PARIS LODRON UNIVERSITÄT SALZBURG

Auditory Neuroscience Group

Salzburg Brain Dynamics Lab

Toronto, 22 Nov. 2022

How do human beings process degraded speech?

Ya-Ping Chen

Centre for Cognitive Neuroscience,

University of Salzburg,

Salzburg, Austria

How human beings process degraded speech?

Two studies

- Study 1: on a **short**-time level (under review at NeuroImage)
  - How speech intelligibility modulates neural speech tracking within 400 ms?
- Study 2: on a **long**-time level (in preparation)
  - How speech intelligibility representations of non-CI ear change over a year?

Study 1

How does speech intelligibility modulate neural speech tracking within 400 ms?

Ya-Ping Chen, Fabian Schmidt, Anne Keitel, Sebastian Rösch, Anne Hauswald, & Nathan Weisz

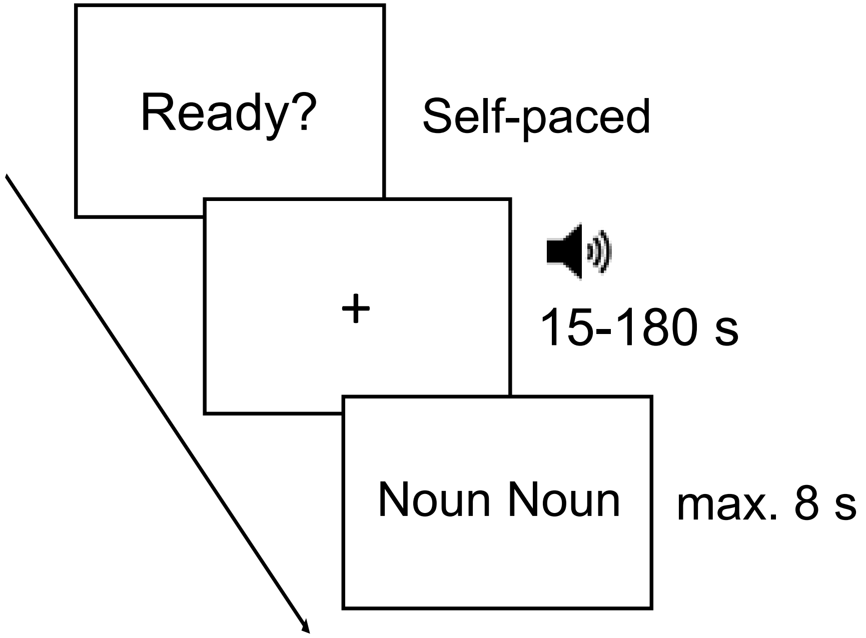
Background

- Higher neural speech tracking on attended speech (Ding & Simon, 2012; Fiedler et al., 2019; Hausfeld et al., 2018).

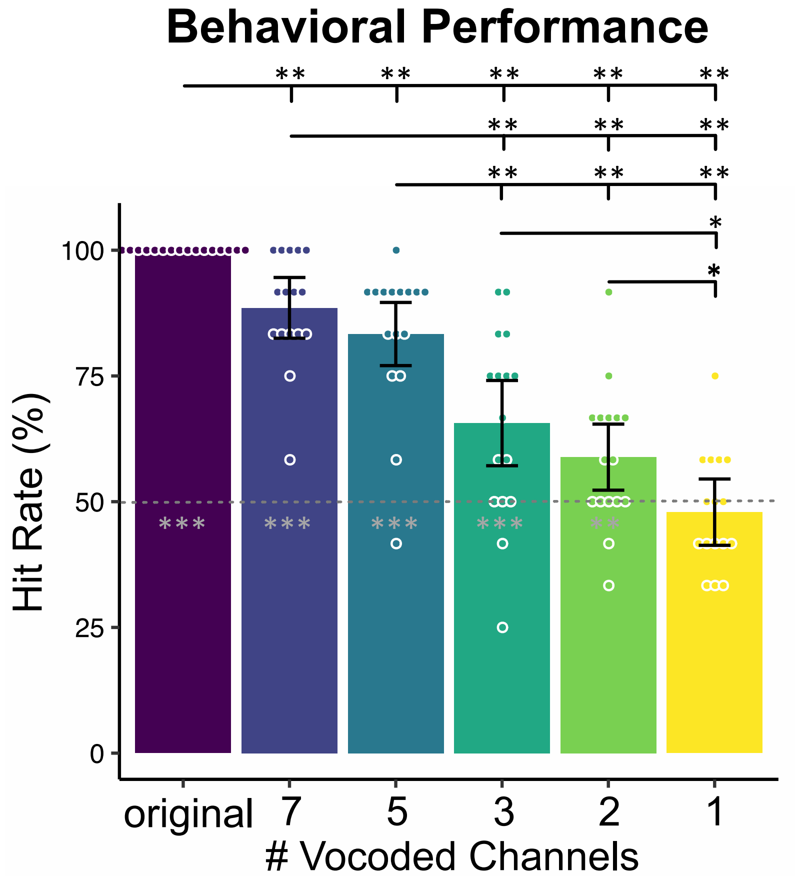
Background

- Few studies focused on how speech intelligibility affects the temporal dynamics of neural speech tracking (xxx).
- Research Question
  - How does speech intelligibility modulate neural speech tracking?

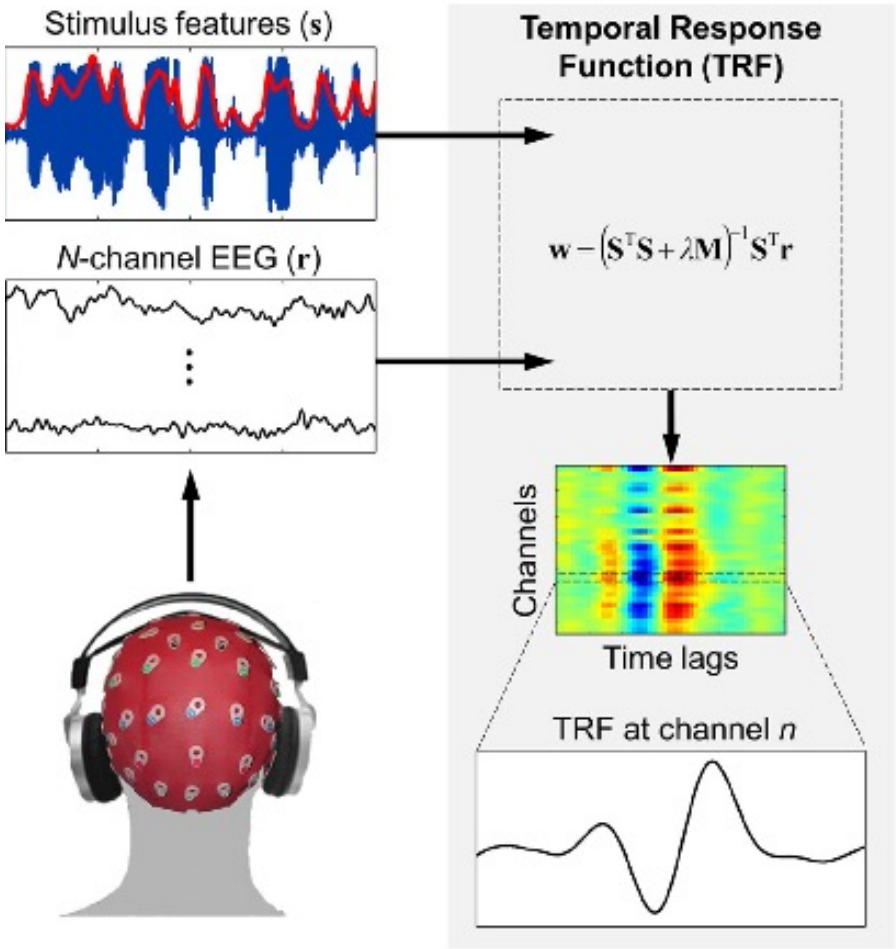
Study Paradigm

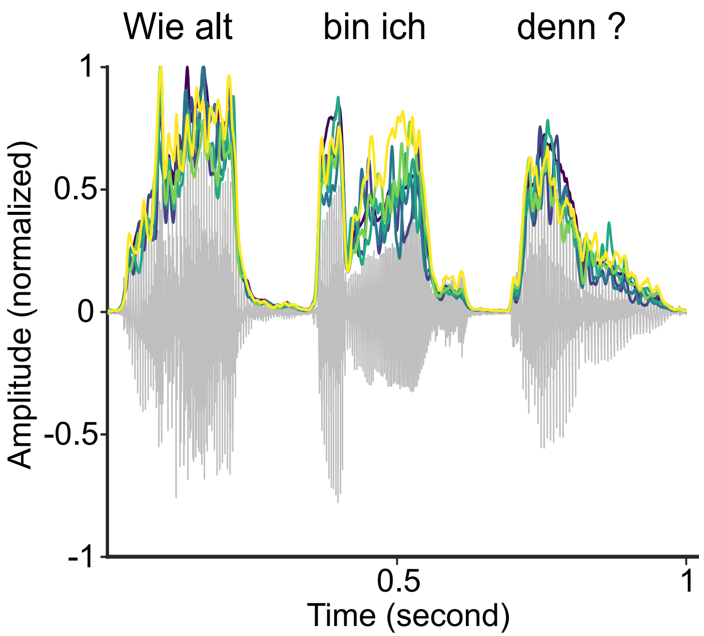


- original
- 7-channel vocoded
- 5-channel vocoded
- 3-channel vocoded
- 2-channel vocoded
- 1-channel vocoded

