

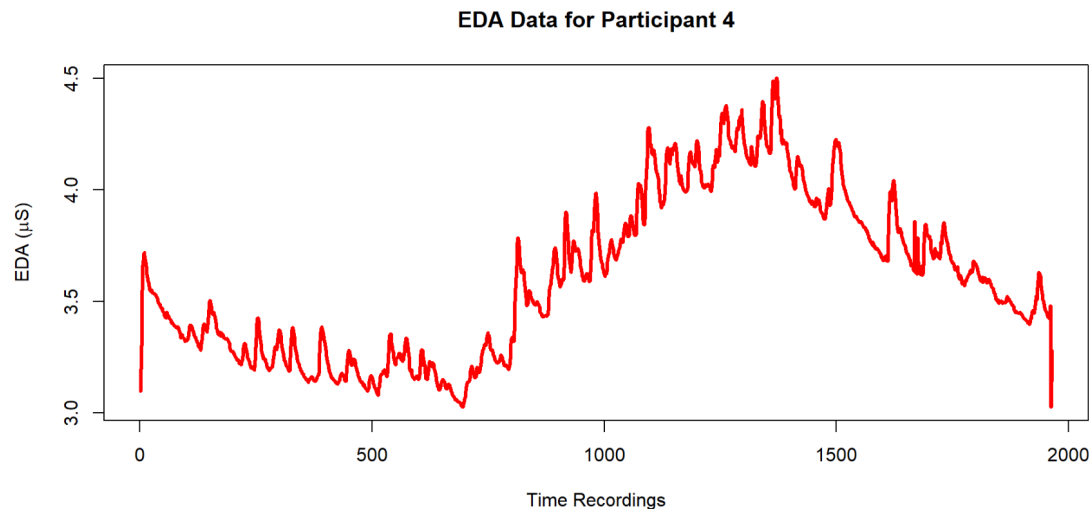
OBSERVING & EVALUATING EDA AS A FUNCTIONAL PREDICTOR FOR INTELLECTUAL TRAITS

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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

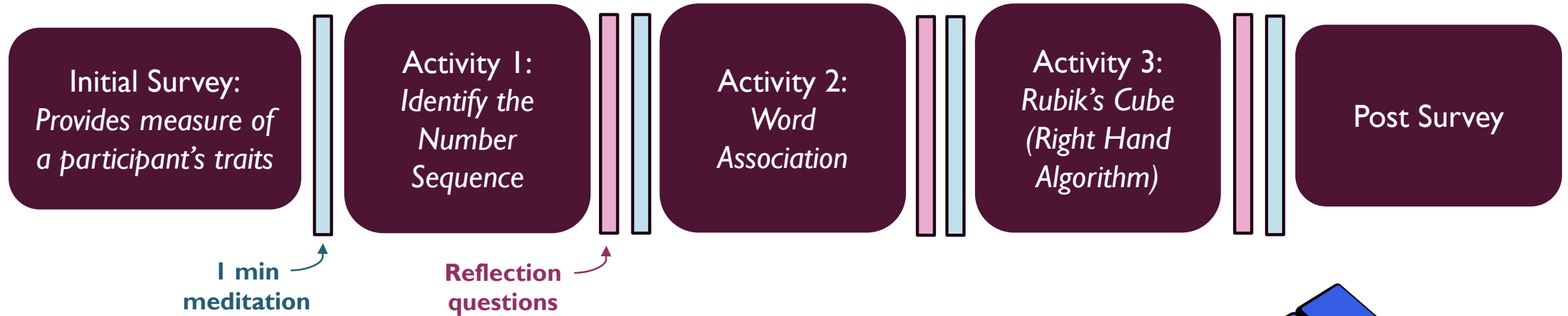
WHAT DO YOU THINK?

Consider the sequence:

2, 4, 6



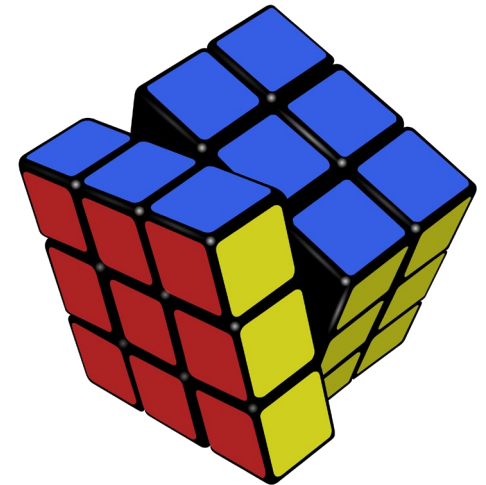
STUDY DESIGN



BREAD

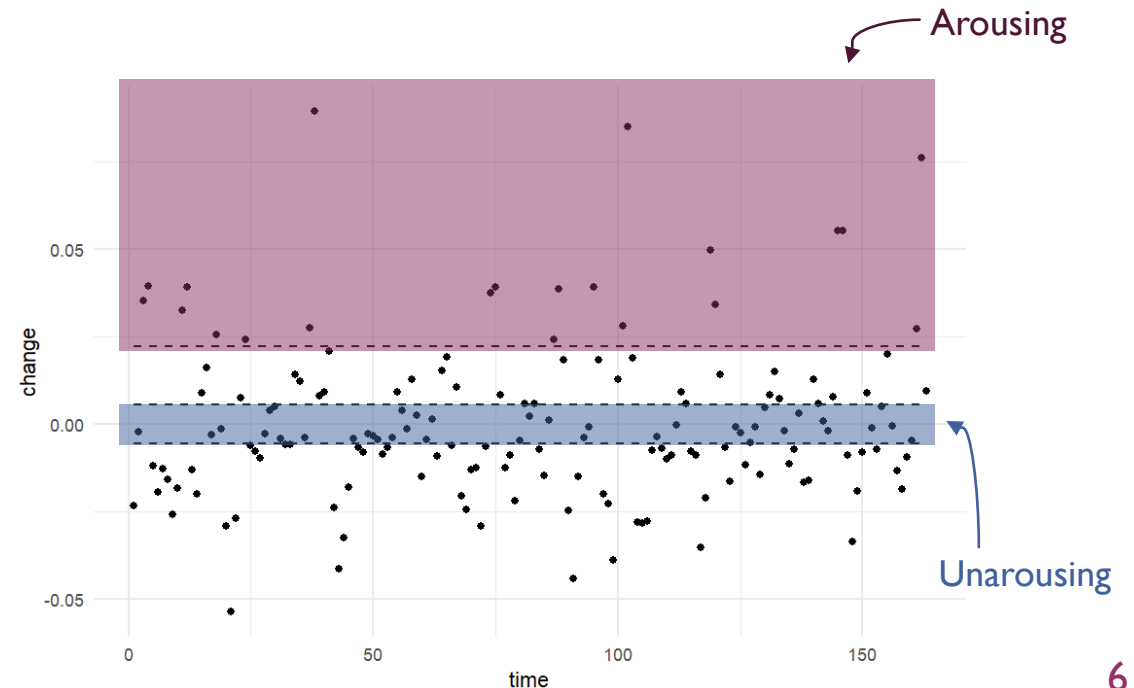
STICK
WINNER
BASKET

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



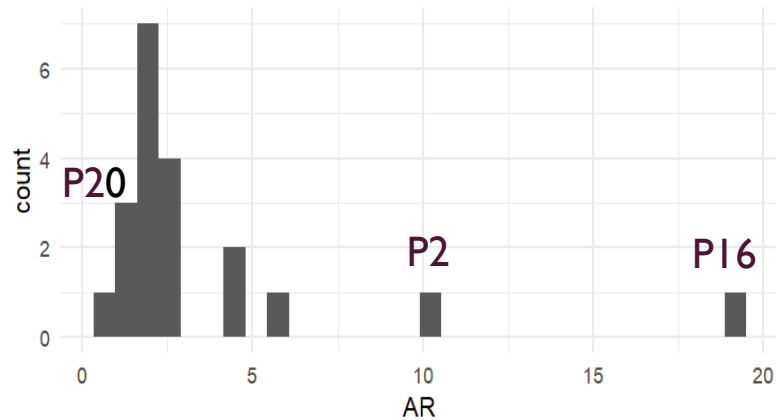
EDA & ENGAGEMENT

- 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

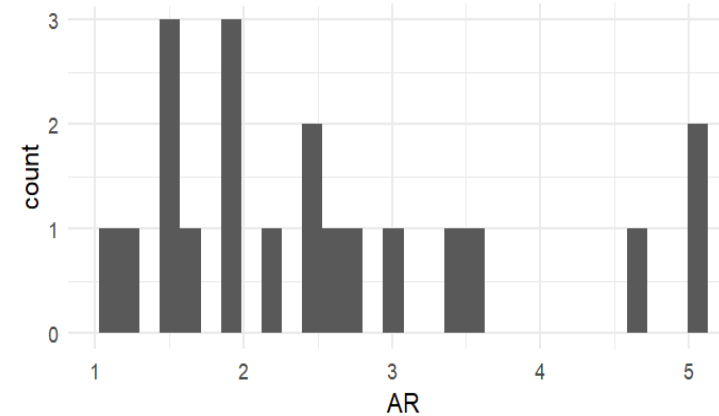


AROUSAL RATIOS

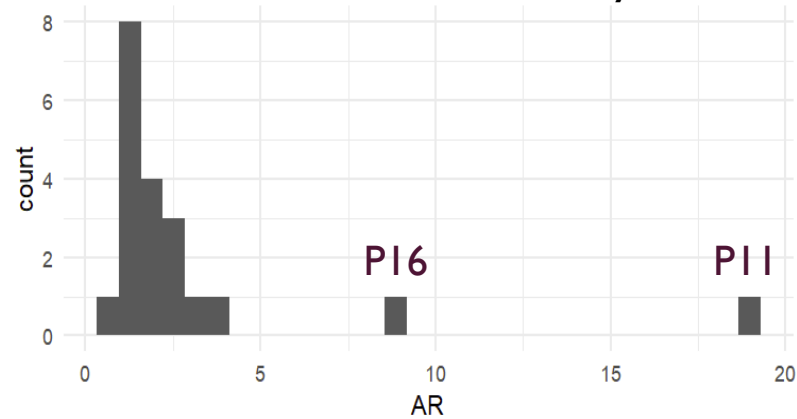
Number Sequence Activity



Word Association Activity



Rubik's Cube Activity



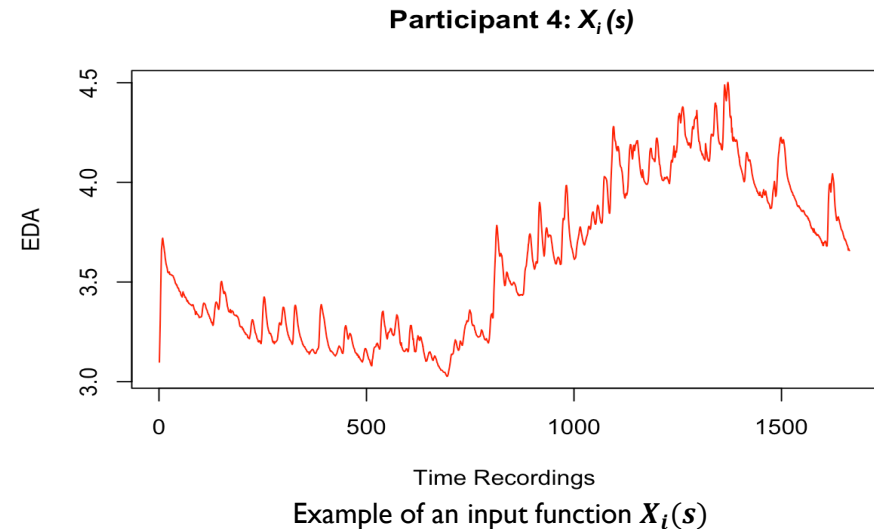
EDA & PROFESSED INTELLECTUAL / ACADEMIC TRAITS

- 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*

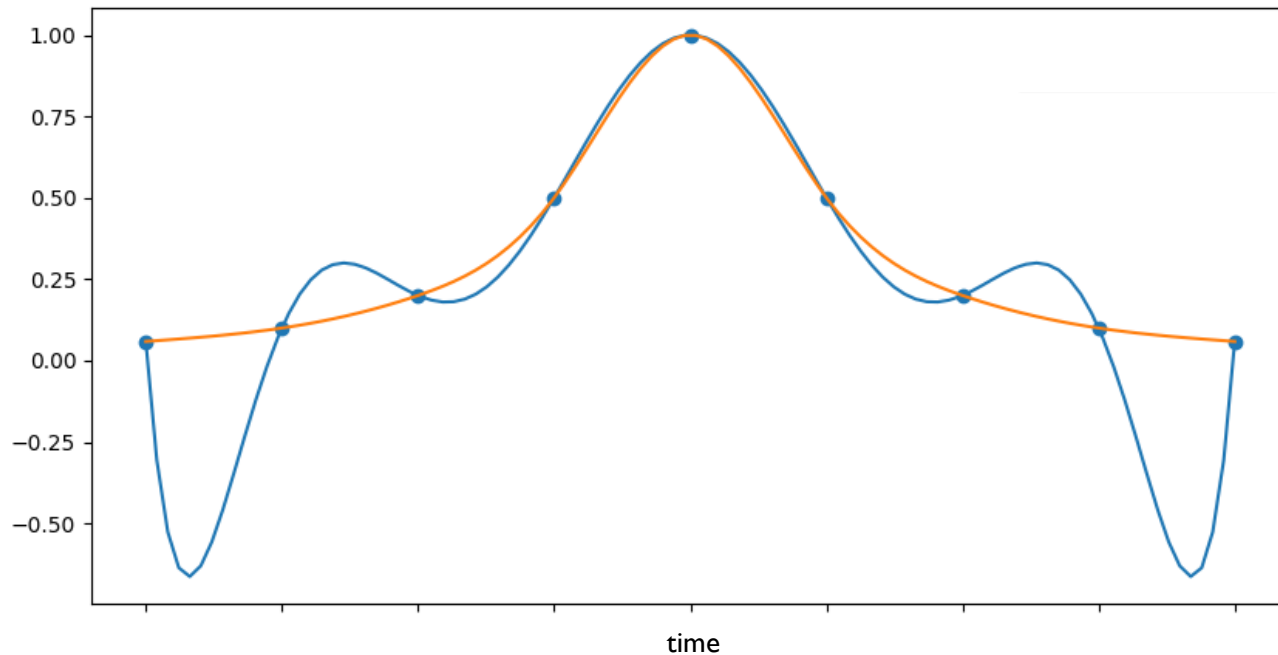
- Simple Linear Regression model: $Y = \beta_0 + \beta_1 x + \varepsilon$
- SoFR model: $Y_i = \beta_0 + \int_S \beta_1(s) X_i(s) ds + \varepsilon_i$



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



- **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

$$E[Y_i] = \beta_0 + \int_S \sum_K \beta_{1k}(B(s))X_i(s)ds = \beta_0 + \sum_K \beta_{1k} \underbrace{\left[\int_S B_k(s)X_i(s)ds \right]}_{C_{ik}} = \beta_0 + C_{ik}\beta_{1k}$$

