

Perception compared to clustered intonation variation in German *wh*-questions

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Contour clustering: background

- Cluster analysis of F0 contours: emerging method in the analysis of tone and intonation (Kaland, 2023; Kaland, Steffman & Cole, 2024)
 - Post-lexical intonation in Cantonese (Li, Nolan & Post, 2023)
 - MAE-ToBI inventory (Steffman, Cole & Shattuck-Hufnagel, 2024)
 - Sarcasm in AmE (Tatár, Brennan, Krivokapić & Keshat, 2024)
 - Intonation and tone in under-researched languages (e.g., Zahrer, 2024)
- App: <https://constantijnkaland.github.io/contourclustering/>
- Today: Link of cluster analysis to **perception**?



Background for this study: Seeliger & Kaland (2022)



- Dataset: 1109 German *wh*-questions and *wh*-exclamatives (Repp & Seeliger, under review)
- Q: Can cluster analysis of F0 contours result in **phonologically meaningful** clusters?
- A: Yes, for example:
 - “Late low accents followed by rise”
 - “Rise-fall-rise contours starting in the middle of the utterance”
 - “Unexpected medium-high plateaus, some followed by late falls”

L* H-^H%

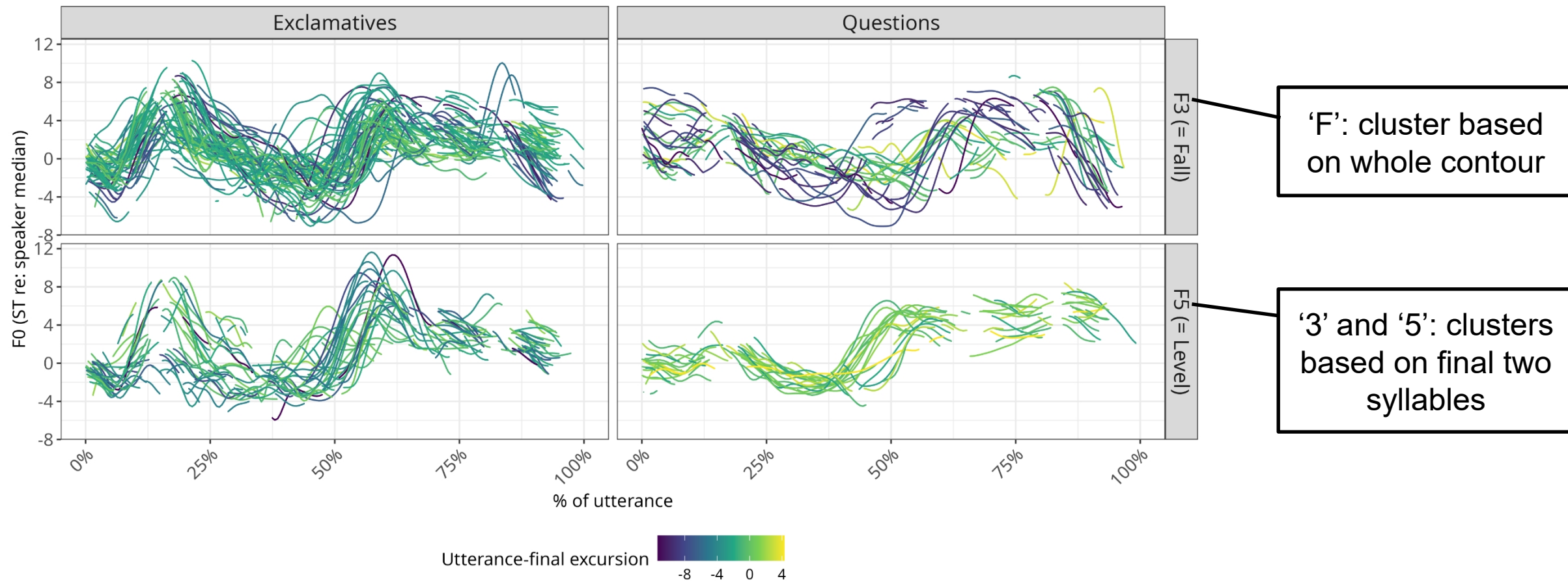
L+H* L-H%

H-% ?

!H-% ?

H-L% ?

