



Time-frequency analyses and MCCA on Naturalistic Stimuli in EEG and MEG experiments

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Learning Goal

Present stories, music, or movies to participants while recording their brain signals using EEG or MEG

Extract meaningful signals related to the stimuli

Conduct a time-frequency decomposition

Quickly clean signals and prepare for high-level analyses

Segmenting and Predicting Musical Phrase Structure Exploits Neural Gain Modulation and Phase Precession

7.6GB

Make Private

Public

0

...

Contributors: [Xiangbin Teng](#), [Pauline Larrouy-Maestri](#)

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Category:  Project

Description: *Add a brief description to your project*

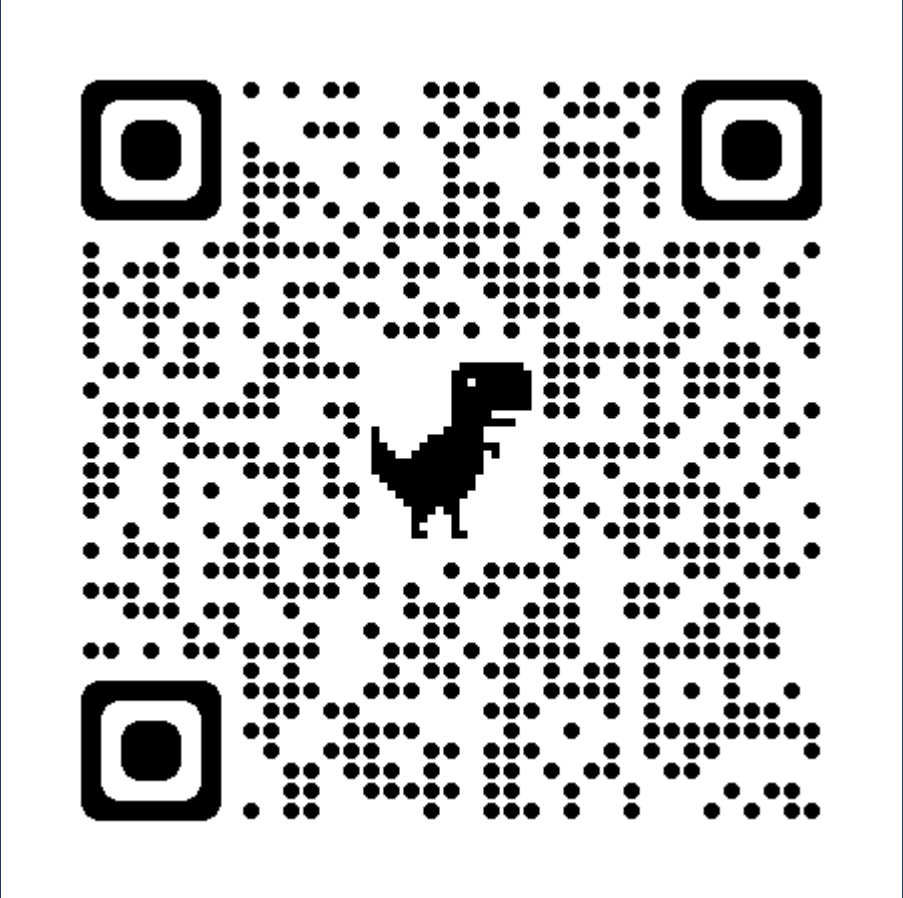
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Teng, X., Larrouy-Maestri, P., & Poeppel, D. (2021).

Segmenting and Predicting Musical Phrase Structure Exploits Neural Gain Modulation and Phase Precession. *bioRxiv*.

https://www.dropbox.com/sh/rml9z6hkw5in5du/AAAR3Wcy_66fnQms24wfM9Ipa?dl=0



Sounds, speech, and music

Speech

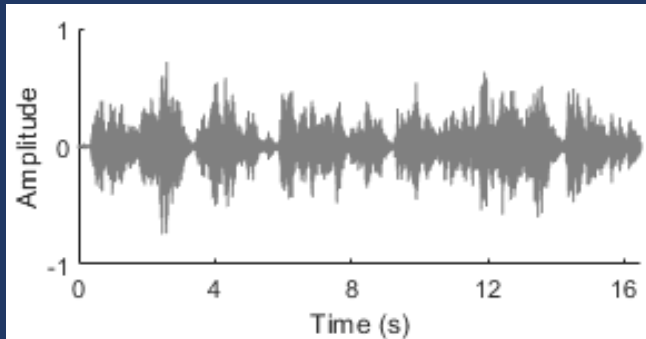


Music



From sounds to meanings

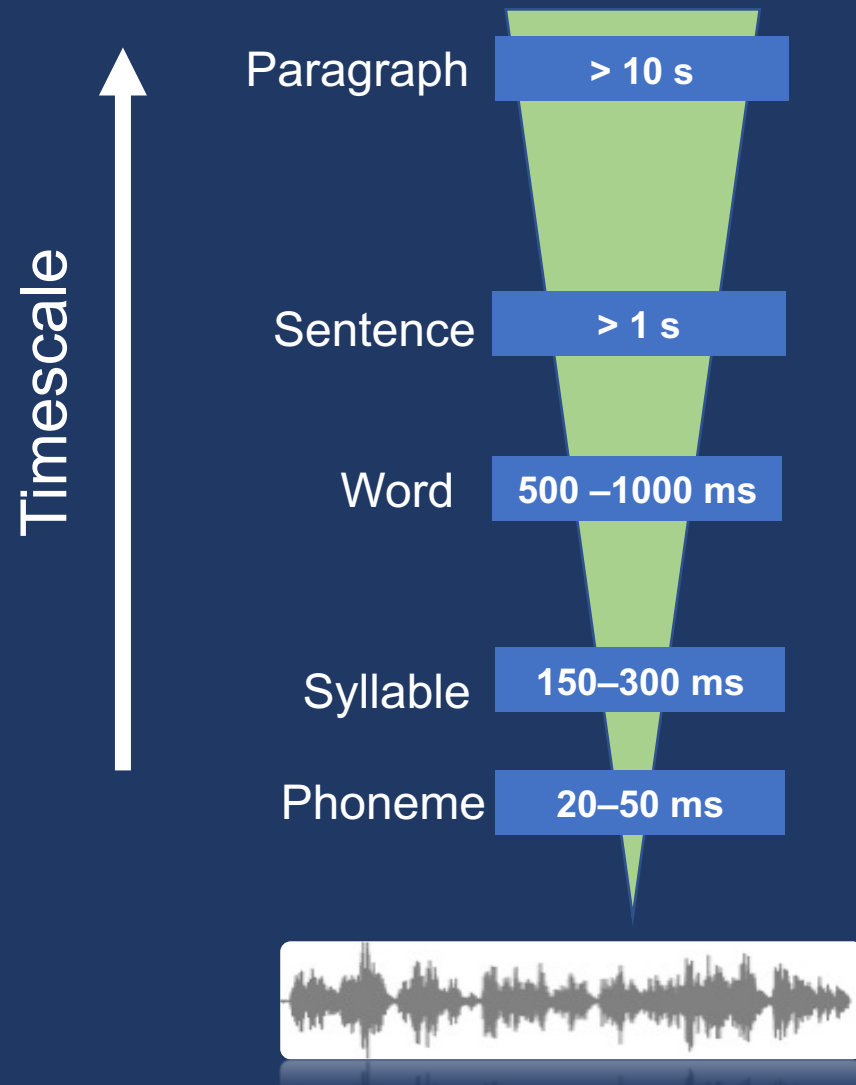
Continuous and linear



Discrete and hierarchical

The train is arriving. Please
let passengers exit first.

Multi-timescale information in linear sequences



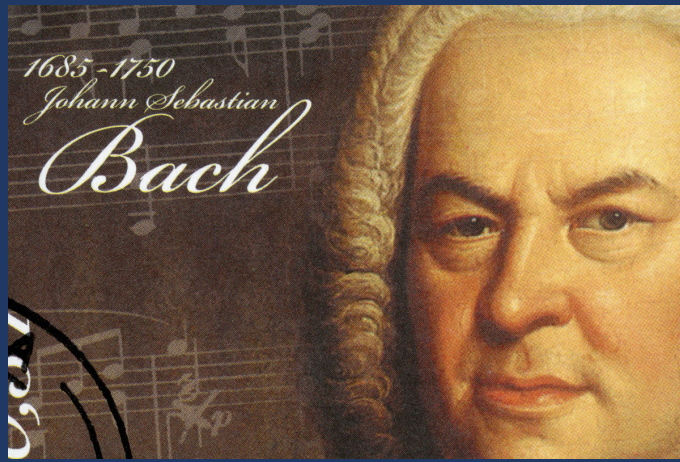
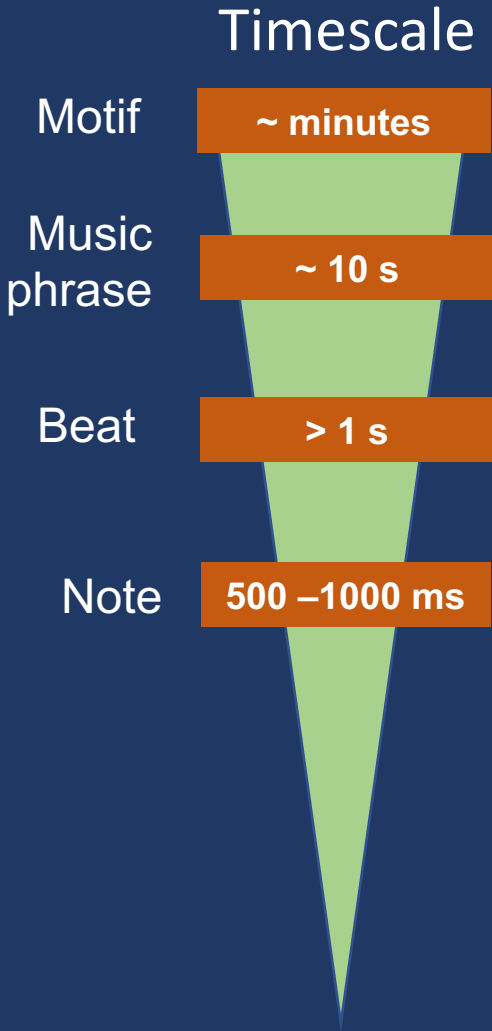
The train is arriving. Please let passengers exit first.

The train is arriving.

Train, arrive, passengers, exit

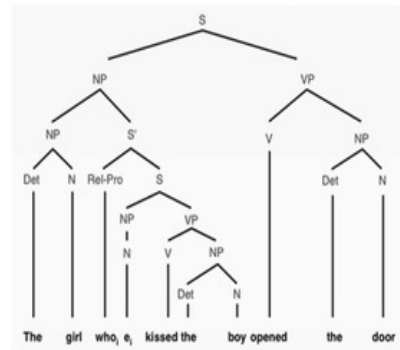
ðə treɪn ɪz ə'raɪvɪŋ

Multi-timescale information in linear sequences



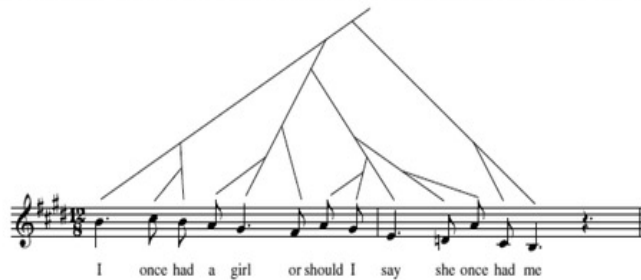
The world is dynamic and hierarchical

a) Syntactic structure in language: hierarchical phrase structure



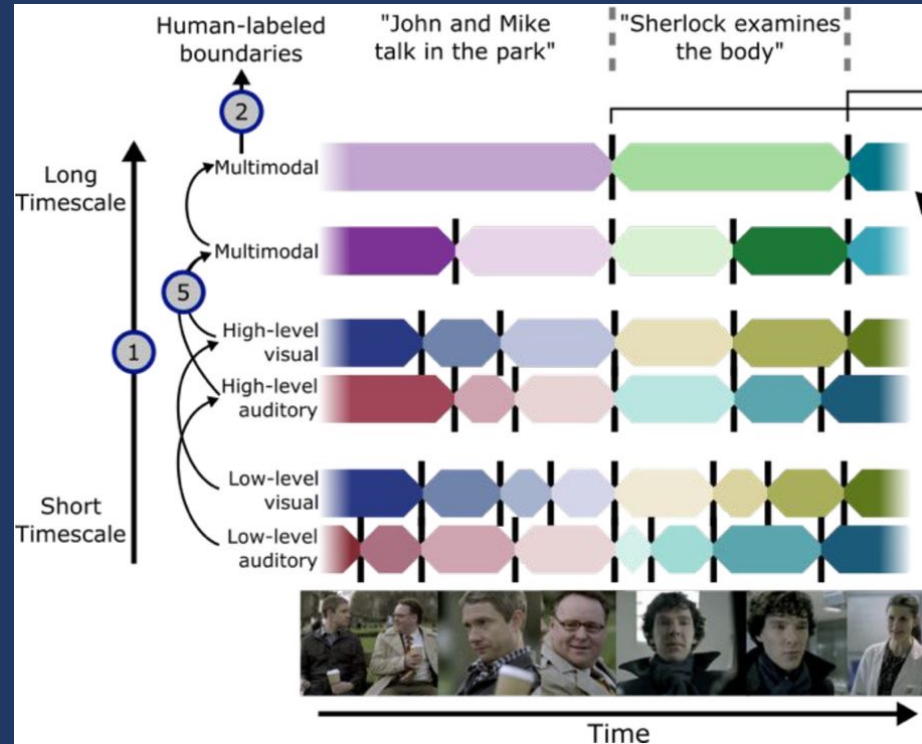
Patel, A. D. (2003). *Language, music, syntax and the brain*. *Nature Neuroscience*, (6) 7, 675.

b) Syntactic structure in music: hierarchical patterns of pitch, tension and resolution



Jackendoff, R., Lerdhal, F. (2006). *The capacity for music: What is it, and what's special about it?*. *Cognition* (100) 1, 56.

