EEG-Based Attention Classification

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Motivation

The Problem

The Pomodoro technique (25 min study, 5 min break) may not suit everyone due to:

- Individual cognitive differences
- Task complexity
- Situational factors

Manually adjusting the timer is inefficient:

- Cutting study time short can disrupt deep focus
- Overextending can lead to fatigue and wasted time

Our solution

Goal: Develop a neurofeedback-based Pomodoro system that dynamically adjusts study and break durations using real-time EEG data.

- Analyze features like Alpha, Beta, and Theta wave activity to track attention levels
- Identify optimal measures of attention for accuracy
- Adapt session length based on focus fluctuations

Experimental Design

- **Thought about what experiment would be best given the constraints of EEG**
  - First wanted to do a writing task, easy math problems - low attention and summarize a text - high attention → too many artifacts
  - Thought of a listening task to avoid eye movements → didn't choose that because realized it wouldn't be able to record visual attention
  - Decided on lecture, on a small computer screen → tradeoff was better in this case

Experimental Design

- Have students watch a lecture for 10 minutes, take a 5 minute break, and another 10 minute break (25 minute recording) while recording their EEG data
- Participant Input (Keyboard Buttons):
  - 1 for “Lost focus”
  - 2 for “Focused Again”
  - 3 for “Lecture started”
  - 4 for “Lecture paused”

Data Collection

CH1: Fp1 -> Prefrontal region, associated with attention and cognitive control

CH2: Fp2, Same as Fp1

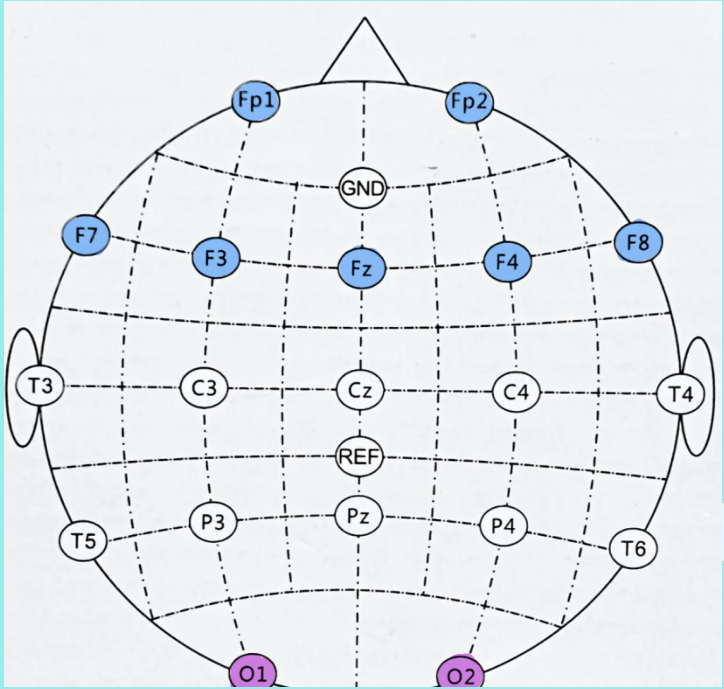
CH3: F3, Frontal lobe, linked to working memory and focus

