Reconstructing *Pink Floyd* from human auditory cortex

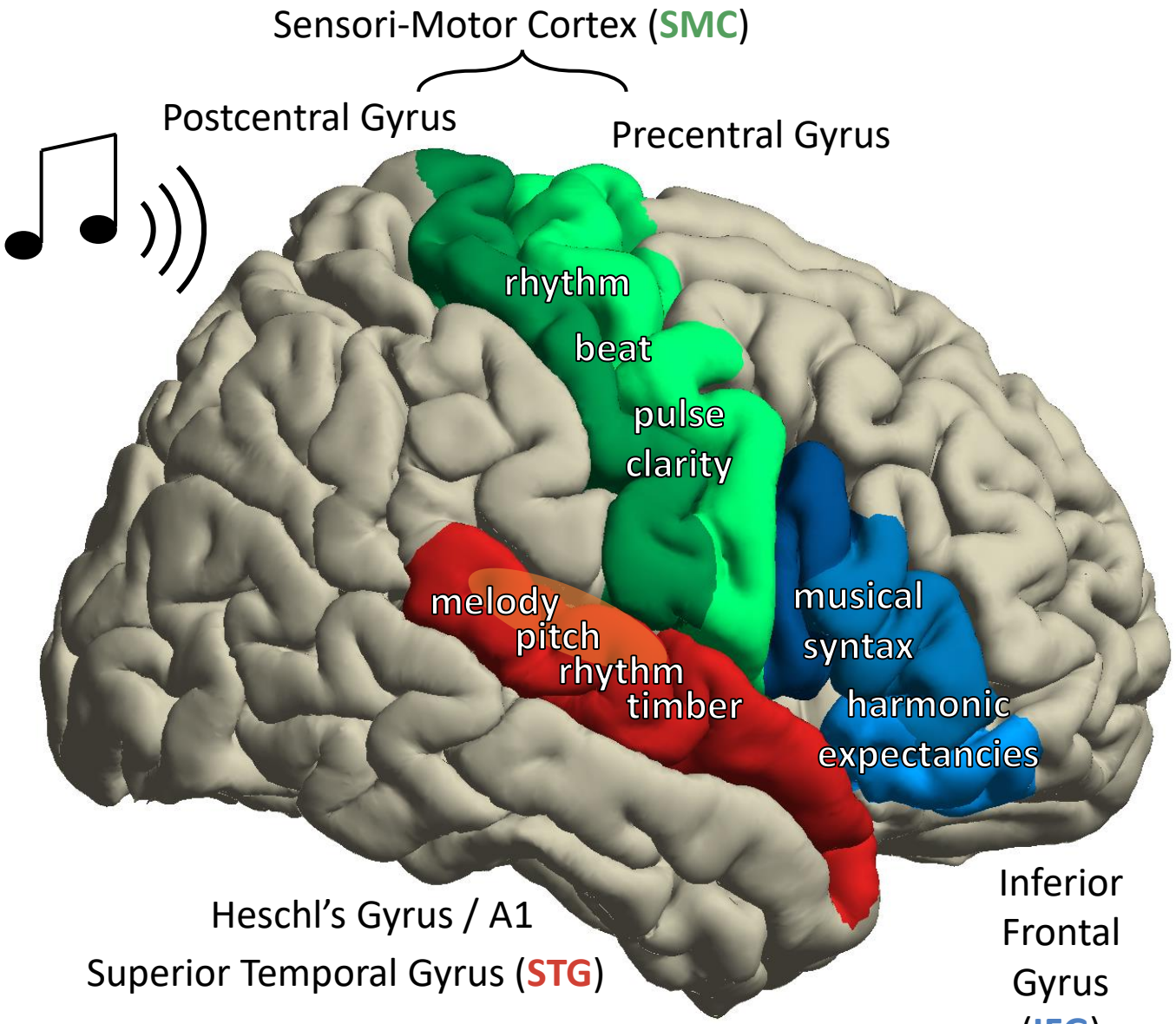
Ludovic Bellier, Knight lab, UC Berkeley

(now at INSCOPIX A BRUKER COMPANY)

Berkeley UNIVERSITY OF CALIFORNIA

FONDATION POUR L'AUDITION À L'ÉCOUTE DE LA VIE

Music perception in the human brain



- relative preference for the right hemisphere
- + planum temporale, STS, supramarginal gyrus, anterior insula, frontal operculum, SMA, dlPFC…
- (emotion, social cognition, memory and attention)

Peretz & Zatorre, 2005; Limb, 2006; Koelsch, 2011; Zatorre & Salimpoor, 2013; Janata, 2015

Rationale

We know **where**, we kind of know **what**, but…

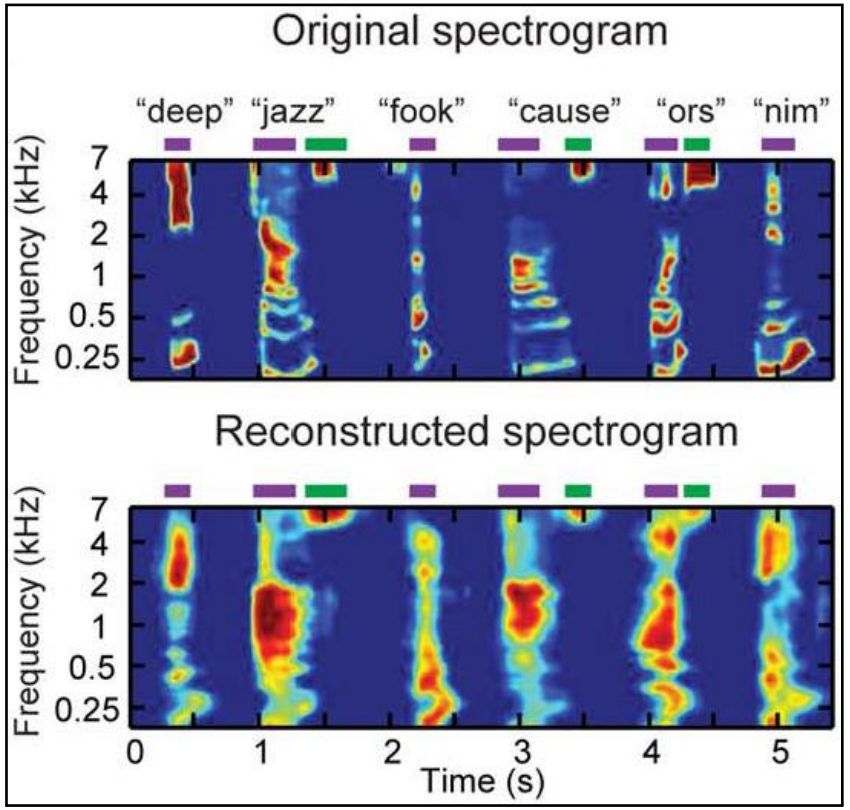
How is musical information encoded in the human brain?

Neural dynamics of music perception?
Neural code for music?

BCI motivations:

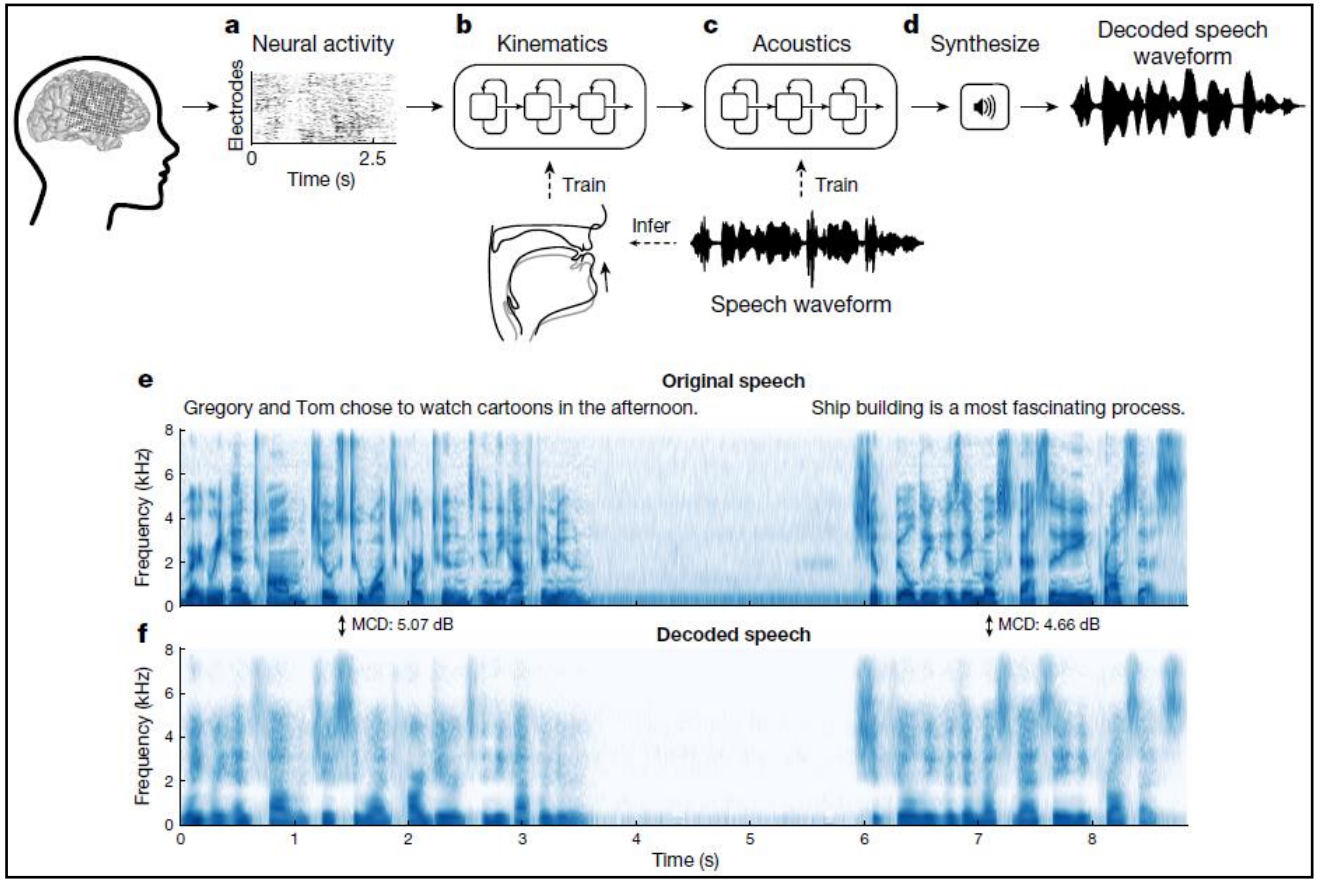
- feature engineering for reconstructing music and beyond
- improve prosody in speech decoding

