Why is learning so often difficult to achieve?

Iowa Summer Institute in Biostatistics 2023

University of Iowa Department of Biostatistics

Hannah Mullins (Wheaton College)

Iramir Neto (Kean University)

Andres Vazquez (University of Puerto Rico-Mayaguez)

Rachel Watson (Bradley University)

Difficulty in Learning

- Discomfort from failure generates emotion that can be reflected through different physiological mechanisms:
  - Increased sweat production
- Cognition and emotion interact to form the psychological mechanisms responsible for discomfort during learning

Electrodermal Activity (EDA)

Mechanism of EDA

- EDA is based on the changes in skin conductivity during moments of increased psychological arousal.
- Changes in skin conductivity captured by passing small current through the skin and measuring resistance (Cain and Lee, 2022)
- Wearable devices, like wristbands, have made it possible to collect EDA data

EDA is a proxy for engagement.

- Surges in EDA observed when participants are engaged in an intellectual activity (Lee 2021; Cain and Lee, 2022)
- EDA technique further developed by incorporating first-person video to validate EDA readings (Lee, 2021)

EDA in teaching

- Electrodermal activity (EDA) identified engagement in youth completing makerspace activities.
- Can guide better ways to disseminate instruction

Objectives

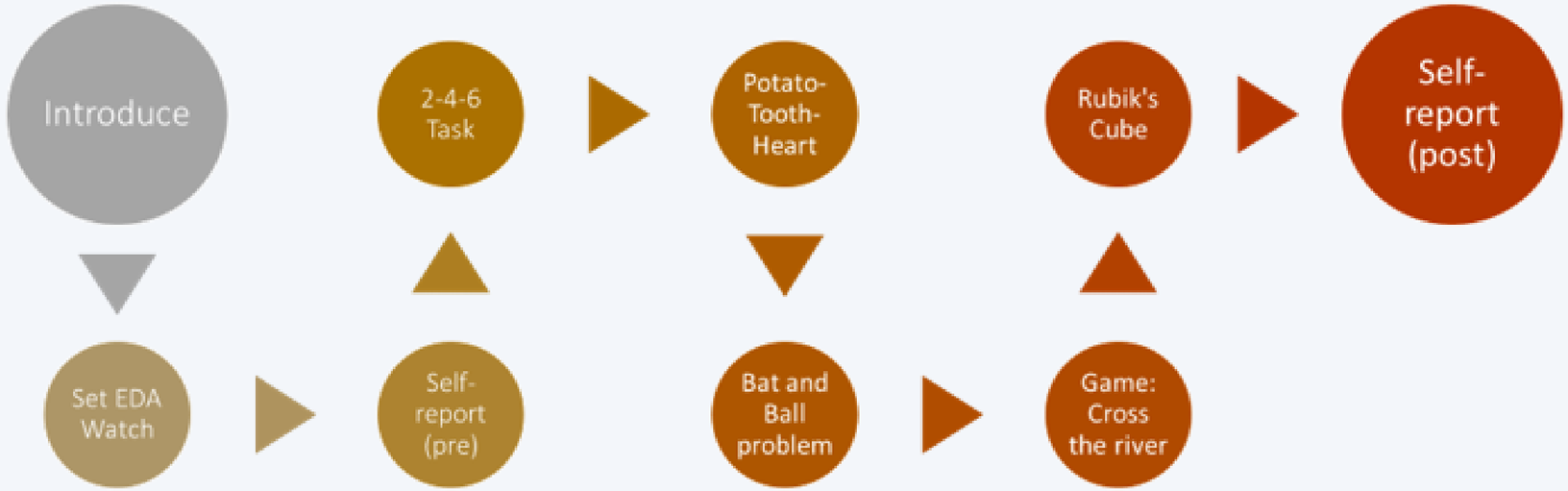
The project aims to determine how EDA measurements explain student engagement with intellectual activity.

Analyze correlation between EDA and engagement of participant

Pilot Study Design at UI

Dept. of Neuropsychology
PIs: Matthew Lira and Stacy McElroy
RA: Minzhi Liu

- Wrist sensor EDA data collected.
- Third-person video evidence.
- Before the interview, both finished an online questionnaire of intellectual humility.
- Before and after each activity, ~1 minute rest.



1st Task – 2, 4, 6 Task (Wason, 1960)

Confirmation bias assessment

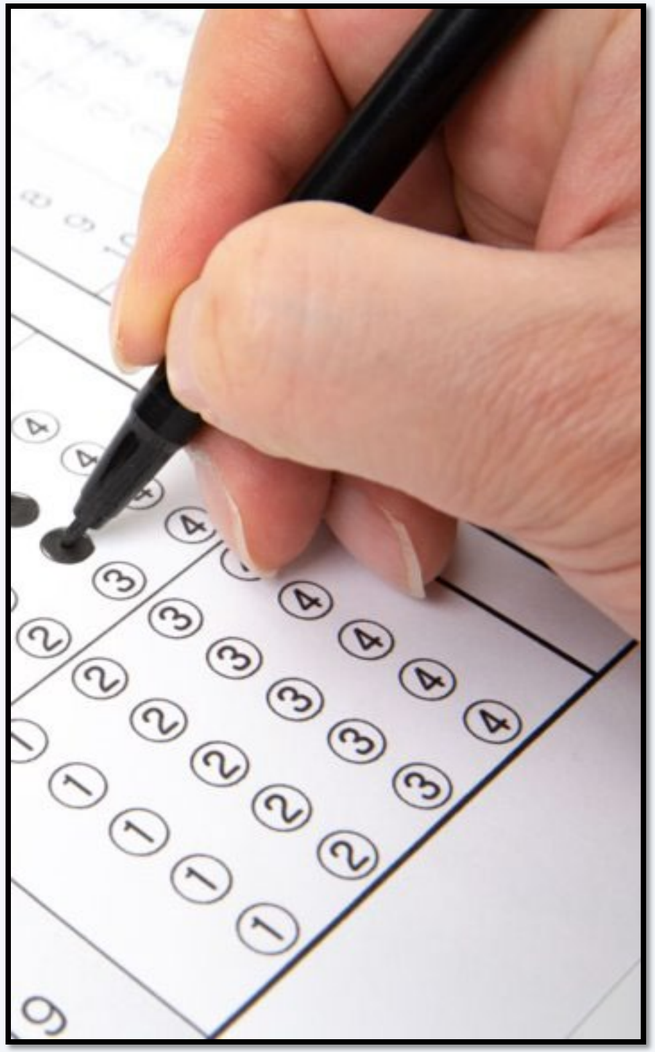
The aim of this task is to discover a simple rule given by the interviewer. This rule is concerned with any three numbers, with reasons for their choice of them.

