OBSERVING & EVALUATING EDA AS A FUNCTIONAL PREDICTOR FOR INTELLECTUAL TRAITS

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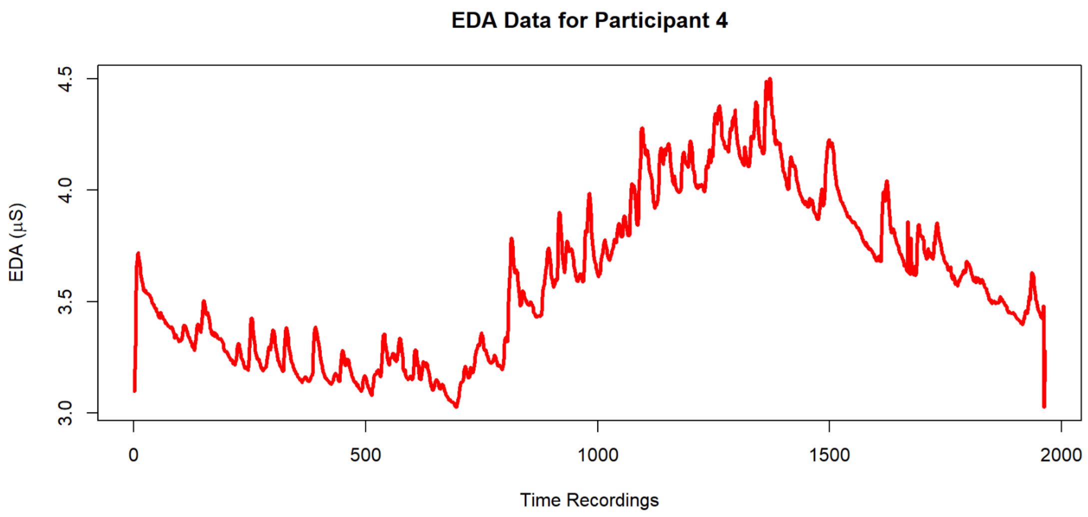
ELECTRODERMAL ACTIVITY (EDA)

- Slight changes in the electrical conductivity of a person's skin due to orienting response (activation of the sympathetic nervous system)
- Skin conductivity increases as sweat glands produce more sweat
- Changes are monitored by passing a small current through the skin and measuring the resistance (collected using a wearable device on the wrist)



time	EDA
1	3.098233
2	3.197894
3	3.302628
4	3.434590
5	3.552590
6	3.660955
7	3.683101
8	3.713844
9	3.720248
10	3.705198
11	3.688225
12	3.674455
13	3.656842
14	3.643712
15	3.620975

OBJECTIVES

- Continue to assess the use of EDA as a proxy for engagement
- Investigate EDA as a predictor for professed intellectual traits

WHAT DO YOU THINK?

Consider the sequence:

2, 4, 6




STUDY DESIGN

Initial Survey: *Provides measure of a participant's traits*

Activity 1: *Identify the Number Sequence*

Activity 2: *Word Association*

Activity 3: *Rubik's Cube (Right Hand Algorithm)*

Post Survey

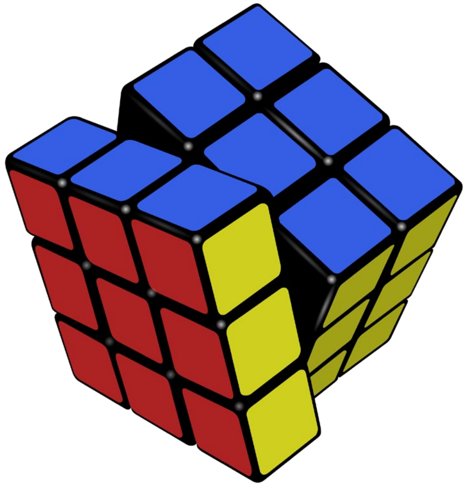
1 min meditation

Reflection questions

BREAD

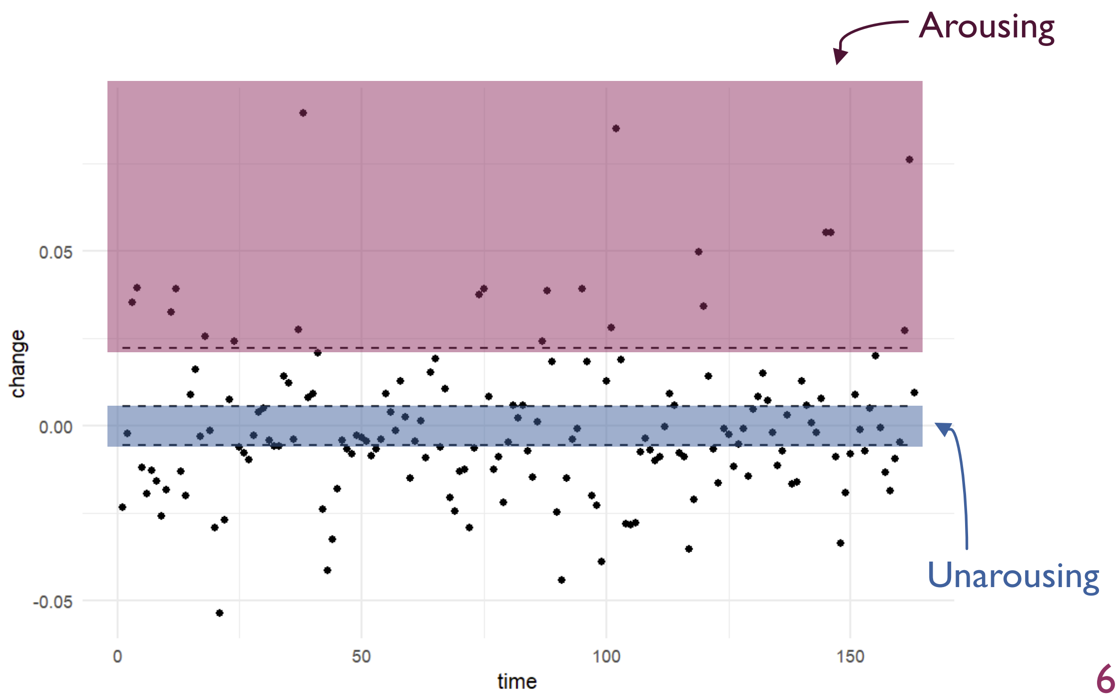
STICK
WINNER
BASKET

- EDA measured during each activity
- Video recorded the participant's behaviors



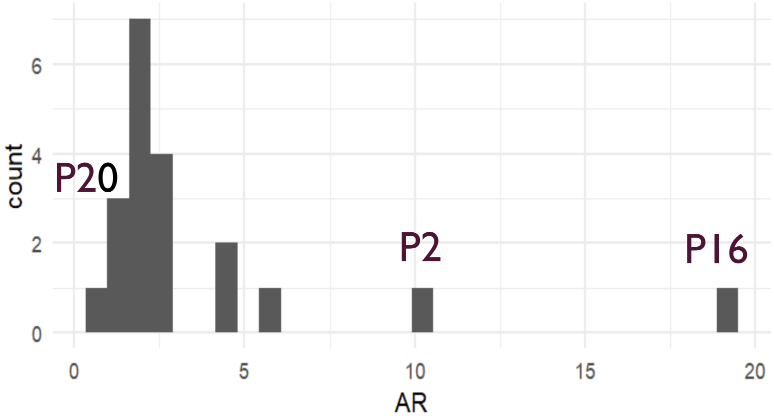
EDA & ENGAGEMENT

- EDA is generally regarded as a *trusted* proxy for measuring a subject's **engagement** in an activity
  - Orienting response → heightened sensitivity → increased intake and processing of information (Raskin, 1973)
  - *Arousal ratio (Cain and Lee, 2022):* $\frac{\text{\# of unarousing moments}}{\text{\# of arousing moments}}$
  - *Why use EDA?*
    - Determines specific times during the experiment in which the participant was seemingly engaged
    - Compare arousal ratios between subjects

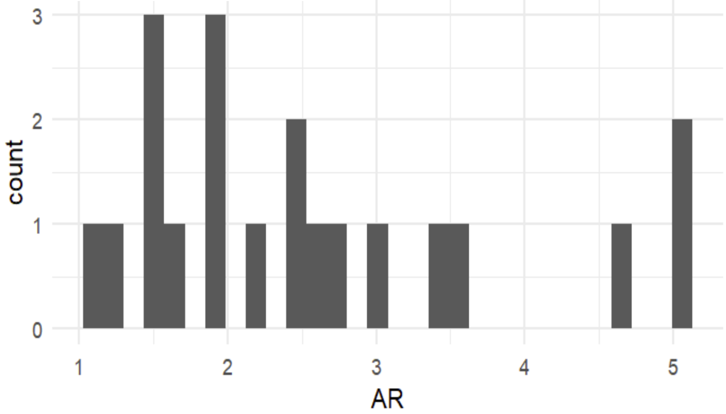


AROUSAL RATIOS

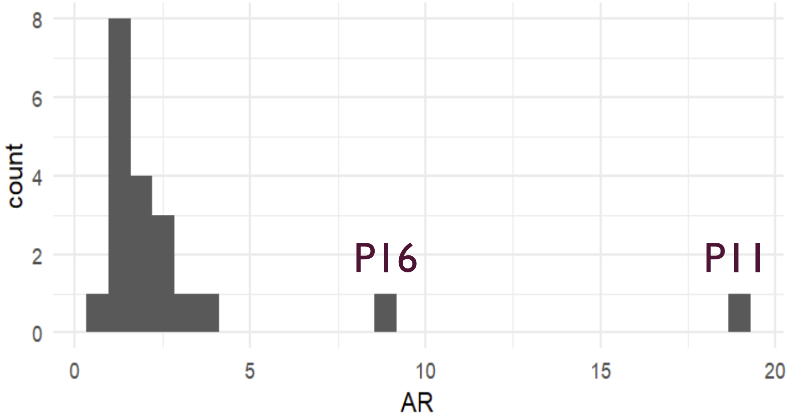
Number Sequence Activity



Word Association Activity



Rubik’s Cube Activity



EDA & PROFESSED INTELLECTUAL / ACADEMIC TRAITS

- Used EDA to approximate professed intellectual traits
  - Negative and positive affective states associated with academic tasks
    - **Test Anxiety (TA)**
    - **Mathematical Attitude - Valuation and Enjoyment (MA_v and MA_E)**
  - Cognitive process ability
    - **Intellectual humility (IH)**
    - **Need for Cognition (NC)**