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

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

3. Use the extracted β , plug back into basis expansion equation to get $\beta_1(s)$

GRAPHING $\beta_1(s)$

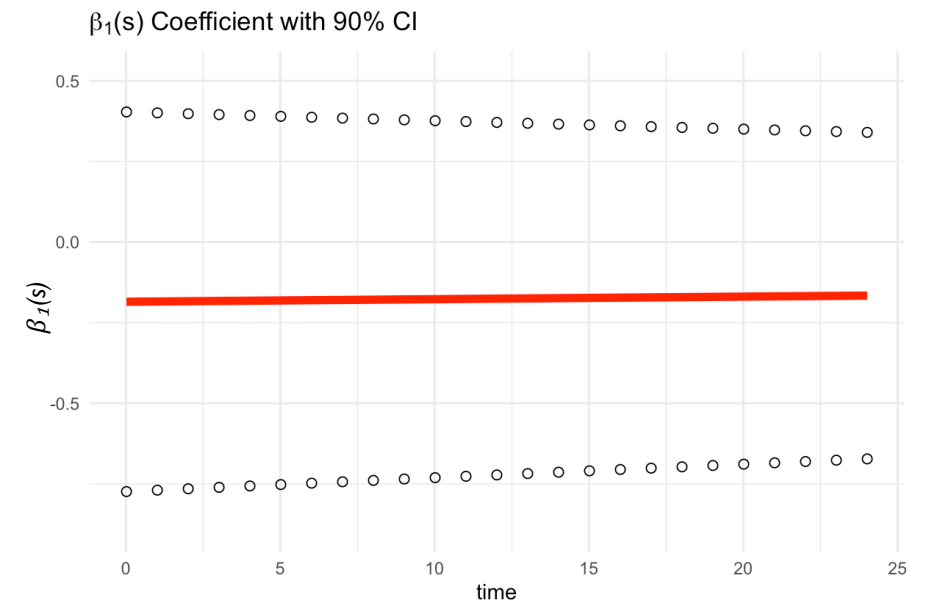
Creating the Confidence Band

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

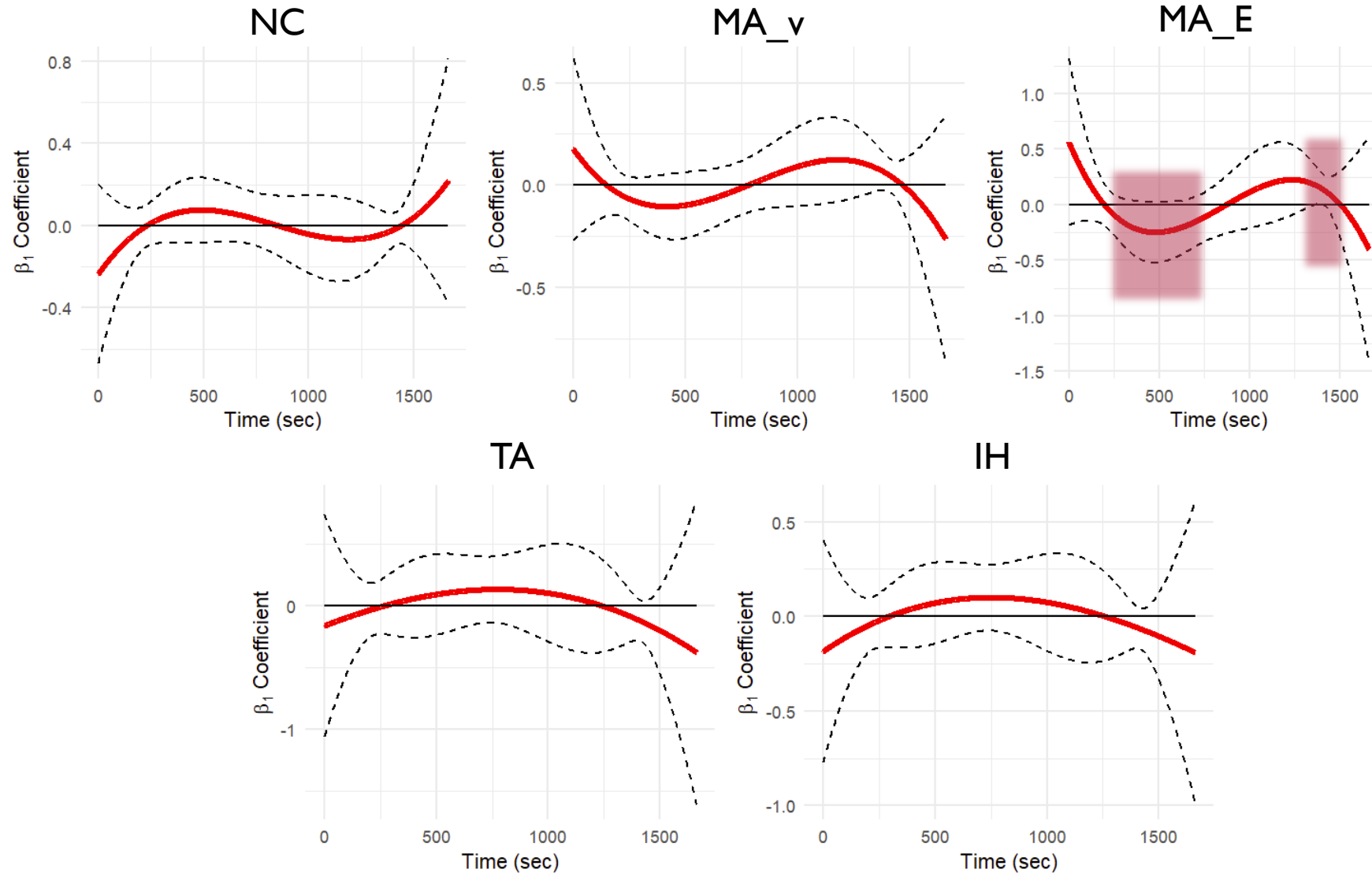
- $Var(\beta_1)$: variance-covariance of the basis coefficient vector (based on OLS)

$$\begin{bmatrix} \sigma_{1,1}^2 & COV_{1,2} & \cdots & COV_{1,1664} \\ COV_{2,1} & \sigma_{2,2}^2 & \cdots & COV_{2,1664} \\ \vdots & \vdots & \ddots & \vdots \\ COV_{1664,1} & COV_{1664,2} & \cdots & \sigma_{1664,1664}^2 \end{bmatrix}$$

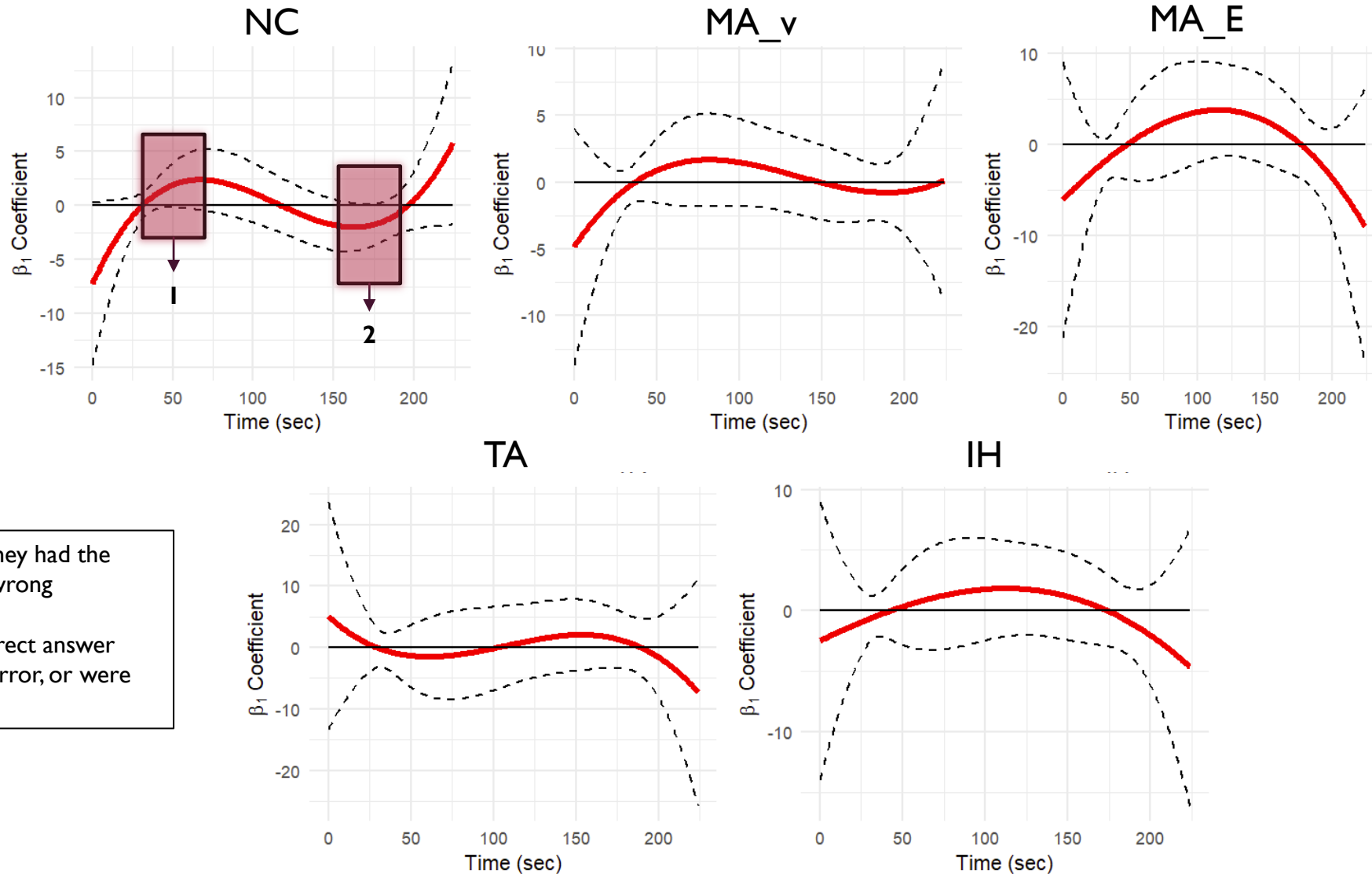
2. Use $\hat{\beta}_1(s) \pm Z_{\alpha/2} * \sqrt{Var(\beta_1(s))}$ to get pointwise CI's