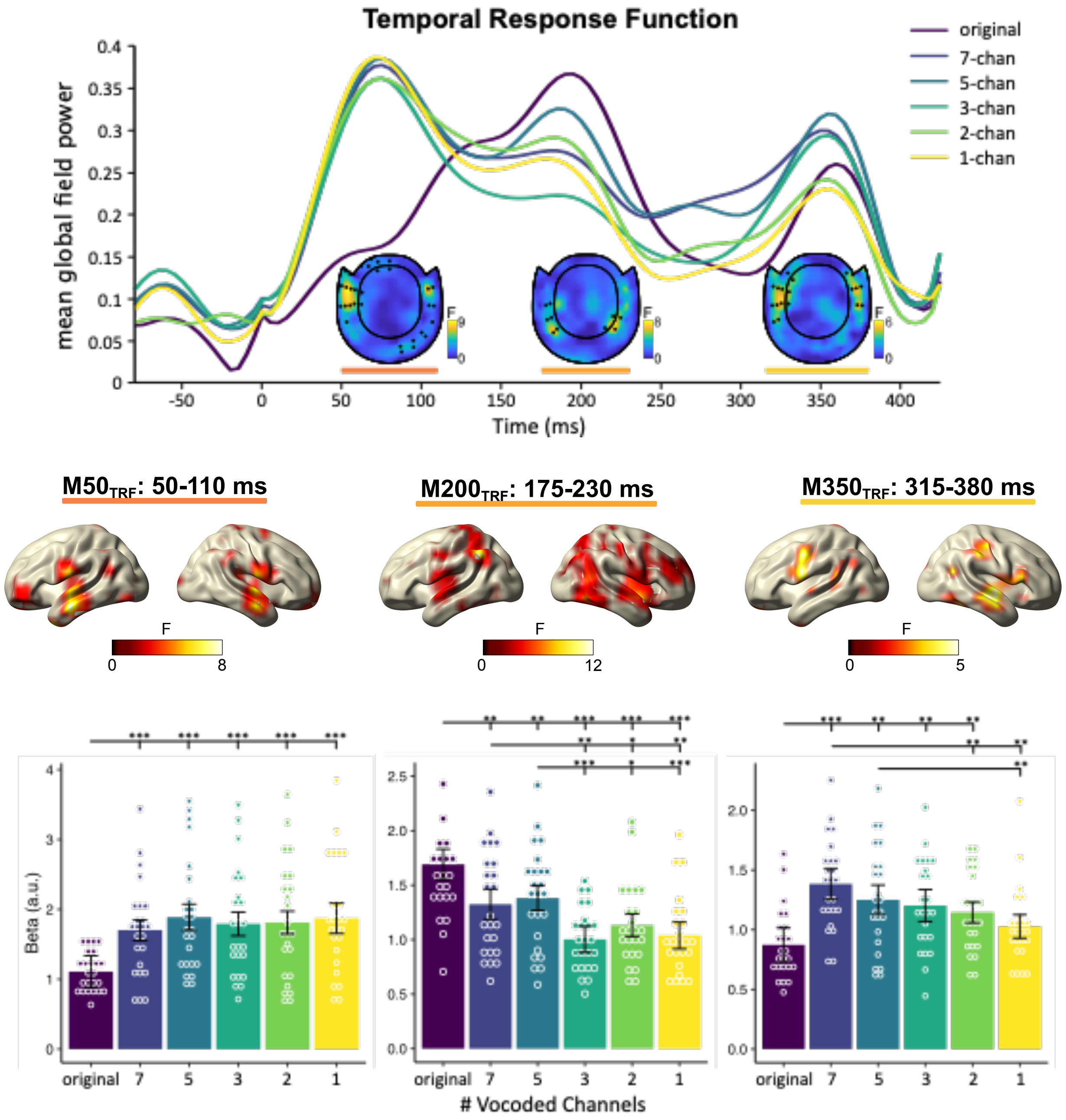


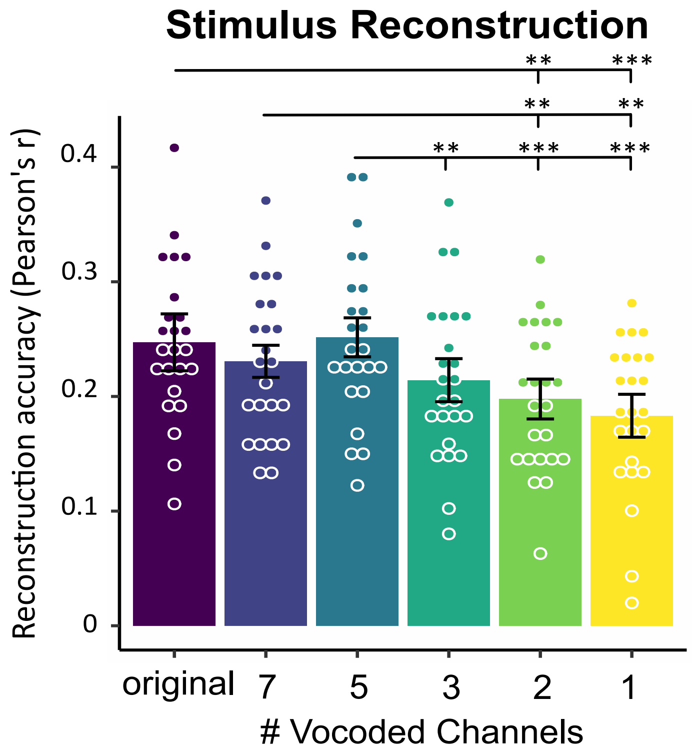
Computing TRFs to depict dynamic neural speech tracking



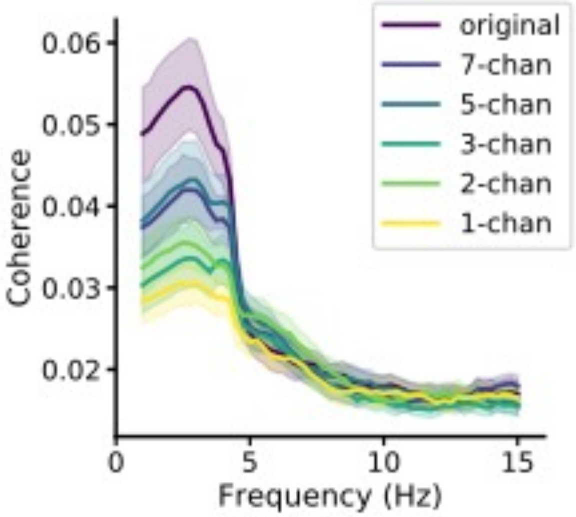


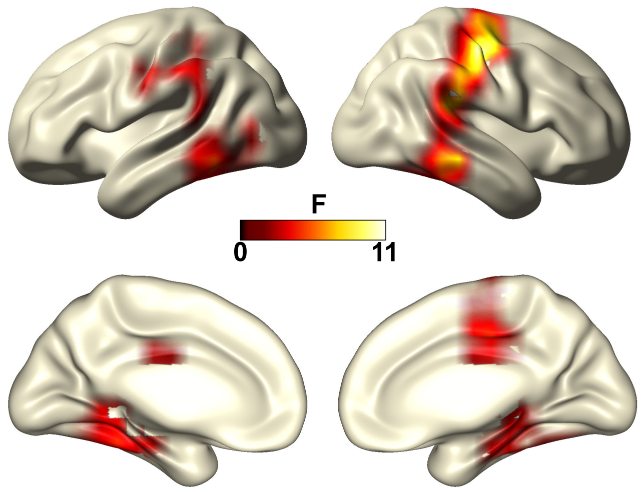
Crosse et al., 2016, Frontiers in Human Neuroscience


Temporal Response Function
mean global field power
Time (ms)
original
7-chan
5-chan
3-chan
2-chan
1-chan
M50TRF: 50-110 ms
M200TRF: 175-230 ms
M350TRF: 315-380 ms
Beta (a.u.)
Vocoded Channels

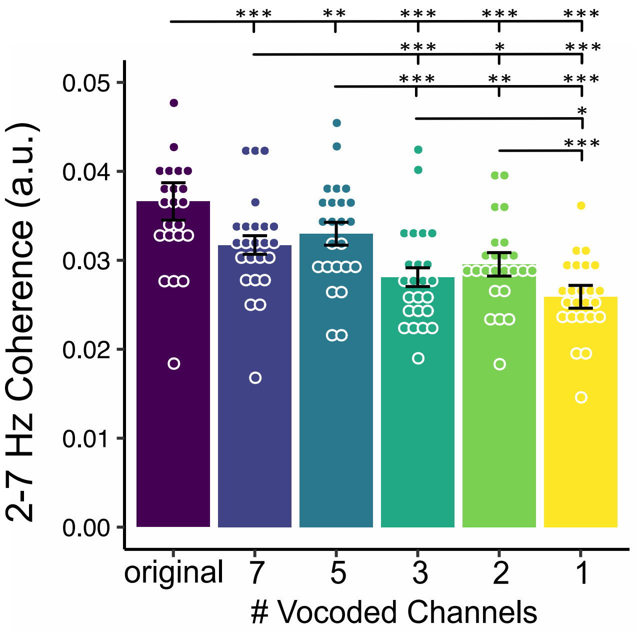

Stimulus Reconstruction
Reconstruction accuracy (Pearson's r)
Vocoded Channels
original
7
5
3
2
1