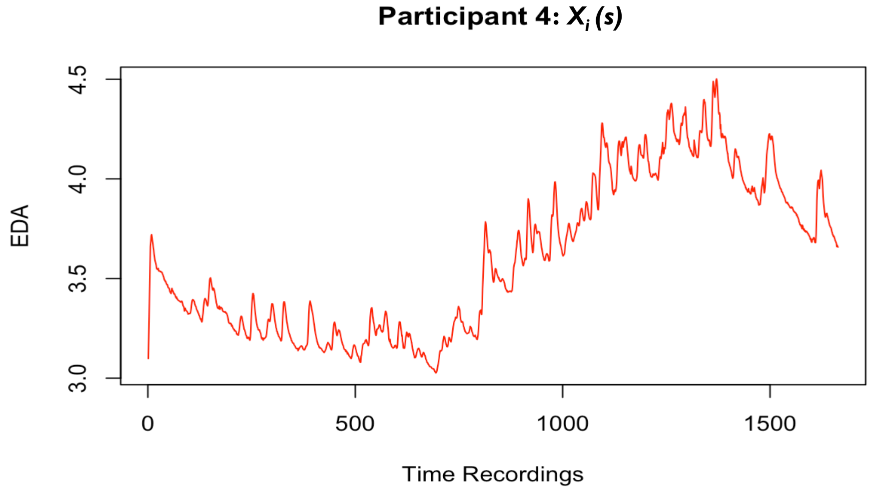
MODELING EDA

- **Functional Data Analysis (FDA):** analyzes data where *variables are functions* rather than a single scalar point

- **Scalar-on-Function Regression (SoFR):** predictor is a *function*

  - Simple Linear Regression model: $\boldsymbol{Y = \beta_0 + \beta_1 x + \varepsilon}$

  - *SoFR model:* $\boldsymbol{Y_i = \beta_0 + \int_S \beta_1(s) X_i(s)\, ds + \varepsilon_i}$

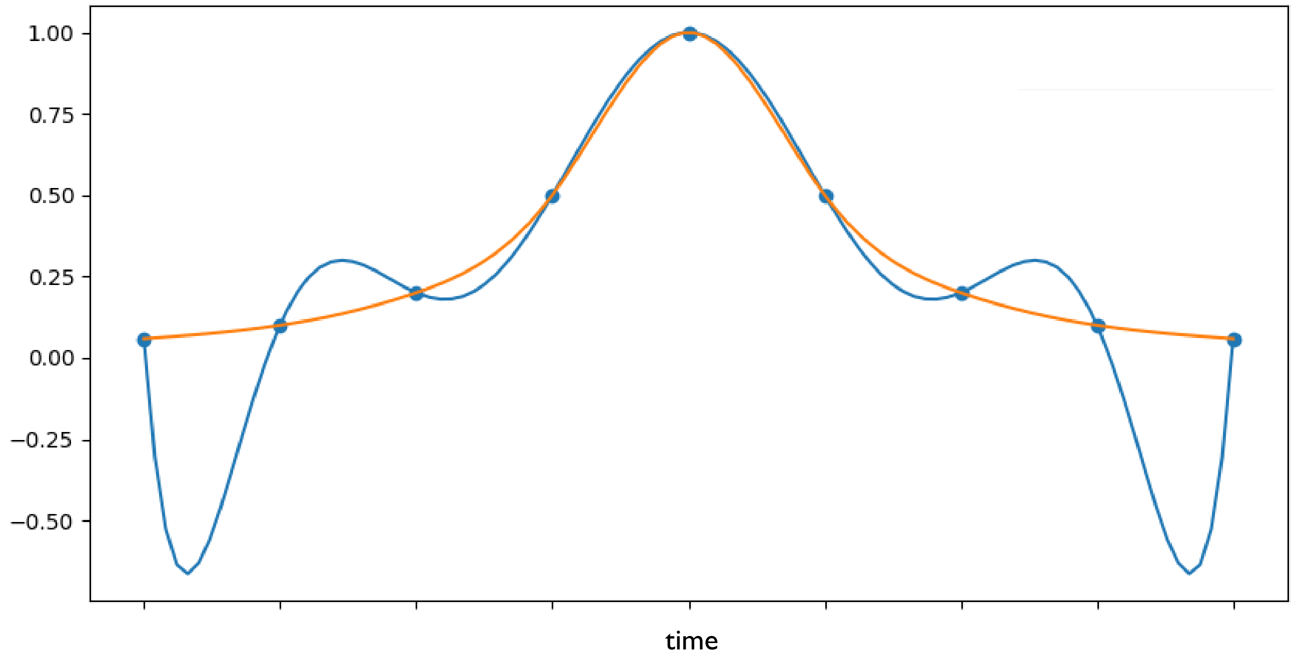


Example of an input function $X_i(s)$

- Models full temporal pattern of physiological arousal for all subjects instead of relying on summary statistics
- Can make connections between surprising behavior in the data and video evidence
- Integral term gives the overall contribution of EDA for each specific intellectual trait

BASIS EXPANSION

- Estimate the coefficient function using a *basis expansion:* $\boldsymbol{\beta_1(s) = \sum_{k=1}^{K} \beta_{1k} B_k(s)}$
  - Since $\boldsymbol{\beta_1(s)}$ is an unknown continuous function (infinitely-dimensional), we approximate it as a *finite* linear combination of known *cubic* polynomial basis functions $\boldsymbol{B_k(s) = [1, s, s^2, s^3]}$



- **Binning**: prepares the functional data for modeling by discretizing $X_i(s)$, reducing dimensionality and noise
- **Splining**: improves flexibility and smoothness of the binned data by approximating intervals of $\beta_1(s)$

OBTAINING $\beta_1(s)$

1. Plug basis equation into original equation for simplification

$$E[Y_i] = \boldsymbol{\beta}_0 + \int_S \sum_K \boldsymbol{\beta}_{1k}(\boldsymbol{B}(\boldsymbol{s}))\boldsymbol{X}_i(\boldsymbol{s})\boldsymbol{ds} = \boldsymbol{\beta}_0 + \sum_K \boldsymbol{\beta}_{1k} \underbrace{\left[\int_S \boldsymbol{B}_k(\boldsymbol{s})\boldsymbol{X}_i(\boldsymbol{s})\boldsymbol{ds}\right]}_{C_{ik}} = \boldsymbol{\beta}_0 + \boldsymbol{C}_{ik}\boldsymbol{\beta}_{1k}$$

2. Create a final model in matrix form, ***E[Y] = Zβ***, and use *ordinary least squares* (Arg $\min_{\beta}\|\boldsymbol{Y} - \boldsymbol{Z\beta}\|^2$) to estimate the best-fitting regression

$$\underbrace{\begin{bmatrix} y_1 \\ \vdots \\ y_{20} \end{bmatrix}}_{\boldsymbol{Y}} = \underbrace{\begin{bmatrix} 1 & C_{1,1} & C_{1,2} & \cdots & C_{1,4} \\ 1 & C_{2,1} & C_{2,2} & \cdots & C_{2,4} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & C_{20,1} & C_{20,2} & \cdots & C_{20,4} \end{bmatrix}}_{\boldsymbol{Z}} \times \underbrace{\begin{bmatrix} \beta_0 \\ \beta_{1,1} \\ \beta_{1,2} \\ \beta_{1,3} \\ \beta_{1,4} \end{bmatrix}}_{\boldsymbol{\beta}}$$

3. Use the extracted $\boldsymbol{\beta}$, plug back into basis expansion equation to get $\boldsymbol{\beta}_1(\boldsymbol{s})$