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

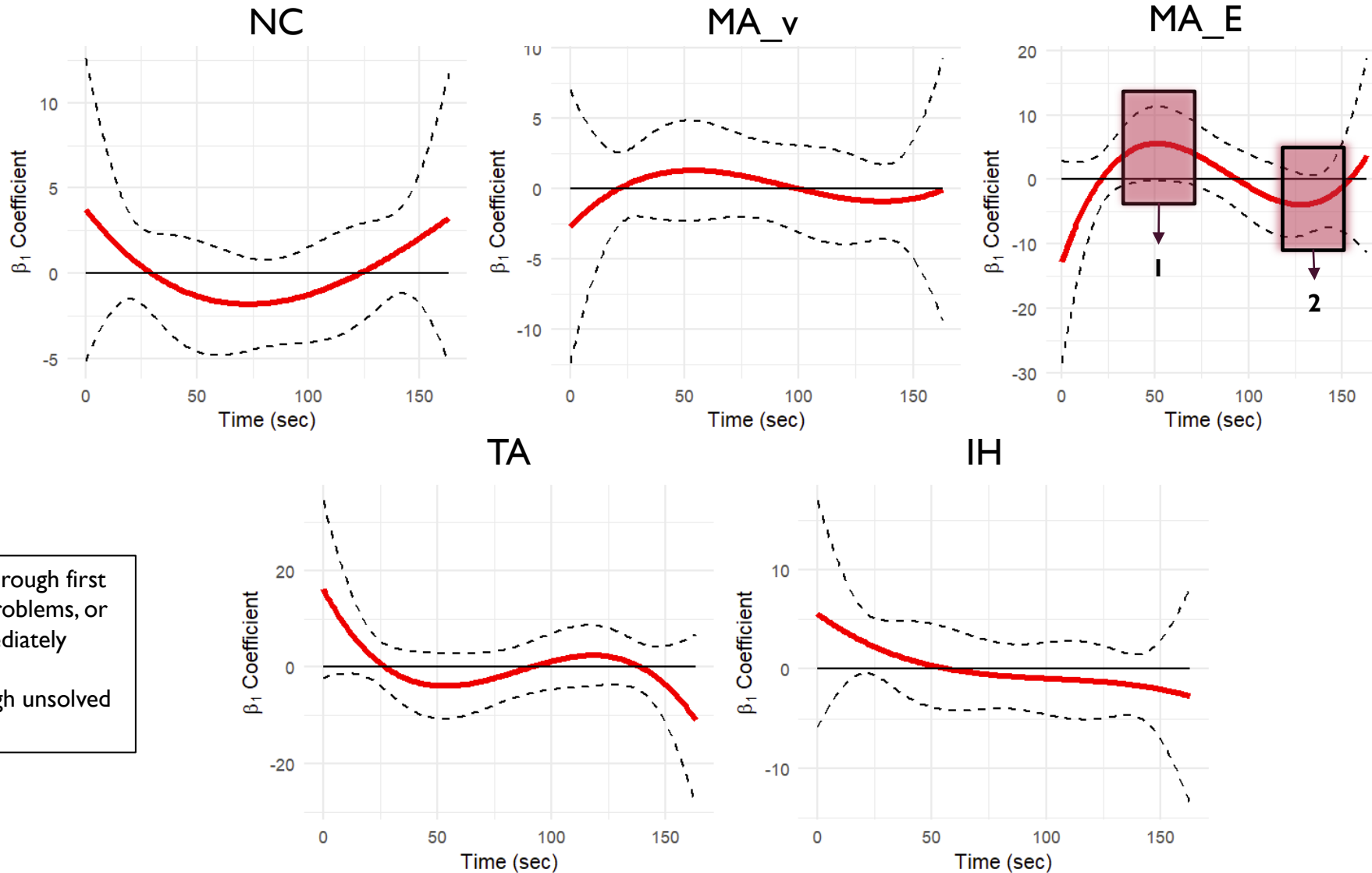


$\beta_1(s)$ FOR NUMBER SEQUENCE ACTIVITY (90% CI)



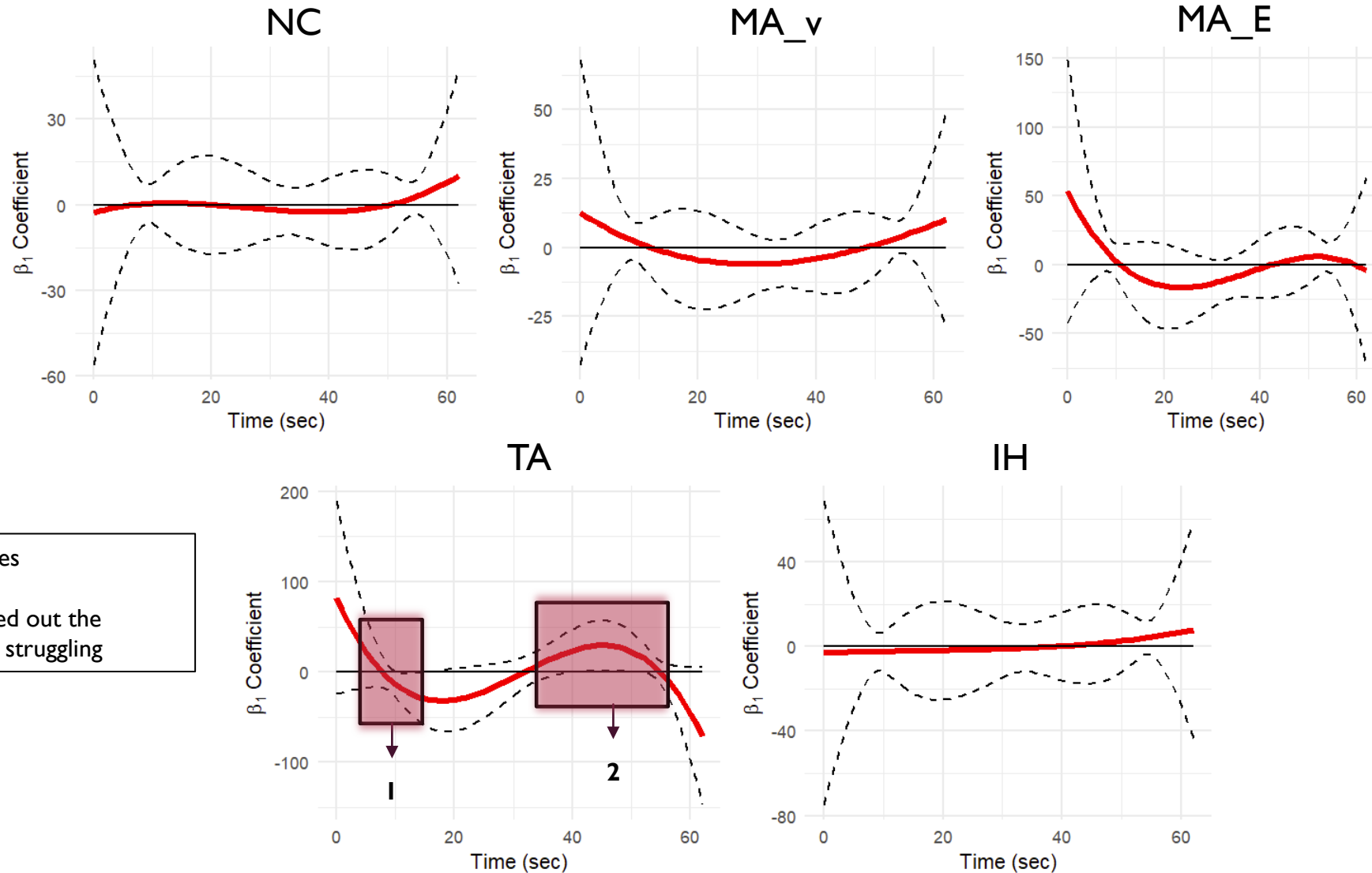
1. Quickly believed they had the answer, but were wrong
2. Either had the correct answer through trial and error, or were far from it