Speech-Brain Phase Coherence

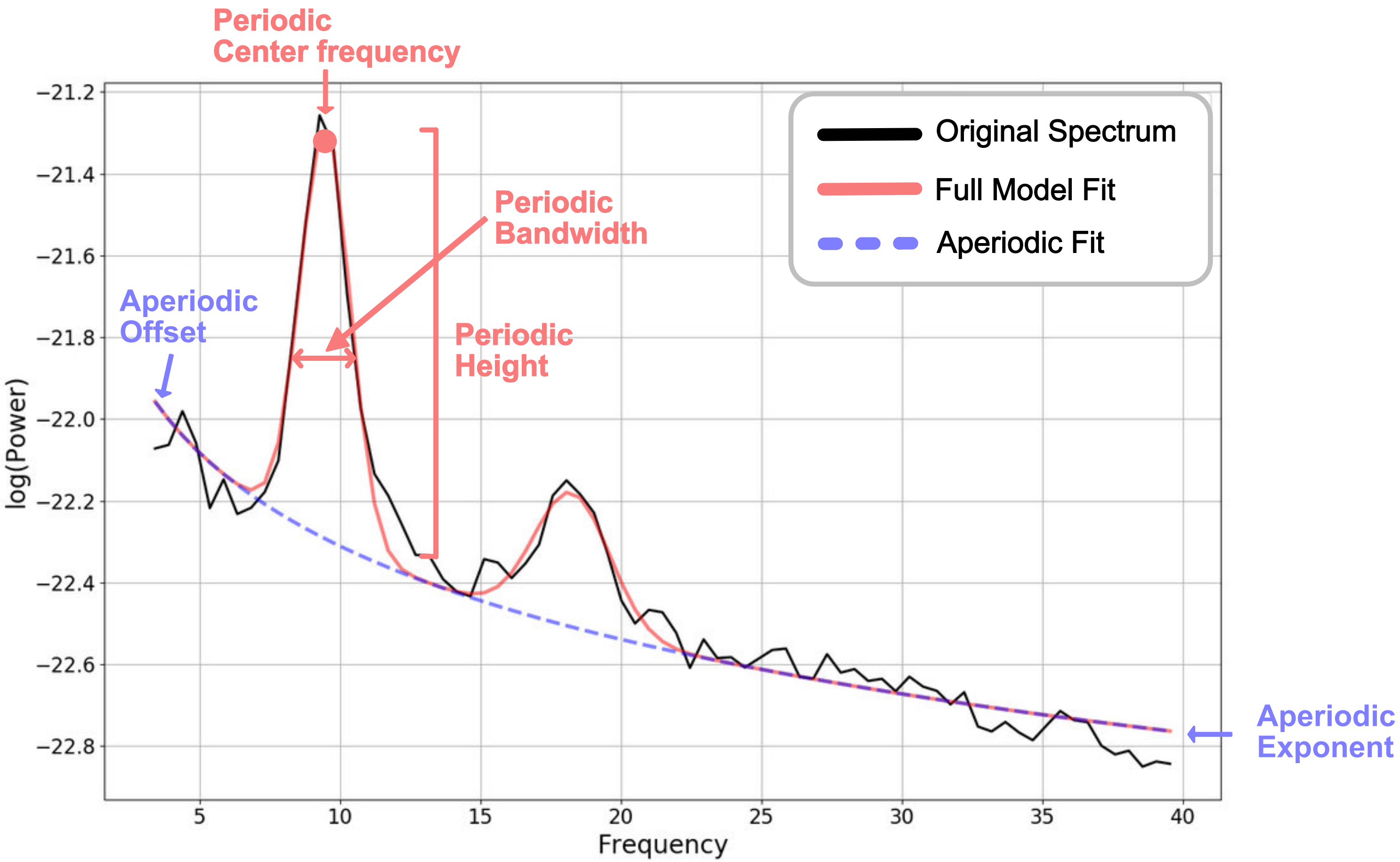




2-7 Hz Coherence



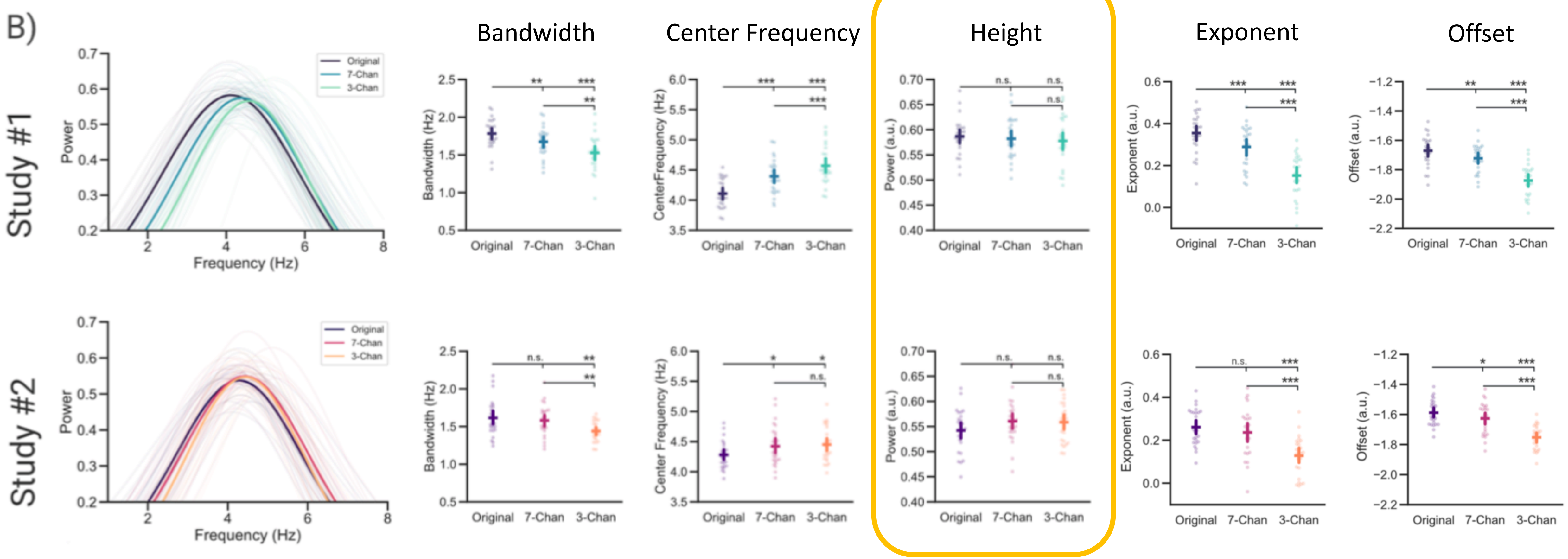
Parameterizing Power Spectrum



adapted from https://fooof-tools.github.io/fooof/

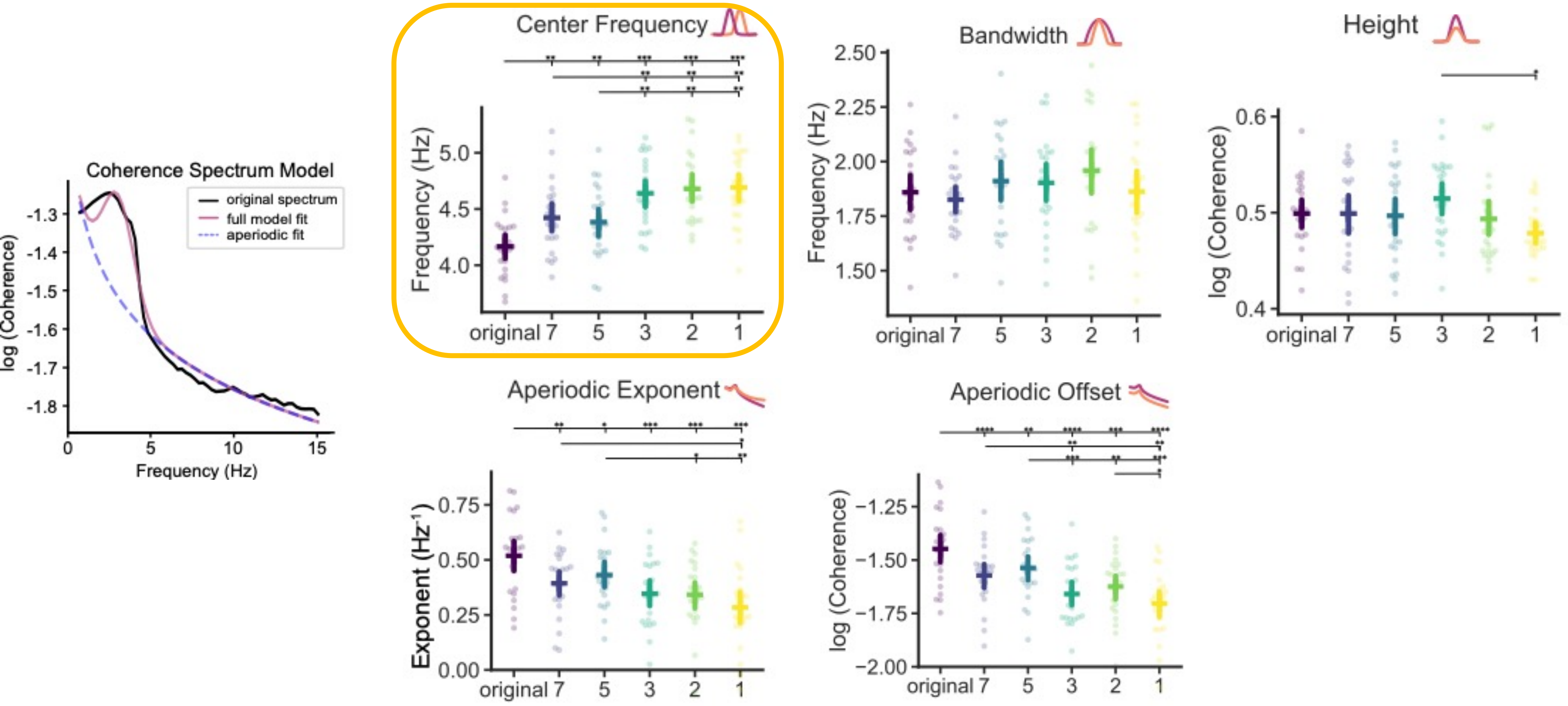
Donoghue et al. (2020) Nature Neuroscience