Previous reconstruction successes in speech



"reconstruction quality at present is not clearly intelligible to a human listener"

Pasley et al., 2012



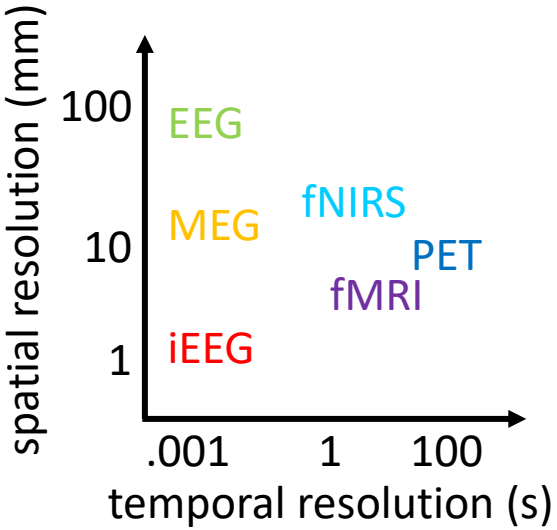
Anumanchipalli et al., 2019

➢ **to what extent can we reconstruct music itself?**

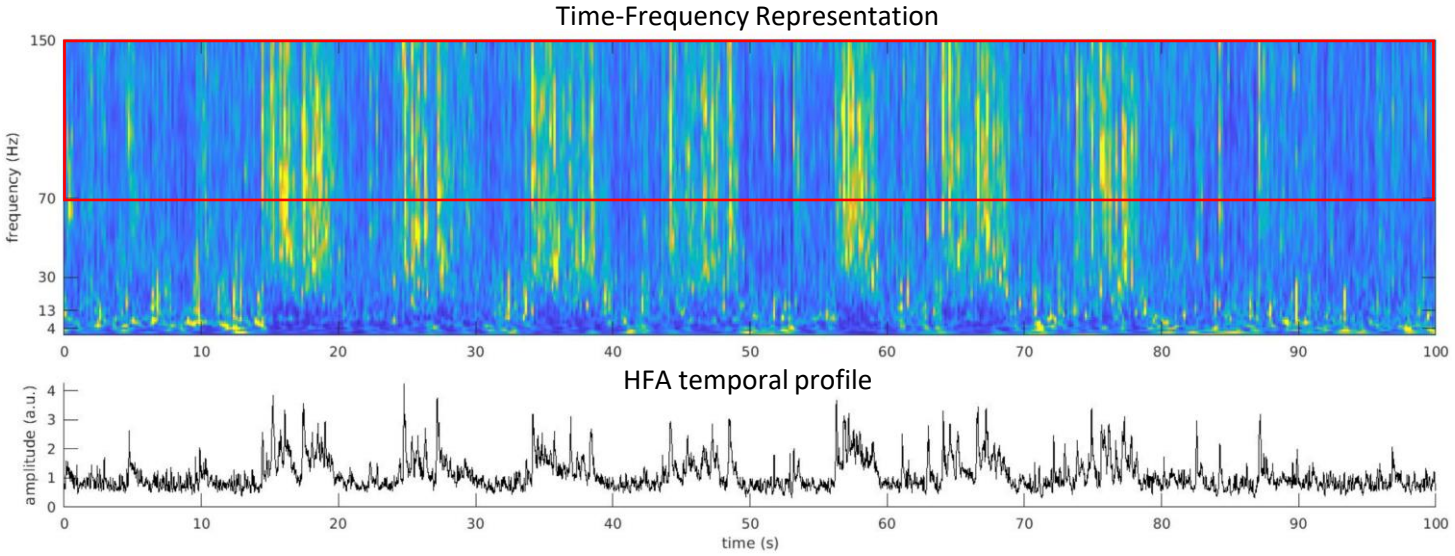
(its acoustics in a regression-based approach)