Stephanie et al., 2019



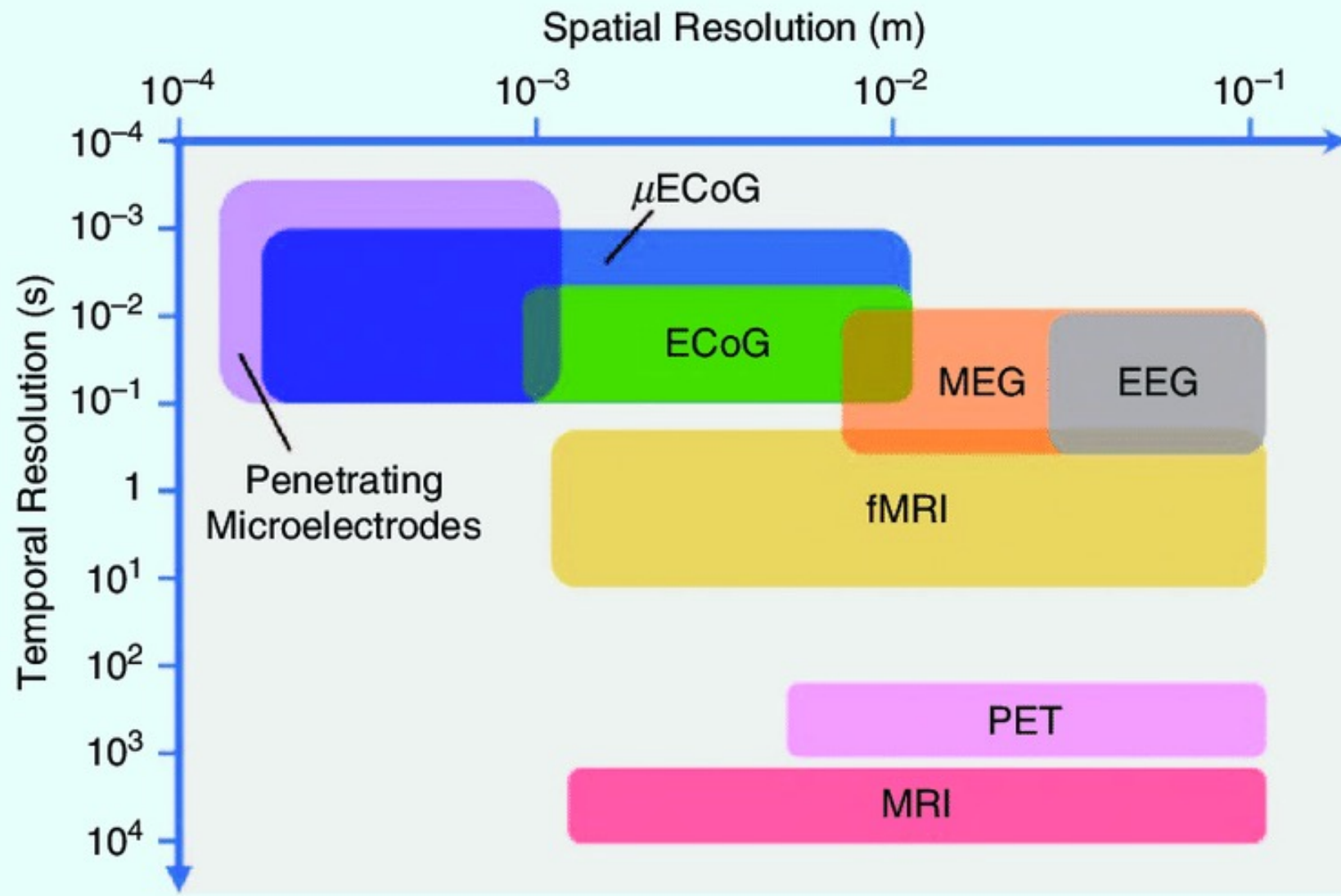
Zacks et al., 2007

Baldassano et al., 2017

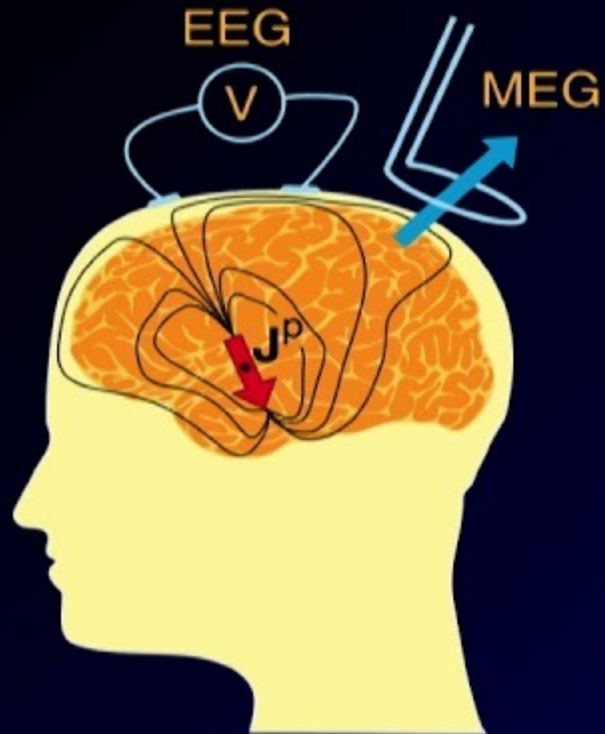
Time

**Naturalistic stimuli are continuous
and are composed of discrete units
across many timescales**

**How do you extract neural responses
to units at each timescale?**



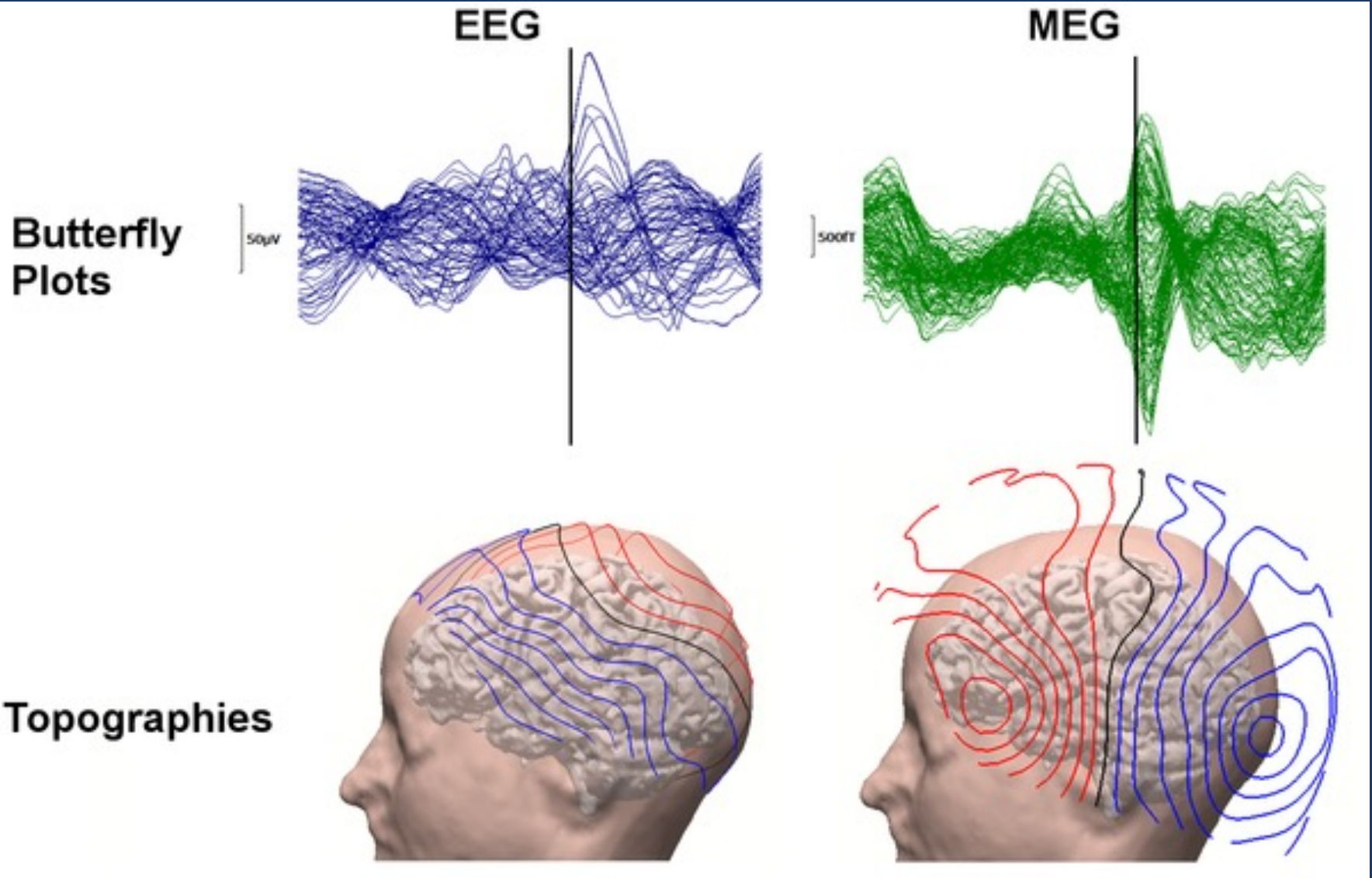
MEG and EEG



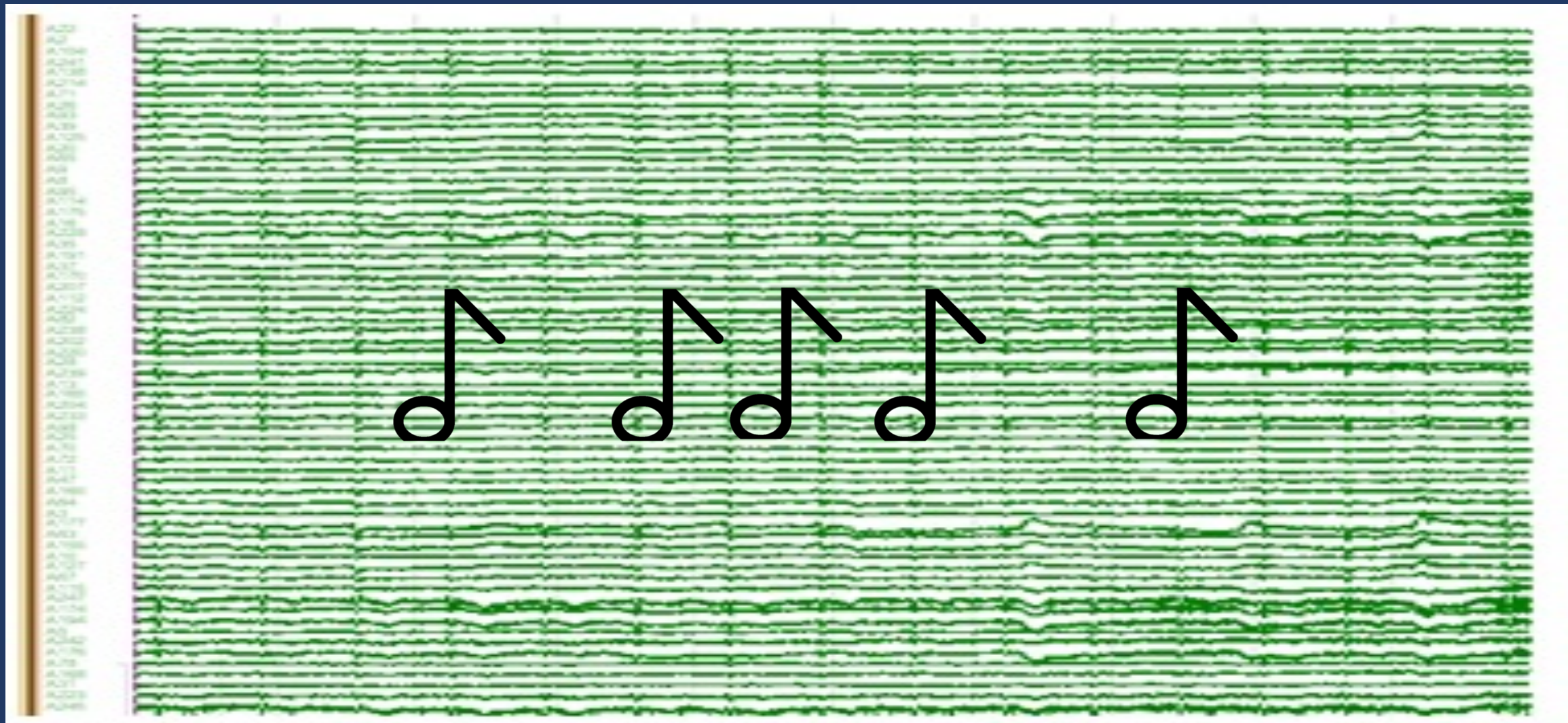
- Measure the electric potential (EEG) magnetic field (MEG) generated by neural currents
- Reasonable spatial resolution
- Real-time measures of brain activity
- Frequency-specific measures of association (connectivity)

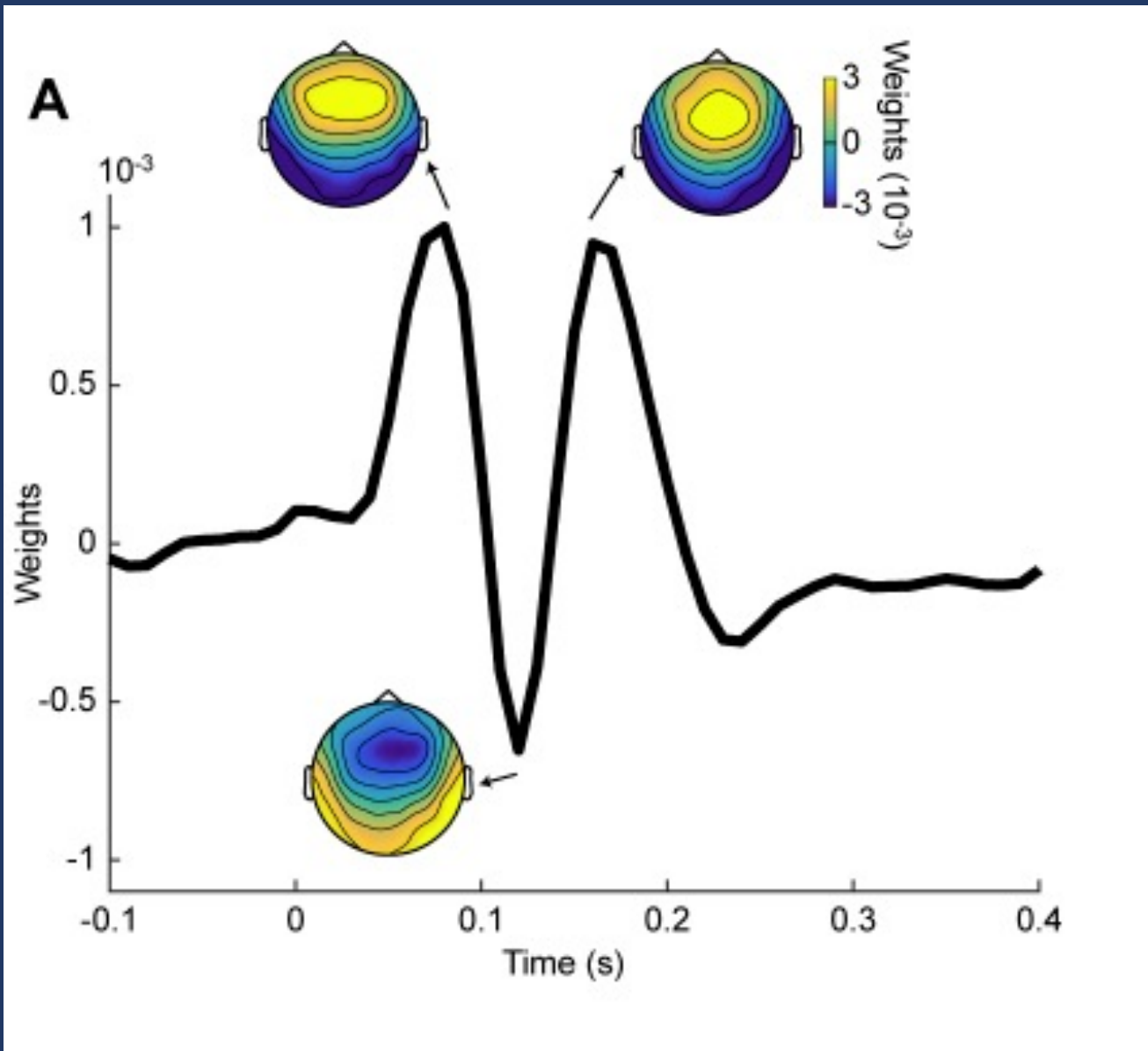


Matti Hämäläinen 5/2019 5



Event-related paradigm





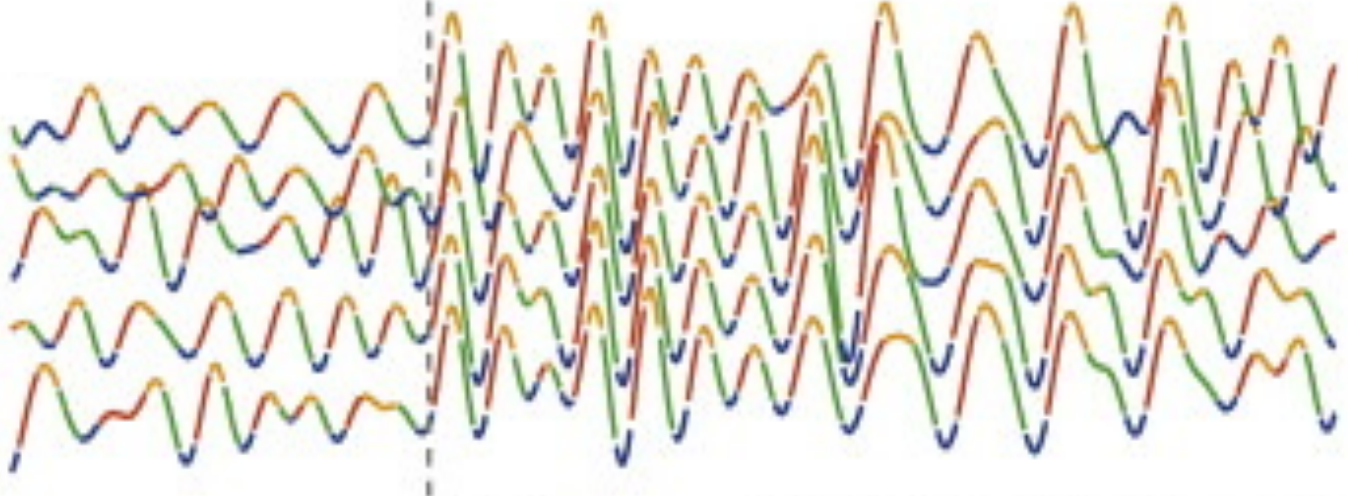
Event-related paradigm

Sound

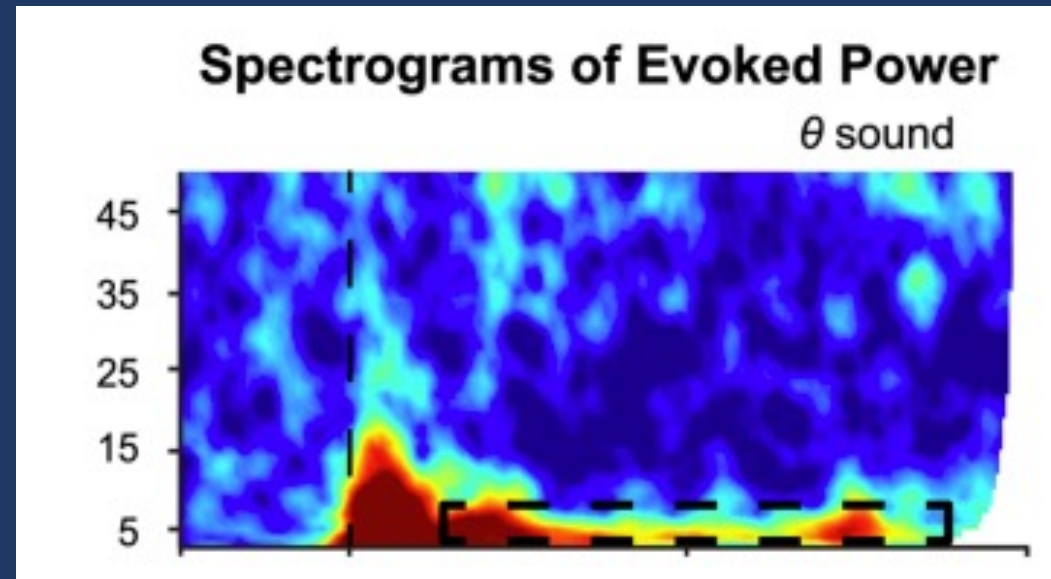


Repetition

- 1
- 2
- 3
- 4
- 5
- 6



Evoked/Induced Power Inter-trial phase coherence



We don't hear a sentence many times.

We don't watch a video many times.

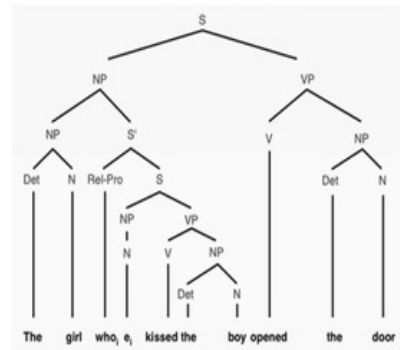
We don't listen to music many times.