Example:

What is the rule for the following sequence?

2, 4, 6

Rule: Increasing Numbers



2nd Task – Potato-Tooth-Heart

Compound remote associate problem

Example:

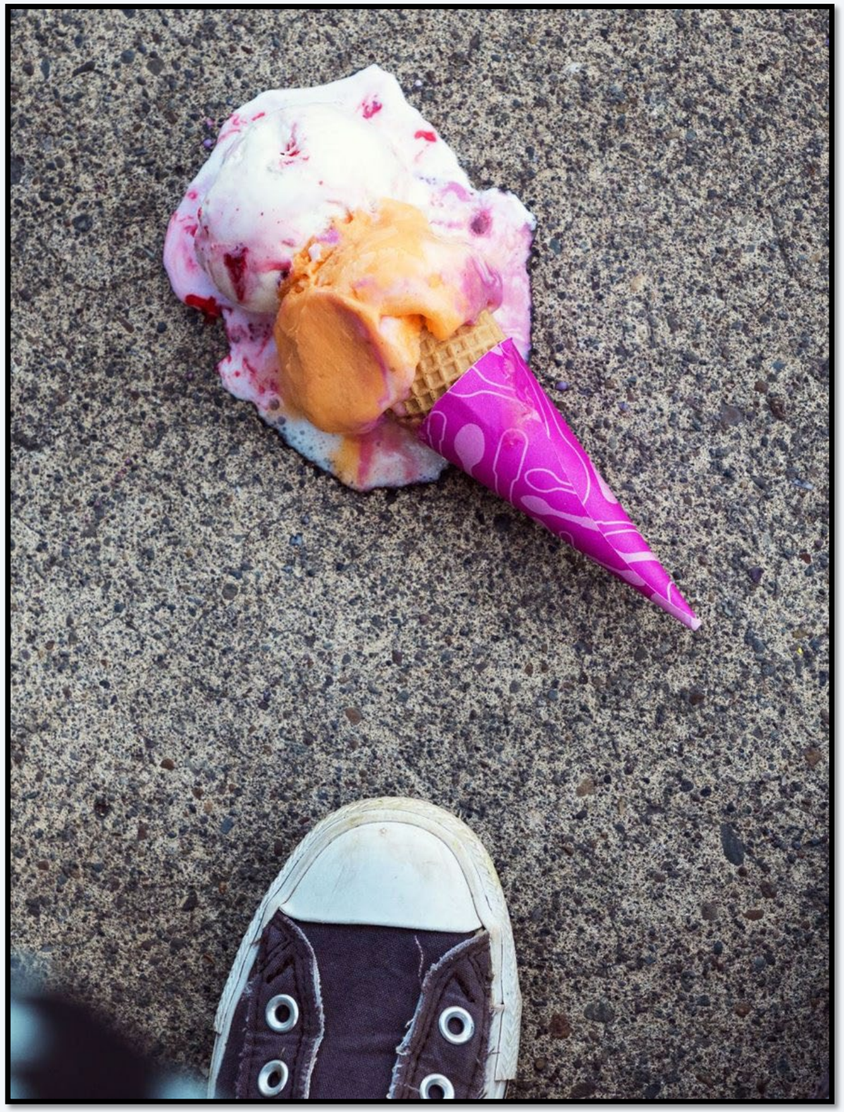
Key Word

____ cream

____ skate

____ water

Answer: Ice



3rd Task – Bat and Ball

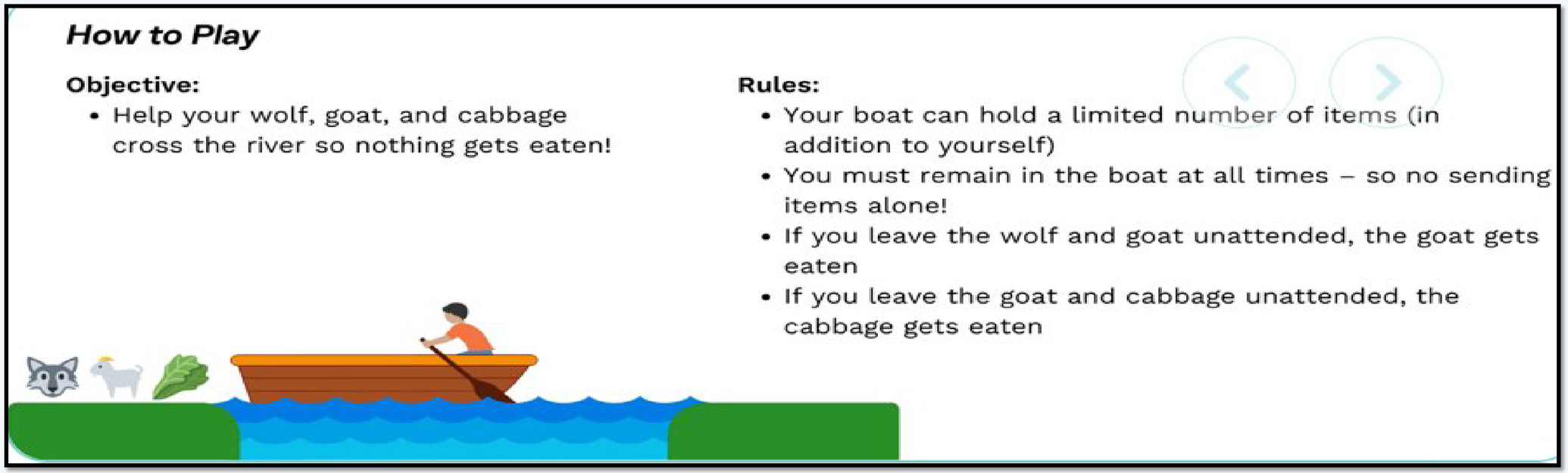
Assessment

Example:

A bat and a ball cost 110 cents in total. The bat costs 100 cents more than the ball. How much does the bat cost?