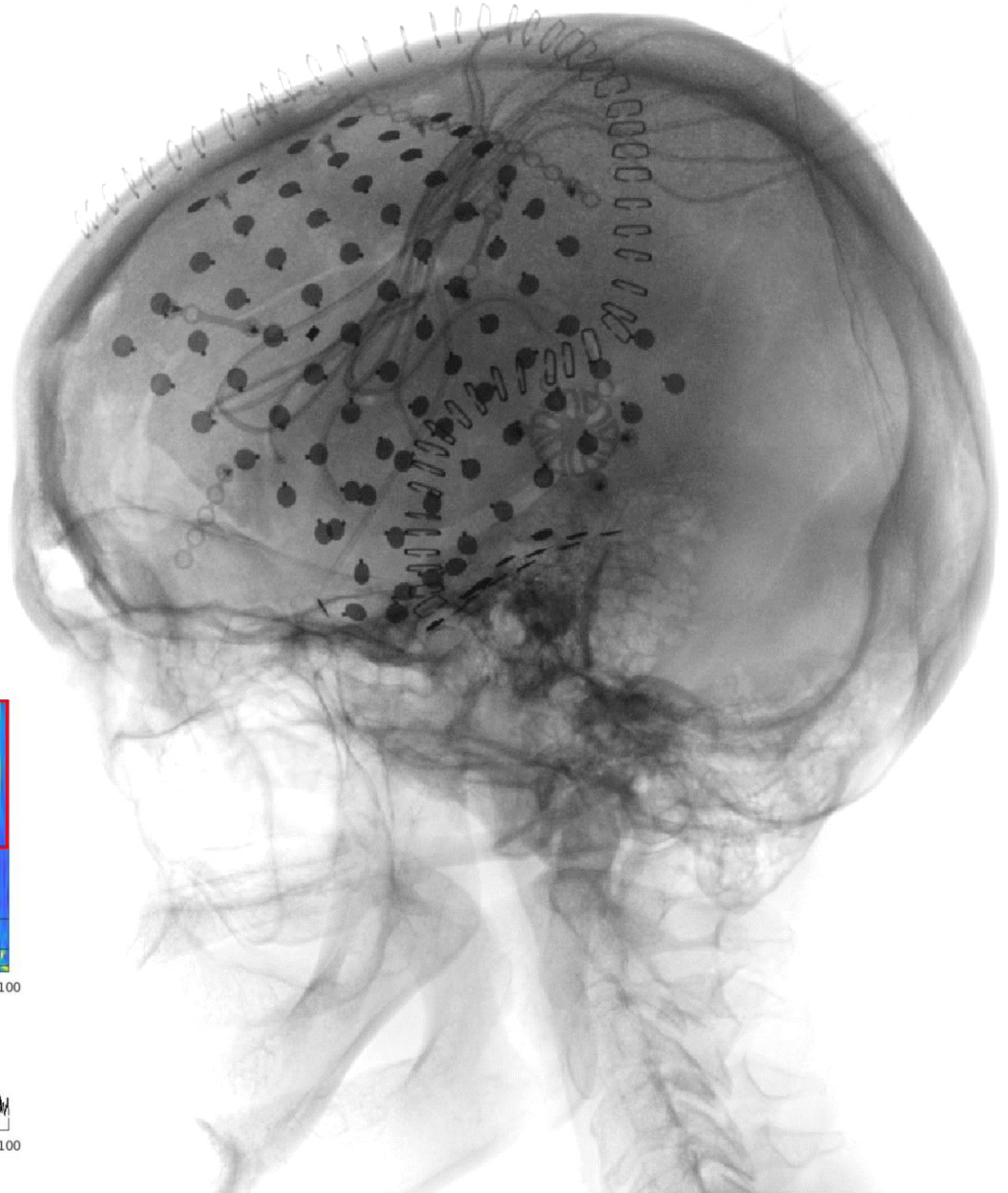
Intracranial EEG

Lachaux et al., 2003; Conner et al., 2011

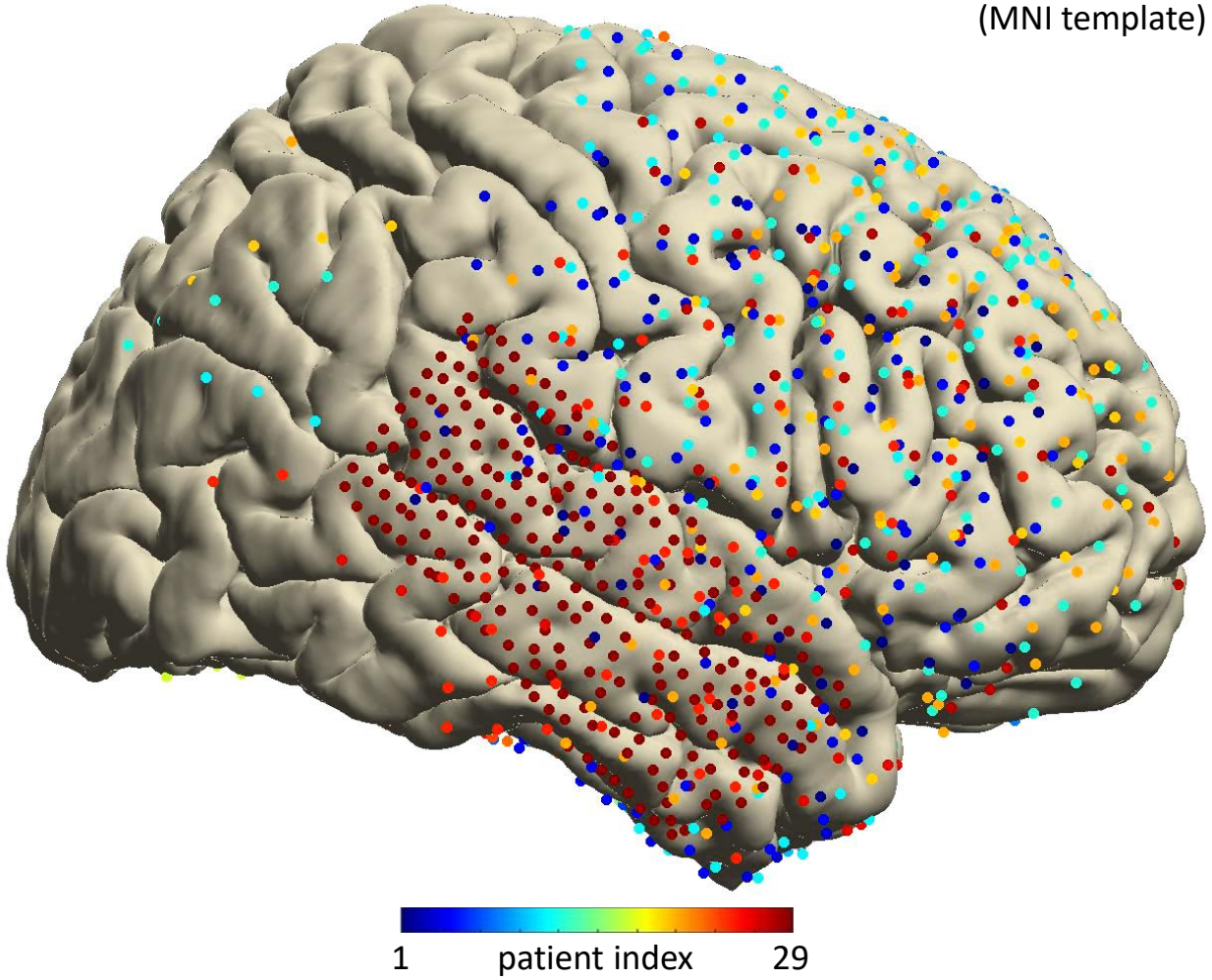


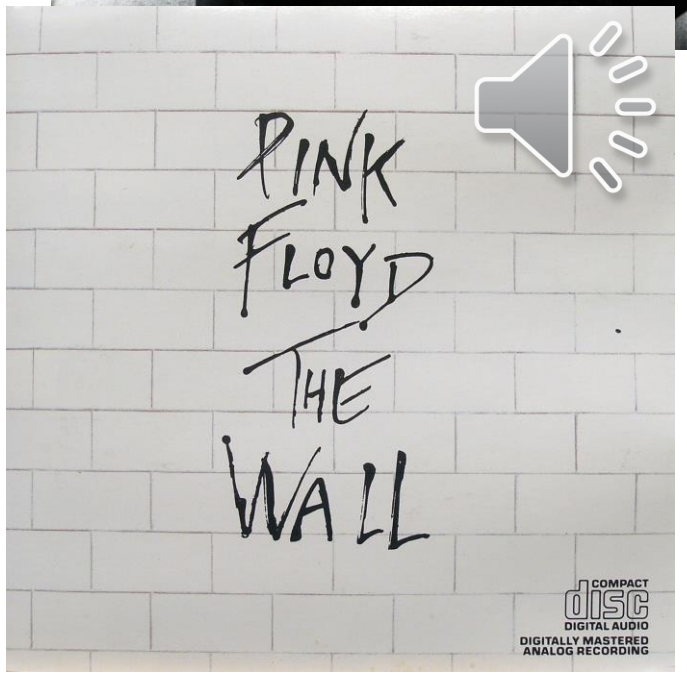
- stereotactical EEG (SEEG) or electrocorticography (**ECoG**)
- high signal-to-noise ratio, enabling single-trial analyses
- access to High-Frequency Activity (HFA; index of local neural activity, related to BOLD signal in fMRI)





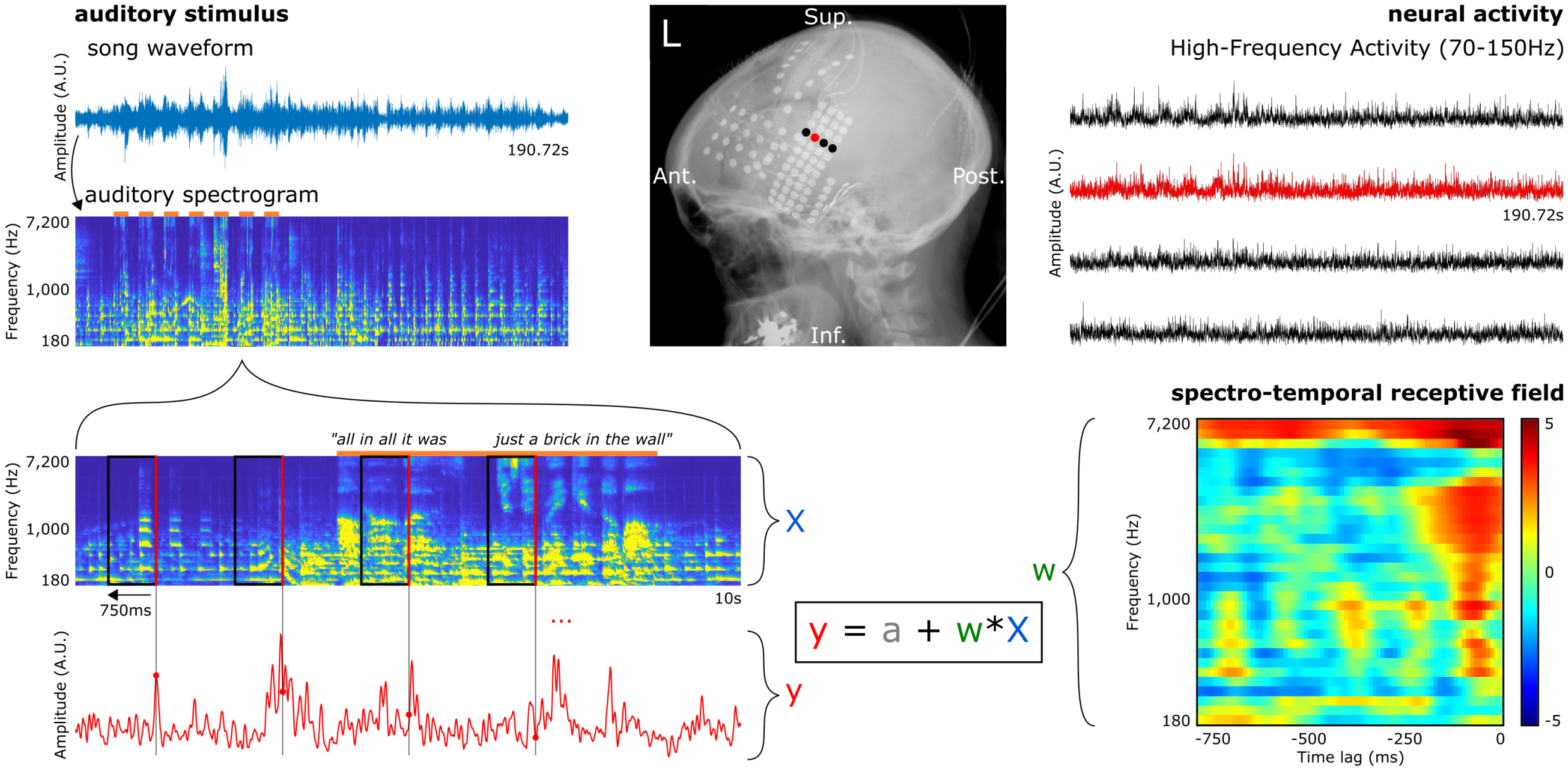
Dataset & protocol



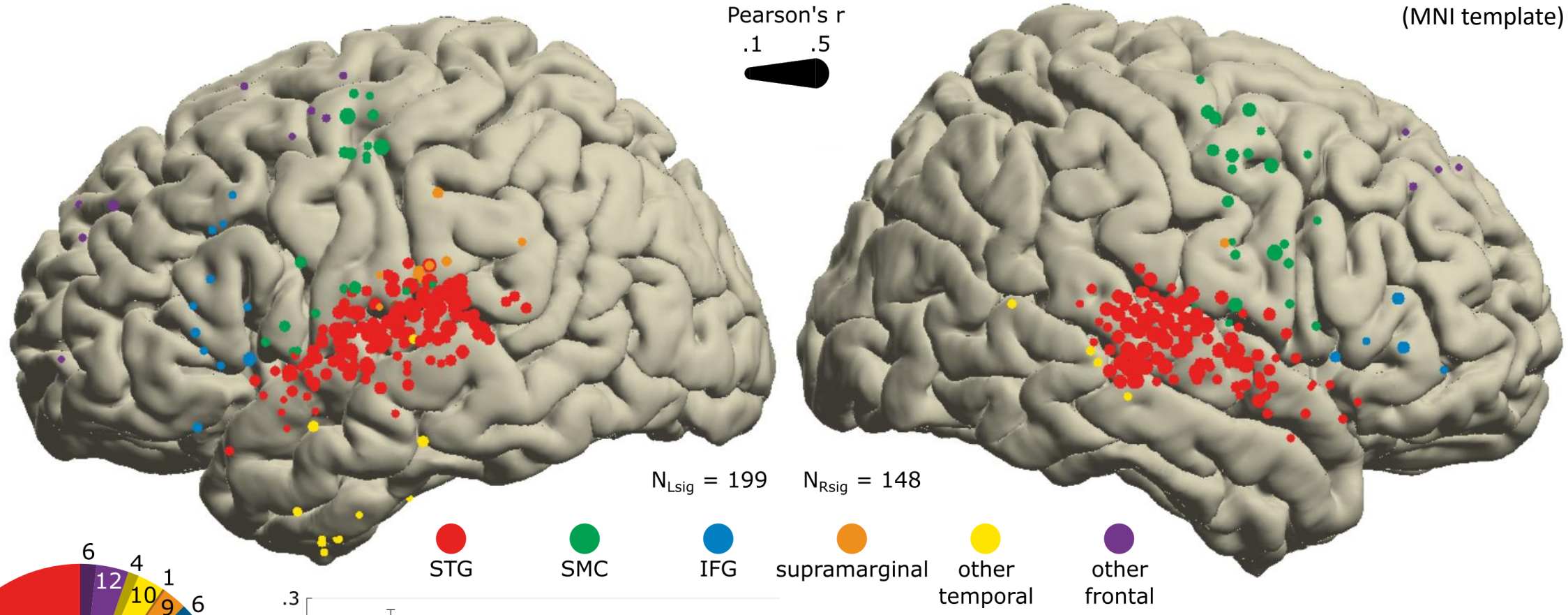


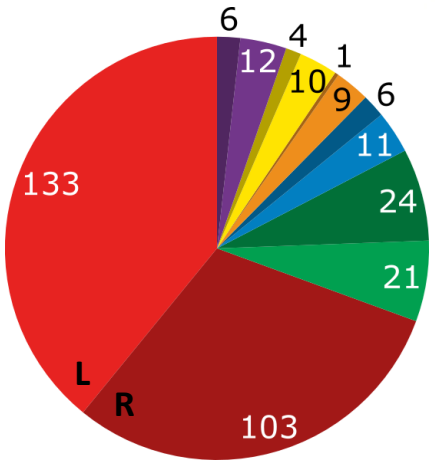
- 29 patients
- dense frontotemporal coverage
- 1,479 left – 900 right
- 2,379 clean ECoG electrodes
- mean 82 (min–max 36–239)
- 424 in STG, 389 SMC, 229 in IFG
- passive listening to a song
- *Another Brick in the Wall, Part 1*, by Pink Floyd (190.72s)