Plateau clusters from Seeliger & Kaland (2022)



Background for this study:

Seeliger, Lützeler & Kaland (2023) [SLK 2023]



- **Perception study**: subset of the **plateau contours** (only questions)
- Hummed contours: no lexical/segmental information
- Q: Are the clusters distinct in perception?
- A: Yes, but...
 - Yes: within-cluster comparisons more similar than between-cluster
 - But: very large influence from duration and F0 register differences
 - Late falls differed in pitch movement, register *and* duration

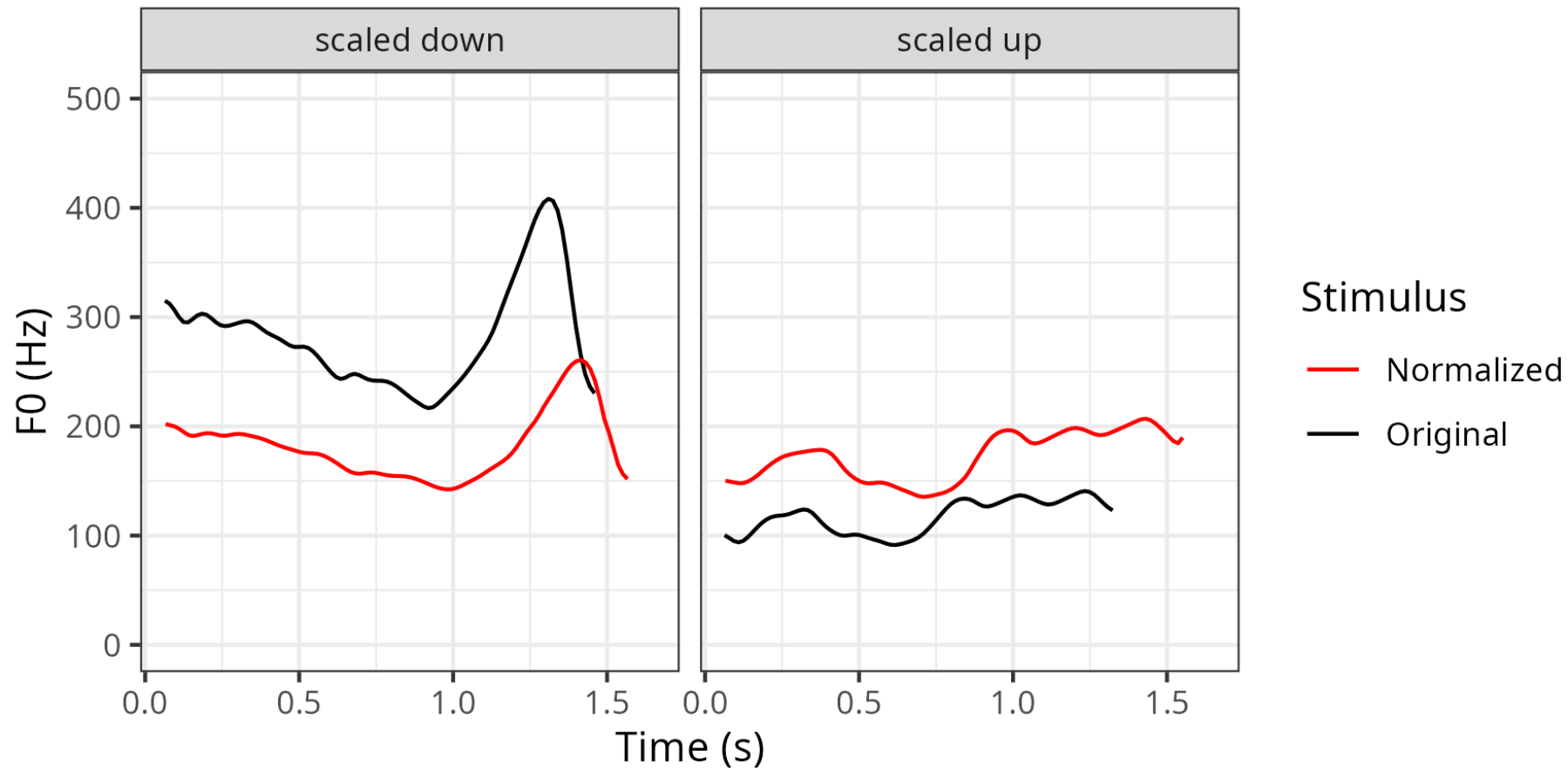
Research question today

- If we control **contour duration** and **F0 register**:
 - Are same-cluster contours still judged to sound more similar than different-cluster contours?