CH4: F4, Right frontal region, complements F3 for hemispheric comparison

CH5: F7, Involved in processing complex cognitive tasks and emotional regulation

CH6: F8, Tracks frontal asymmetry, associated with focus and distraction

CH7: Fz, Central frontal, important for monitoring overall attention



Ground and reference at O1, O2 respectively

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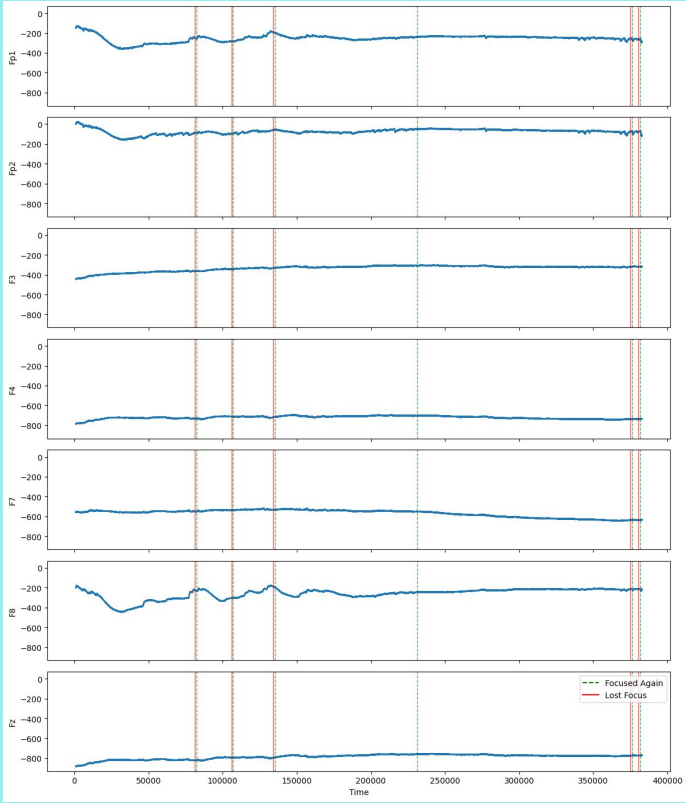
Our Dataset

	Timestamp	Fp1	Fp2	F3	F4	F7	F8	Fz	Time	Label
963	1.741819e+09	-147.644898	4.954151	-443.739489	-785.031405	-556.989579	-201.662482	-883.628357	4.325314	NaN
964	1.741819e+09	-145.115619	7.337559	-441.206712	-782.355754	-554.508257	-199.151686	-881.070603	4.325401	NaN
965	1.741819e+09	-143.203797	9.322317	-439.109053	-780.307552	-552.432079	-196.938129	-878.957957	4.325451	NaN
966	1.741819e+09	-145.126609	7.444465	-440.962426	-782.249847	-554.214515	-198.873930	-880.808832	4.325459	NaN
967	1.741819e+09	-147.495030	5.036579	-443.379804	-784.712185	-556.570447	-201.380729	-883.242196	4.325467	NaN

Analysis

Preprocessing and Filtering

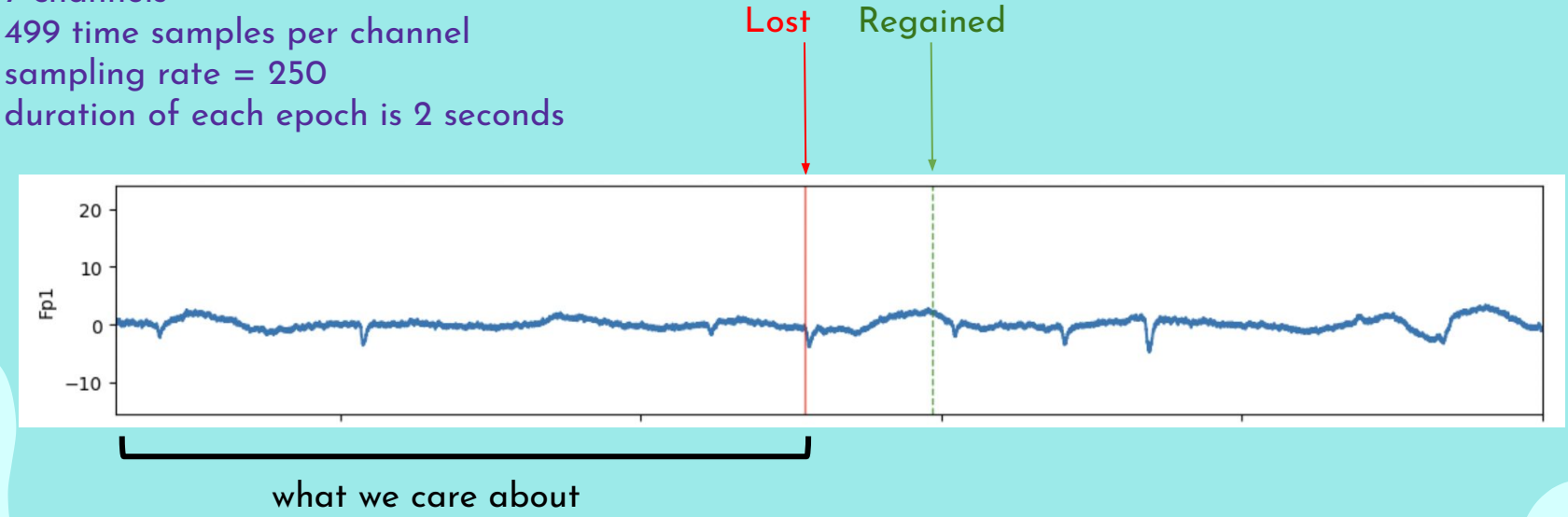
- Realigned time so that it starts at zero
- Dropped
  - unused channel (EEG_8)
  - flat line “zeros”
  - incorrect markers accidentally pressed: "Lecture Started/Paused" markers
- Merged EEG data with labels data
- Scaled EEG data by 0.02235 to convert raw EEG signal values
- Used a bandpass filter between 0.1 and 50 Hz, to filter out noise due to:
  - <0.1 Hz (e.g. shifting in seat, general movement)
  - >50 Hz (e.g. clenching jaw, eye blinks, electrical interference)