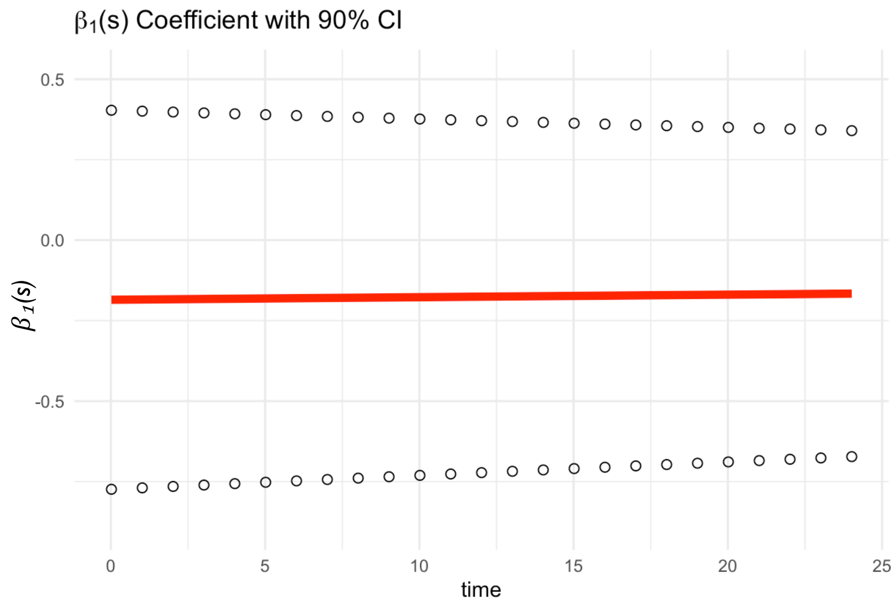
GRAPHING $\beta_1(S)$

Creating the Confidence Band

1. Calculate variance-covariance matrix of $\beta_1(s)$: $\boldsymbol{B(s)Var(\beta_1)B(s)^T}$

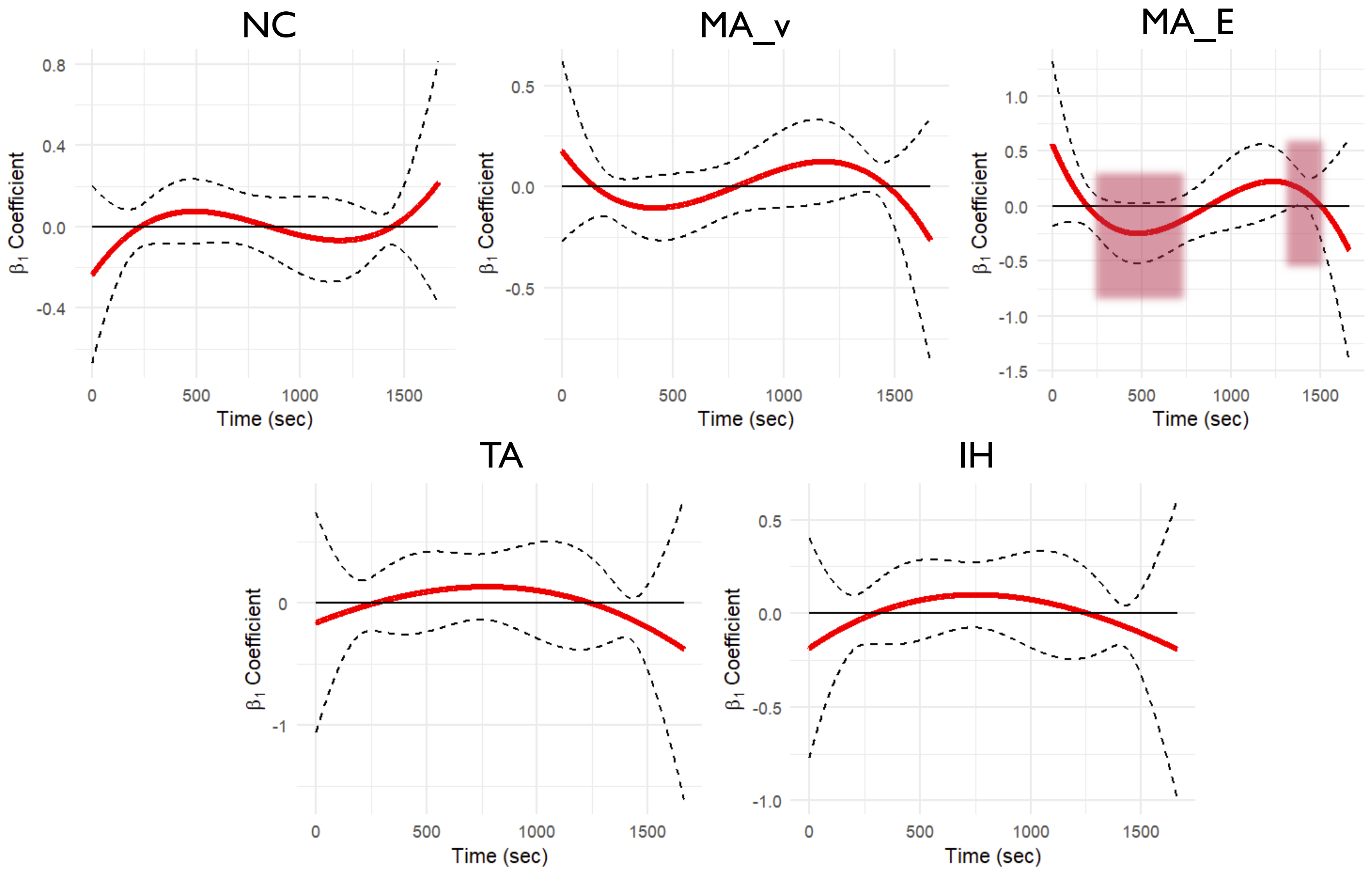
   - $\mathbf{Var}(\boldsymbol{\beta_1})$: variance-covariance of the basis coefficient vector (based on OLS)

$$\begin{bmatrix} \sigma^2_{1,1} & \text{cov}_{1,2} & \cdots & \text{cov}_{1,1664} \\ \text{cov}_{2,1} & \sigma^2_{2,2} & \cdots & \text{cov}_{2,1664} \\ \vdots & \vdots & \ddots & \vdots \\ \text{cov}_{1664,1} & \text{cov}_{1664,2} & \cdots & \sigma^2_{1664,1664} \end{bmatrix}$$

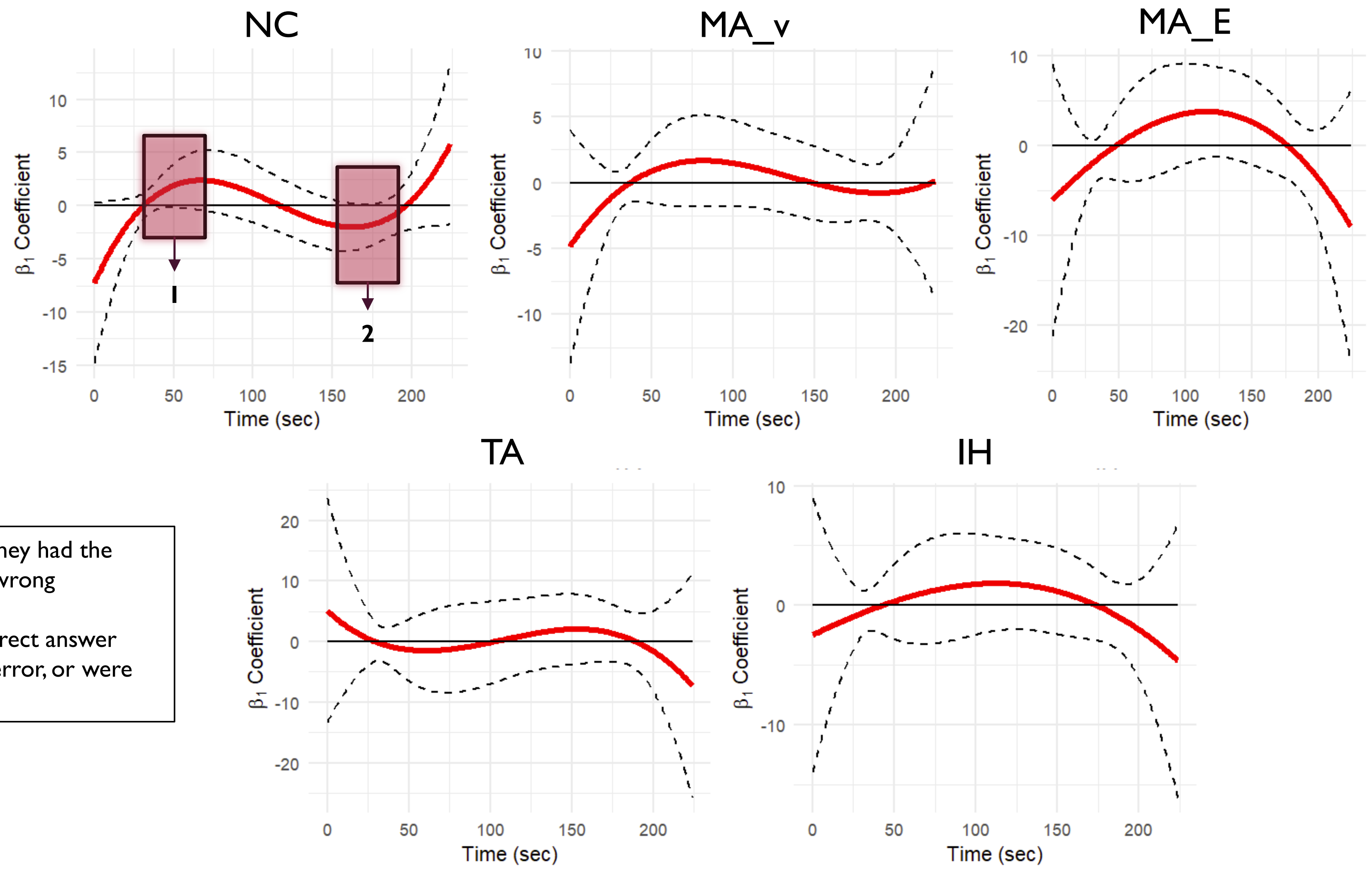


2. Use $\boldsymbol{\hat{\beta}_1(s) \pm Z_{\alpha/2} * \sqrt{Var(\beta_1(s))}}$ to get pointwise CI's

3[RD] DEGREE MODELS OF $\beta_1(s)$ FOR ALL ACTIVITIES (90% CI)

