

# An Unknown B Matrix with Unknown Inputs

T. Griffith

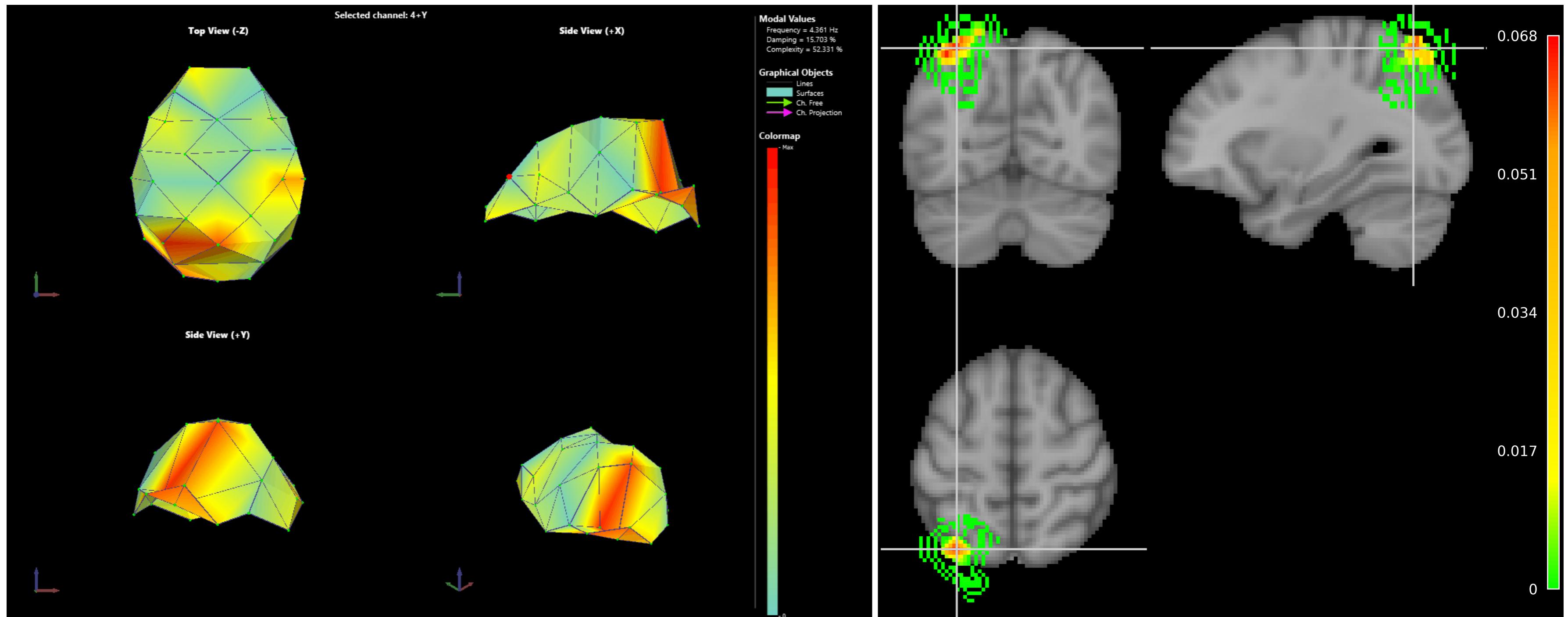
Quantum Seminar

July 09, 2021

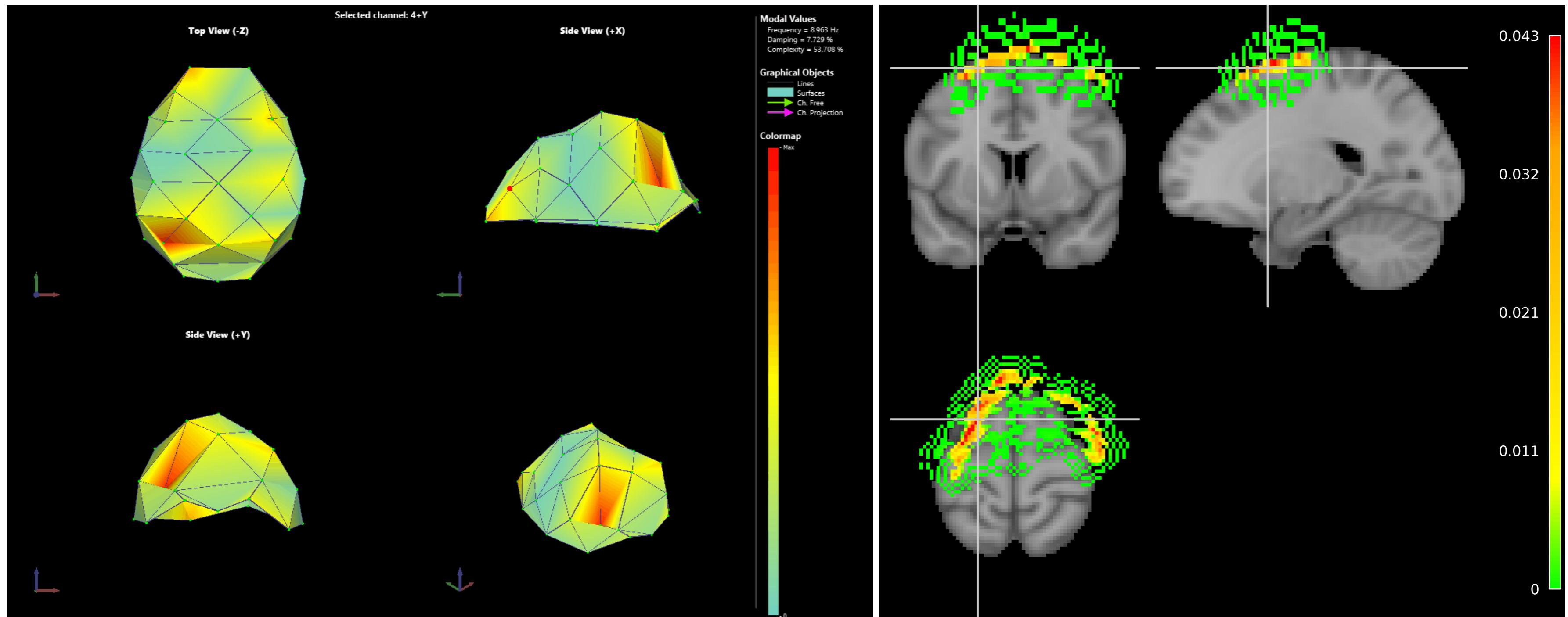
1. fMRI Comparisons
2. UIO Recap
3. Optimized Parameterizations
4. Identifying the “Best Fit” B Matrix for the Brain
5. Application to Emotion Data
6. Application to Movement Data
7. Perturbations (time permitting)