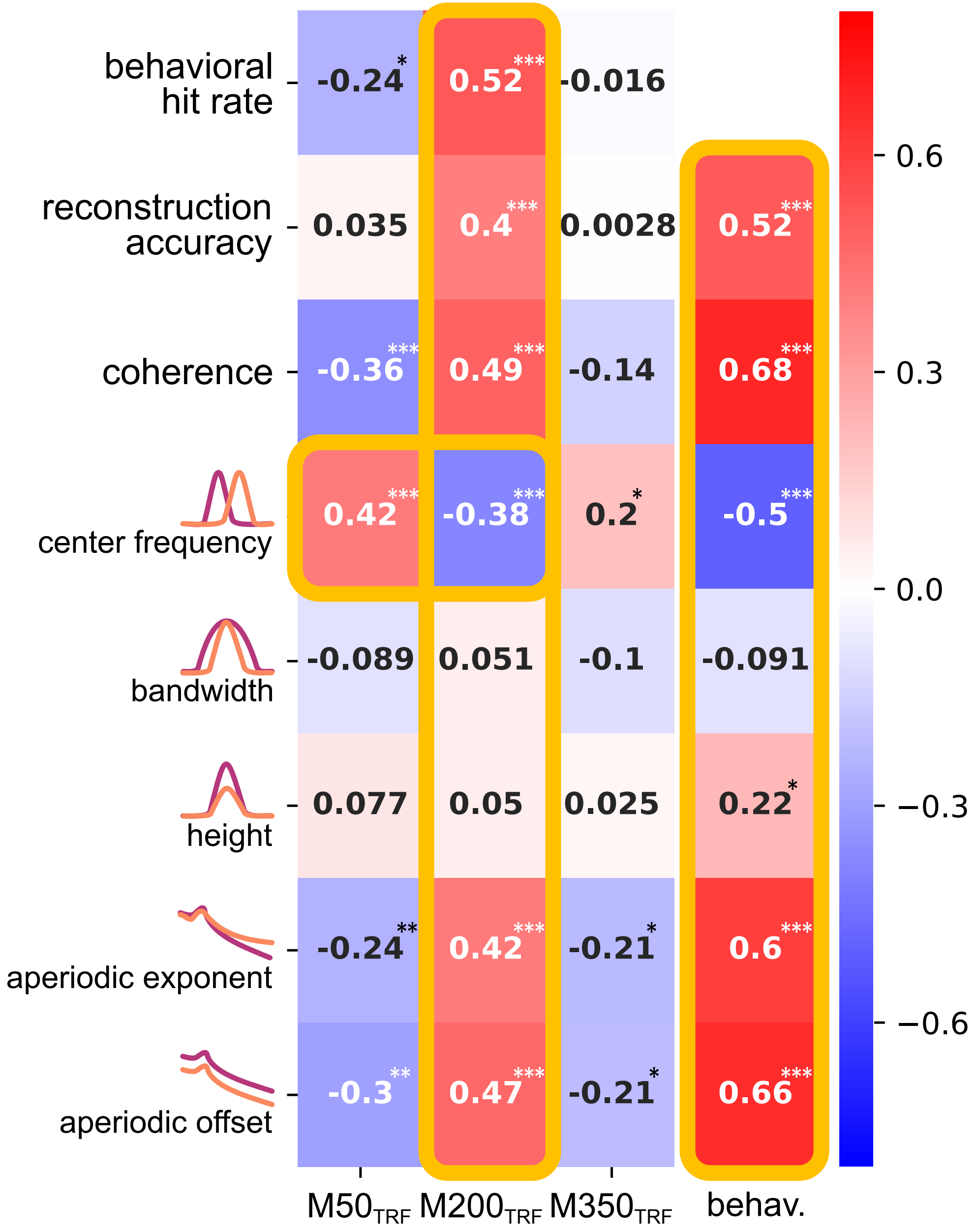
Parameterizing Phase Coherence



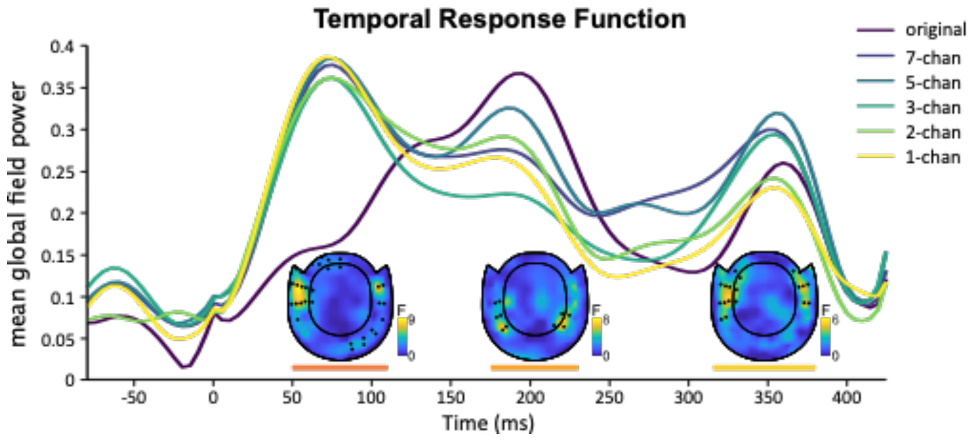
Schmidt et al. (2022) under review at Psychophysiology

Parameterizing Phase Coherence

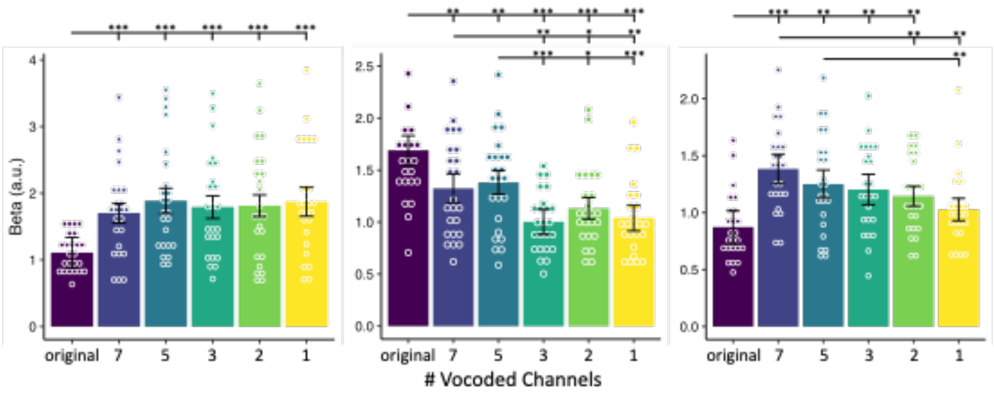




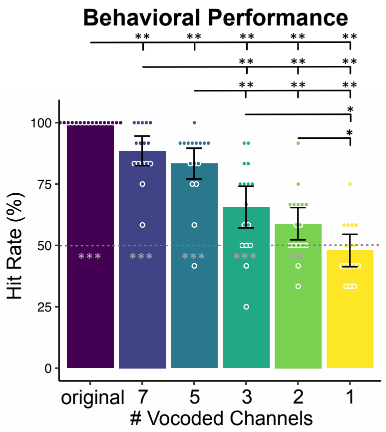
behavioral hit rate
reconstruction accuracy
coherence
center frequency
bandwidth
height
aperiodic exponent
aperiodic offset
-0.24* 0.52*** -0.016
0.035 0.4*** 0.0028 0.52***
-0.36*** 0.49*** -0.14 0.68***
0.42*** -0.38*** 0.2* -0.5***
-0.089 0.051 -0.1 -0.091
0.077 0.05 0.025 0.22*
-0.24** 0.42*** -0.21* 0.6***
-0.3** 0.47*** -0.21* 0.66***
$M50_{TRF}$ $M200_{TRF}$ $M350_{TRF}$ behav.
0.6
0.3
0.0
−0.3
−0.6



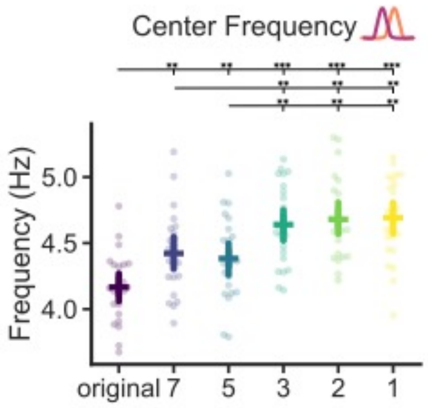
Temporal Response Function
mean global field power
Time (ms)
original
7-chan
5-chan
3-chan
2-chan
1-chan



Beta (a.u.)
original 7 5 3 2 1
Vocoded Channels



Behavioral Performance
Hit Rate (%)
original 7 5 3 2 1
Vocoded Channels



Center Frequency
Frequency (Hz)
original 7 5 3 2 1

Conclusion of Study 1

- We demonstrate that at least three neural processing stages ($M50_{TRF}$, $M200_{TRF}$, and $M350_{TRF}$) when processing continuous degraded speech.
- Only $M200_{TRF}$ highly correlates with behavior and other neural measures (i.e., speech brain coherence) of speech intelligibility.
- Correlation between center frequency of coherence and $M50_{TRF}$ as well as $M200_{TRF}$ can reflect shifts in the neural speech tracking from more linguist level to more acoustic level as speech intelligibility declined.