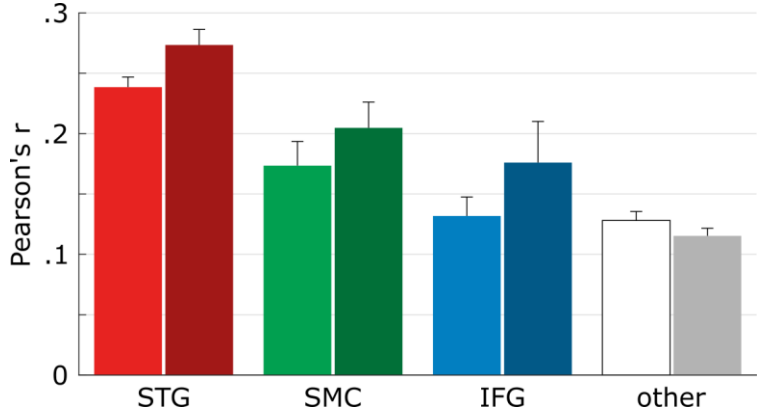
Predictive modeling



Location of song-responsive electrodes



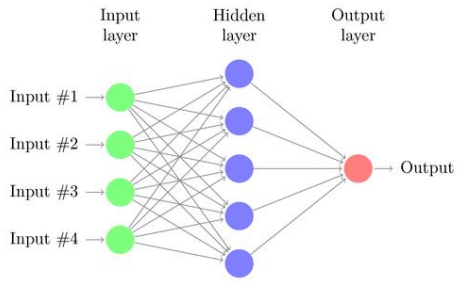


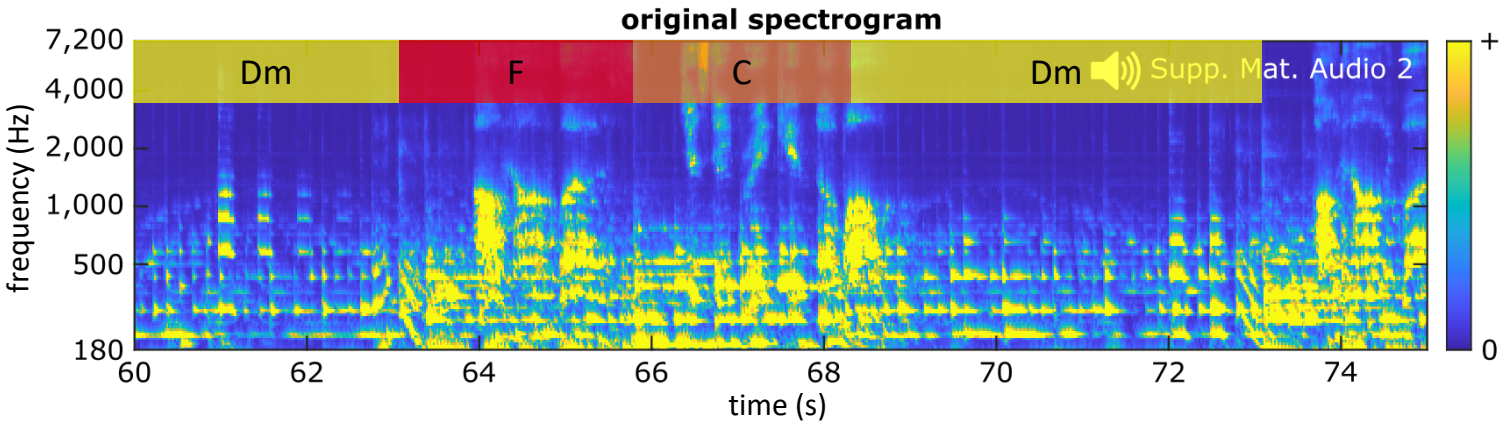


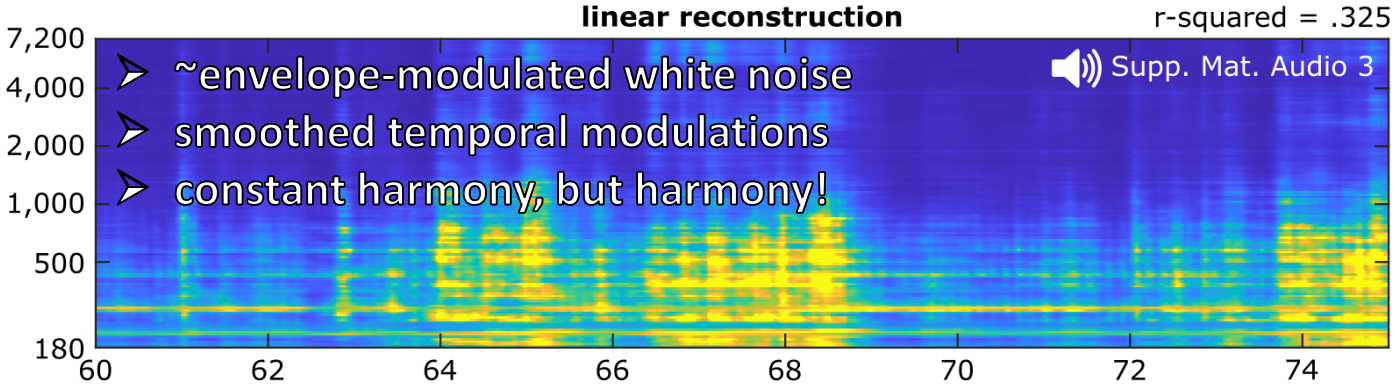
- 347 significant electrodes
- crucial role of STG in encoding the song's acoustics
- involvement of SMC and IFG
- right hemispheric preference

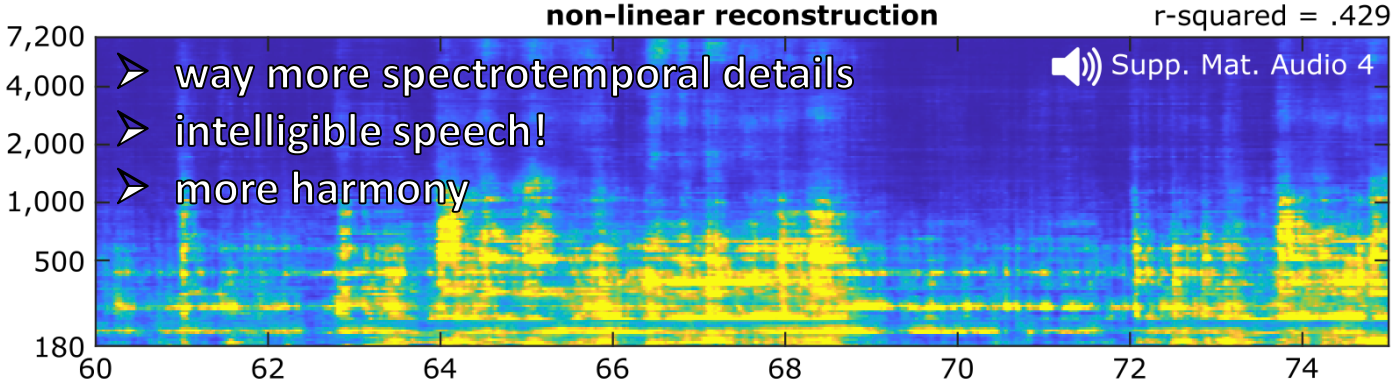
Reconstruction of the song spectrogram

$$x_j = Yw + \varepsilon$$









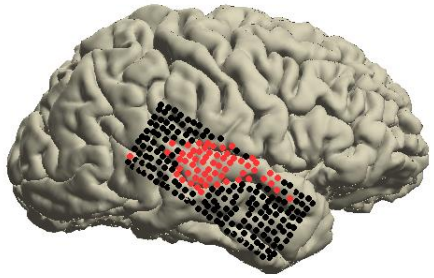
target stimulus
(wav -> spectrogram -> wav)

