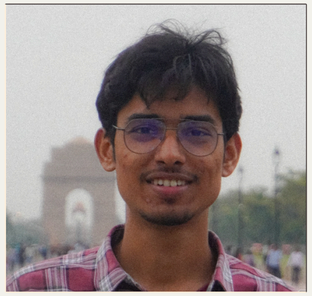
EEG AND DECISION GAME-BASED PREDICTION OF TRAIT ANXIETY

Presented by: Infirmity of Purpose

GROUP MEMBERS



Ahmad Raza

Manasvi Nidugala

Anya Rajan

Poojal Katiyar

Debarpita Dash

Nischay Patel

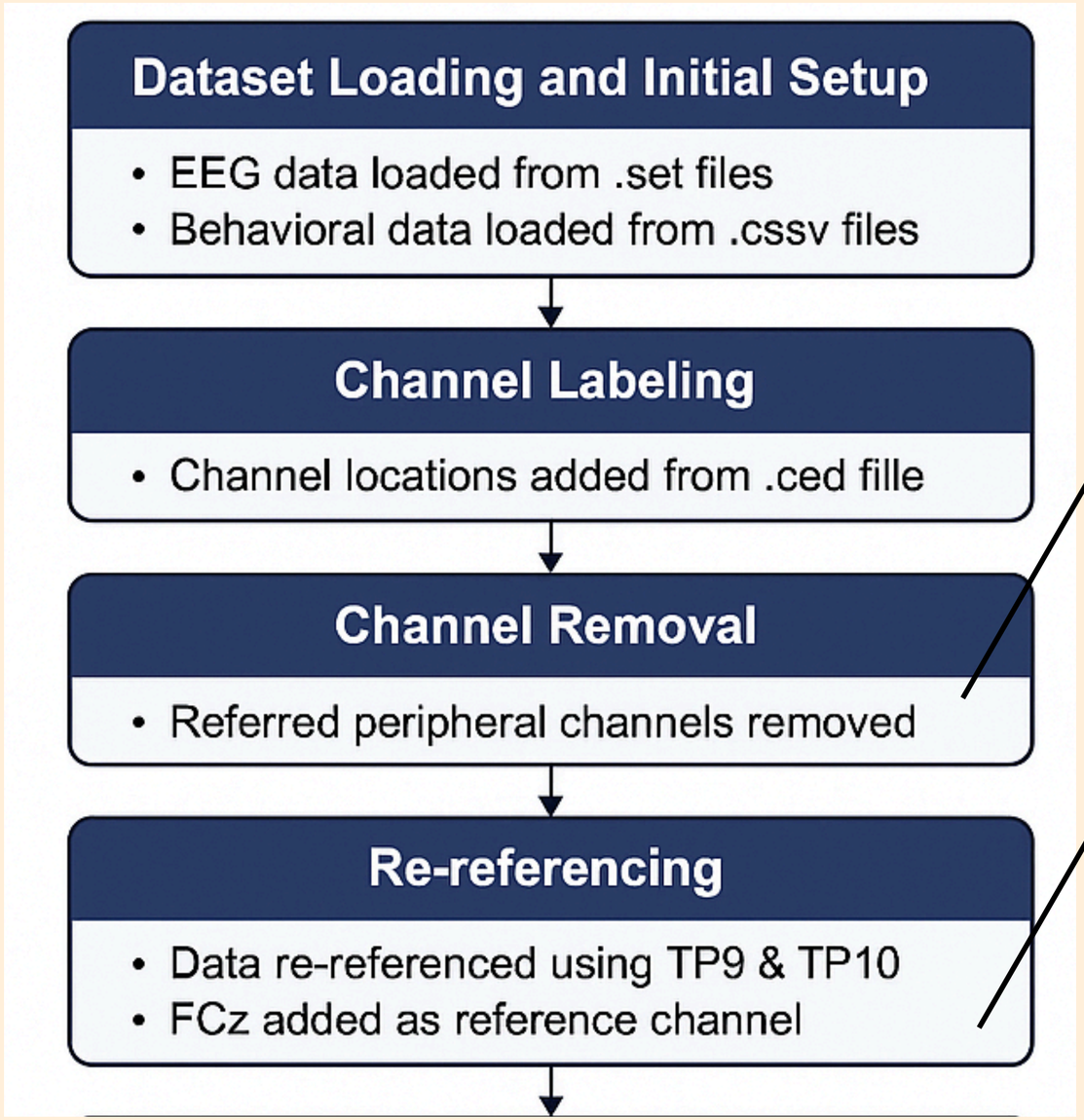
WHAT DO WE WANNA DO IN OUR PROJECT?

-predict trait anxiety from features we have extracted

-see dependence between game parameters and behavioral data on EEG features

-predict tendency of stay and leave using EEG features

DATA PREPROCESSING



FP9 & FP10 Removed (Often noisy and prone to muscle and movement artifcats)

FCz was added back as it was removed after initial EEG data collection. Fcz was the original Reference channel

DATA PREPROCESSING

Notch and Bandpass Filtrering

- Notch filter at 50 Hz
- High-pass filter at 0. 5 Hz
- Low-pass filter at 49 Hz

Behavioral Label Assignment

- Event markers “c" used for decisions
- Behavioral labels mapped to “c” events

Epoching

- Decision-related epochs extracted (-1000 to 100 ms)

Final Channel Cleaning

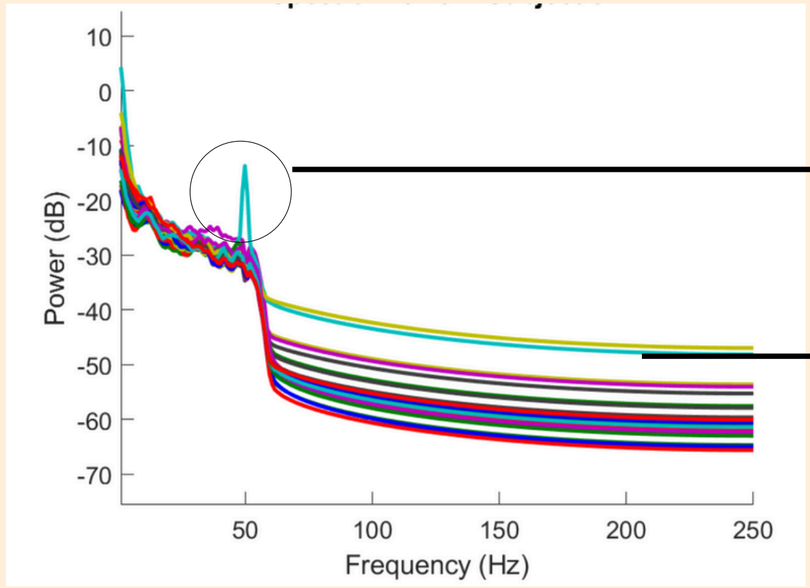
- Additional peripheral channels removed

Spectral Power Calculation

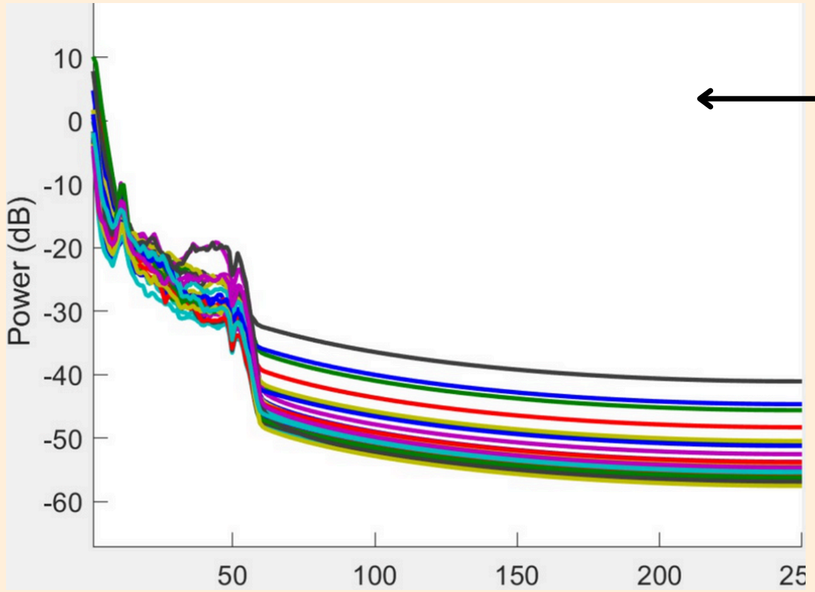
- Power spectral density calculated using spectoiopo