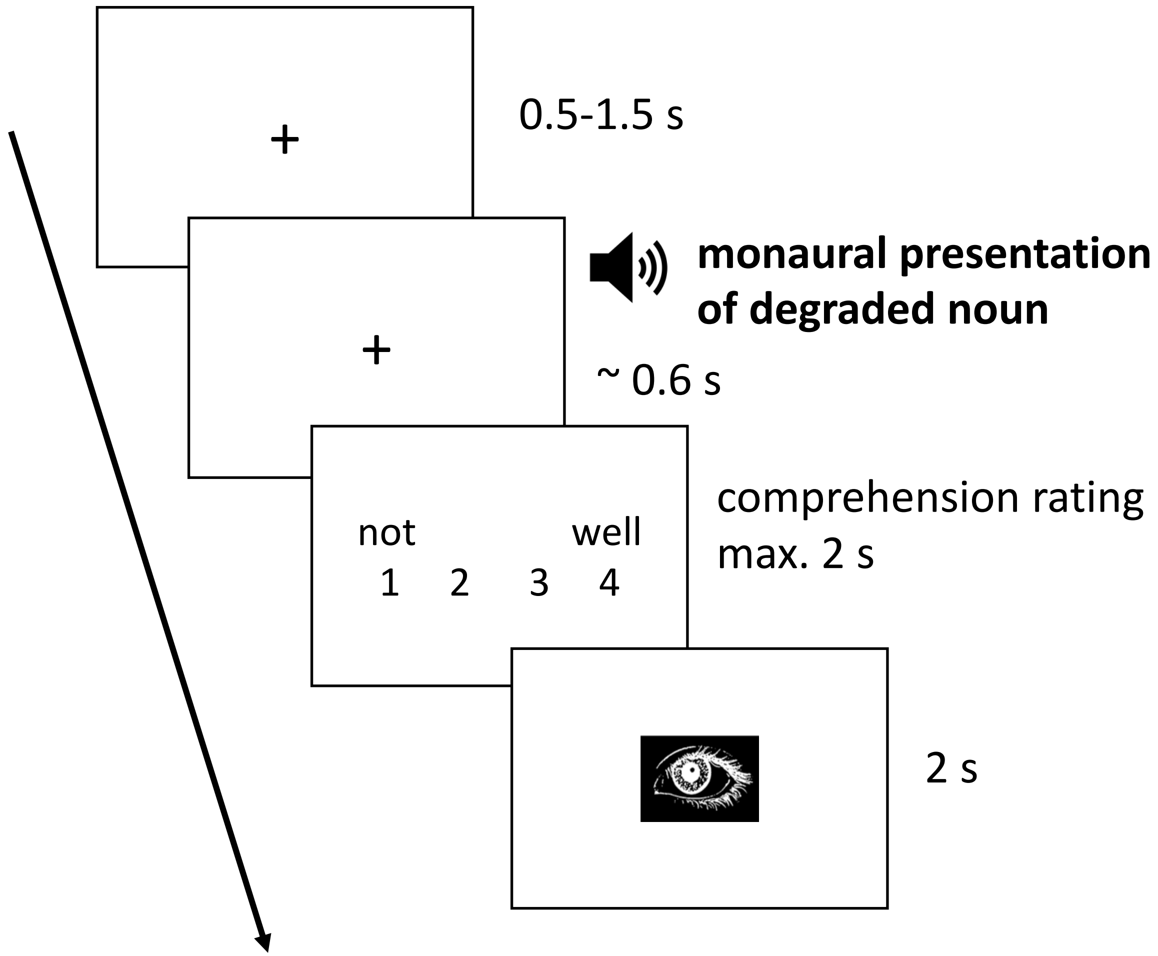
Study 2

Speech intelligibility representations of non-CI ear gradually normalize over a year.

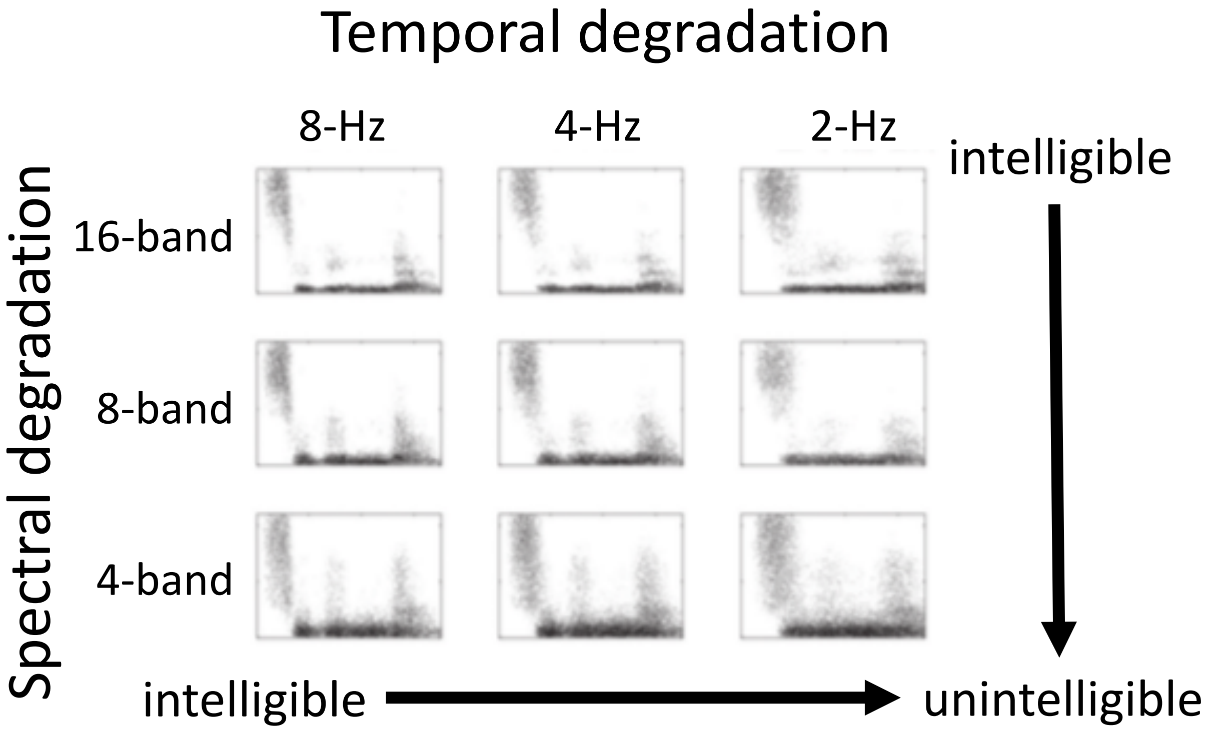
Ya-Ping Chen, Patrick Neff, Sabine Leske, Daniel D.E. Wong, Nicole Peter,
Jonas Obleser, Tobias Kleinjung, Andrew Dimitrijevic, Sarang Dalal, Nathan Weisz

Background

- Individuals with a cochlear implant (CI) for treating single-sided deafness have experienced improved speech perception in noise (Peter et al., 2019).
- However, it is not clear how single-sided CI users' speech perception improves and how neural speech representation of speech intelligibility changes over a year.
- Research Question
  - How neural speech representation of speech intelligibility changes over time in single-sided CI users **(SSD-CI)**?