In MEG/EEG experiments with naturalistic stimuli

- 1. Present a natural stimulus once**
- 2. Record MEG/EEG signals**
- 3. Derive meaningful neural signatures**
- 4. Answer our scientific questions**

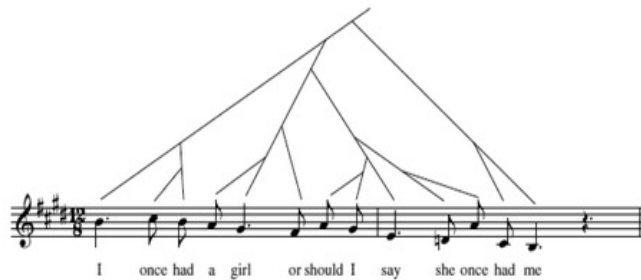
The world is dynamic and hierarchical

a) Syntactic structure in language: hierarchical phrase structure



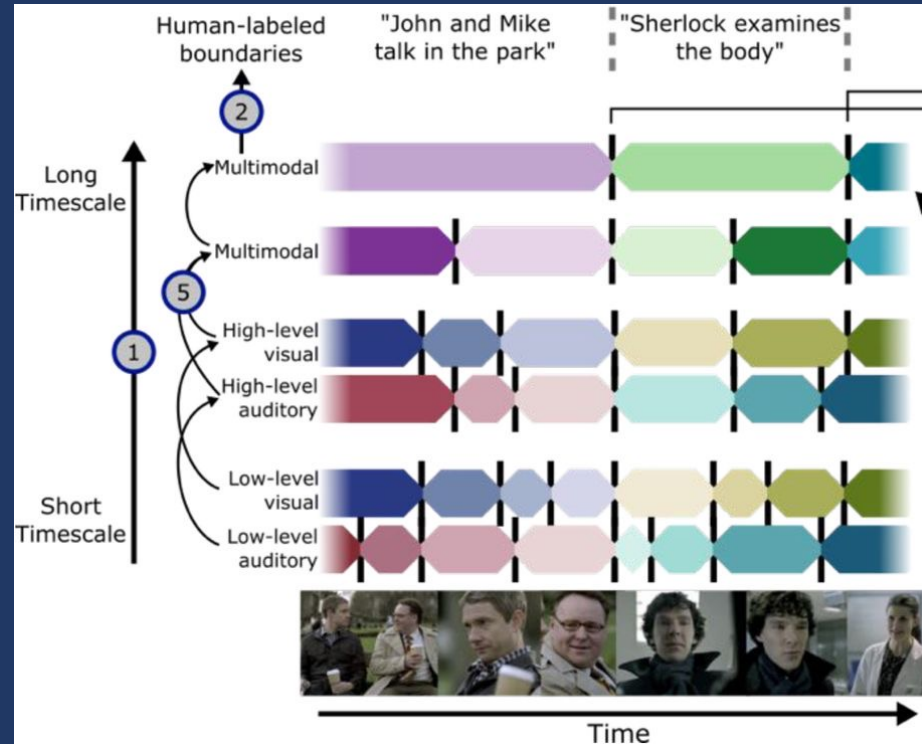
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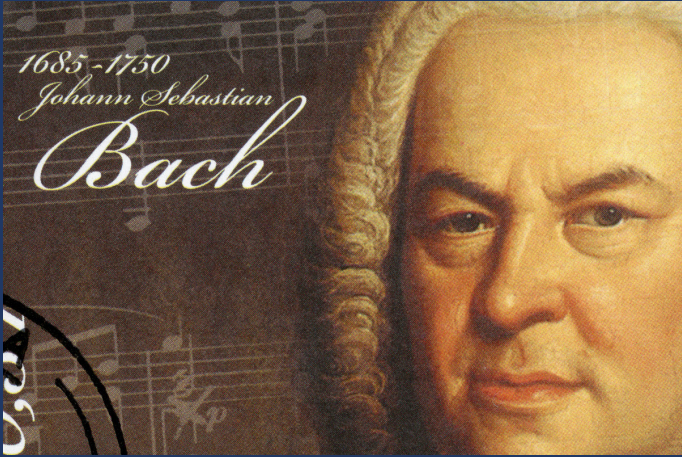
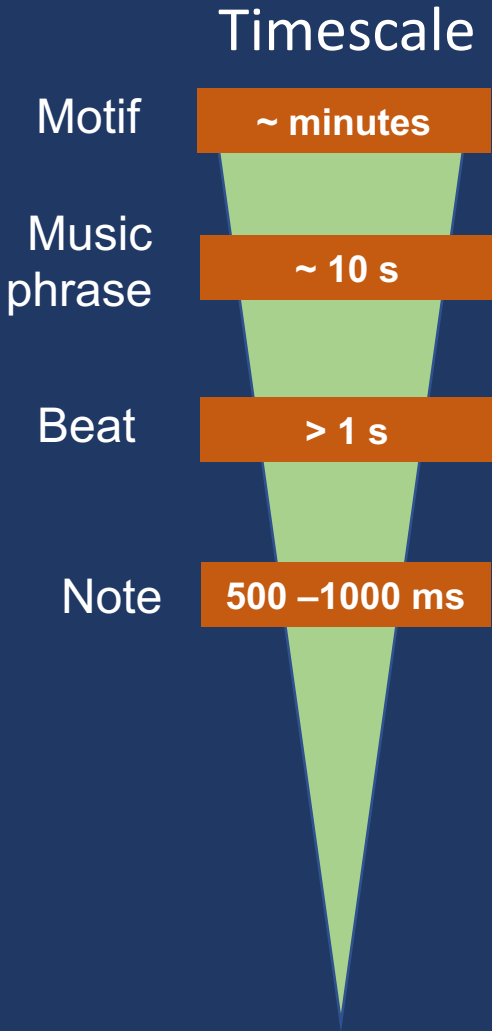


Zacks et al., 2007

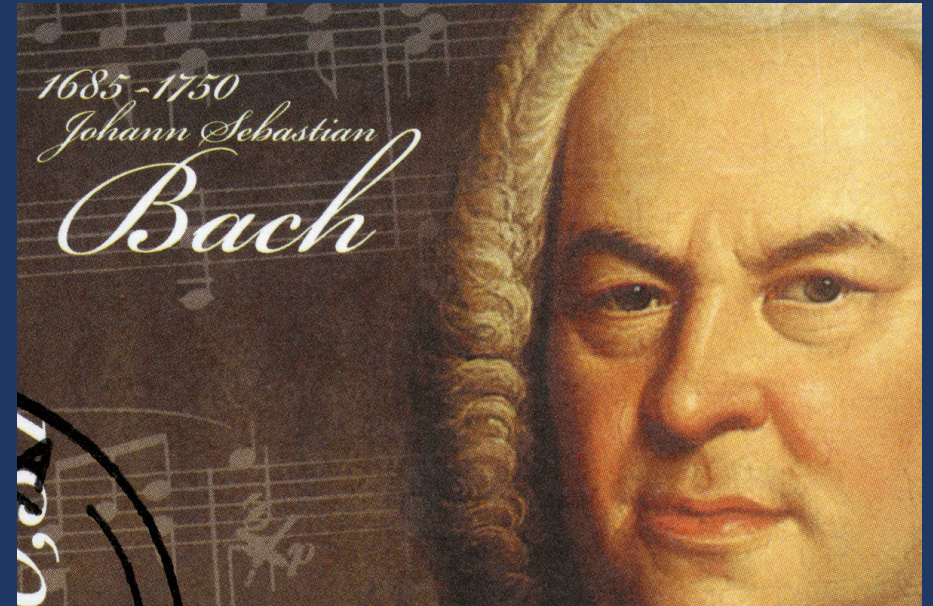
Baldassano et al., 2017

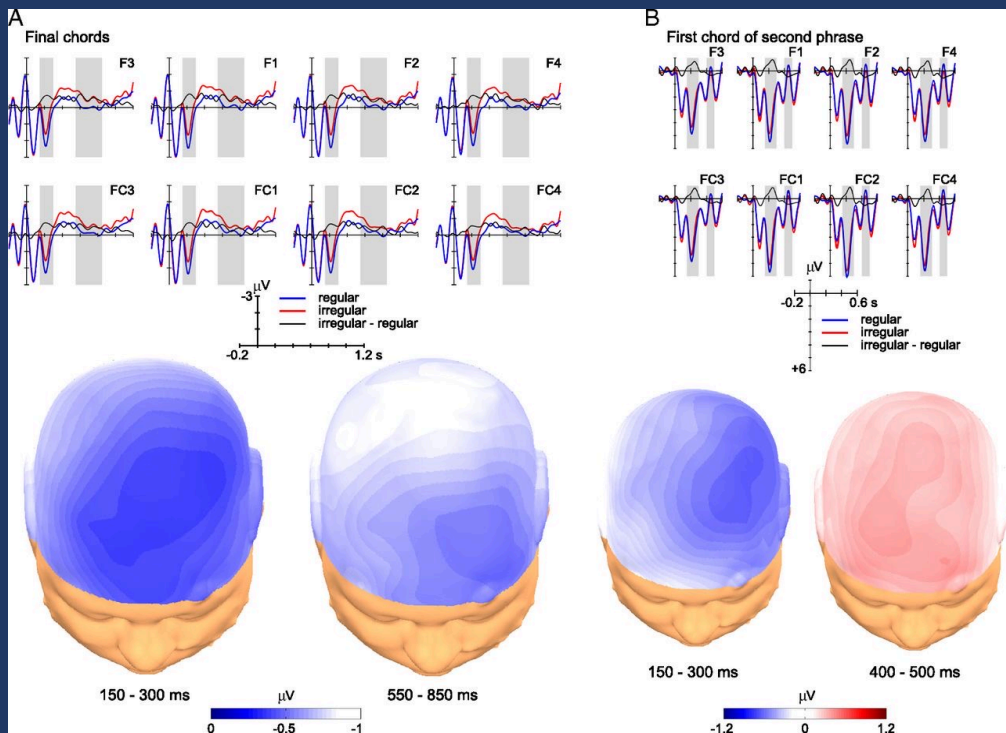
Time

Multi-timescale information in linear sequences

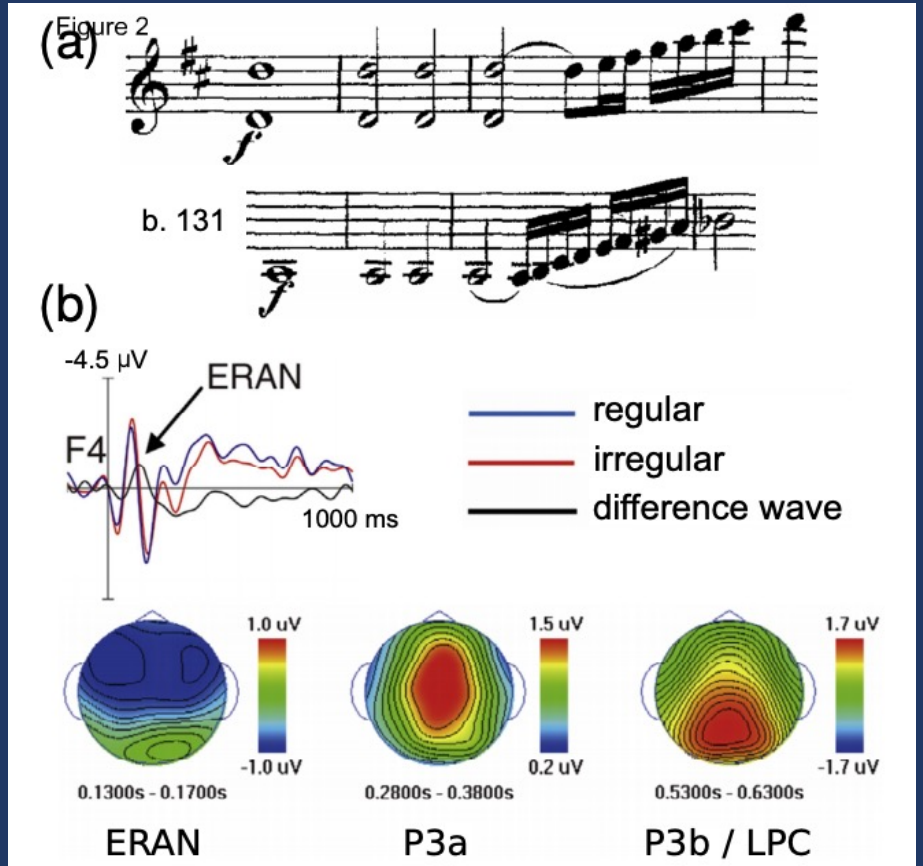


Listen to naturalistic music





Knösche et al., 2005;
 Neuhaus et al., 2006;
 Koelsch et al., 2013;
 Silva et al., 2014; Koelsch et al., 2019




Koelsch, Vuust, and Friston, TiCS, 2019

Music material: Bach chorale

Original

Reversal manipulation on music materials



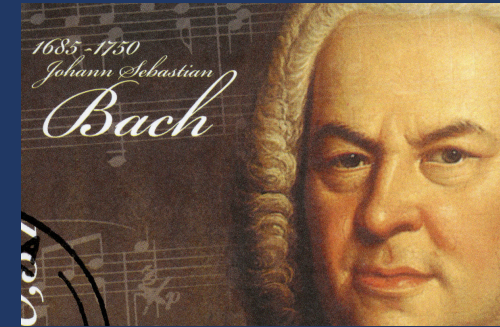
The image shows a musical score for a Bach chorale in G major, C major, and G major. The score is divided into two parts: 'Original' and 'Reversal manipulation on music materials'. The 'Original' part is on the left, and the 'Reversal manipulation' part is on the right, indicated by a red arrow pointing from left to right. The score is written in treble and bass clefs. The notes are labeled with letters: a1, a2, a3, a4, a5, a6, a7, a8, b1, b2, b3, b4, b5, b6, b7, b8, c1.

Tempo(bpm)

85 75 65

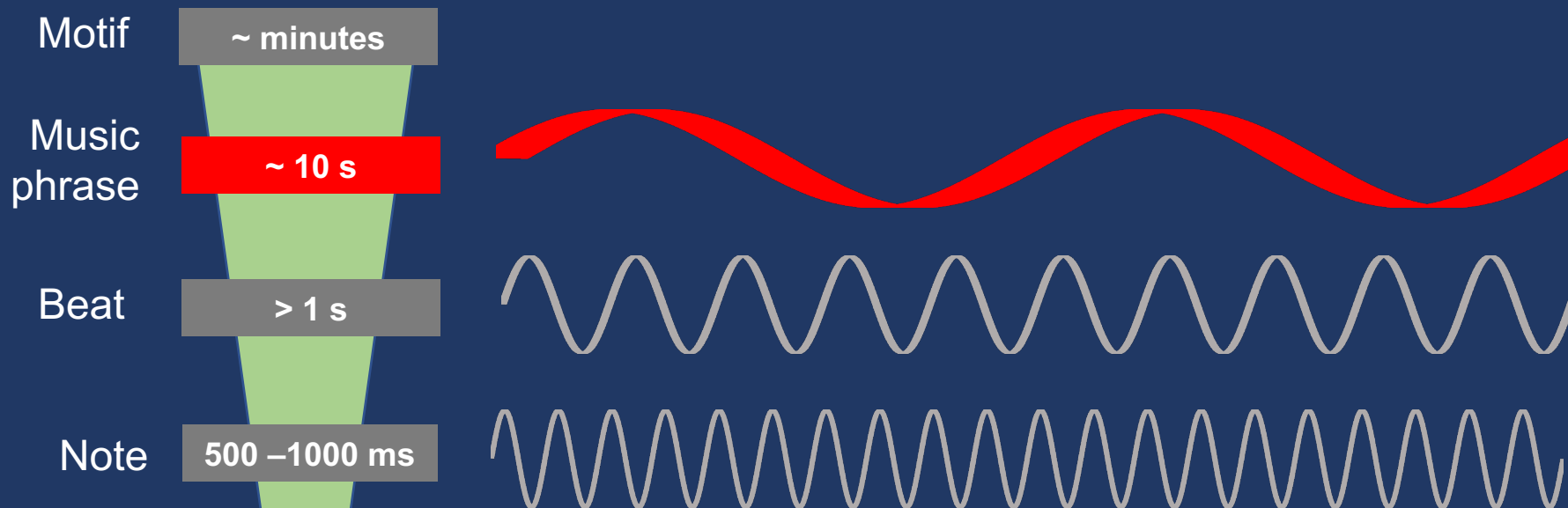


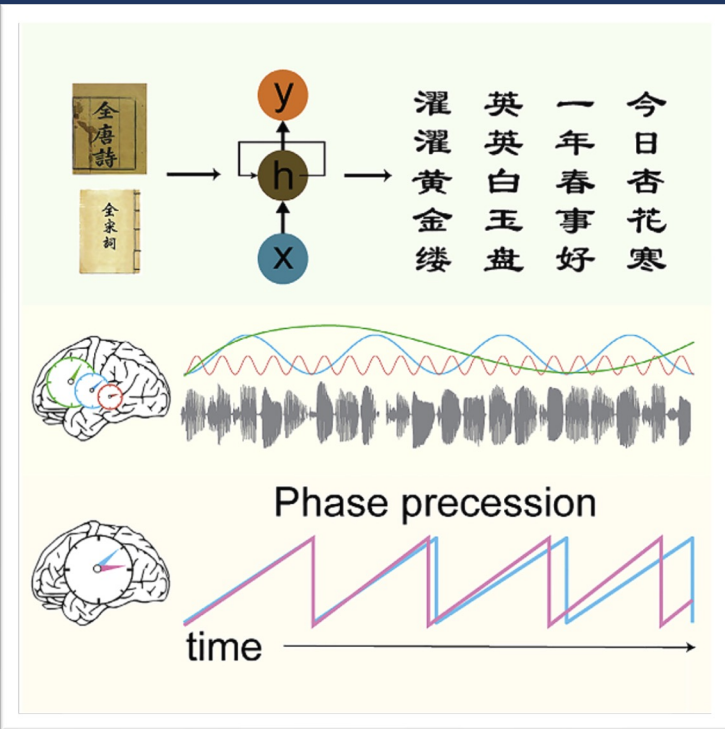
The image shows three speaker icons, each representing a different tempo setting. The first icon is labeled '85', the second '75', and the third '65'. The icons are arranged horizontally and are enclosed in red boxes.



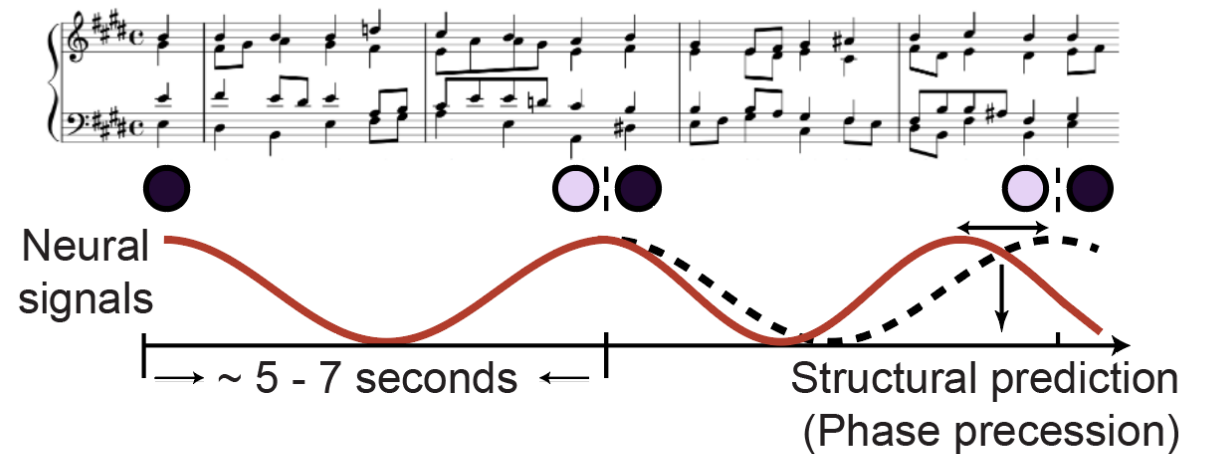
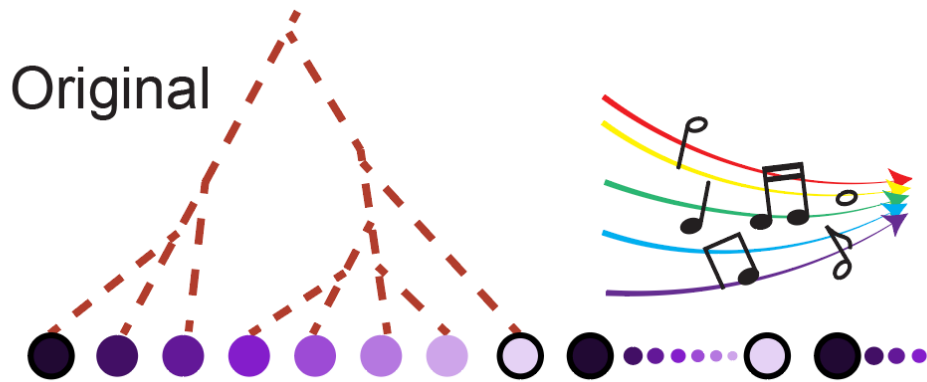
- 1 Ach Gott vom Himmel, sieh' da rein
- 2 Ach Gott wie manches Herzeleid
- 3 An wasserflussen Babylon
- 4 Erhalt uns, Herr, bei deinem Wort
- 5 Ermuntre dich, mein schwacher Geist
- 6 Es ist das Heil uns kommen her
- 7 Es spricht der Unweisen Mund wohl
- 8 Ich danke dir, o Gott, in deinem Throne
- 9 O Ewigkeit, du Donnerwort
- 10 Vater Unser im Himmelreich