Frequency Band Analysis

- Power computed within Delta, Theta, Alpha, Beta, and Gammıa



Was removed from multiple particapants to clean the data



FEATURE EXTRACTION

1. SAMPLE ENTROPY
2. EVENT-RELATED POTENTIALS
3. PHASE-AMPLITUDE COUPLING
4. FRONTAL ALPHA COHERENCE
5. FRONTAL THETA COHERENCE

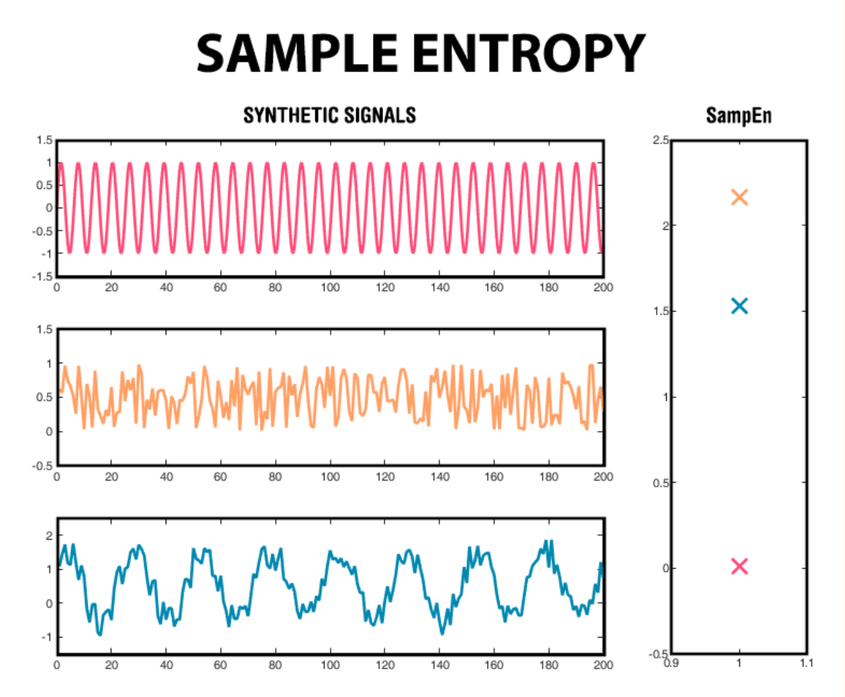
Sample Entropy

- Captures Non-Linear Dynamics: It is suited for analyzing complex, non-linear brain dynamics than traditional measures like mean or power.
- Measures Unpredictability: Quantifies the unpredictability of a signal by comparing matching patterns of length m and m+1.

$$\mathrm{SampEn}(m, r, N) = -\ln\left(\frac{A}{B}\right)$$

A = number of matches of length m+1

B = number of matches of length m



EVENT RELATED POTENTIALS(ERP)

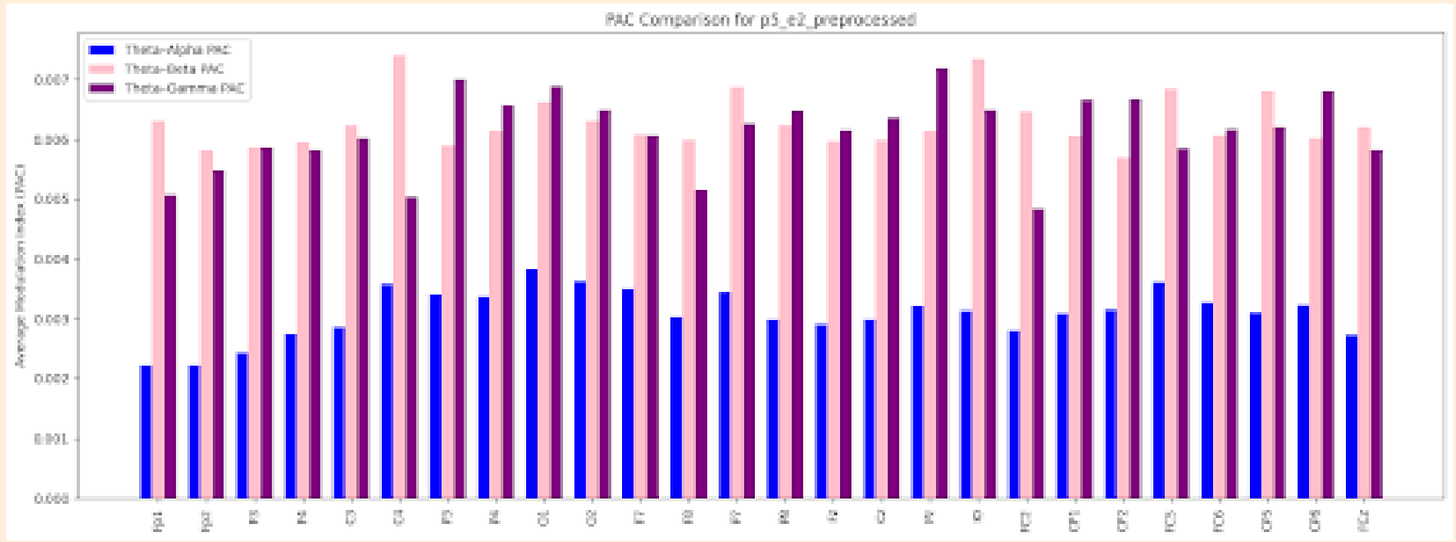
ERP Component	Latency	Electrodes	Function	Anxiety Link
P1	-0.05 to 0.05	Positive	Early visual attention	Altered P1 amplitudes in anxious individuals may reflect heightened early visual attention to threat-related stimuli.
N170	-0.10 to 0.00	Negative	Facial recognition and categorization	Increased N170 amplitudes in anxiety are often associated with enhanced processing of emotional or threatening facial expressions
N200	-0.10 to 0.00	Negative	Conflict monitoring and cognitive control	Enhanced N200 amplitudes in anxious individuals during tasks involving conflict or error detection, reflecting heightened conflict monitoring
P300	-0.10 to 0.10	Positive	Attention allocation and stimulus evaluation	Reduced P300 amplitude in high-anxiety individuals suggests diminished attentional resource allocation and impaired uncertainty processing

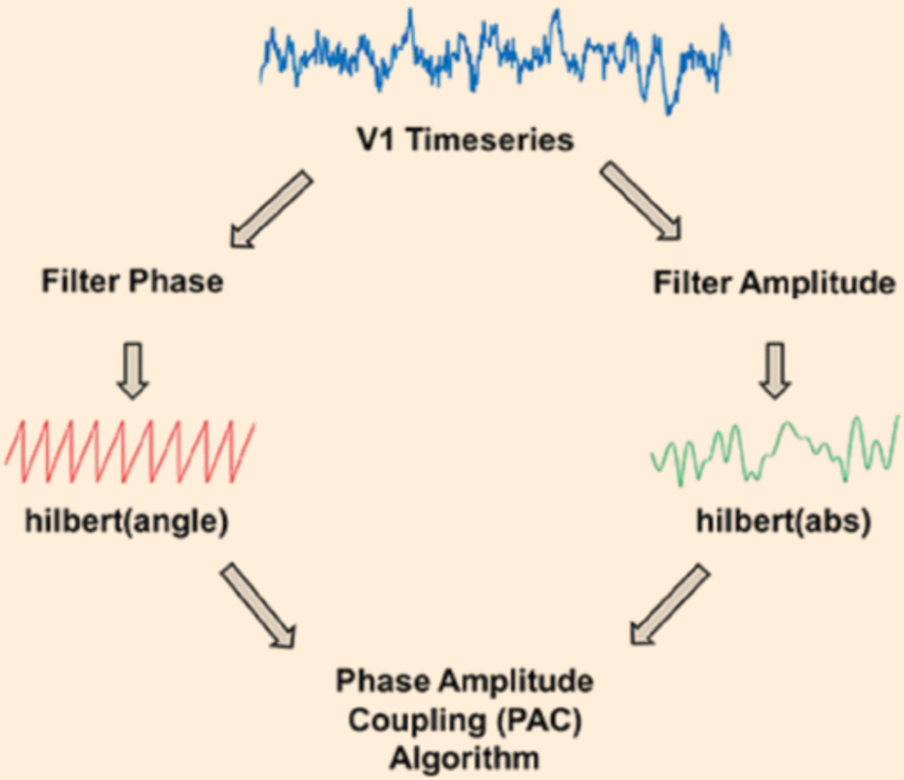
EVENT RELATED POTENTIALS (ERP)