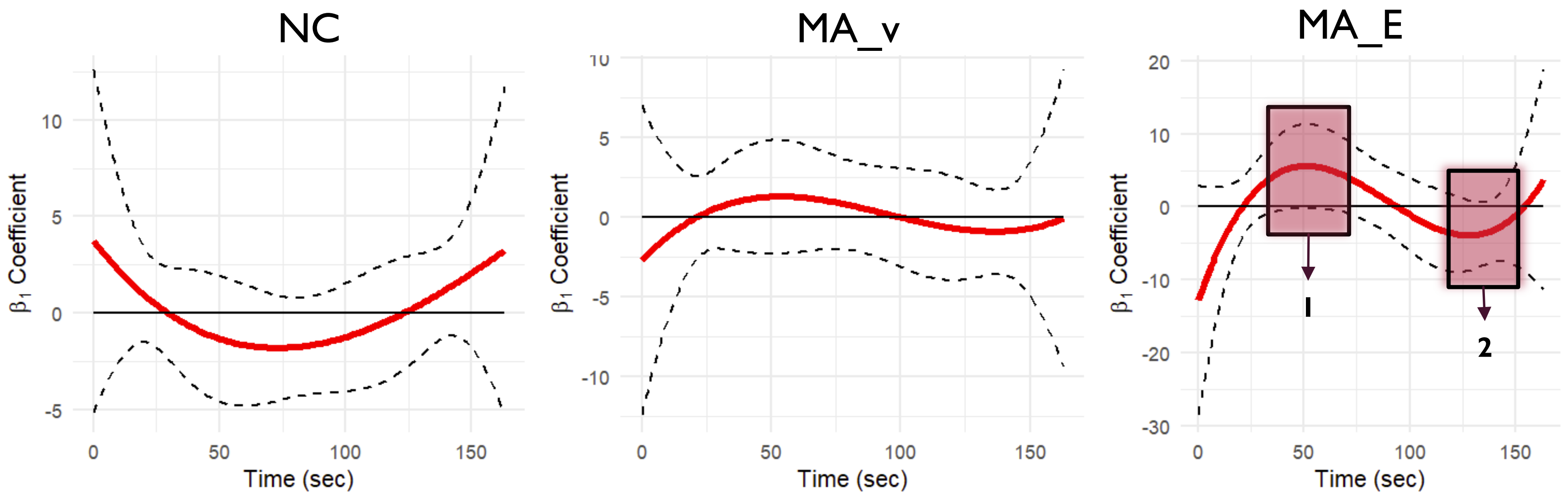


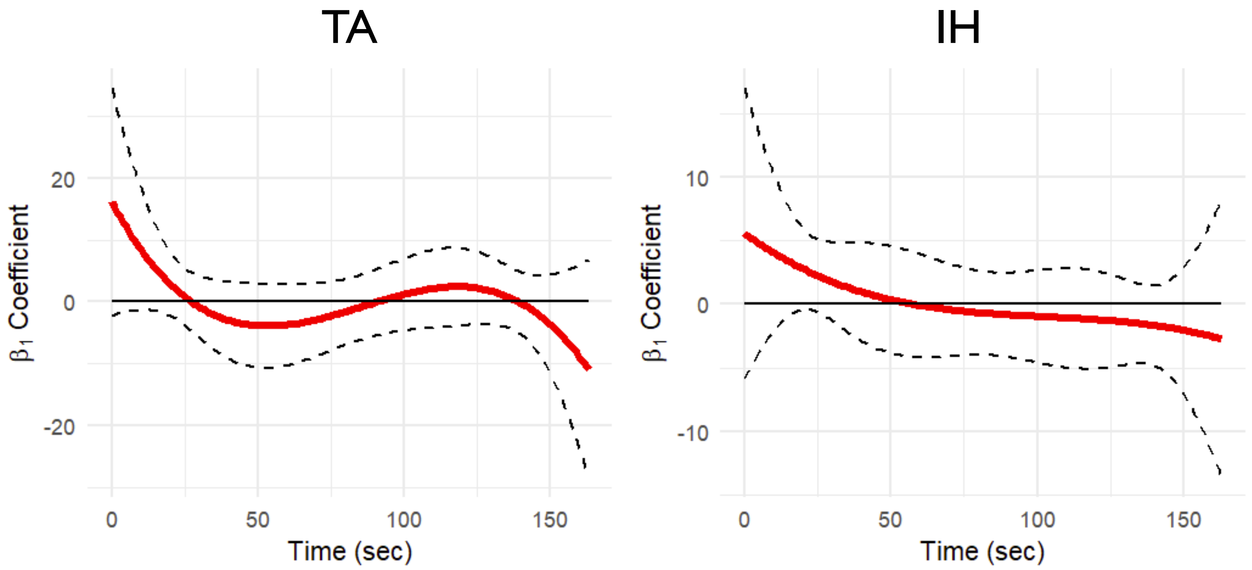
$\beta_1(s)$ FOR NUMBER SEQUENCE ACTIVITY (90% CI)



1. Quickly believed they had the answer, but were wrong
2. Either had the correct answer through trial and error, or were far from it

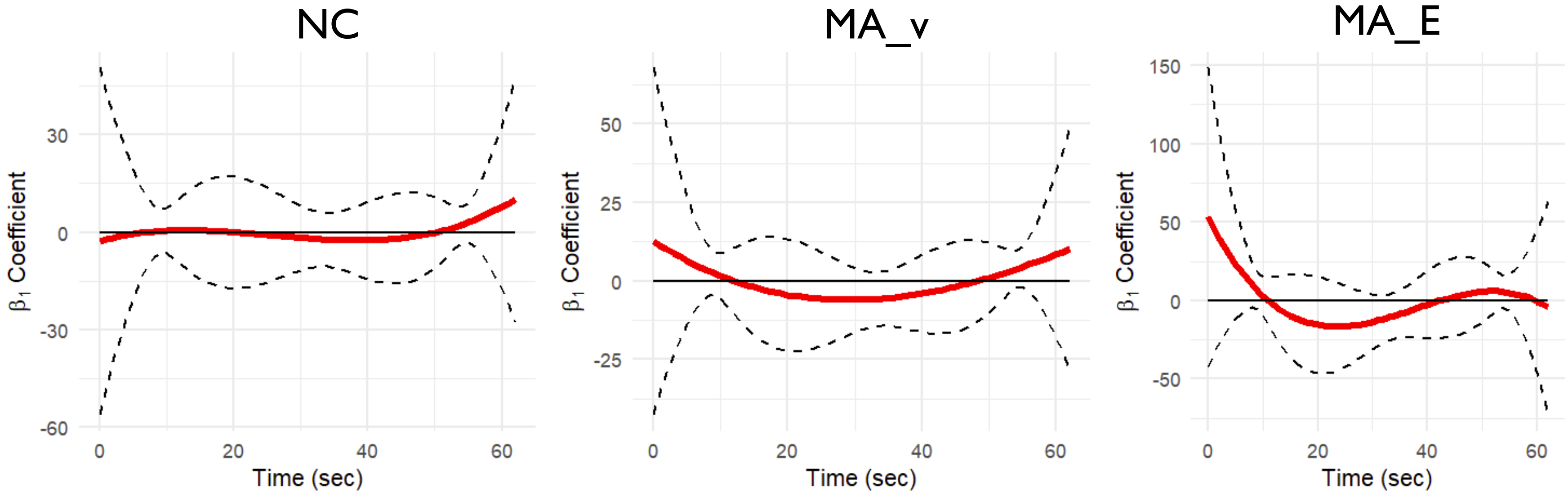
$\beta_1(s)$ FOR WORD ASSOCIATION ACTIVITY (90% CI)