Timescale





Teng, Ma, et al., 2020, *Current Biology*

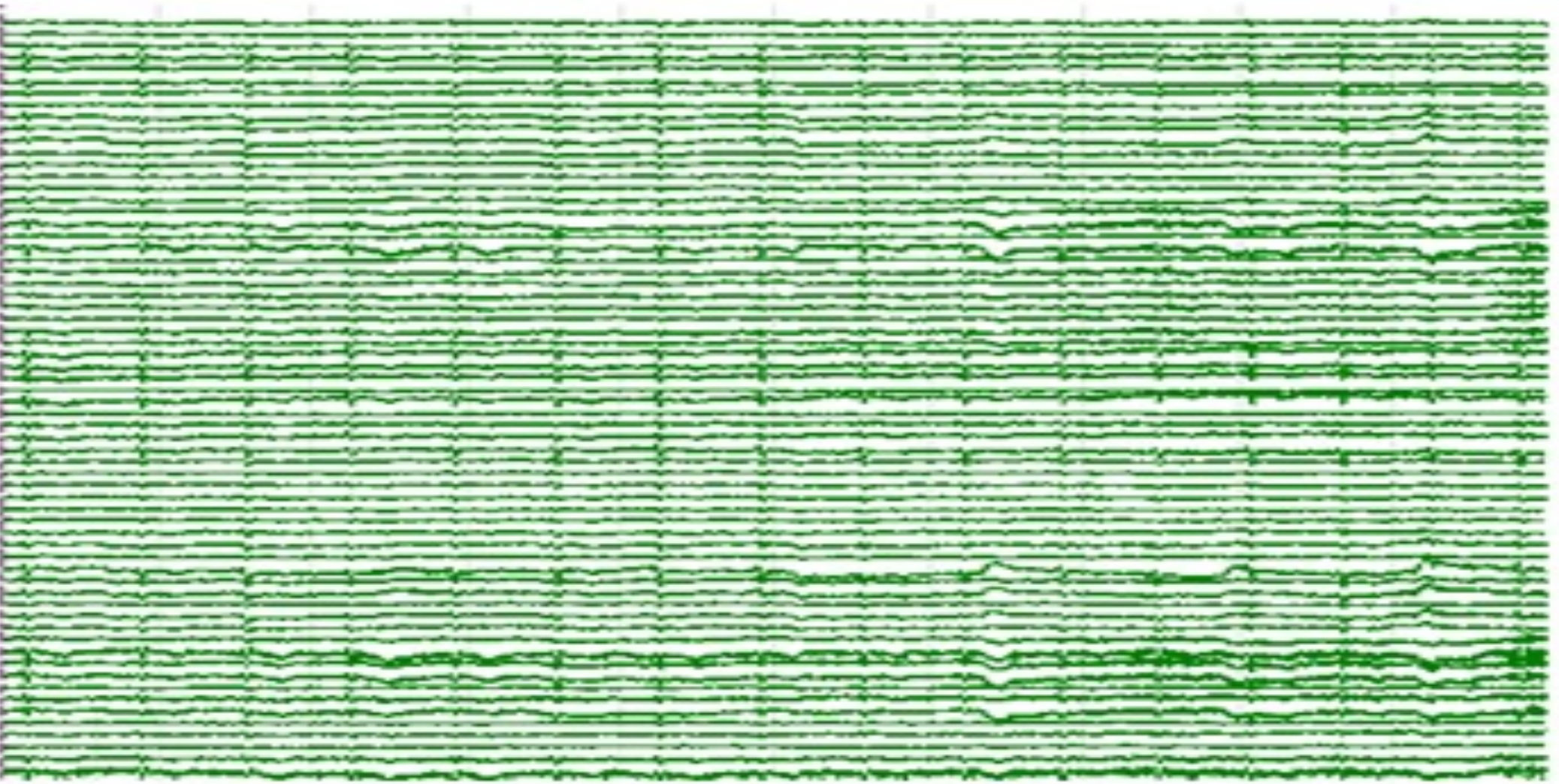


Teng et al., 2021a, bioRxiv

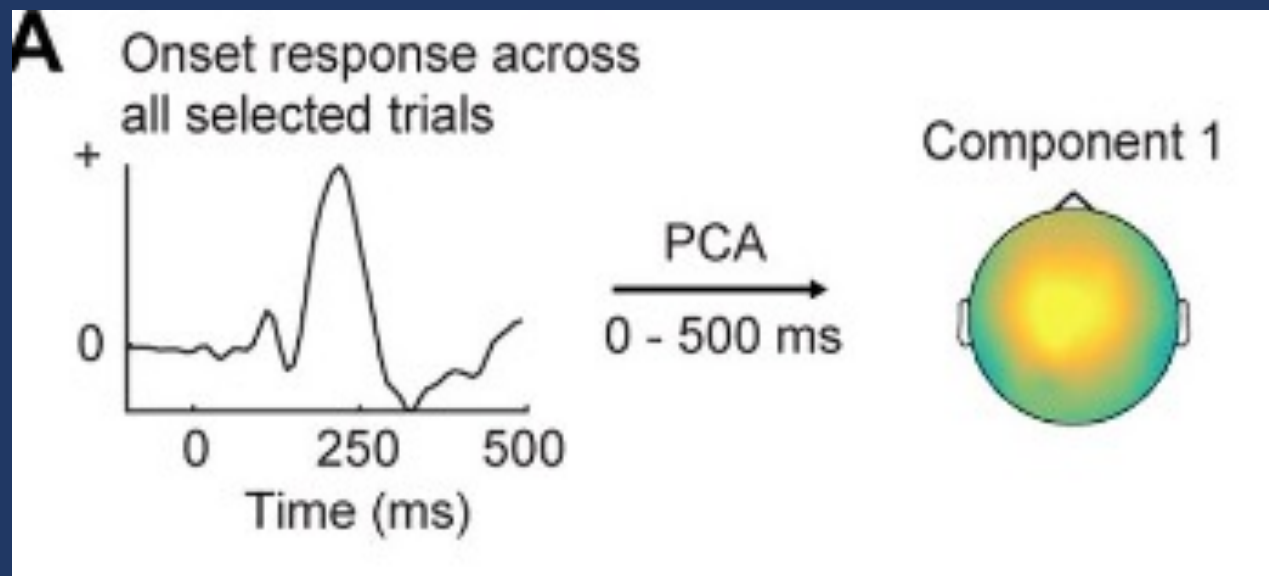
Each music piece is only presented once

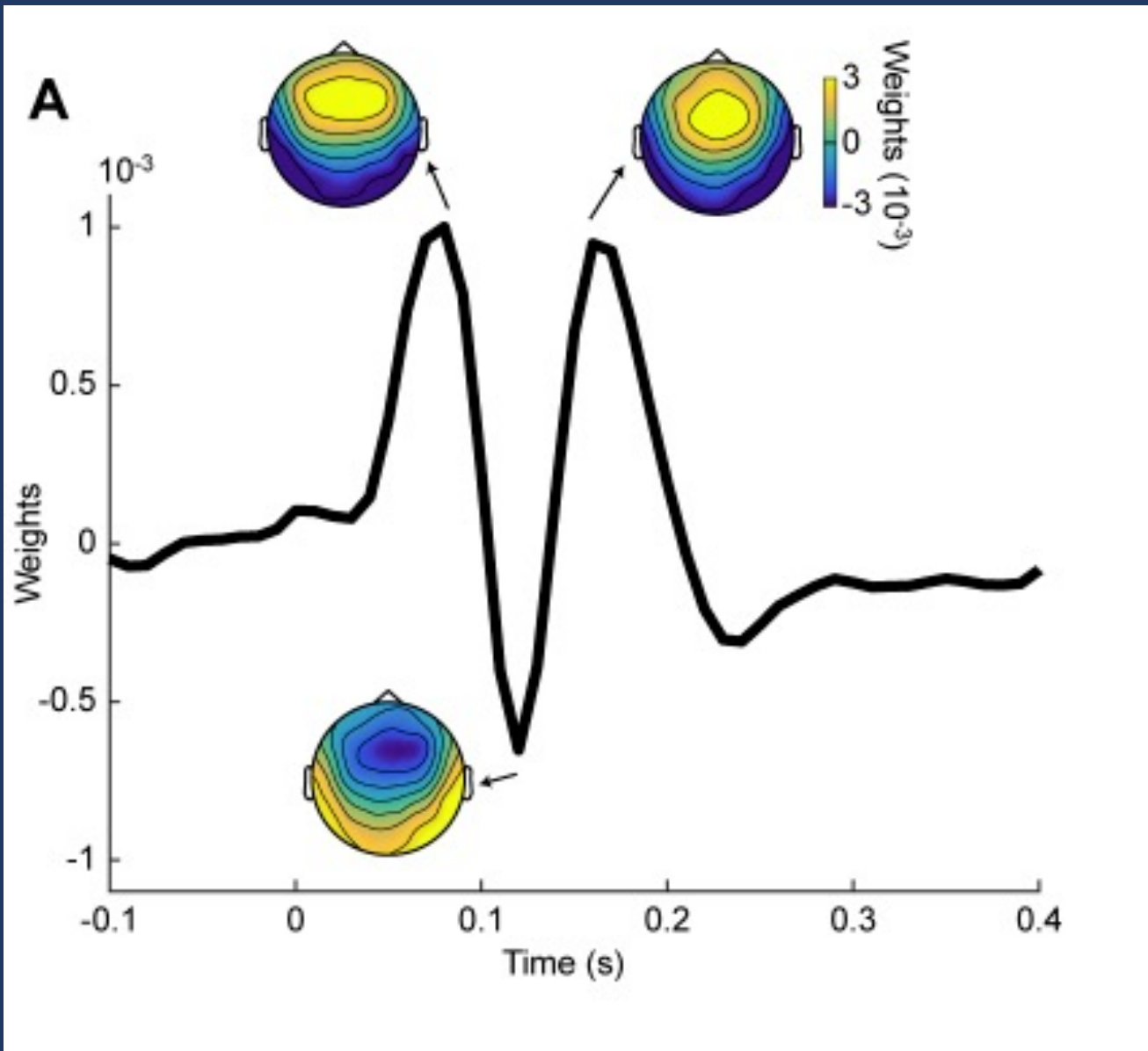
EEG recording





ECG tracing showing a regular rhythm with a rate of approximately 75 bpm, narrow QRS complexes, and a PR interval of about 160 ms. The rhythm is consistent with sinus bradycardia.



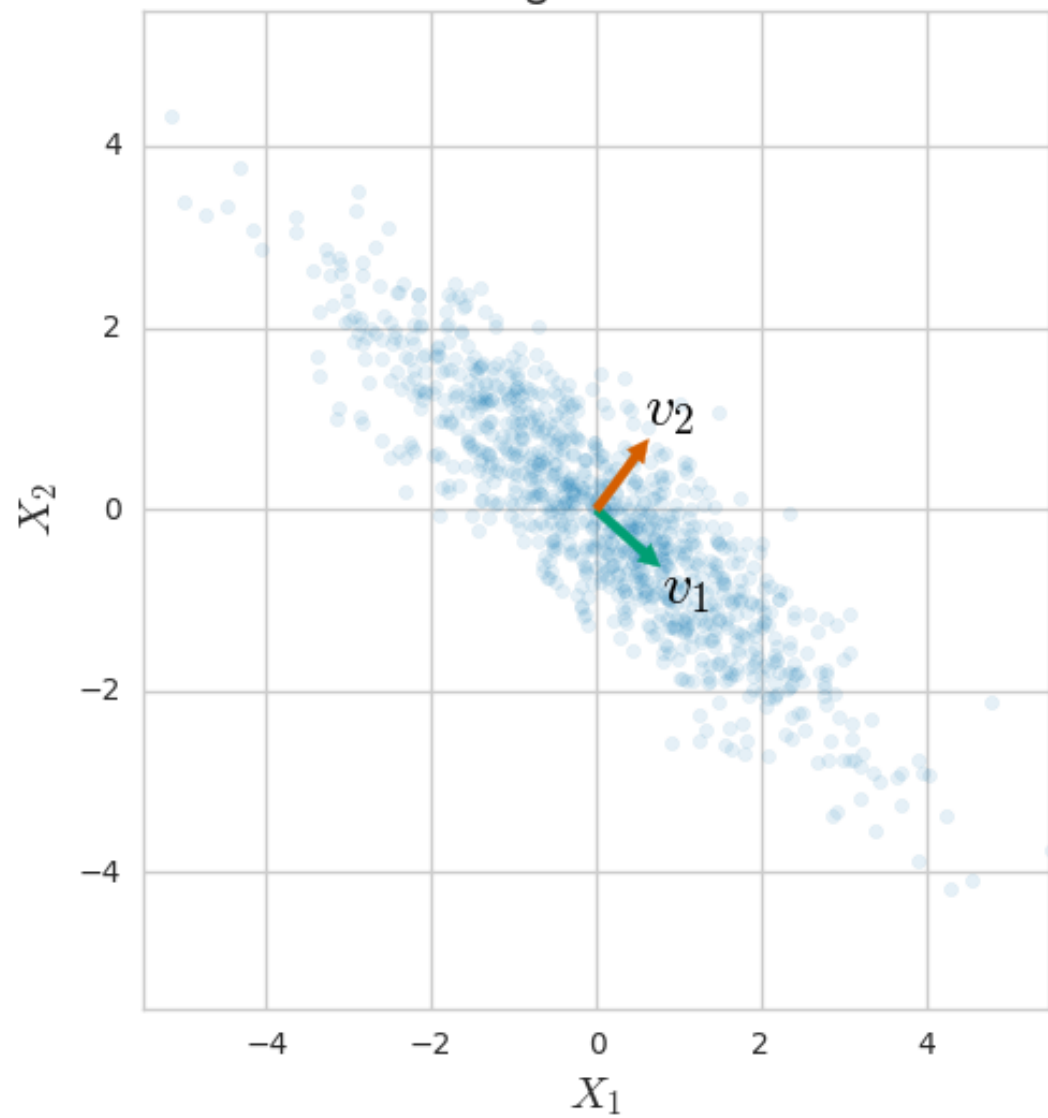


$$A = \begin{bmatrix} | & | & | \\ \mathbf{v}_1 & \mathbf{v}_2 & \mathbf{v}_3 \\ | & | & | \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} | & | & | \\ \mathbf{v}_1 & \mathbf{v}_2 & \mathbf{v}_3 \\ | & | & | \end{bmatrix}^{-1}$$

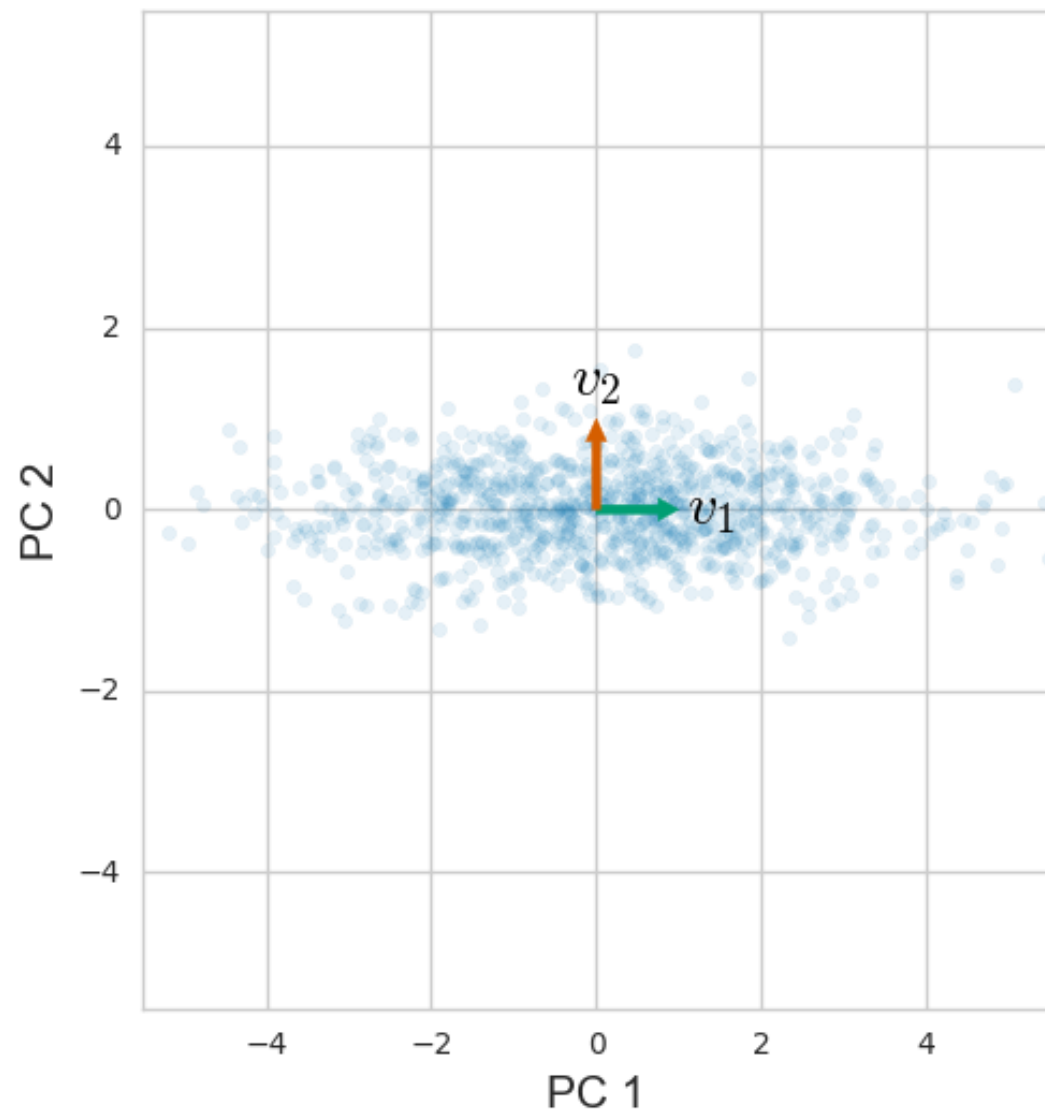
square matrix
Covariance Matrix

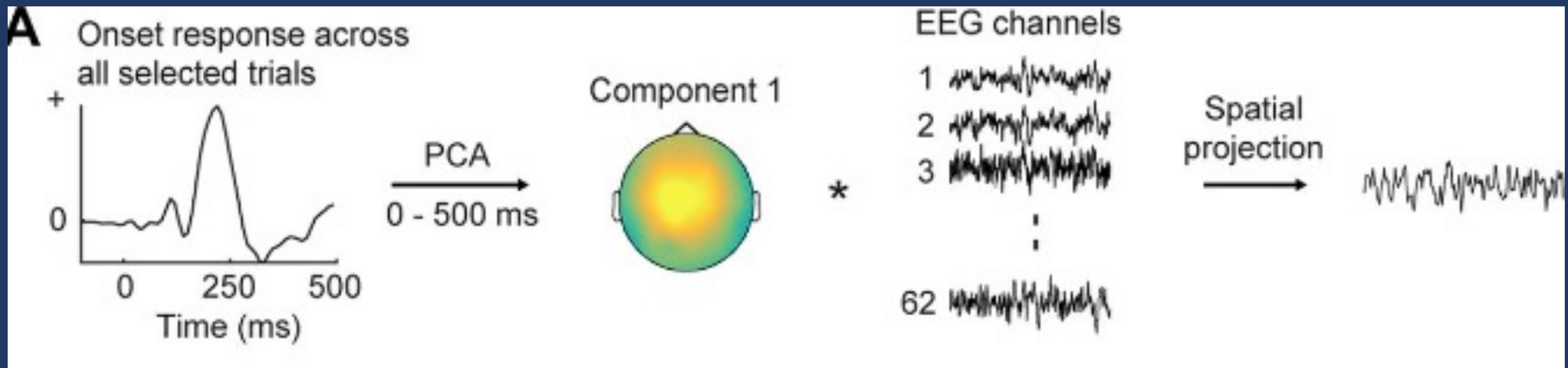
the inverse exists only if
eigenvectors are linearly independent

