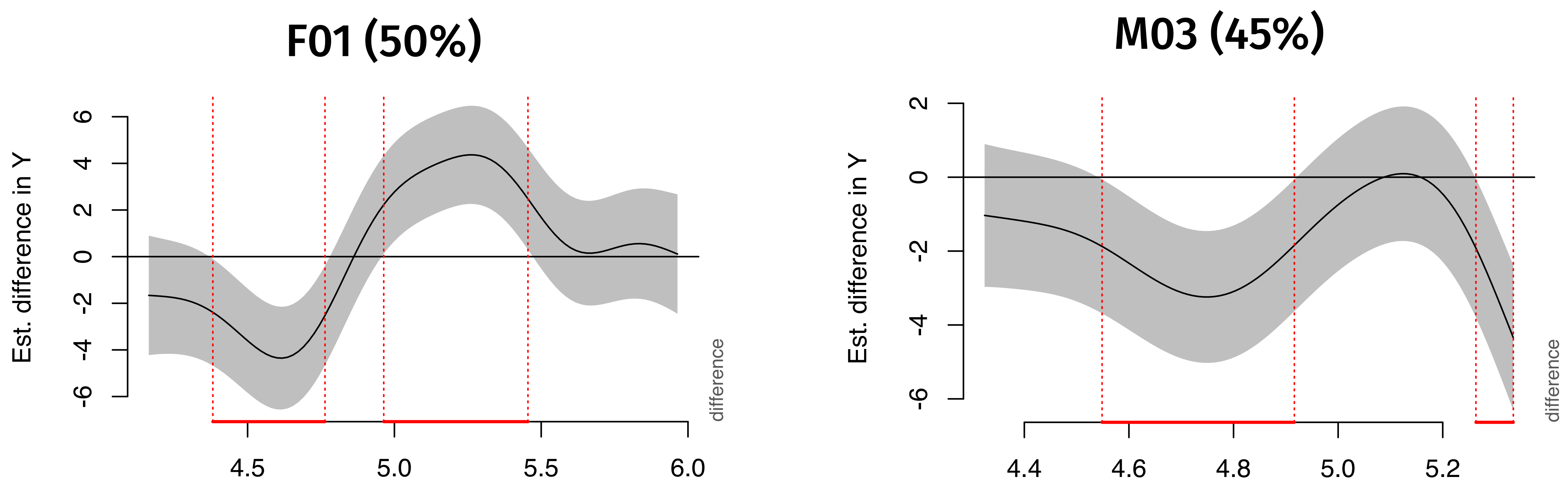


M02 (95%)



DIFFERENCE SMOOTHS

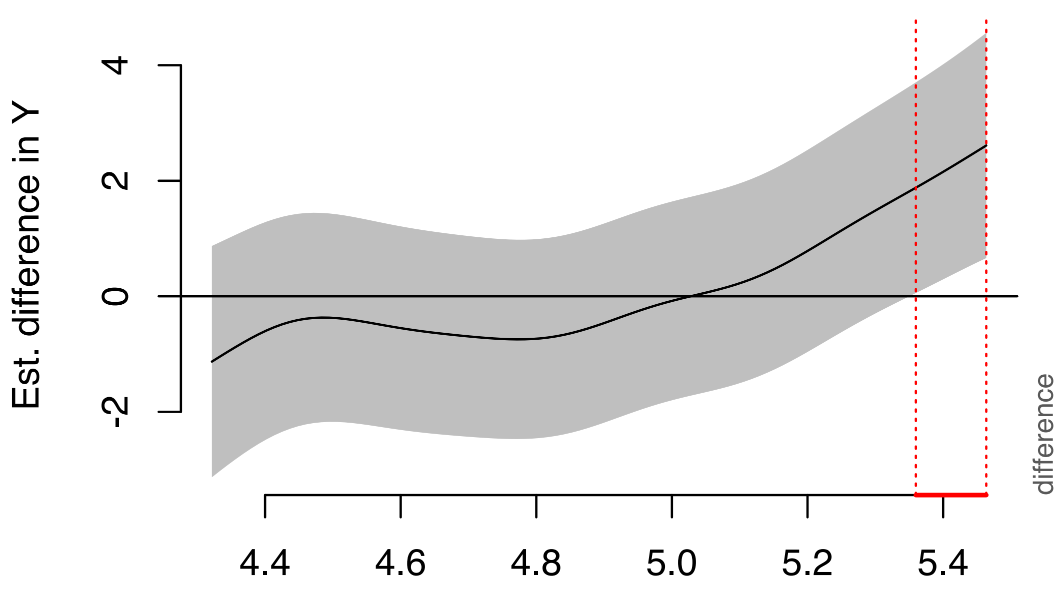
- In addition to visual inspection of the splines, difference smooths can be used for pairwise comparisons of **/s/** and **/ʃ/** tongue shapes
  - Differences between the two curves are highlighted in red (where confidence interval of difference smooth does not contain 0)
  - Broadly speaking, more **red** = more differentiation in tongue shape
  - **/s/** and **/ʃ/** largely distinct (but to a lesser extent) for F01 and M03



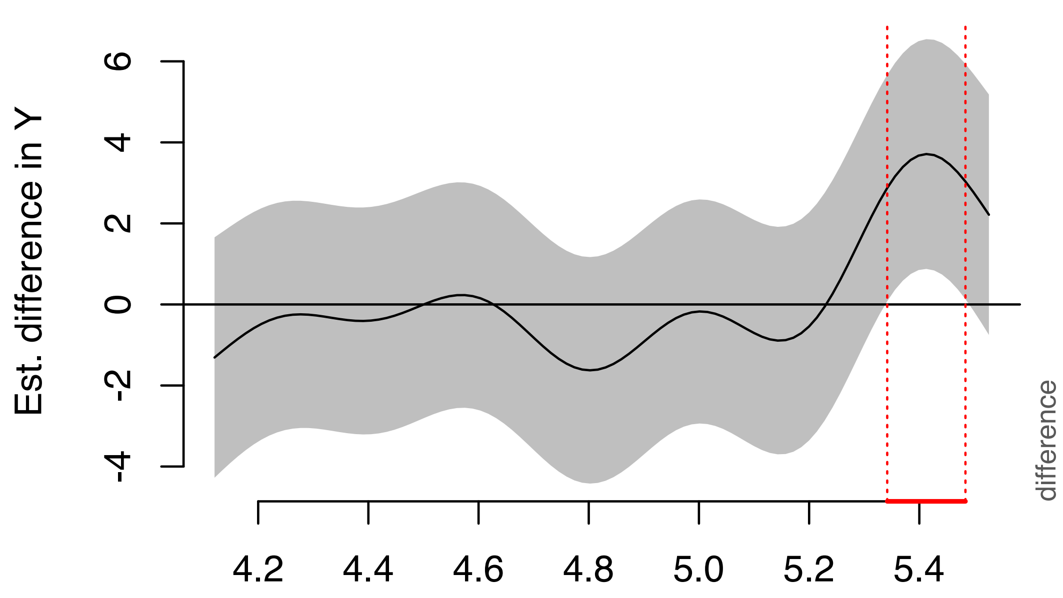
Difference smooths

- In addition to visual inspection of the splines, difference smooths can be used for pairwise comparisons of /s/ and /ʃ/ tongue shapes
  - Differences between the two curves are highlighted in red (where confidence interval of difference smooth does not contain 0)
  - Broadly speaking, more **red** = more differentiation in tongue shape
  - /s/ and /ʃ/ not at all different for F03 and F08 (also F06 and F07)

F03 (10%)



F08 (11%)



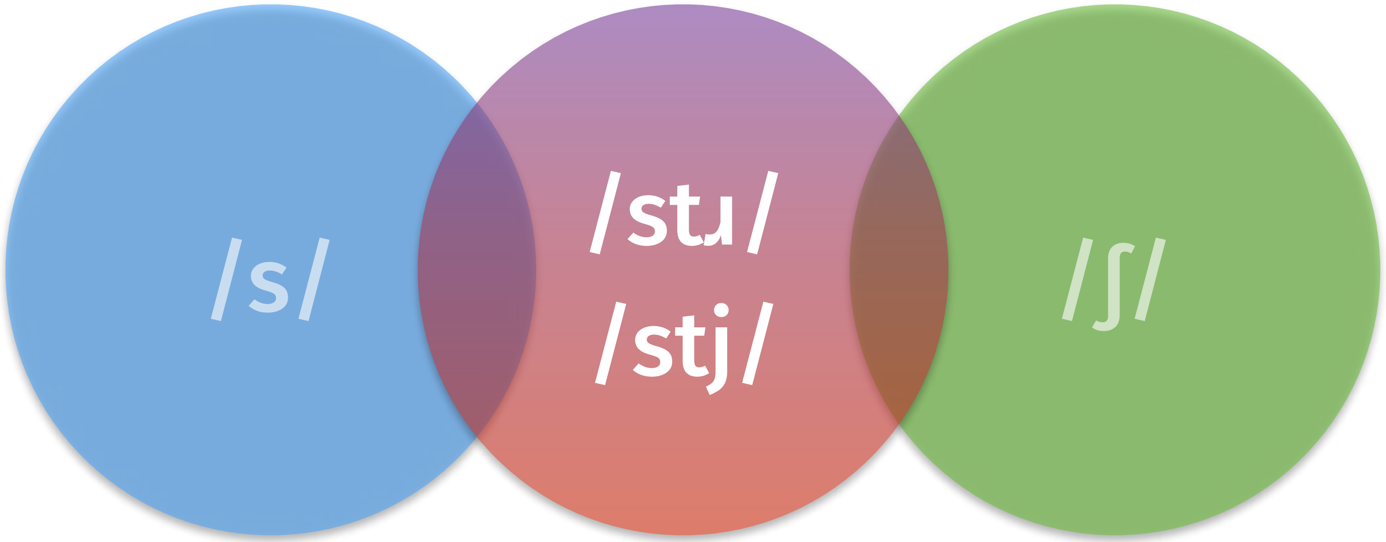
INTERIM SUMMARY

Some speakers exhibit clear tongue body retraction, such that there are two groups:

/s/ v. /ʃ/-/stɹ/-/stj/

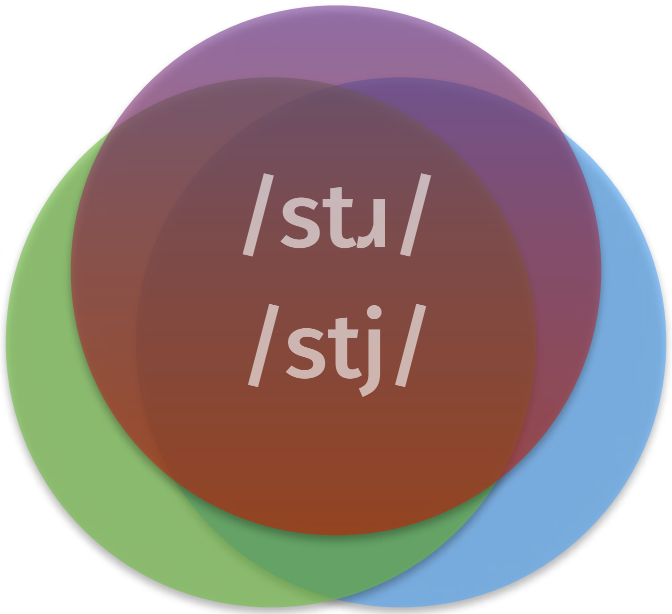
Interim Summary

Others show a more intermediate pattern where the tongue body for **/stɹ/** and **/stj/** is somewhere between **/s/** and **/ʃ/**