ERP Component	Latency	Electrodes	Function	Anxiety Link
FRN	0.00 to 0.10	Negative	Feedback processing and outcome monitoring	Increased FRN amplitude in anxiety reflects greater sensitivity to perceived failure, punishment, or negative feedback.
LPP	0.00 to 0.10	Positive	Sustained emotional attention	Heightened LPP in anxious individuals is linked to sustained emotional attention, particularly toward emotionally salient or threatening stimuli
MMN	0.00 to 0.10	Negative	Detection of auditory deviation	Altered MMN responses in anxiety indicate hypervigilance and heightened automatic detection of auditory changes, even when irrelevant

Phase-Amplitude Coupling (PAC): Theta-Alpha/Beta/Gamma

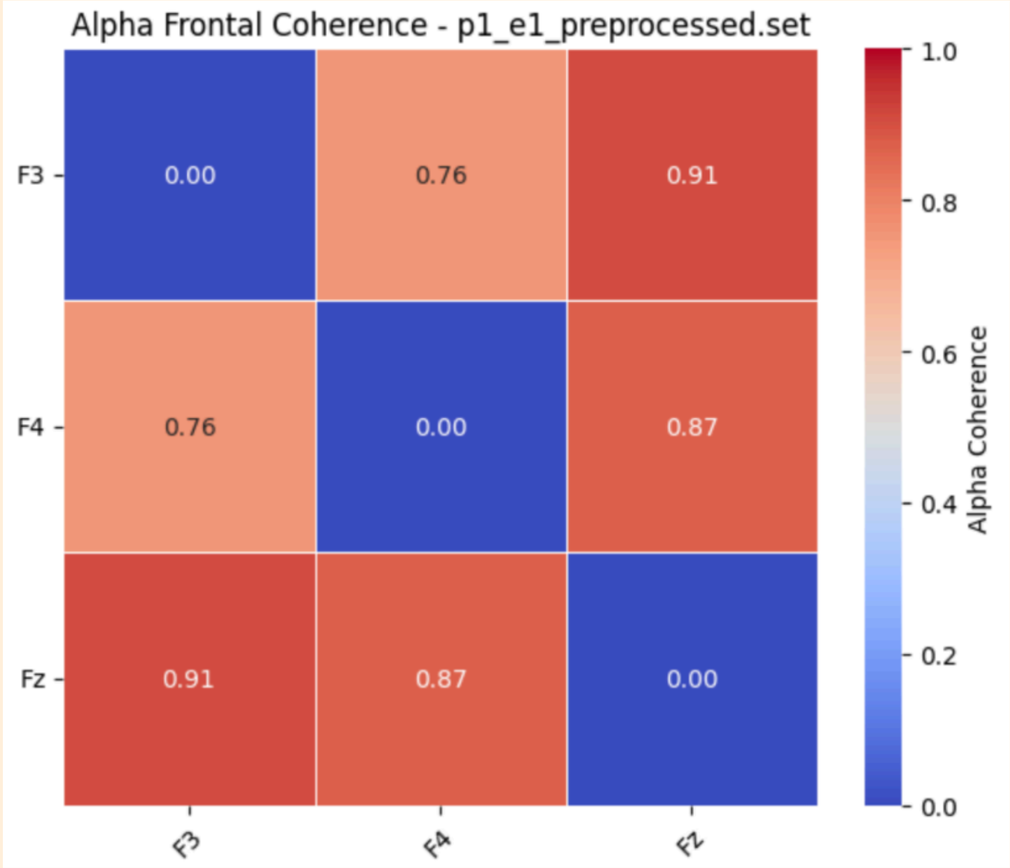
PAC measures how the phase of slower brain waves (e.g., theta) modulates the amplitude of faster waves. These metrics are calculated using an entropy-based Modulation Index (MI)





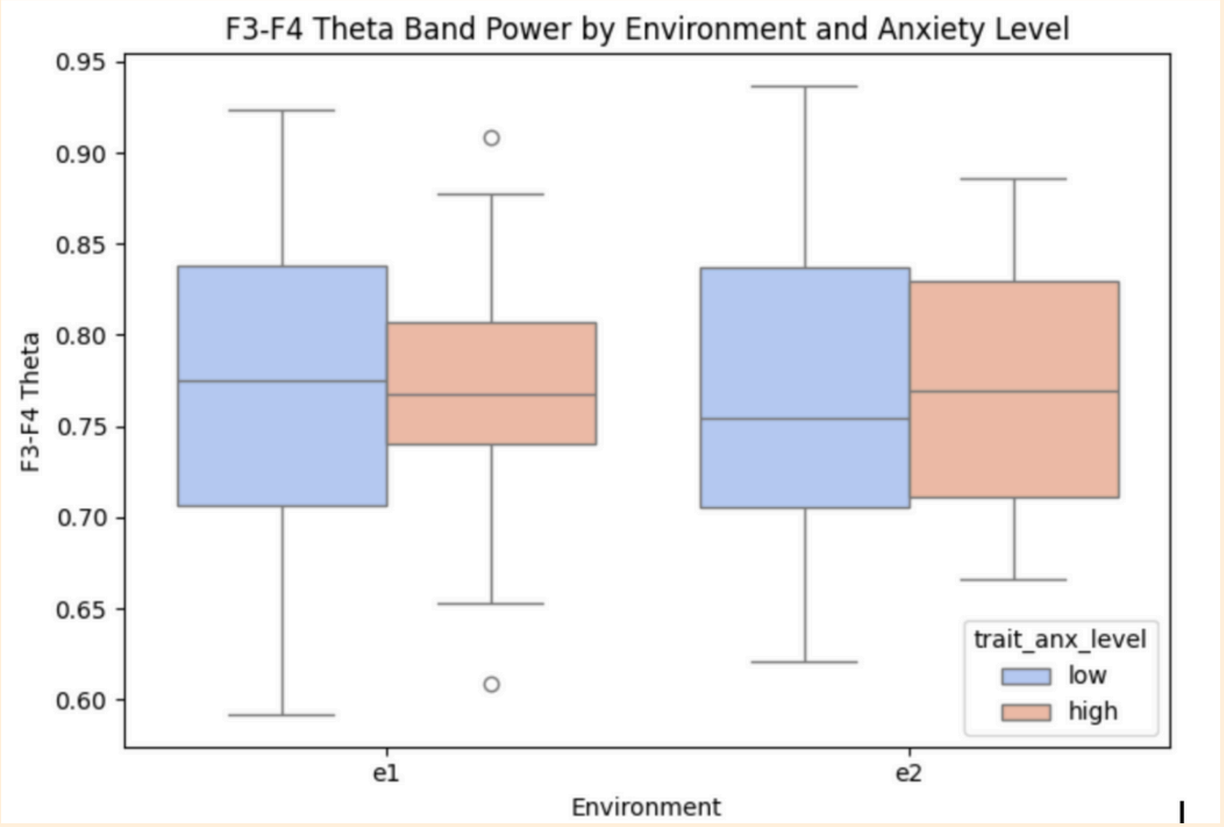
Alpha Band Coherence in Frontal Regions

Alpha coherence is a measure of the synchronization between different brain regions in the alpha frequency band (8–12 Hz), typically associated with relaxed and alert states. Reduced or altered alpha coherence can indicate impaired emotional regulation and cognitive flexibility, which are often observed in anxiety disorders.



Theta Band Coherence in Frontal Regions

Theta Band Coherence in Frontal Regions refers to the synchronization or connectivity of brain regions in the frontal lobe in the theta frequency band (4-8 Hz). Theta brain waves are often associated with emotional processing, deep relaxation, meditation, and cognitive tasks such as memory retrieval.