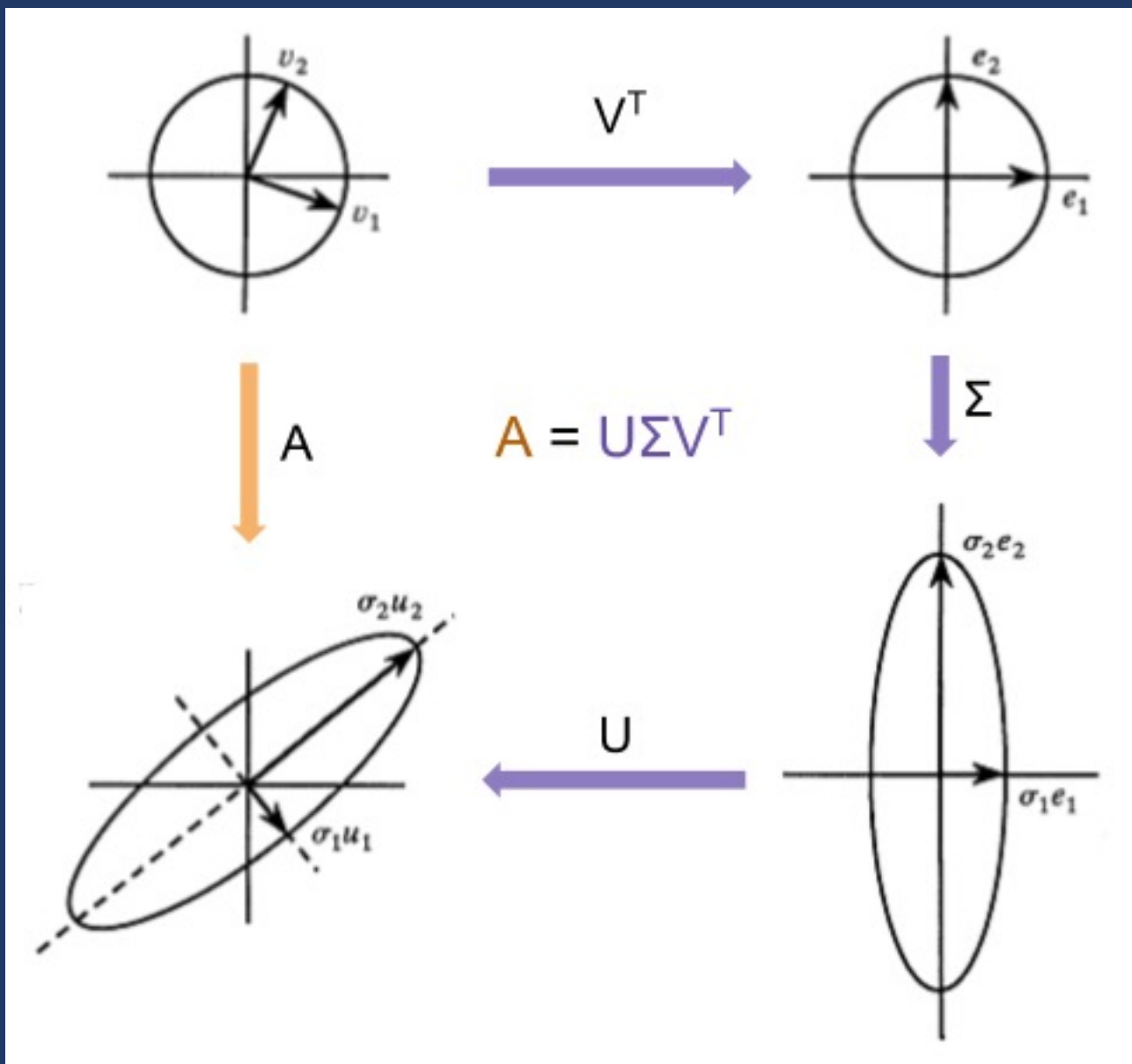
Data in Original Coordinates

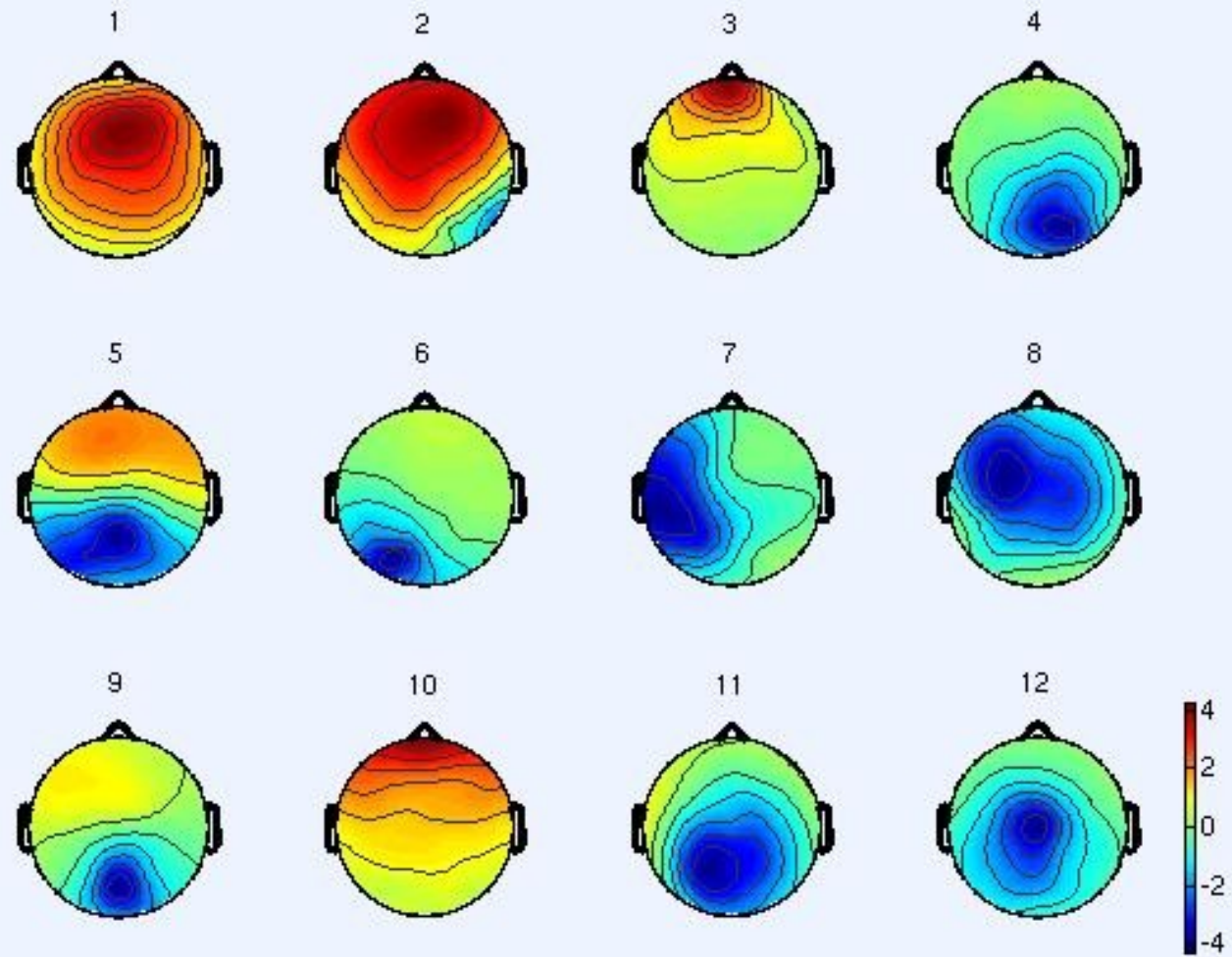


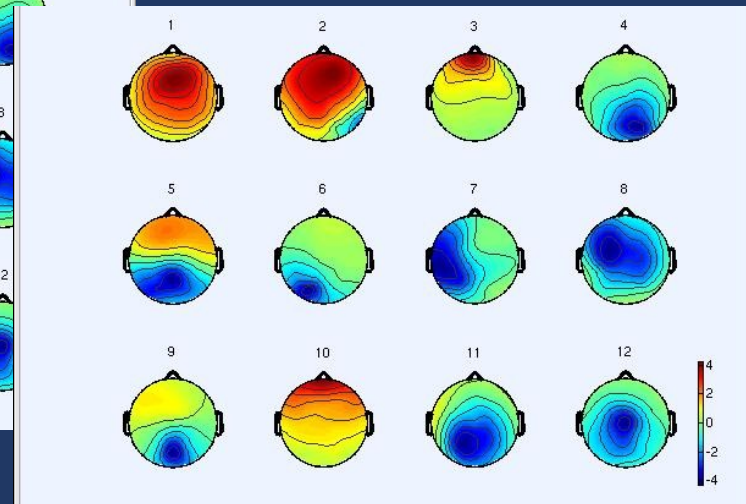
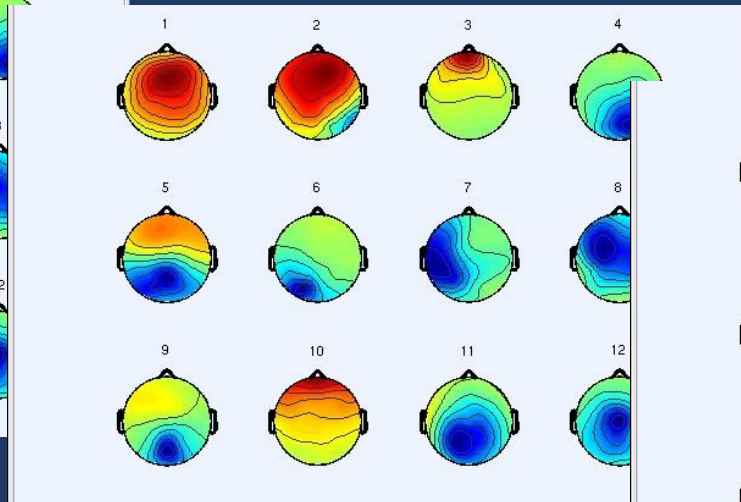
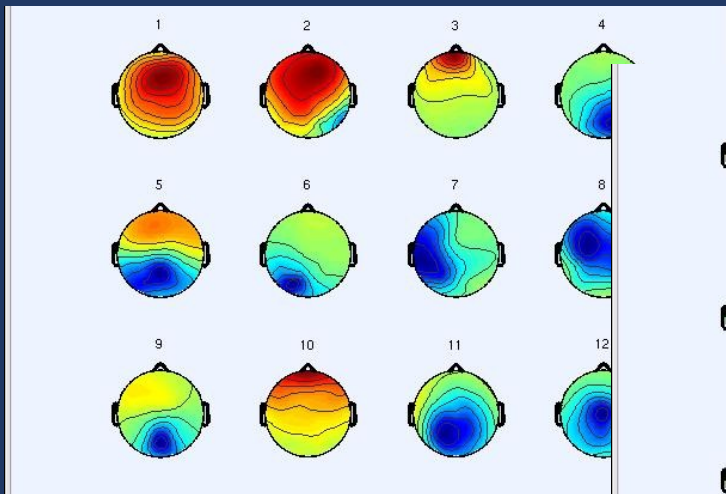
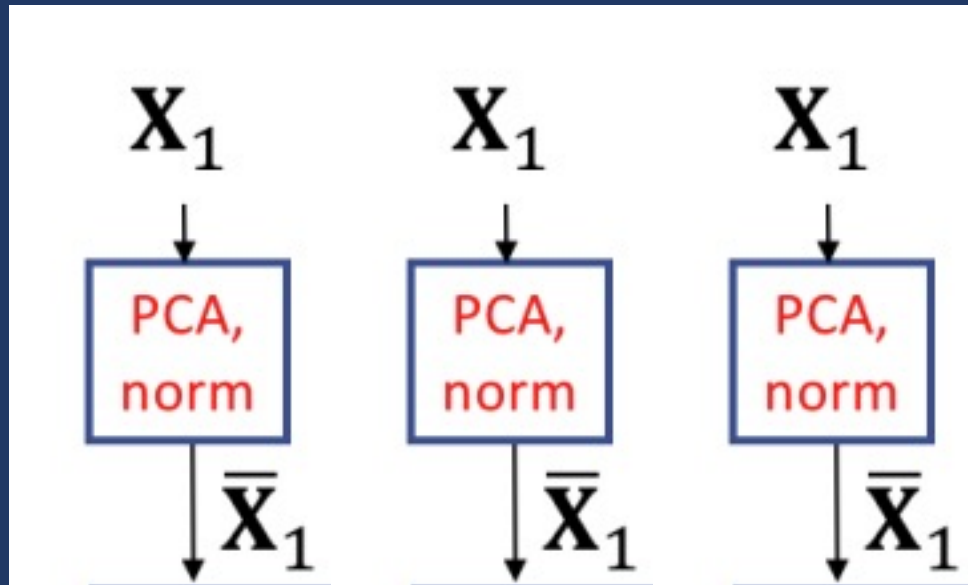
Data in PC Coordinates

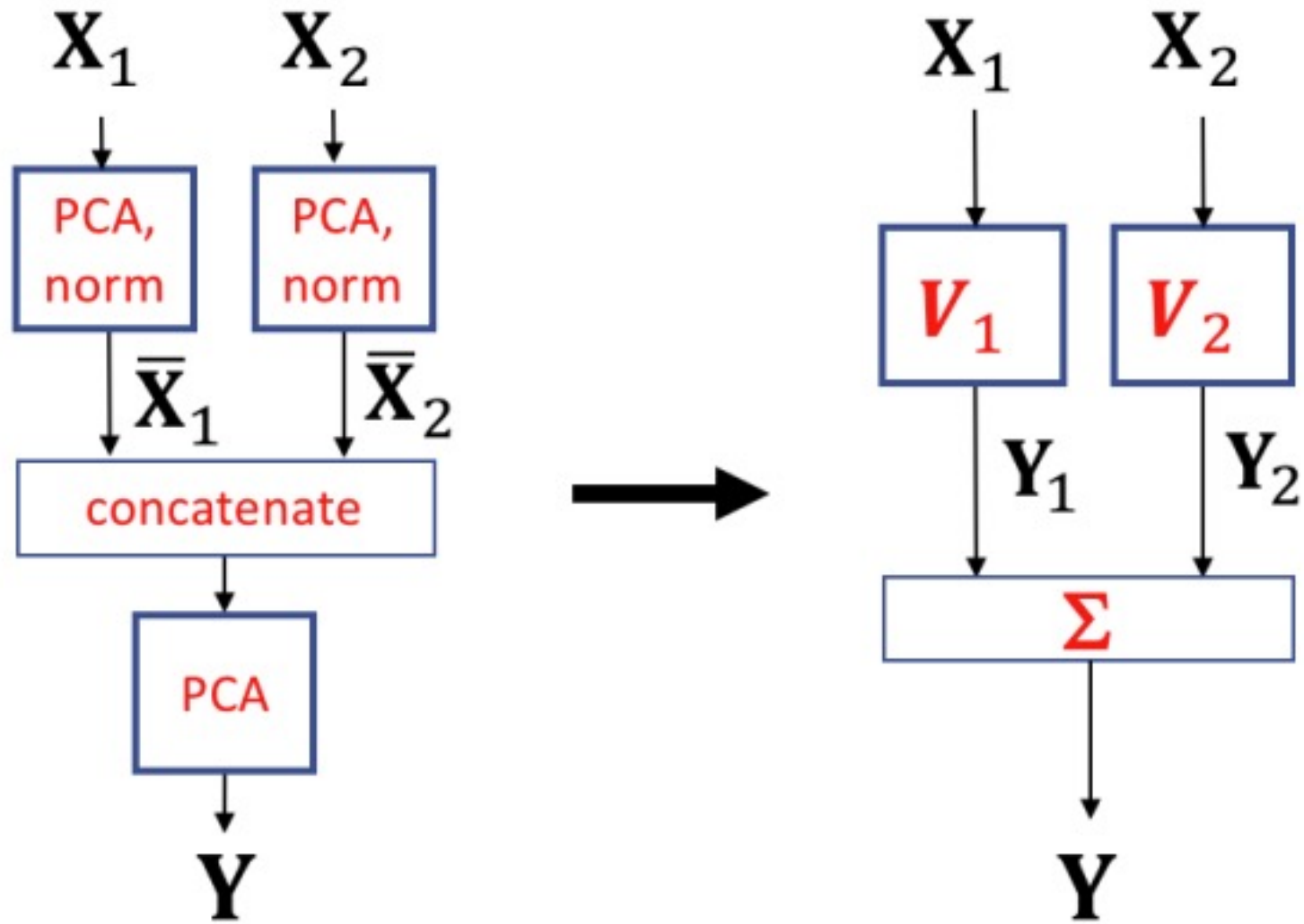












The 1st PCA extracts shared components across EEG channels

The 2nd PCA is applied on the PCA components from all the participants.

The 2nd PCA should extract shared components across all the participants.

What is shared among all the participants?

Each music piece is only presented once

EEG recording



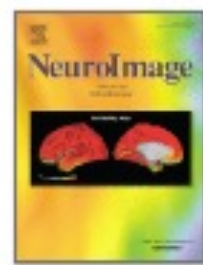
Every participant is listening to the same stimulus.

The 2nd PCA extracts the neural responses shared among participants – music-related components.