INTERIM SUMMARY

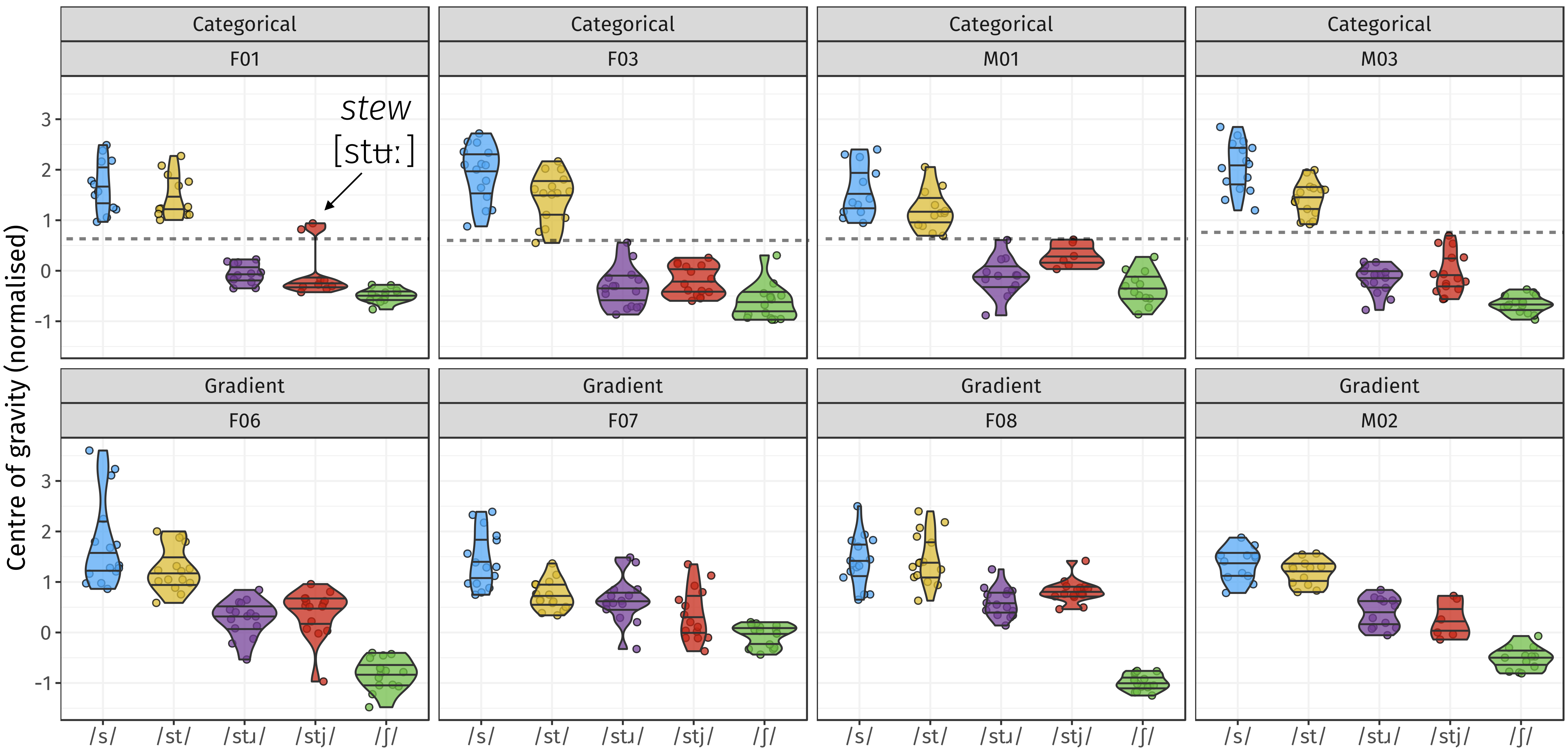
Finally, other speakers have no apparent lingual difference, even between /s/ and /ʃ/



RESULTS

ACOUSTICS

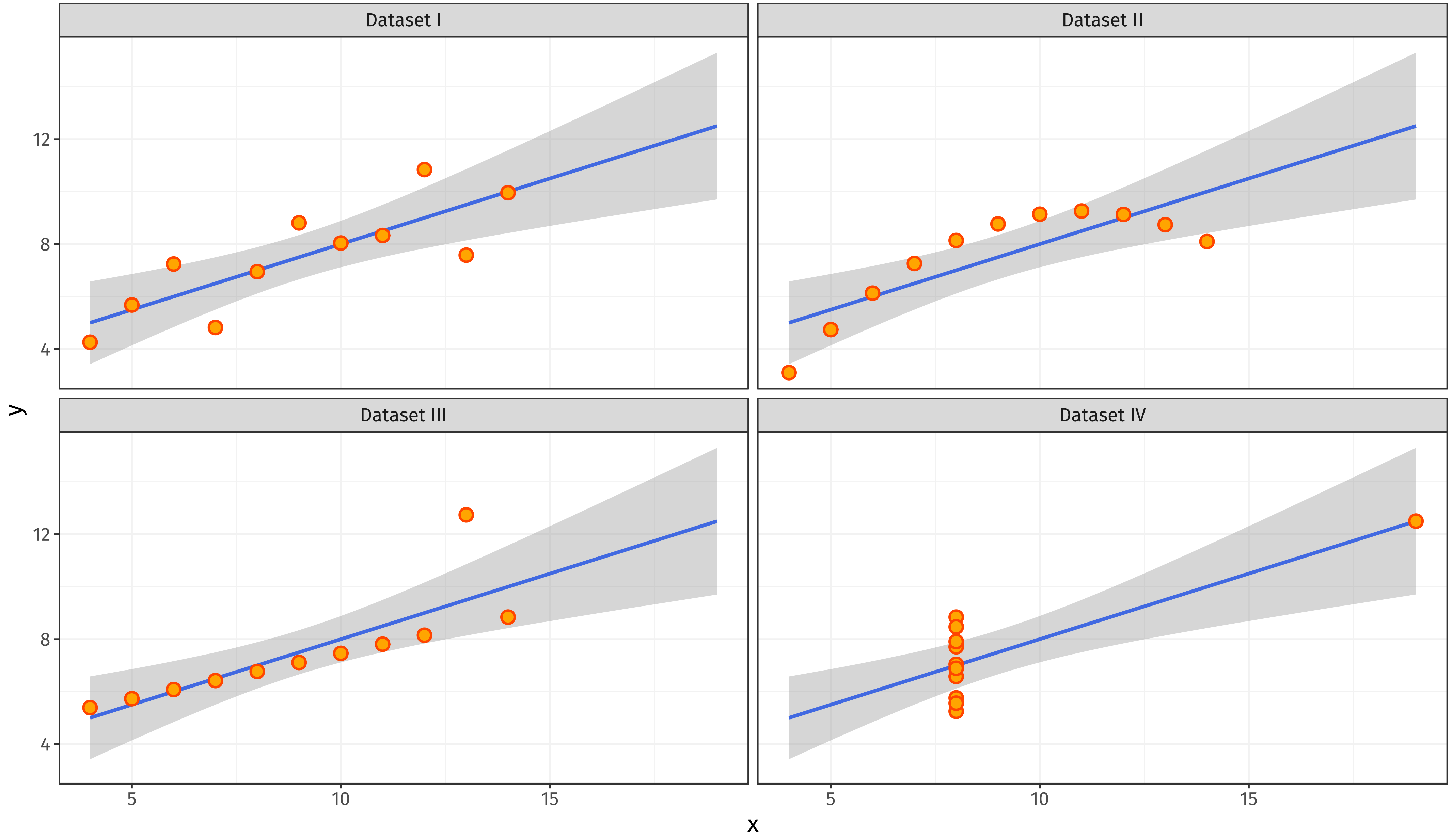
Centre of gravity



- All speakers still have an acoustic contrast between **/s/** and **/ʃ/**
- Categoricity/gradience determined by Tukey contrasts for post-hoc pairwise significance tests in linear regression models (i.e. whether or not **/stɹ/** and **/stj/** are significantly different from **/ʃ/**)

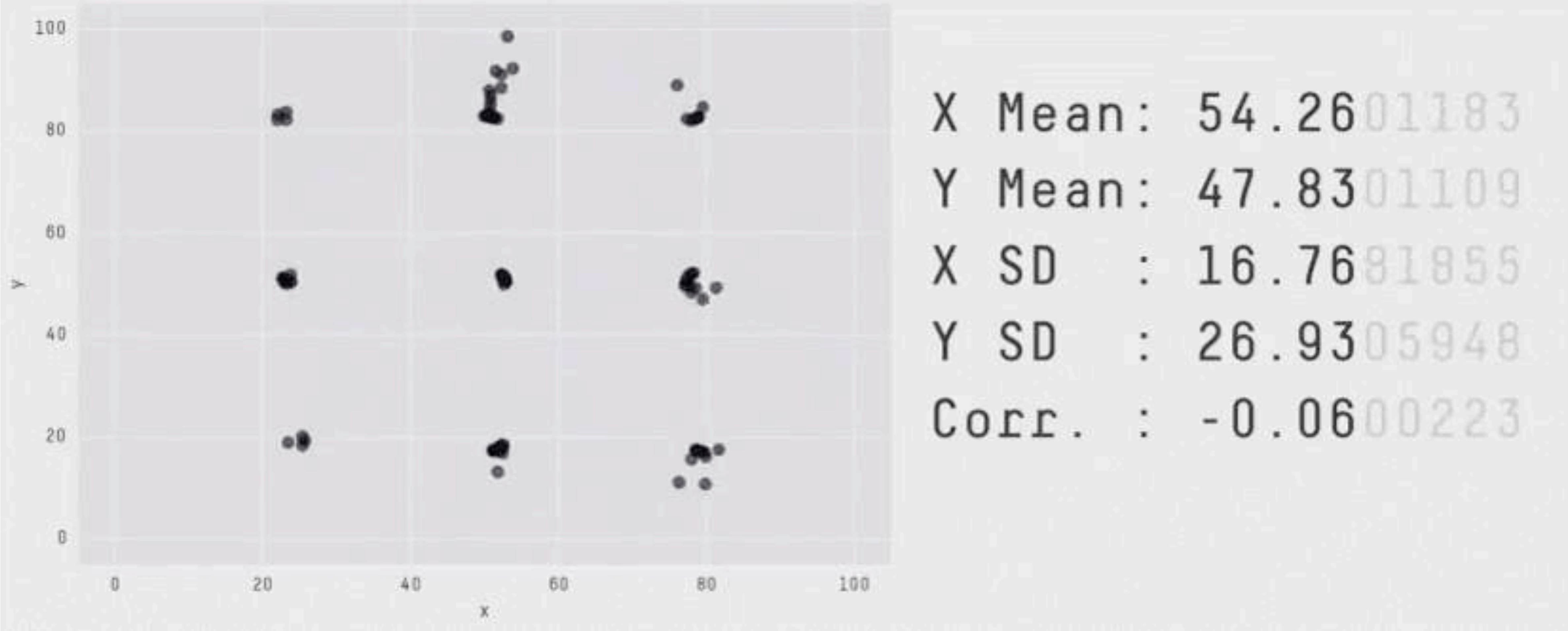
Centre of Gravity

- However, CoG is a single-point measure of a complex curve
  - There could still be differences in the acoustic signal, which this obscures
  - For an illustration of this, see **Anscombe's** (1973) **Quartet**