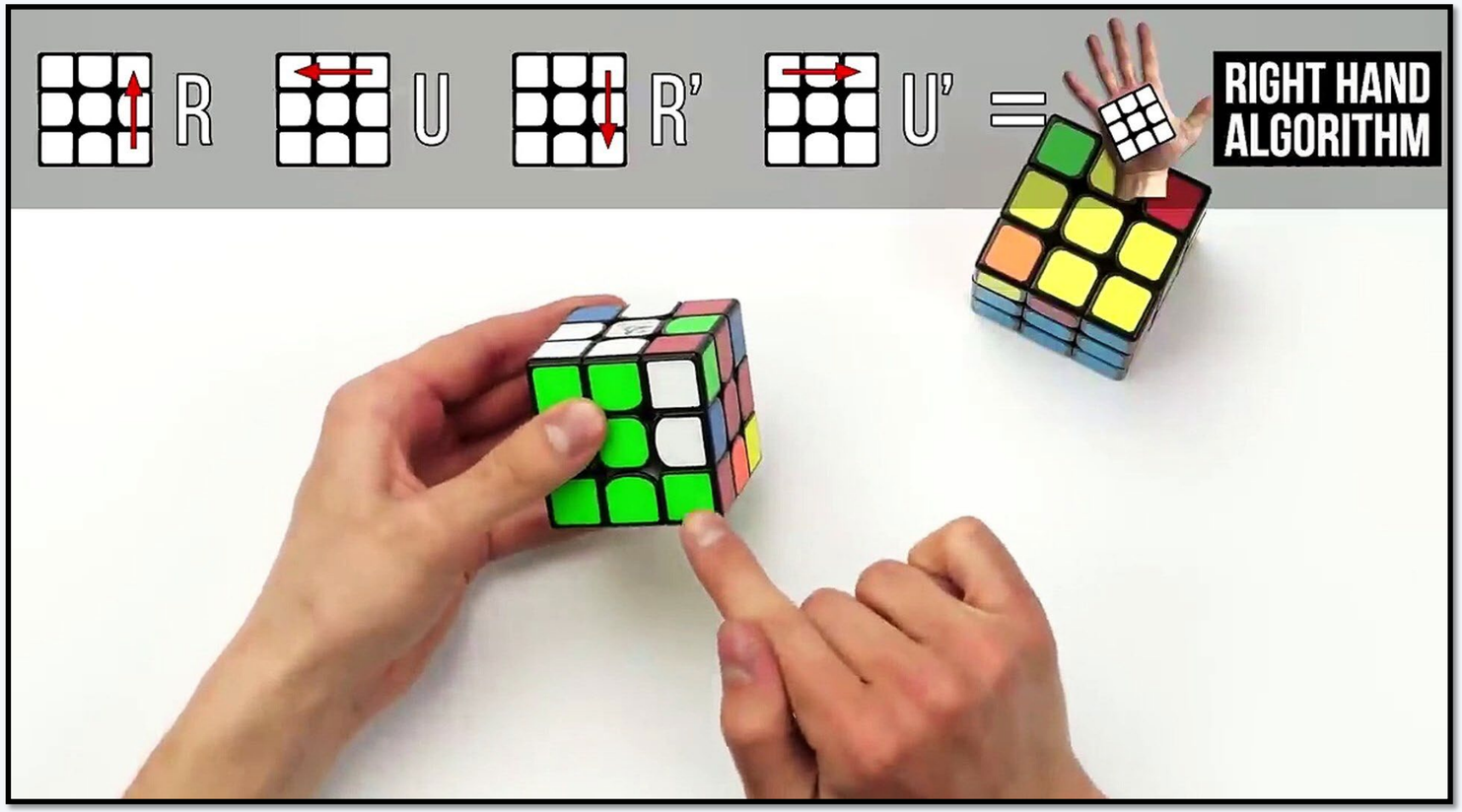
Rule: Bat 105 cent and Ball 5 cent

4th Task – Game: Cross the River



5th Task – Rubik's Cube

Right Hand Algorithm



Achieving an answer with this design

- The primary objective of these tasks was to observe electrodermal activity (EDA) patterns exhibited by the participants in response to failure and the resulting frustration.
- By analyzing EDA activity, the study aimed to identify instances of non-engagement, indicating periods where participants were not actively involved in the tasks.
- To gain a comprehensive understanding of these periods, the use of a video camera was employed to precisely pinpoint the specific activities or lack thereof occurring during these intervals.

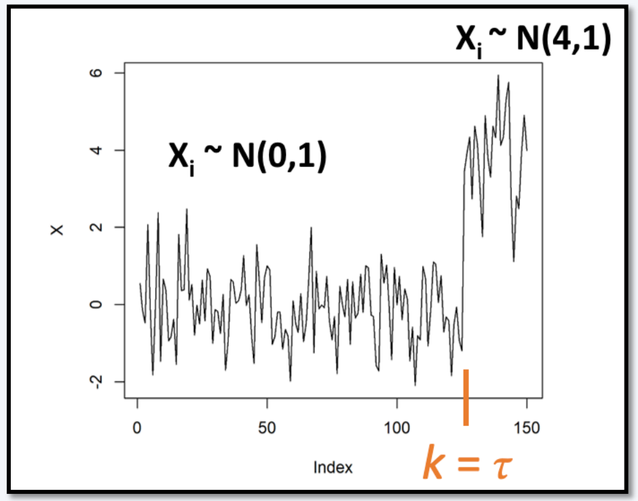
Methodology

Statistical Changepoint Model

- Given a process with a *known* changepoint:

$$X_i \sim \begin{cases} N(\mu_1, \sigma_1^2) & i = 1, ..., \tau \\ N(\mu_2, \sigma_2^2) & i = \tau + 1, ..., n \end{cases}$$

- Mean (μ), variance (σ^2), or both can change when the process crosses the changepoint.



Methodology

Likelihood Ratio

$$\theta = [\theta_1, \theta_2] \quad H_0 : \theta_1 = \theta_{1_0}\,; \quad \theta_2 \text{ nuisance parameter}$$

$\hat{\theta_1}$ and $\hat{\theta_2}$ are the maximum likelihood estimators based on a sample

$$\Lambda = \frac{L(\theta_{1_0}, \hat{\theta}_2)}{L(\hat{\theta}_1, \hat{\theta}_2)}$$

$$-2log\Lambda \sim \chi^2_{dim(\theta_1)}$$

Methodology

Statistical Changepoint Model

- Maximize $G_{k,n}$ over all possible split points k, yielding $G_{max,n} = \max_k G_{k,n}$.