3 x 3 Stimulus Manipulation



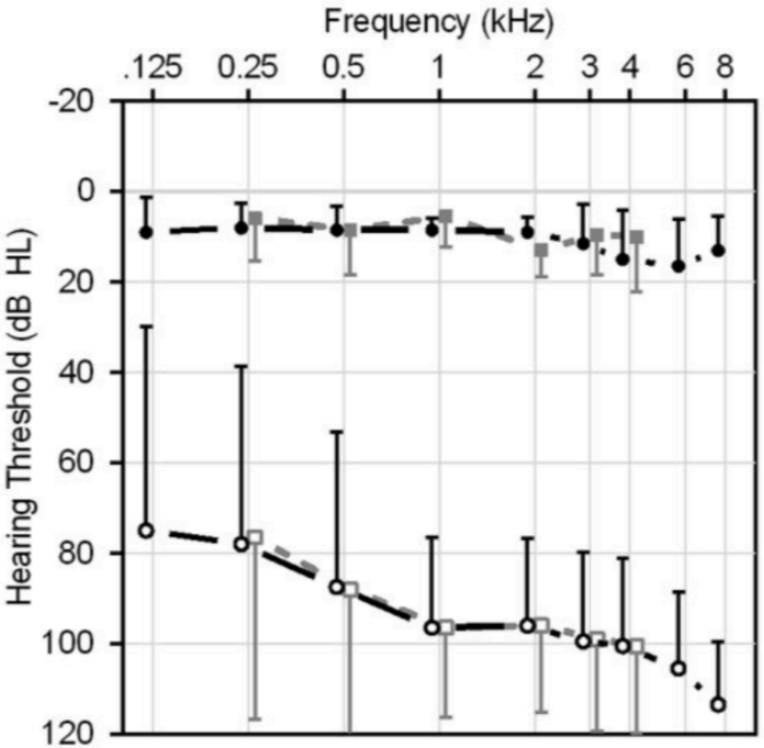
- Participant
  - 10 single-sided cochlear implant users (**SSD-CI**) (5 right-sided + 5 left-sided)
    - 4 female, mean age 46.9 (27-63)
  - 10 age-and-sex matched controls
    - 4 female, mean age 48.2 (29-61)
- Stimuli
  - 216 standard German nouns presented monaurally to each ear
    - 3 levels of temporal smoothing x 3 levels of spectral degradation
- EEG measurement
  - 128 channel EEG (ANT-Neuro system)
  - 1 session for healthy controls
  - 4 sessions for CI users
    - Pre-op (only healthy ear) & 3 Post-op (3, 6 & 12 months)

CI Sub ID	Age at CI Activation (yrs)	Duration of Deafness (yrs)
CI1	27	1.0
CI2	36	1.7
CI3	42	1.6
CI4	45	4.6
CI5	48	0.8
CI6	48	1.5
CI7	50	1.5
CI8	54	1.2
CI9	56	1.3
CI10	63	1.4