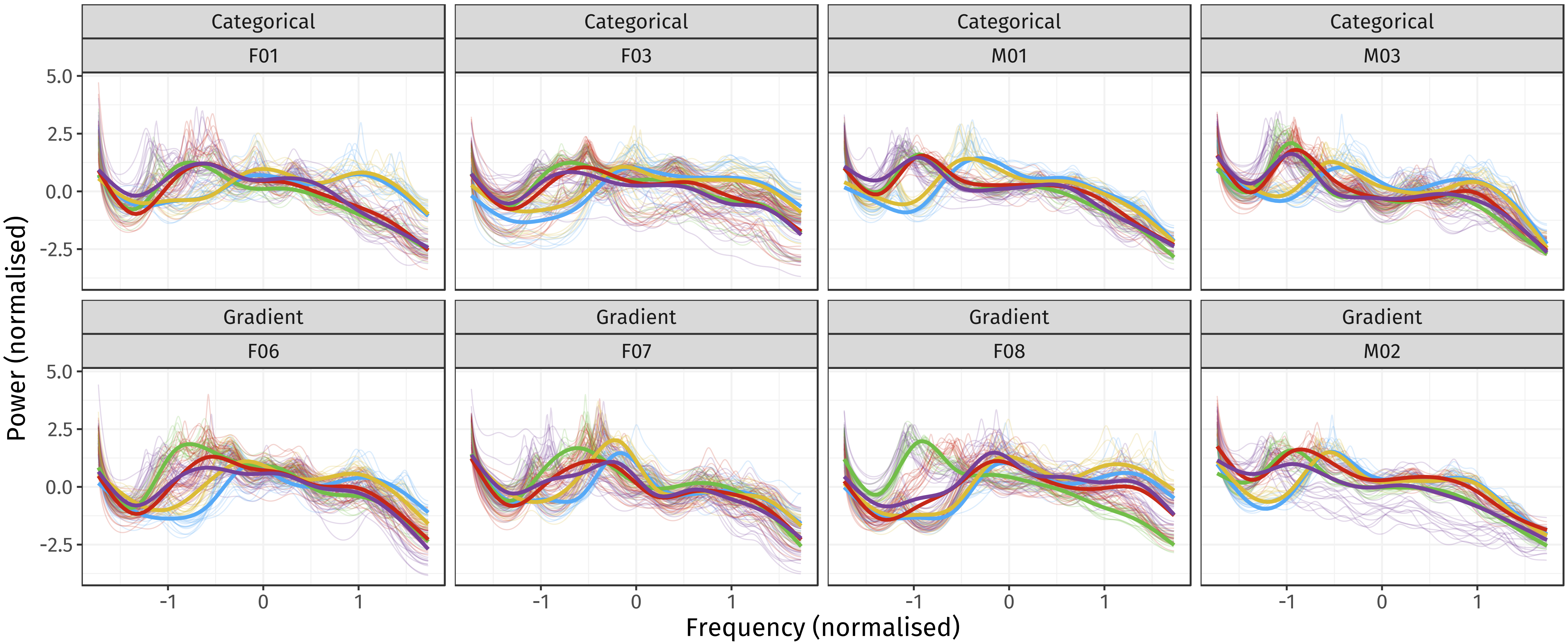


Centre of Gravity

- However, CoG is a single-point measure of a complex curve
  - There could still be differences in the acoustic signal, which this obscures
  - For an illustration of this, see **Anscombe's** (1973) **Quartet**
  - Or the **Datasaurus Dozen** (Matejka & Fitzmaurice 2017)

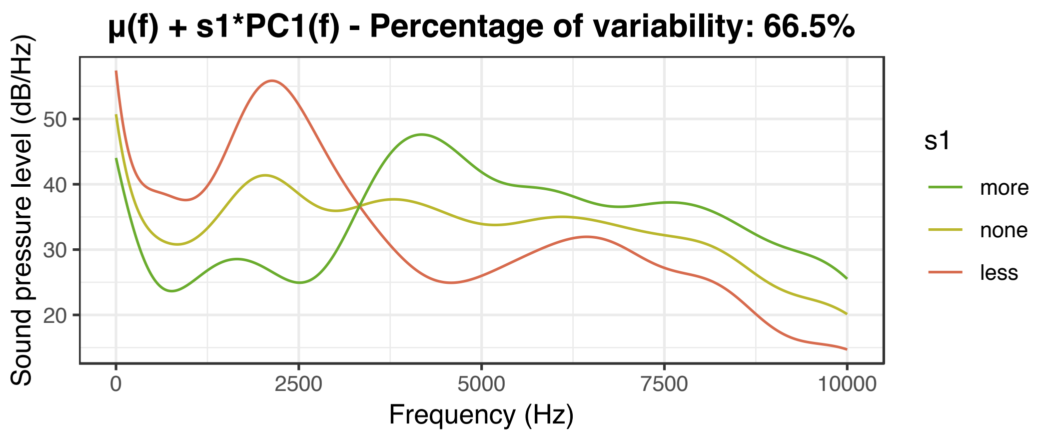


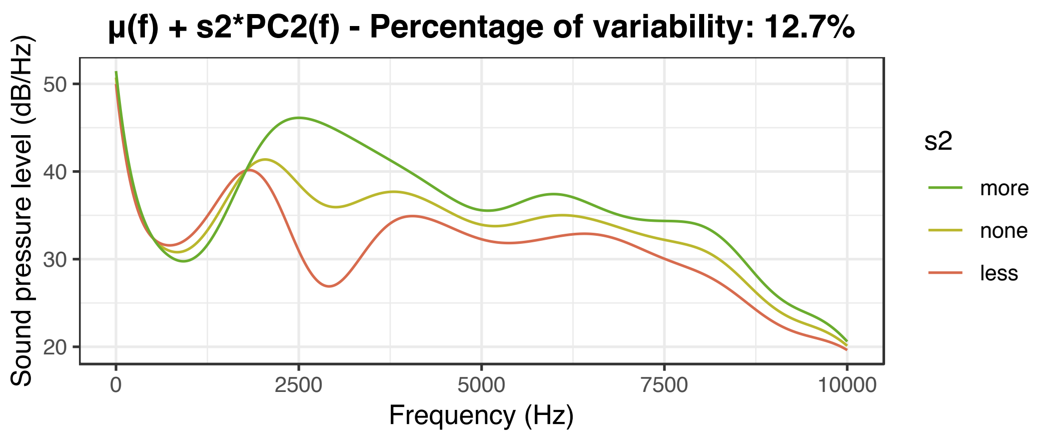
LPC-SMOOTHED SPECTRAL SLICES

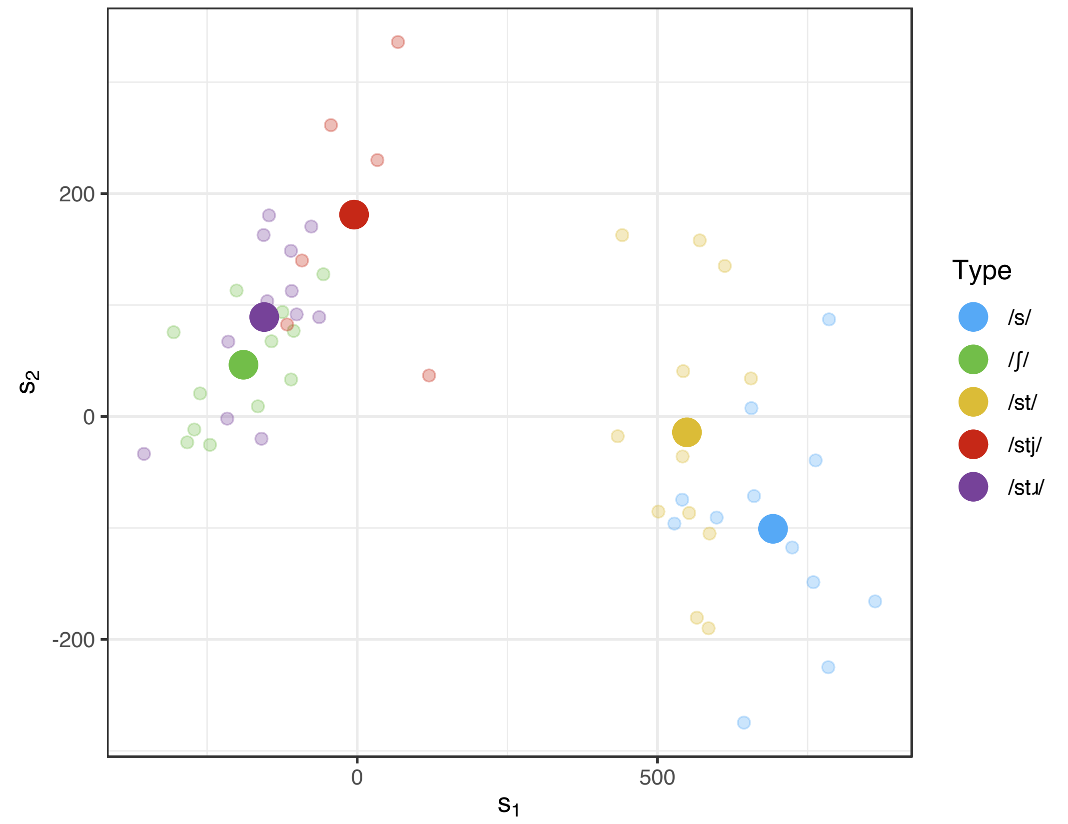


- Looking at the entire spectral profile, the same two patterns emerge:
  - “Categorical” speakers, where **/stɹ/** and **/stj/** patterns with **/ʃ/**
  - “Gradient” speakers, where **/stɹ/** and **/stj/** are intermediate between **/s/** and **/ʃ/**

FUNCTIONAL PRINCIPAL COMPONENTS ANALYSIS (FPCA)