Methodology: Differences to previous study

	SLK 2023	This study
Stimuli	10 from each cluster	5 from each cluster
Comparisons	Mostly between-cluster	All combinations
Selection criteria	Most typical contours	Balancing for speakers & gender
Duration	Original	Normalized → mean
F0 register	Original	Normalized → median
F0 range	Original	Original

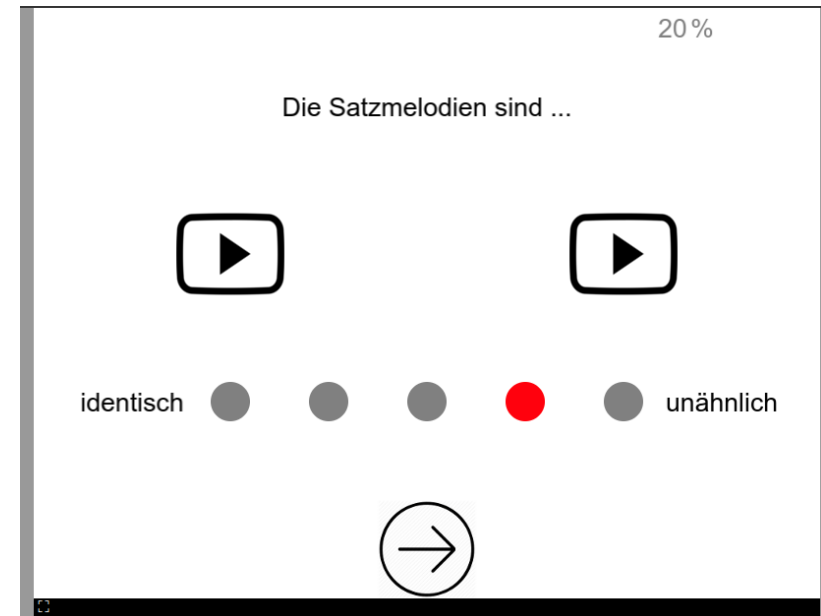
Methodology: F0 normalization



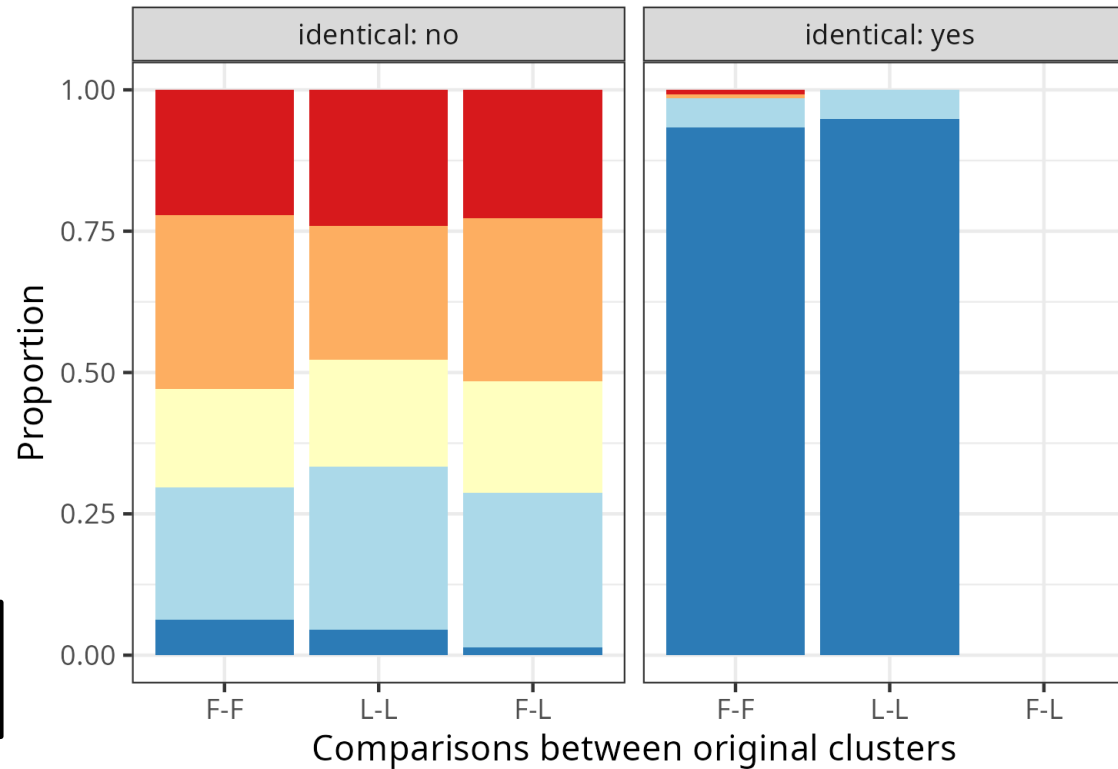
$$Norm(F0_i) = \frac{F0_i \times median(F0_{data})}{median(F0_{contour})}$$

Methodology: Perception task

- Run on PsyToolkit (Stoet, 2010, 2017)
- 27 native listeners of German
- Contours were played in pairs; similarity of pair judged
- 5-point rating scale (end points: *identisch*, 'identical' and *unähnlich*, 'dissimilar')
- 1485 total similarity ratings