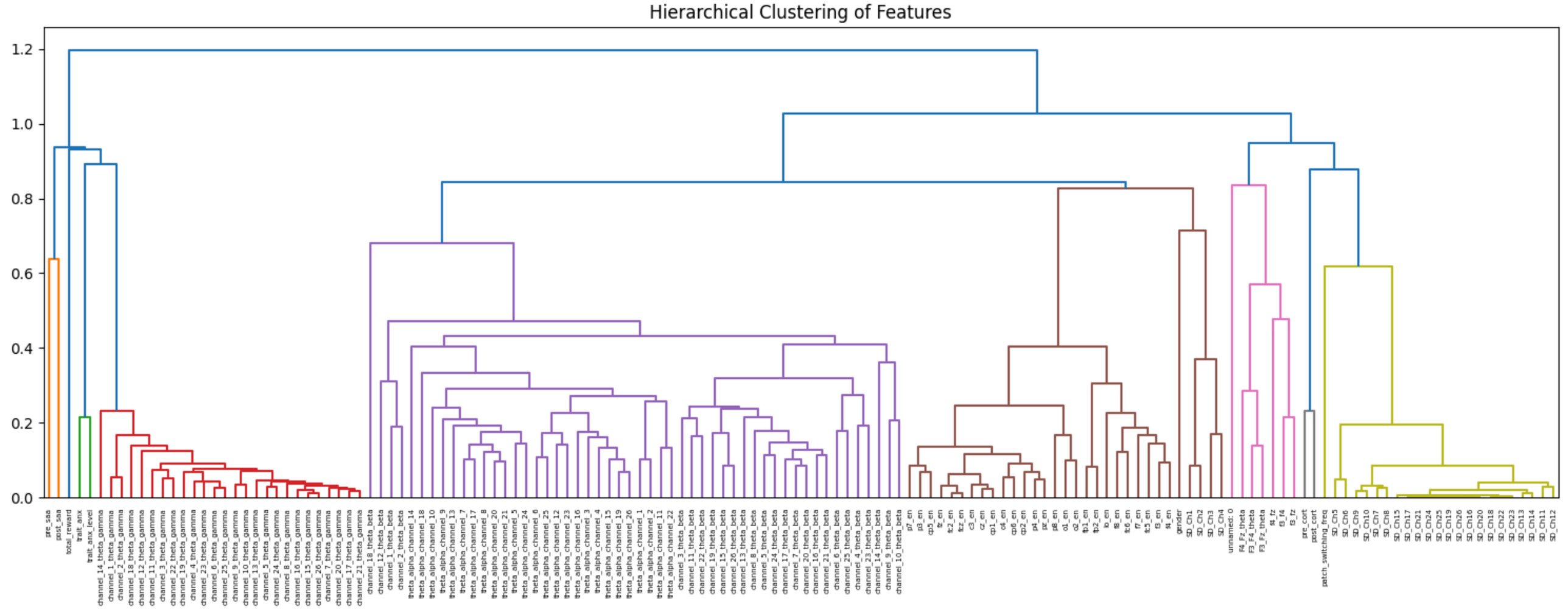


DENDROGRAM

PARTICIPANT WISE:

We see the following clusters:

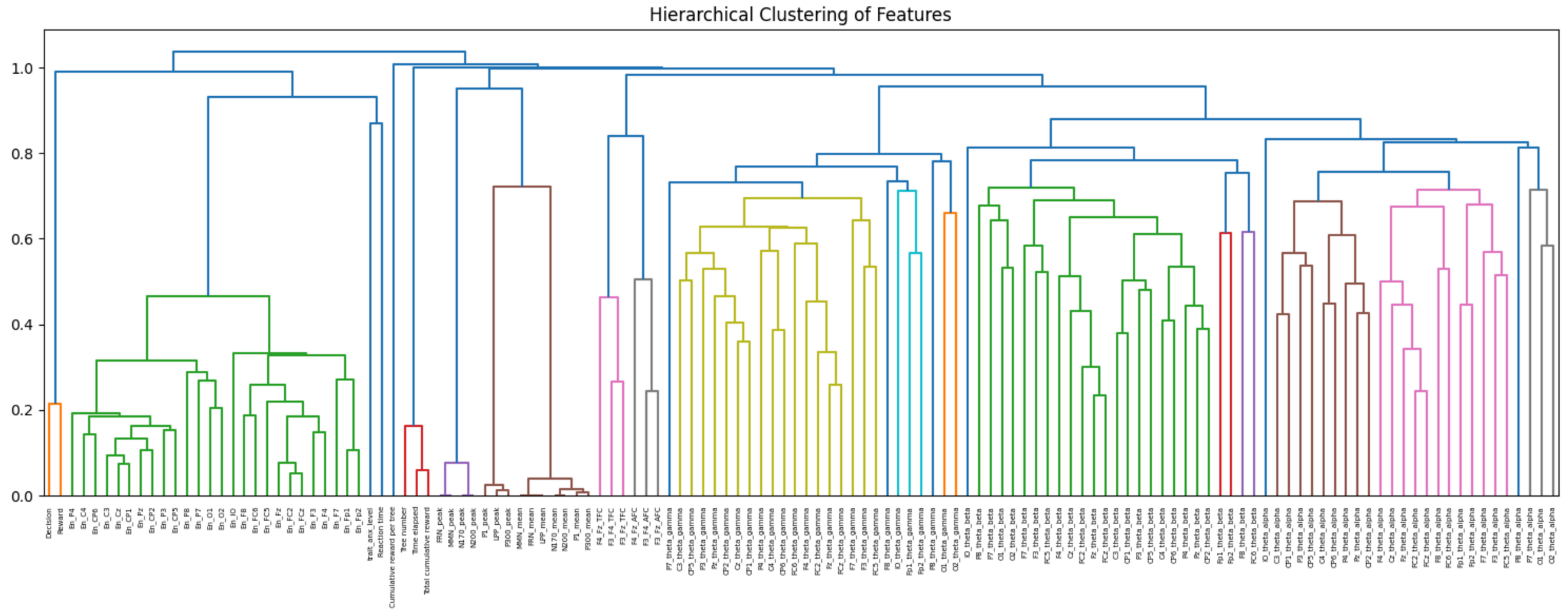
- Total_reward - theta_gamma - saa
- Patch_switching_freq - sd_ch - cort
- Trait_anx - coherence