# 1. fMRI Comparisons

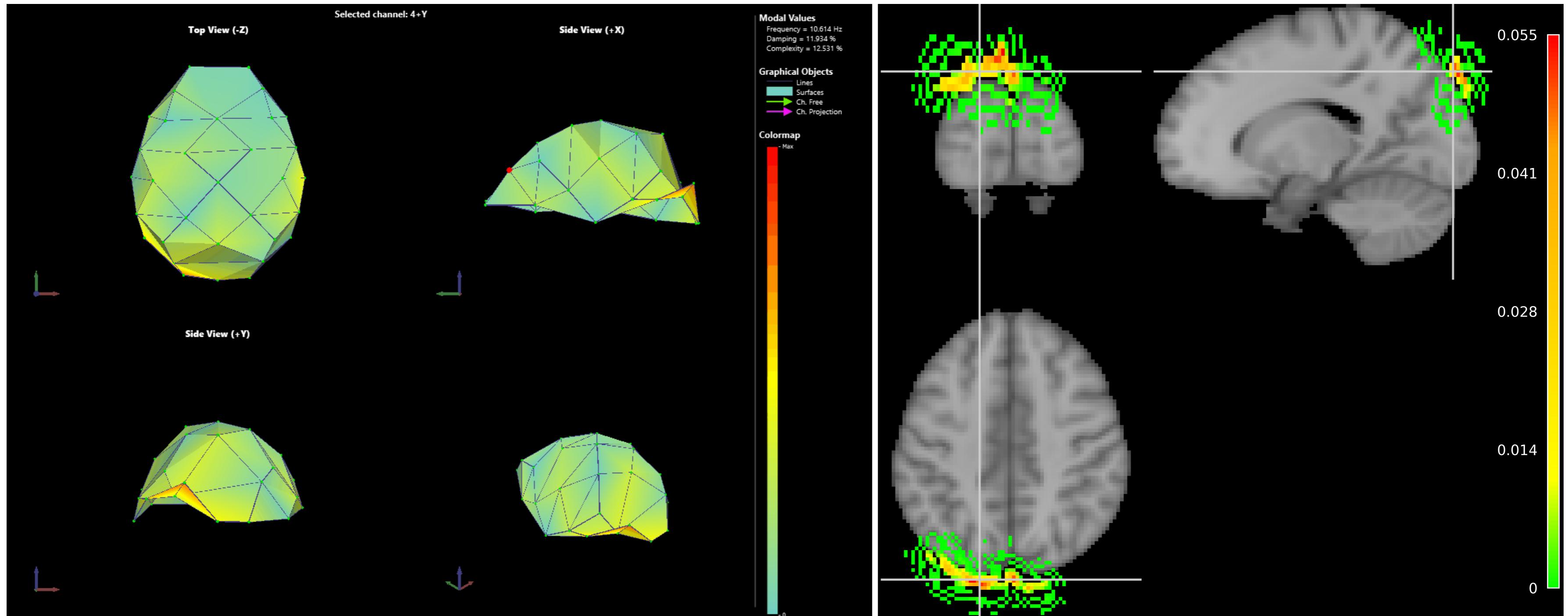
# Mode 1



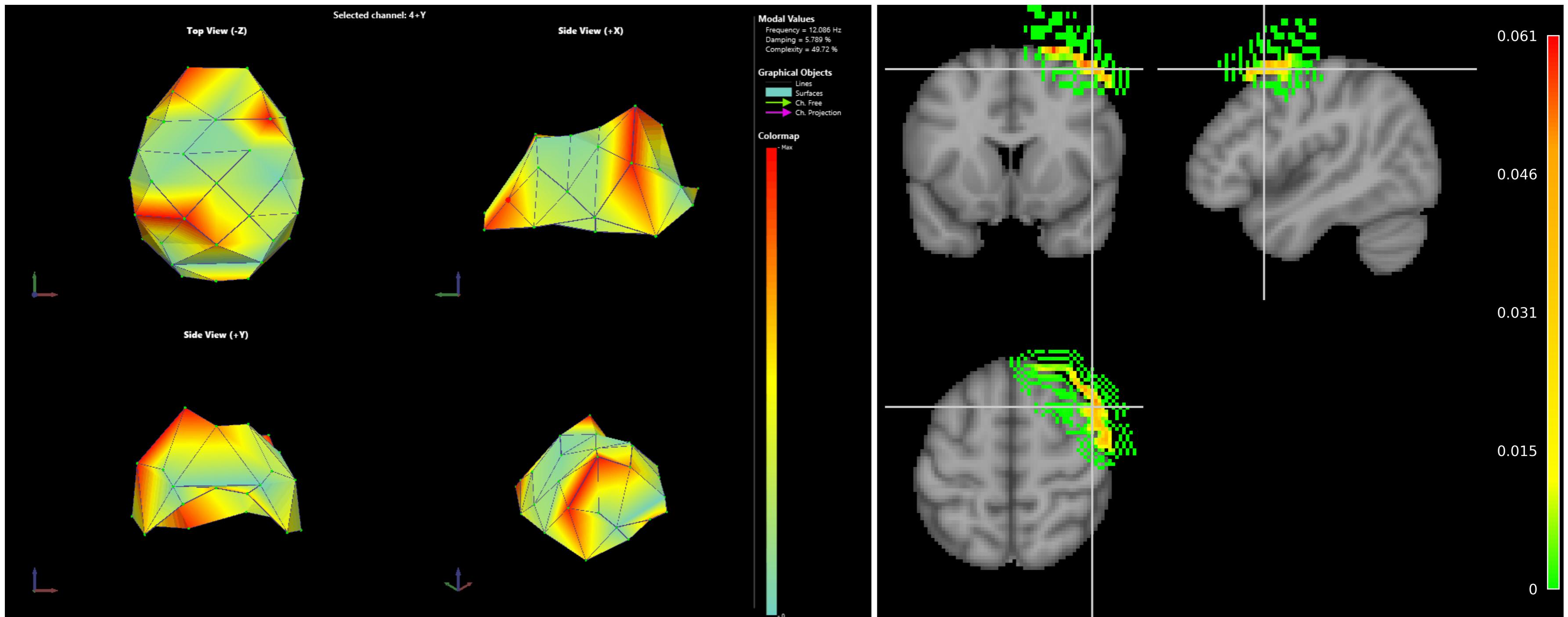
## Mode 2



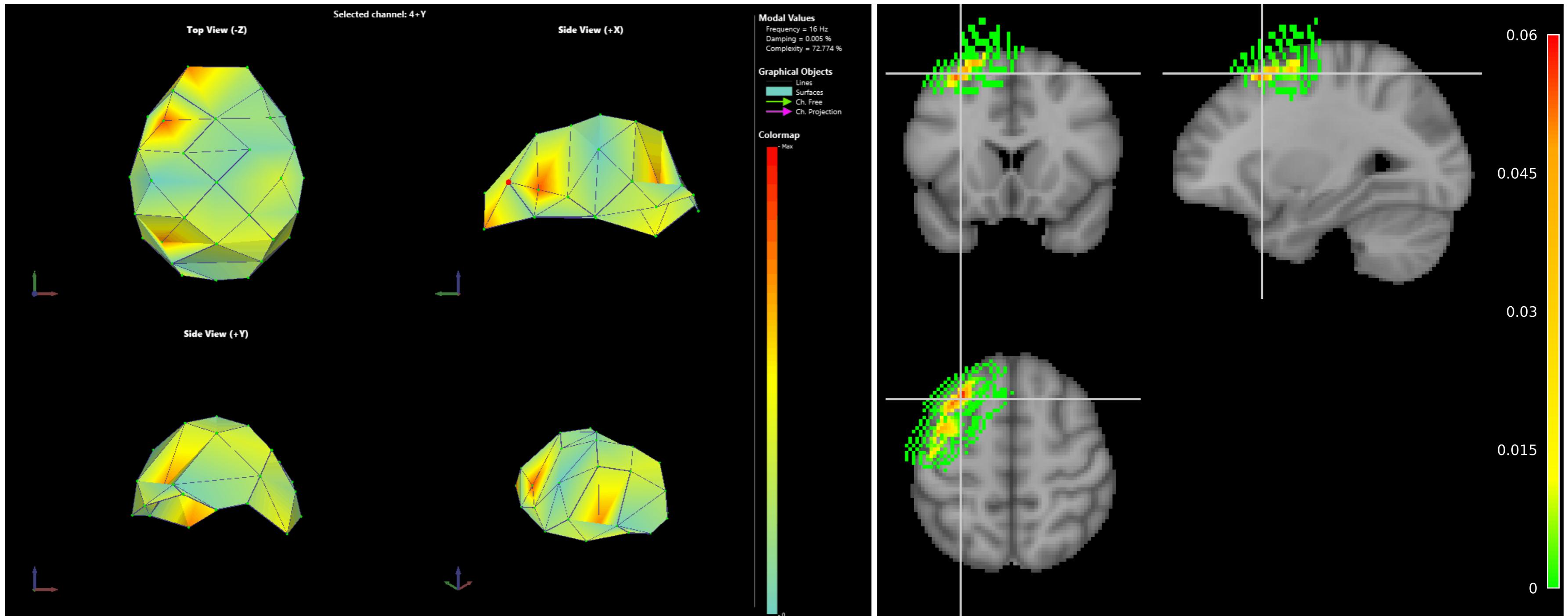
## Mode 3



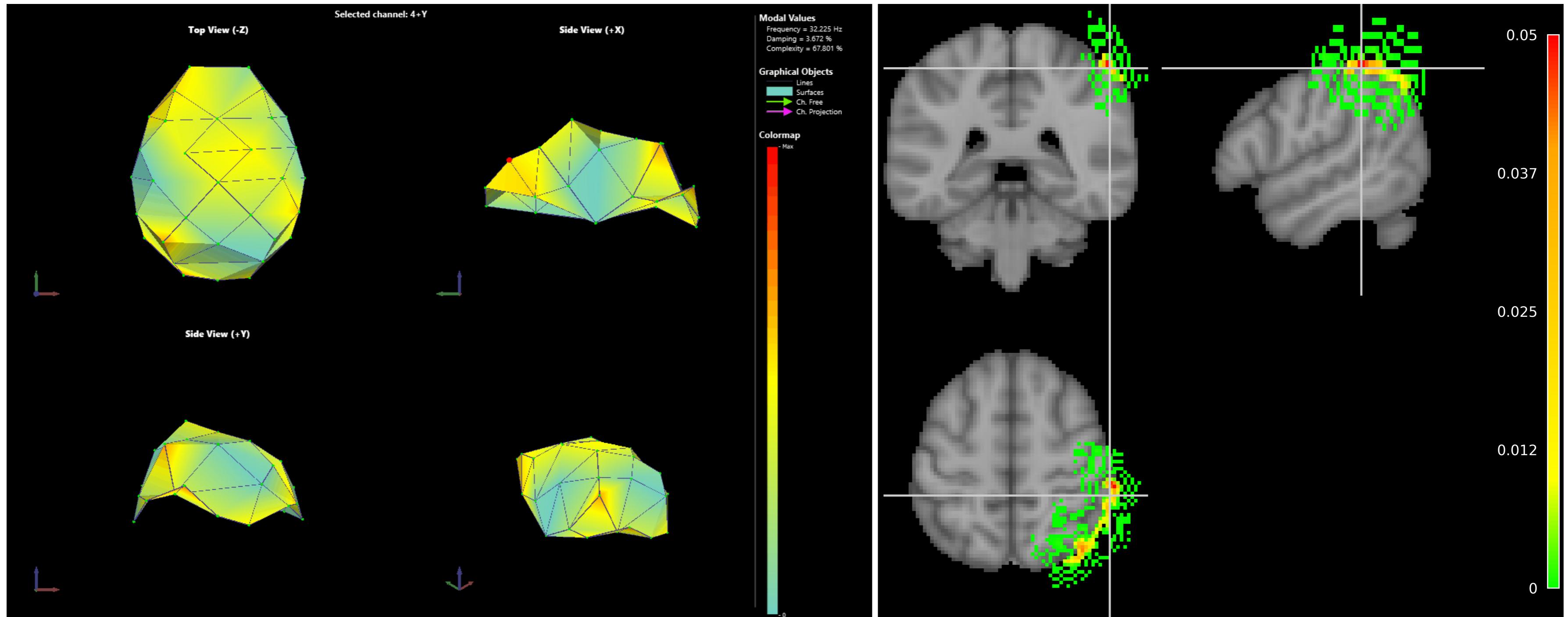
## Mode 4



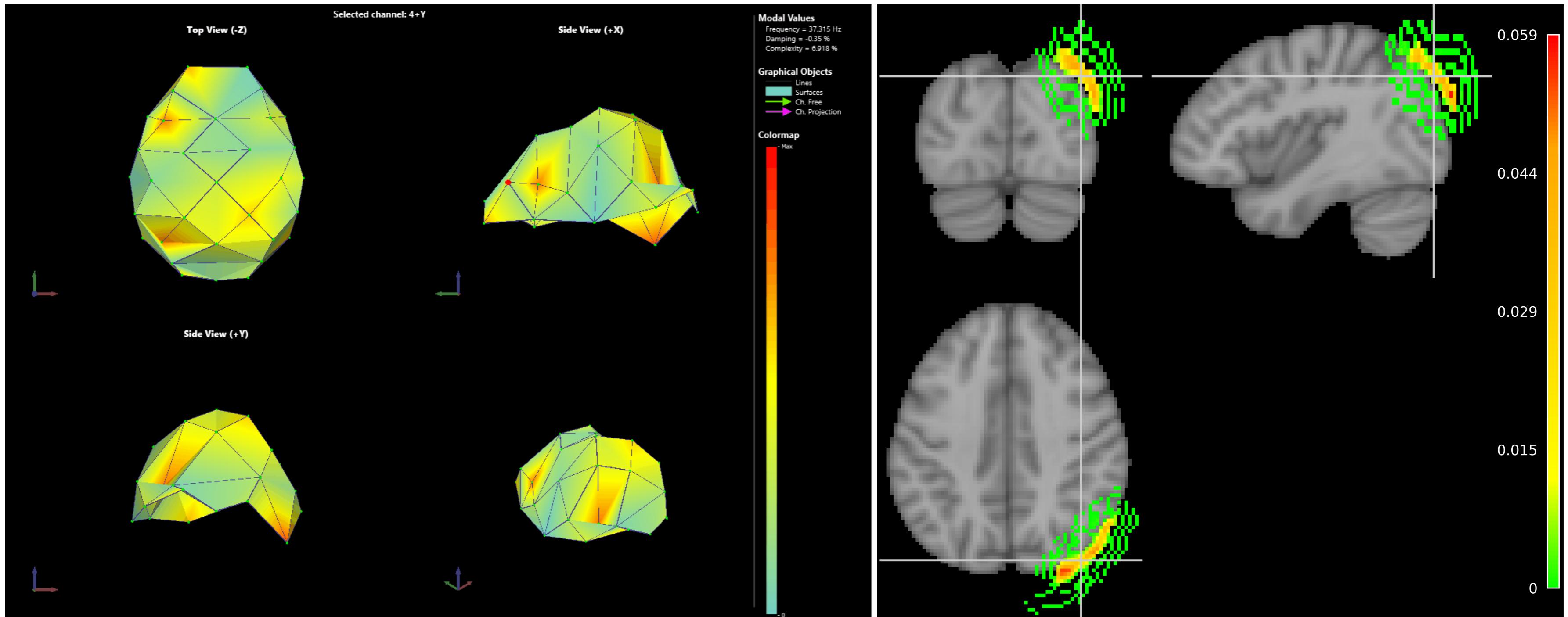
## Mode 5



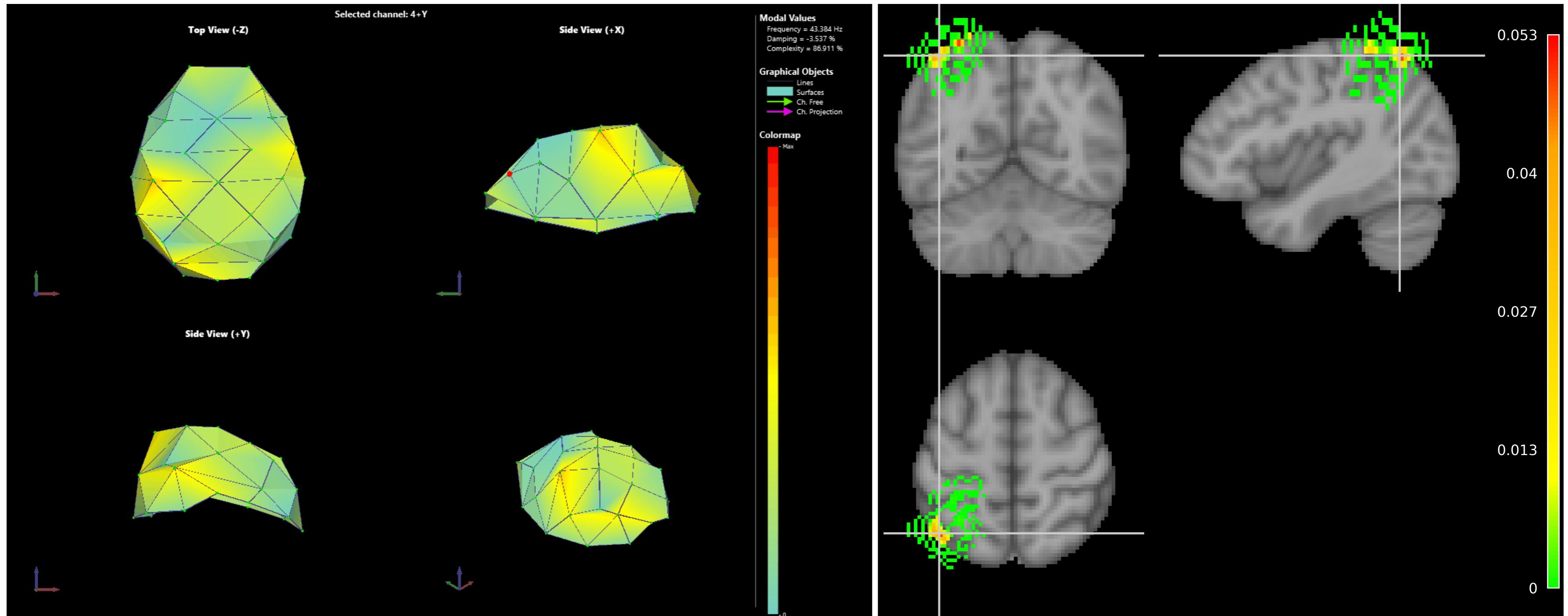
## Mode 6



## Mode 7

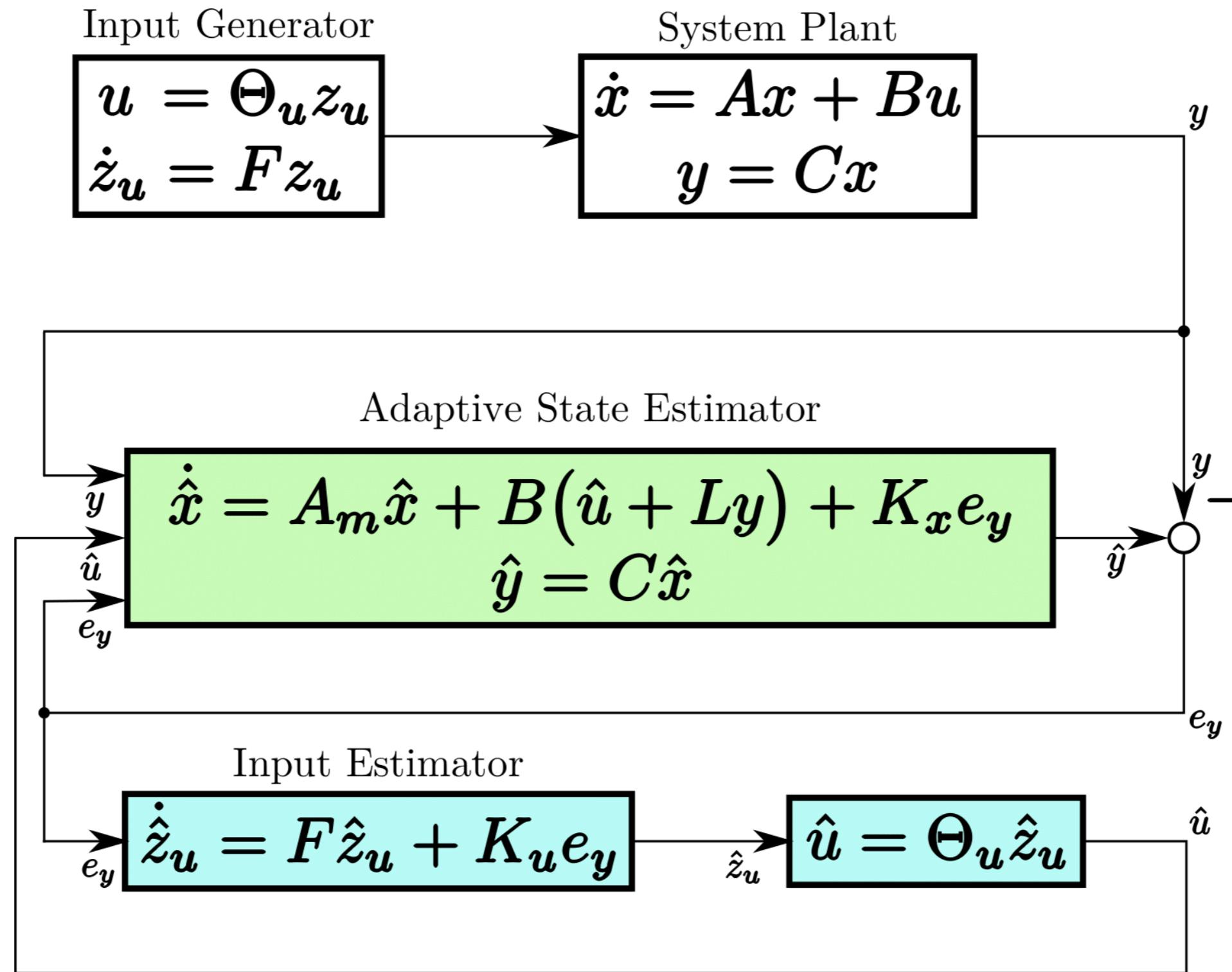


## Mode 8



## 2. UIO Recap

# UIO Review: Estimator Architecture

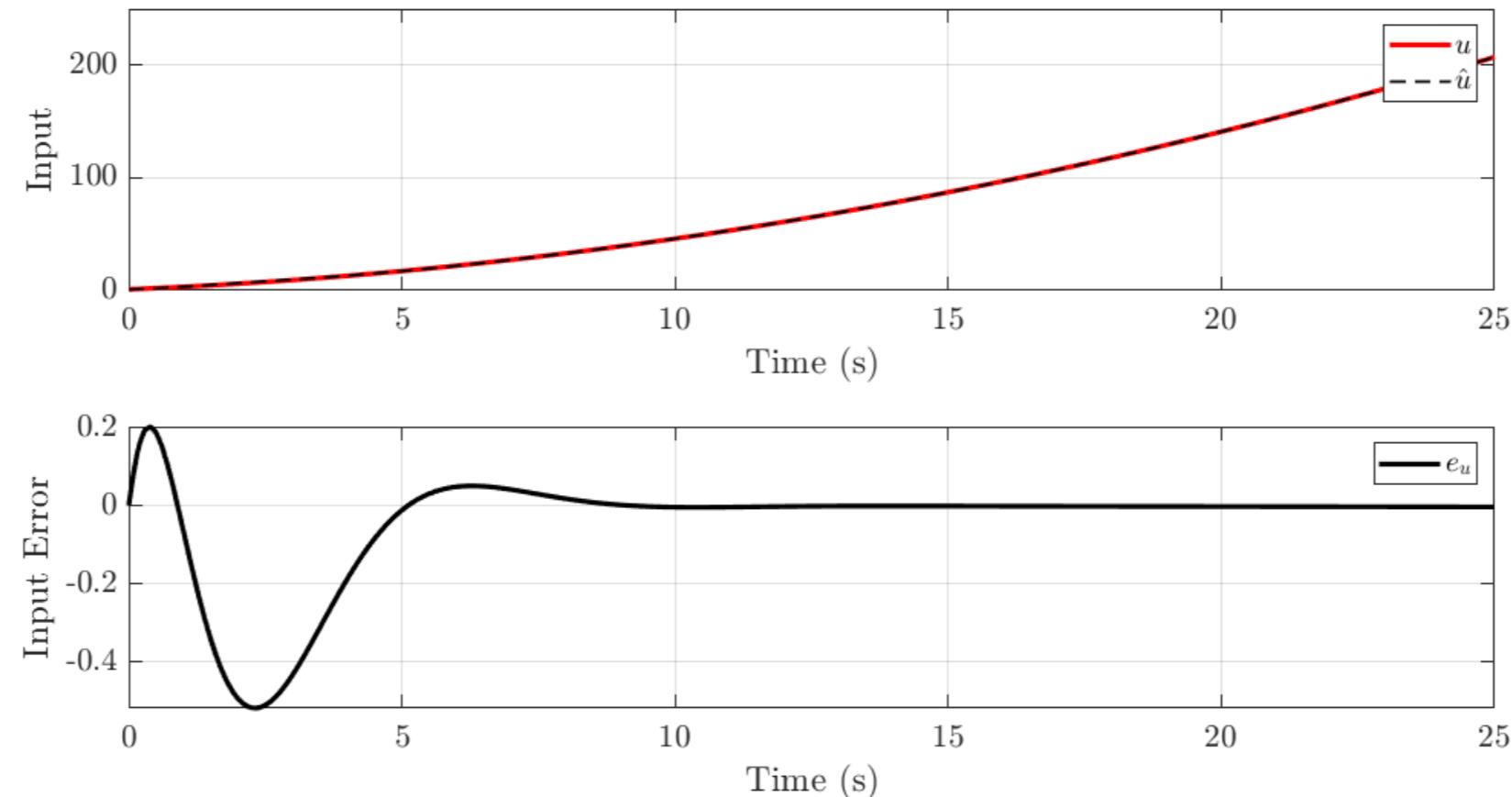


# A Polynomial Basis

$$\{1, x, x^2, x^3, \dots, x^n\}$$

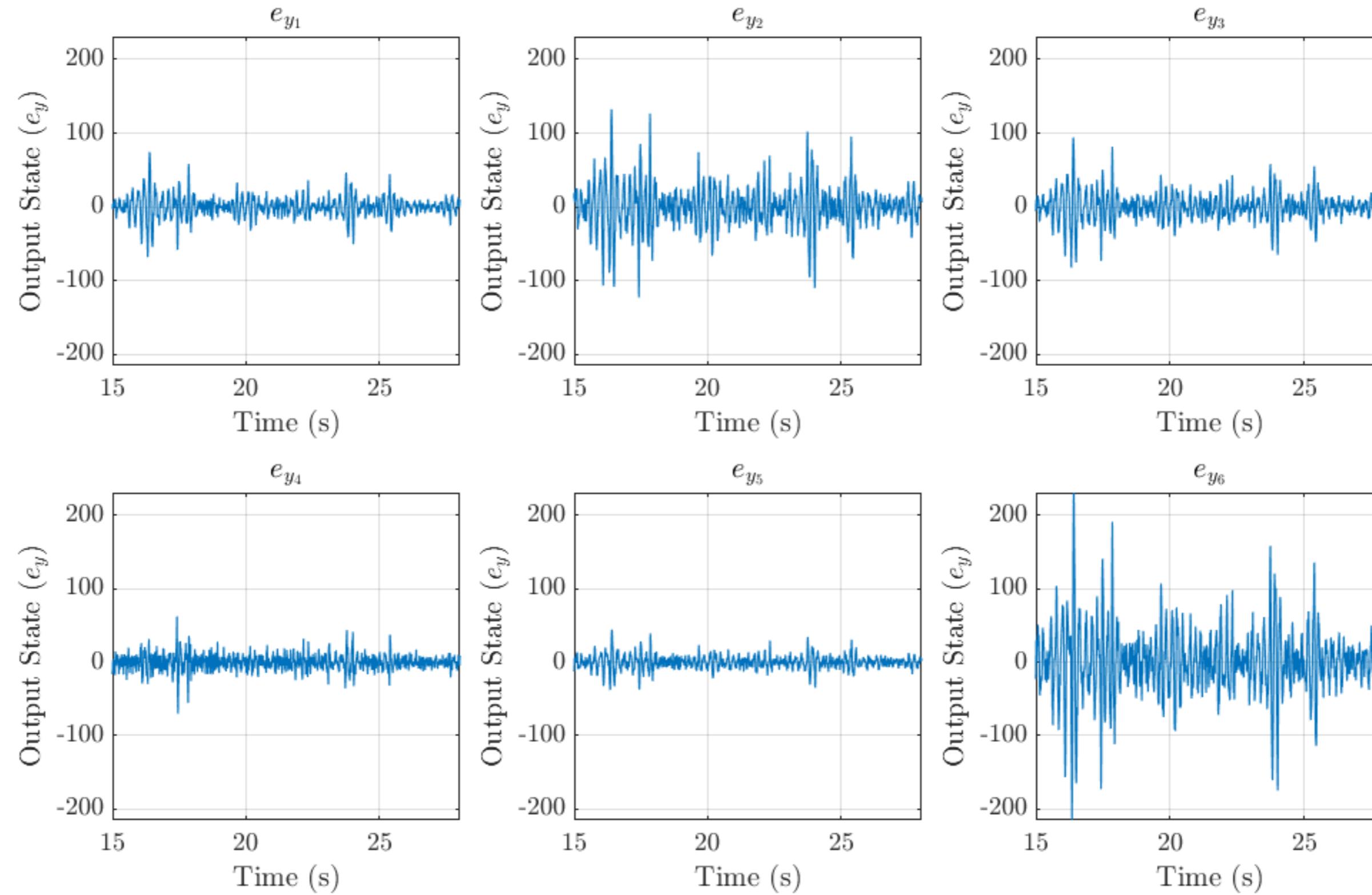
$$u(t) = 1 + 2t + 0.5t^2$$

*In some cases the natural basis functions for  $u(t)$  are not clearly defined by the available data. For such cases it is usually effective to use a polynomial spline waveform-model*