$$G_{k,n} = \left(k \log \frac{S_{0,n}}{S_{0,k}} + (n-k) \log \frac{S_{0,n}}{S_{k,n}} \right) / C$$

$$V_{i,k} = \sum_{j=i+1}^{k} (X_j - \bar{X}_{i,k})^2$$

$$C = 1 + \frac{11}{12} \left[\frac{1}{k} + \frac{1}{n-k} - \frac{1}{n} \right] + \left[\frac{1}{k^2} + \frac{1}{(n-k)^2} - \frac{1}{n^2} \right]$$

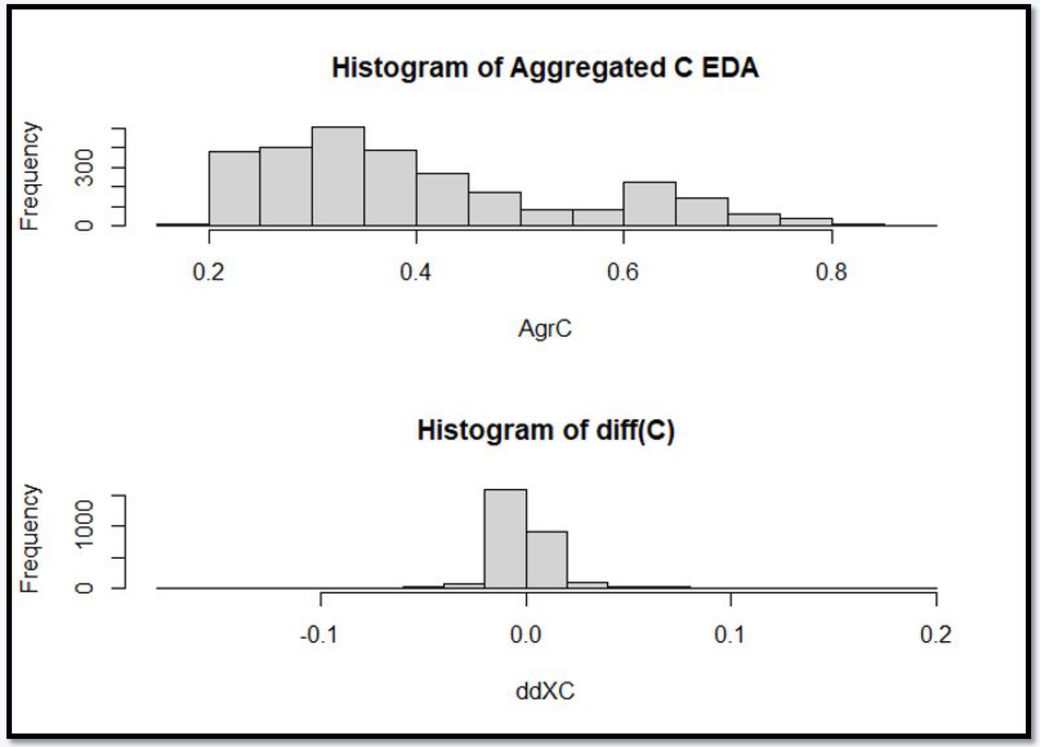
$$S_{i,j} = V_{i,j}/(j-i)$$

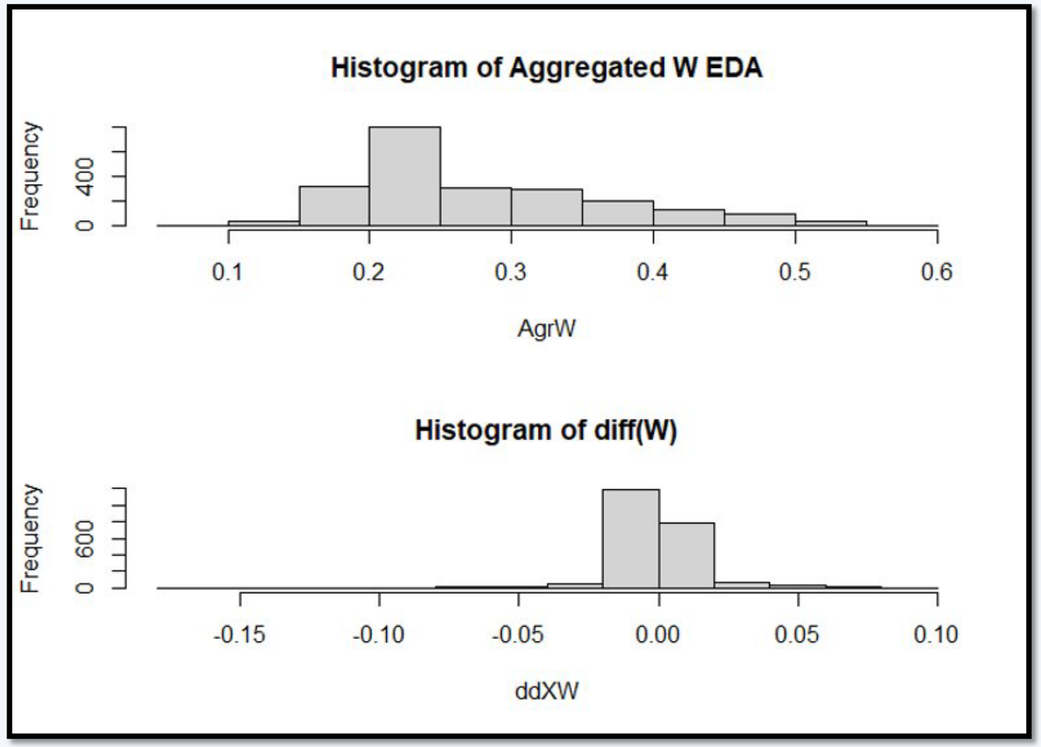
- Compare $G_{max,n}$ to hazard function (h) to identify evidence of a shift in mean and/or variance.
- Each split point k at which $G_{max} \geq h_{n,\alpha}$ is a changepoint.