DENDROGRAM

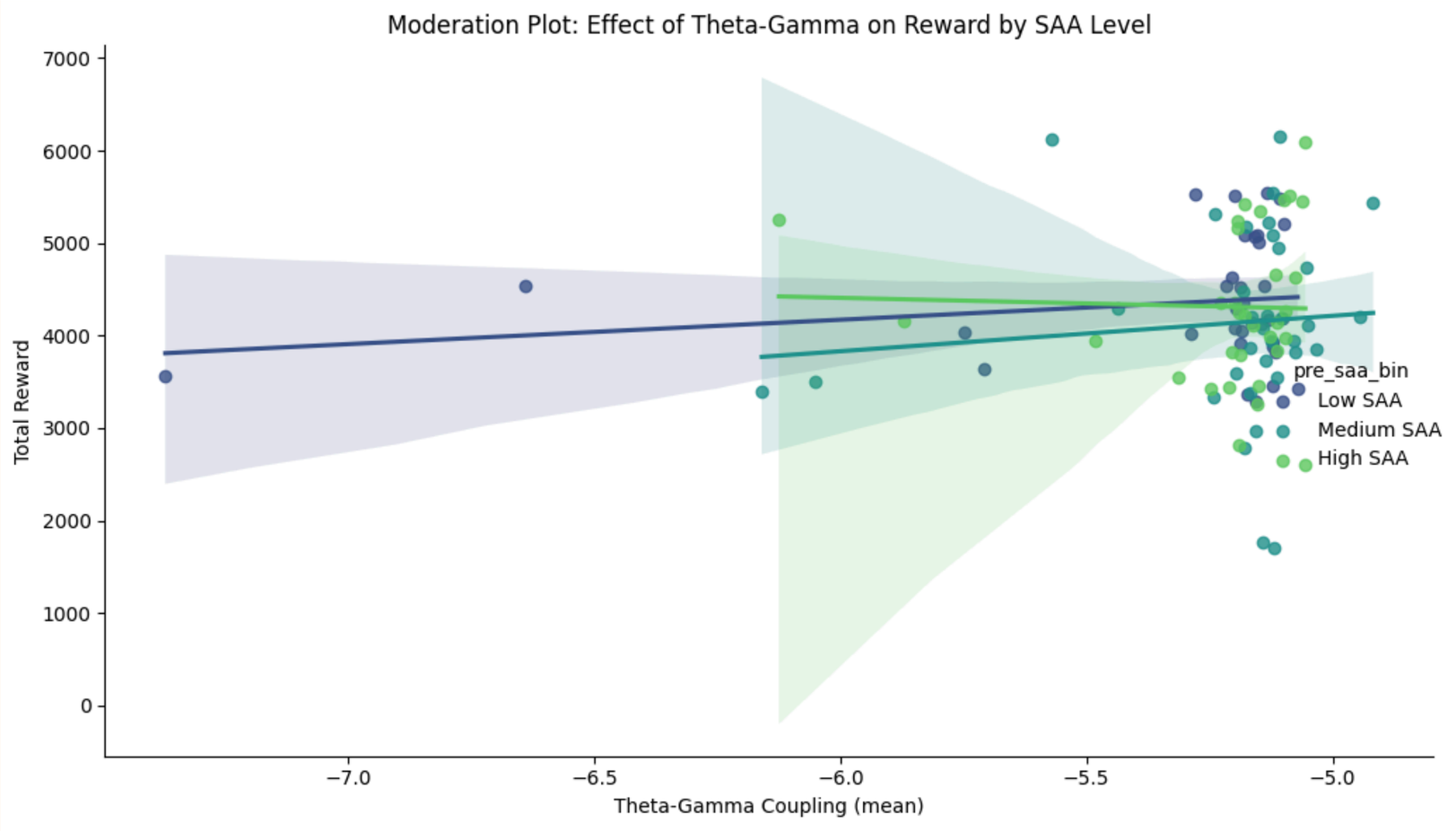
ALL EPOCHS:

We see the following major clusters:
Decision - Reward
Train_anx - Reaction_time - Entropy
Tree number - time_elapsed - total_cumulative_reward



MEDIATION AND MODERATION

- **SAA (Salivary Alpha-Amylase)**: Biomarker of sympathetic nervous system activity
- **Theta-Gamma Coupling:** Linked to cognitive control and memory integration
- **Combined approach:** Tests both mediation ("through what mechanism?") and moderation ("under what conditions?")



MEDIATION AND MODERATION

Aspect	Details
Model Fit	Poor fit: R-squared = 0.015; adjusted R-squared = -0.016 (minimal explanatory power).
Model Significance	Non-significant overall: F-statistic = 0.4714, $p = 0.703$.
Predictor Significance	No significant predictors: Theta-gamma coupling ($p = 0.958$), Pre-SAA levels ($p = 0.703$), Interaction term ($p = 0.699$).
Interaction Term	Coefficient = 74.8126, $p = 0.699$ (no significant moderation).
Multicollinearity	High condition number (3.12e+03), indicating strong multicollinearity and unreliable coefficient estimates.

Although visual trends suggest slope differences across SAA groups, statistical analysis finds no evidence of moderation. High variability and multicollinearity limit the interpretability of results. We need a lot more data to effectively utilise this model.

PREDICTING TRAIT ANXIETY USING ML MODELS

Using Baseline models

- Random Forest with 5-fold stratified cross-validation

whose mean CV Accuracy: 0.74 ([0.7, 0.85, 0.8, 0.6, 0.75])

- Model Comparison: (80:20 split, no CV) vs CrossValidation
- Smote applied on training data for class balanace
- PCA applied for differenct channels data

Key Findings:

- Random Forest overfits without CV.
- Gradient Boosting (CV accuracy: 0.711) is most reliable

No significant change in pre-SAA and post-SAA levels

ACCURACY(WITHOUT CV USING 80:20 SPLIT):

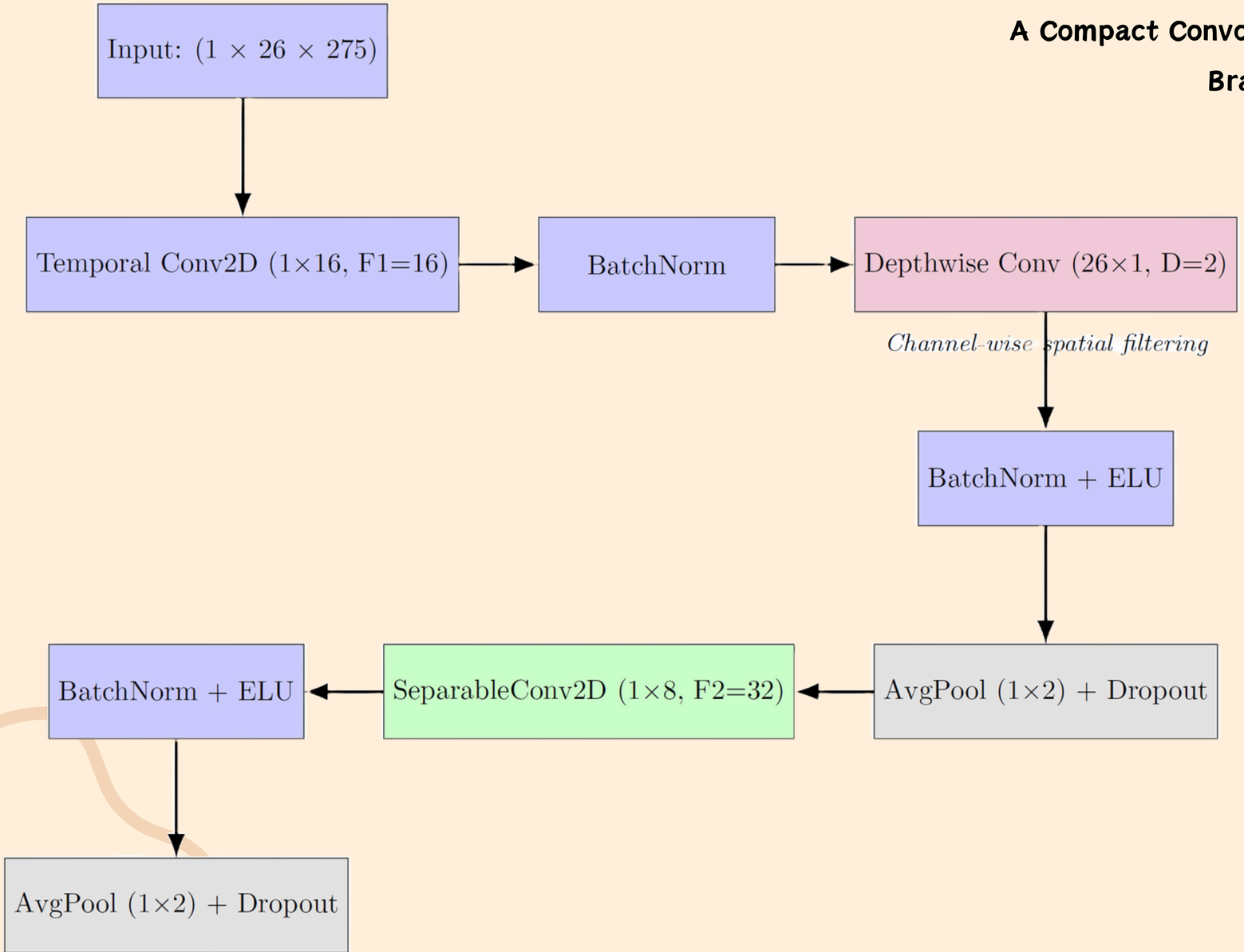
MODEL	ACCURACY	F1 SCORE
RANDOM FOREST	0.90	0.898
GRADIENT BOOSTING	0.75	0.749
MLP NEURAL NETWORK	0.65	0.651
KNN	0.65	0.637
SVM	0.55	0.547
LOGISTIC REGRESSION	0.45	0.446

ACCURACY(WITH CV):