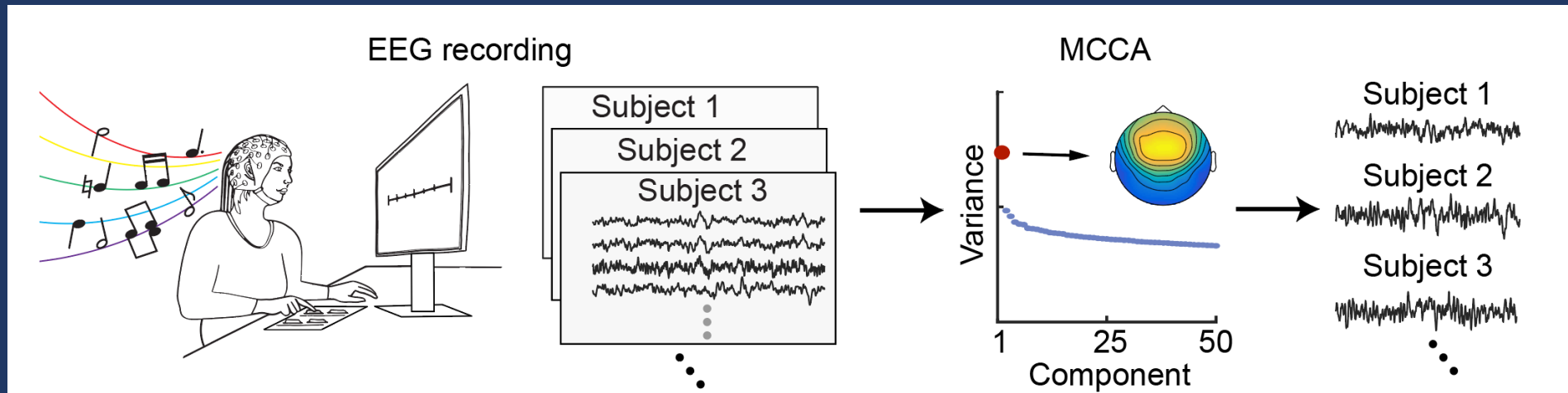
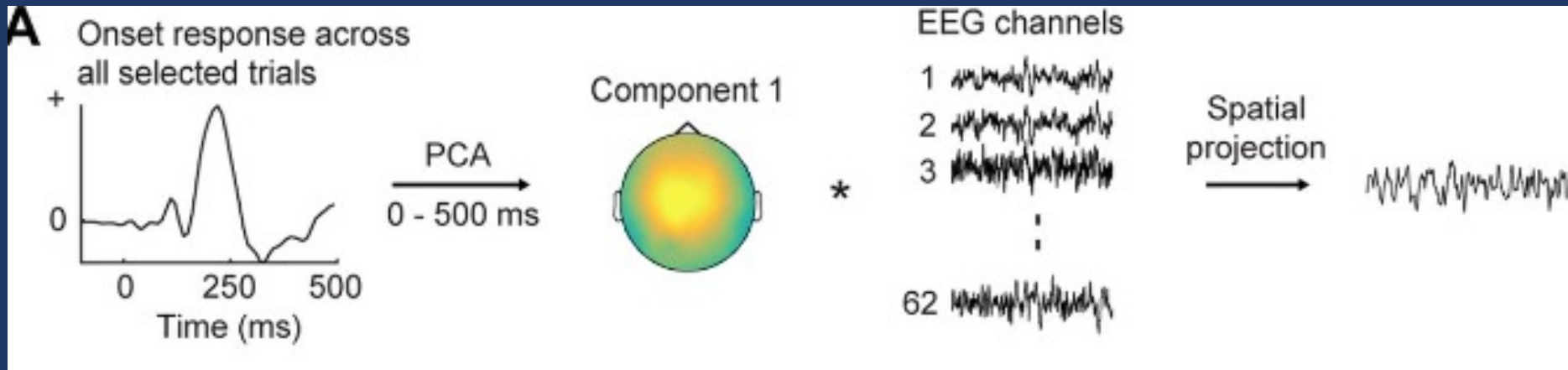
NeuroImage

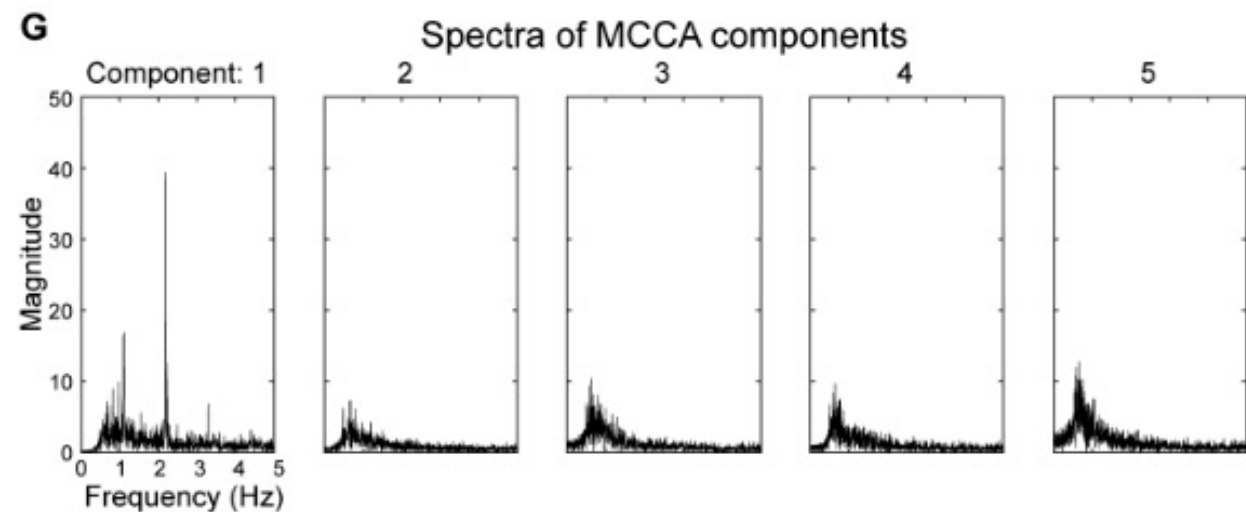
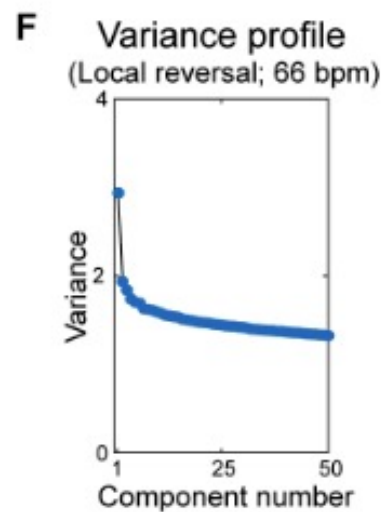
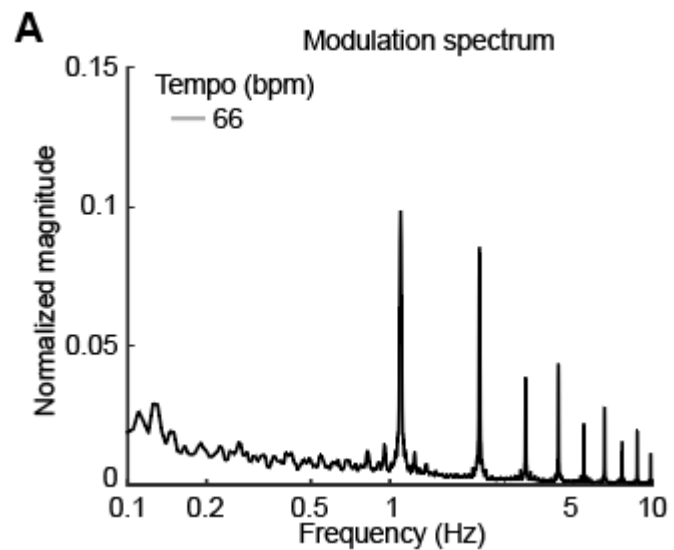
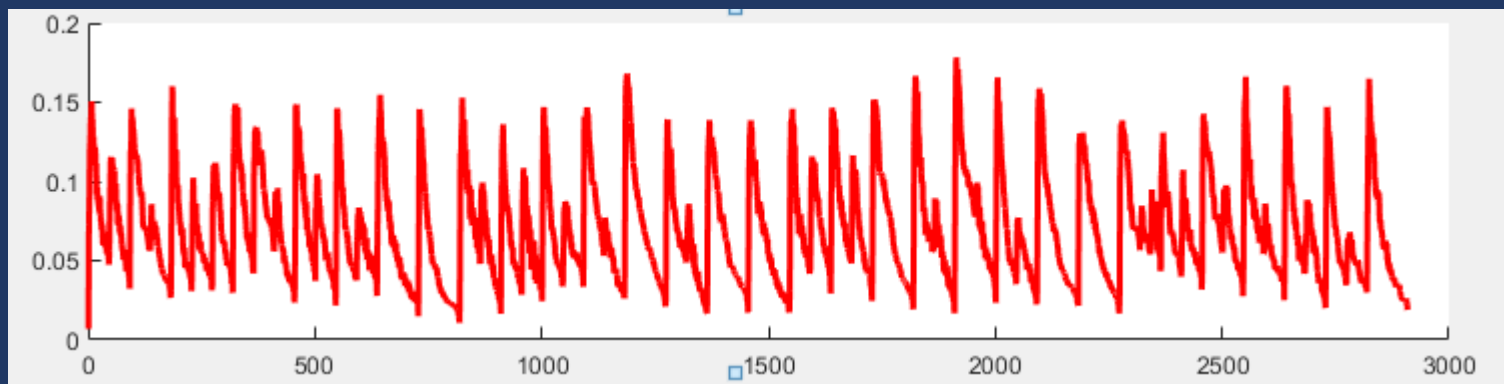
Volume 186, 1 February 2019, Pages 728-740

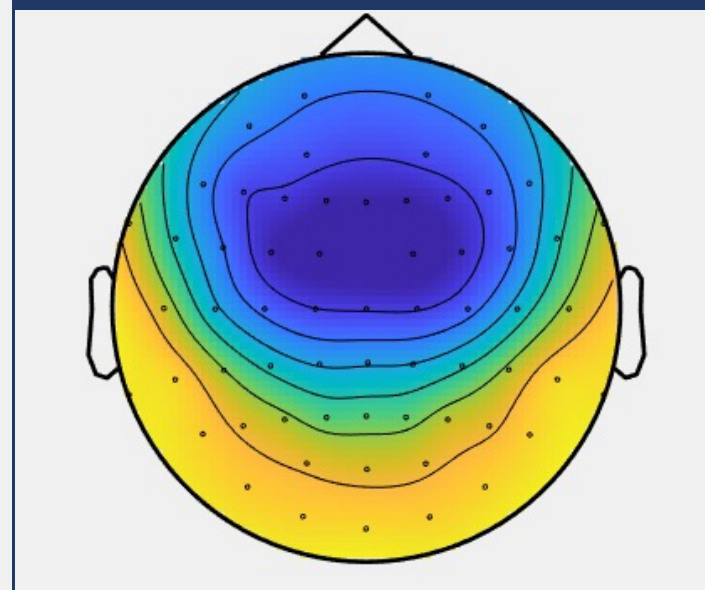
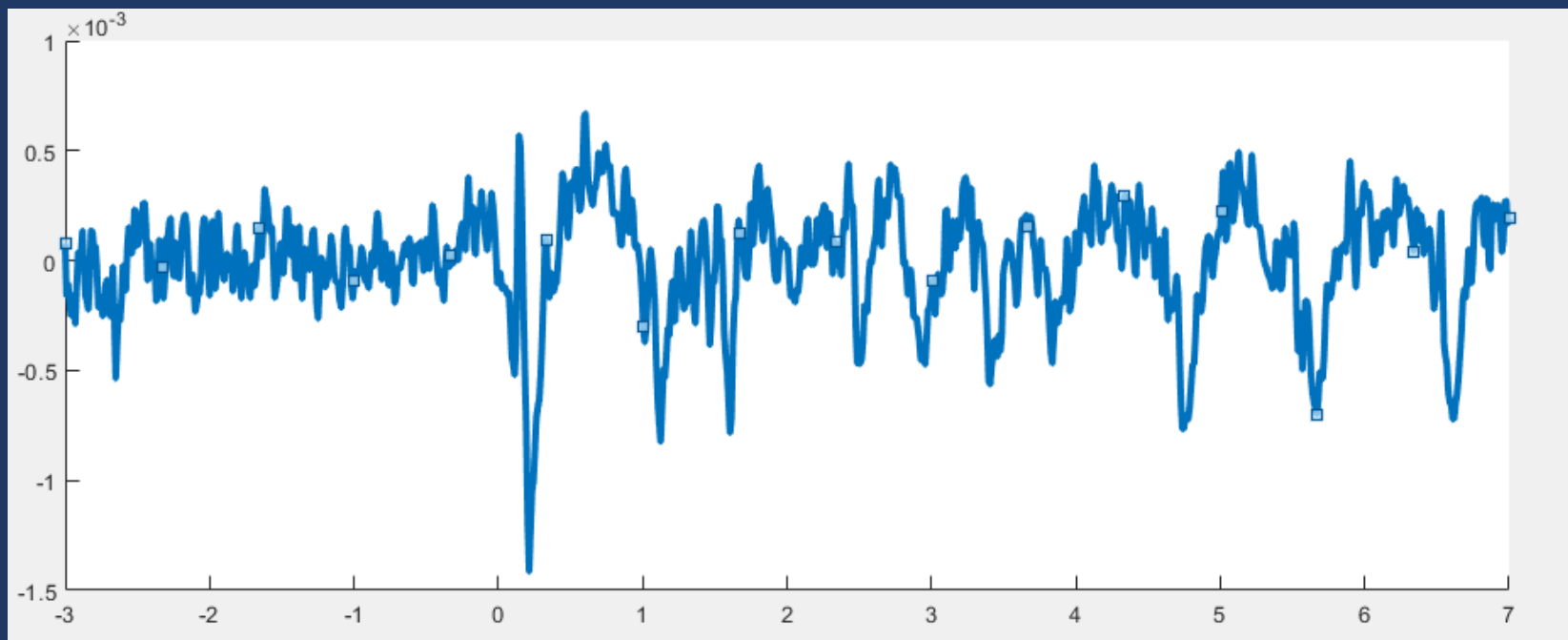


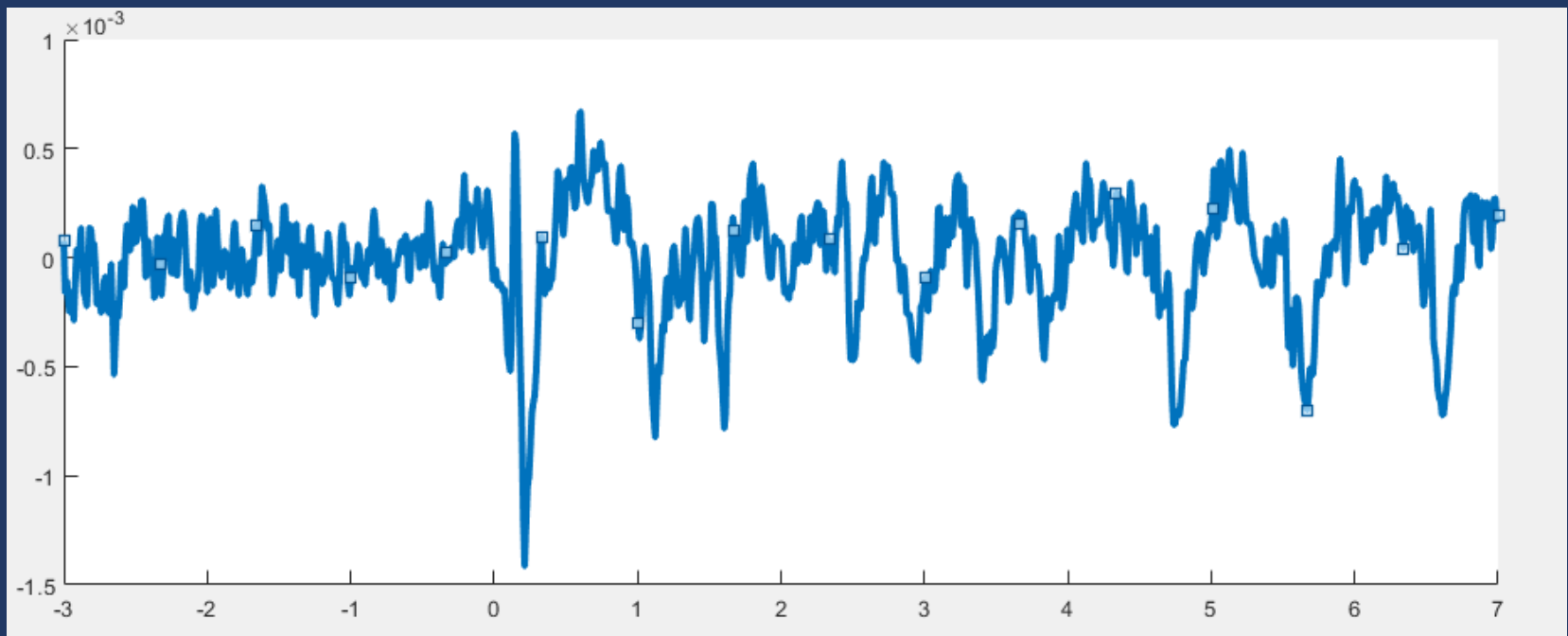
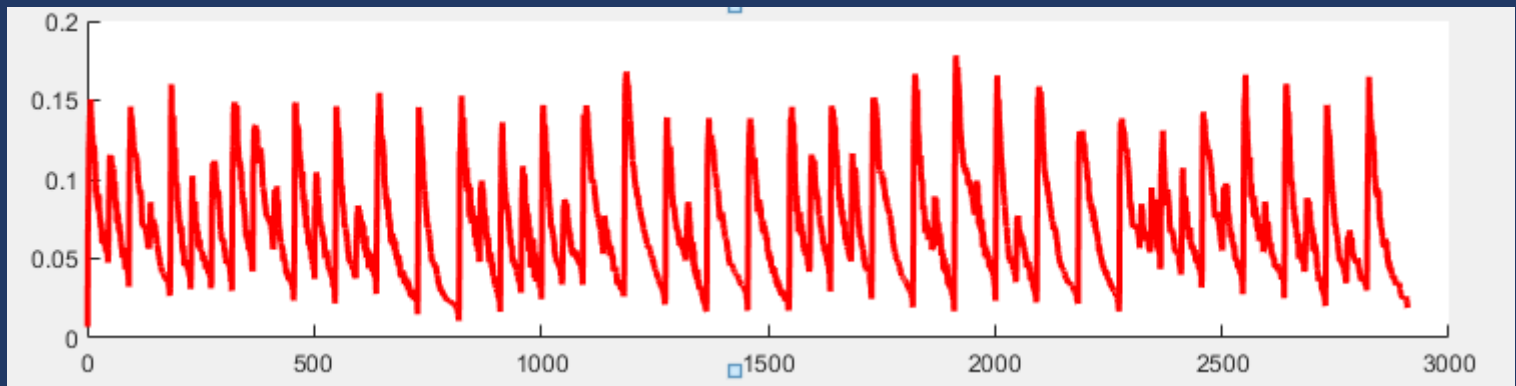
Multiway canonical correlation analysis of brain data

Alain de Cheveigné^{a, b, c}  , Giovanni M. Di Liberto^{a, b}, Dorothée Arzounian^{a, b}, Daniel D.E. Wong^{a, b}, Jens Hjortkjær^{d, e}, Søren Fuglsang^d, Lucas C. Parra^f