$$P[G_{\max,n} > h_{n,\alpha} | G_{\max,j} \leq h_{j,\alpha},\ j < n] = \alpha$$

Results

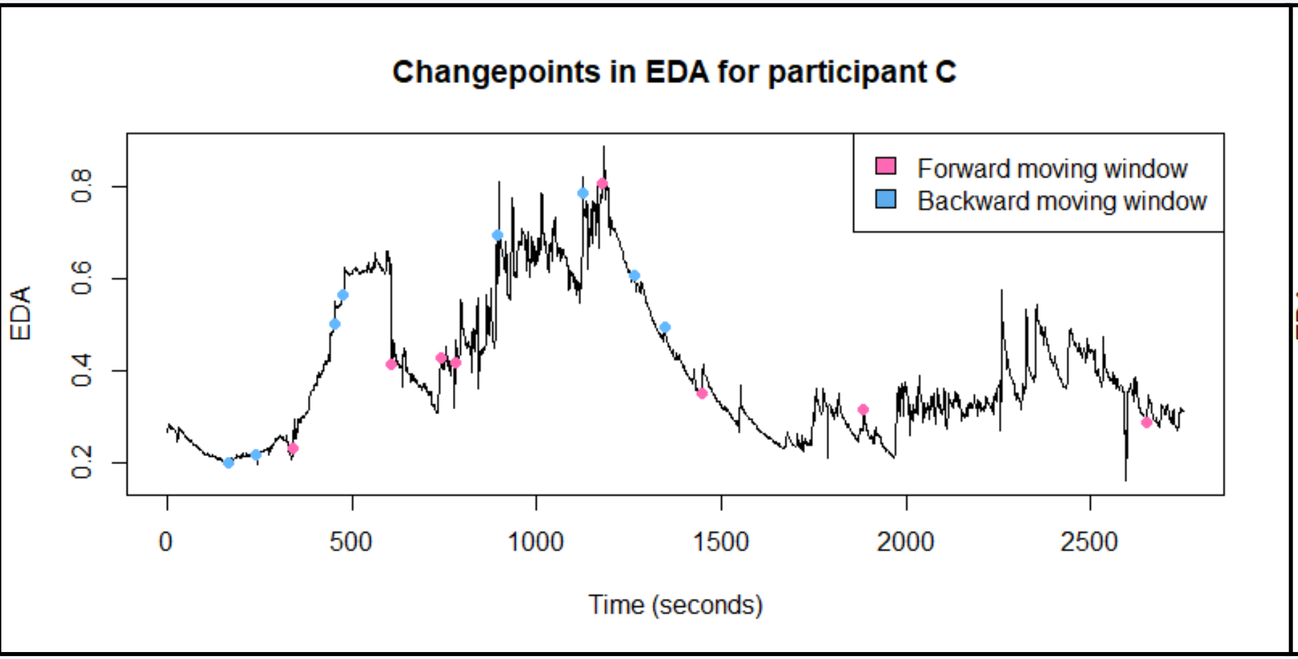
Using a normal distribution

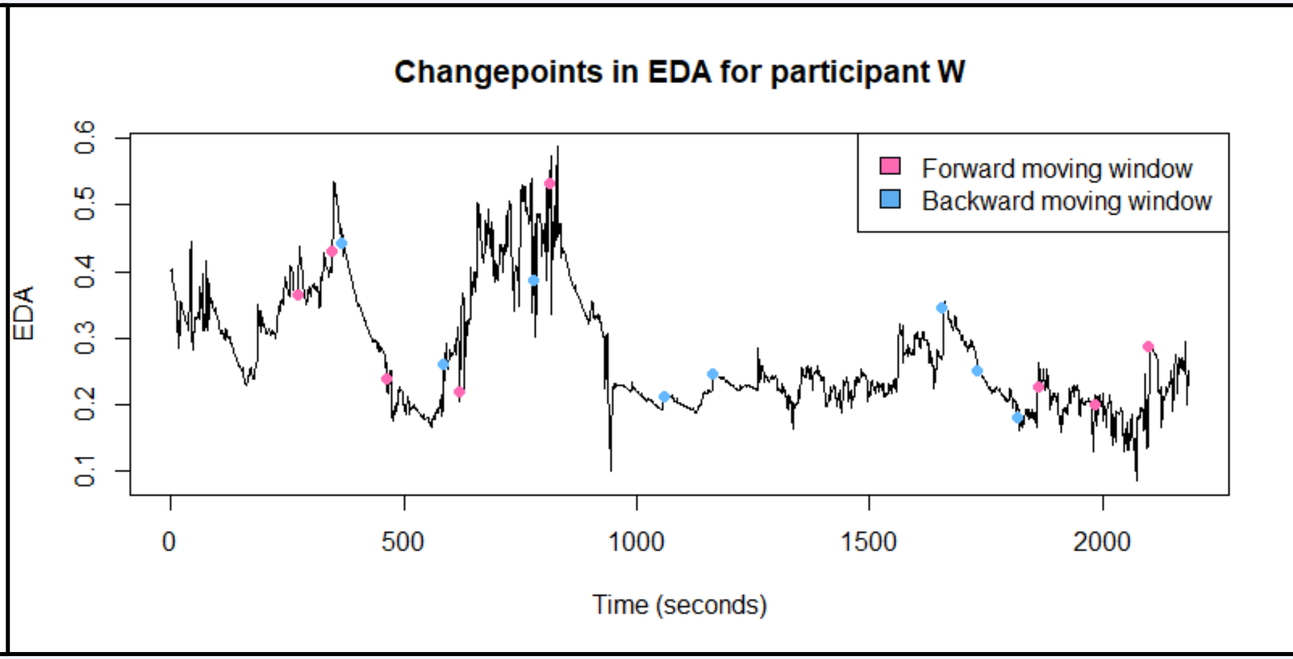




Results

Applying the changepoint model to EDA



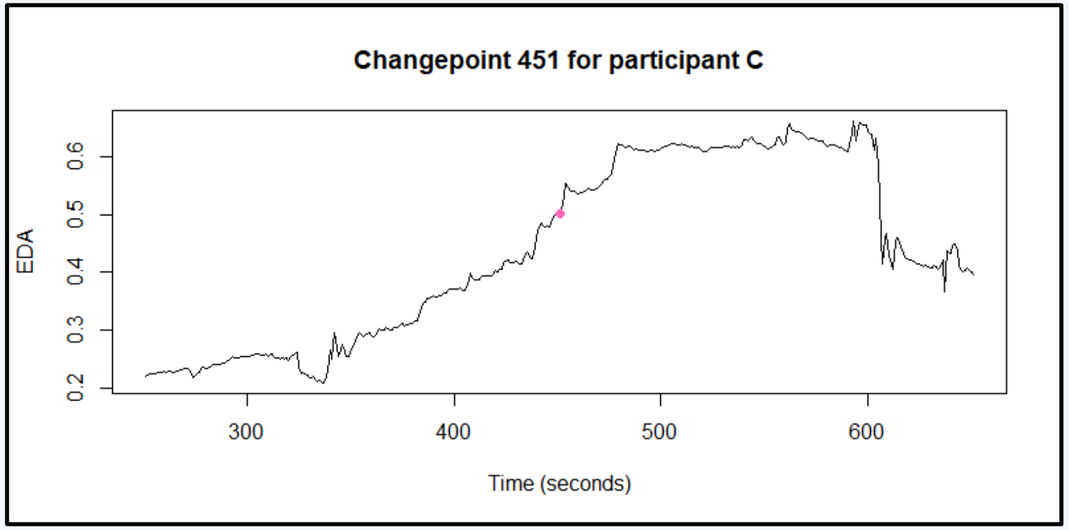


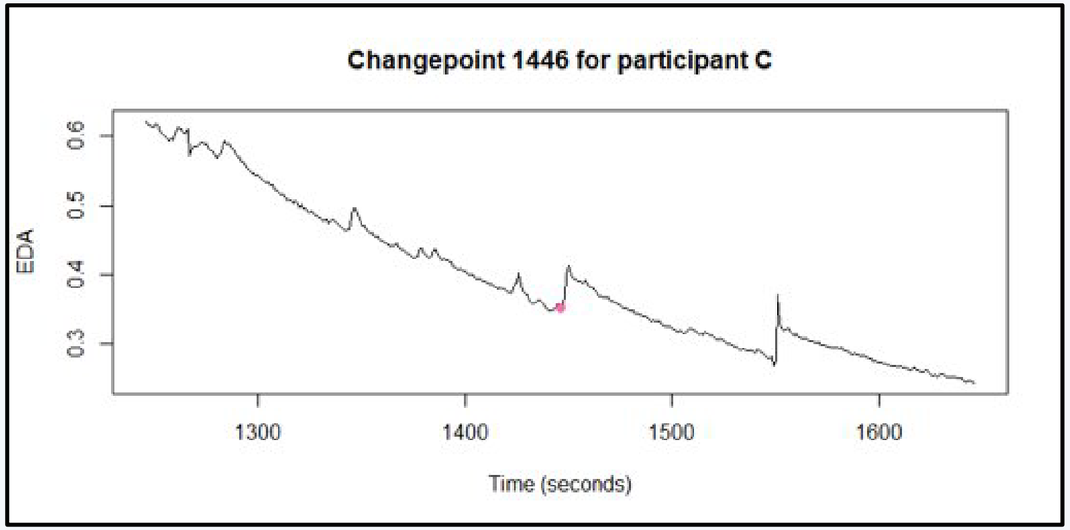
- Most frequently occurring changepoints
- Use a moving window and test every value k within the window for $G_{k,n}$.
- Identify first occurrence

Results

Participant C — Changepoints