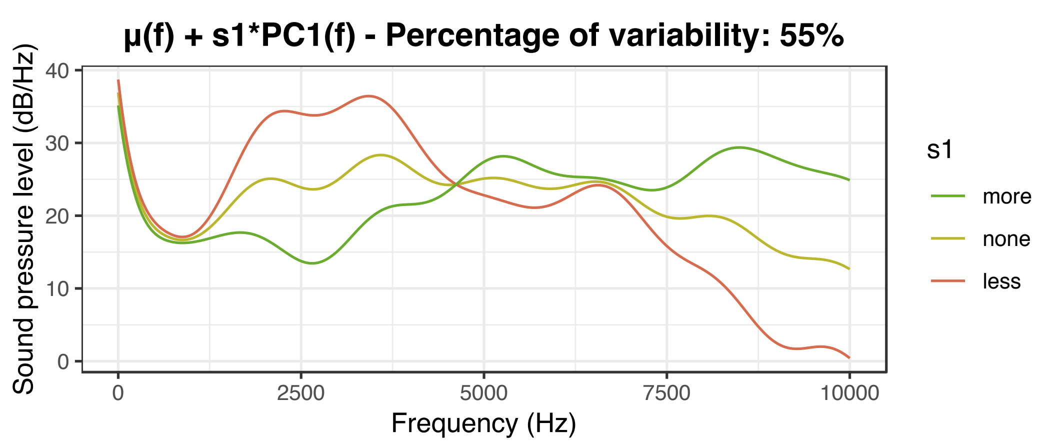


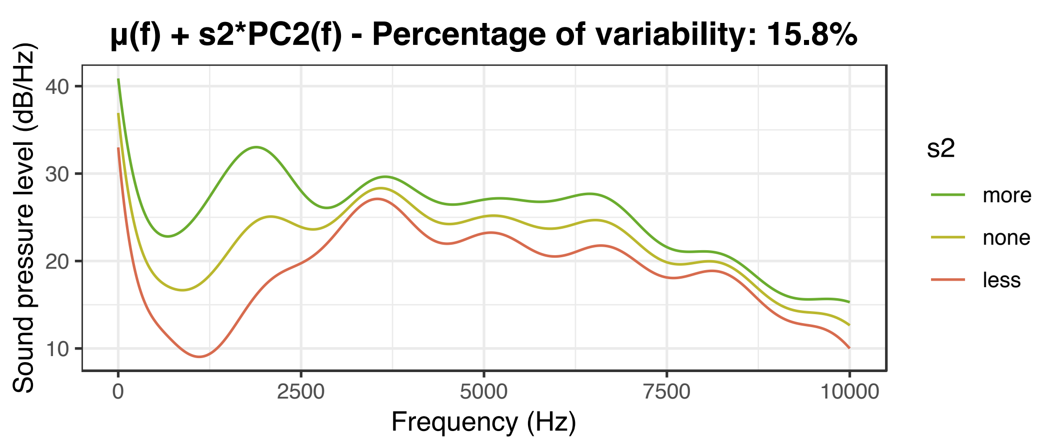


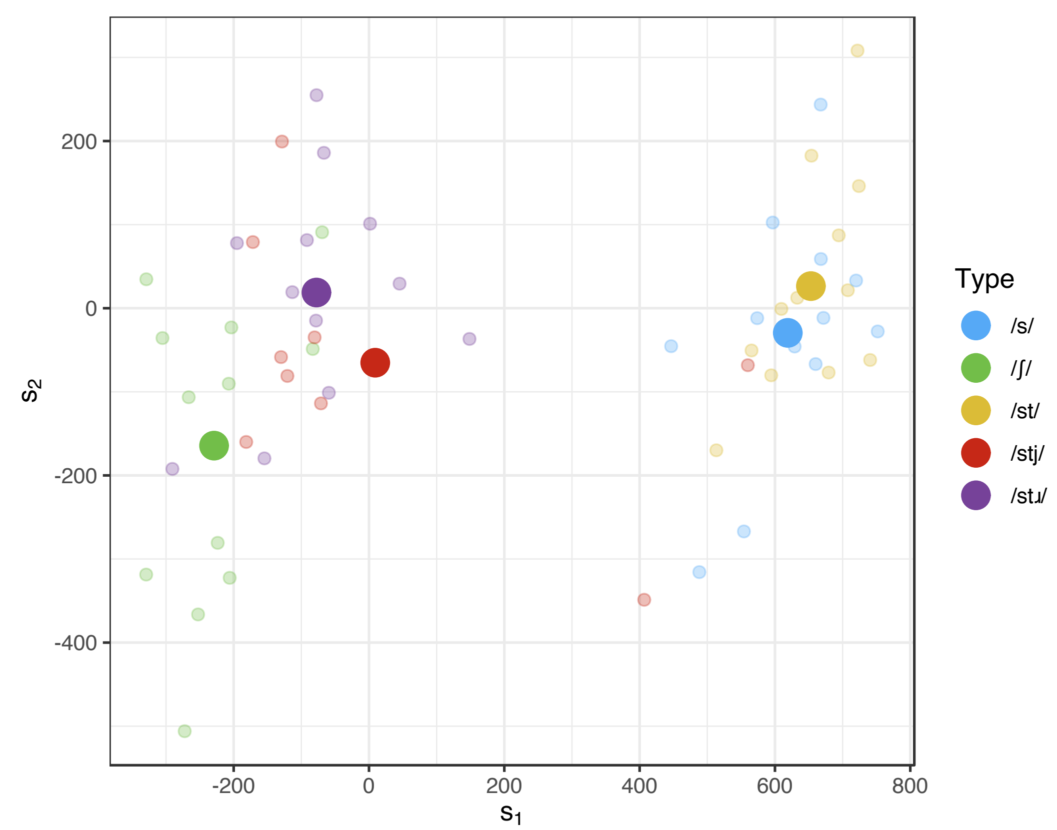


M01

categorical



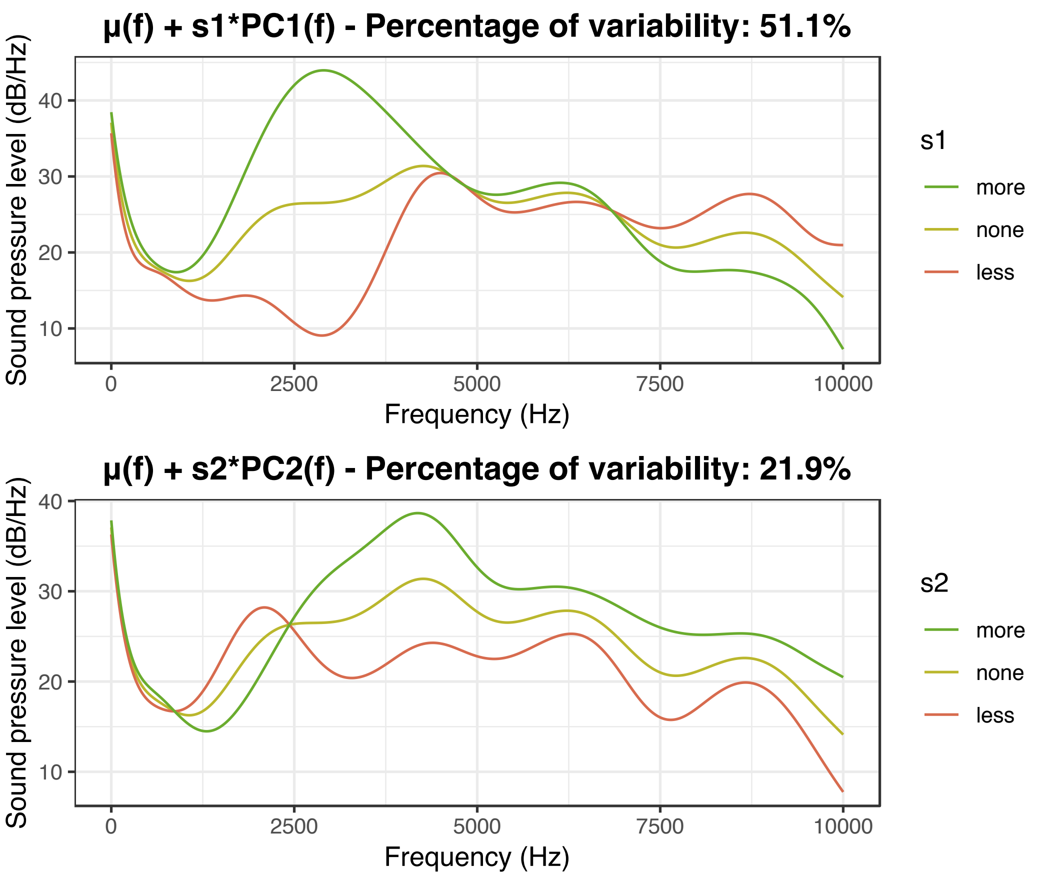


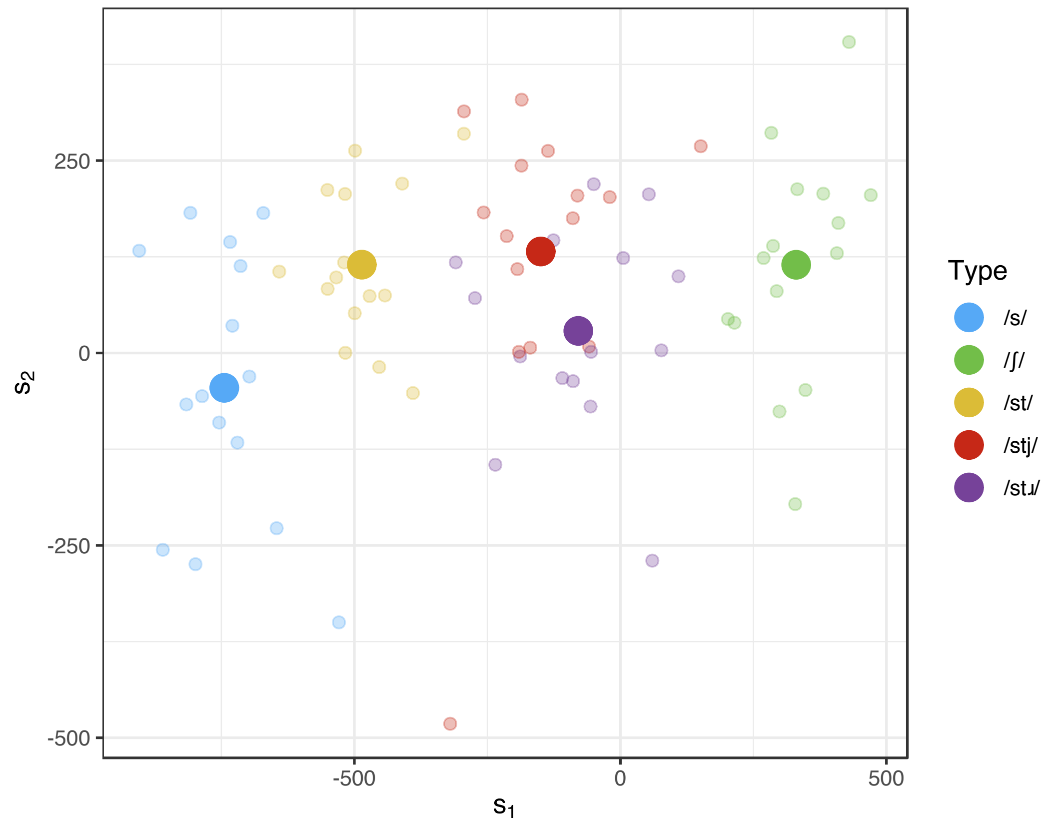


F01

categorical

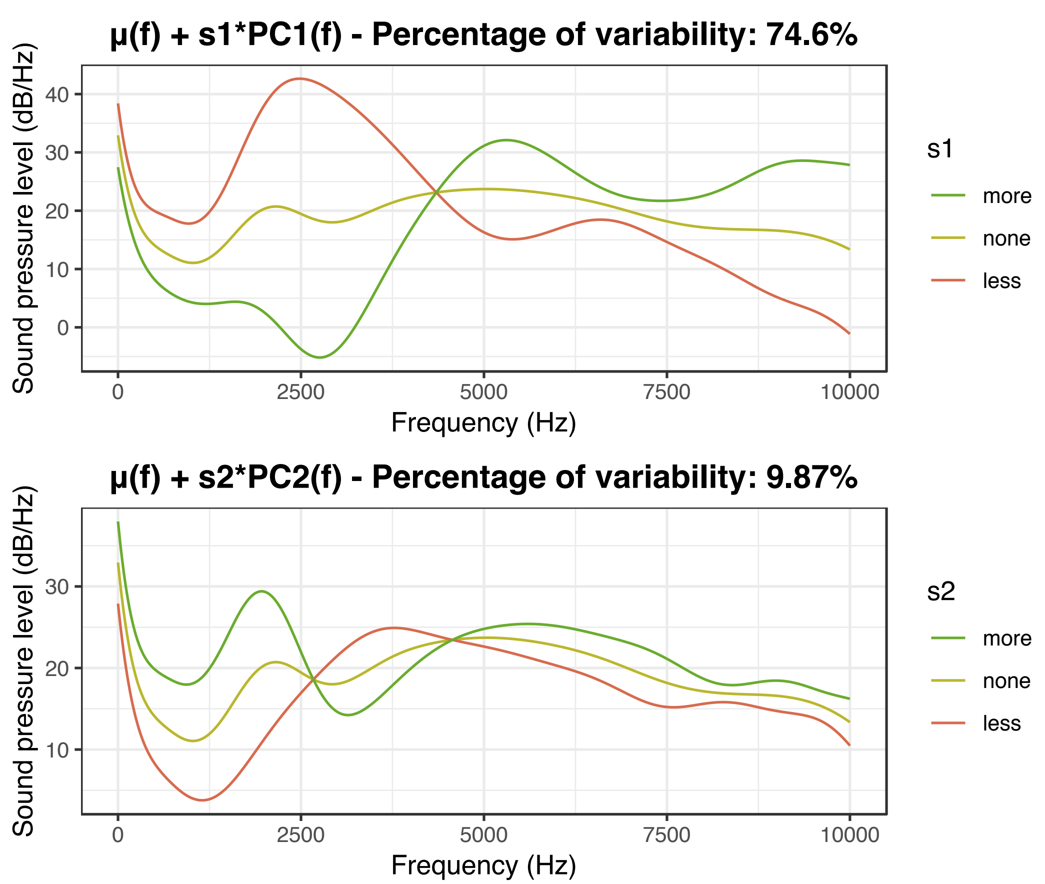
Functional principal components analysis (FPCA)