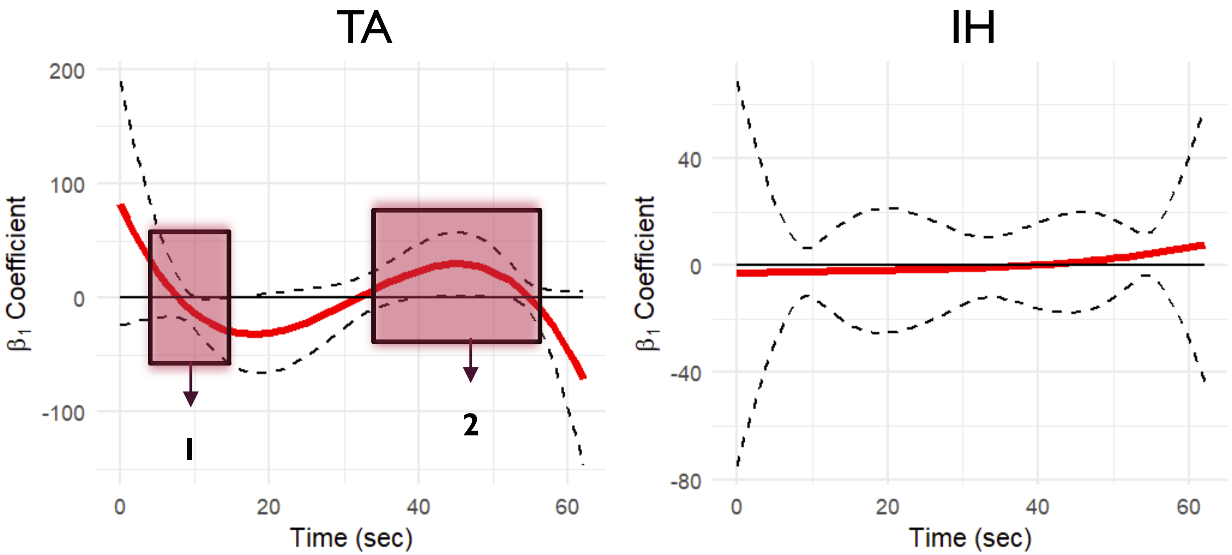




1. Either rolling through first several word problems, or struggling immediately
2. Thinking through unsolved word problems

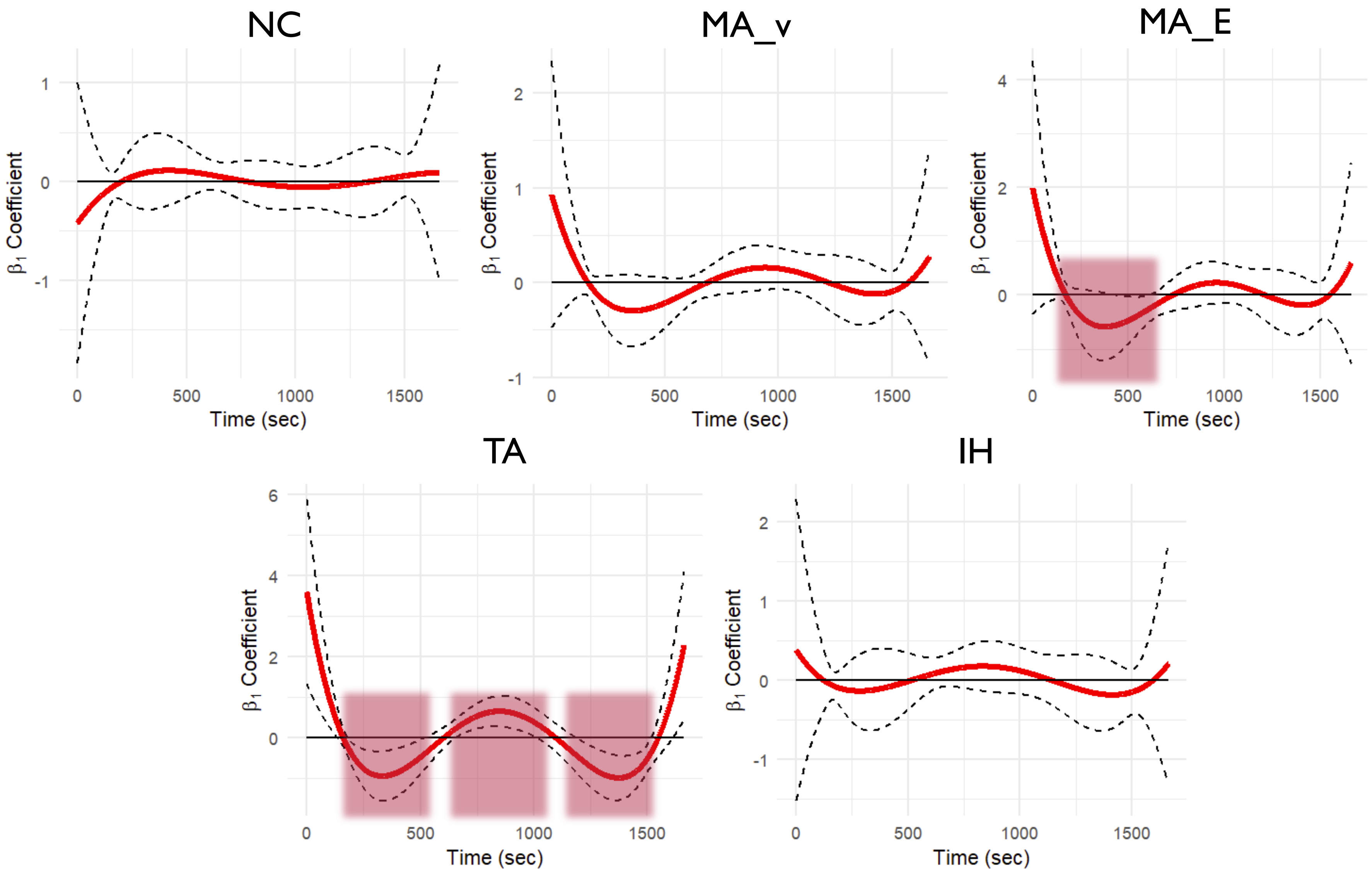
$\beta_1(s)$ FOR RUBIK'S CUBE ACTIVITY (90% CI)