Changepoint (s)	Changepoint (mins)	Observations
451	10:11	• Minzhi asks participant C how she felt after the first task • Participant C admits feelings of frustration
1446	26:46	• Participant C faces difficulty in completing one of the mini games during the 4th activity • Participant C restarts the mini games at the time of the changepoint

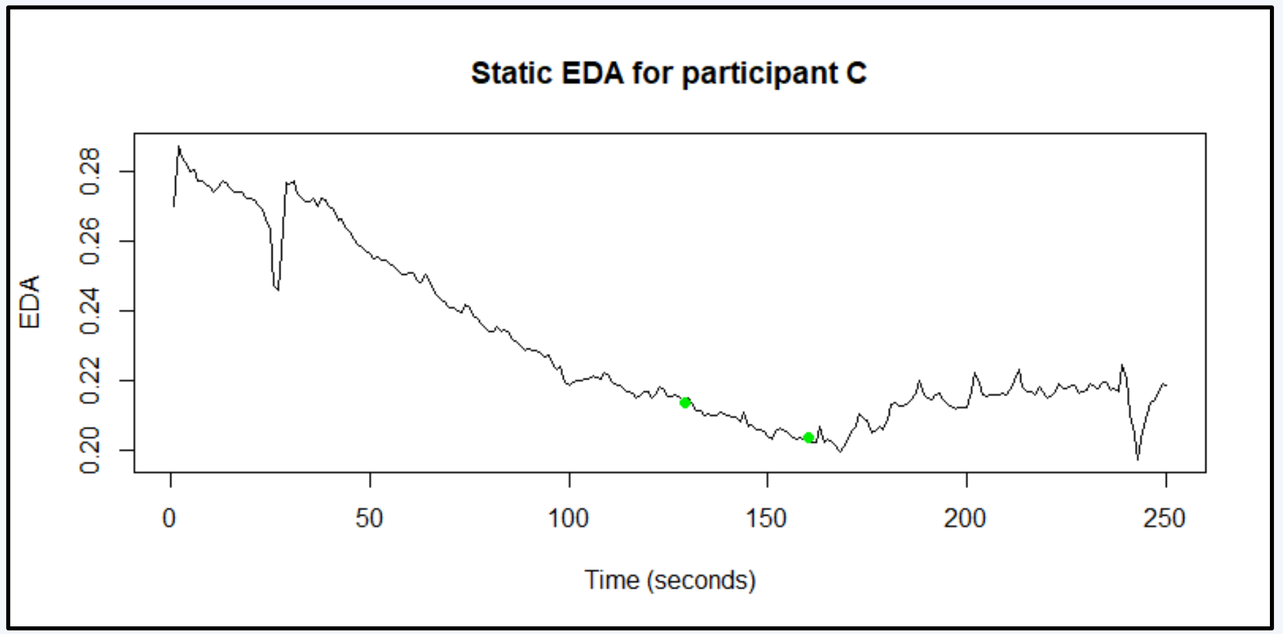




Results

Participant C — Static

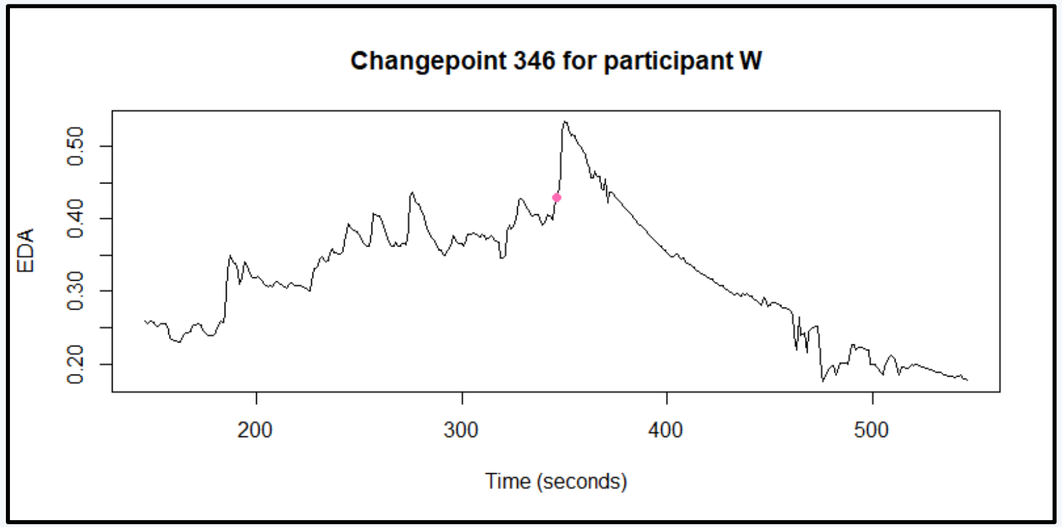
- Participant is watching a relaxing video before starting the first task