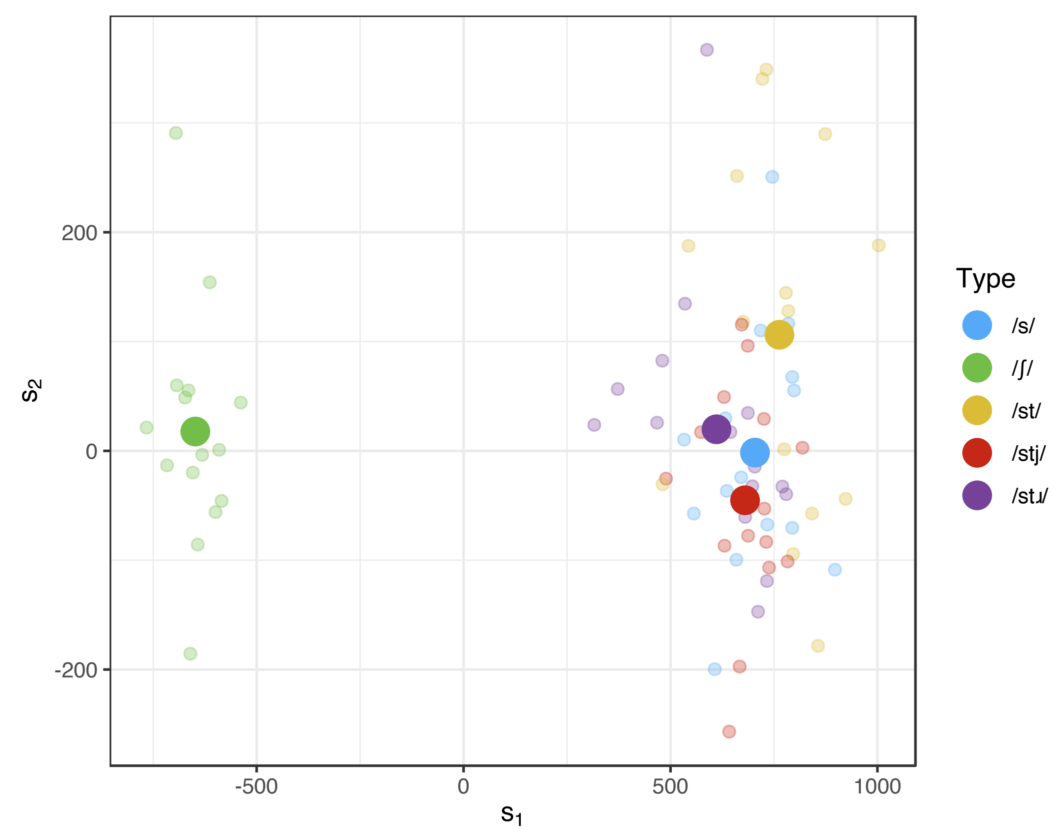




F06

gradient





F08

gradient (none)

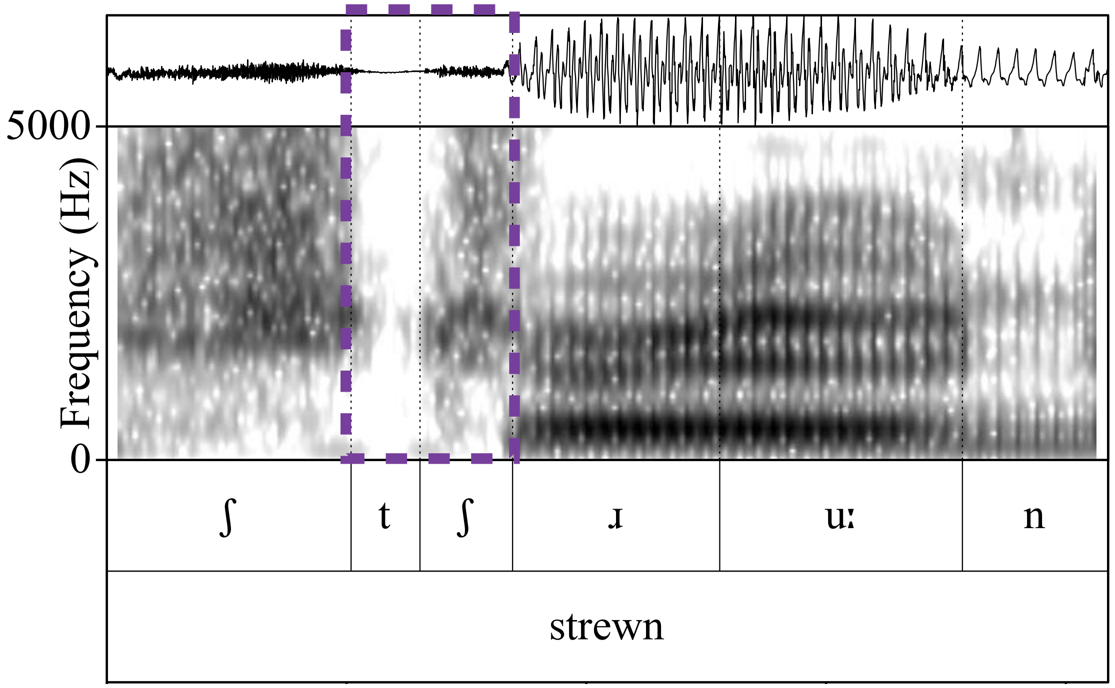
Centre of Gravity

- The acoustic analysis reveals that:

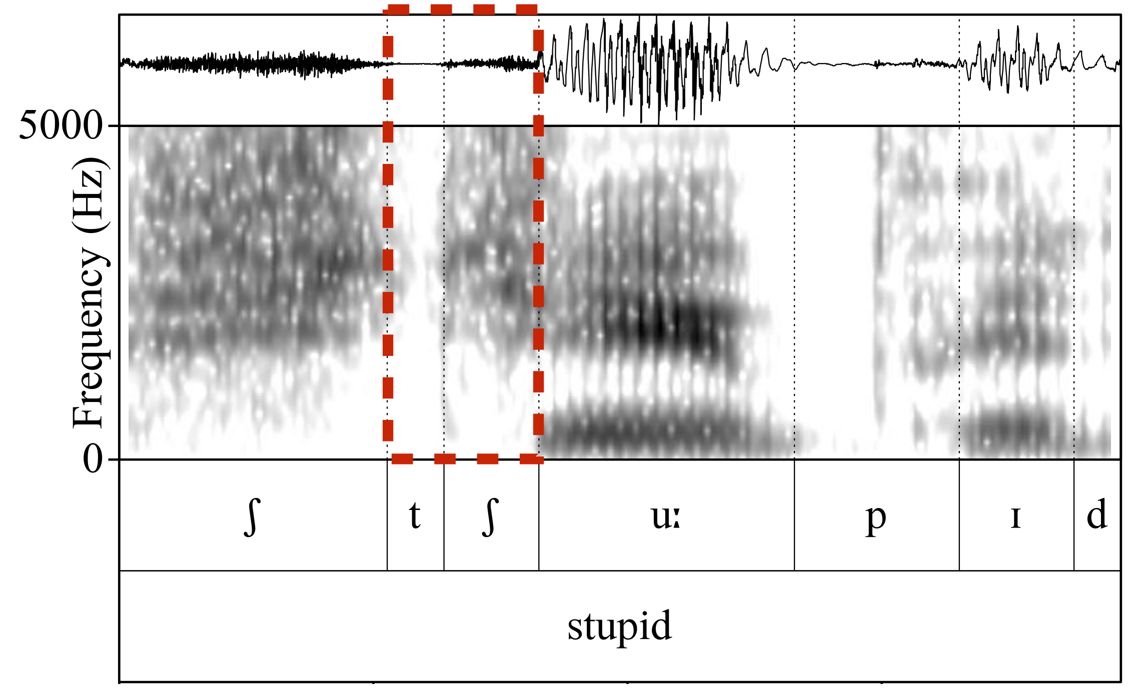
1. **All** speakers maintain an acoustic contrast between /s/ and /ʃ/
2. **All** speakers exhibit some degree of acoustic “retraction” in /stɹ/ and /stj/
3. This retraction can be categorical or gradient but, crucially:
    - Speakers are either categorical in **both** or gradient in **both**
    - That is, there is no evidence that for a single speaker retraction is more advanced in one than the other
    - Which suggests that retraction in both environments is governed by the same underlying process or at least the same phonetic motivations

AFFRICATION?

M01: /stɹ/

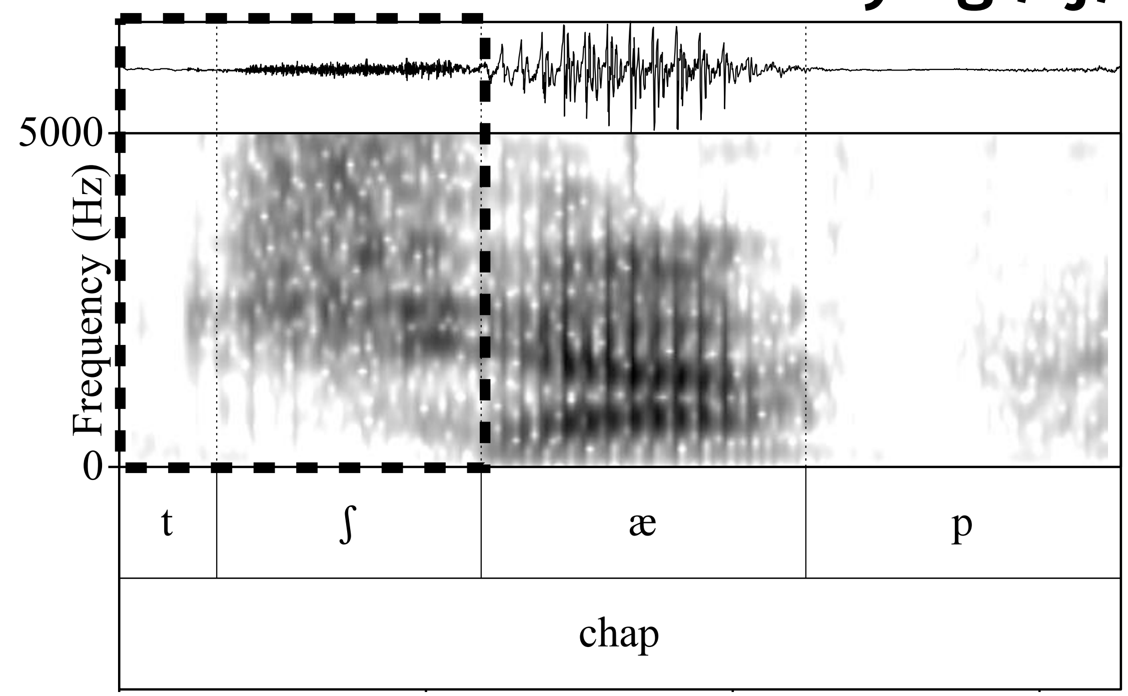


M01: /stj/



- **All** speakers exhibit comparable affrication of **/t/** in both **/stɹ/** and **/stj/**
- Phonetically similar to underlying **/tʃ/** (just shorter in duration)
- Some evidence that speakers can affricate **/t/** with only minimal *s*-retraction (e.g. F08)
  - But no evidence that speakers retract **/s/** without affricating **/t/**
    - e.g. *[ʃtjʉːpɪd]