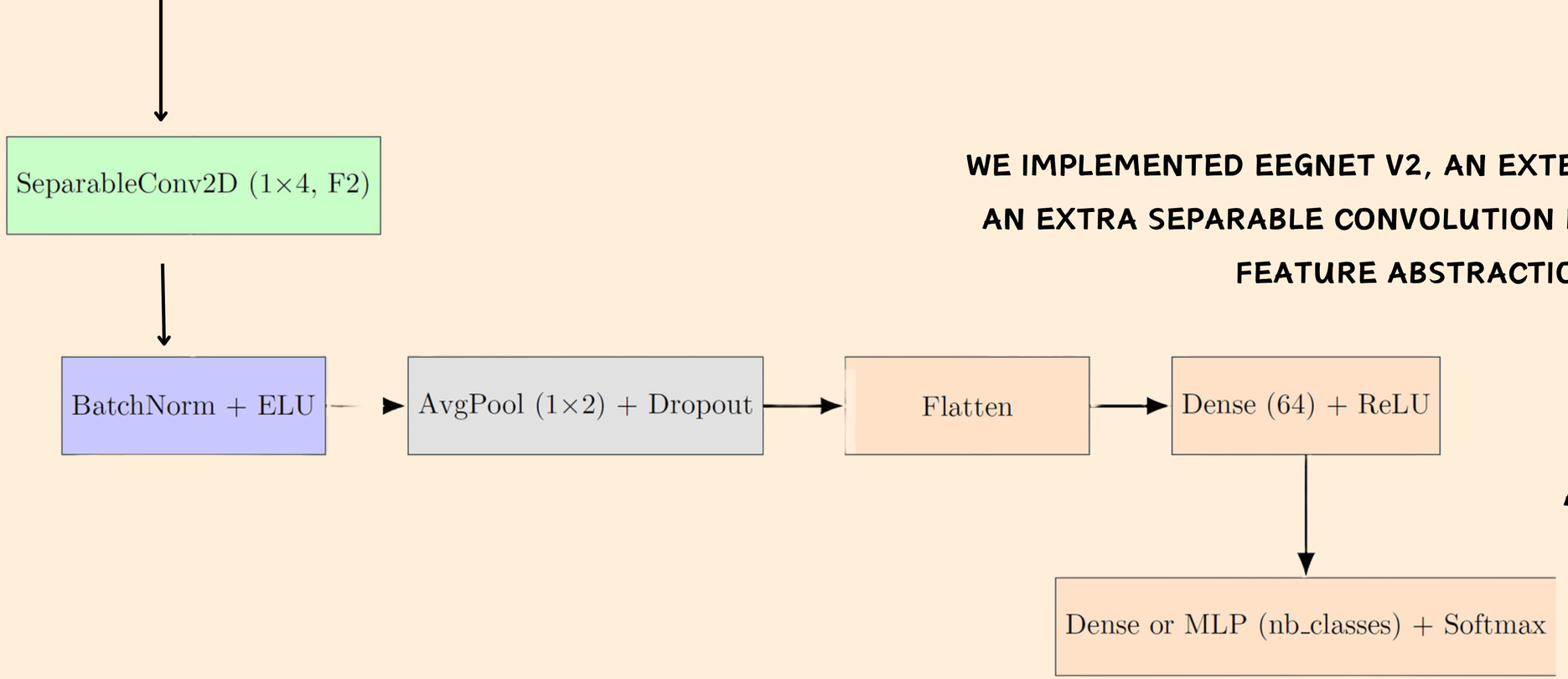
MODEL	ACCURACY	F1 SCORE
GRADIENT BOOSTING	0.71	0.68
RANDOM FOREST	0.67	0.70
MLP NEURAL NETWORK	0.68	0.70
KNN	0.63	0.62
SVM	0.63	0.62
LOGISTIC REGRESSION	0.58	0.58

PREDICTING TRAIT ANXIETY USING EEGNET

A Compact Convolution Neural Network for EEG-based Brain Computer Interfaces



ARCHITECTURE OF APPLYING EEGNET



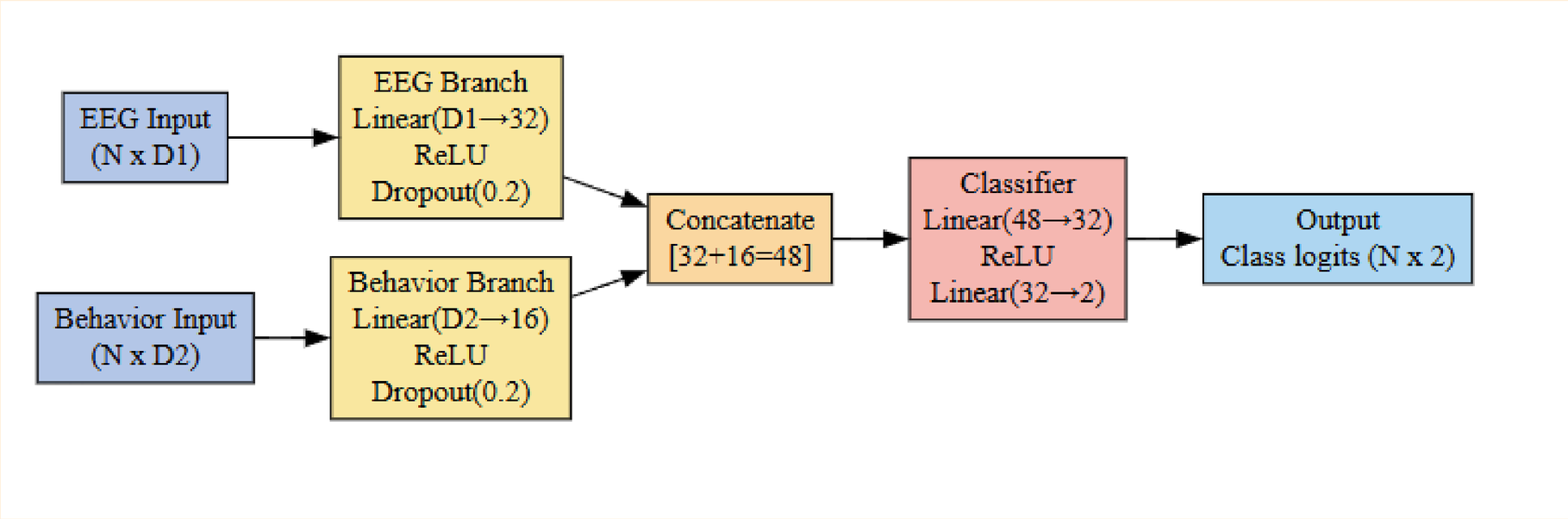
WE IMPLEMENTED EEGNET V2, AN EXTENDED VERSION WITH AN EXTRA SEPARABLE CONVOLUTION BLOCK TO ENHANCE FEATURE ABSTRACTION.

ARCHITECTURE OF APPLYING EEGNET

1. MODEL	ACCURACY	LOSS
2. ENV1 WITH DENSE	0.71	0.68
3. ENV1 WITH MLP	0.66	0.749
4. ENV2 WITH DENSE	0.70	0.55
5. ENV2 WITH MLP	0.67	0.62