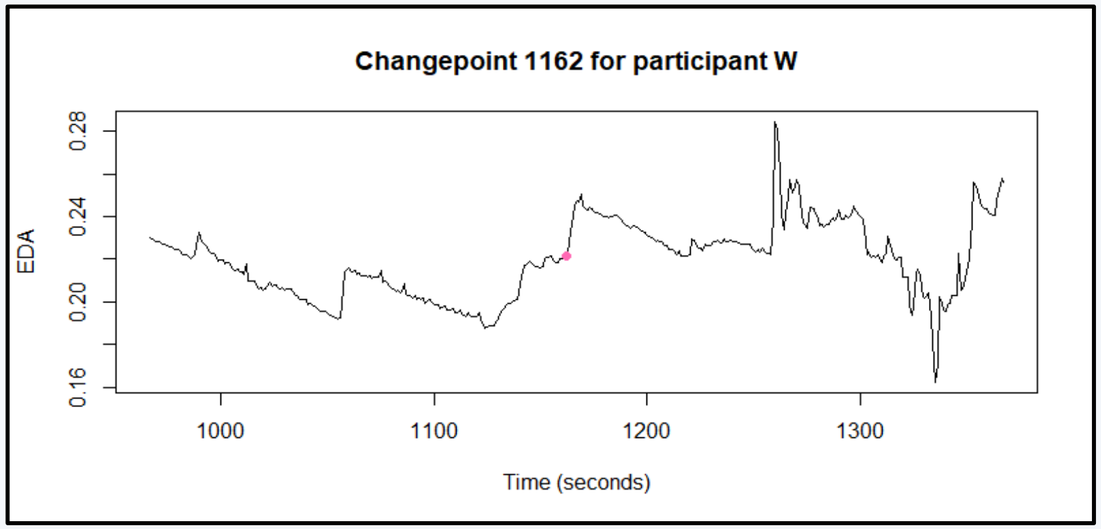


Results

Participant W — Changepoints

Changepoint (s)	Changepoint (mins)	Observations
346	8:09	• Changepoint occurs 9 seconds after W says that she's ok with the answer, but it is not the pattern she would have chosen to describe the set of numbers.
1162	21:45	• Changepoint occurs during 4th activity, 9 seconds after Minzhi points to the computer screen to tell her that she can move on to another puzzle.