Results: Overall

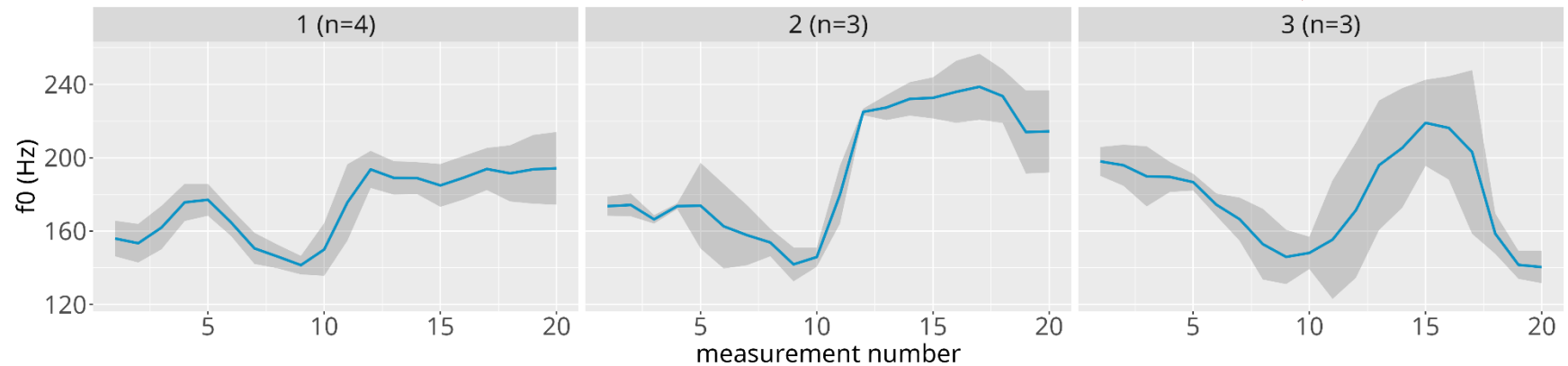
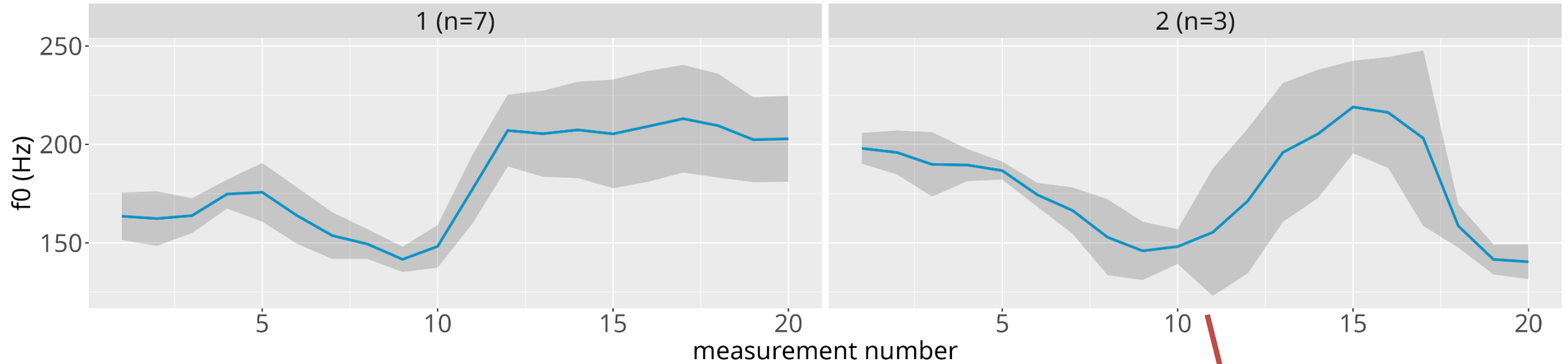