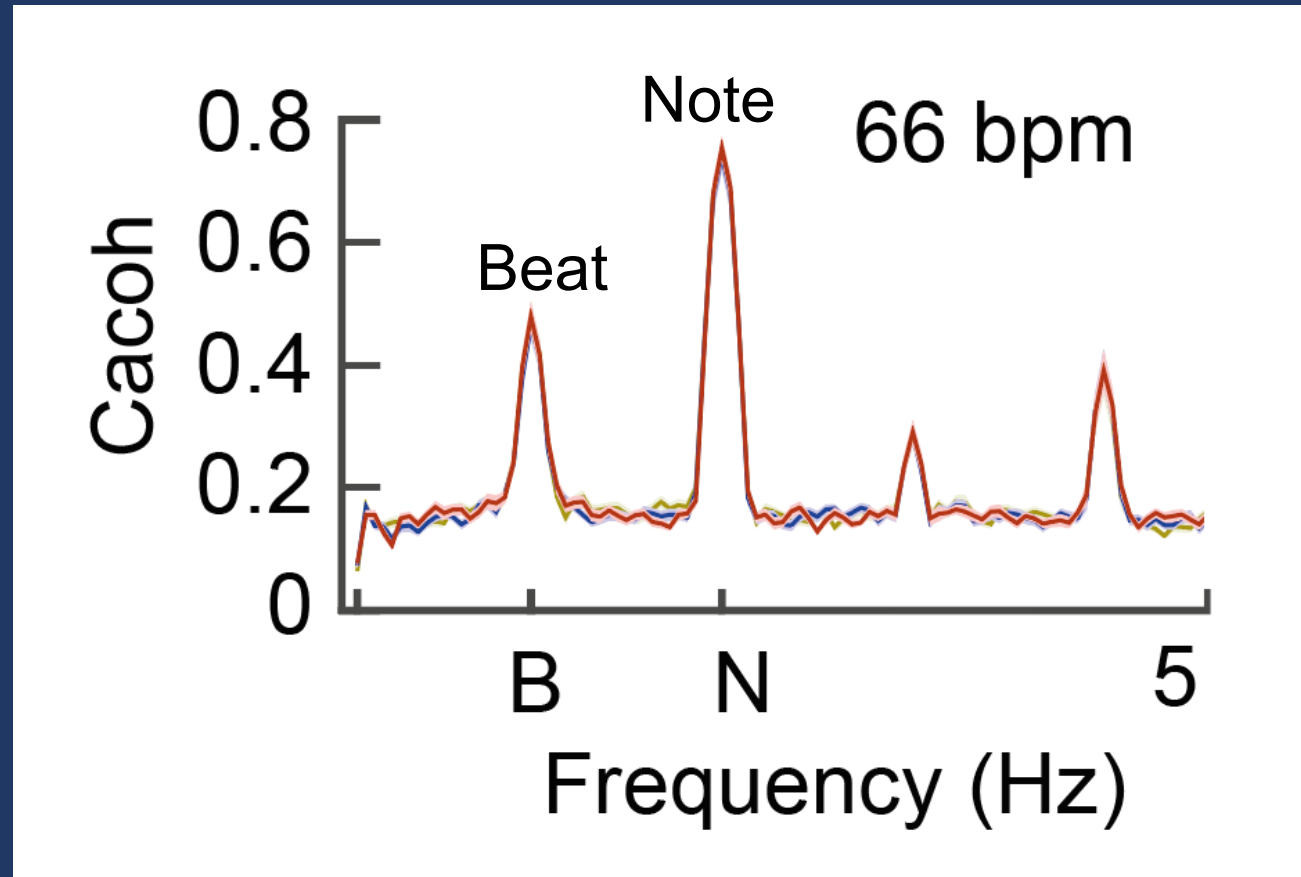




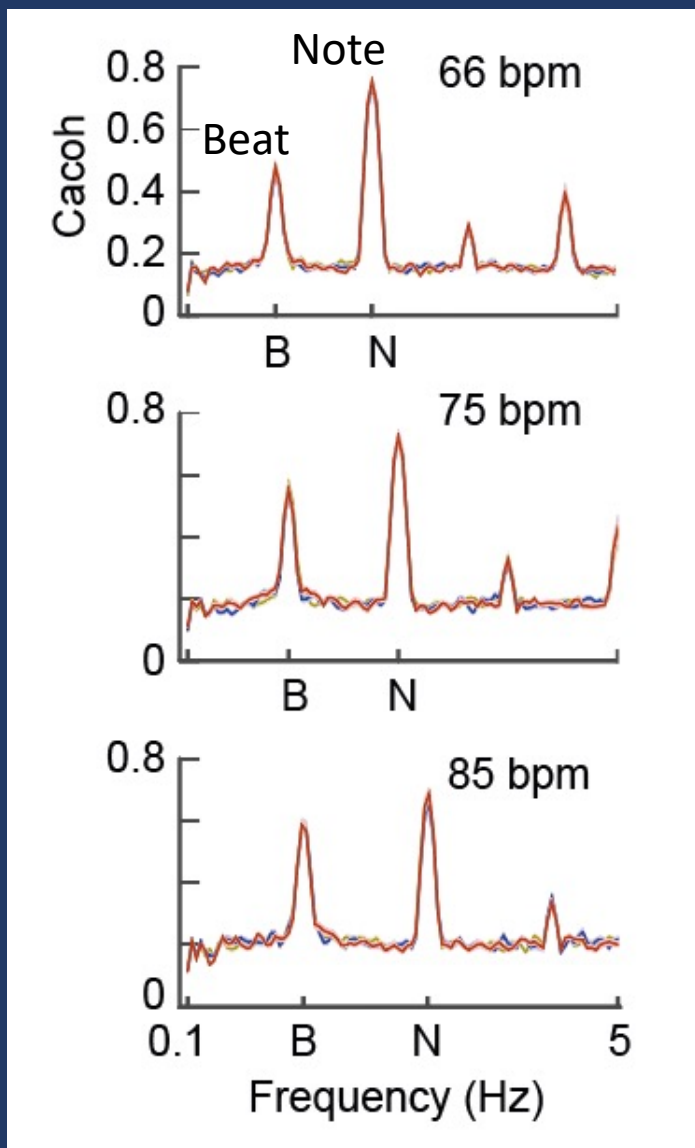




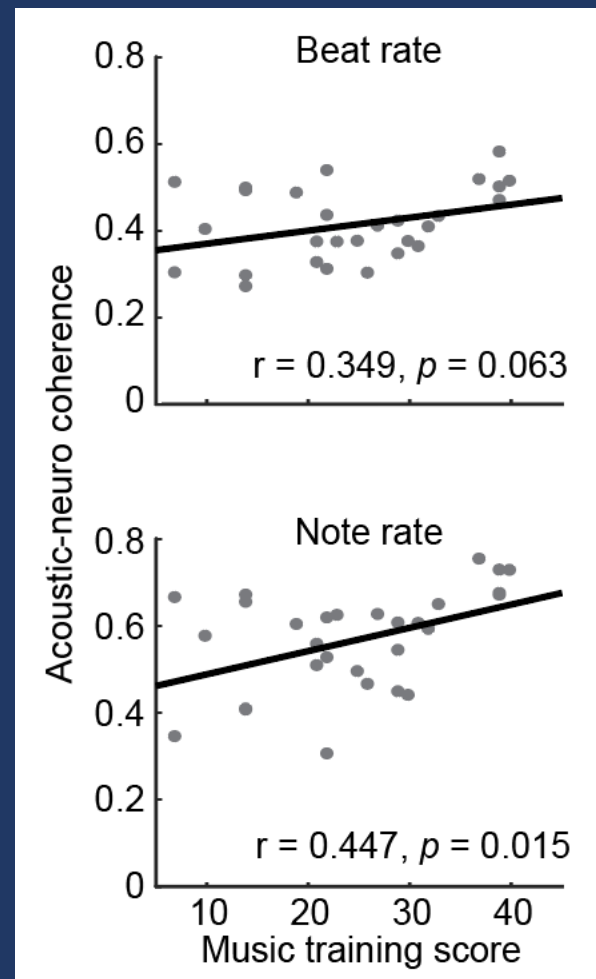
Replication: neural tracking of note and beat

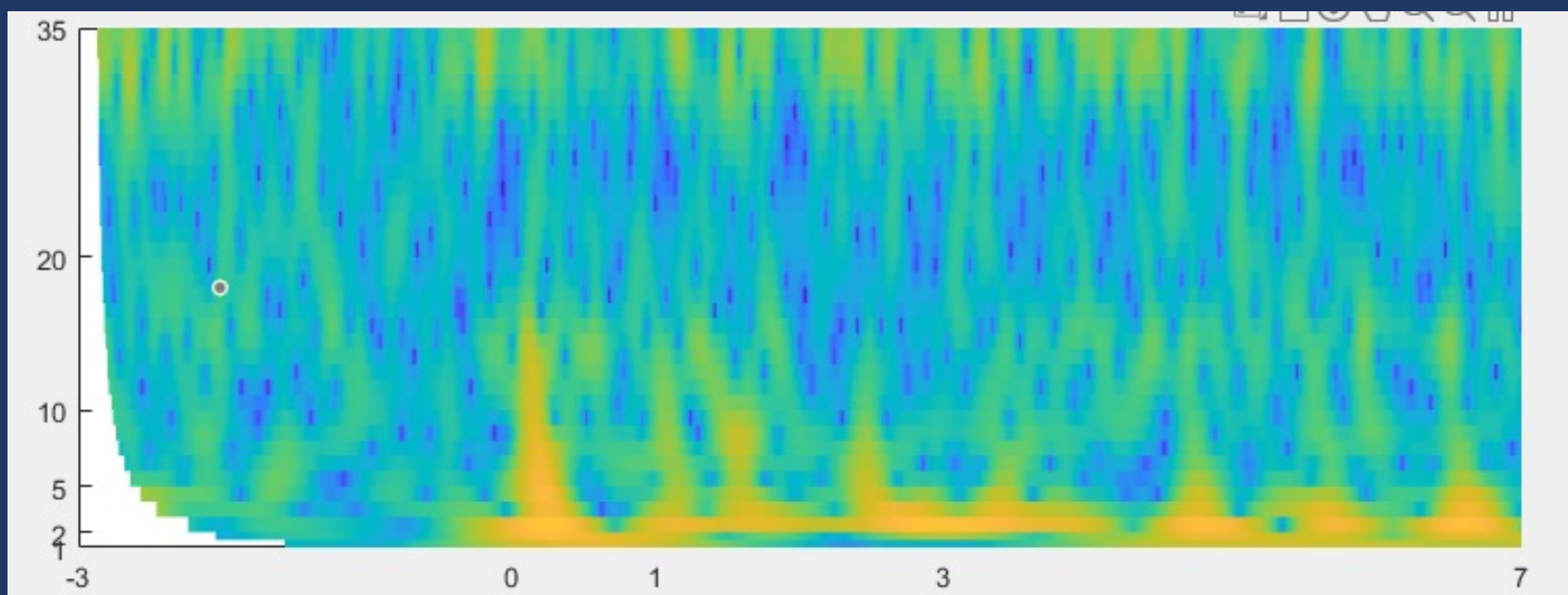
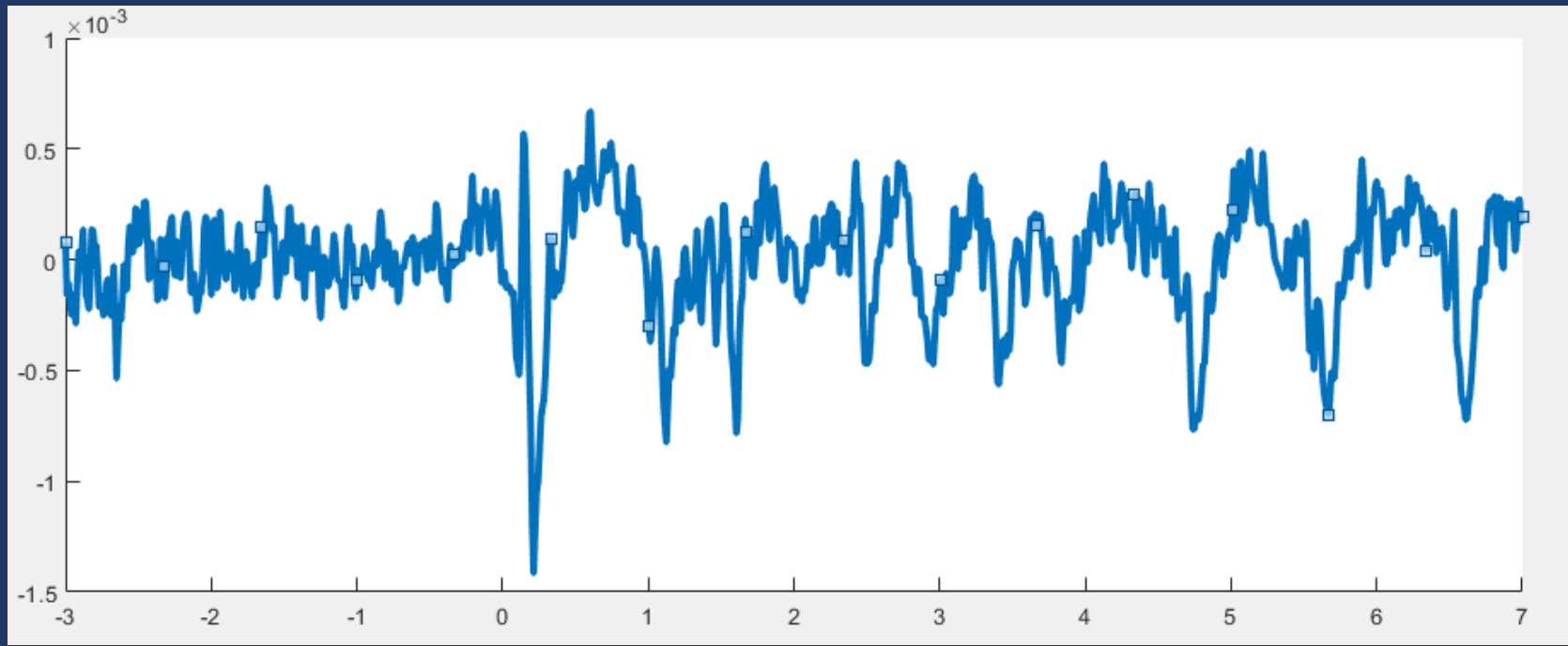