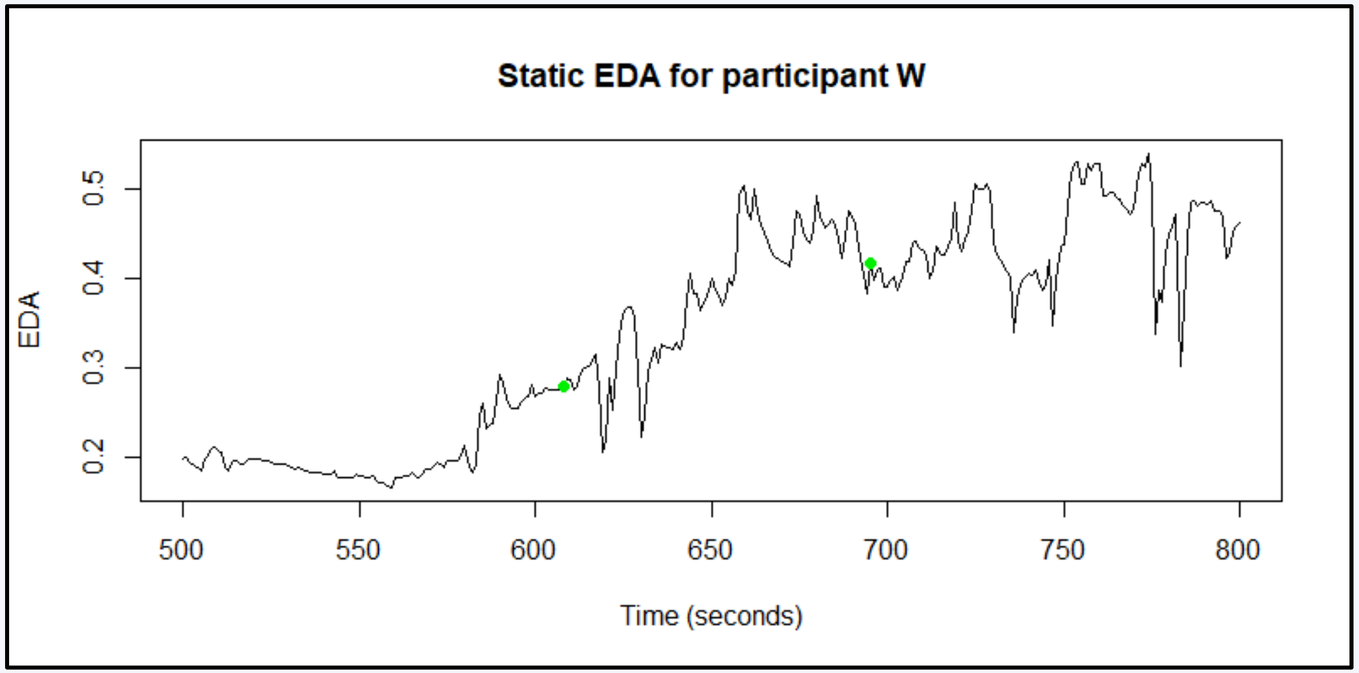




Results

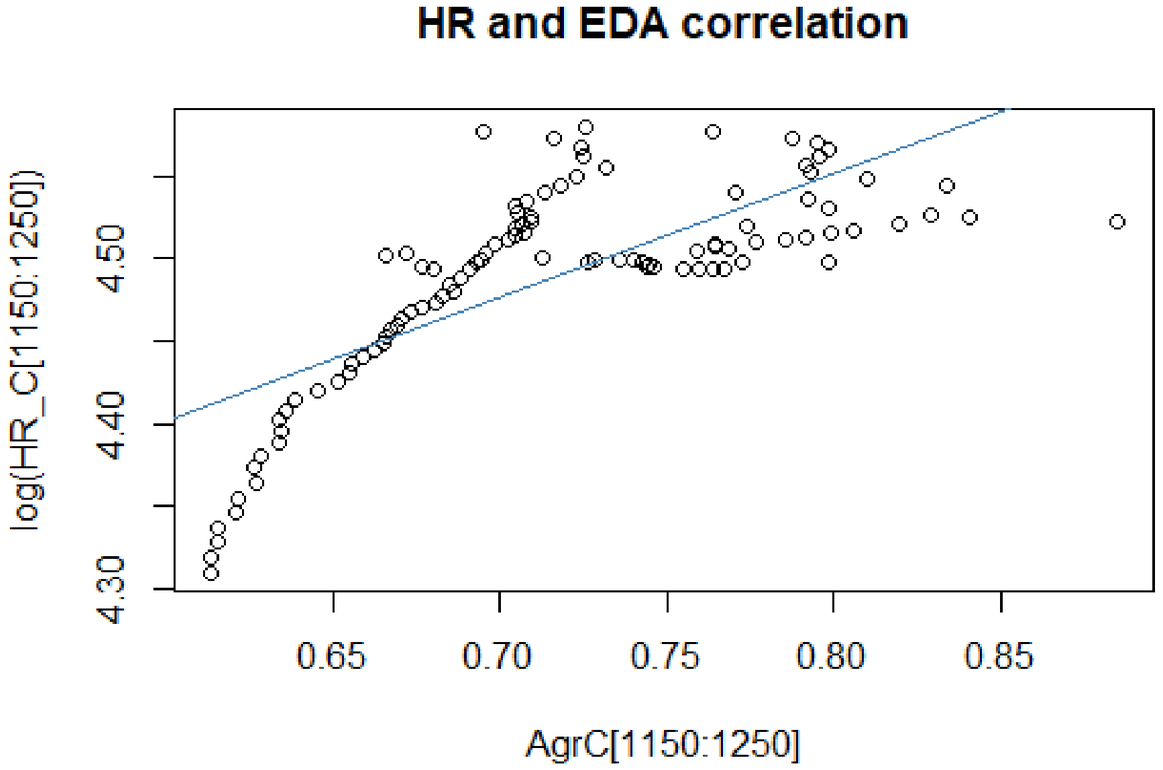
Participant W — Static

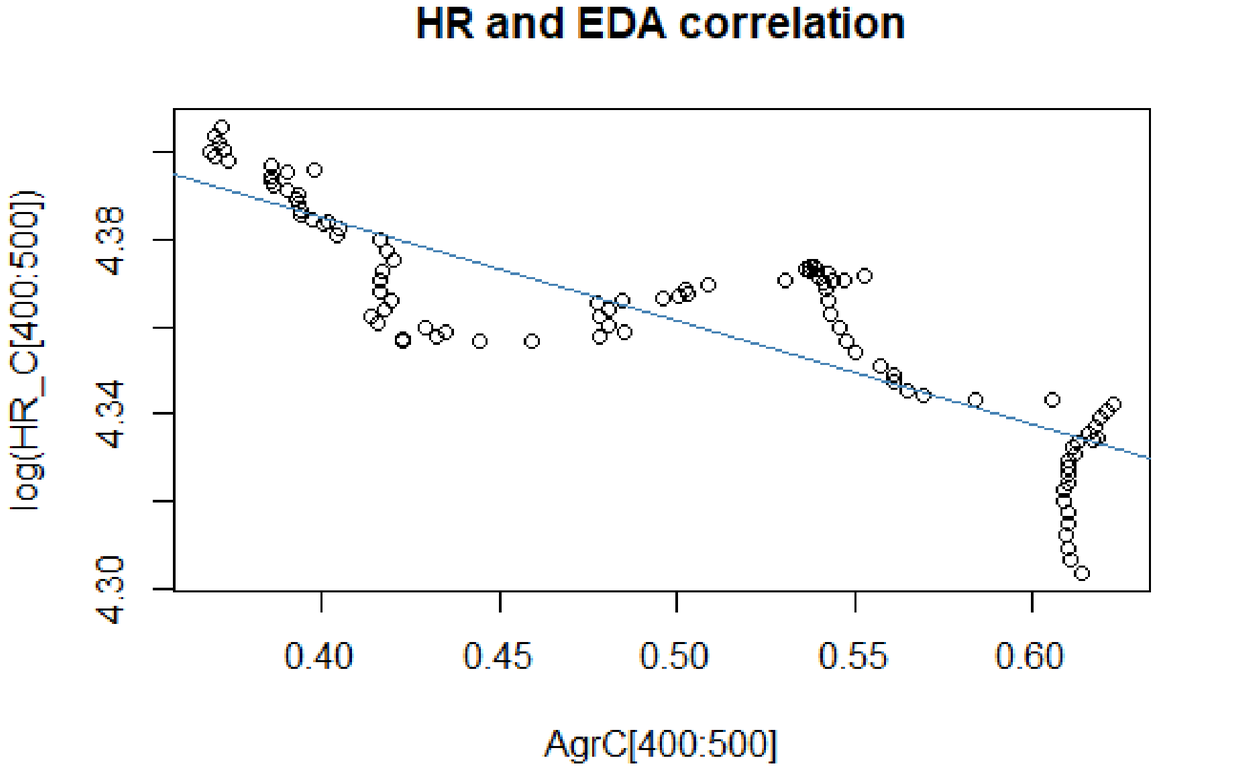
- Participant is describing her strategy for solving the bat and ball activity
- Participant expresses her confidence in solving mathematical questions
- Static window ends as participant discusses her current major



Results

Comparing HR and EDA





Future Work

- Use of the joint model to simultaneously consider multiple variables such as heart rate and electrodermal activity in order to faster detect peaks of engagement.

- Borrow strength from blood volume pressure to improve the accuracy or precision of estimates or predictions.

- Analyse the connection between the engagement and intellectual humility.

Conclusions

- EDA gives insight as to when participants are experiencing moments of engagement and non-engagement
- Guide for learning
- Allows instructors to recognize when students are engaged as well as when they are experiencing discomfort

References

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Enid Blyton

Questions?