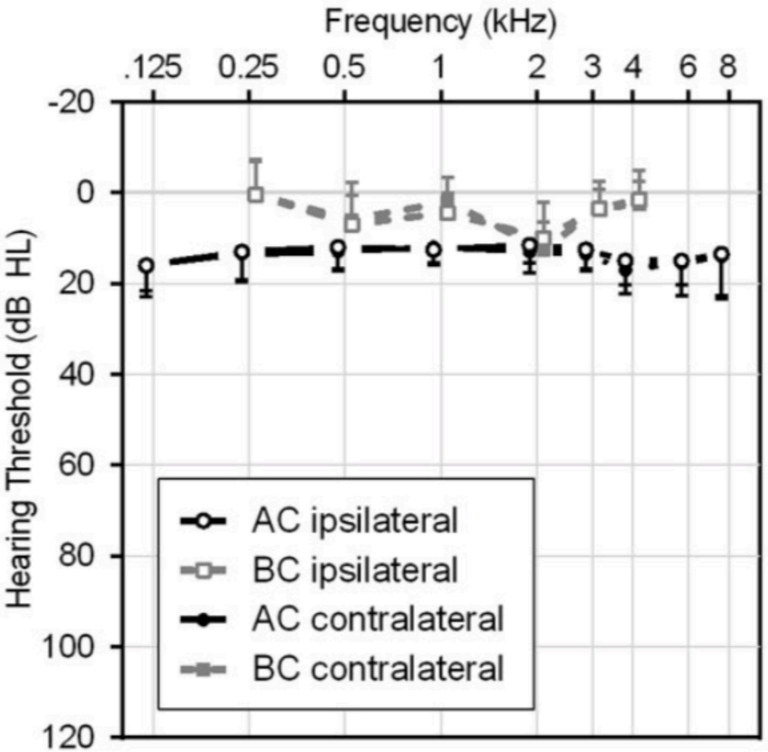
b

Preoperative Pure Tone Audiograms

SSD-CI

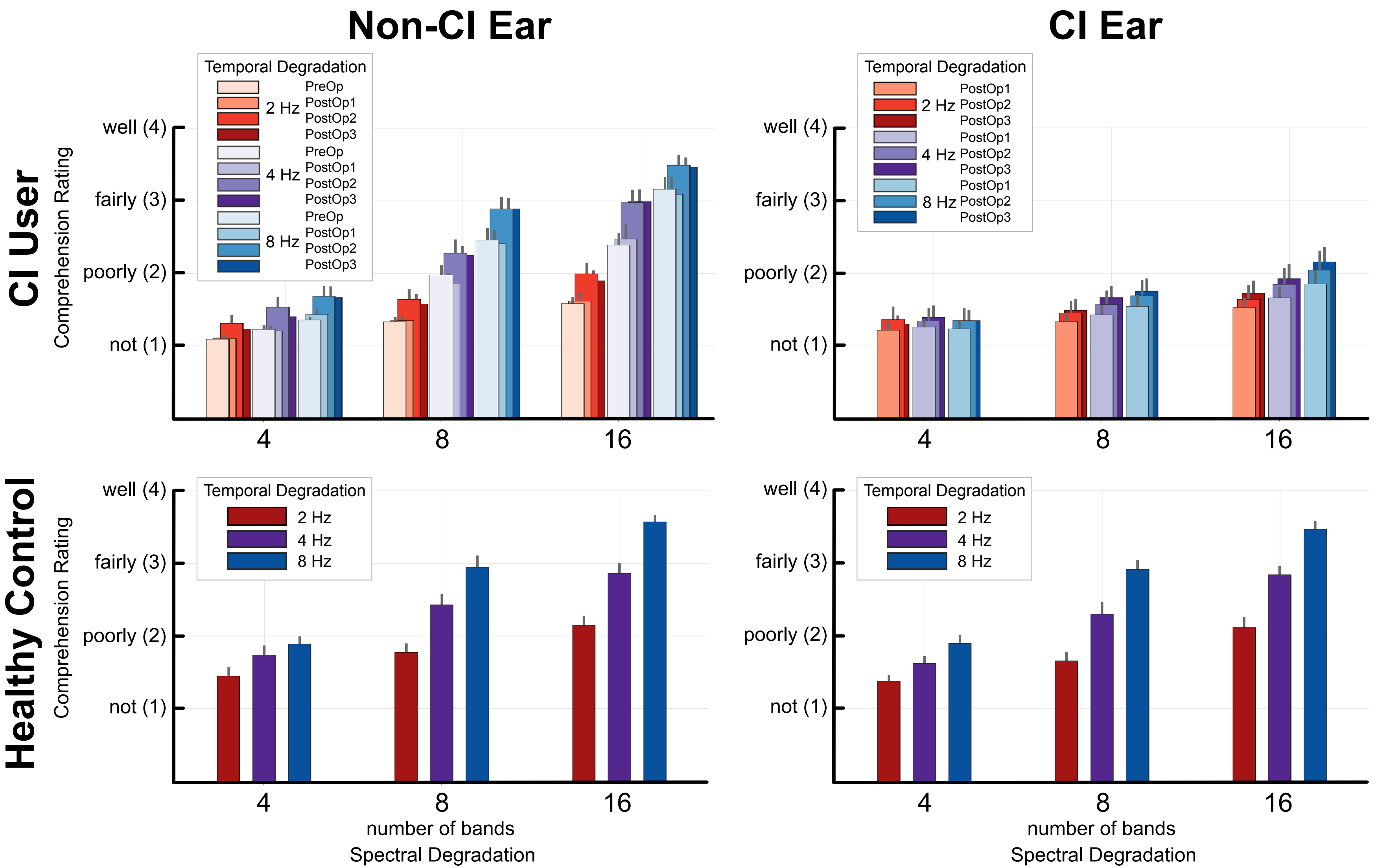


Healthy Control

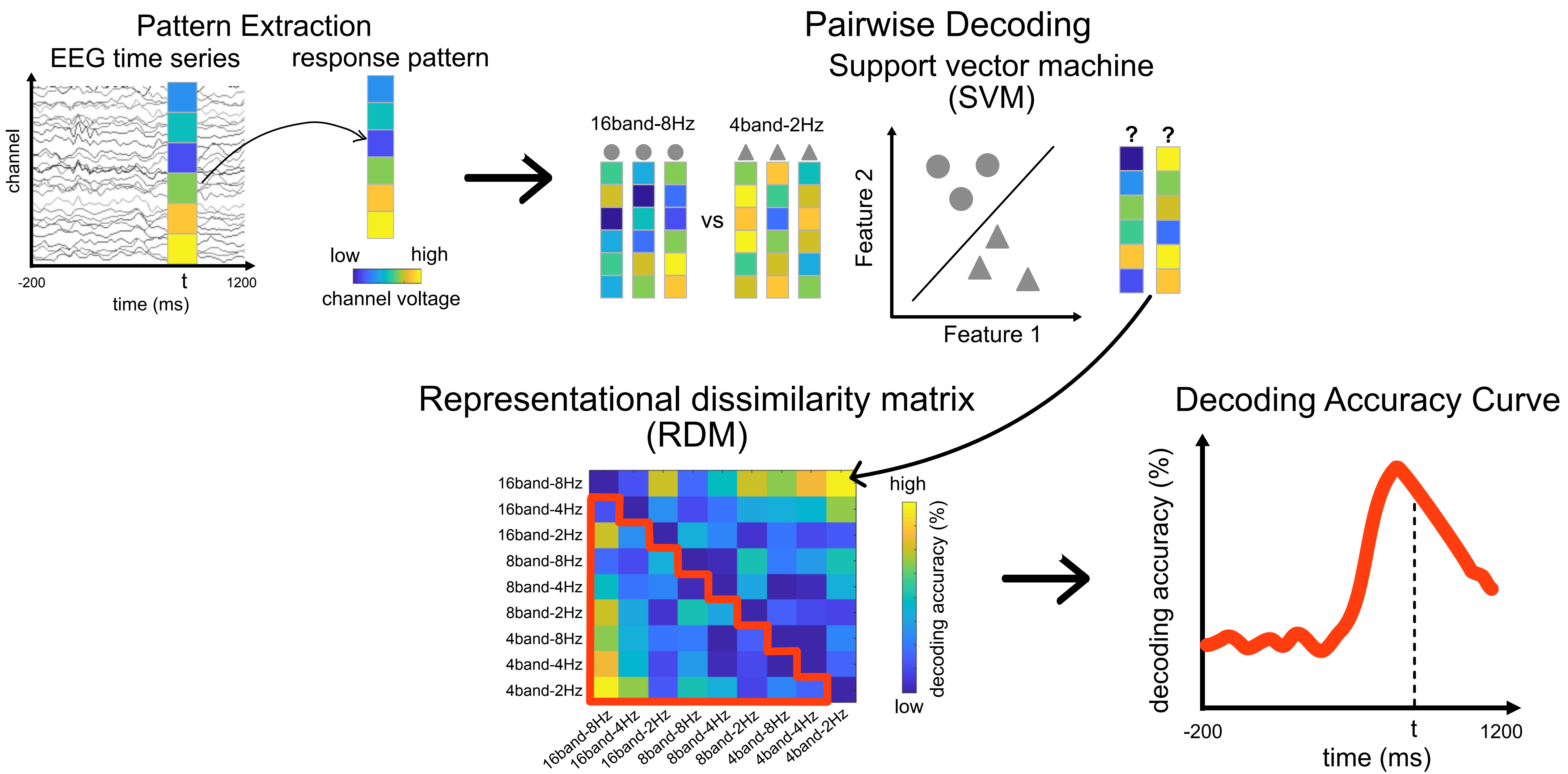


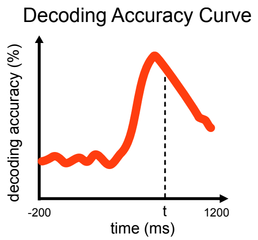
Peter et al. (2019) Swiss Med Wkly

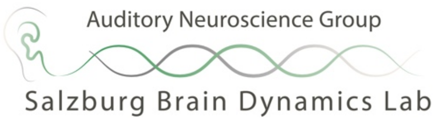
Behavioral Results



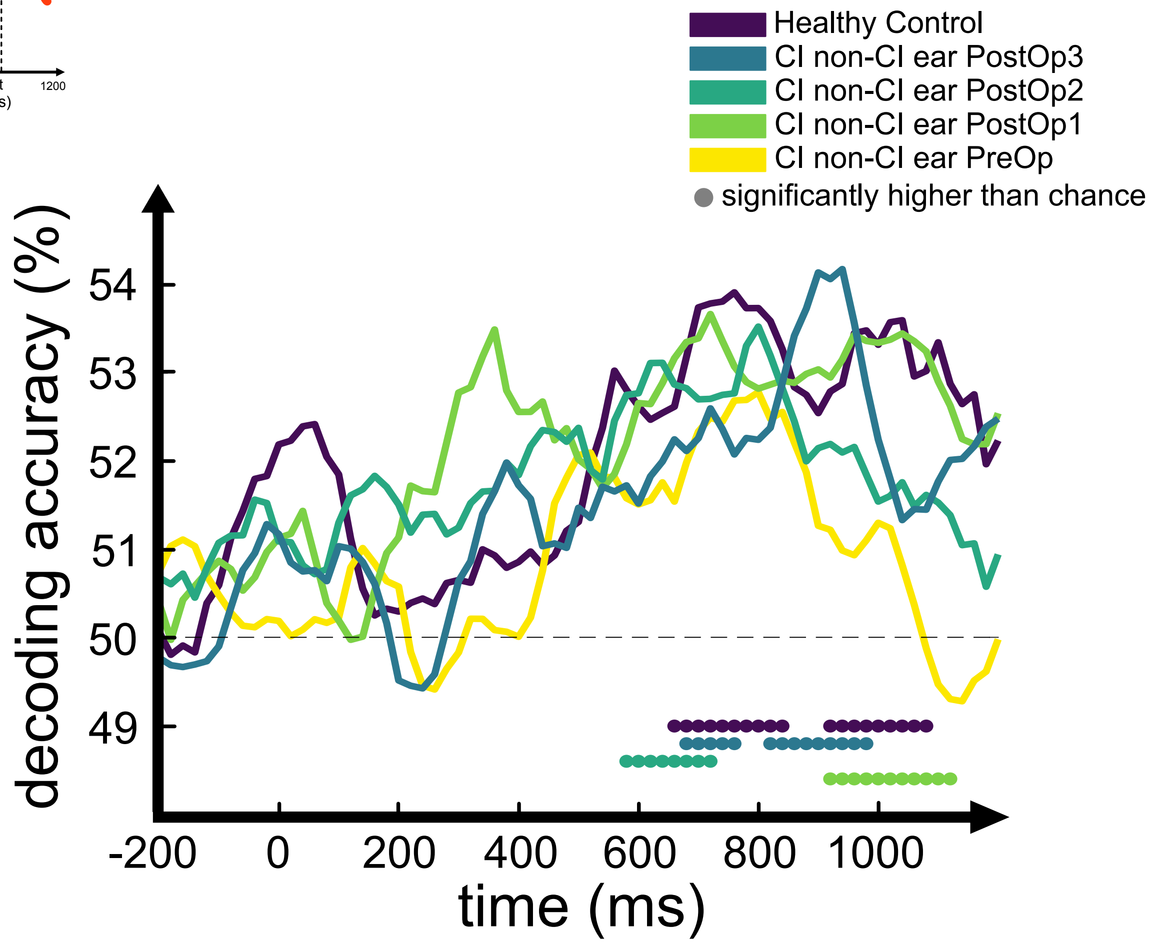
Representational Similarity Analysis (RSA)