M01: underlying /tʃ/



DISCUSSION

THE ARTICULATION-ACOUSTICS MAPPING

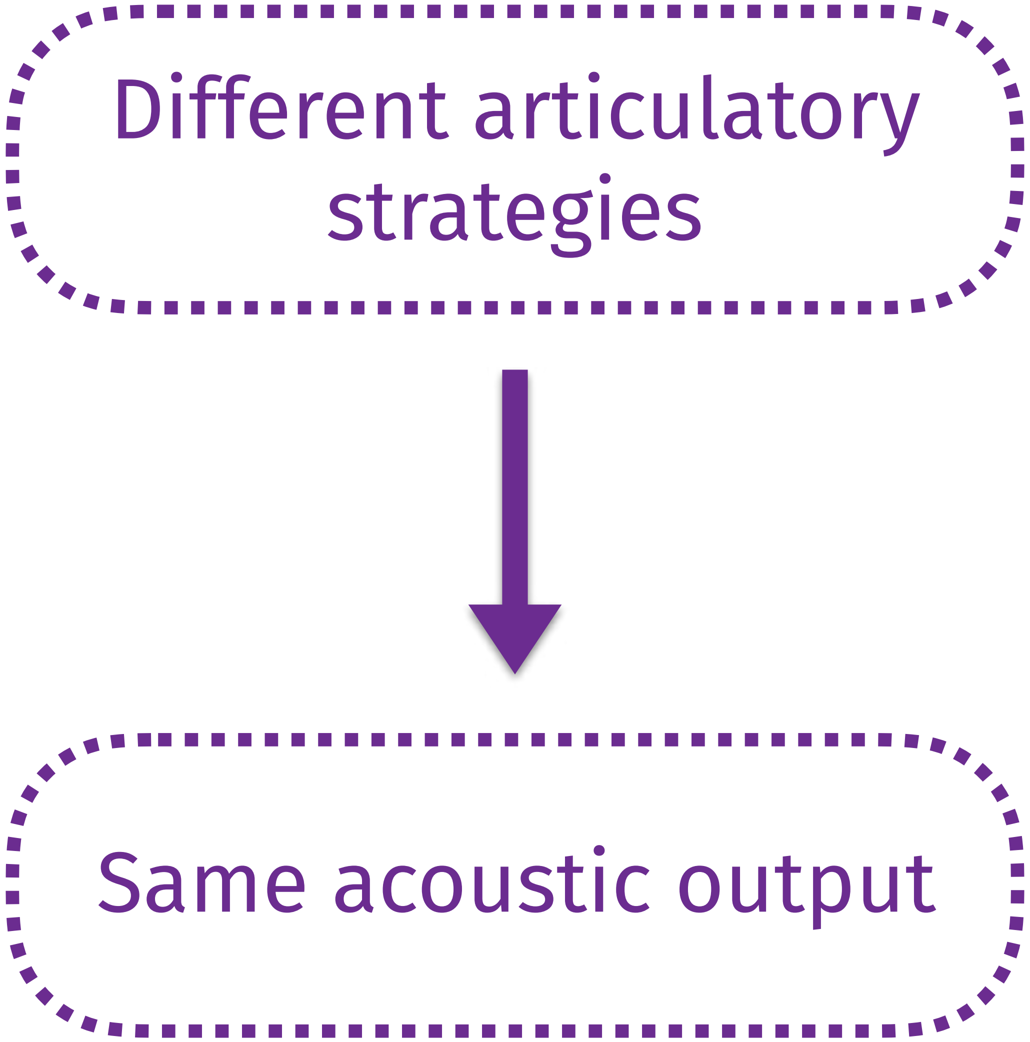
COVERT ARTICULATION

- Even though some speakers show no apparent lingual difference, even between underlying /s/ and /ʃ/, the acoustic contrast is still maintained
- Rutter (2011) highlights the other phonetic parameters that could be involved in the /s/-/ʃ/ contrast:
  - **TONGUE BODY POSITION**
    - alveolar for /s/, post-alveolar for /ʃ/
  - **TONGUE SURFACE**
    - grooved for /s/, flat for /ʃ/
  - **LIP SHAPE**
    - strong labialisation for /ʃ/
  - Also **TONGUE TIP**
    - laminal v. apical constriction

‘It is also worth noting that changes in one of the phonetic parameters discussed above may not necessarily co-occur with changes in the other two’

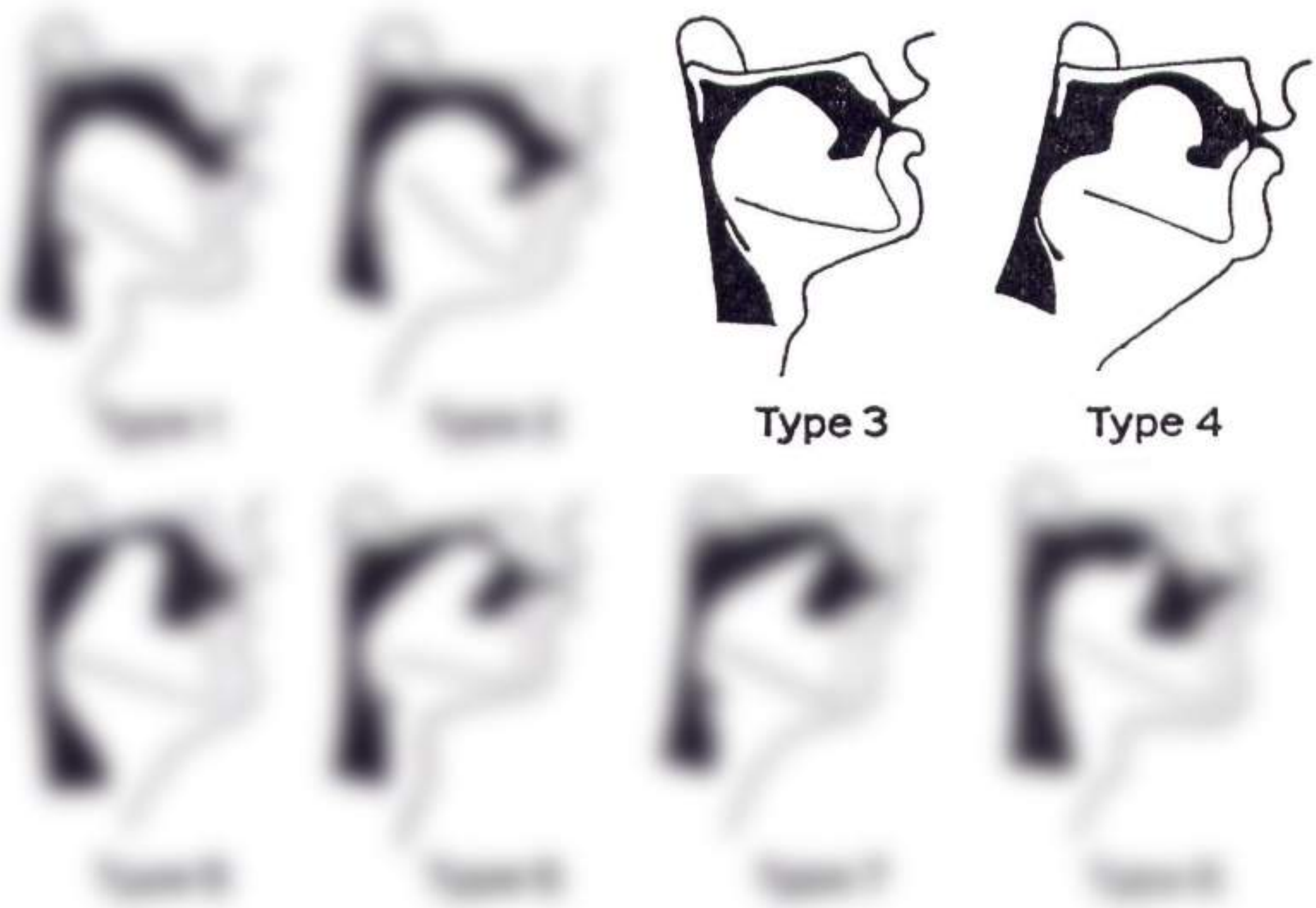
(Rutter 2011:31)

Covert articulation



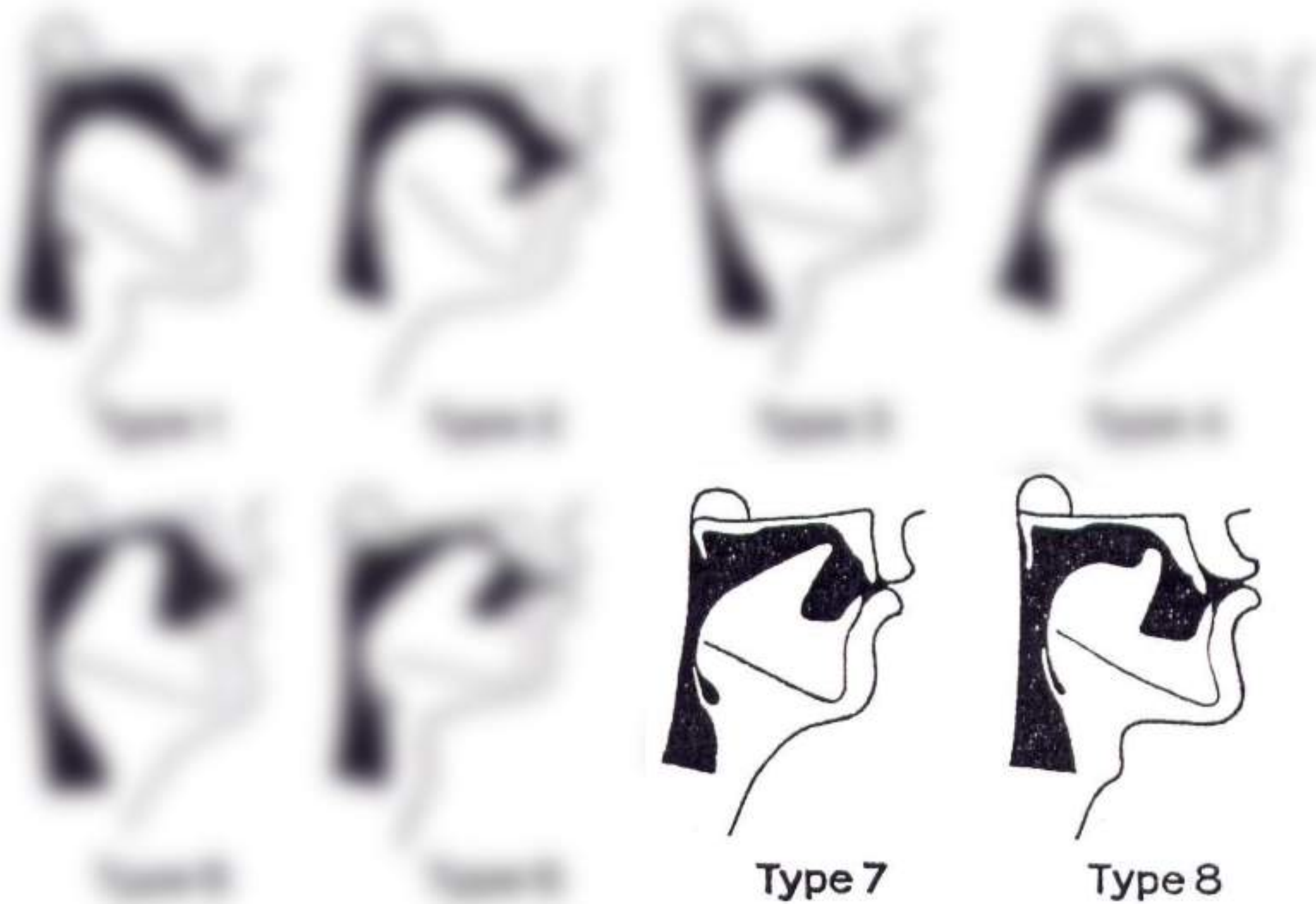
- Parallel with the covert articulation in ***/ɹ/*** reported by Mielke et al. (2016)
    - Bunchers and retroflexers