Cumulative link mixed model:
no significant differences

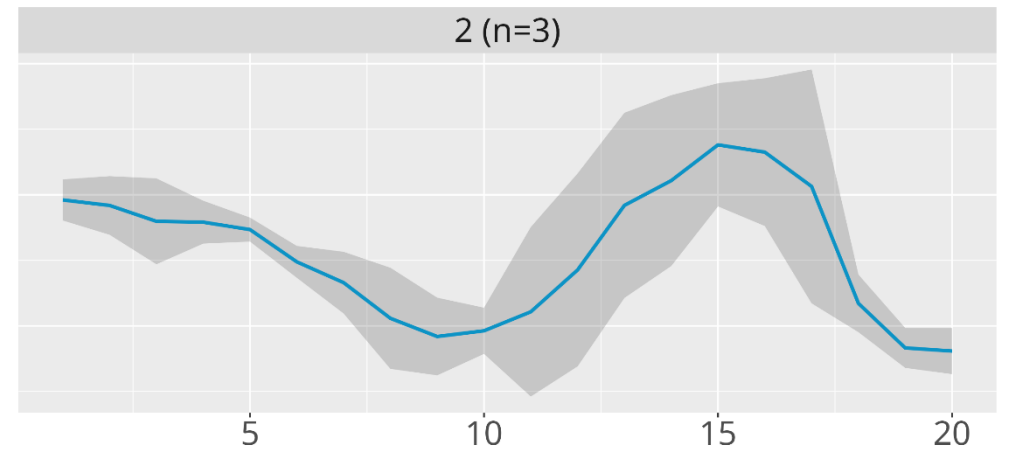
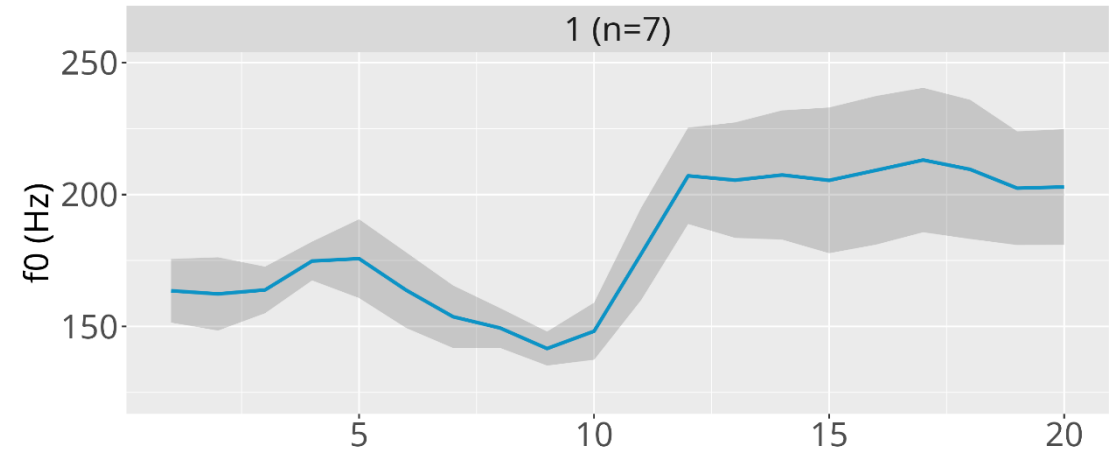
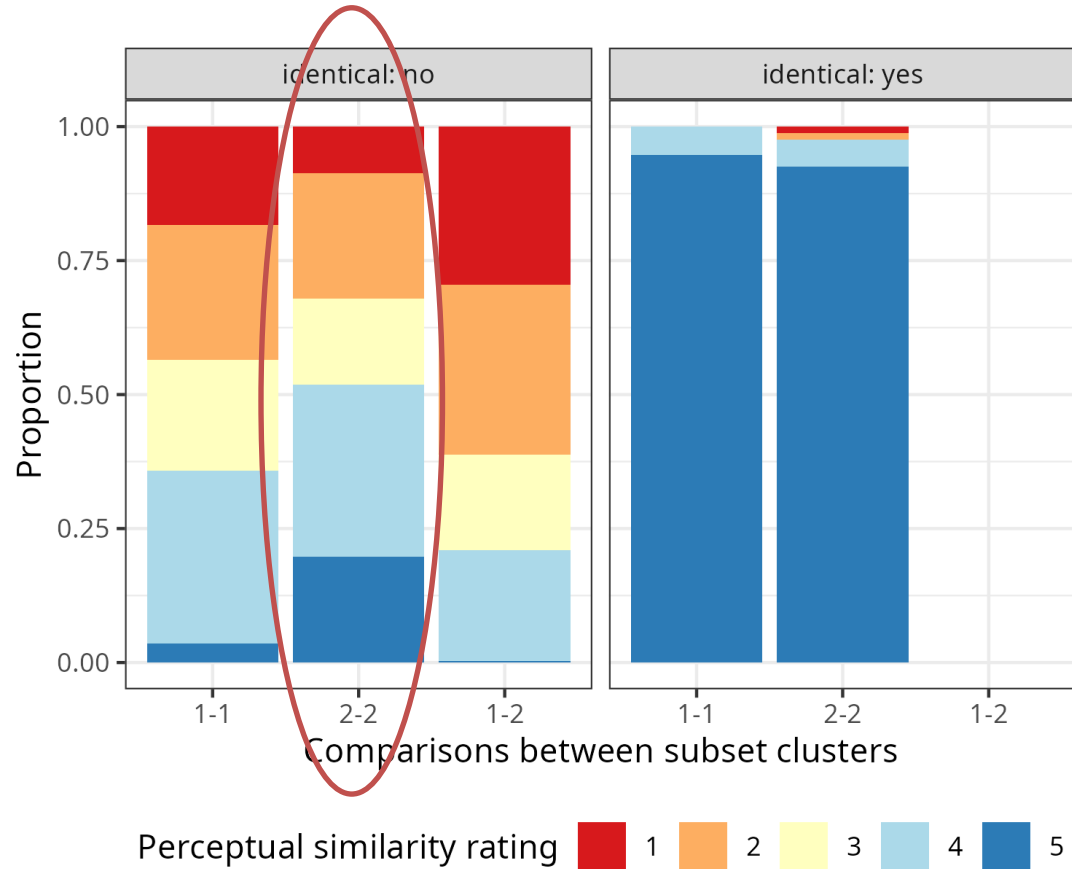
F: Falling cluster
L: Level cluster