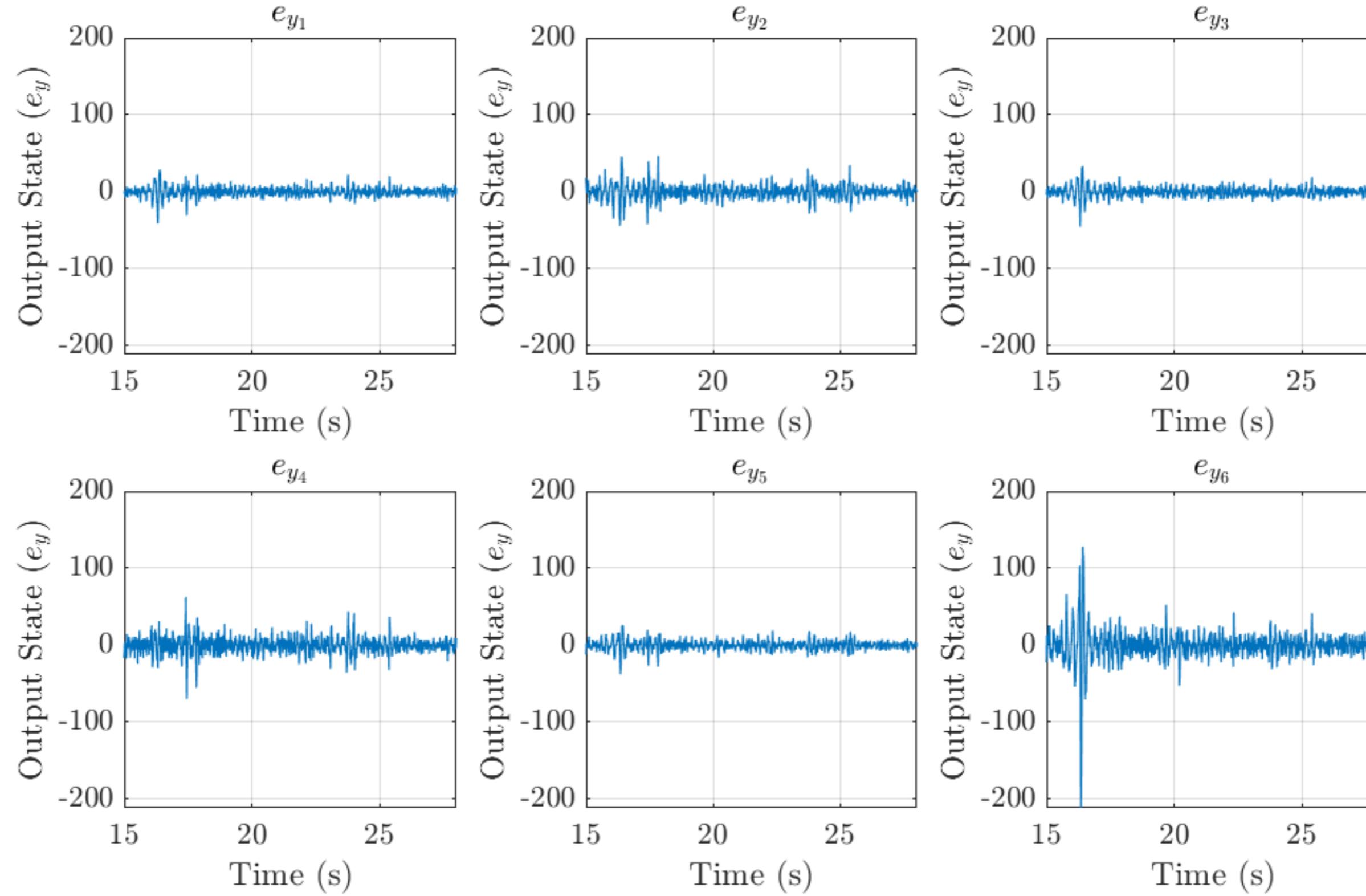


Johnson, C. D. (1989, January). Effective techniques for the identification and accommodation of disturbances. In Pros. 3rd Annual NASA/DOD Controls-Structures Interaction (CSI) Technical Conf. (p. 163).

# Polynomial Basis Comparison: Fourier 1-300 hz



# Polynomial Basis Comparison: 1-6th



# Some Obscured Assumptions

- $B = I$ 
  - $\dot{x} = Ax + Bu$
- SIMO



# A Better B Matrix?

- Alter B to improve modeling error  $e_y$ 
  - Convex Optimization

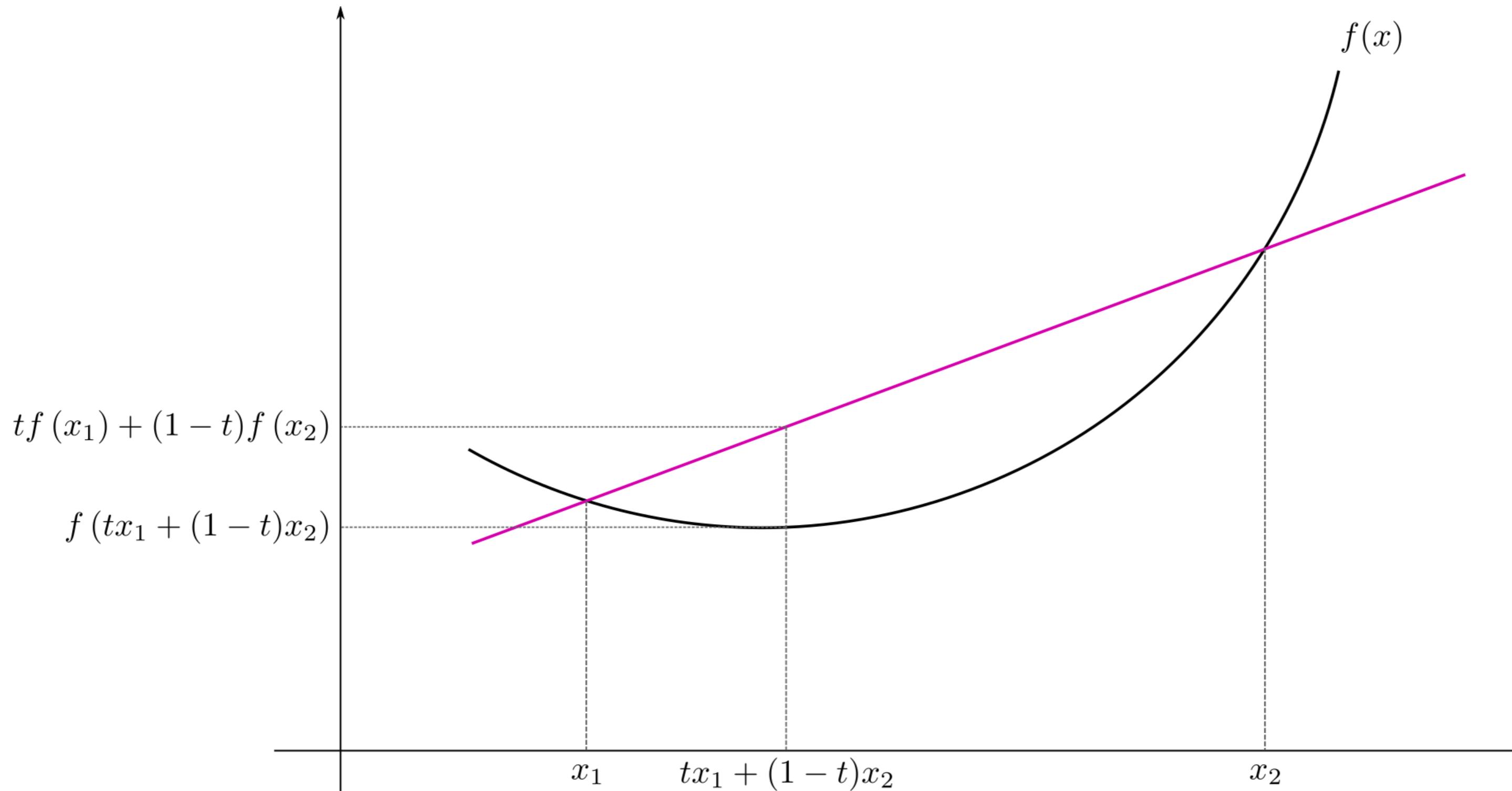


### 3. Optimized Parameterizations

# Convex Optimization

an optimization problem in which the objective function is a **convex function** and the feasible set is a **convex set**

the objective function is a **convex function**



[Image Source](#)