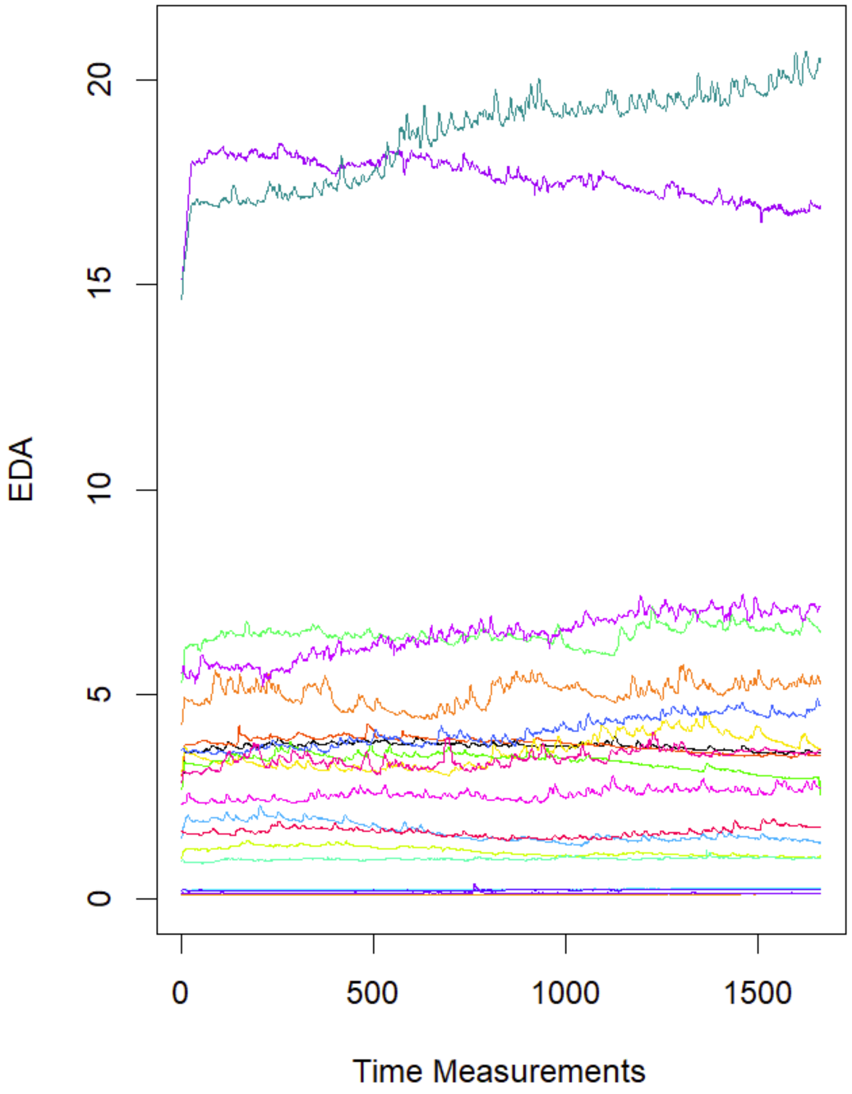


1. Making first moves
2. Either have figured out the algorithm or still struggling

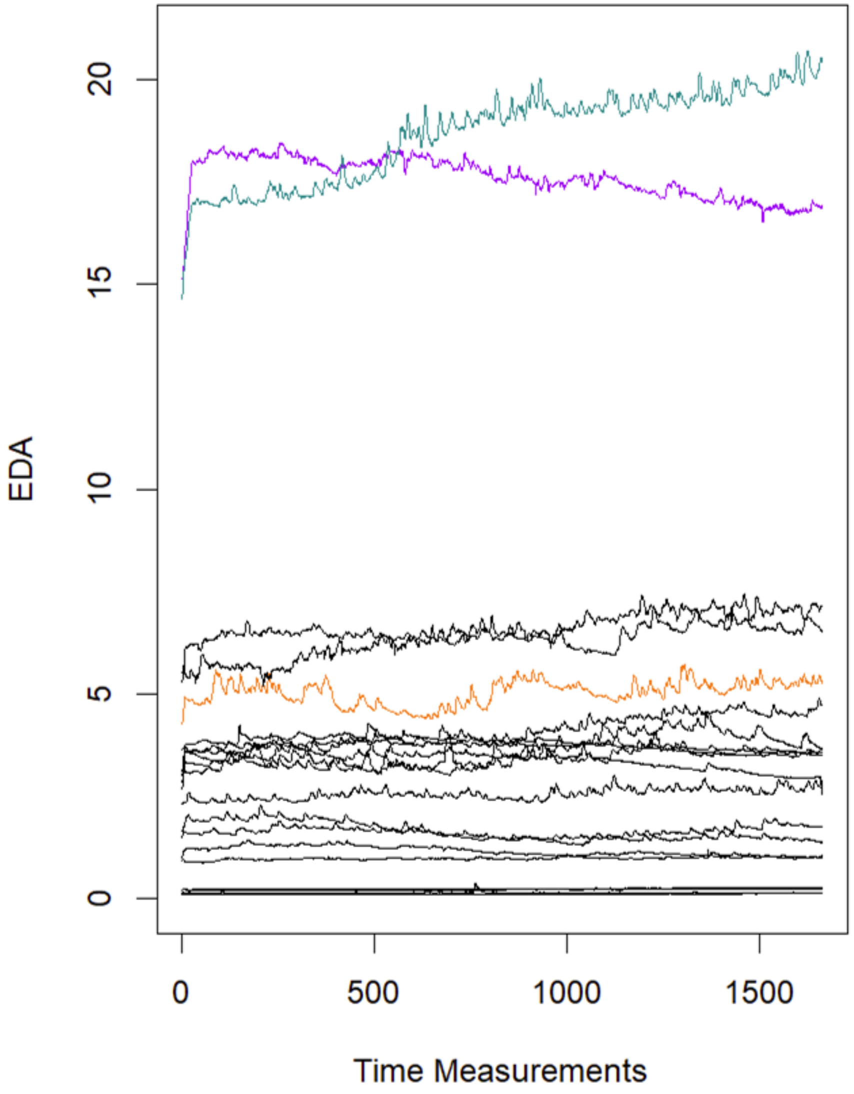
4^{TH} DEGREE MODELS OF $\beta_1(s)$ FOR ALL ACTIVITIES (90% CI)