Perceptual similarity rating 1 2 3 4 5

Results: Subset cluster analysis

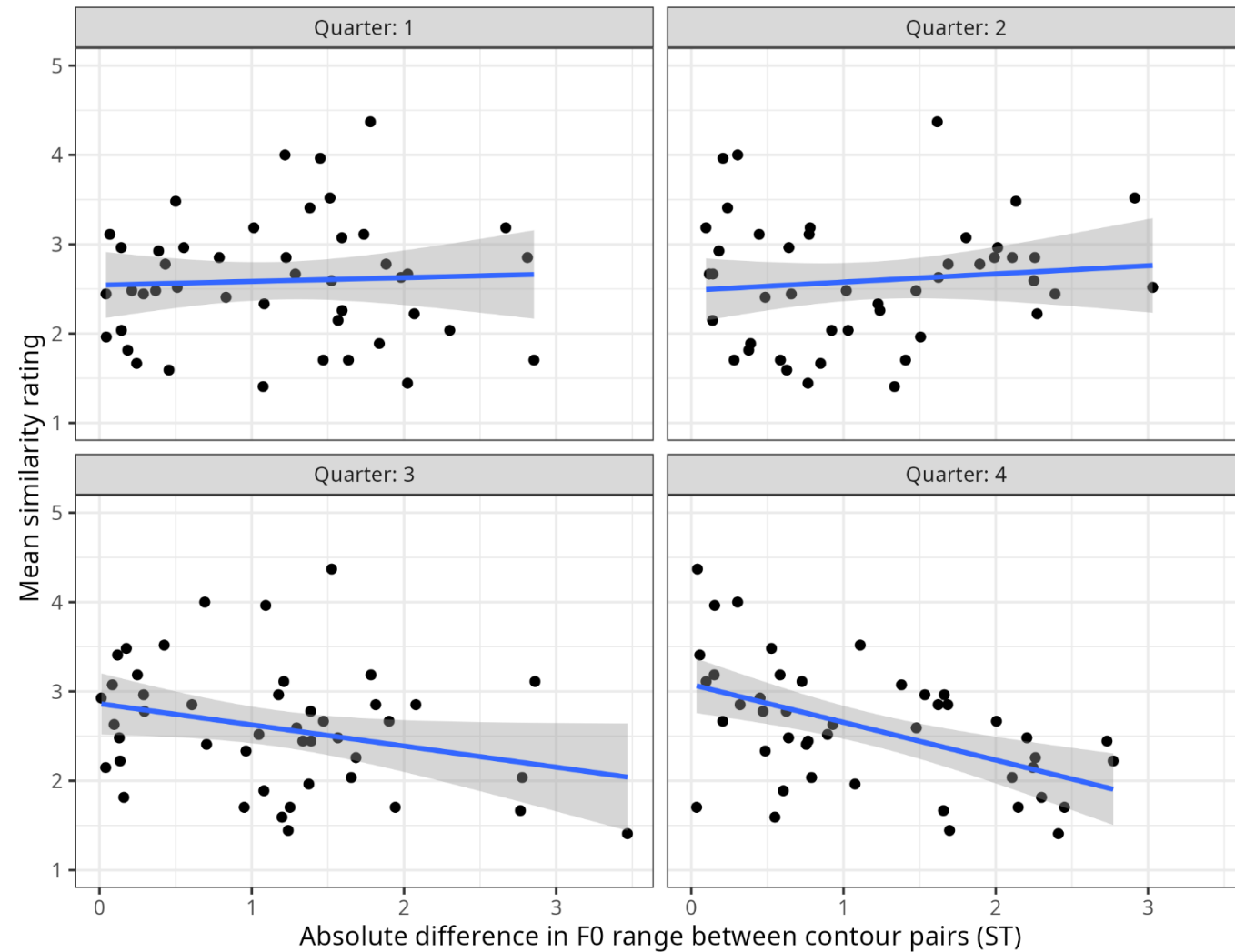


Results: Perceived similarity in new clusters