the feasible set is a **convex set**

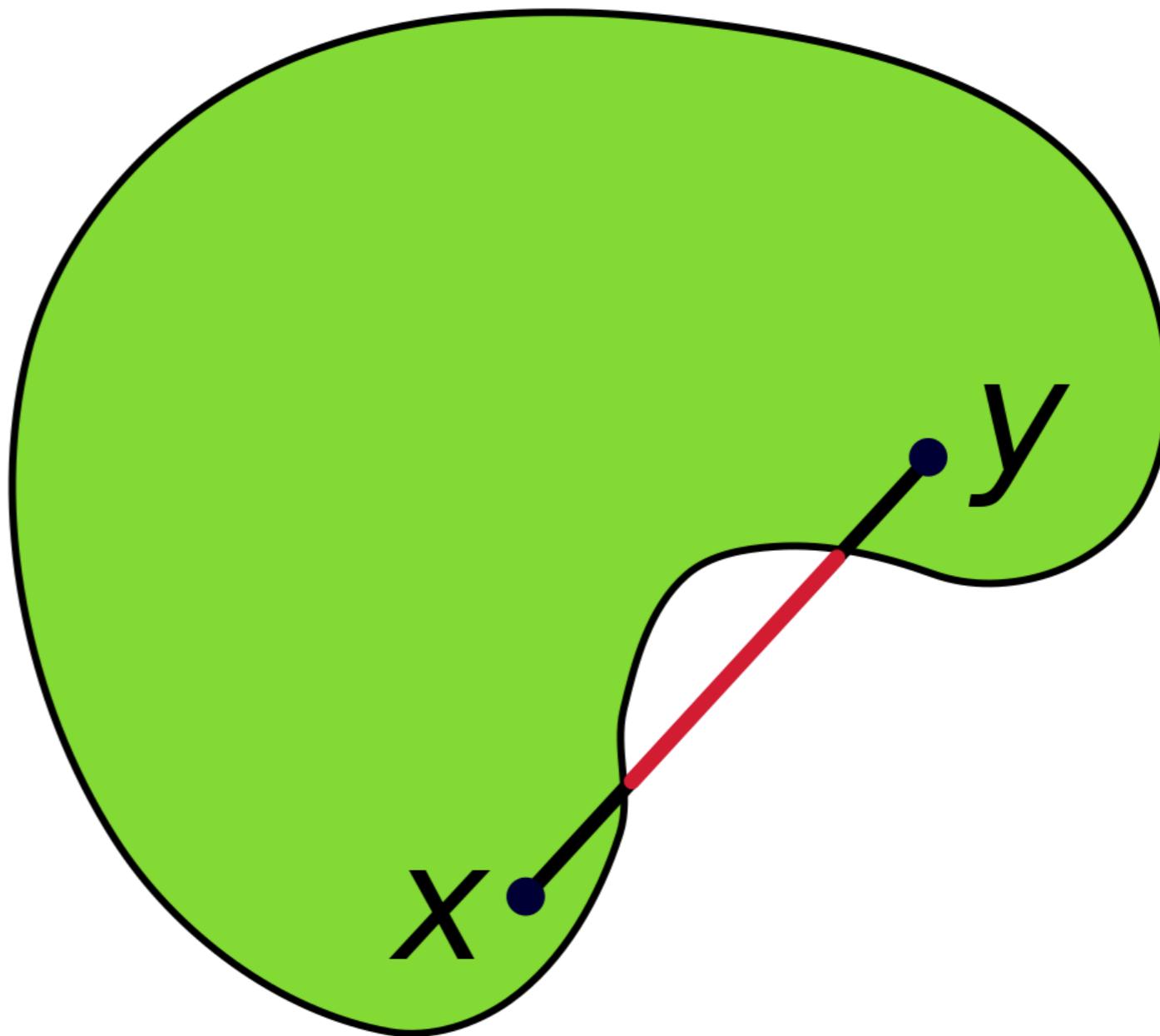
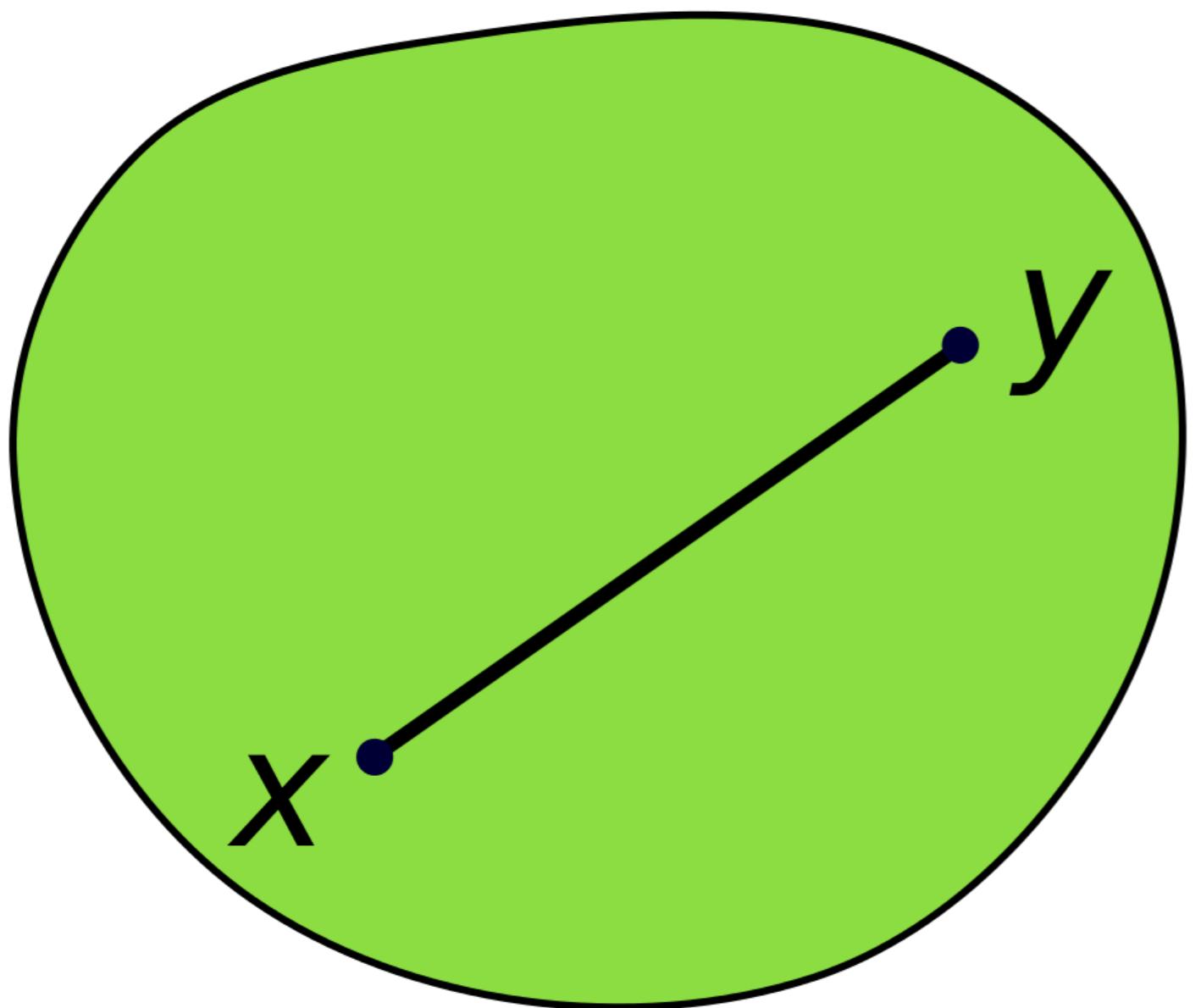


Image Source

# Important Properties of Convex Problems

- every local minimum is a global minimum
- gradient descent converges in polynomial time

## 4. Best Fit B Matrices



# A Convex Function for B matrix optimization

- $\min ||y - \hat{y} - C\Delta B\hat{u}||_2$
- **not** the only possible minimization

# B Matrix Optimization Example

- 3x3 example
  - $\dot{\hat{x}} = A_m x + B \hat{u}$
  - $A_m \neq A$
- $\min ||y - \hat{y} - C \Delta B \hat{u}||_2$
- $B = \begin{bmatrix} 1.2 \\ 1 \\ 1.6 \end{bmatrix},$
- $B_m = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$



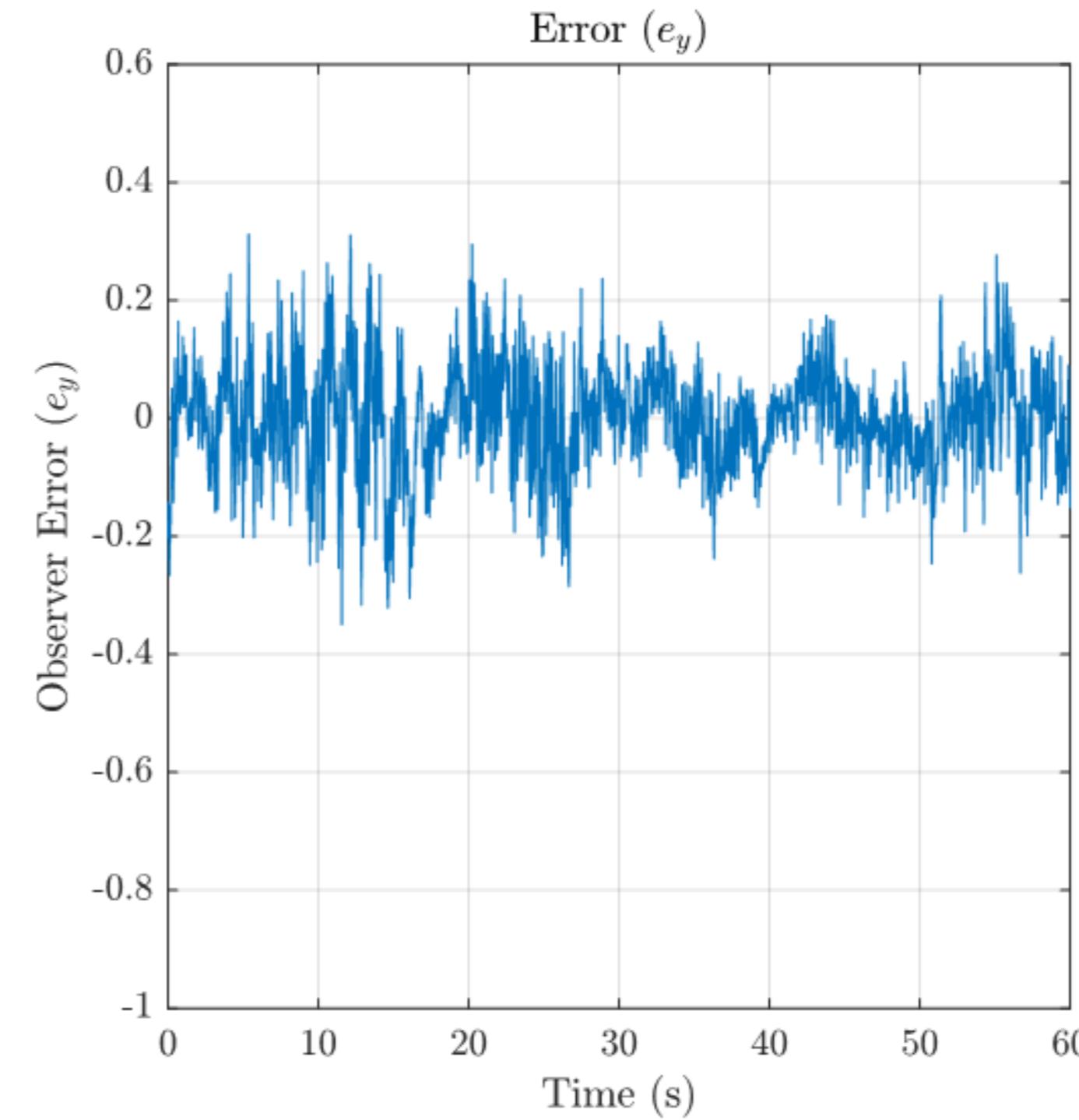
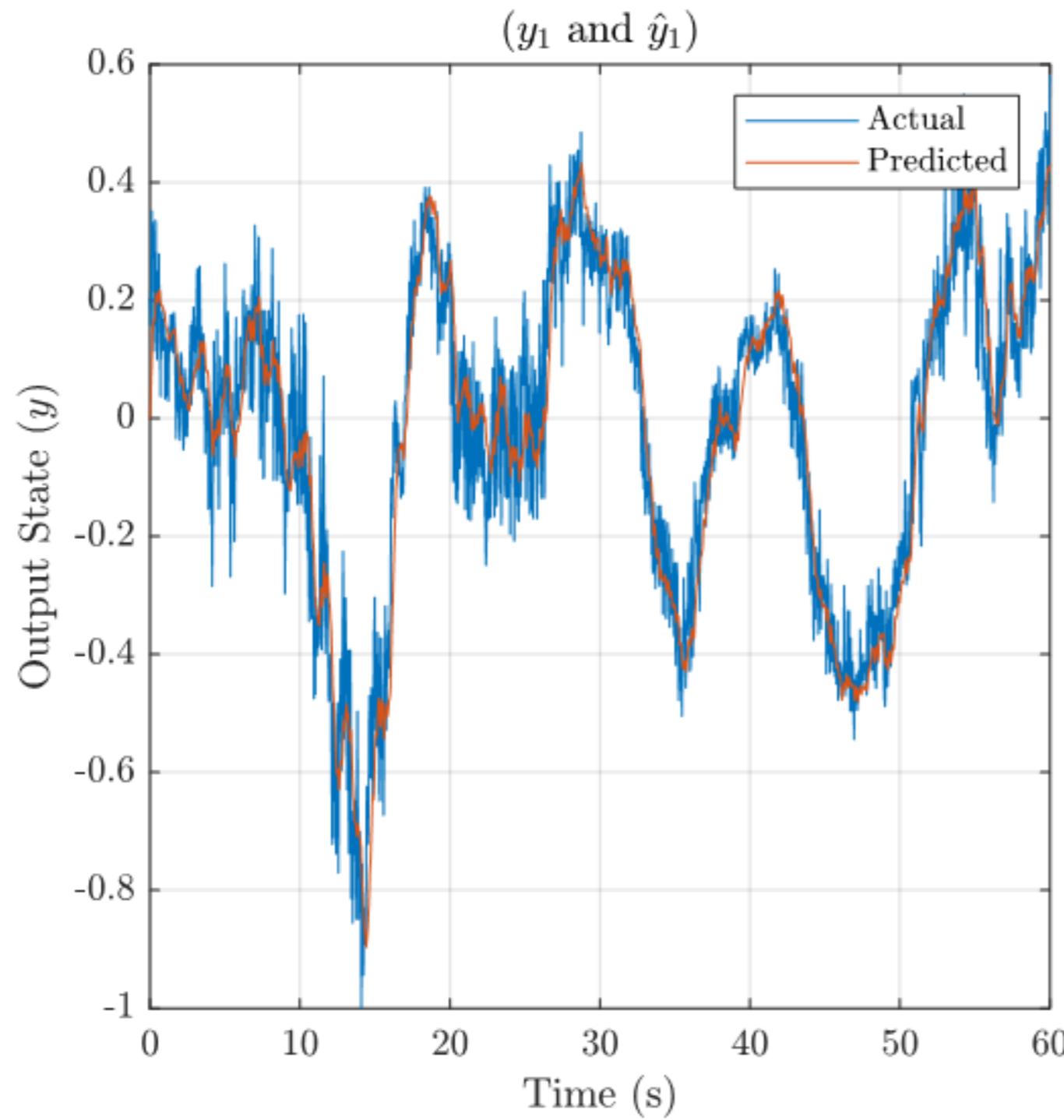
# B Matrix Optimization Example

- $\min ||y - \hat{y} - C\Delta B\hat{u}||_2$
- $\Delta B = \begin{bmatrix} 0.18 \\ 0 \\ 0.37 \end{bmatrix},$
- $B_f = \begin{bmatrix} 1.18 \\ 1 \\ 1.37 \end{bmatrix}$

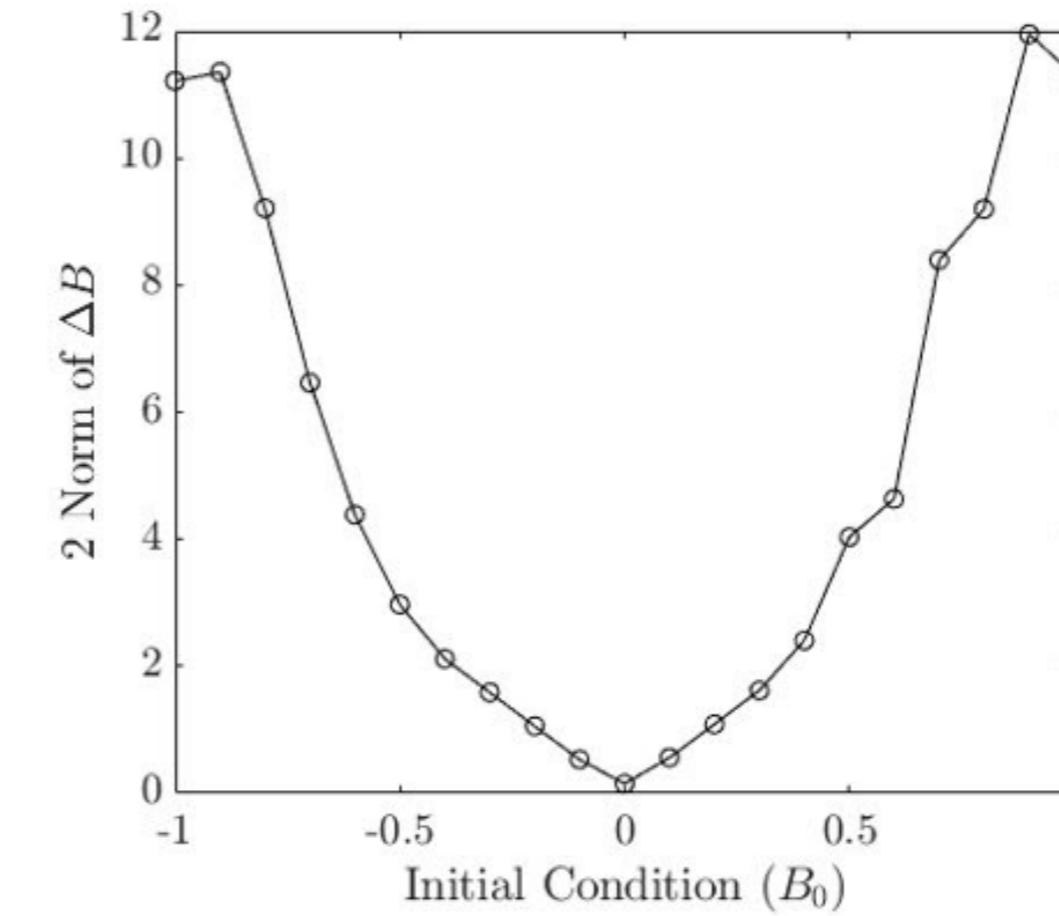
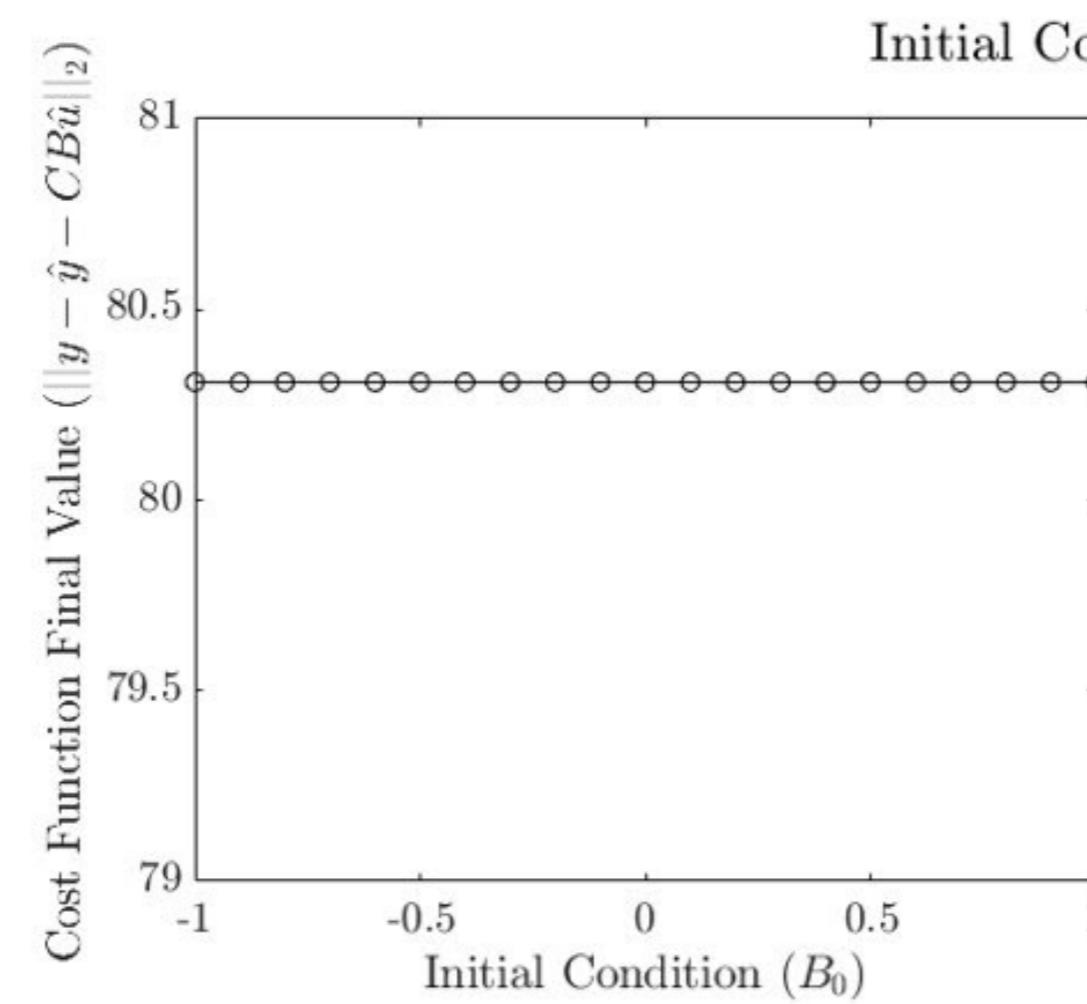