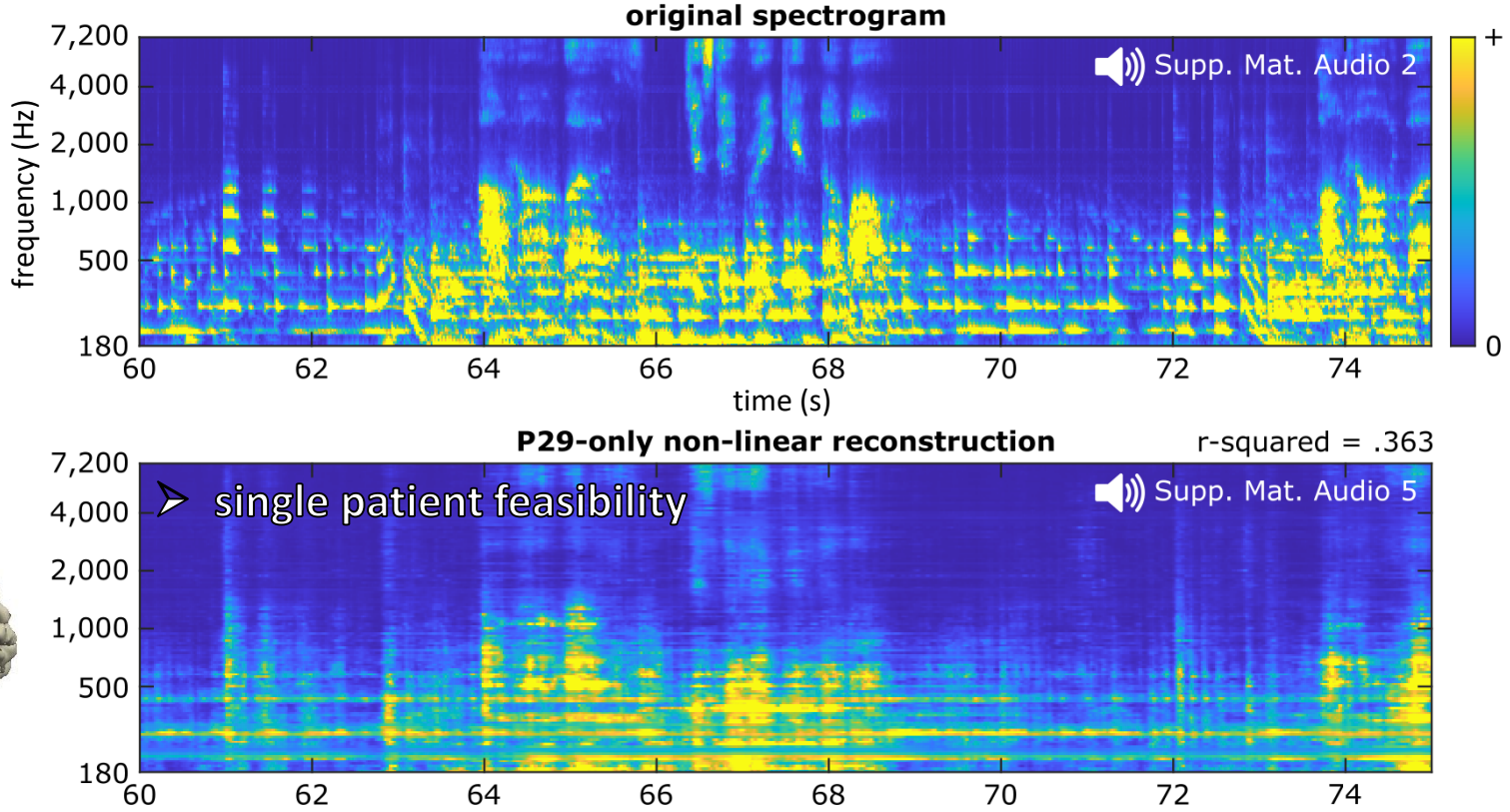
(S1 Audio in the PLoS Biology paper)

(S2 Audio)

(S3 Audio)

Reconstruction of the song spectrogram

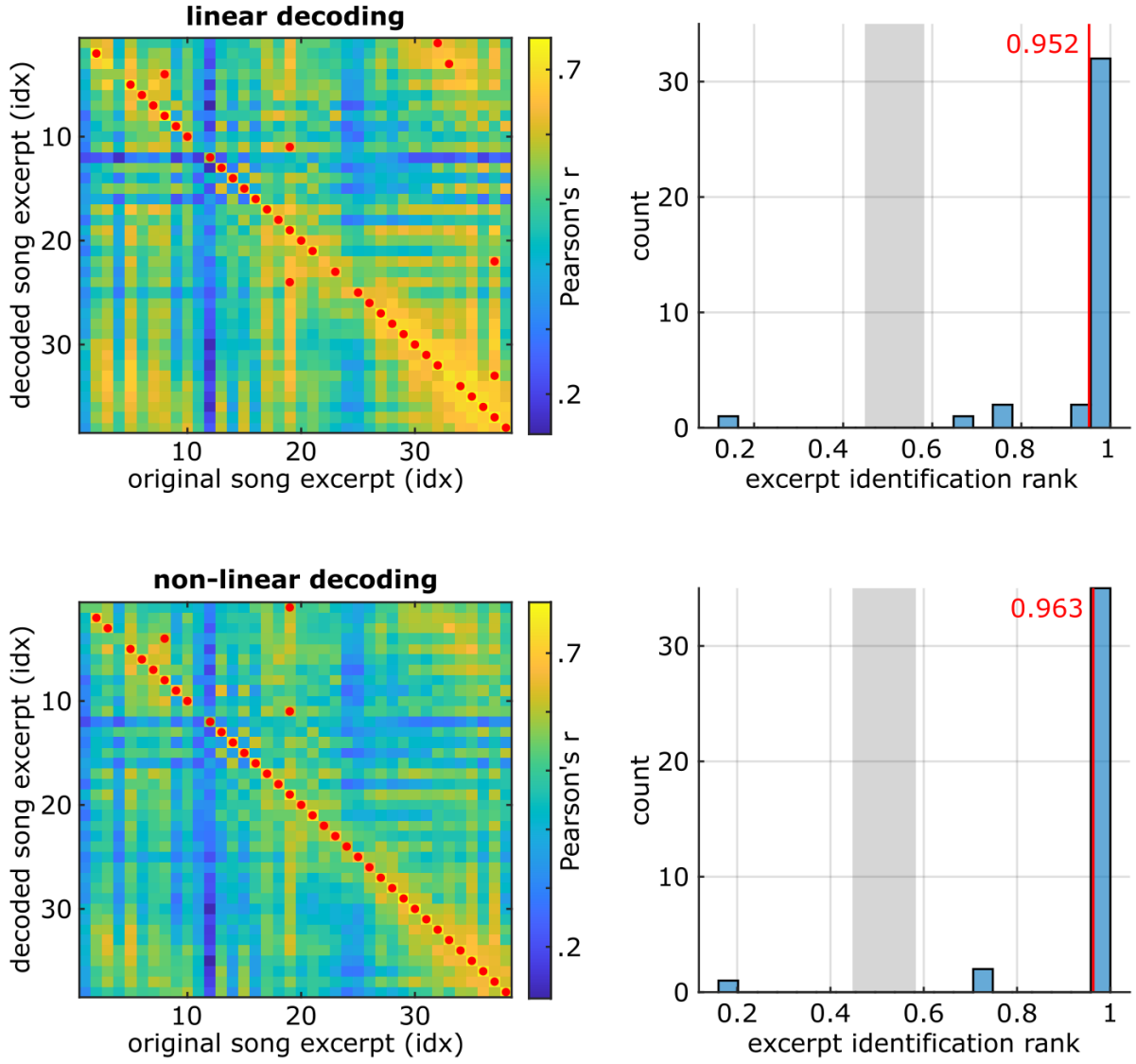




(S4 Audio)

- first reconstruction of a song!!
- first successful reconstruction based on spectrotemporal decoding
- limitations of linear models extended to music decoding
- some musical elements still missing (rhythm guitar, bass)
- information loss (too transformed) or requires more data?

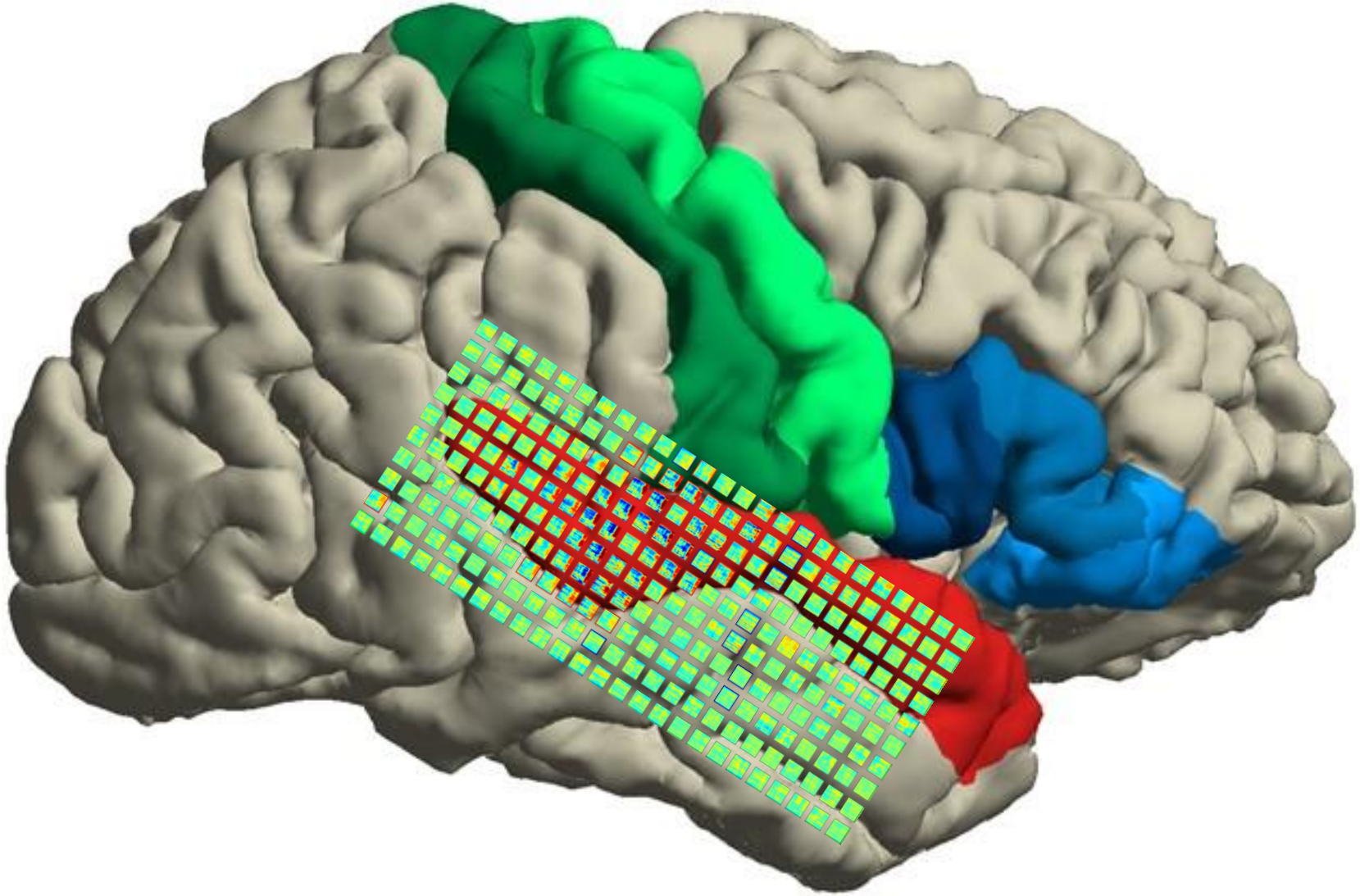
Identification of reconstructed song spectrogram excerpts