COVERT ARTICULATION OF /ɹ/



(Twist et al. 2007:208; figure adapted from Delattre & Freeman 1968:41)

COVERT ARTICULATION OF /ɹ/



(Twist et al. 2007:208; figure adapted from Delattre & Freeman 1968:41)

The articulation-acoustics mapping

- No one-to-one mapping between articulation (ultrasound) and acoustics (CoG)

	ultrasound		acoustics (CoG)
M01	categorical	↔	categorical
M02	categorical	↔	gradient
M03	gradient	↔	categorical
F01	gradient	↔	categorical
F03	none	↔	categorical
F06	none	↔	gradient
F07	none	↔	gradient
F08	none	↔	gradient

The articulation-acoustics mapping

- No one-to-one mapping between articulation (ultrasound) and acoustics (CoG)
- We have attested all but one of the six possible mappings (using these categories)
  - But, with a larger sample size, we would likely find examples of this

- categorical ↔ categorical
  - M01
- categorical ↔ gradient
  - M02
- gradient ↔ categorical
  - F01, M03
- none ↔ categorical
  - F06, F07, F08
- none ↔ gradient
  - F03
- gradient ↔ gradient
  - ...

CONCLUSIONS

Conclusions

- The /stɹ/ and /stj/ contexts behave similarly in terms of acoustic *s*-retraction and *t*-affrication

- This lends support to the idea that retraction is triggered locally by affrication and not by **/ɹ/** in a case of non-local assimilation

  - In turn, the explanation proposed by Baker et al. (2011) for the actuation of this change does not find support in BrE

- Evidence that the articulatory mechanisms behind the **/s/**-**/ʃ/** contrast are more complicated than a simple retraction of the place of articulation

  - Calls into question the suitability of “retraction” as a label for this phenomenon:

    - *s*-hushing? (i.e. hissing **/s/** > hushing **/ʃ/**)

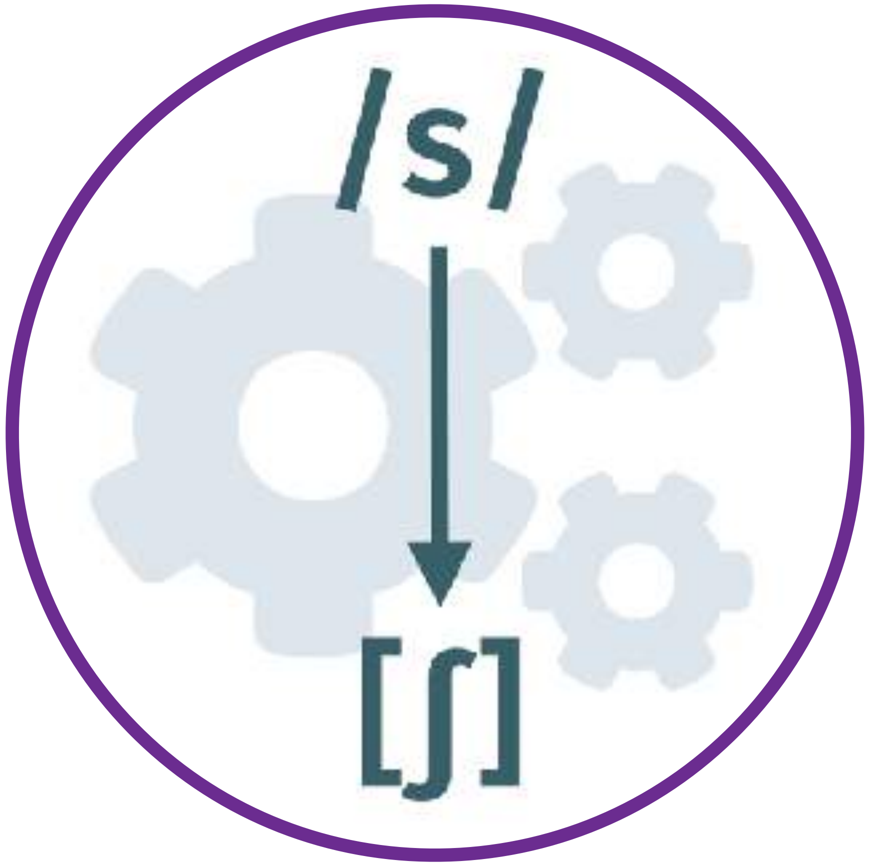
Implications

- Highlights the importance of studying in more detail the correspondences between acoustics and articulation
  - Results fit better with models where features are defined acoustically with language-specific mapping to articulatory strategies
  - See discussion in Jakobson, Fant & Halle (1952), Durand (1990:§2.5) and Boersma (2011:§4)
- Raises interesting theoretical questions regarding:

1. The acquisition and development of these different articulatory strategies
2. The role of individual differences in community-wide patterns of acoustic and articulatory variation
   - Tension between individual-level variation and the orderly nature of the community

Future work

From individual differences to community-level change: The development of *s*-hushing



- Questions:
  - How and why does similar acoustic input lead to acquisition of different articulatory patterns?
  - Do latent groups emerge due to individual differences in anatomy (e.g. cavity size) or from individual learning pathways and developmental trajectories?
- Approaches:
  - Investigating multiple articulatory dimensions (e.g. with electropalatography, lip video camera, parasagittal ultrasound)
  - Focusing on adolescents to investigate relationship between articulatory strategies and participation in community-level change

Thank you!

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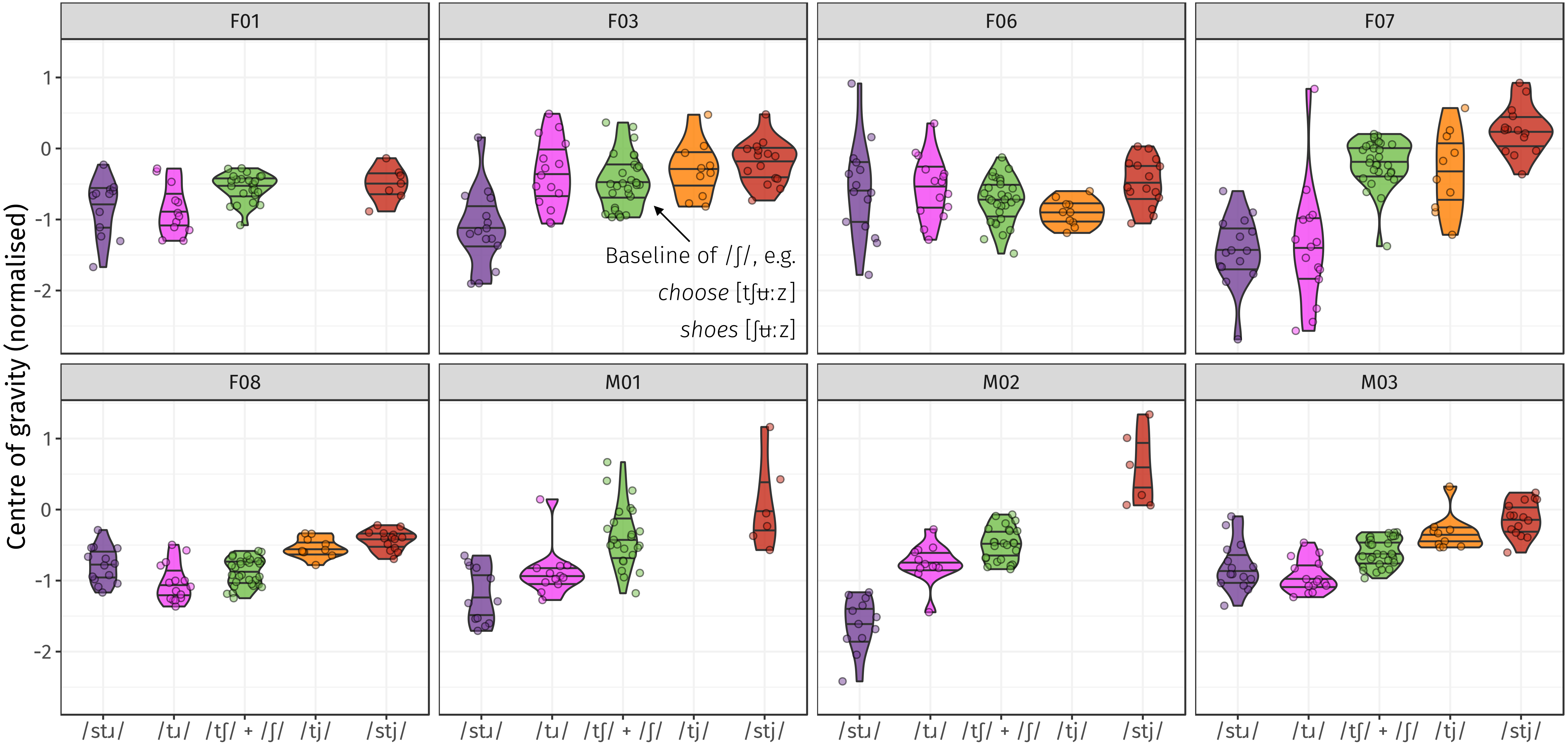
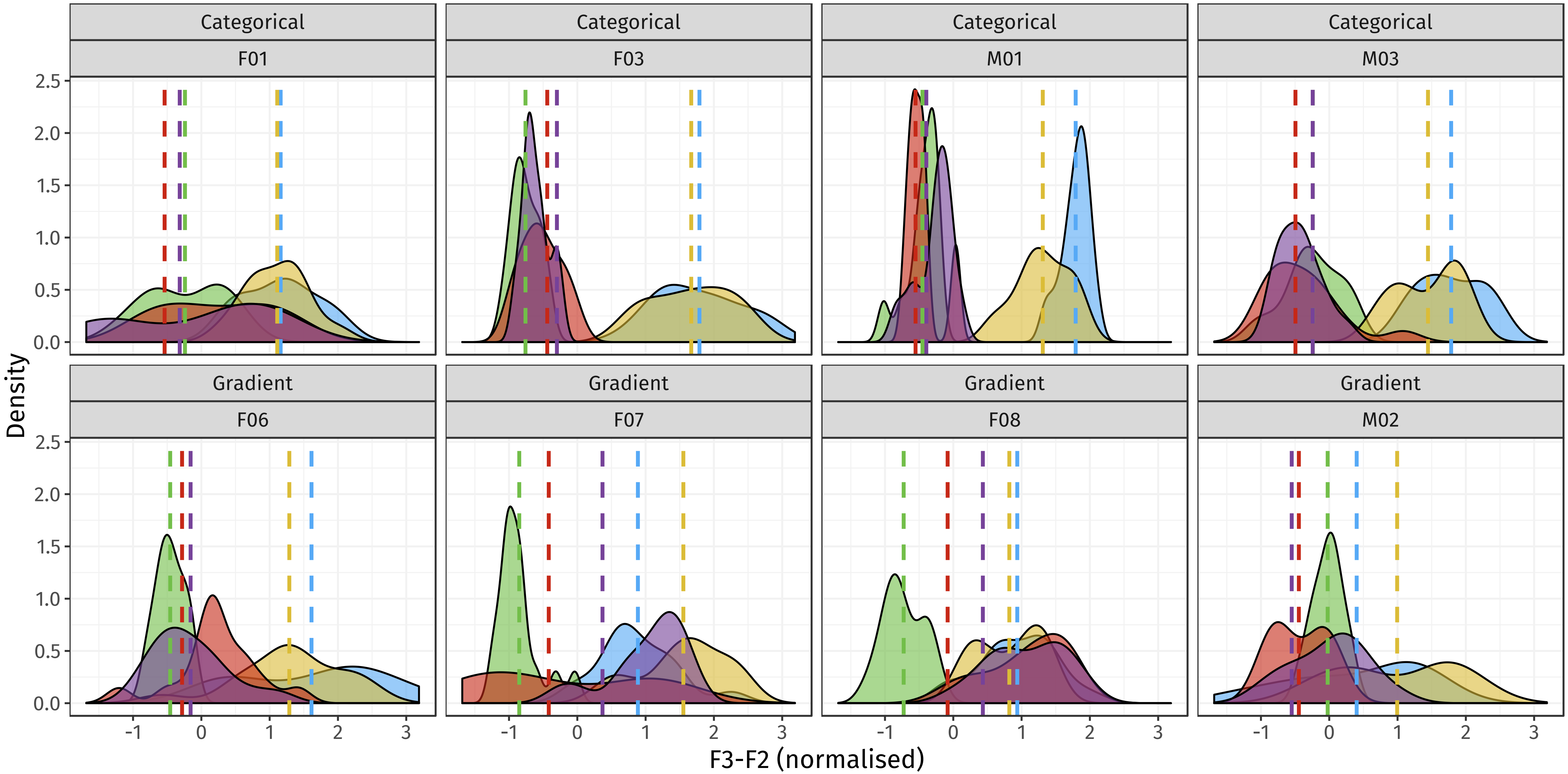
APPENDICES