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



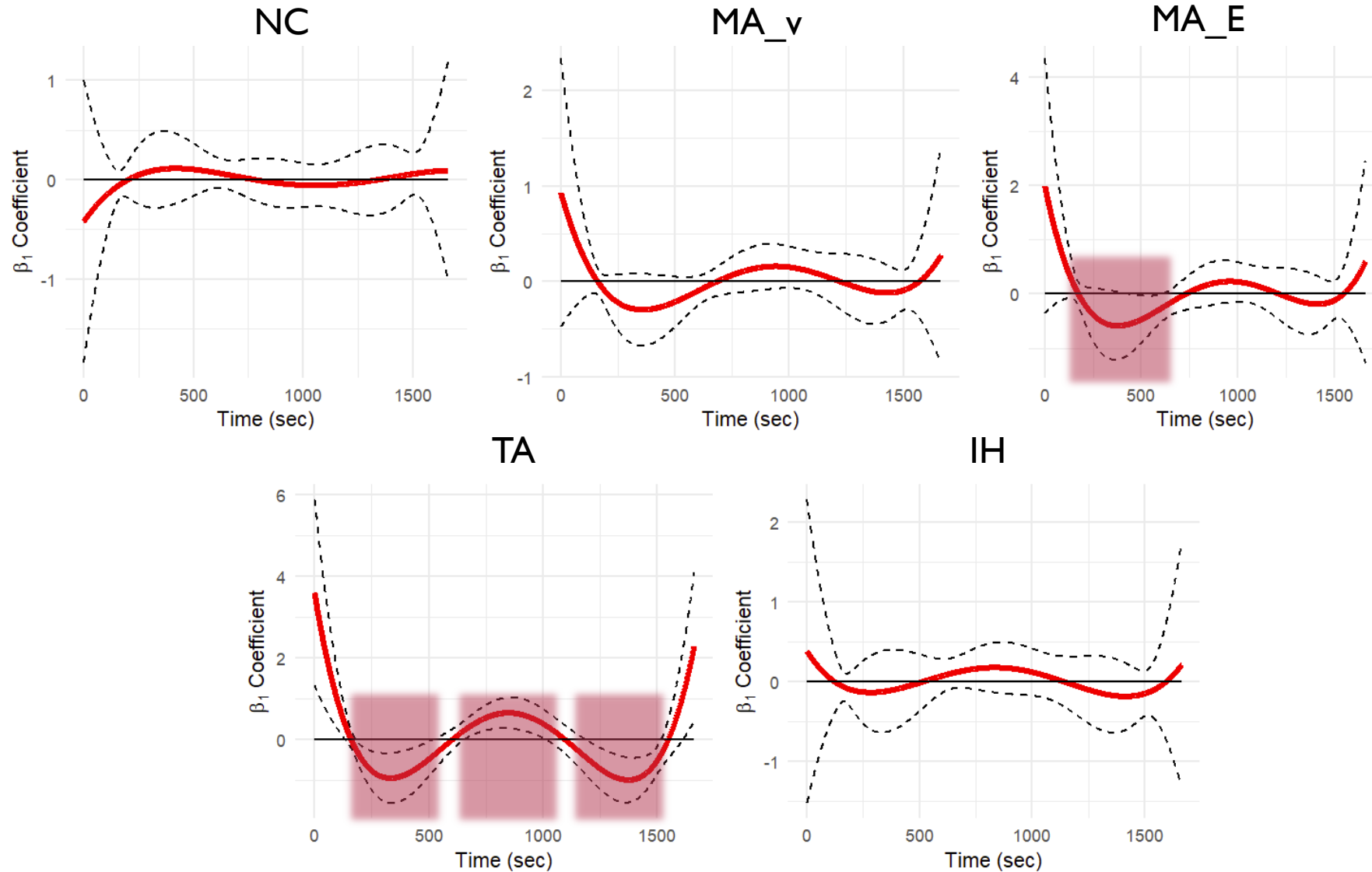
1. Either rolling through first several word problems, or struggling immediately
2. Thinking through unsolved word problems

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



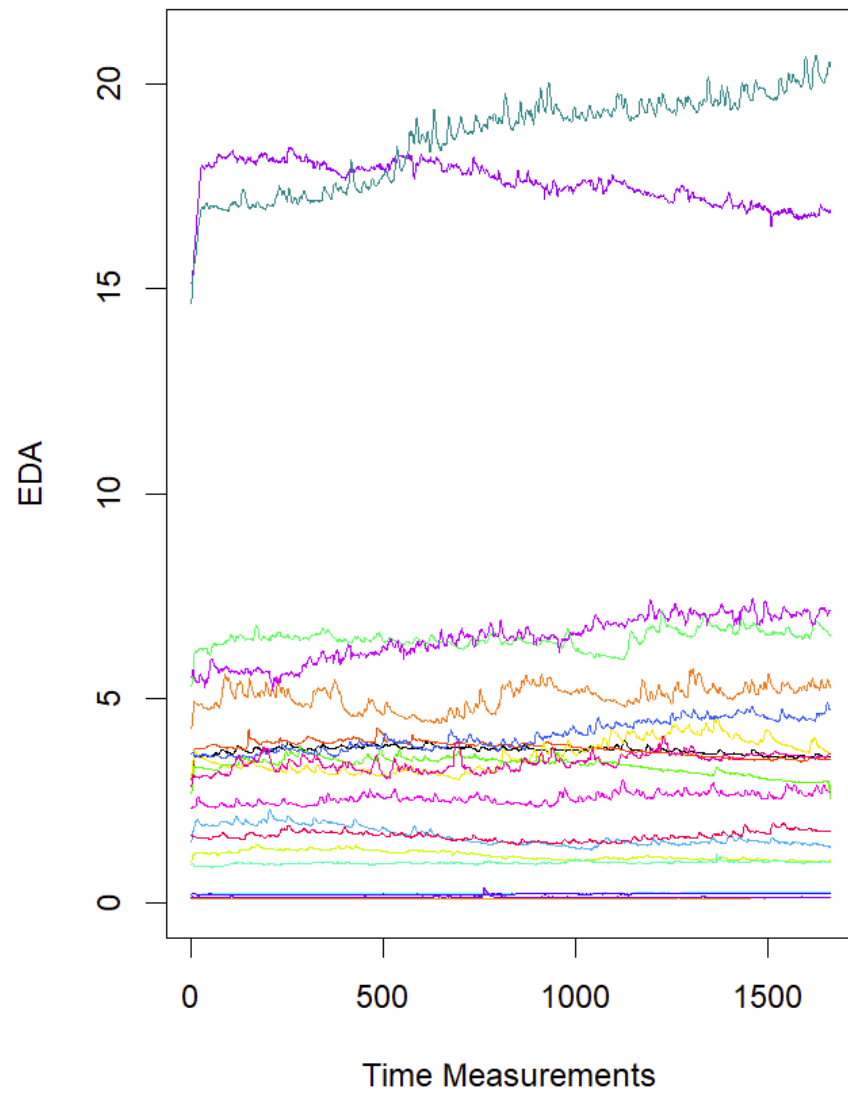
1. Making first moves
2. Either have figured out the algorithm or still struggling