Cumulative link mixed model:
 $2-2 > 1-2; p < 0.01$
 $1-1 > 1-2; p < 0.05$

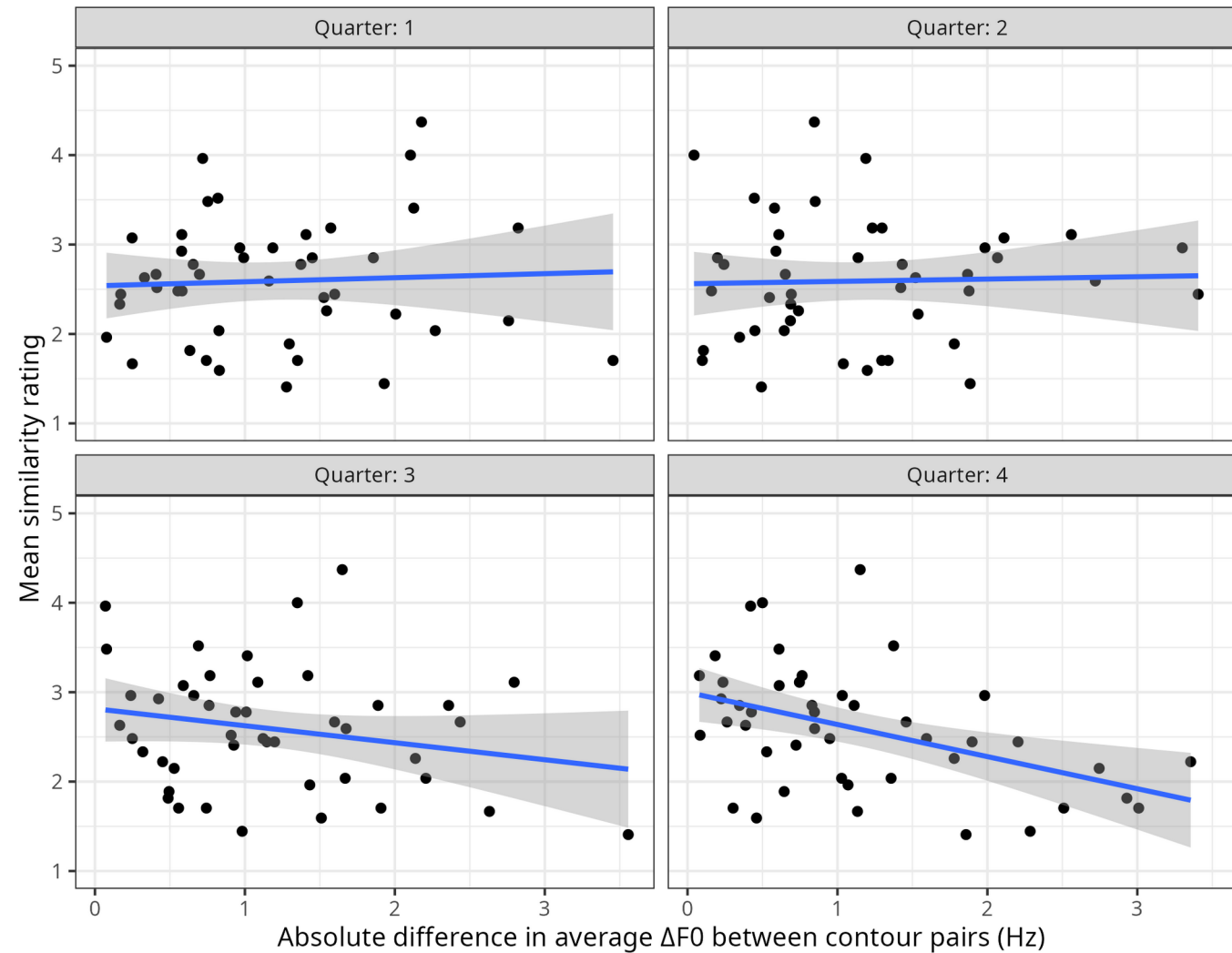
Results: Correlations over time – F0 range



(Identical contours excluded)