PREDICTING STAY-LEAVE USING MULTI MODAL CLASSIFICATION

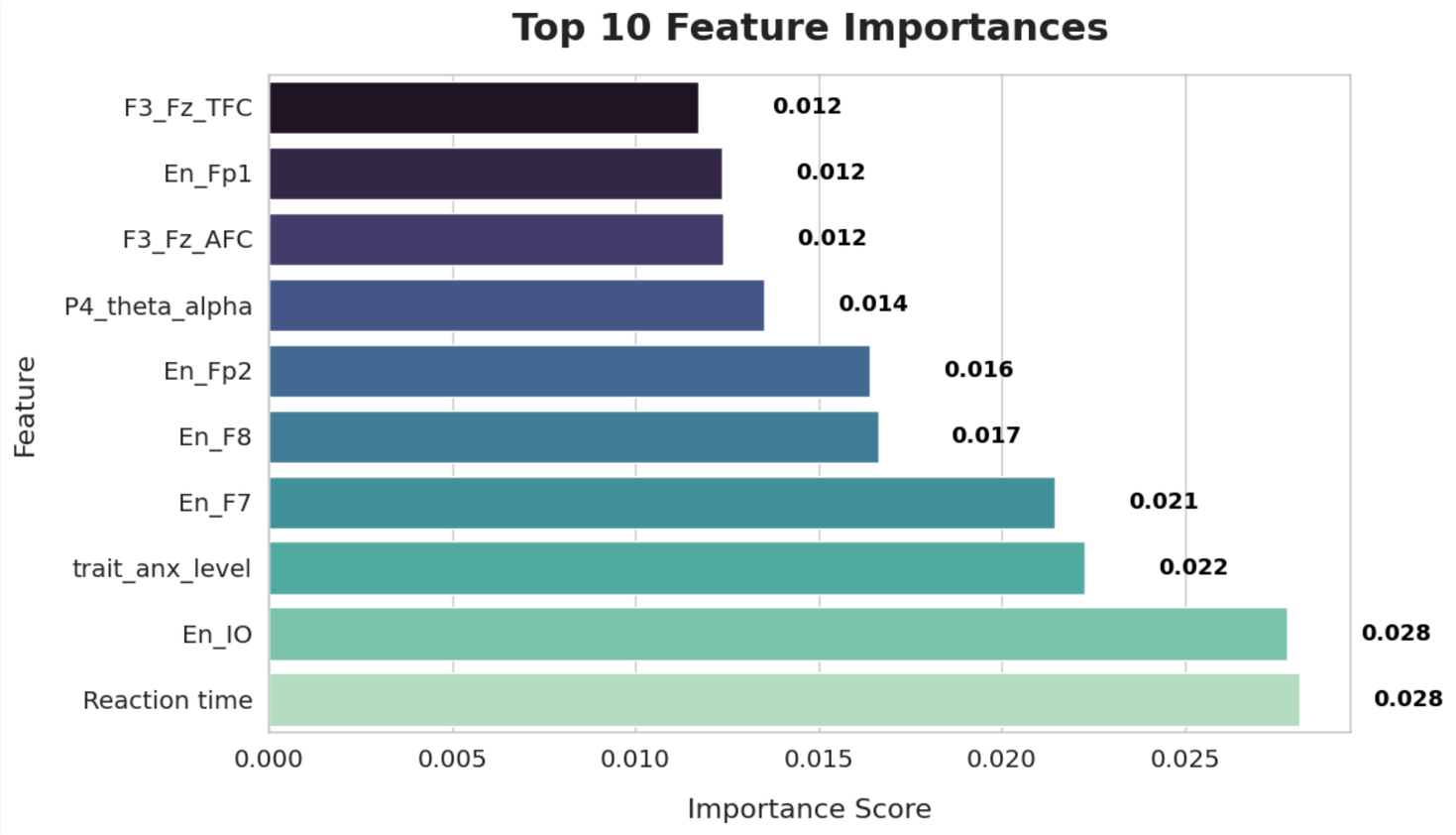
- To exploit complimentary information from both EEG and behavioral features we implemented a multimodal classification model
- Class weighting was used to tackle class imbalance
- Model trained for 10 epochs using Adam optimiser and weighted cross entropy loss
- Test accuracy: 97.03%



PREDICTING STAY-LEAVE USING RANDOM FOREST

Understanding which features most influence the model's predictions provides interpretability and can inform future research.

- Extracted feature importances from the trained Random Forest.
- Visualized all feature importances and highlighted the top 10 most important features.



PREDICTING STAY-LEAVE USING RANDOM FOREST

	precision	recall	f1-score	support
leave	0.84	0.90	0.87	1292
stay	0.89	0.83	0.86	1291
accuracy			0.86	2583
macro avg	0.87	0.86	0.86	2583
weighted avg	0.87	0.86	0.86	2583