$X_i(s)$

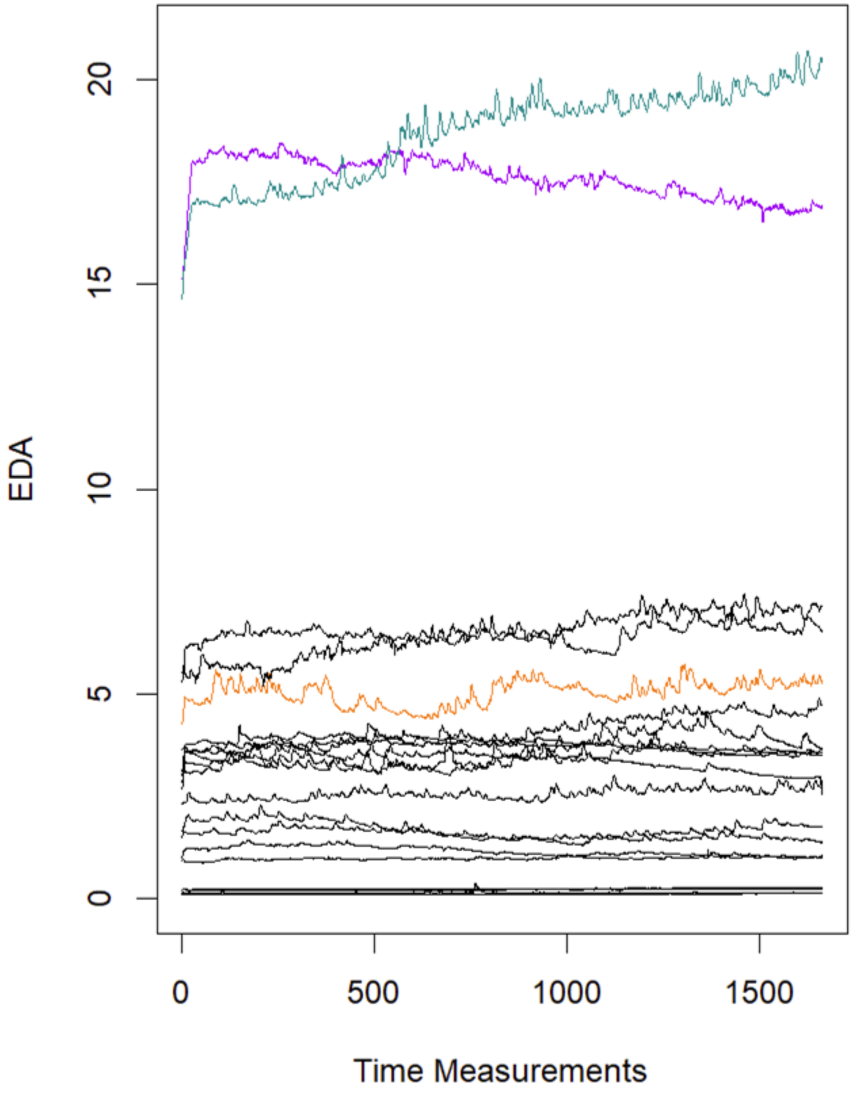


$X_i(s)$

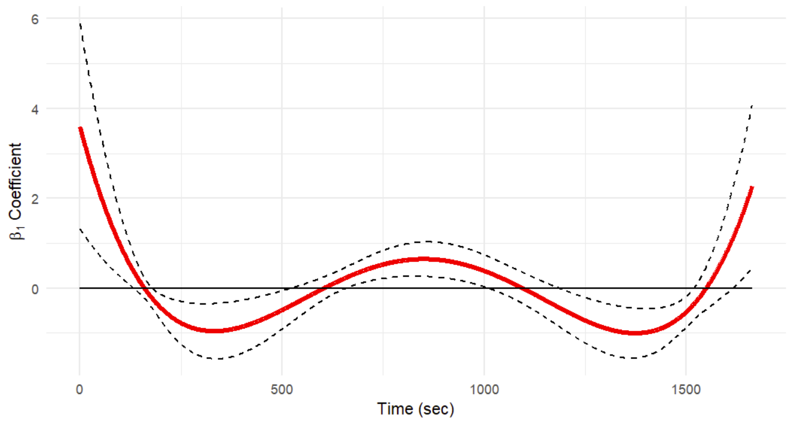


P14
P7
P6

$X_i(s)$

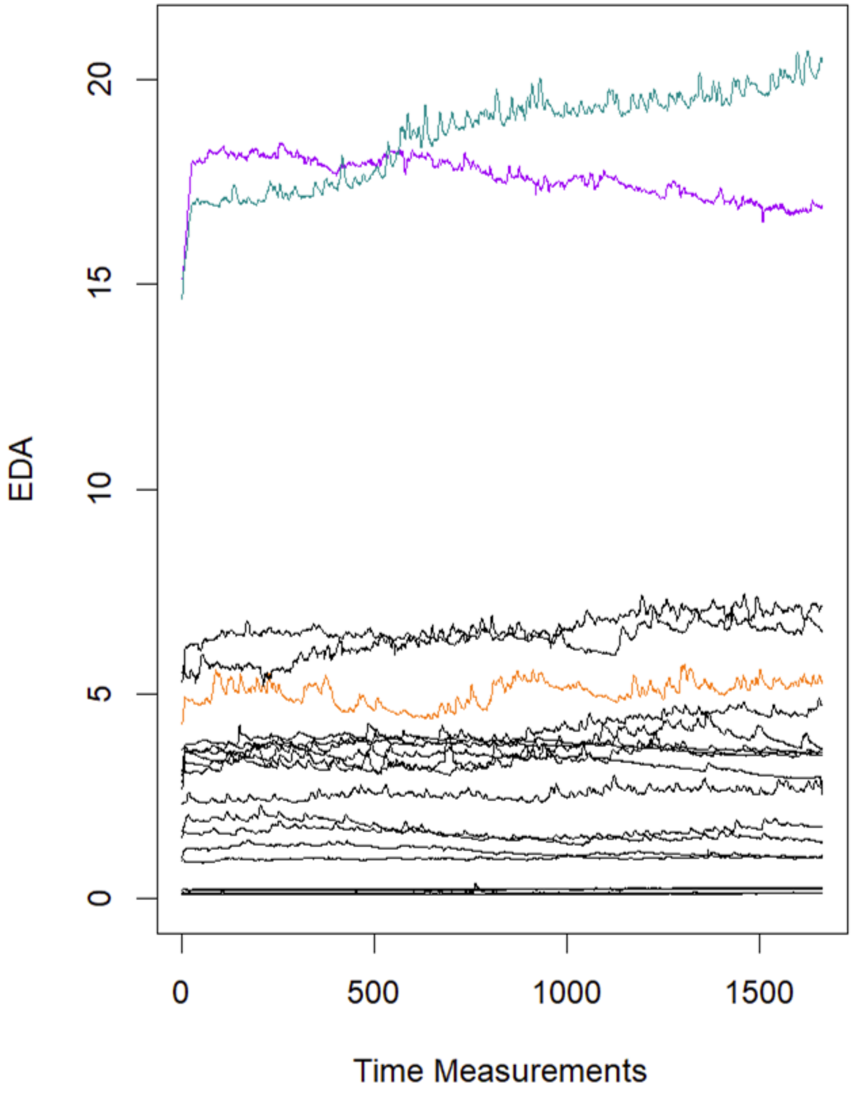


$\beta_1(s)$

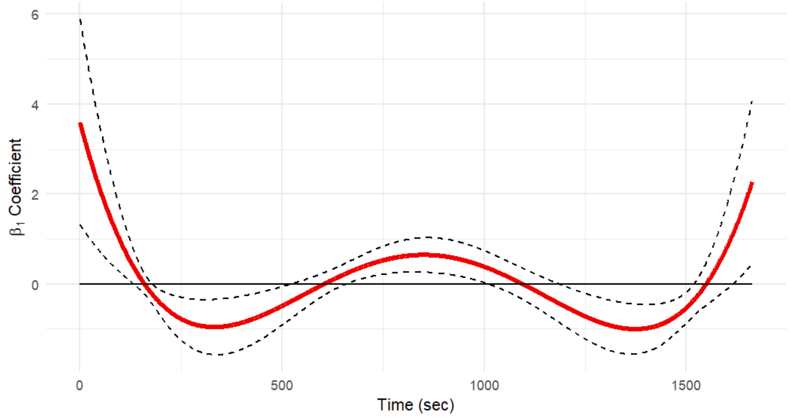


P14
P7
P6

$X_i(s)$



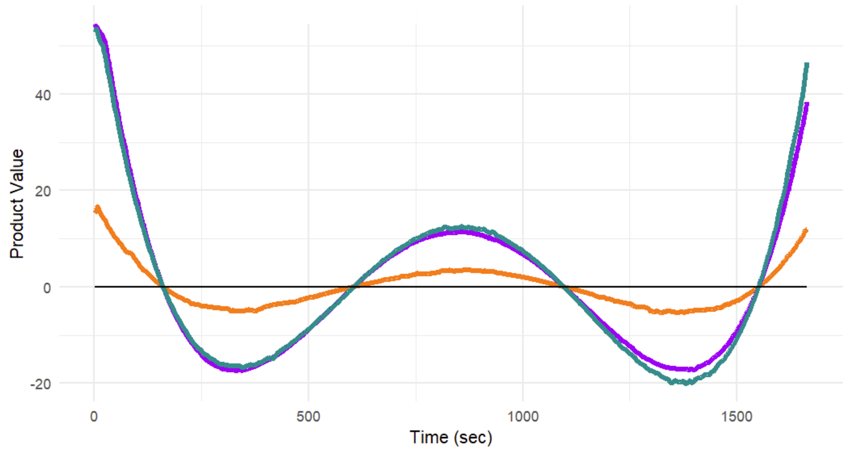
$\beta_1(s)$



$$\int_S \beta_1(s) X_i(s)\, ds$$

P14: -2.31745214
P7: -1.26100259
P6: -0.28121994

$\beta_1(s) * X_i(s)$



INFLUENCE OF EDA ON EACH OUTCOME VARIABLE

Third Degree Models:

	NC	MA_v	MA_E	TA	IH
All Activities	0.1416	0.0531	0.2212	-0.2910	0.0521
Activity 1	0.1289	0.1495	0.6068	-0.0597	0.4507
Activity 2	-0.1154	0.1591	0.5003	-0.4756	0.0424
Activity 3	-0.1130	-0.7689	-1.5574	-0.8488	-0.0458

Fourth Degree Models:

	NC	MA_v	MA_E	TA	IH
All Activities	0.1735	-0.07916	-0.0297	-0.9505	0.0534
Activity 1	-0.1421	-0.4622	0.0653	-0.6677	1.1958
Activity 2	-2.4397	-0.6844	0.5167	2.1038	-0.6372
Activity 3	-0.7945	-0.0952	-4.3513	-2.4603	-0.5532

CONCLUSIONS

- The Relationship between EDA and two variables showed promise, which is encouraging for further study
  - Test anxiety (TA)
  - Enjoyment of math (MA_E)
- Results were not as promising for some traits previously thought to be important
  - Intellectual Humility (IH)
- There is reason to believe that EDA data can be used as a proxy to measure affective engagement

FUTURE WORK

- Analysis of larger samples
- Further exploration of the arousal ratio as a metric
- Analyze why EDA is a better predictor for the more encouraging outcome variables
- Attempt Function-on-scalar Regression
- Additional predictors/Random effect model

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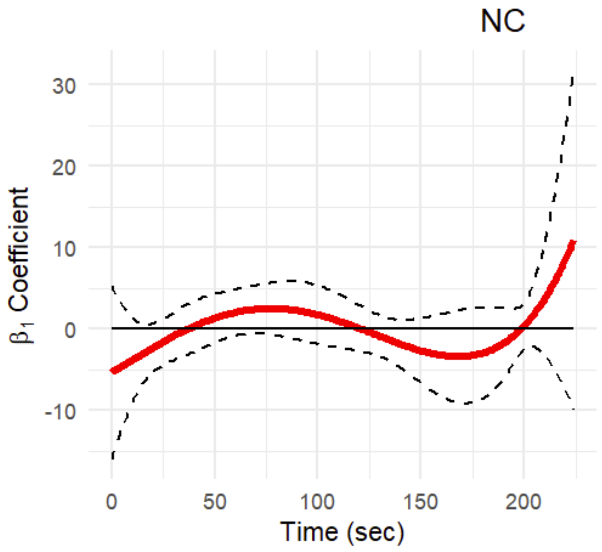
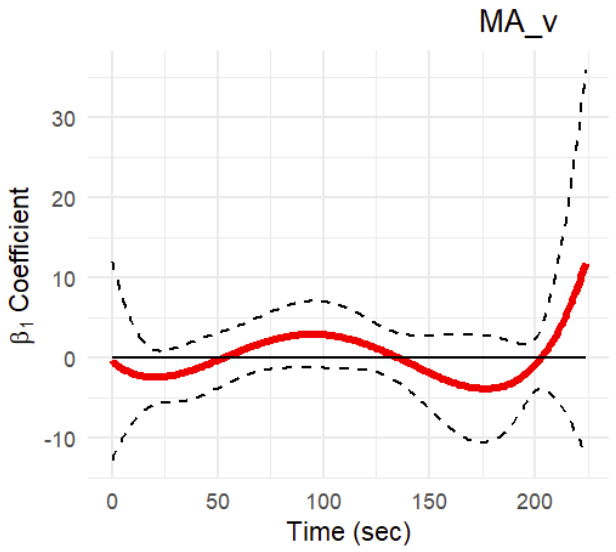
IOWA

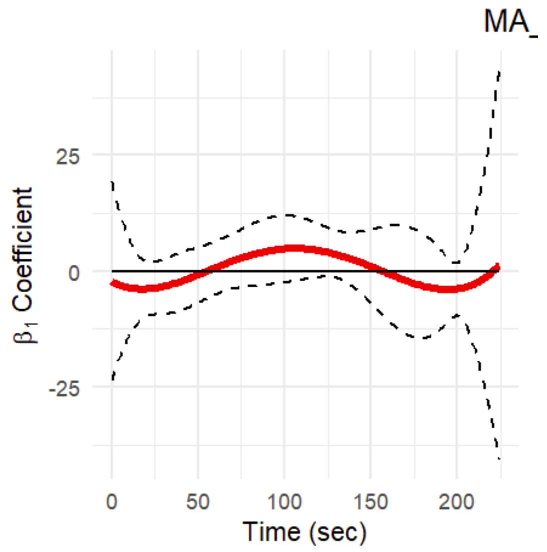
NIH National Heart, Lung, and Blood Institute

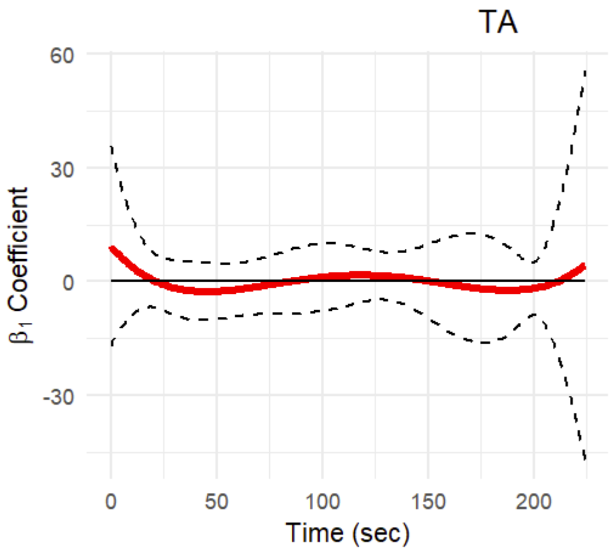
QUESTIONS?