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

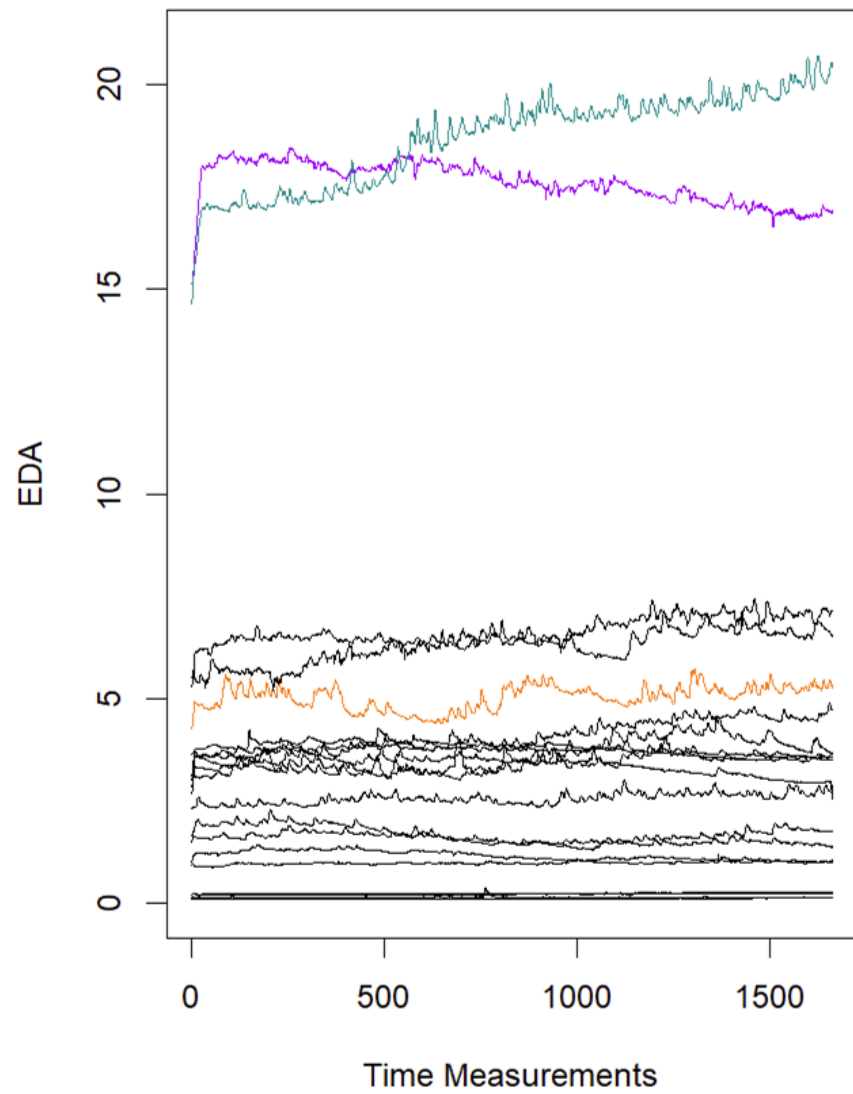




$$X_i(s)$$

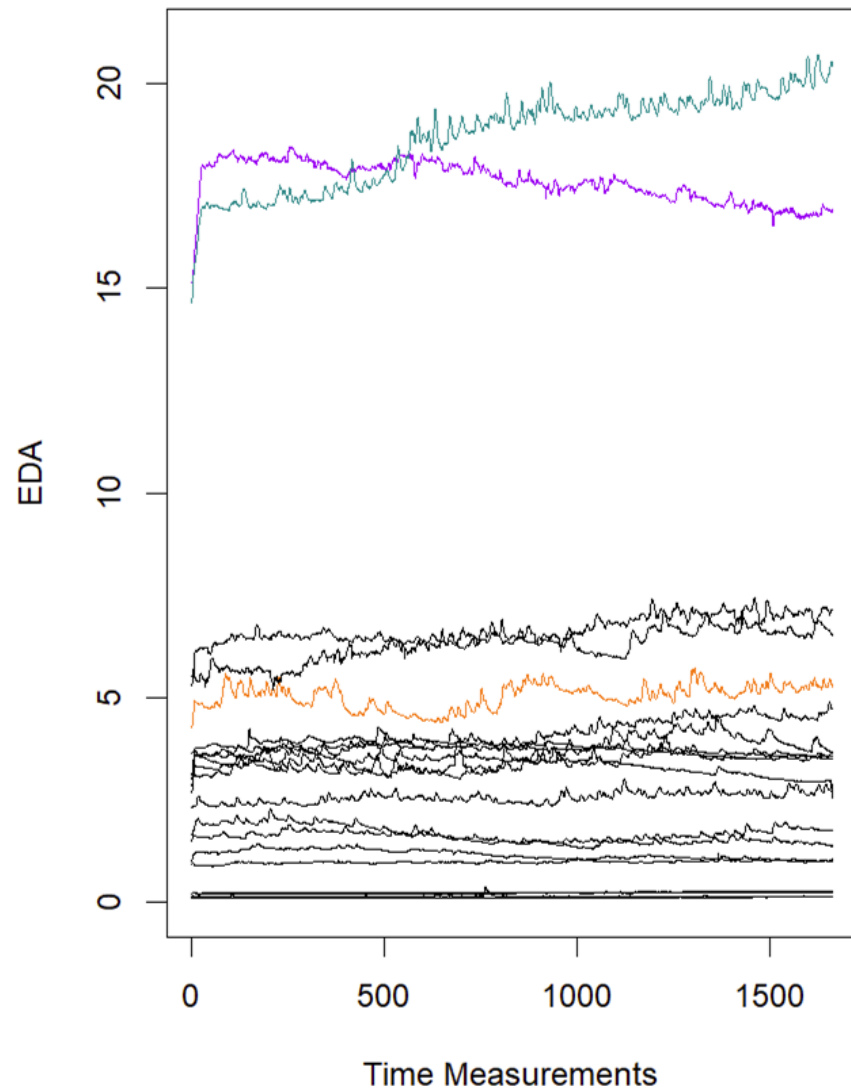


$$X_i(s)$$

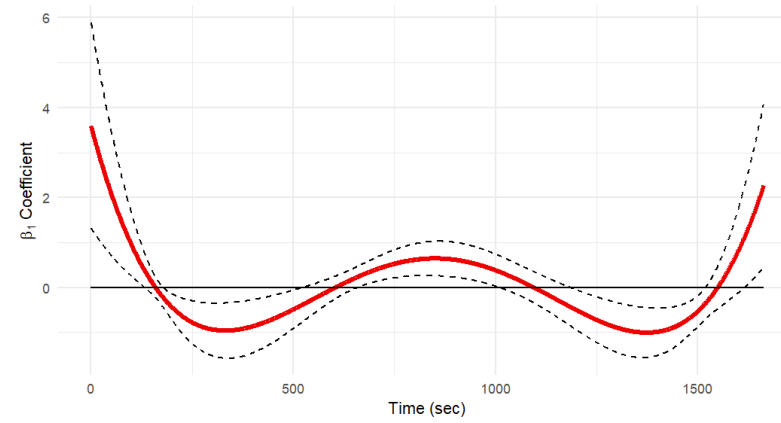




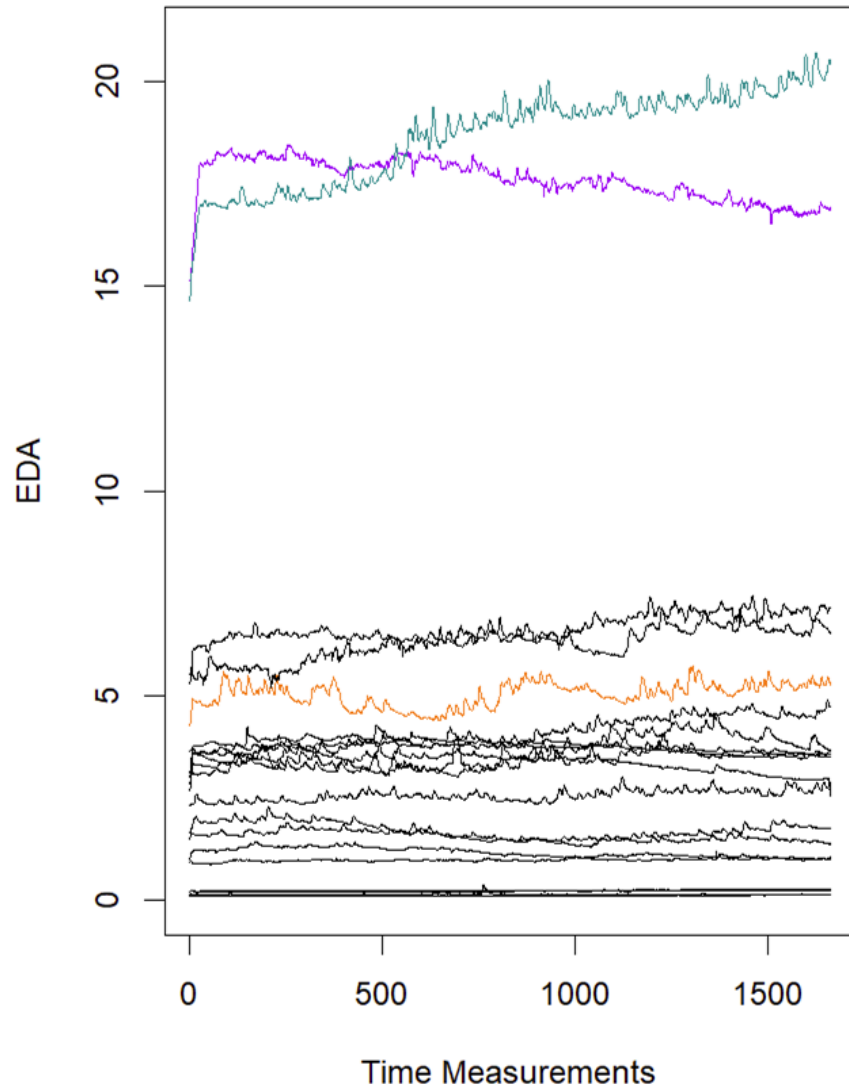
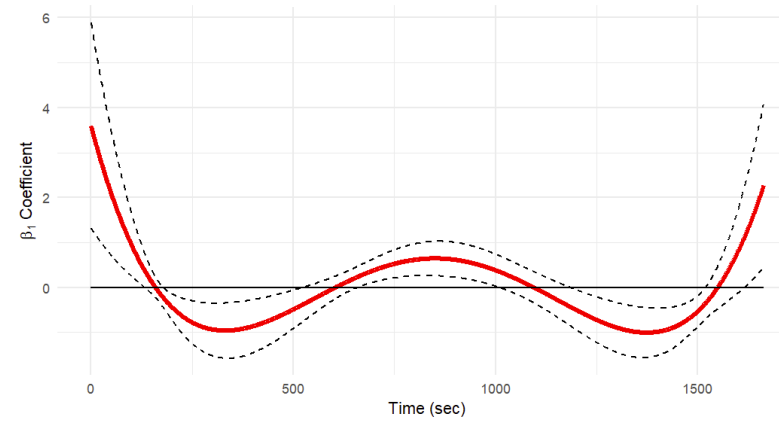
$$X_i(s)$$