# B Matrix on EEG Data

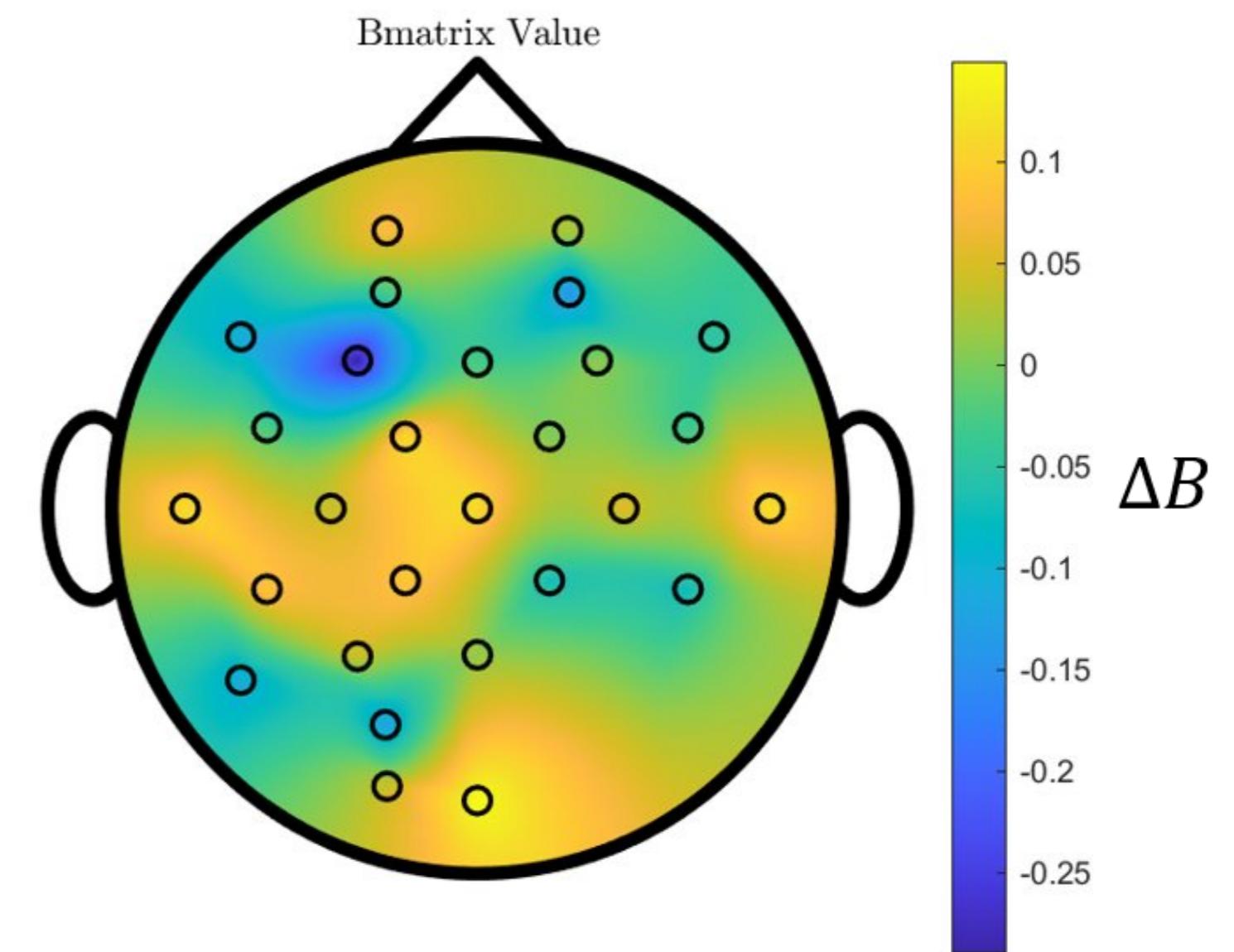
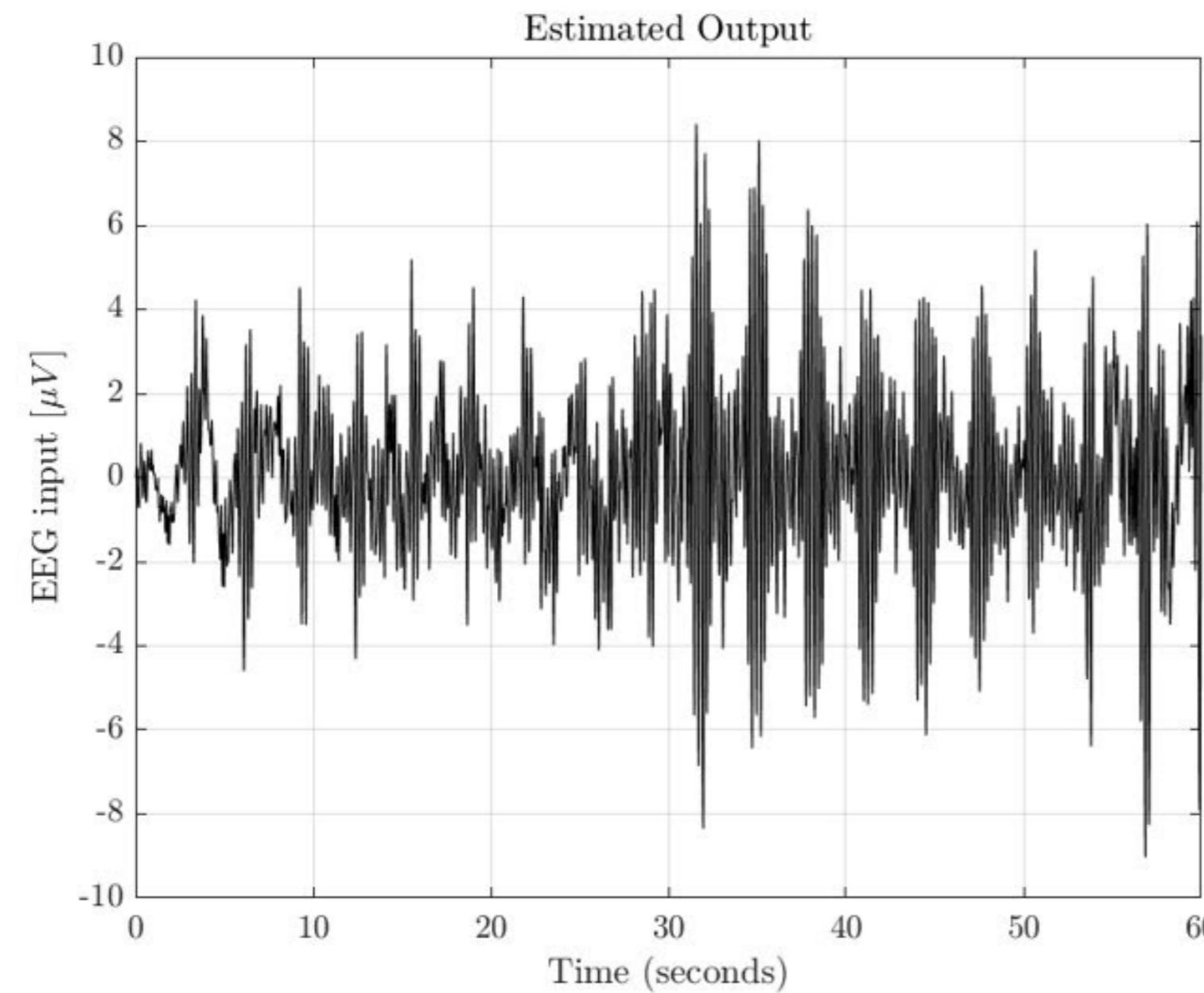
Comparison of Single Channels and Error