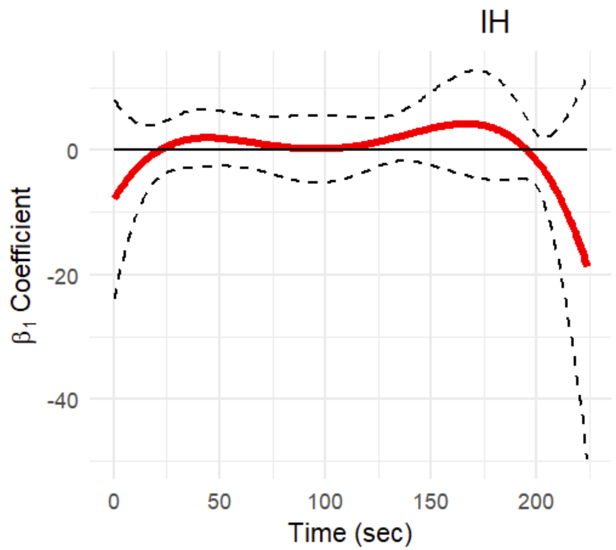
FOURTH DEGREE MODELS OF $\beta_1(s)$ FOR ACTIVITY 1 WITH 90% CI



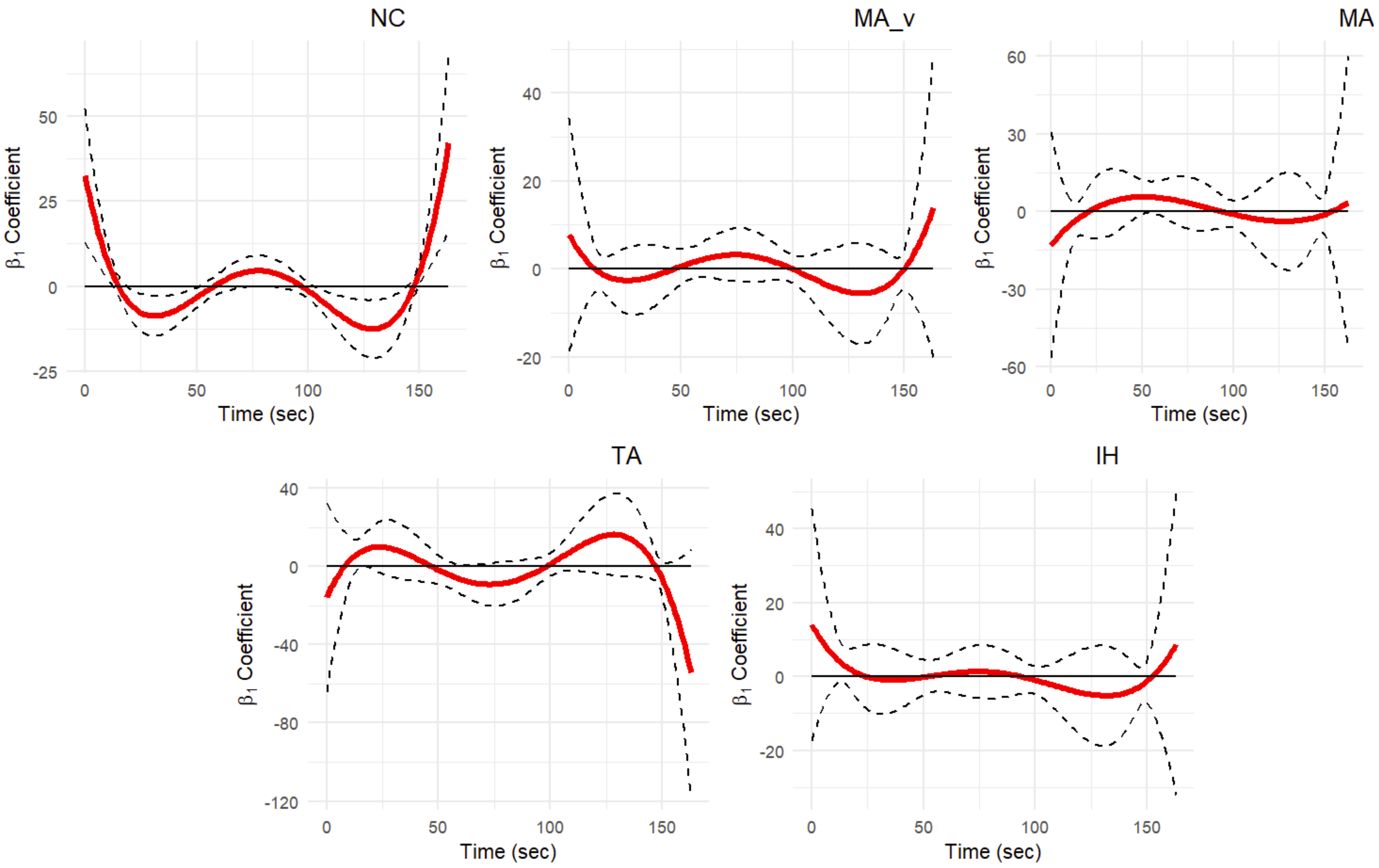




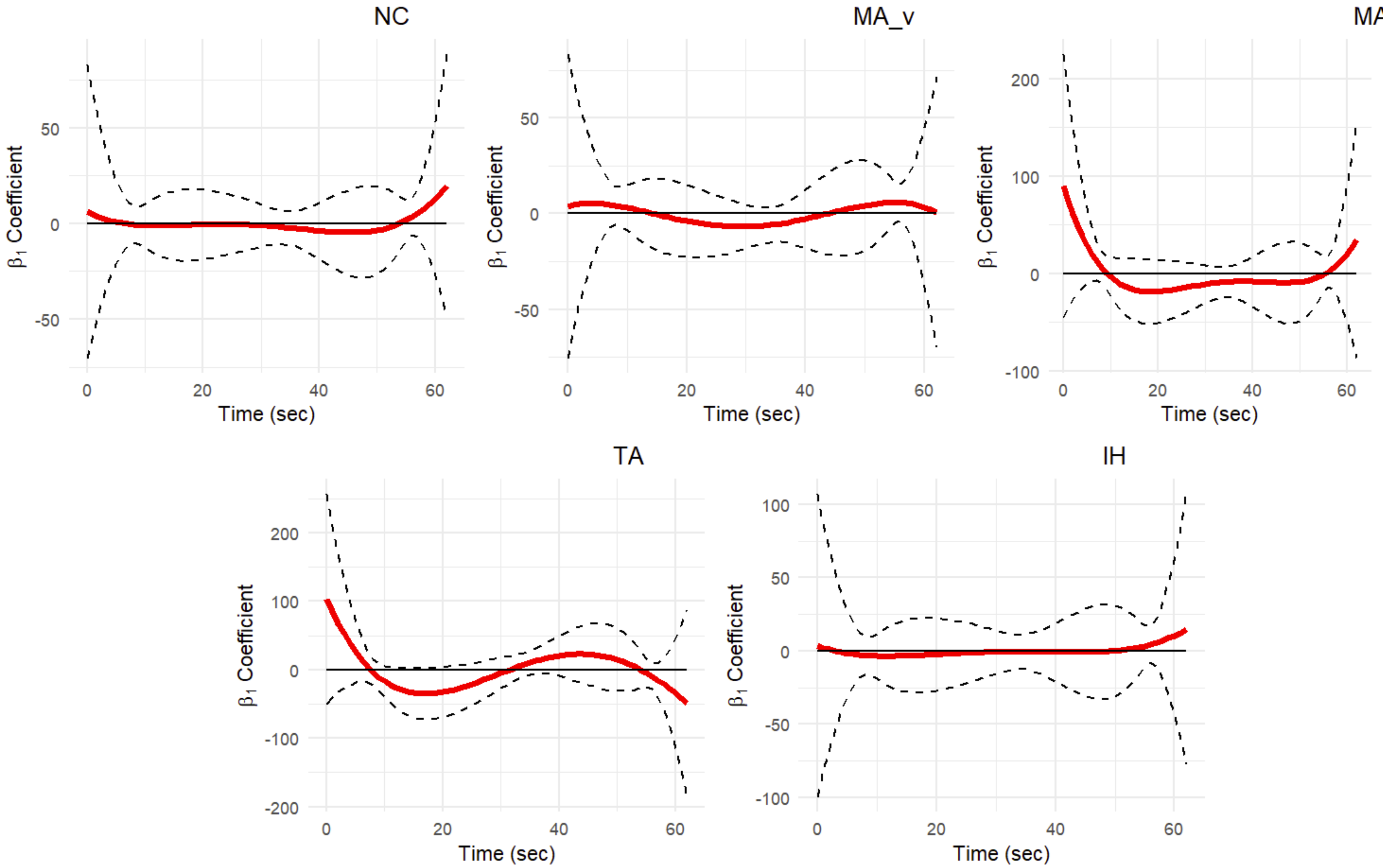




FOURTH DEGREE MODELS OF $\beta_1(s)$ FOR ACTIVITY 2 WITH 90% CI



FOURTH DEGREE MODELS OF $\beta_1(s)$ FOR ACTIVITY 3 WITH 90% CI



INFLUENCE OF EACH OV ON EDA

```
> int_av_table_clusters
     NC         MA_v       MA_E      TA         IH
all  0.1446911  0.1095379  0.5339742 -0.6788169 0.2027478
act1 0.4254922  0.3853355  0.8043042 -0.7700489 0.2057776
act2 0.05297876 0.3005304  0.7559087 -0.6379394 -0.3078745
act3 0.1489526  -0.2527585 -1.408443 -1.31372   -0.0869689
> int_av_table
     NC         MA_v       MA_E      TA          IH
all  0.1415942  0.05314017 0.2212419 -0.2910357  0.1520528
act1 0.1289155  0.1494517  0.6068284 -0.05971377 0.4506964
act2 -0.1153542 0.159079   0.5003212 -0.4756384  0.04244399
act3 -0.1130072 -0.7689471 -1.557352 -0.8488349  -0.04583517
> |
```