

An ultrasound study of frequency and co-articulation

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Research Question

Can we detect the word frequency effect in ultrasound recordings of co-articulation? → YES.

Aims

High
Low

← Freq. Pron. Suffix

sie sa_agen
[zi: za:gn]

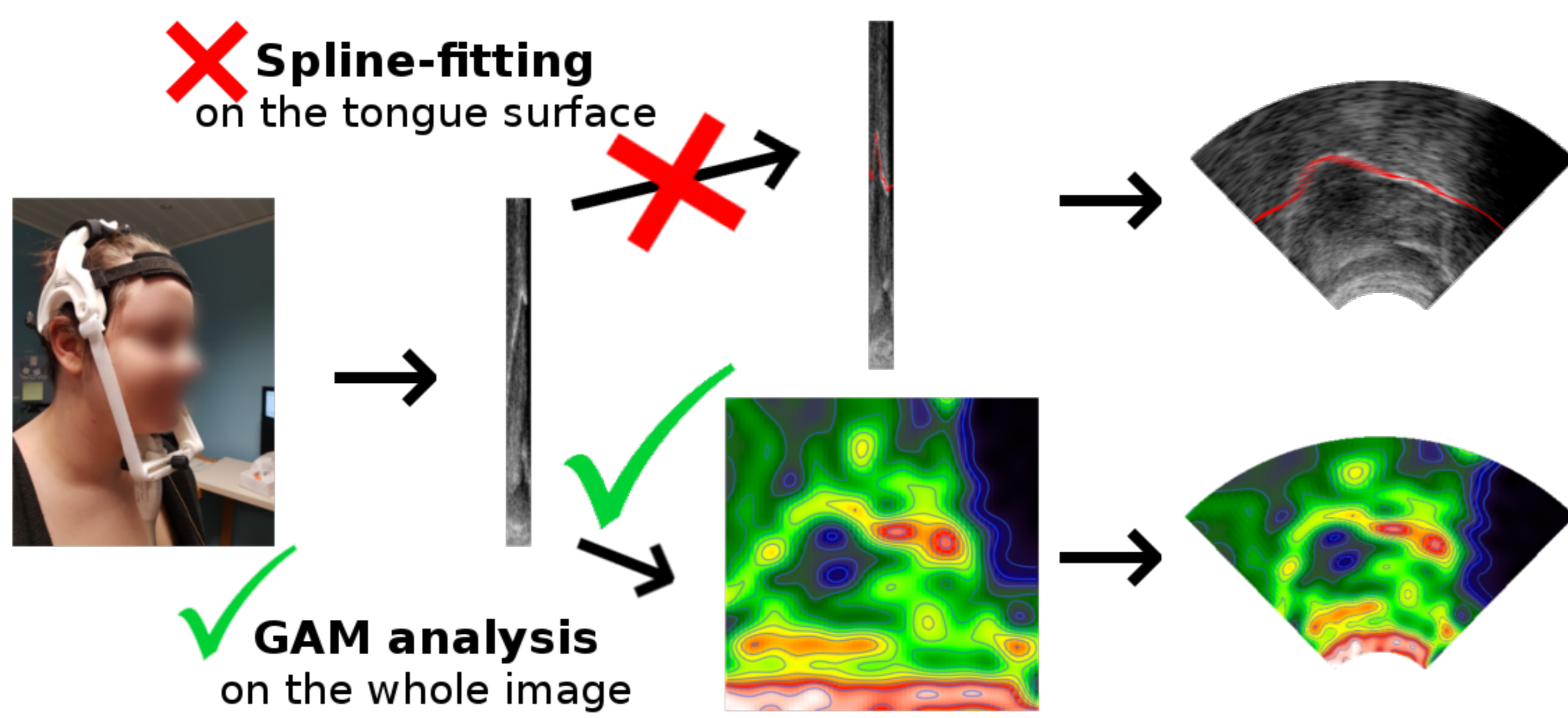
vs.

ihr strah_alt
[i:ɐʃtʁa:lt]

Are they different??