$$\beta_1(s)$$



P14
P7
P6

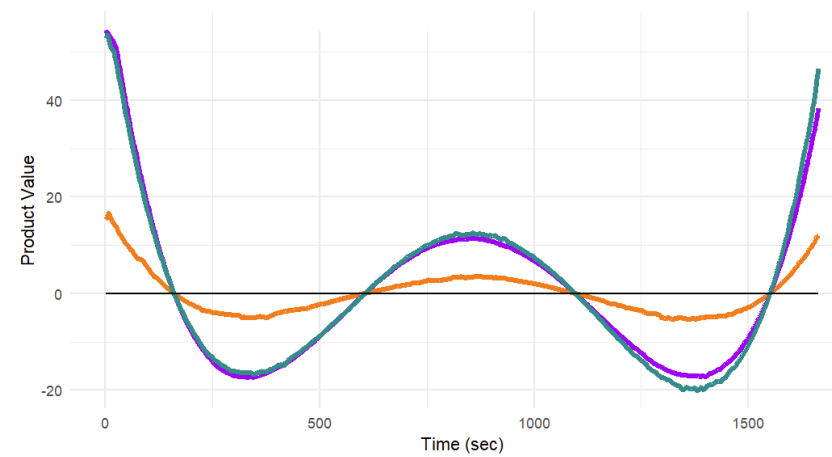
$X_i(s)$

 $\beta_1(s)$


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

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

REFERENCES

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- Haggard, M., Rowatt, W. C., Leman, J. C., Meagher, B., Moore, C., Fergus, T., Whitcomb, D., Battaly, H., Baehr, J., & Howard-Snyder, D. (2018). Finding middle ground between intellectual arrogance and intellectual servility: Development and assessment of the limitations-owning intellectual humility scale. *Personality and Individual Differences*, 124, 184–193. <https://doi.org/10.1016/j.paid.2017.12.014>
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- Raskin, D. C. (1973). *Attention and Arousal. Electrodermal Activity in Psychological Research*. Academic Press, Inc. doi:10.1016/B978-0-12-565950-5.50007-7

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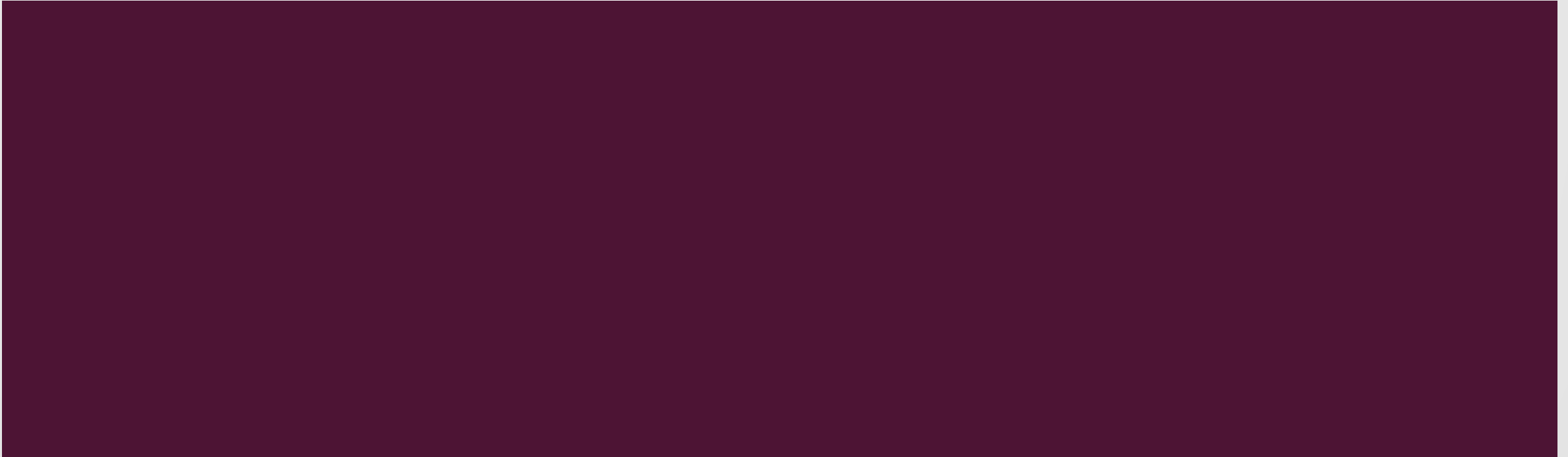
- Dr. Gideon K. D. Zamba, Professor, Dept. of Biostatistics, University of Iowa
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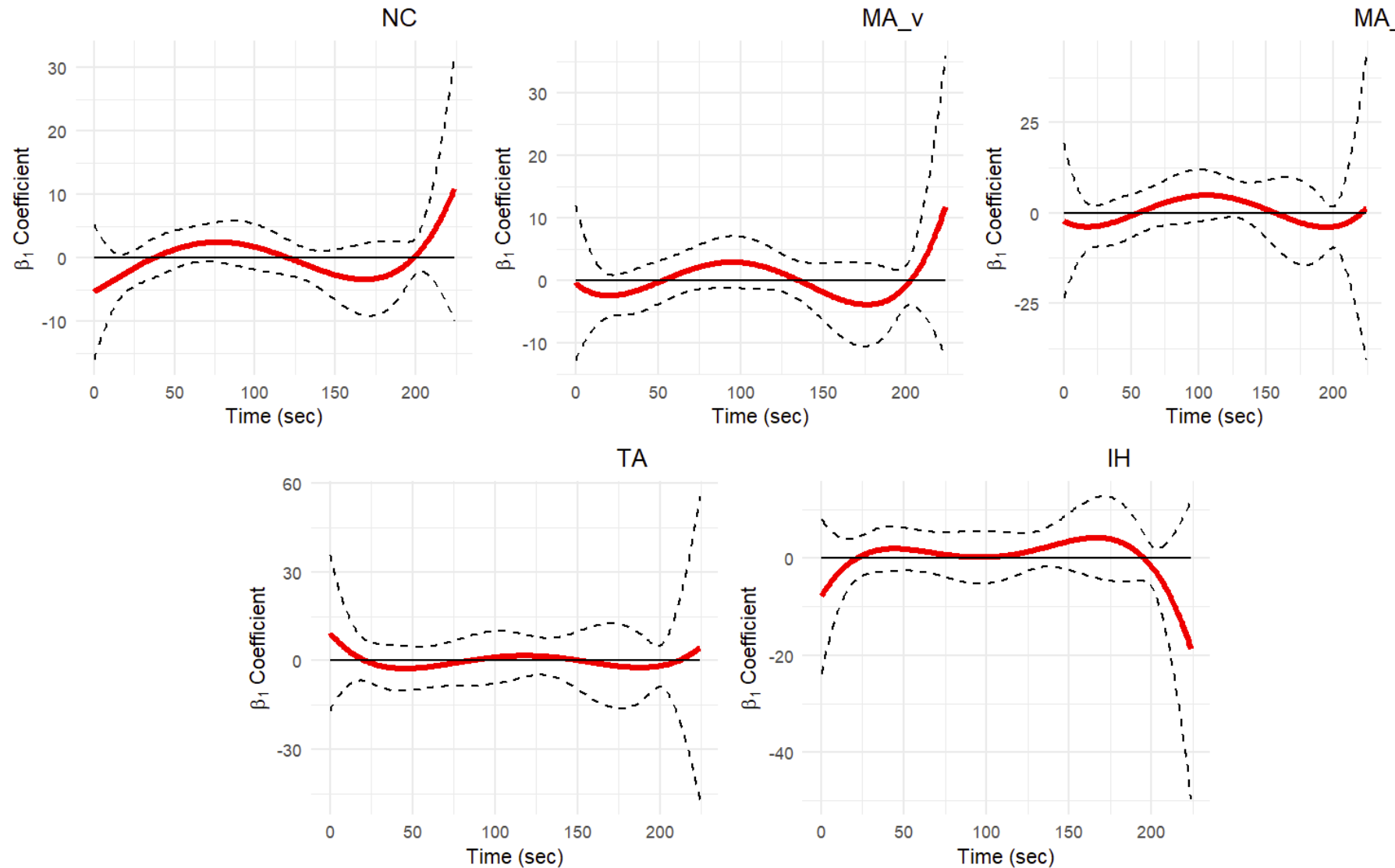
National Heart, Lung,
and Blood Institute