Replication: neural tracking of note and beat

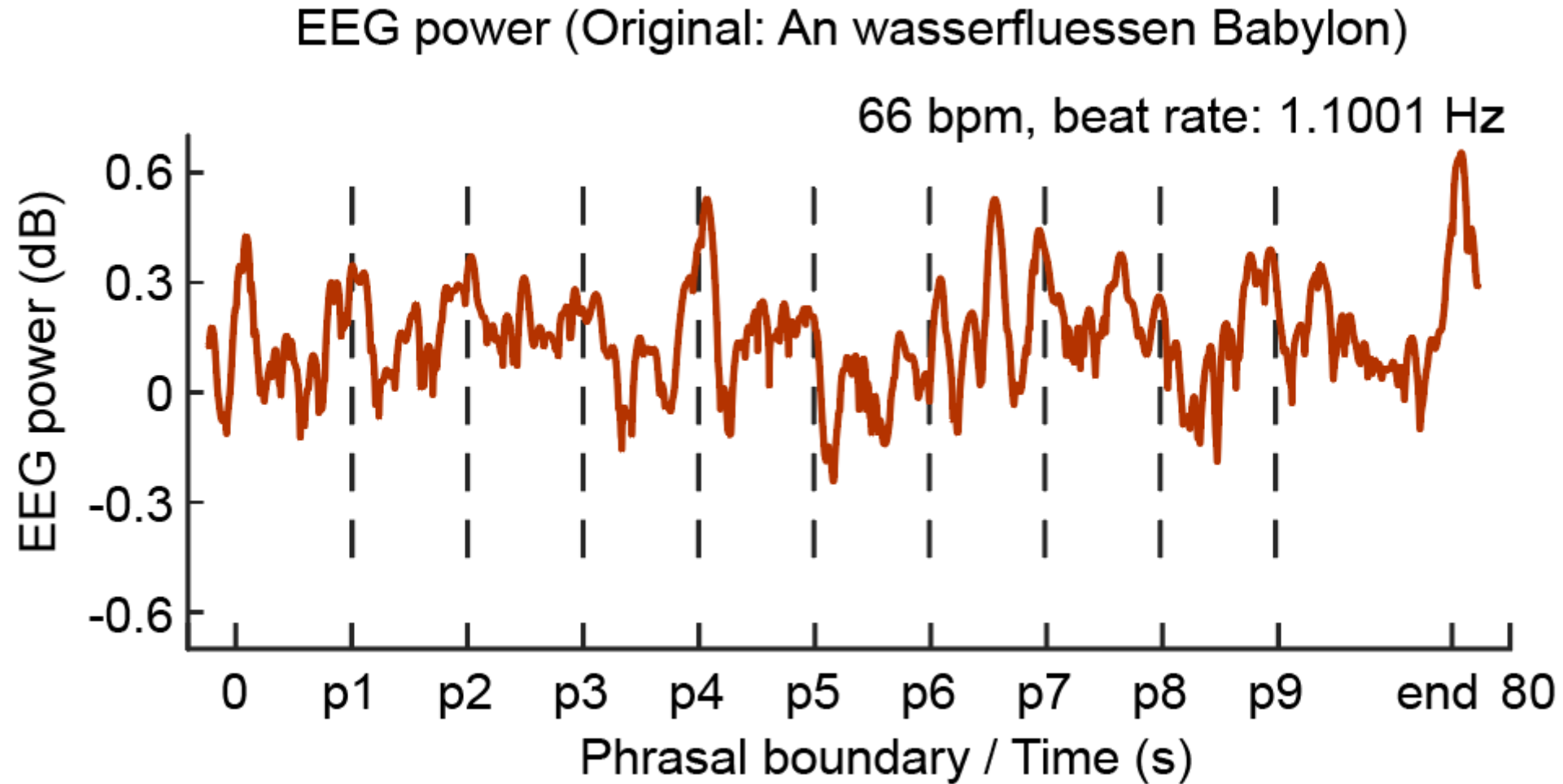


Music training v.s. Neural tracking



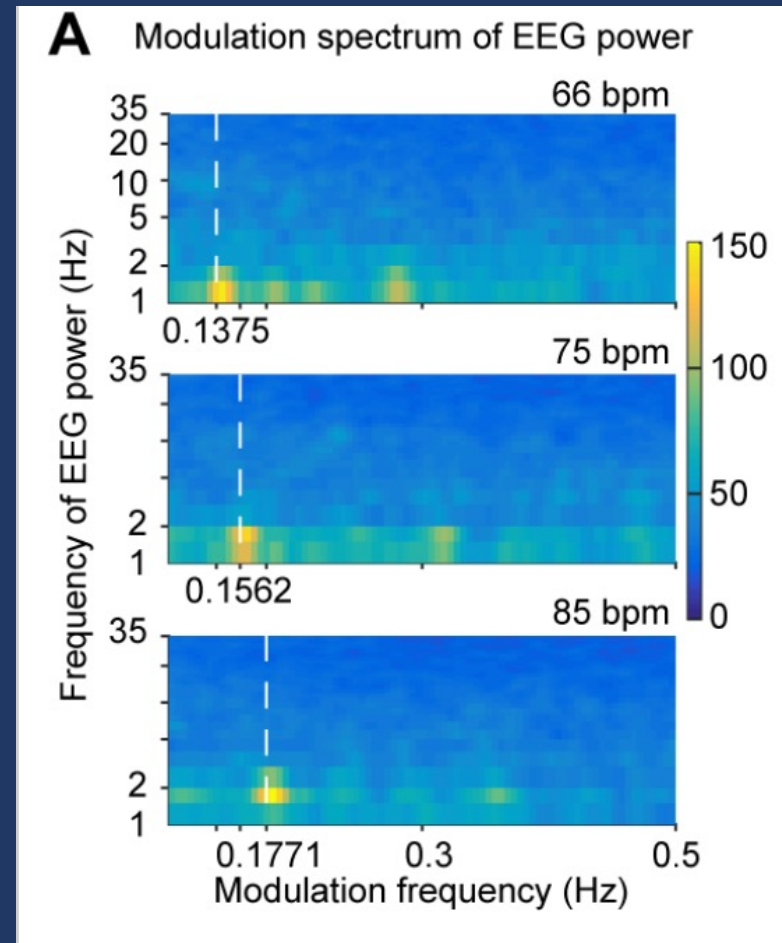
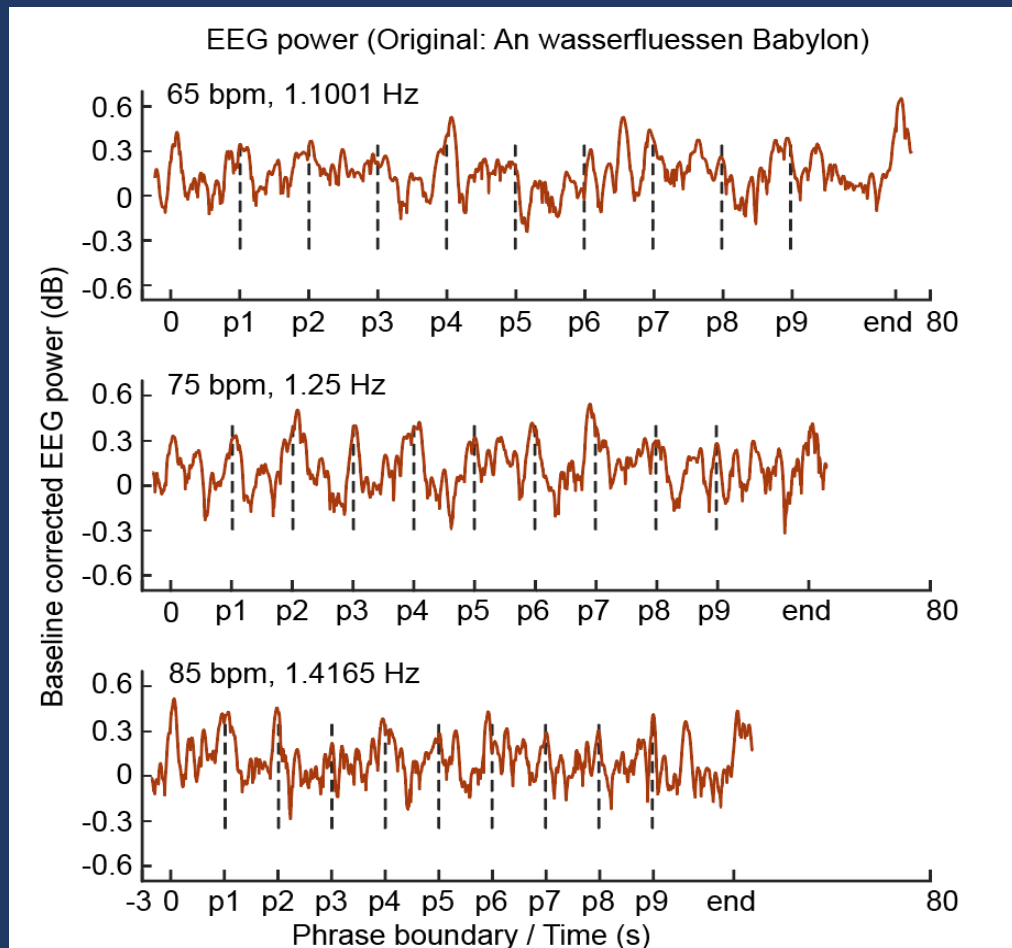


Where is the musical phrase?

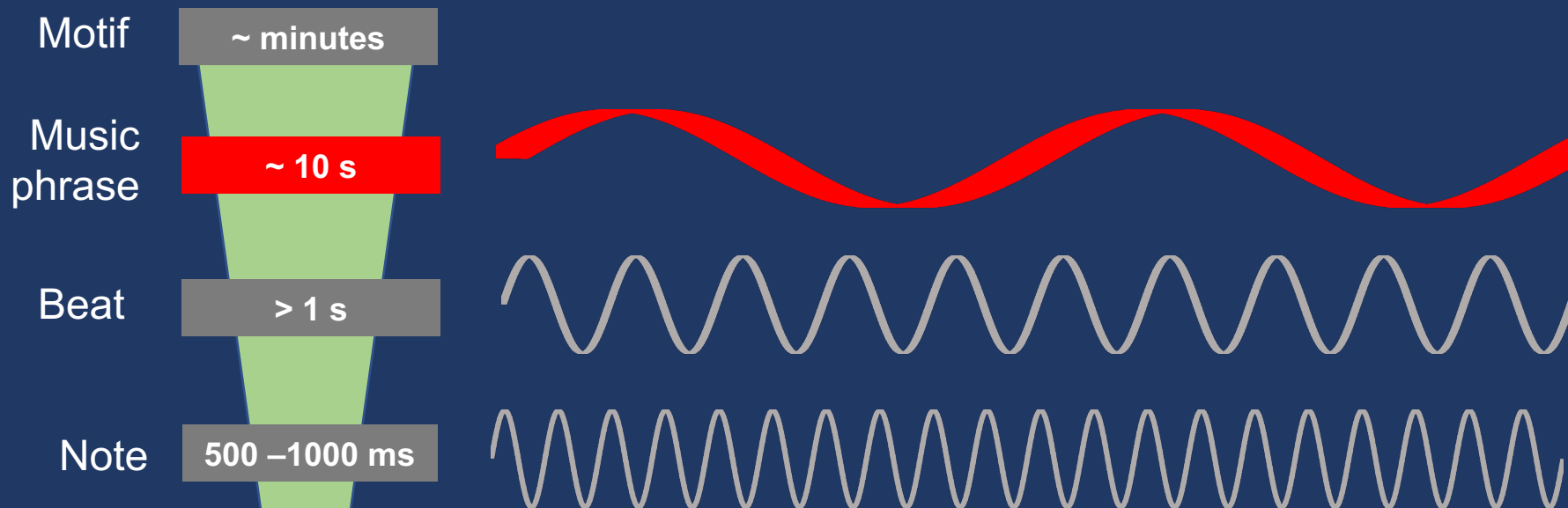


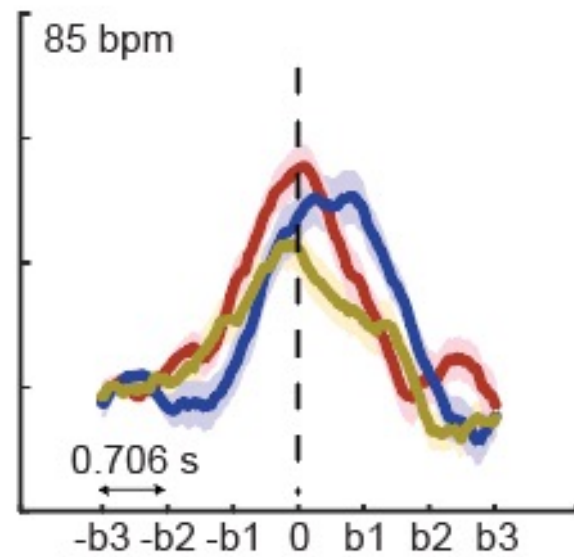
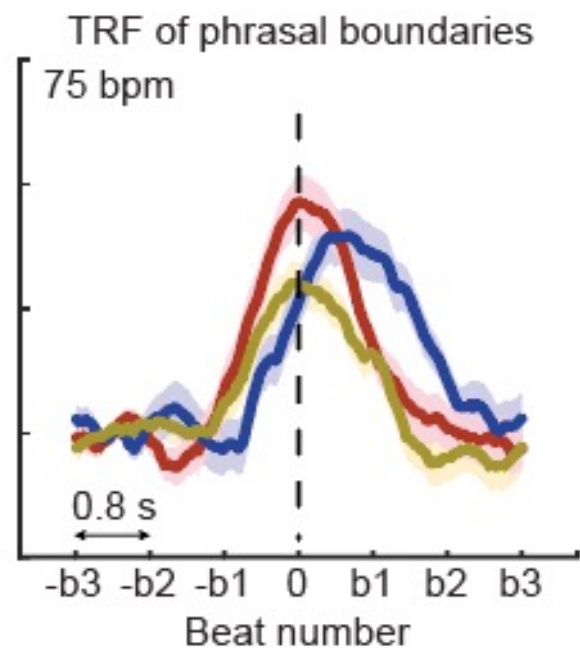
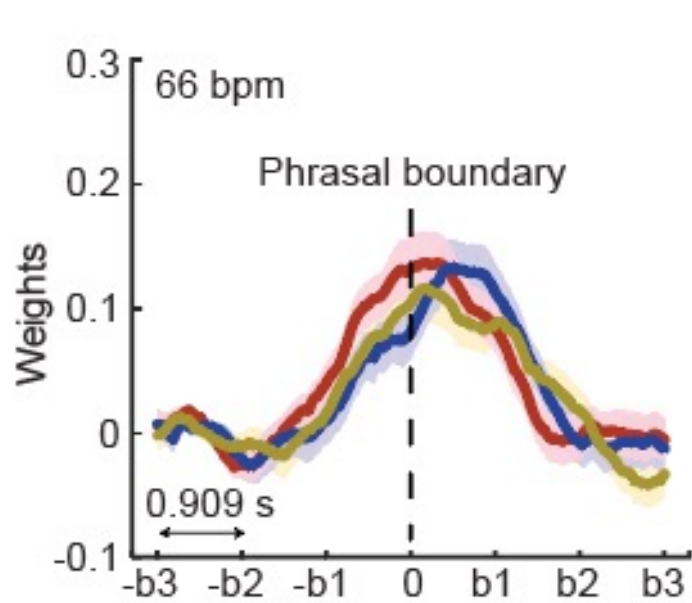
Musical phrasal segmentation below 0.2 Hz

A 'double FFT' (Modulation Spectrum)
Teng et al., 2019

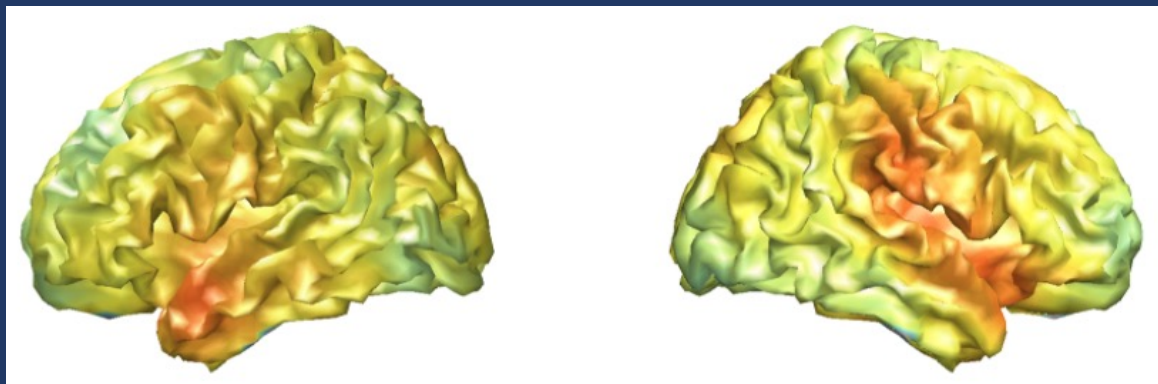


Timescale

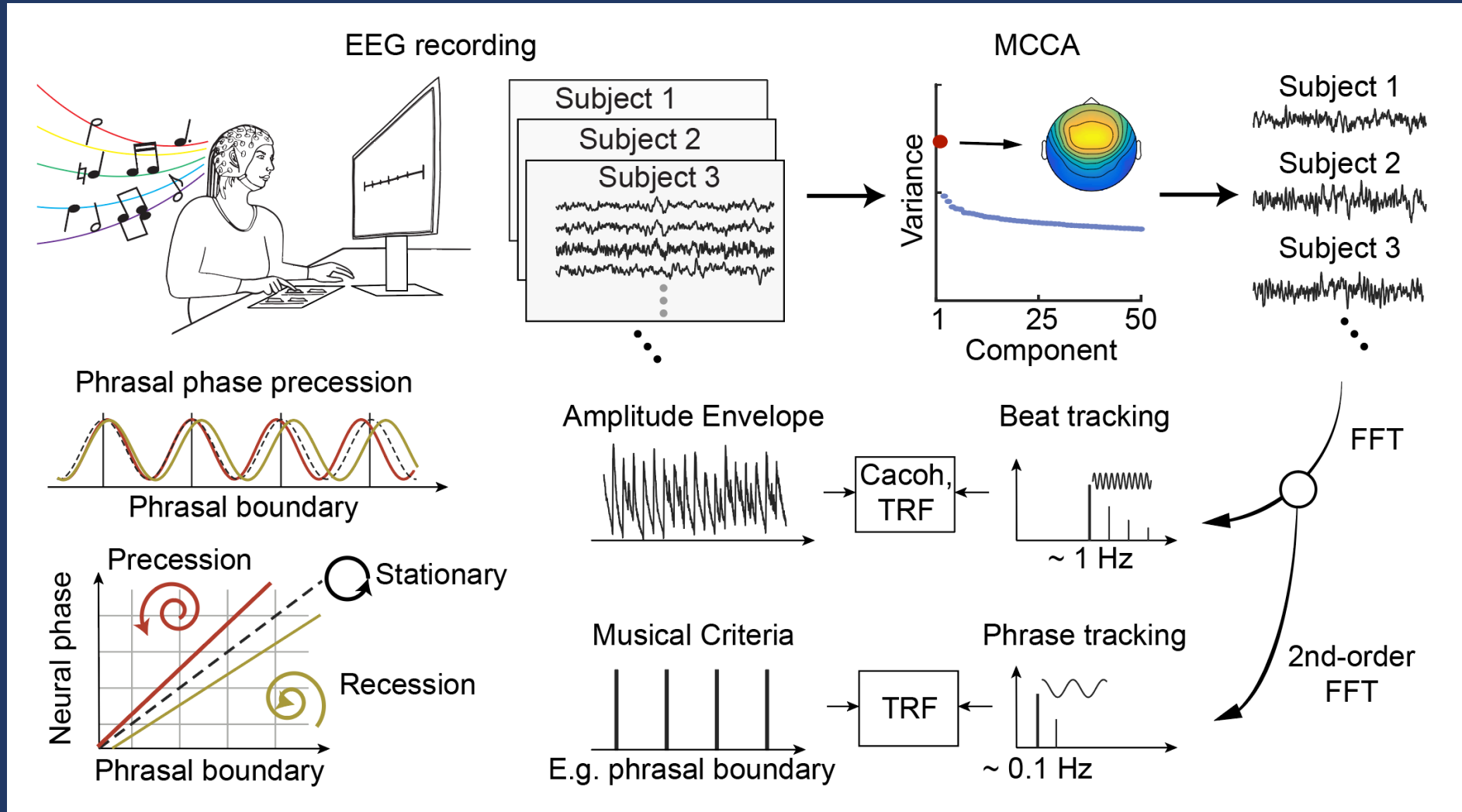


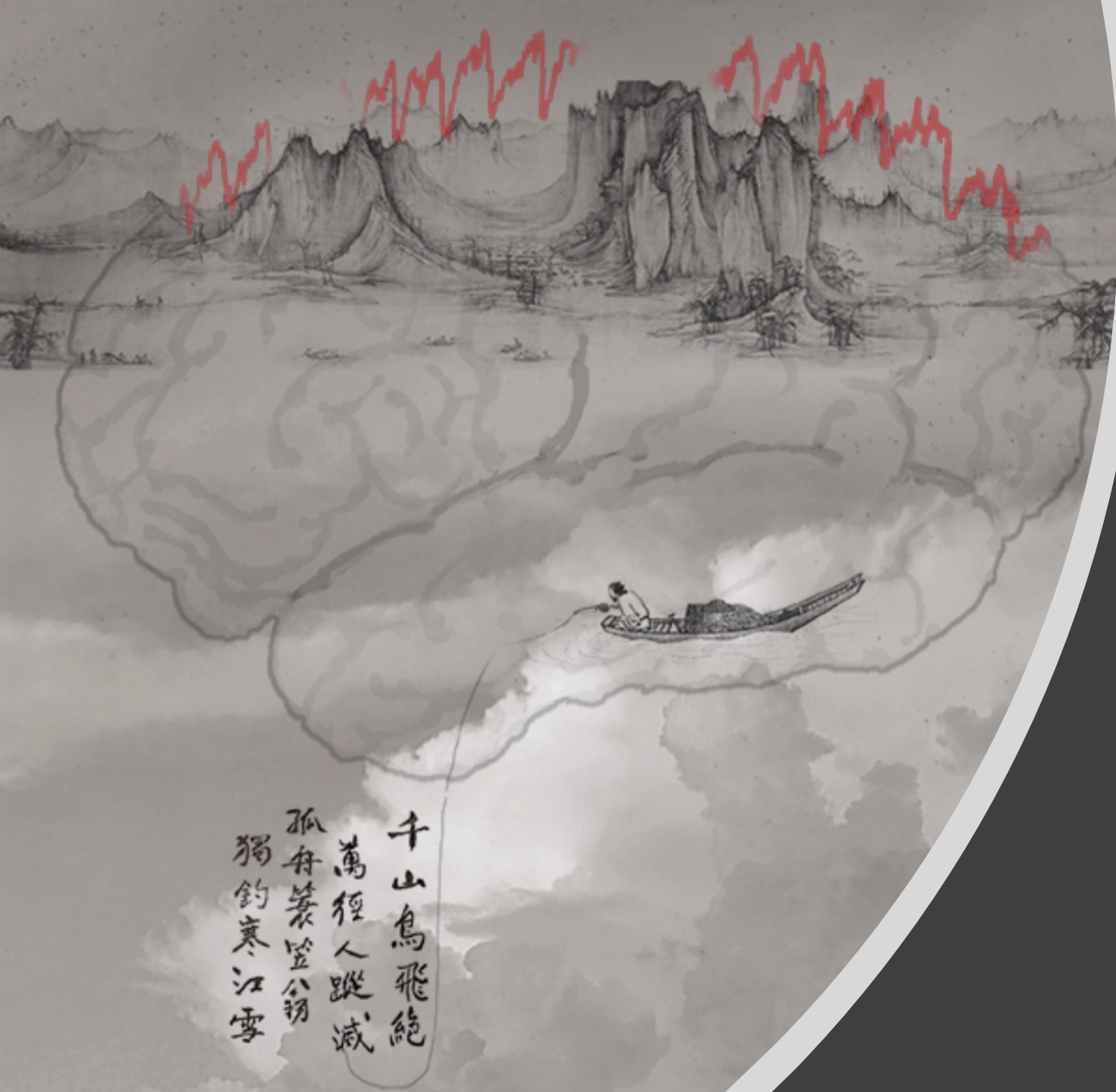


Music



EEG pipeline for naturalistic stimuli





千山鳥飛絕
萬徑人蹤滅
孤舟蓑笠翁
獨釣寒江雪

Thank you