# B Matrix on EEG Data

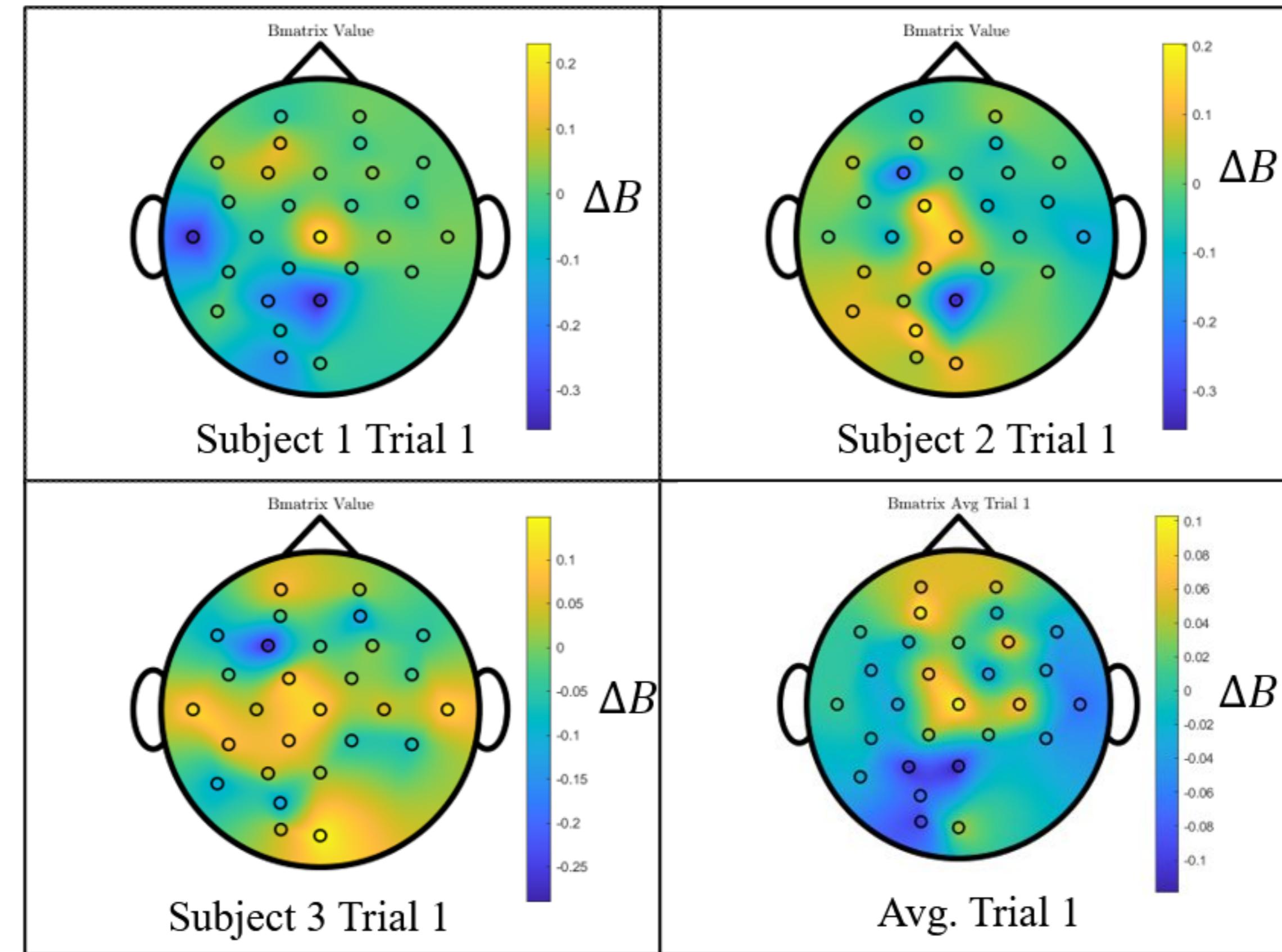


# Current models

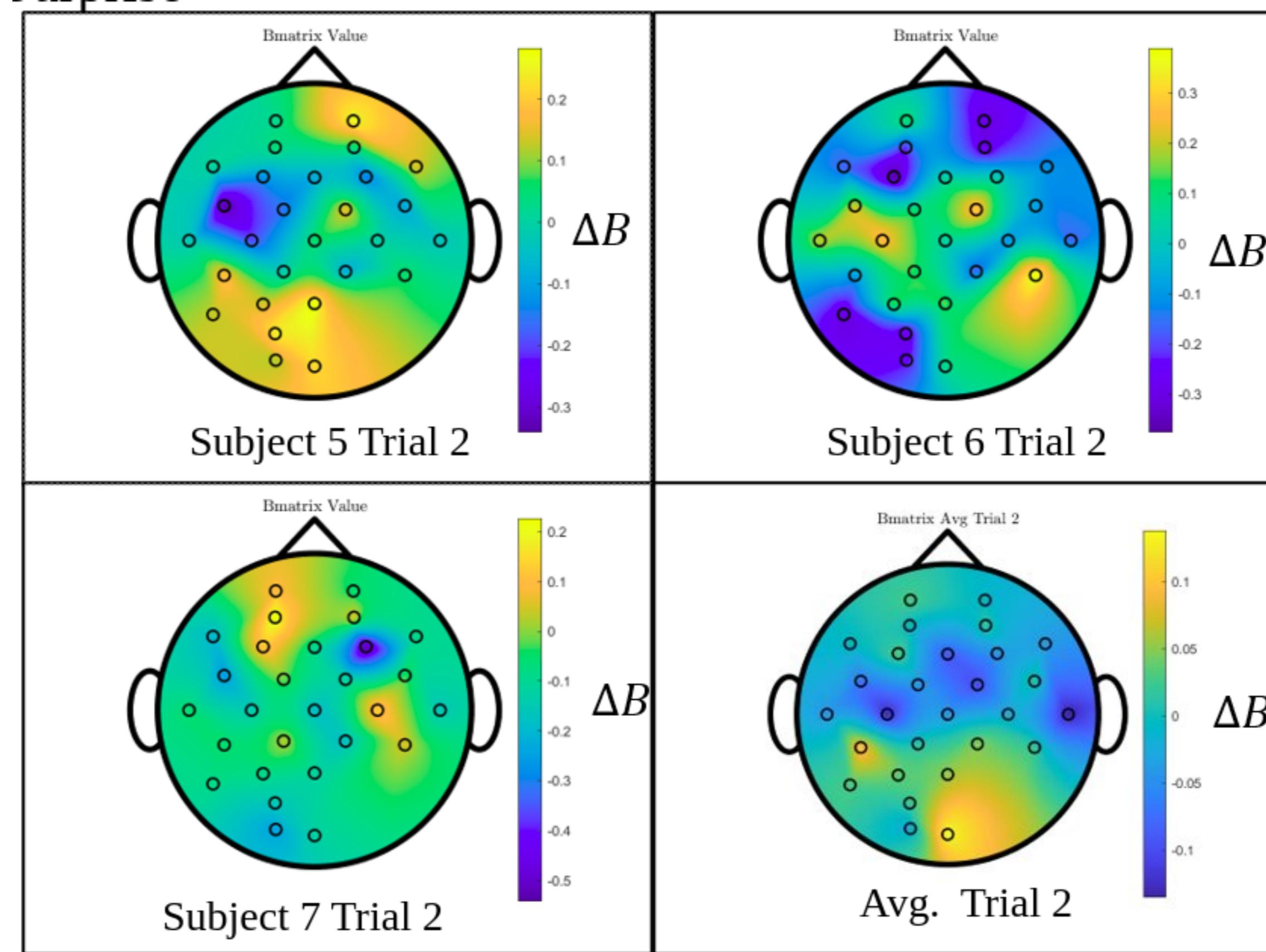


## 5. Application to Emotion Data

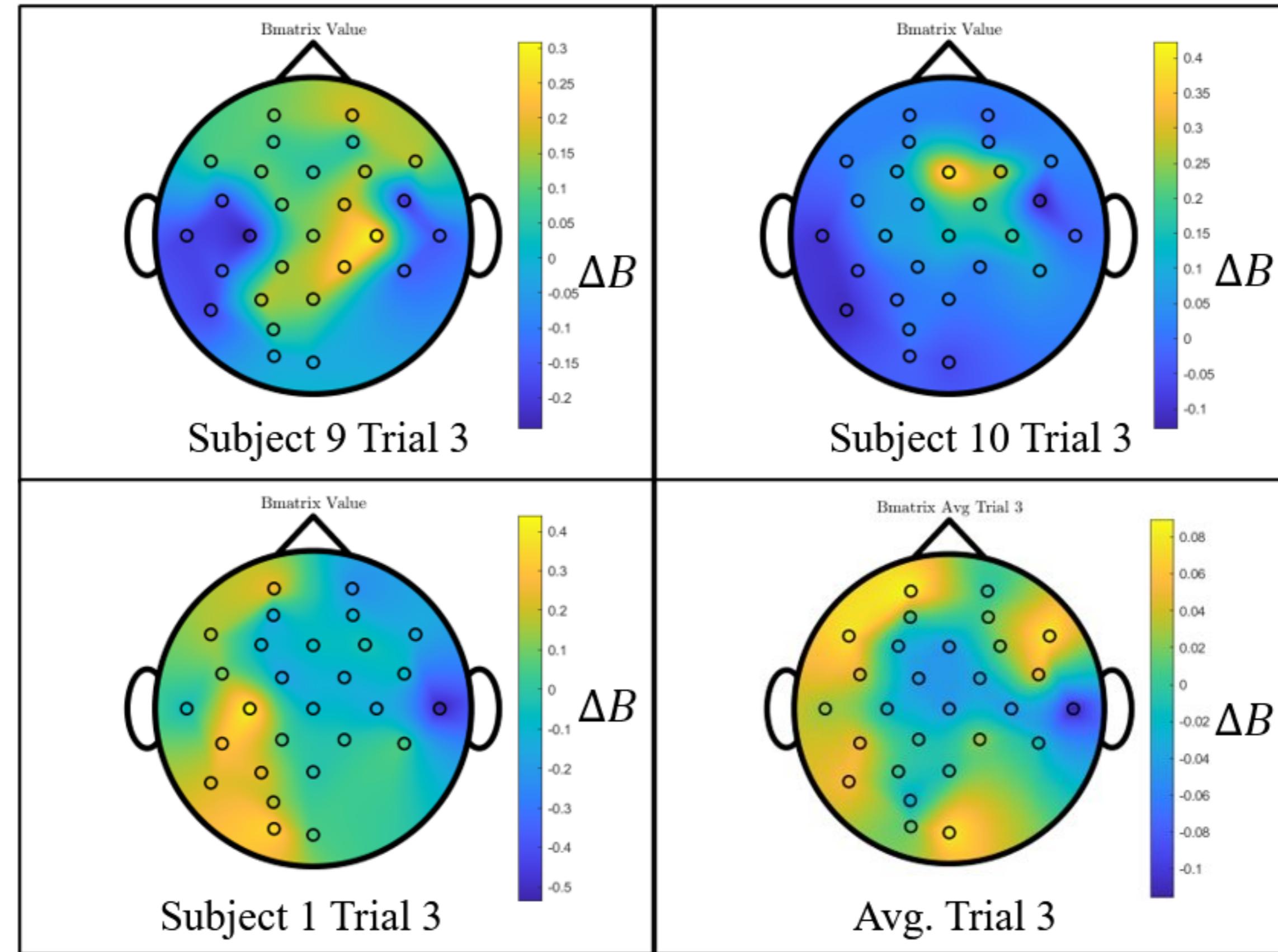
## B Matrix on EEG Data: Satisfaction (T1)



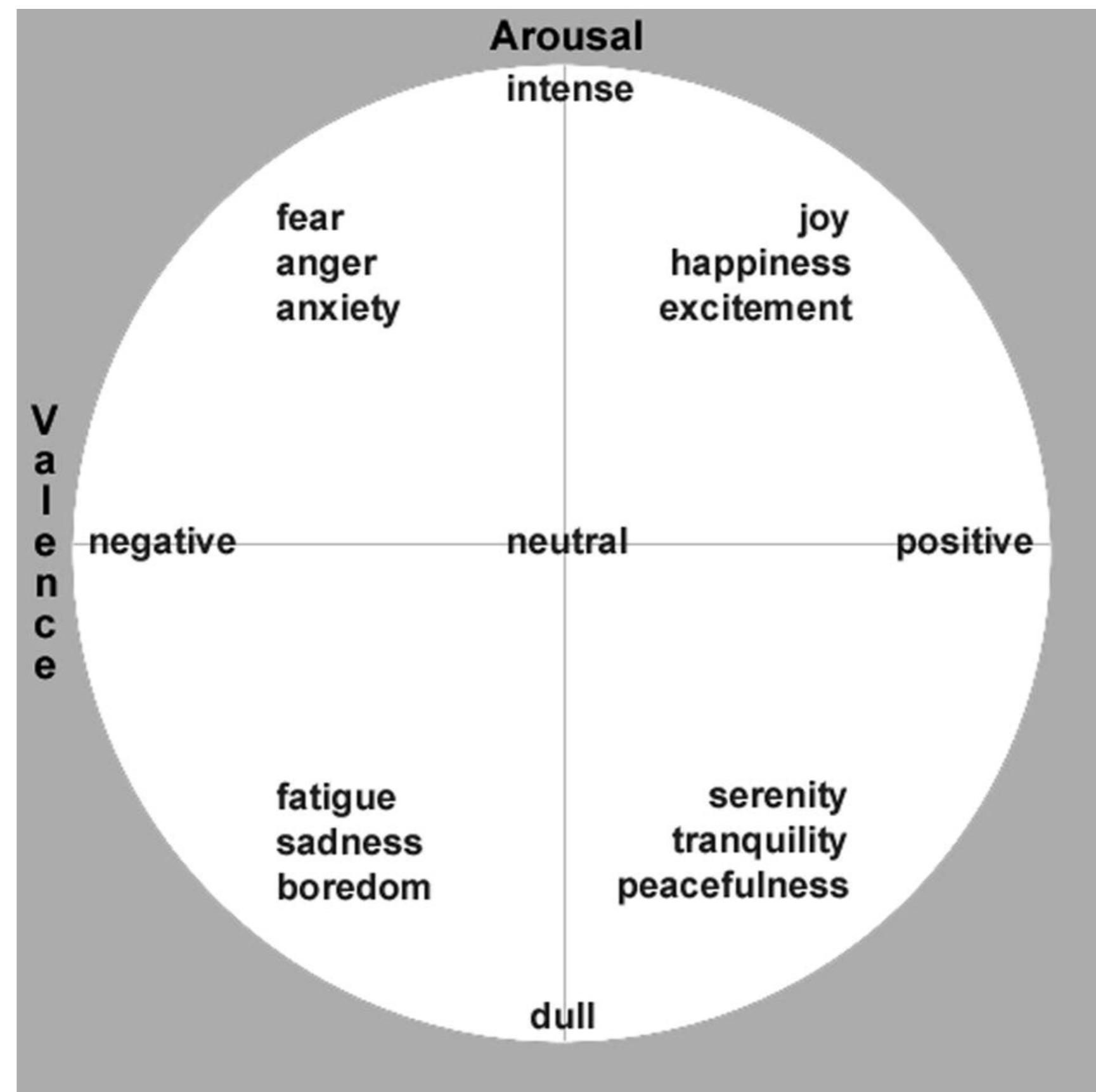
## B Matrix on EEG Data: Surprise (T2)



## B Matrix on EEG Data: **Fear (T8)**

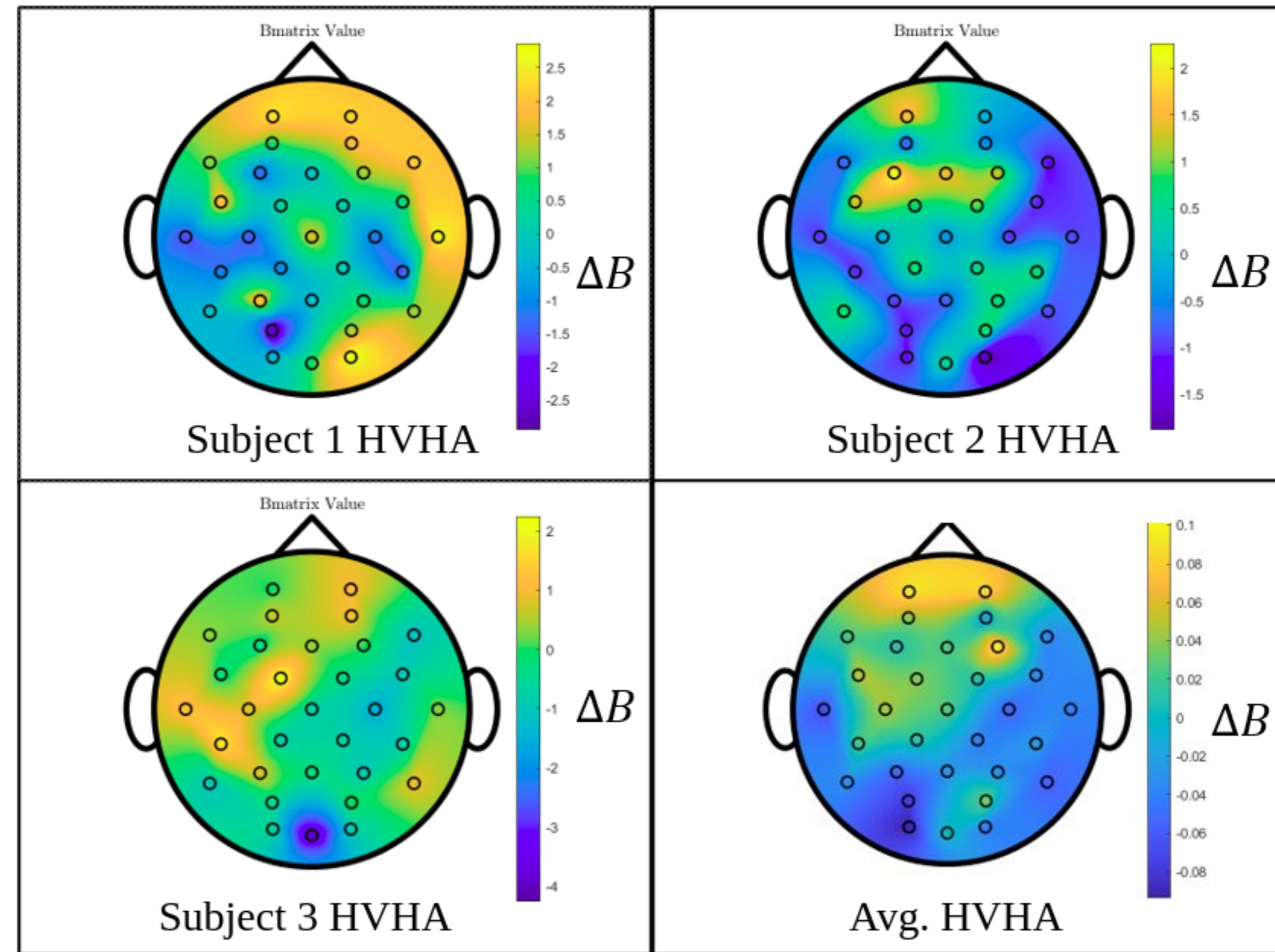


## Comparing the same “emotion”

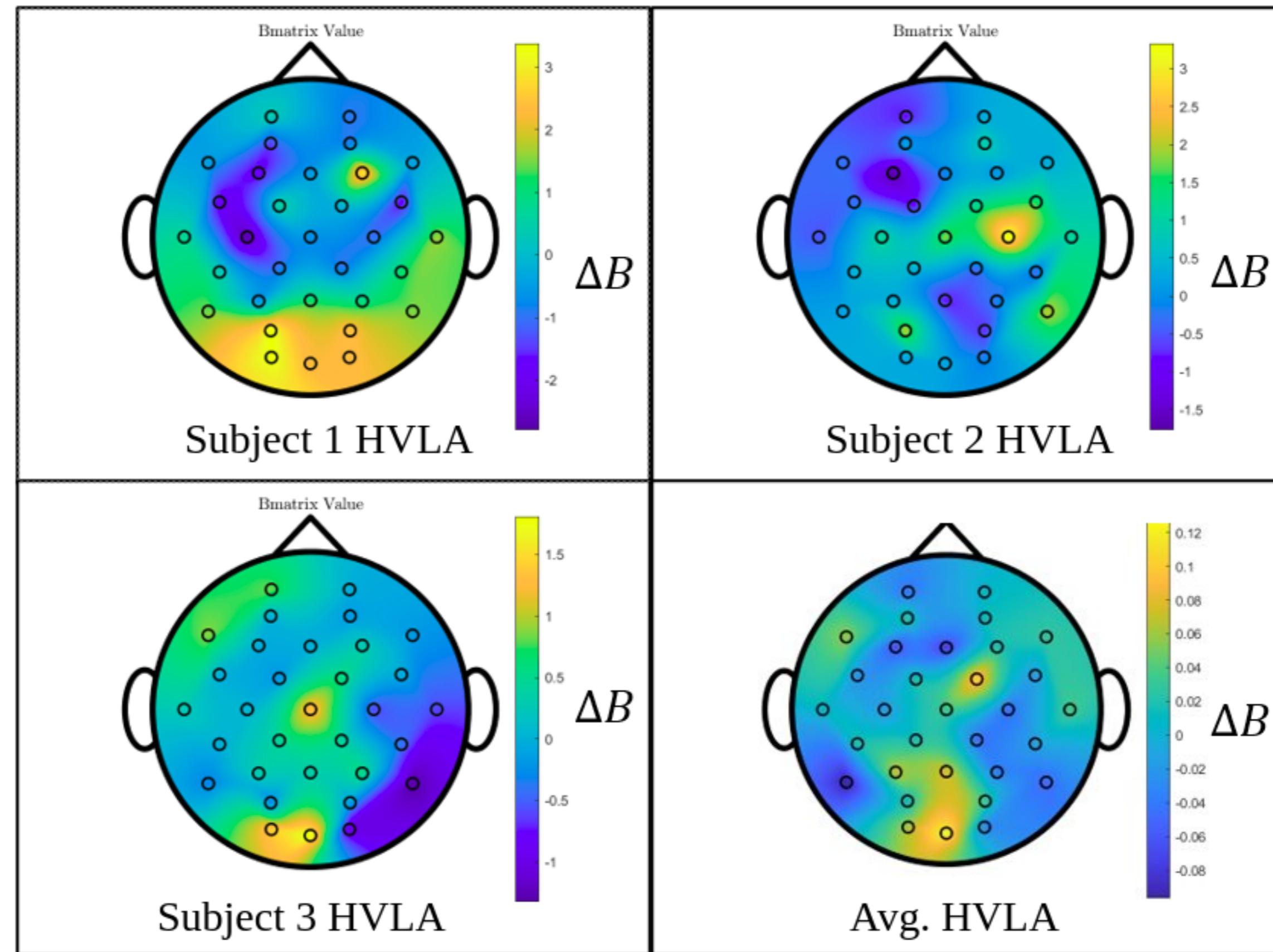


Mneimne, M., Powers, A. S., Walton, K. E., Kosson, D. S., Fonda, S., & Simonetti, J. (2010). Emotional valence and arousal effects on memory and hemispheric asymmetries. *Brain and Cognition*, 74(1), 10-17.