Theoretical
Frequency effect in coarticulation patterns [3, 6, 5]

Methodological
Whole-image analysis with GAM [2, 4, 1]

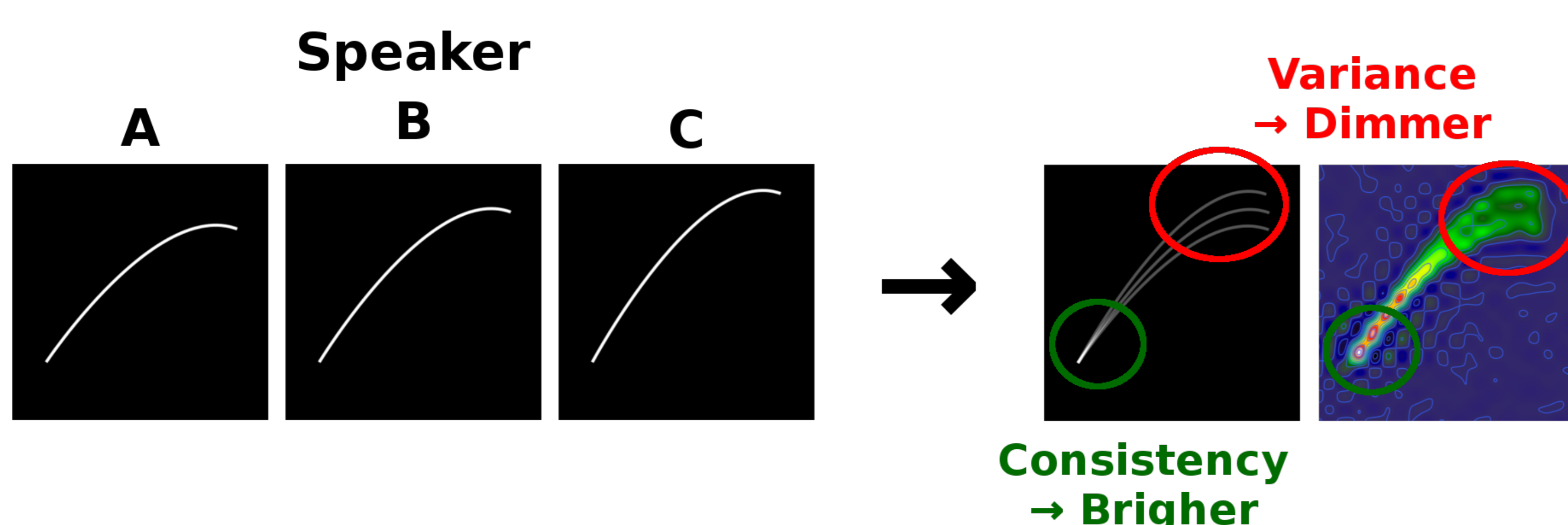


Methods

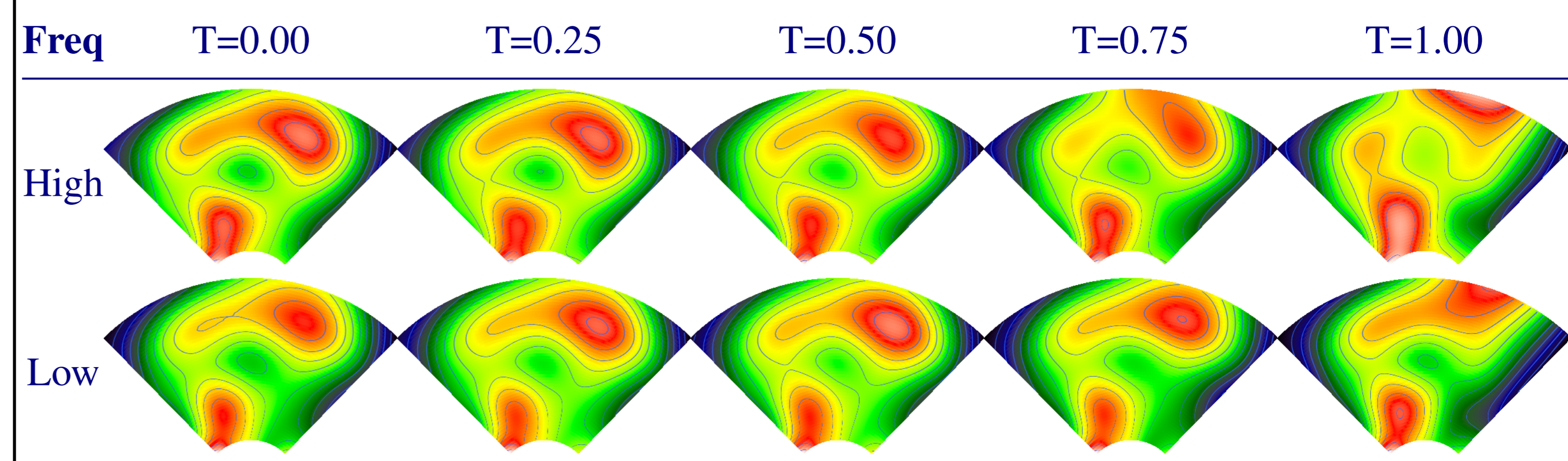
- **Recording**
 - Ultrasound imaging
 - Quantification with Generalized Additive Mixed Effects Models (GAMs)^[7]
- **Participants**
 - 20 native speakers of German
- **Target words**
 - 138 German inflected verbs with their corresponding pronouns
 - Monosyllabic when a suffix is [-t]

- Disyllabic when a suffix is [-ən]
 - Stem vowel = [a:]
 - 4 surroundings conditions
- | | Suffix | |
|---------|----------|-----------|
| Pronoun | [-t] | [-n] |
| [-i:] | sie malt | sie malen |
| [-iɐ] | ihr malt | wir malen |
- **Predictors**
 - x and y coordinates
 - Time (0.00, 0.25, 0.50, 0.75, 1.00)
 - Surroundings condition
 - Frequency (log)