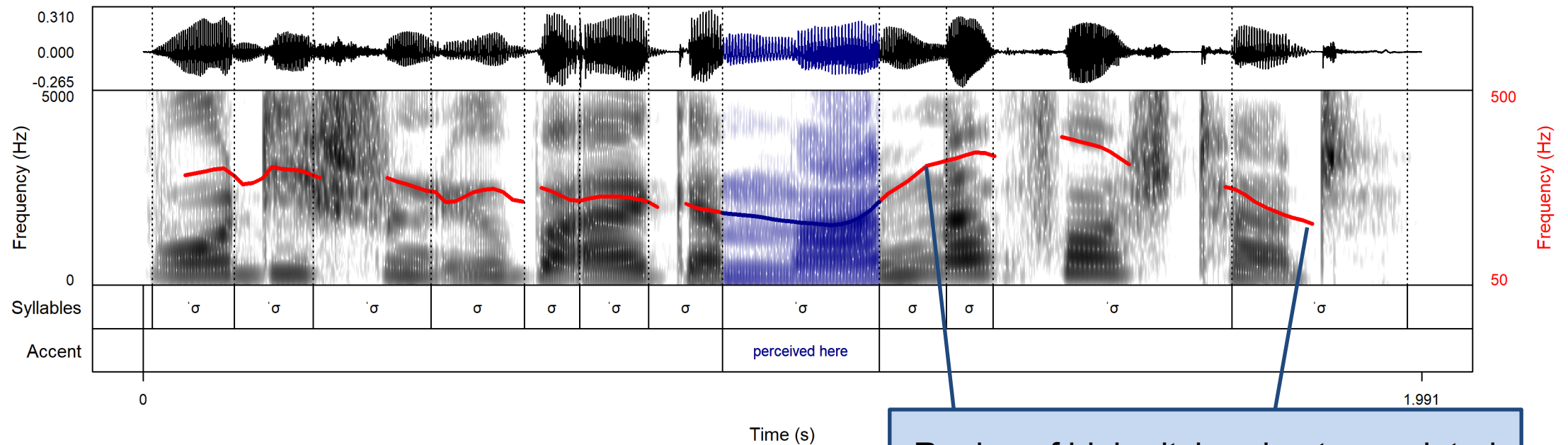
Results: Correlations over time – $\Delta F0$

$$\Delta F0 = \frac{1}{n} \sum_{i=1}^n |F0_i - F0_{i+1}|$$



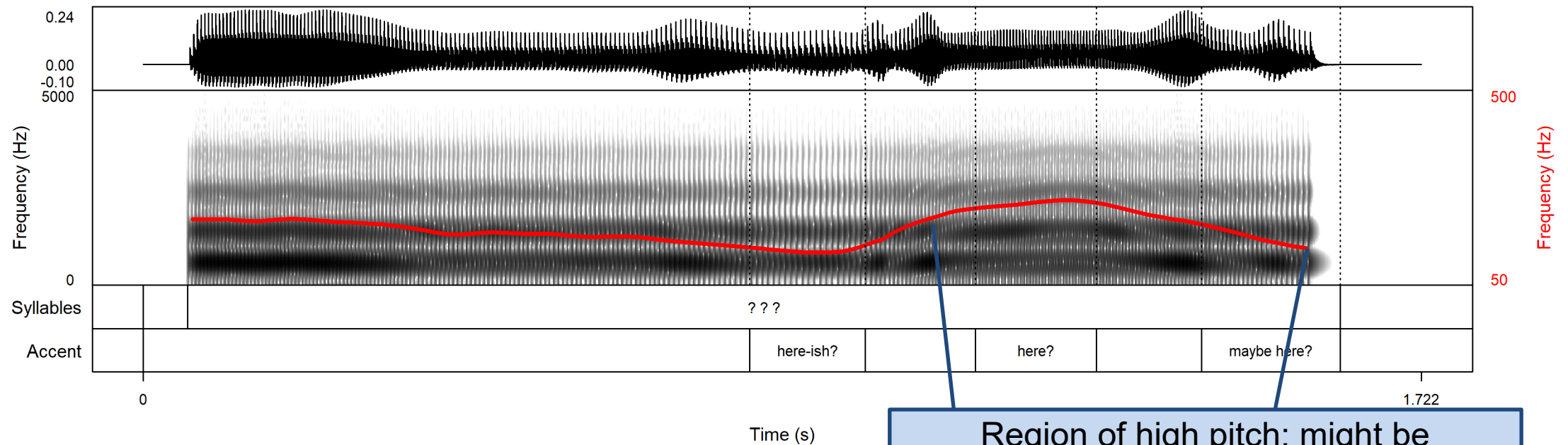
(Identical contours excluded)

Aside: On the phonology of hummed contours



Region of high pitch: edge tone related
(cf. Grice, Ladd & Arvaniti, 2000)

Aside: On the phonology of hummed contours



Summary & discussion

- Duration and register normalization brought out subtle differences
- General finding: Listeners are more sensitive to F0 differences in the second halves of utterances
 - Recency?
 - Influence of nuclear contour?

Summary & discussion

- Original clusters were indeed mixed (maybe not surprising: they formed one cluster based on the whole contour)
- But cluster analysis performed on the stimulus subset results in perceptually distinct clusters
- Clustered differences \approx perceived differences

Acknowledgements

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Appendix