AFFRICATION?

- Based on CoG, for most speakers, the fricated portions of pre-**/ɹ/** affrication and coalescence of **/tj/** are identical both to each other and to underlying **/tʃ/**
- But **some** speakers do differentiate the affricated **/t/** depending on whether it is followed by **/j/** or **/ɹ/** (see F07, M01, M02)

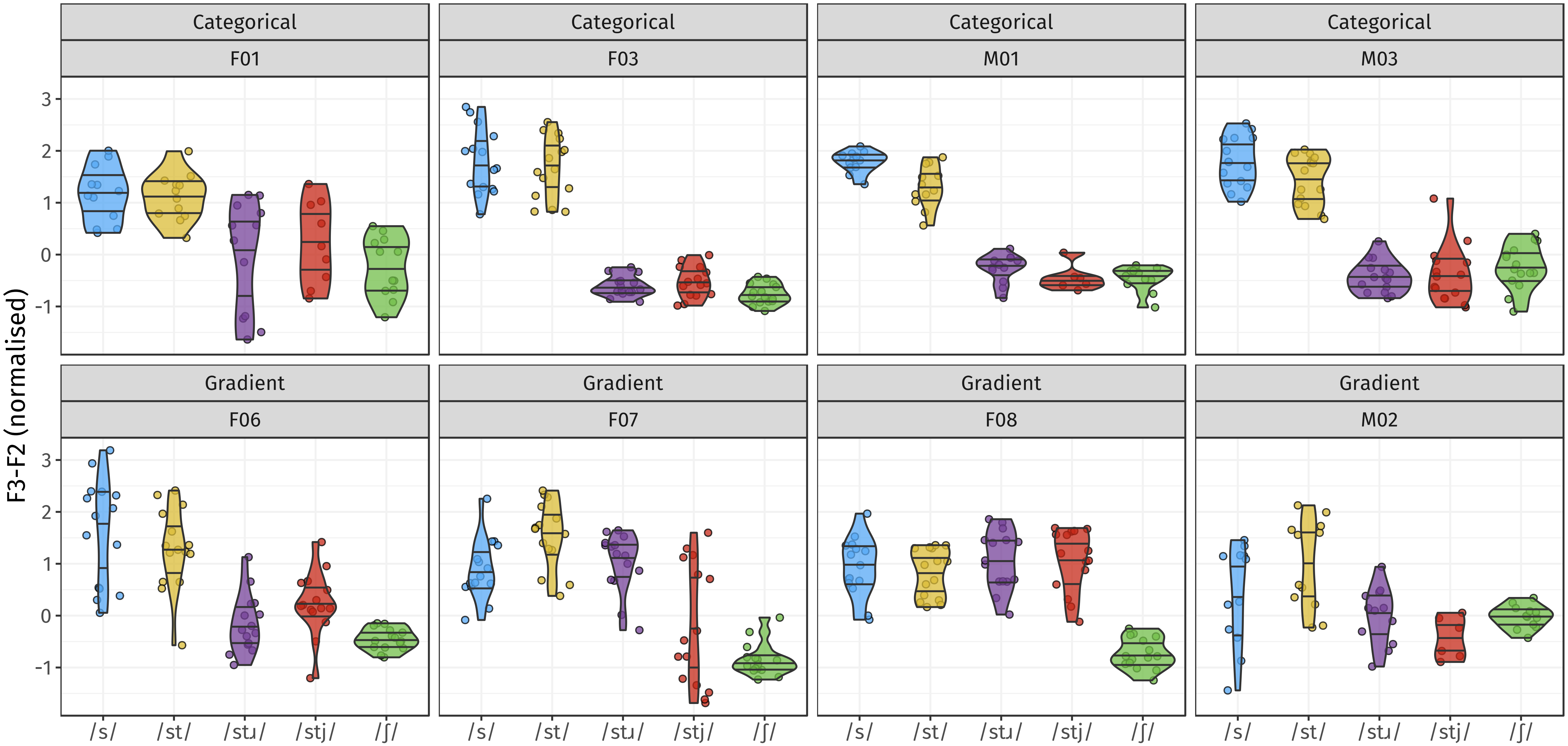


F3-F2 AND CENTRE OF GRAVITY



- F3-F2 can be used as a proxy for lip rounding (Stevens 2000:291)
- For some speakers, there is a clear relationship between CoG and lip rounding
  - More **/ʃ/**-like tokens exhibit lower CoG and more lip rounding
  - More **/s/**-like tokens show higher CoG but less lip rounding
- However, many speakers show no such pattern, with much higher within-category variation
- Perhaps because lip rounding isn't being used as a primary cue in sibilant production? (cf. Bang et al. 2018 on Seoul Korean)

F3-F2 AND CENTRE OF GRAVITY



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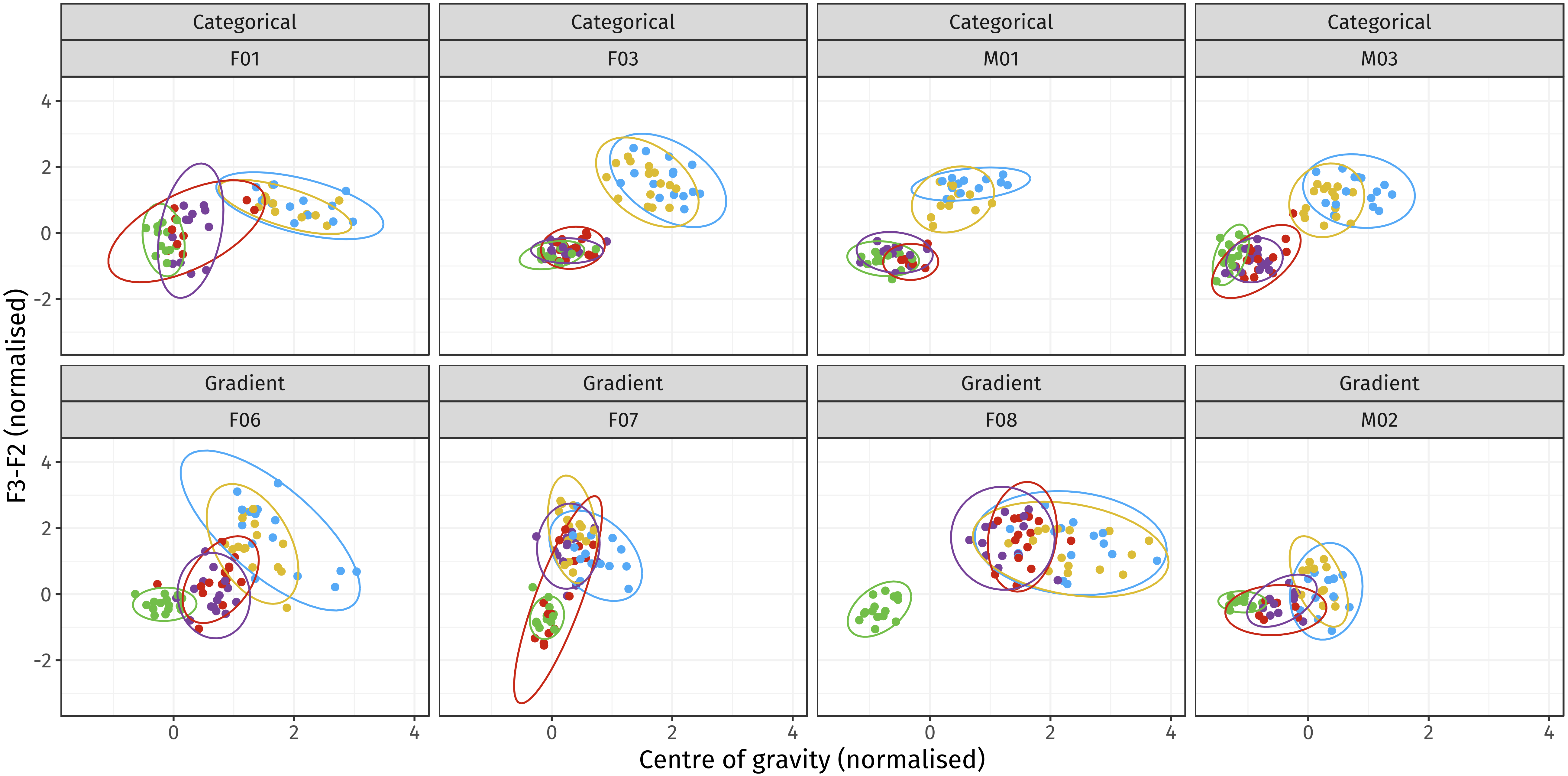
F3-F2 and centre of gravity



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Future work

- **The next steps:** collect direct articulatory data on these other mechanisms
  - Electropalatography (EPG)
  - Electromagnetic articulography (EMA)
  - Parasagittal UTI
  - Video recording for lip-rounding (rather than using F3-F2 as a proxy)
  - Also: dynamic articulatory analysis of /stɹ/ and /stj/ clusters