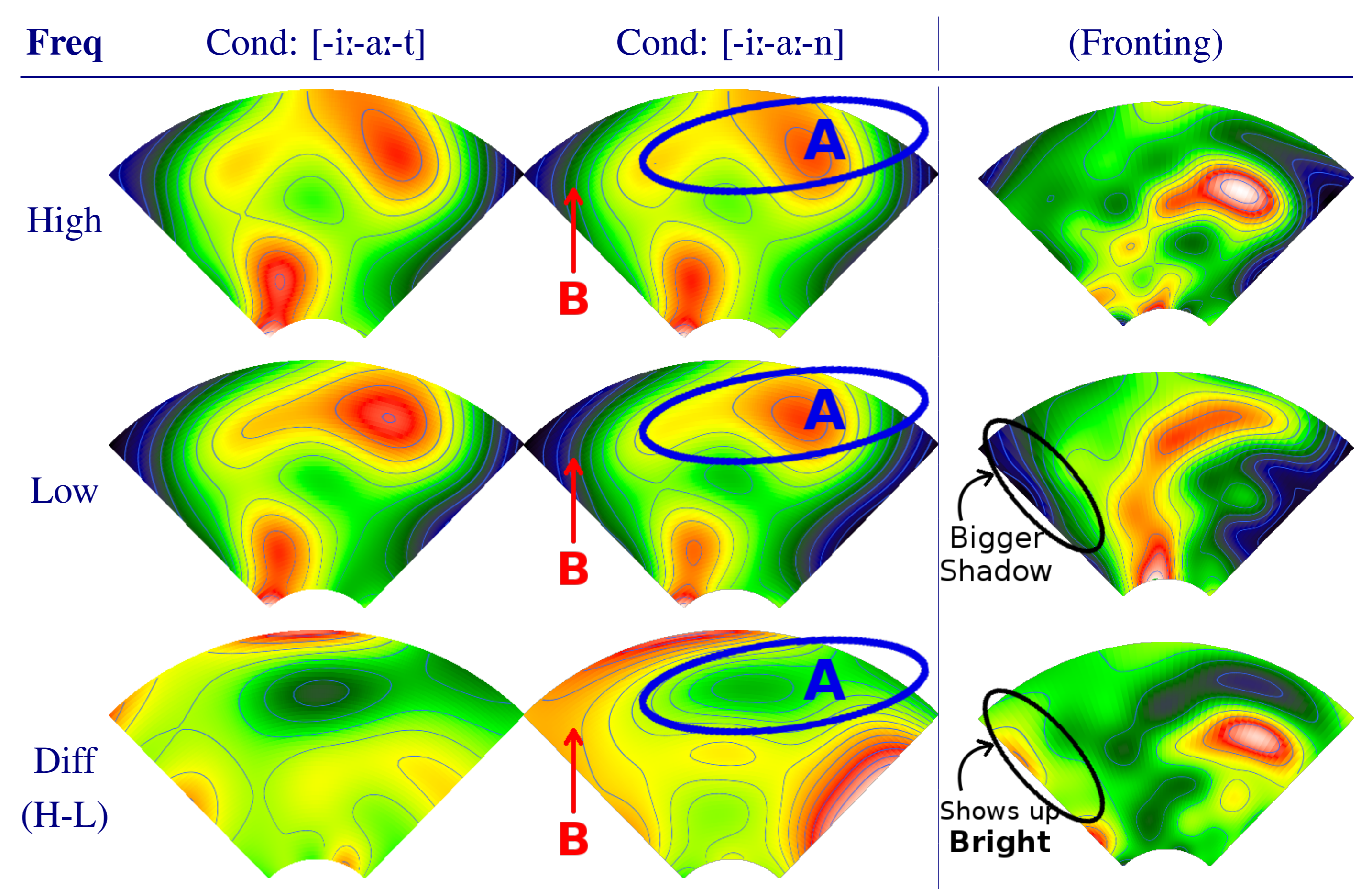
Interpretation of fitted ULT images



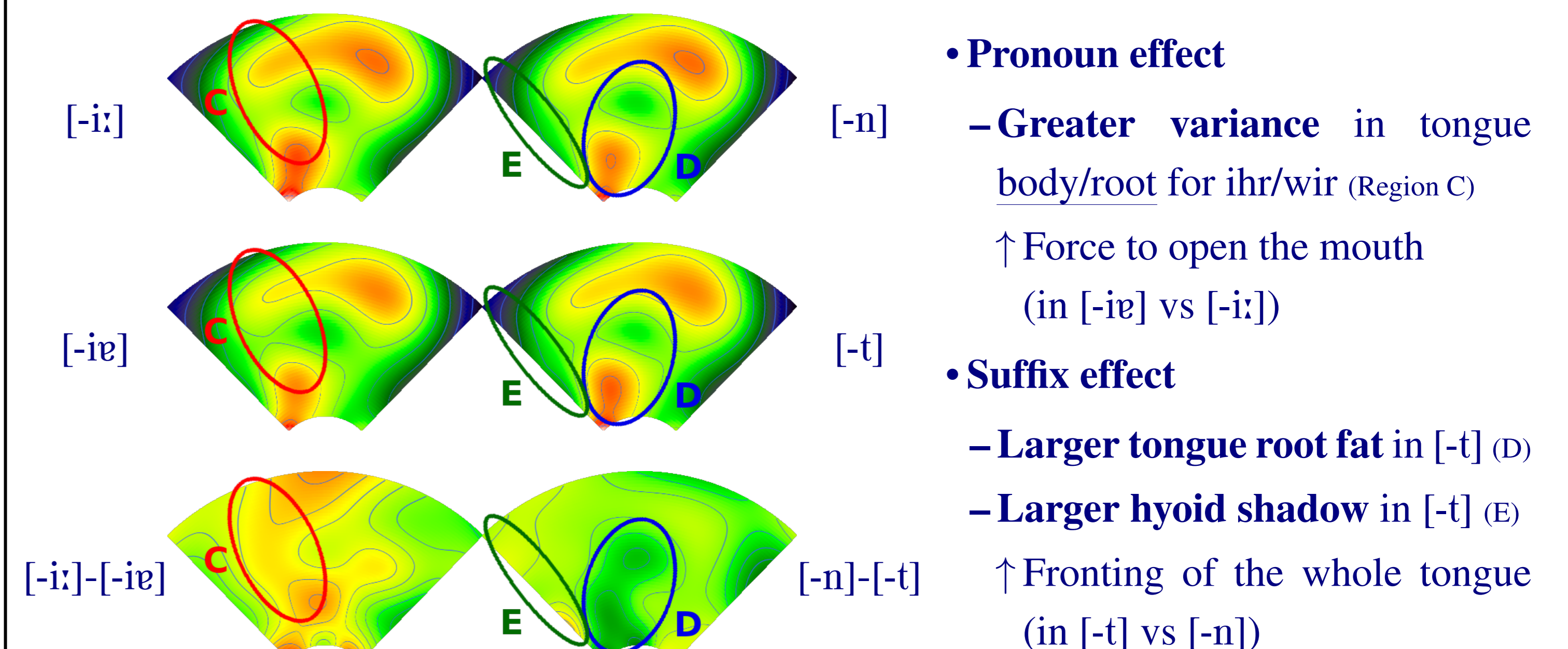
Results



Qualitative difference in coarticulation is the most visible in T=0.75



- **Brighter** in Diff → **Brighter** in High freq.
- **Darker** in Diff. → **Darker** in High freq.
- **Low** frequency (compared to high freq.)
 - **Lower** tongue body (Regions A & B)
 - **Higher** tongue tip (Region A)
 - **More fronted** tongue root (Region B)



Conclusion

1. Qualitative difference in articulation as a function of frequency.
2. Coarticulation with pronouns as well as suffixes.
3. GAM is a useful tool for the analysis of ultrasound images.

References

- [1] Jérôme Aubin and Lucie Ménard. Compensation for a labial perturbation: An acoustic and articulatory study of child and adult French speakers. 7th International Seminar on Speech Production, 2006.
- [2] Lisa Davidson. Comparing tongue shapes from ultrasound imaging using smoothing spline analysis of variance. The Journal of the Acoustical Society of America, 120(1):407–415, 2006. ISSN 0001-4966. doi: 10.1121/1.2205133.
- [3] Willem J. M. Levelt, Ardi Roelofs, and Antje S. Meyer. A theory of lexical access in speech production. Behavioral and Brain Sciences, 22:1–75, 1999.

- [4] Maureen Stone, Moise H. Goldstein, and Yongqing Zhang. Principal component analysis of cross sections of tongue shapes in vowel production. Speech Communication, 22(2-3):173–184, 1997. ISSN 01676393. doi: 10.1016/S0167-6393(97)00027-7.
- [5] Fabian Tomaschek, Denis Arnold, Franziska Bröker, and R. Harald Baayen. Lexical frequency co-determines the speed-curvature relation in articulation. Journal of Phonetics, 68:103–116, 2018.
- [6] Fabian Tomaschek, Benjamin V. Tucker, Matteo Fasiolo, and R. Harald Baayen. Practice makes perfect: the consequences of lexical proficiency for articulation. Linguistics Vanguard, 4, 2018.
- [7] Simon N. Wood. Generalized Additive Models: An Introduction with R. CRC Press, Boca Raton, Florida, U.S.A., 2006. ISBN 9781420010404.