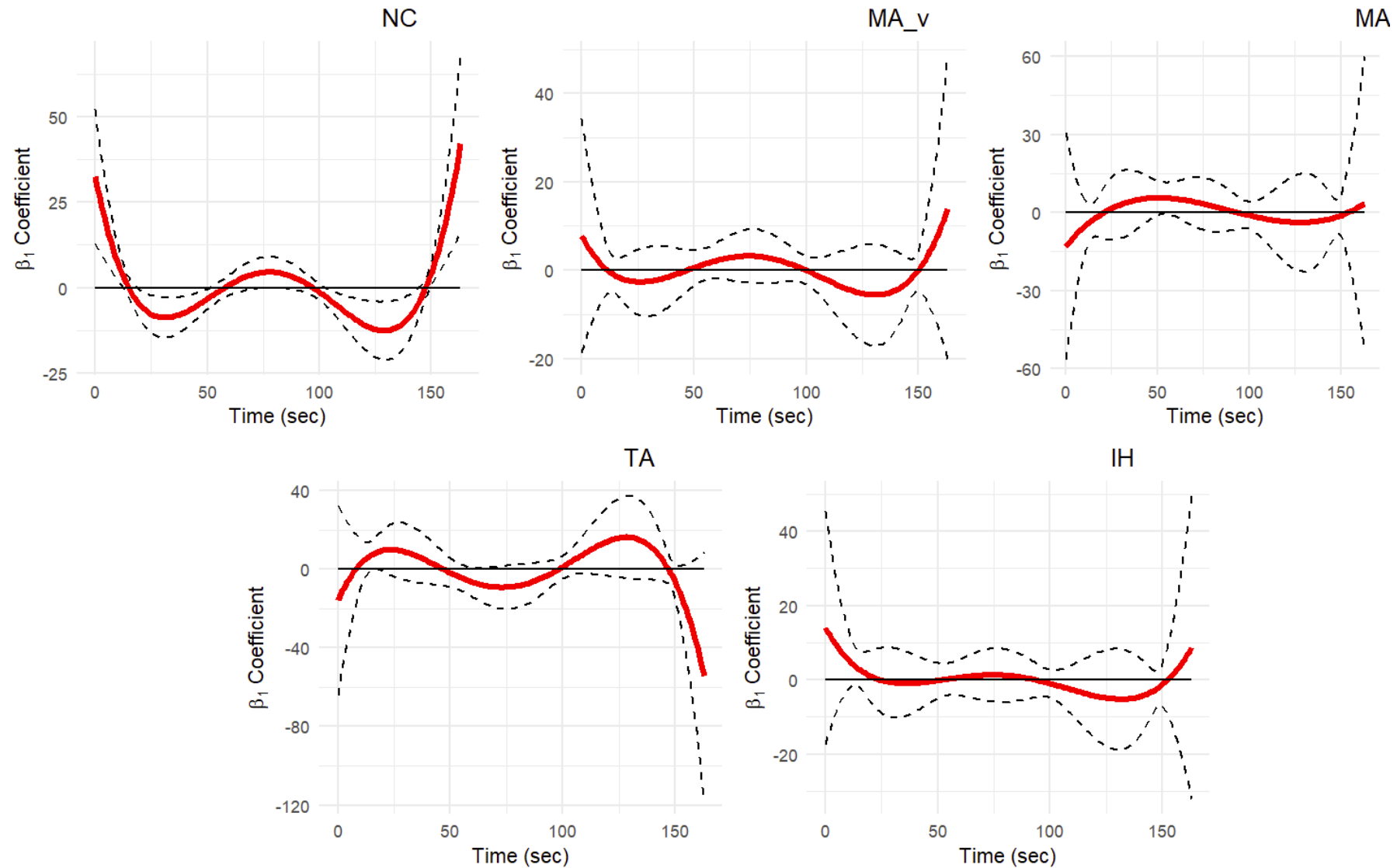
QUESTIONS?



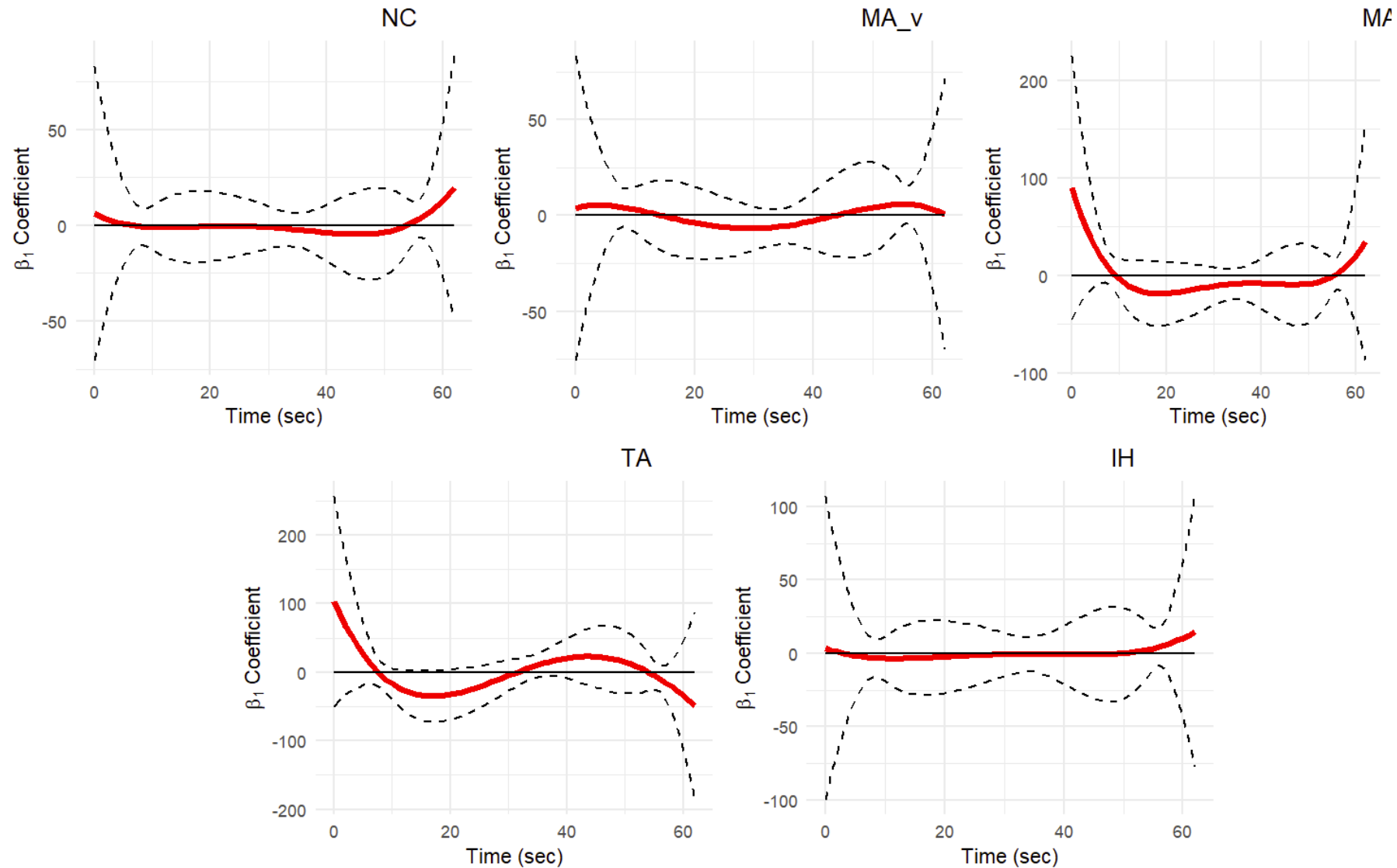
FOURTH DEGREE MODELS OF $\beta_1(s)$ FOR ACTIVITY I WITH 90% CI



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

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