- decoded song excerpts are identifiable well above chance level
- linear model sufficient for classification-like approach

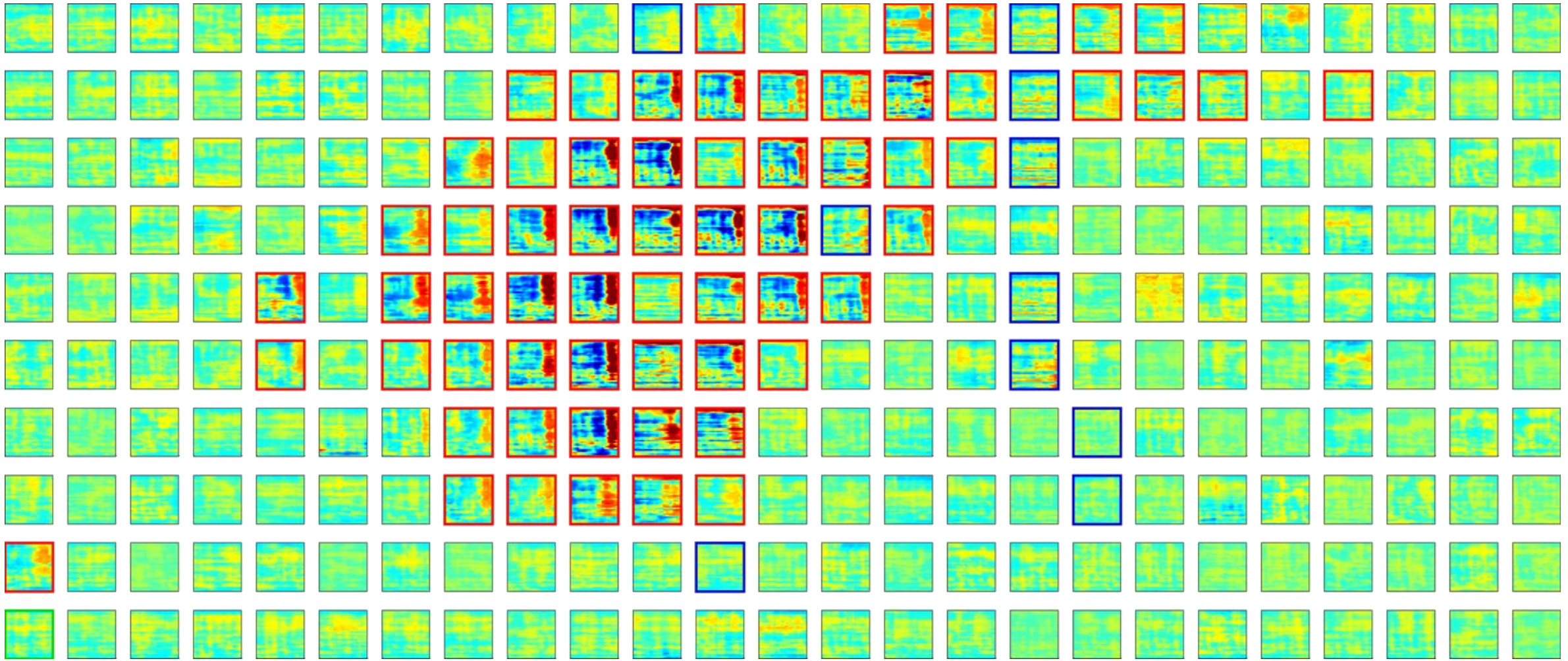
Rich spectrotemporal tuning patterns

(STRFs from P29)



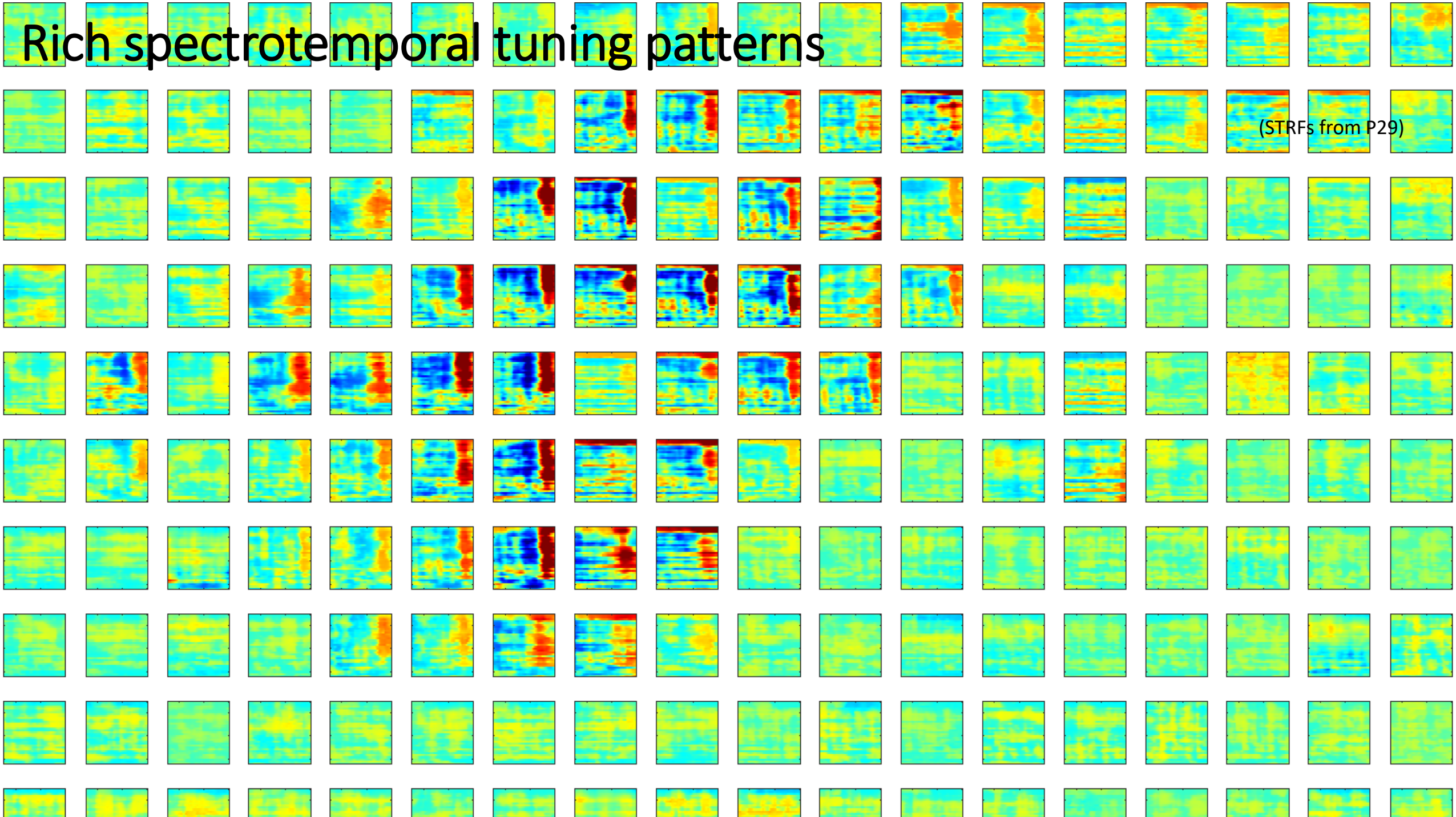
Rich spectrotemporal tuning patterns

(STRFs from P29)