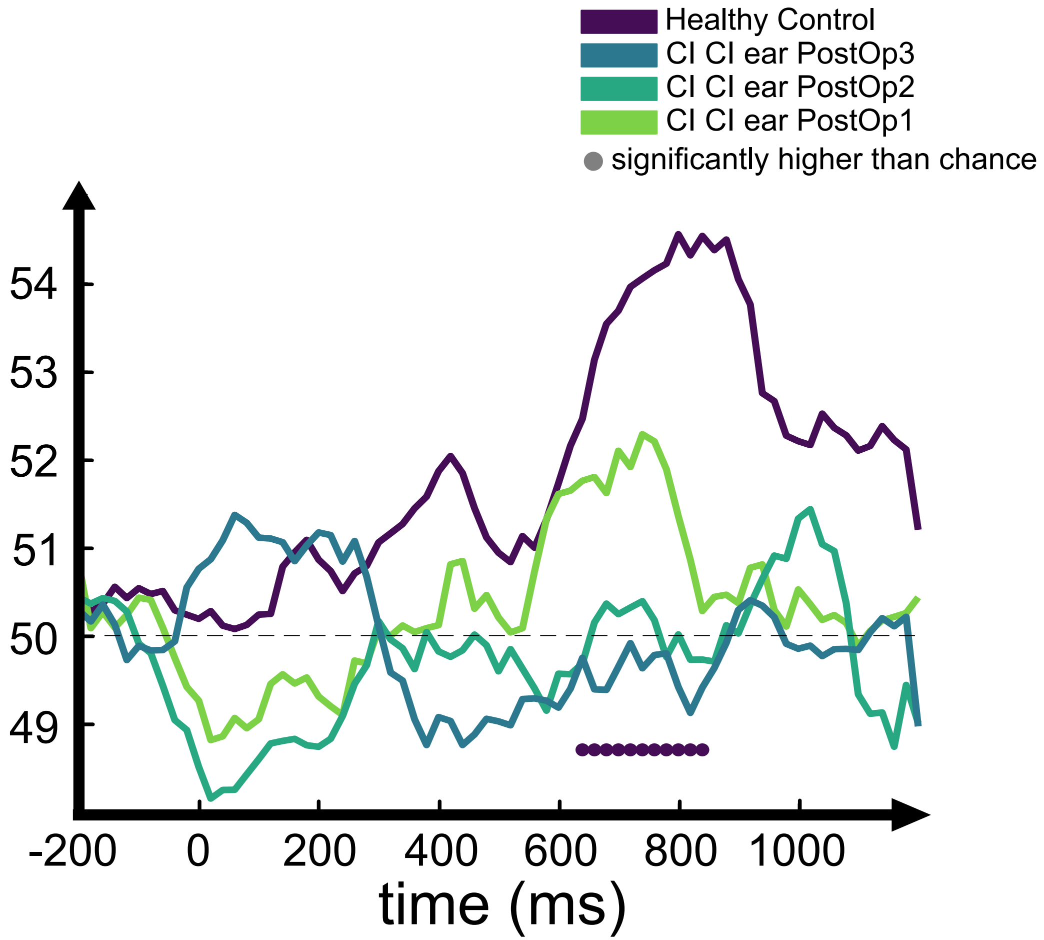


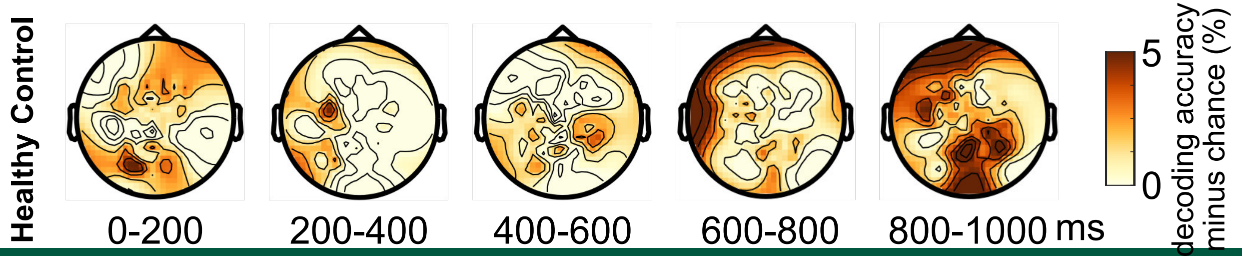


Non-CI Ear

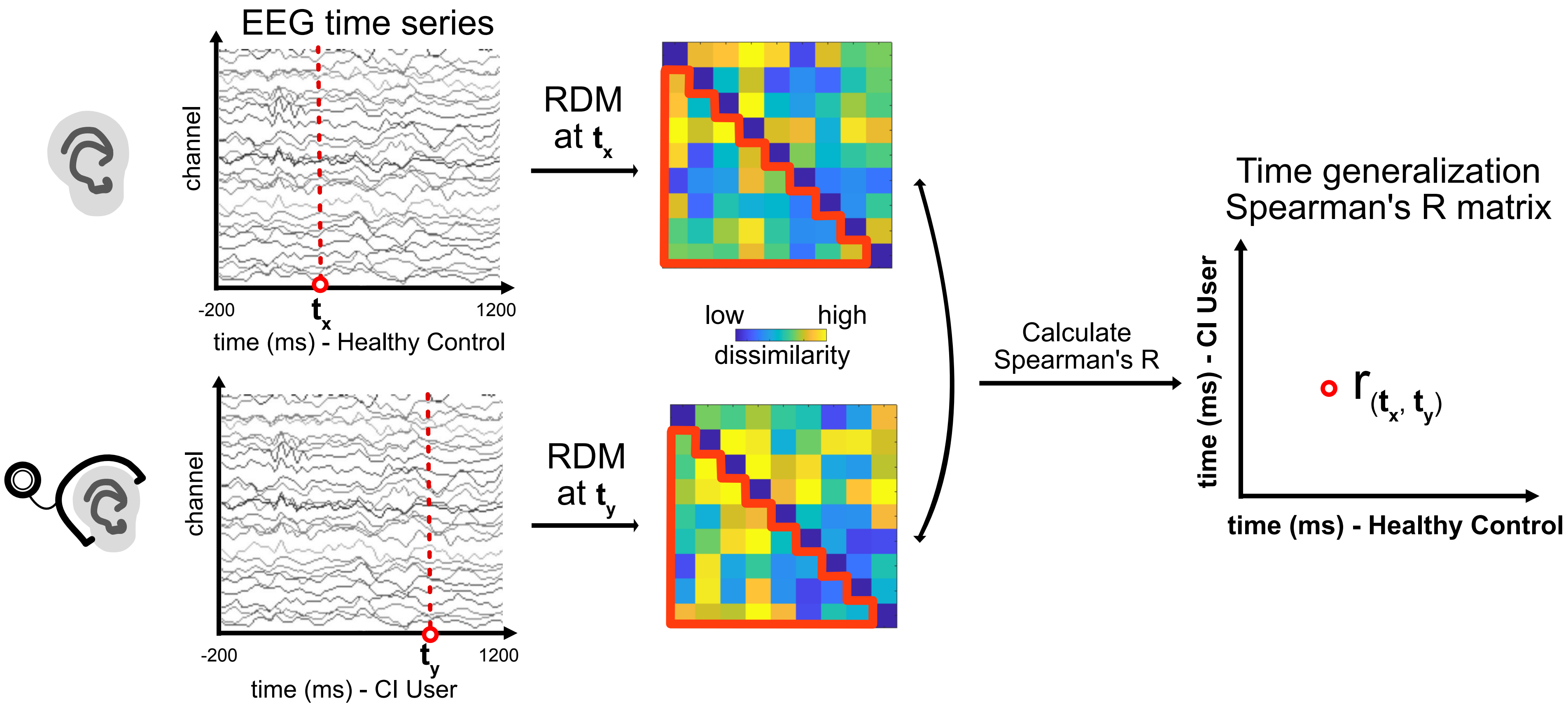


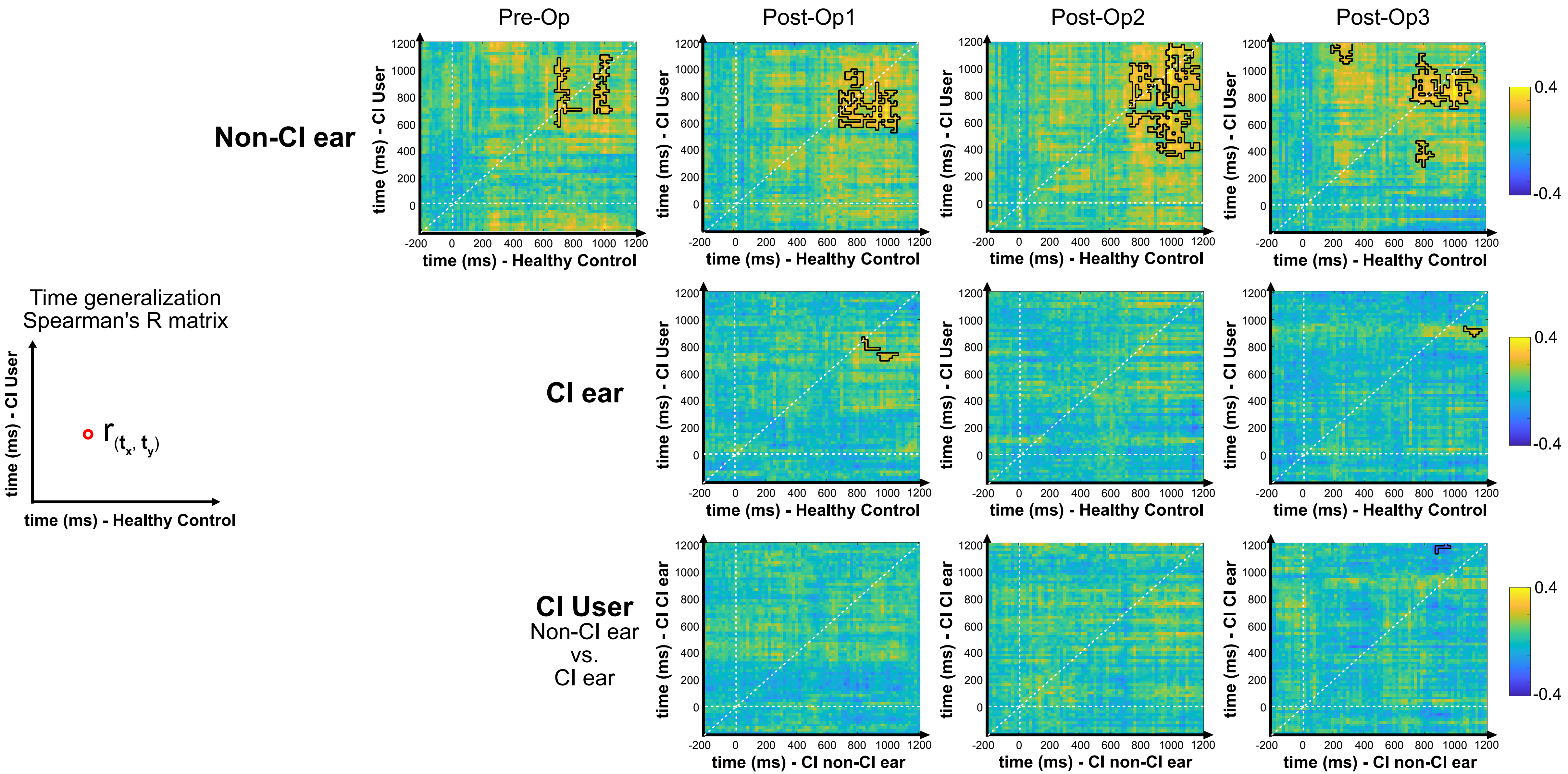
CI Ear





Shared Representations between SSD-CI users and healthy controls




Pre-Op
Post-Op1
Post-Op2
Post-Op3
Non-CI ear
CI ear
CI User
Non-CI ear
vs.
CI ear
Time generalization
Spearman's R matrix
$r_{(t_x, t_y)}$
time (ms) - CI User
time (ms) - Healthy Control
time (ms) - CI CI ear
time (ms) - CI non-CI ear
0.4
-0.4

Conclusion of Study 2

- The CI benefits not only the CI ear but also the non-CI ear.
- We show that auditory cortical speech processing after CI implantation gradually normalizes towards generally normal functioning within months.

Auditory Neuroscience Group

Salzburg Brain Dynamics Lab

FWF Der Wissenschaftsfonds.

Andrew Dimitrijevic
University of Toronto

Anne Keitel
University of Dundee, UK

Daniel D.E. Wong
Universität Konstanz, Germany

Jonas Obleser
University of Lübeck, Germany

Nicole Peter
Tobias Kleinjung
University of Zurich, Switzerland

Sabine Leske
University of Oslo, Norway

Sarang Dalal
Aarhus University, Denmark

Sebastian Rösch
Paracelsus Medical University, Austria

Thank you for your time!