Fig 1

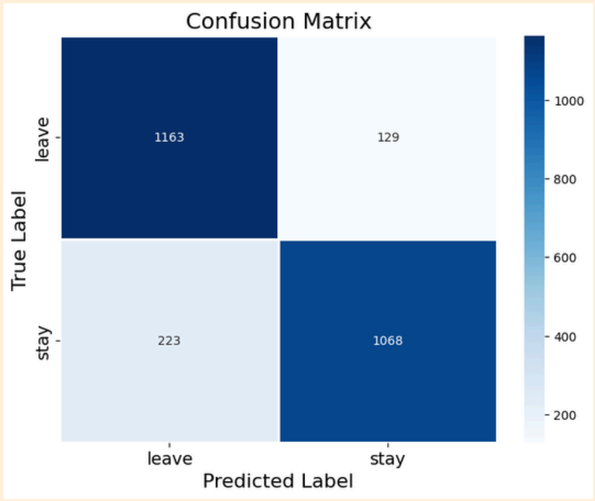


Fig 2

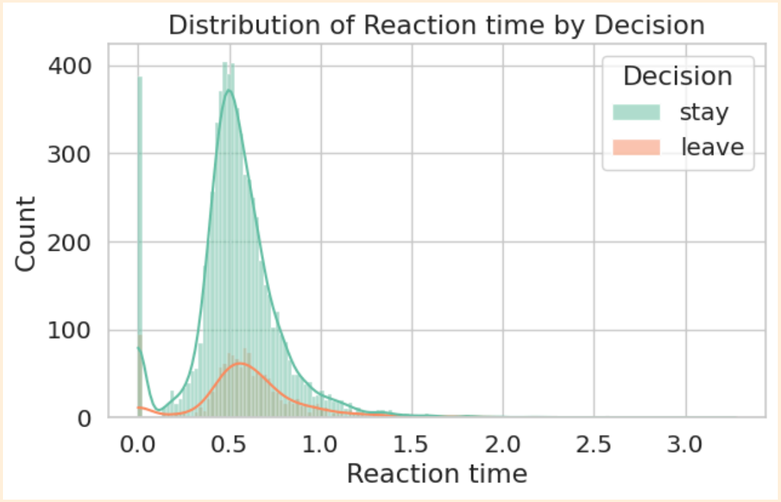


Fig 3

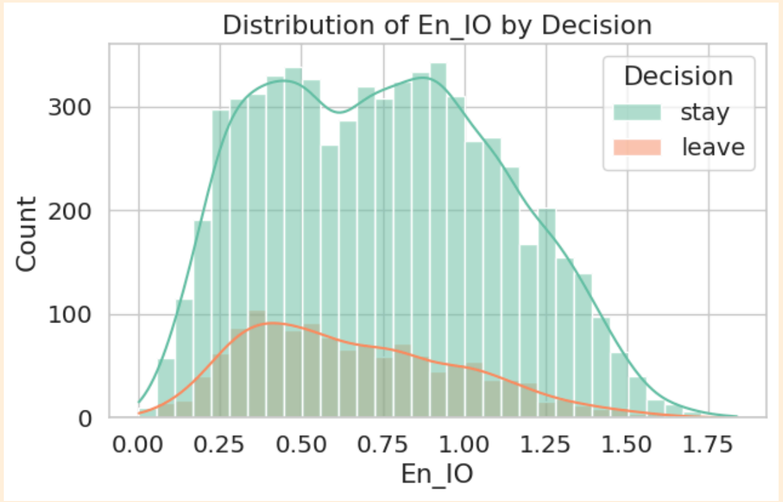


Fig 4

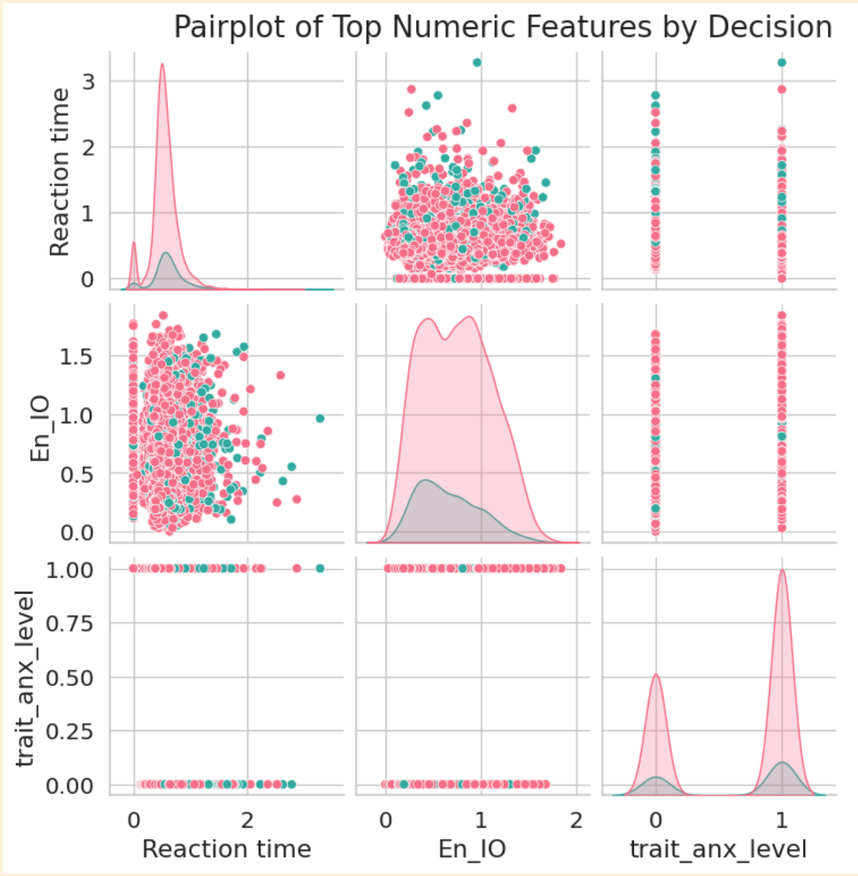
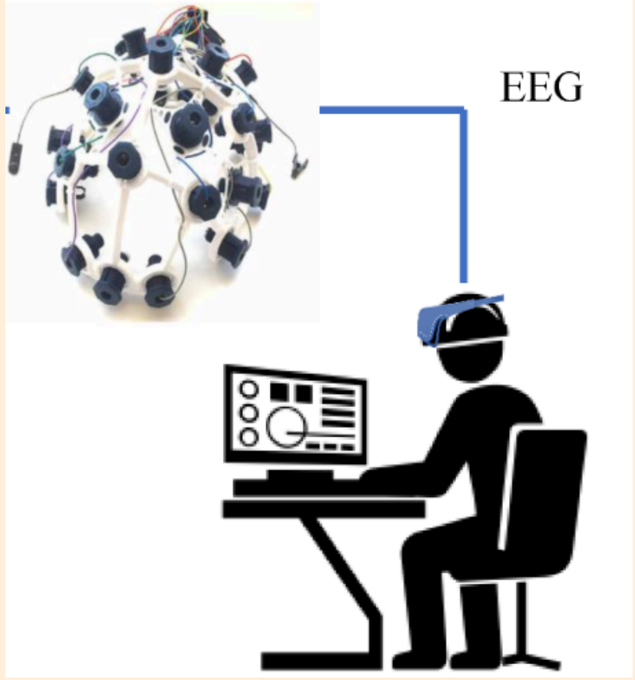


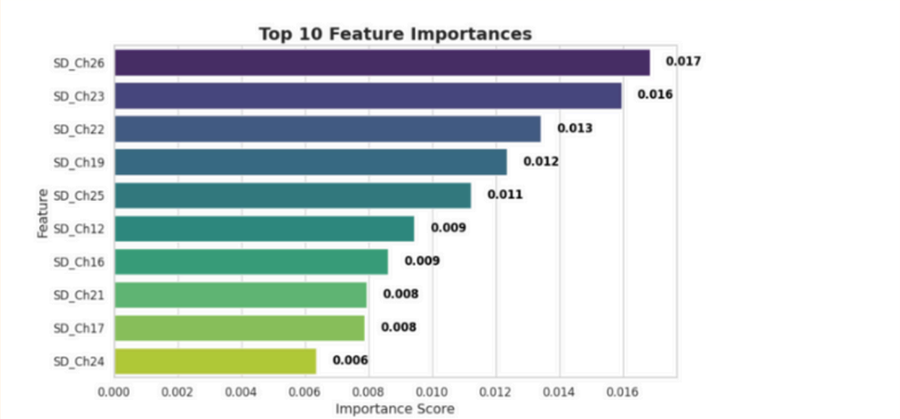
Fig 5

PREDICTING GAME PARAMETERS AND BEHAVIORAL FEATURES FORM EEG FEATURES

PARTICIPANT WISE DATA RESULTS

Feature Predicted	Feature Used	Best Model	Performance Metrics
Patch Switching Frequency	SD of Entropy	MLP Regressor	$R^2 = 0.1045$, RMSE = 8.0836
Cortisol Variation	SD of Entropy	Lasso Regression	$R^2 = 0.1522$, RMSE = 8.8491
Trait Anxiety (Alpha Frontal)	Alpha Frontal	Logistic Regression	Accuracy = 56%
Trait Anxiety (Theta Frontal)	Theta Frontal	KNN	Accuracy = 56%





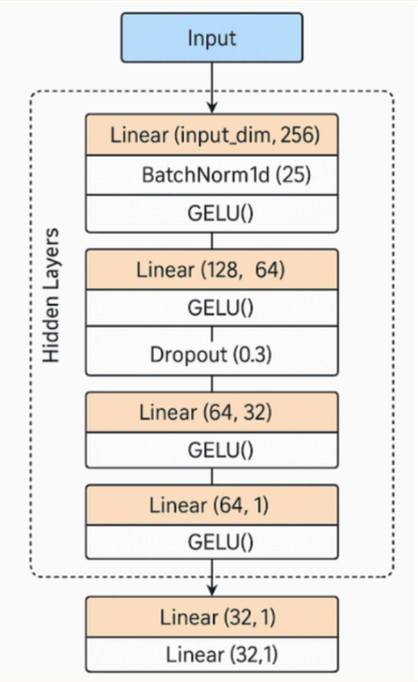
EEG Entropy's role in predicting patch switching behavior.

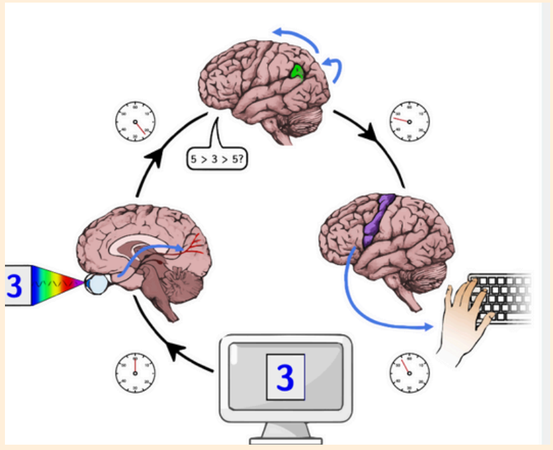
PREDICTING GAME PARAMETERS AND BEHAVIORAL FEATURES FORM EEG FEATURES

EPOCH-WISE DATA RESULTS

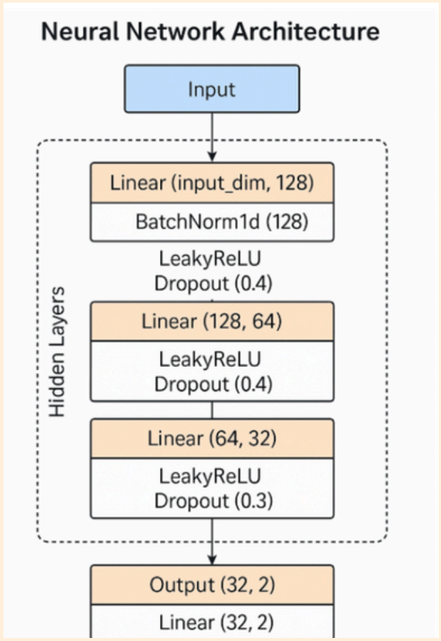
Feature Predicted	Feature Used	Performance Metrics
Reaction Time	Mean of Entropy	MSE: 0.0383, MAE: 0.1397, R^2: 0.2203
Decision	Mean of Entropy	Accuracy = 71.50%

Reaction time from entropy





Decision from entropy



CONTRIBUTIONS

The entire study was conducted by all 6 members of the group, and everyone contributed equally and understood the entire project.

THANK YOU!!