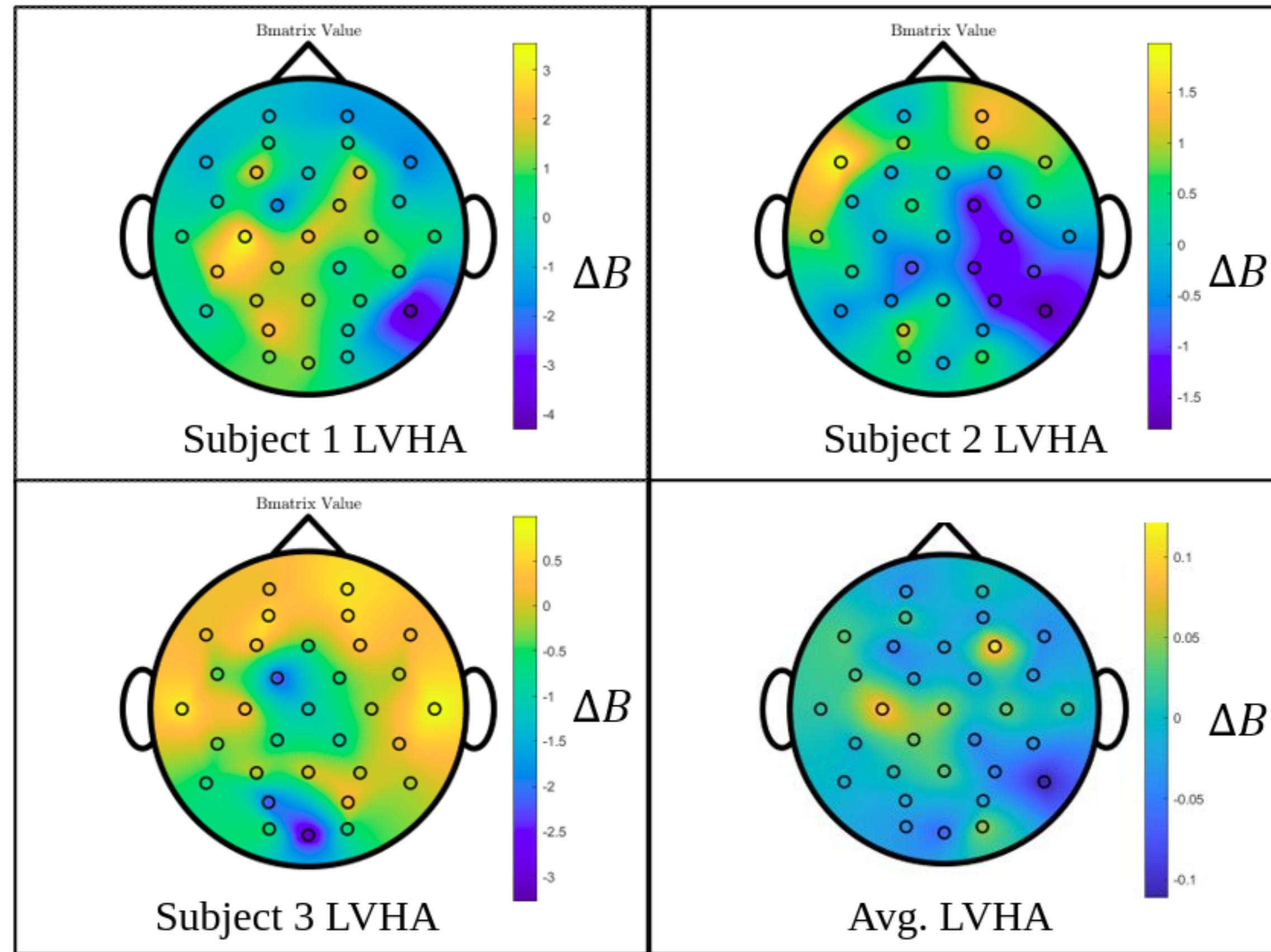
# B Matrix on EEG Data: HVHA



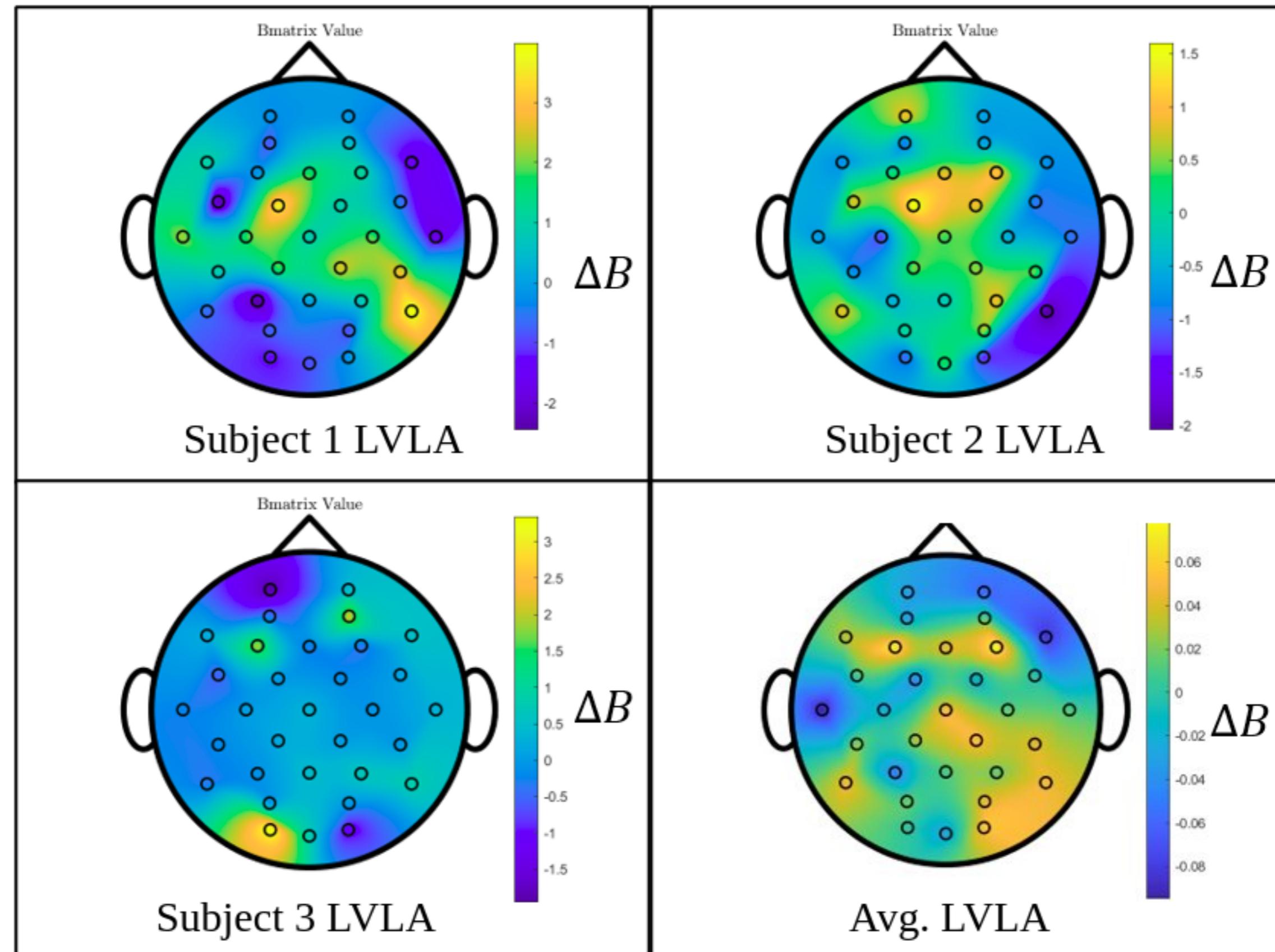
# B Matrix on EEG Data: HVLA



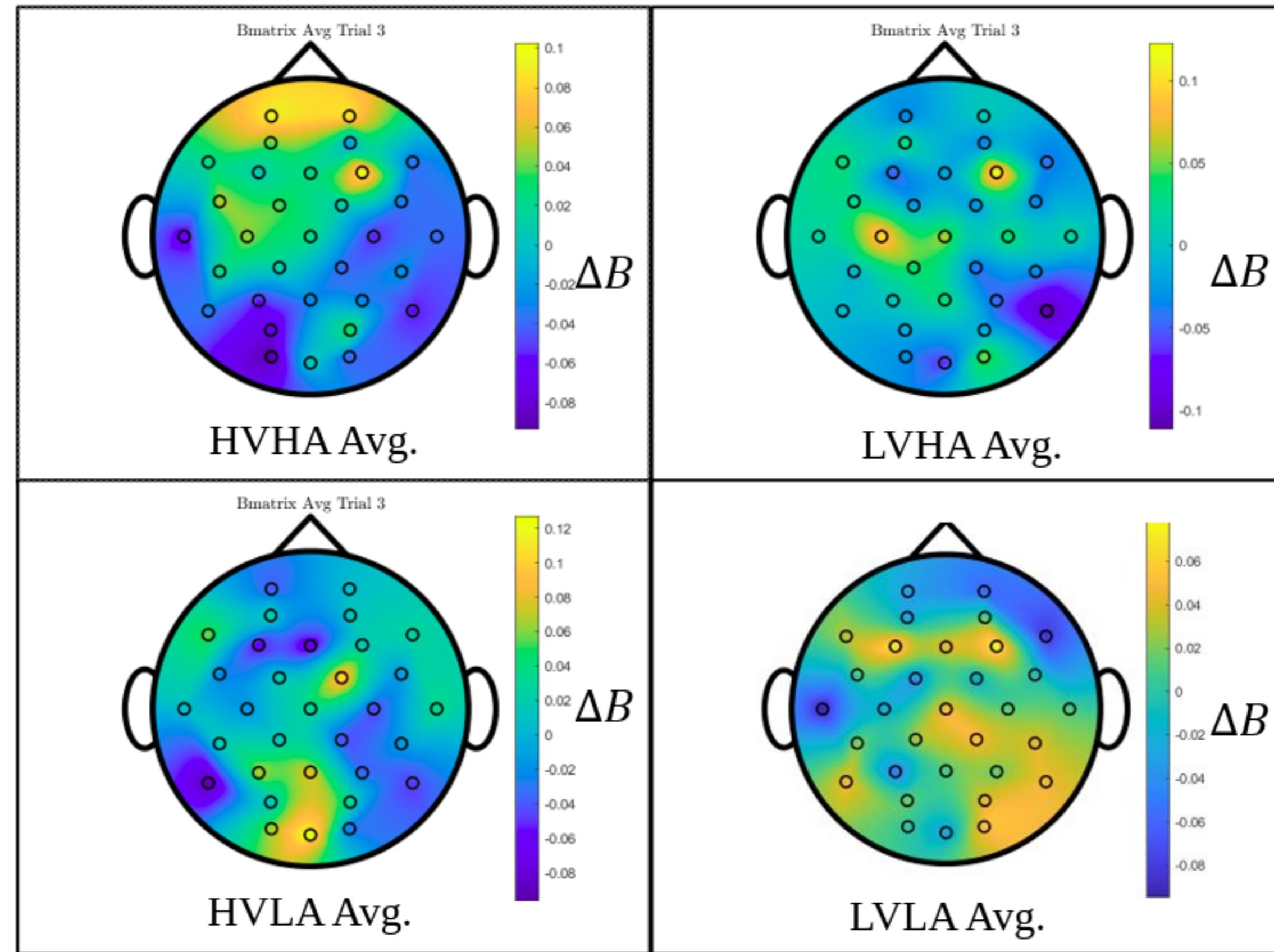
## B Matrix on EEG Data: LVHA



## B Matrix on EEG Data: LVLA



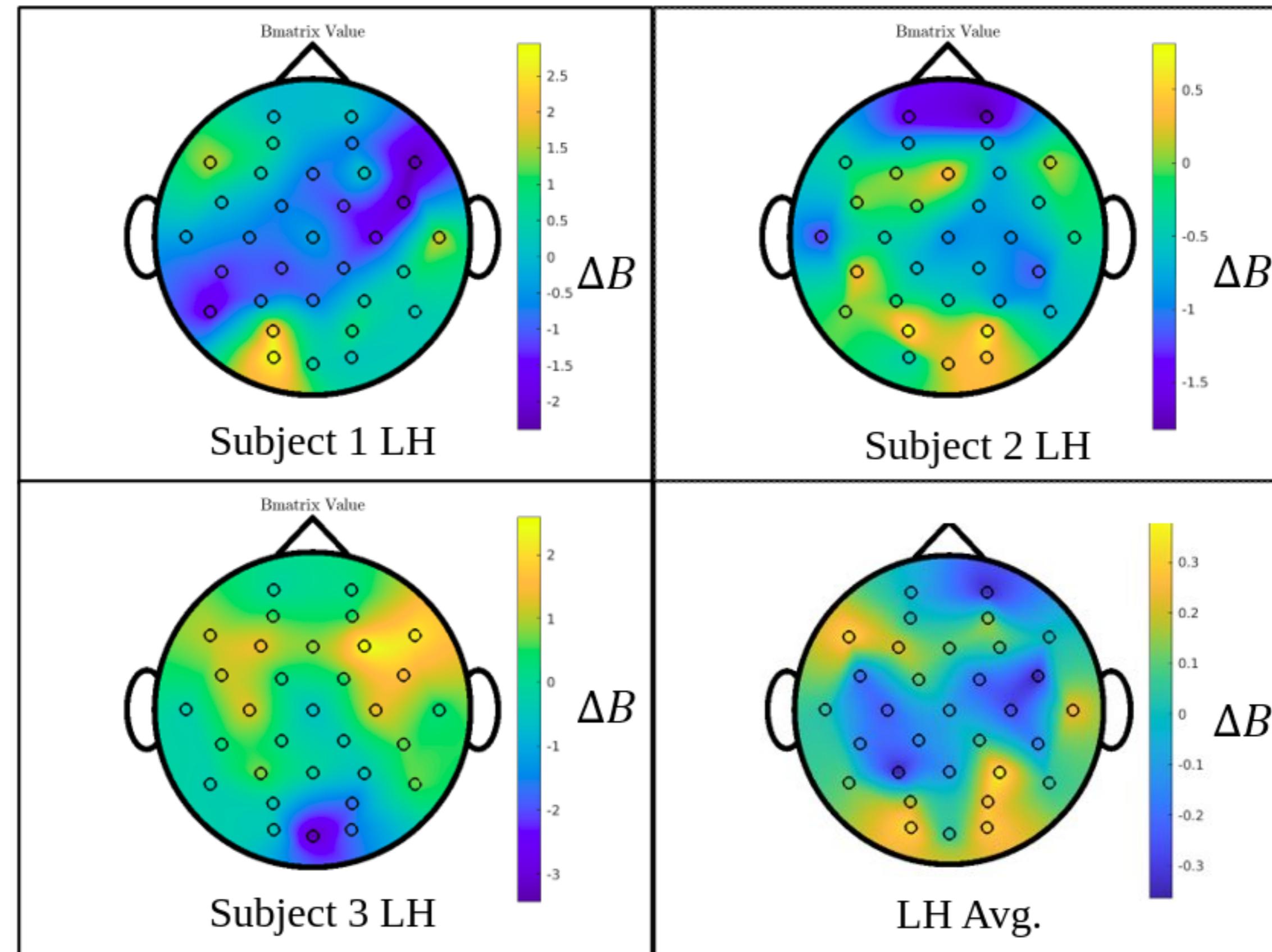
## B Matrix on EEG Data: Avg. Quadrants



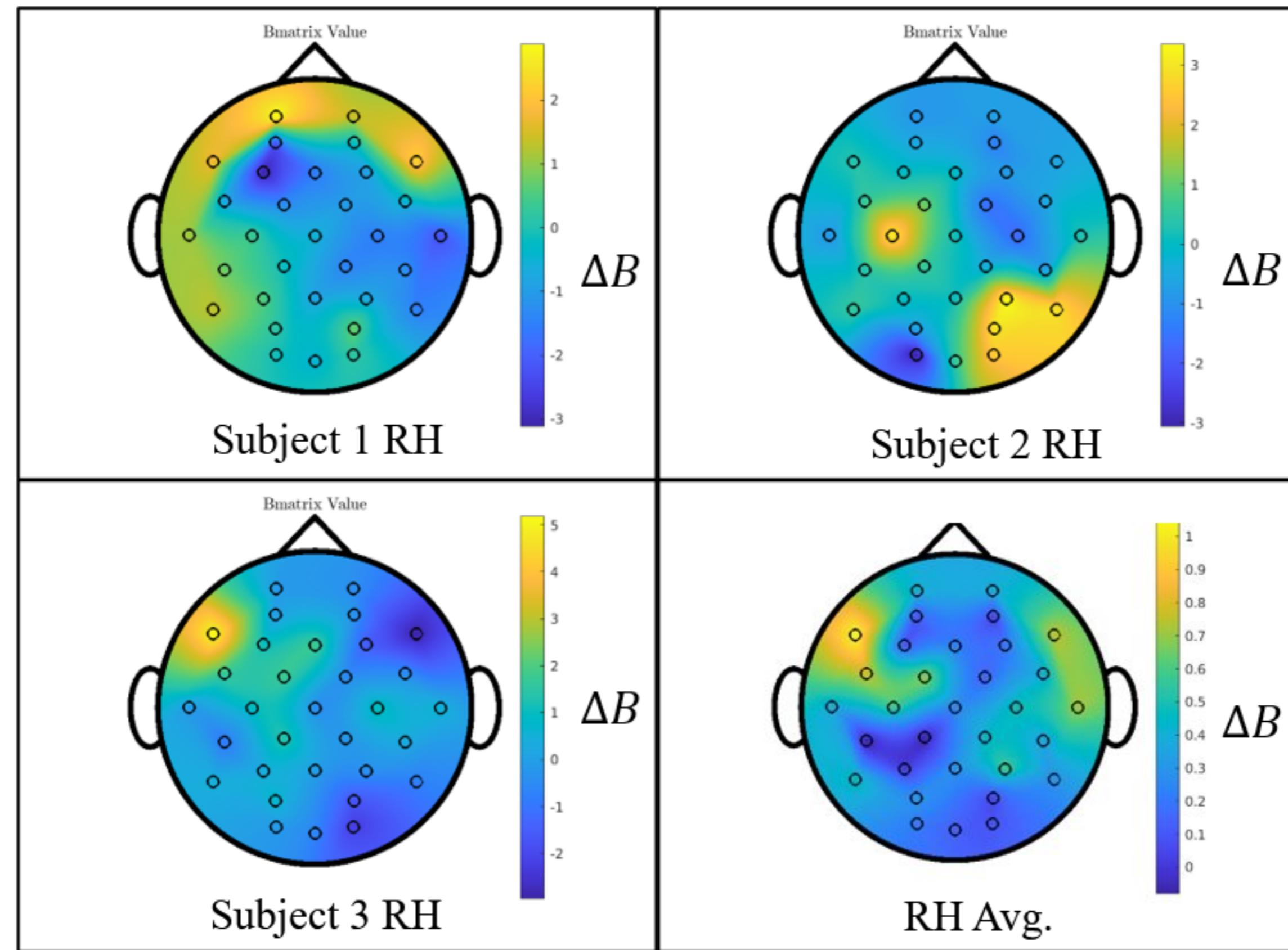
## 6. Application to Movement Data



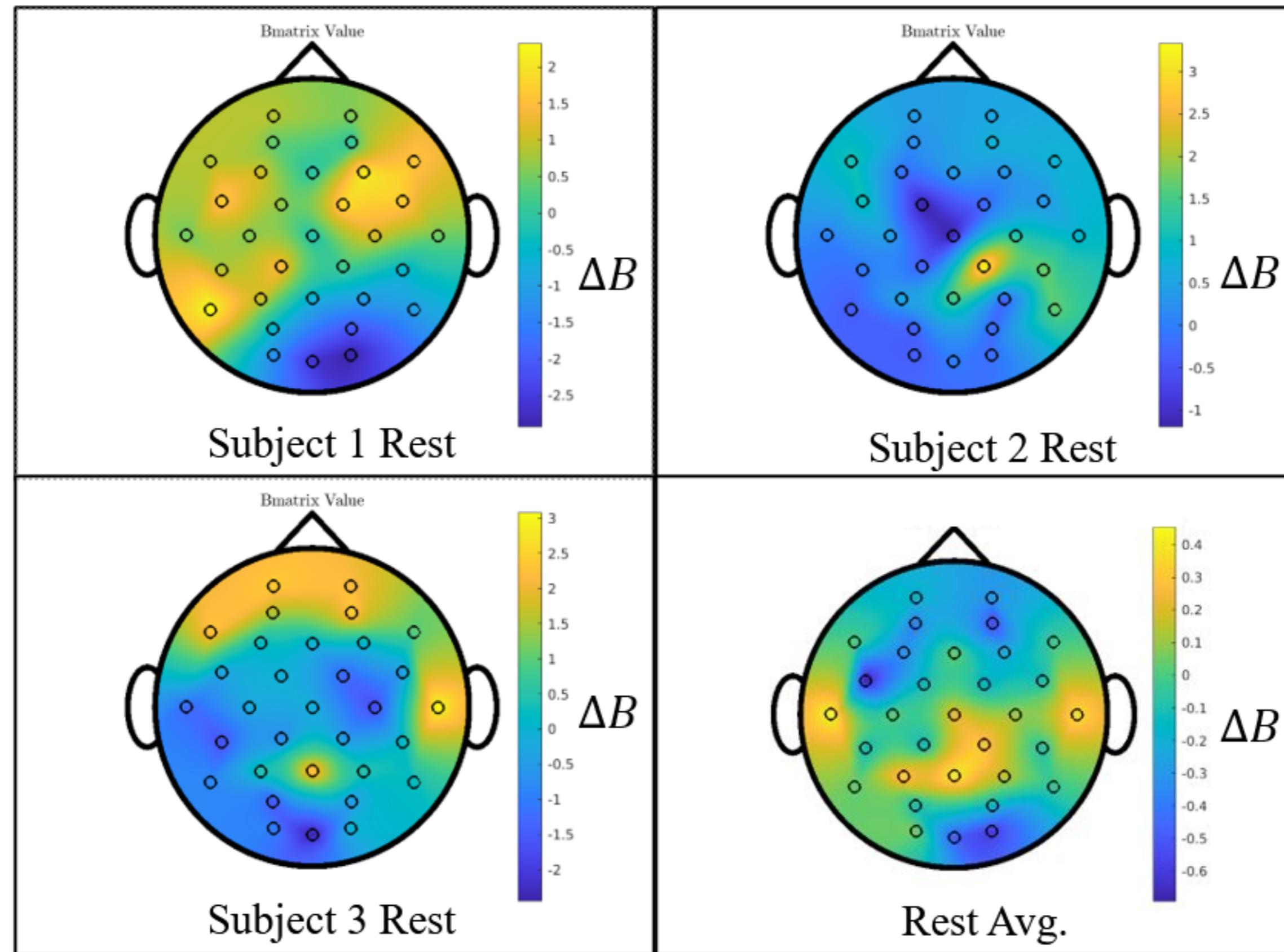
## B Matrix on EEG Data: Left Hand



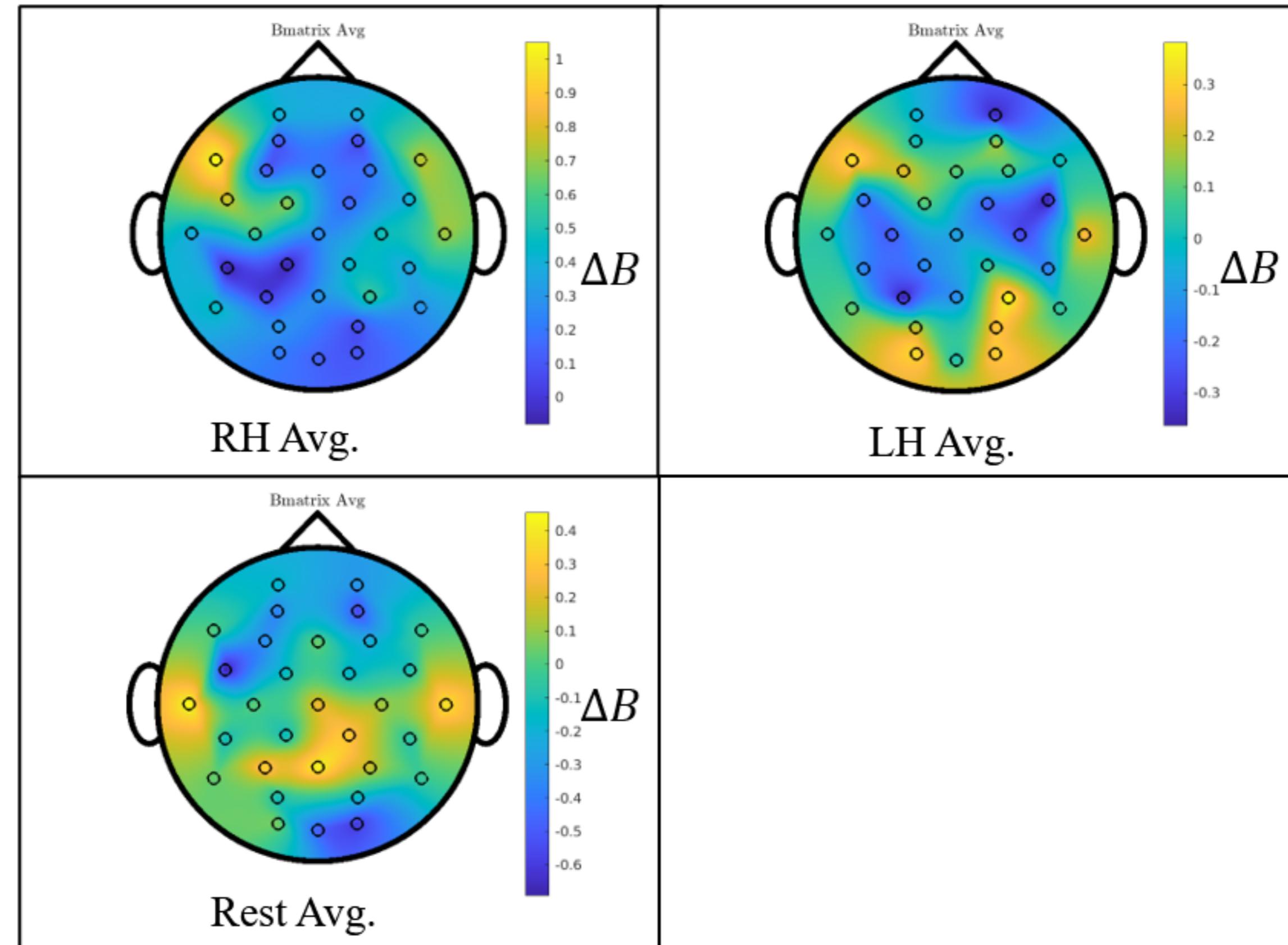
## B Matrix on EEG Data: Right Hand



## B Matrix on EEG Data: Resting



## B Matrix on EEG Data: All Averages



## A unique solution?

- B matrix is different for everyone
  - A math construct or physical significance?
- A unique input?

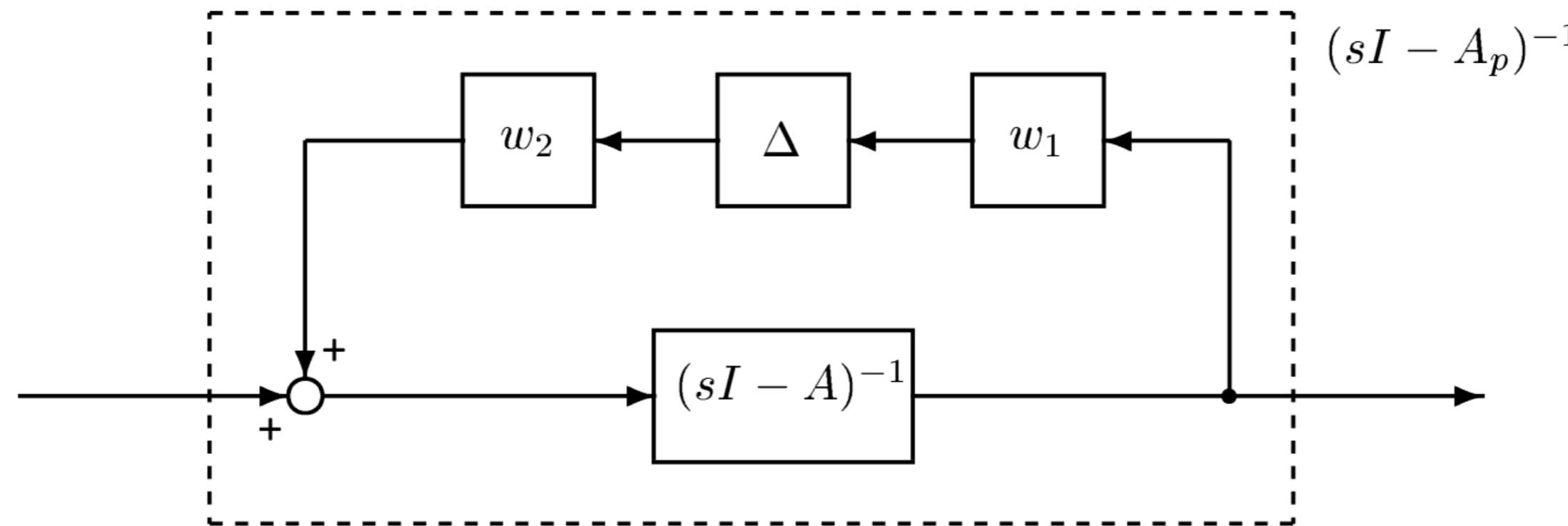
## 7. Perturbations (V.)

## Systems with unmodeled dynamics

- $\dot{x} = A_m x + B_m u$