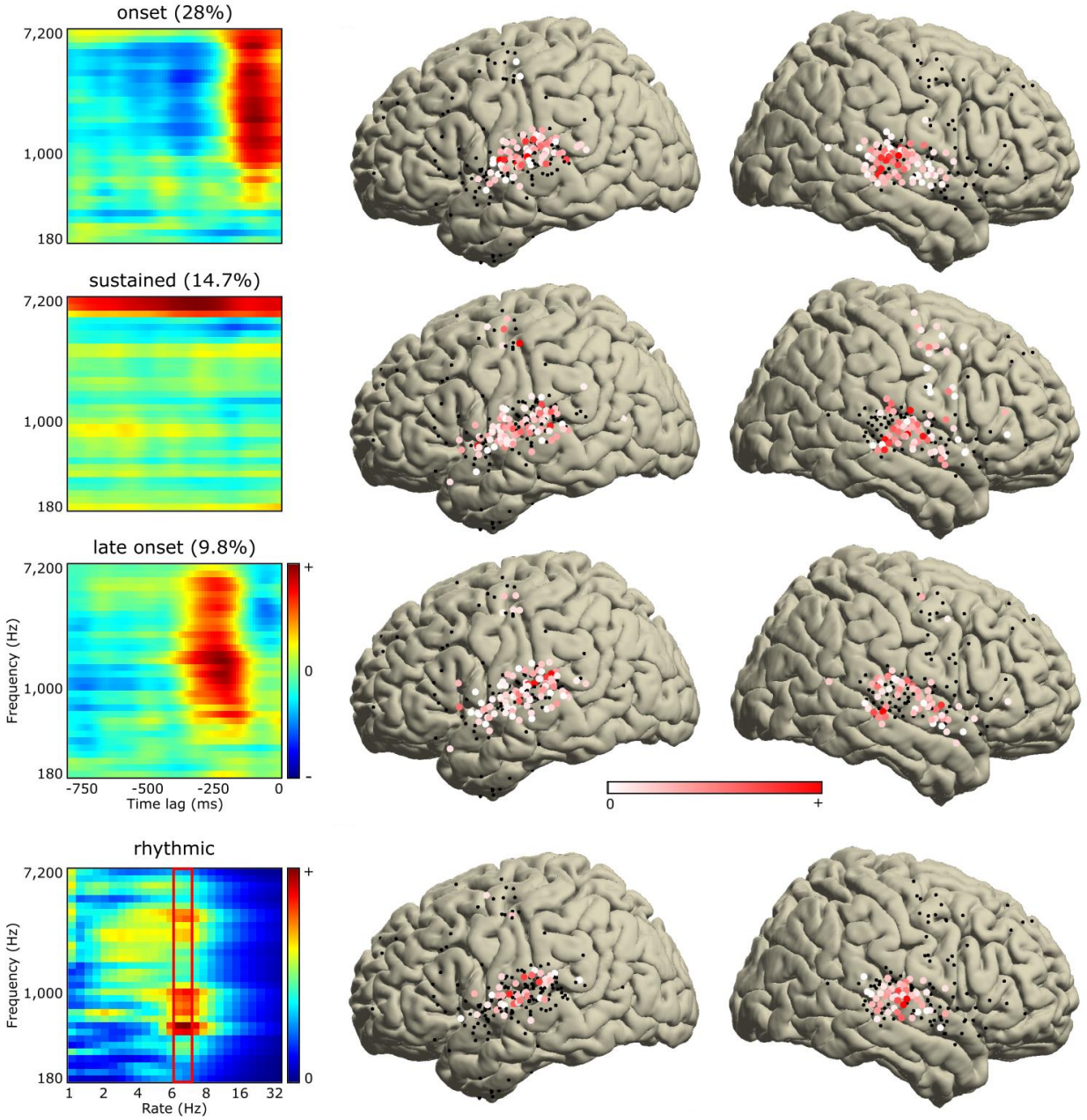


significant reference noisy

Rich spectrotemporal tuning patterns

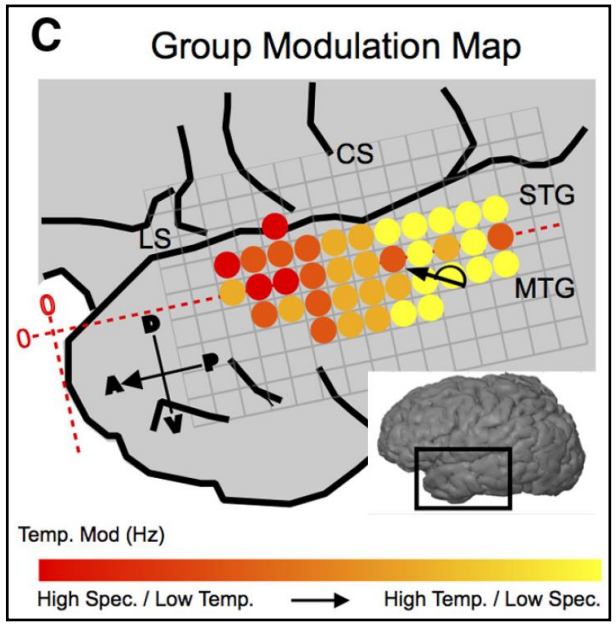


Component analysis

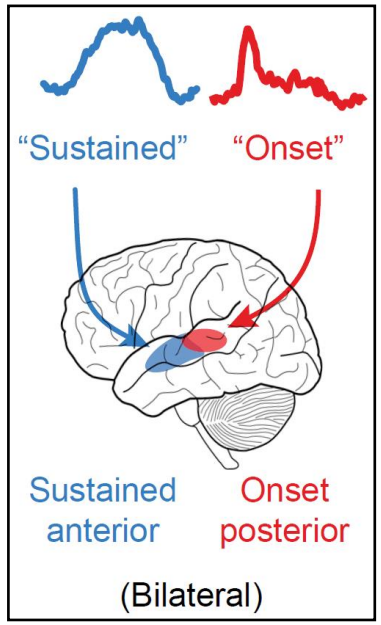


- 3 ICA components representing >5% variance
- rhythmic component through temporal modulations
- onset in posterior/mid STG
- sustained in mid/anterior STG, SMC and IFG
- late onset in STG around onset, SMC and IFG
- rhythmic in mid STG

- represented in overlapping cortical regions
- extends further STG parcellation in speech perception

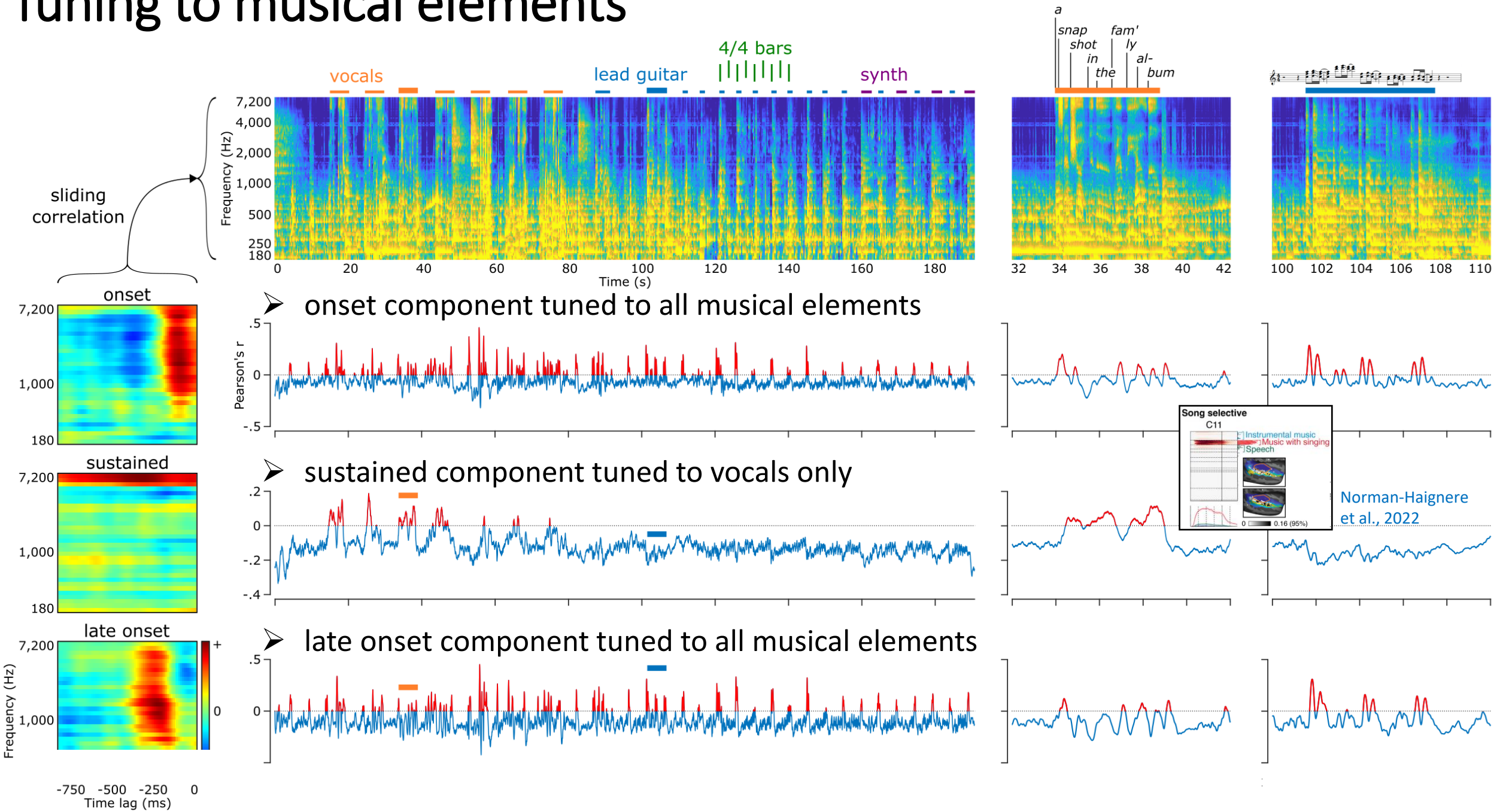


Hullett et al., 2016

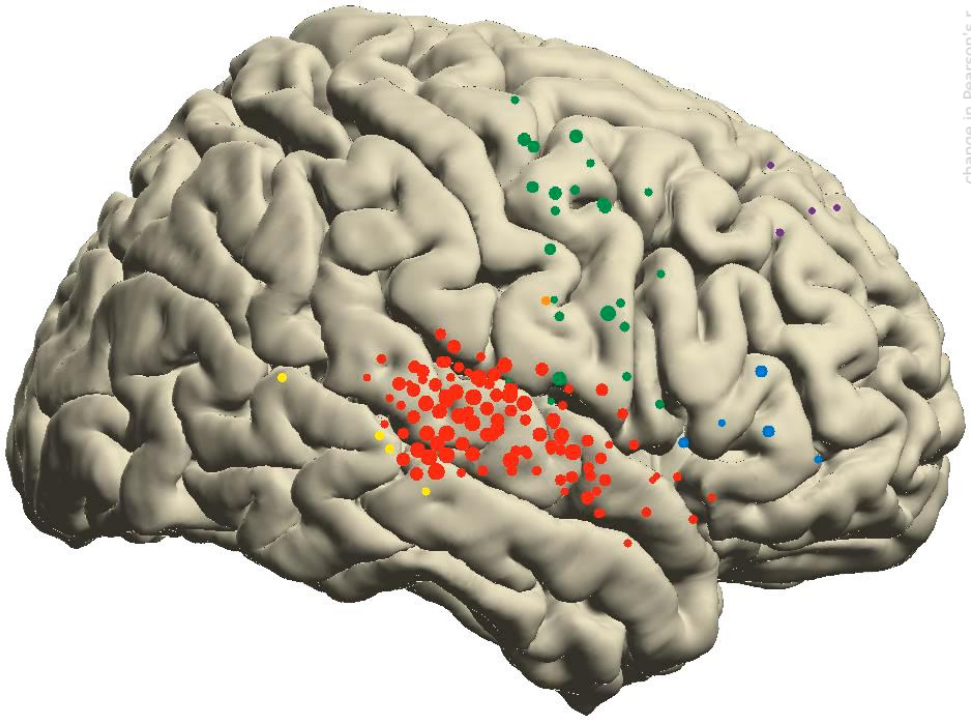


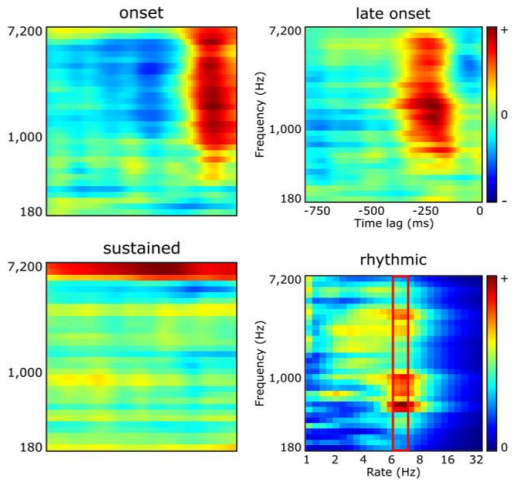
Hamilton et al., 2018

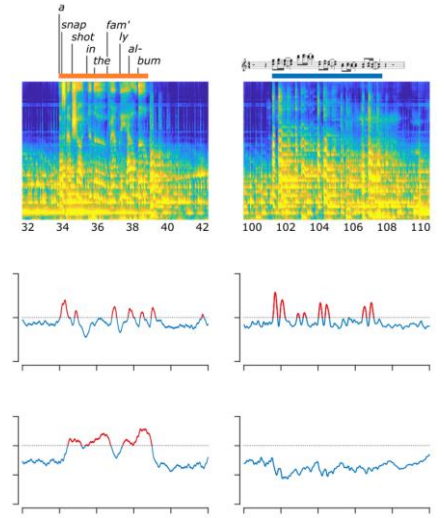
Tuning to musical elements

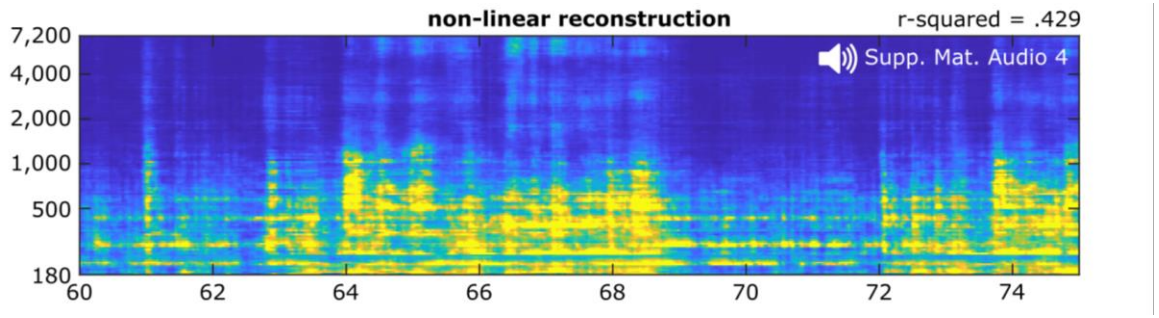


Summary







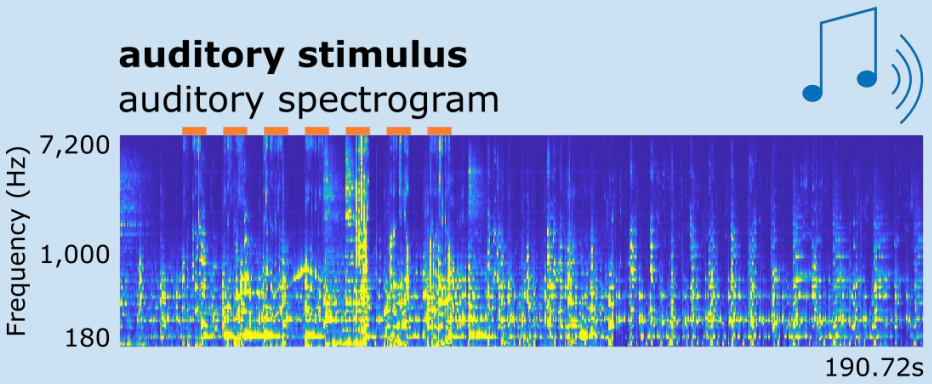


- We located cortical areas encoding musical information, and characterized **right-hemisphere preference** and **crucial role of STG** in music perception

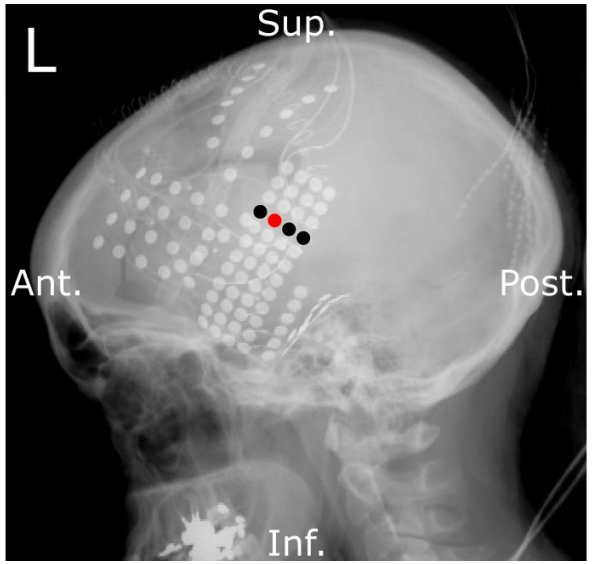
- We reconstructed the **first intelligible song** from direct brain recordings, providing insights into musical information represented across electrodes

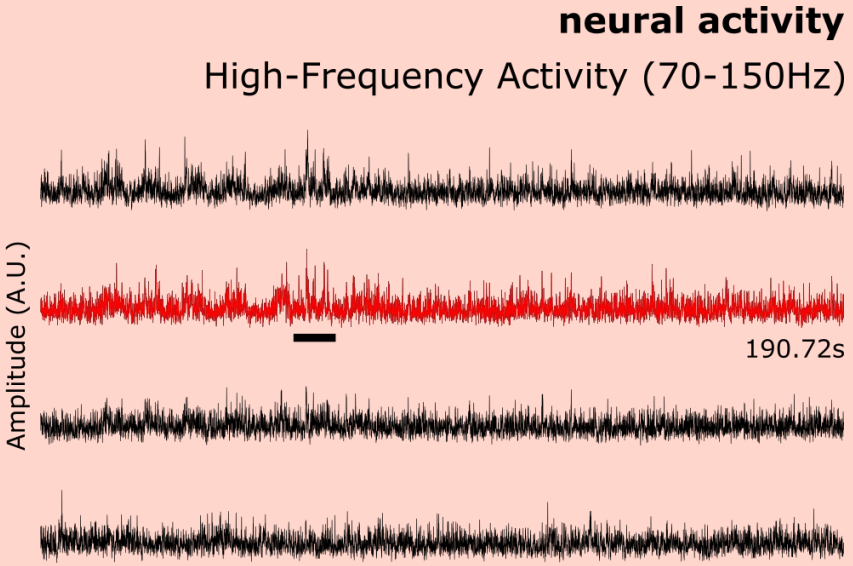
- We identified **4 overlapping STG subregions** tuned to different musical elements, further extending results on speech perception

Next steps



➢ other representations of the song





➢ other neural activity estimates

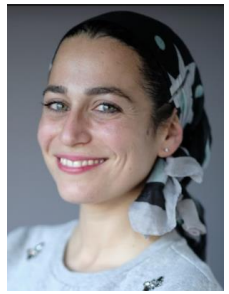
- ➢ record datasets with A1 (-> linear successful?)
- ➢ gather musical/linguistic expertise information
- ➢ extend to music imagery

Acknowledgements

Contact: ludovic.bellier@gmail.com


Robert T. Knight


Anaïs Llorens


Déborah Marciano


Peter Brunner


Gerwin Schalk

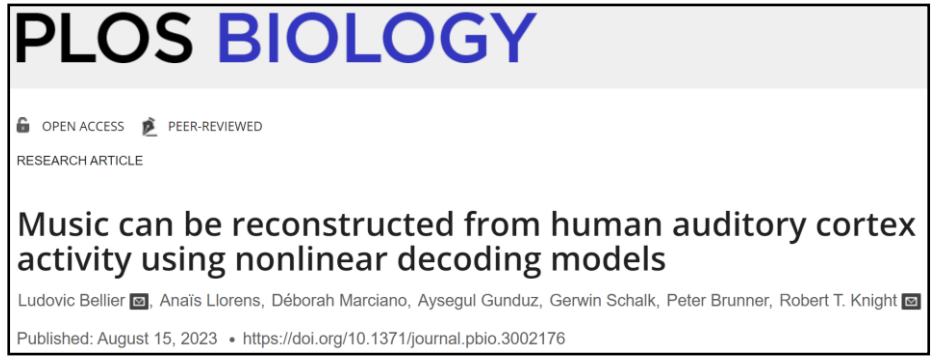

Aysegul Gunduz


Brian N. Pasley

Knight lab former and current members
Chris Holdgraf, Stephanie Martin
Randolph Helfrich, Arjen Stolk

Julie Ashworth
our patients!

NIH National Institute of Neurological Disorders and Stroke
NIH National Institute on Deafness and Other Communication Disorders
NIH National Institute of Biomedical Imaging and Bioengineering


PLOS BIOLOGY

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Music can be reconstructed from human auditory cortex activity using nonlinear decoding models

Ludovic Bellier, Anaïs Llorens, Déborah Marciano, Aysegul Gunduz, Gerwin Schalk, Peter Brunner, Robert T. Knight

Published: August 15, 2023 • https://doi.org/10.1371/journal.pbio.3002176

Thank you for your attention!