- $y = C_m x$
- b.c. of uncertainty in real parameters:
  - $A_m = A + \sum \delta_i A_i$
  - $B_m = B + \sum \delta_i B_i$
  - $C_m = C + \sum \delta_i C_i$

## Collect the uncertainty

- $A_m = A + \sum \delta_i A_i = A + W_2 \Delta W_1$



## Simple Example

- $A = \begin{bmatrix} -3 & -2 \\ 7 & -1 \end{bmatrix}$

- Parametric uncertainty in 2 degrees:

- $A_1 = \begin{bmatrix} -w_1 & w_1 \\ w_1 & -w_1 \end{bmatrix}$
- $A_2 = \begin{bmatrix} 0 & -w_2 \\ 2w_2 & 0 \end{bmatrix}$

- $A_m = A + \delta_1 \begin{bmatrix} -w_1 & w_1 \\ w_1 & -w_1 \end{bmatrix} + \delta_2 \begin{bmatrix} 0 & -w_2 \\ 2w_2 & 0 \end{bmatrix}$

- $A_m = A + \begin{bmatrix} -w_1 & 0 & -w_2 \\ w_1 & 2w_2 & 0 \end{bmatrix} \begin{bmatrix} \delta_1 & 0 & 0 \\ 0 & \delta_2 & 0 \\ 0 & 0 & \delta_2 \end{bmatrix} \begin{bmatrix} 1 & -1 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}$

# EEG Example