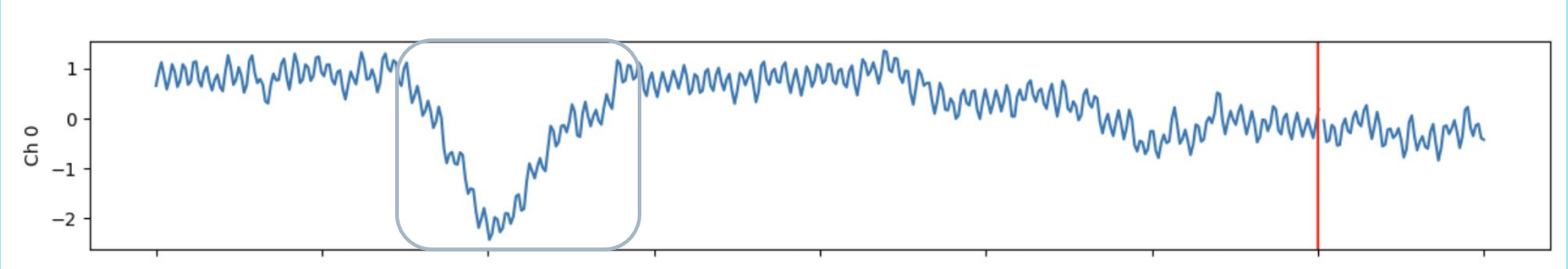


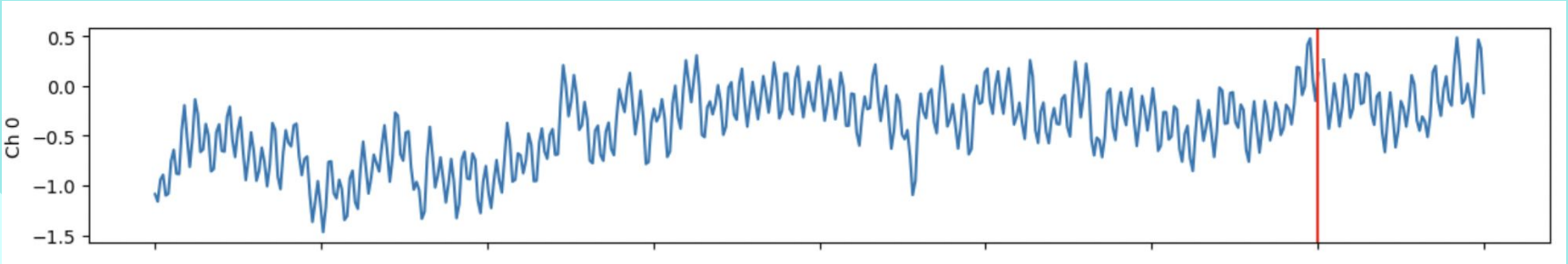
Analysis

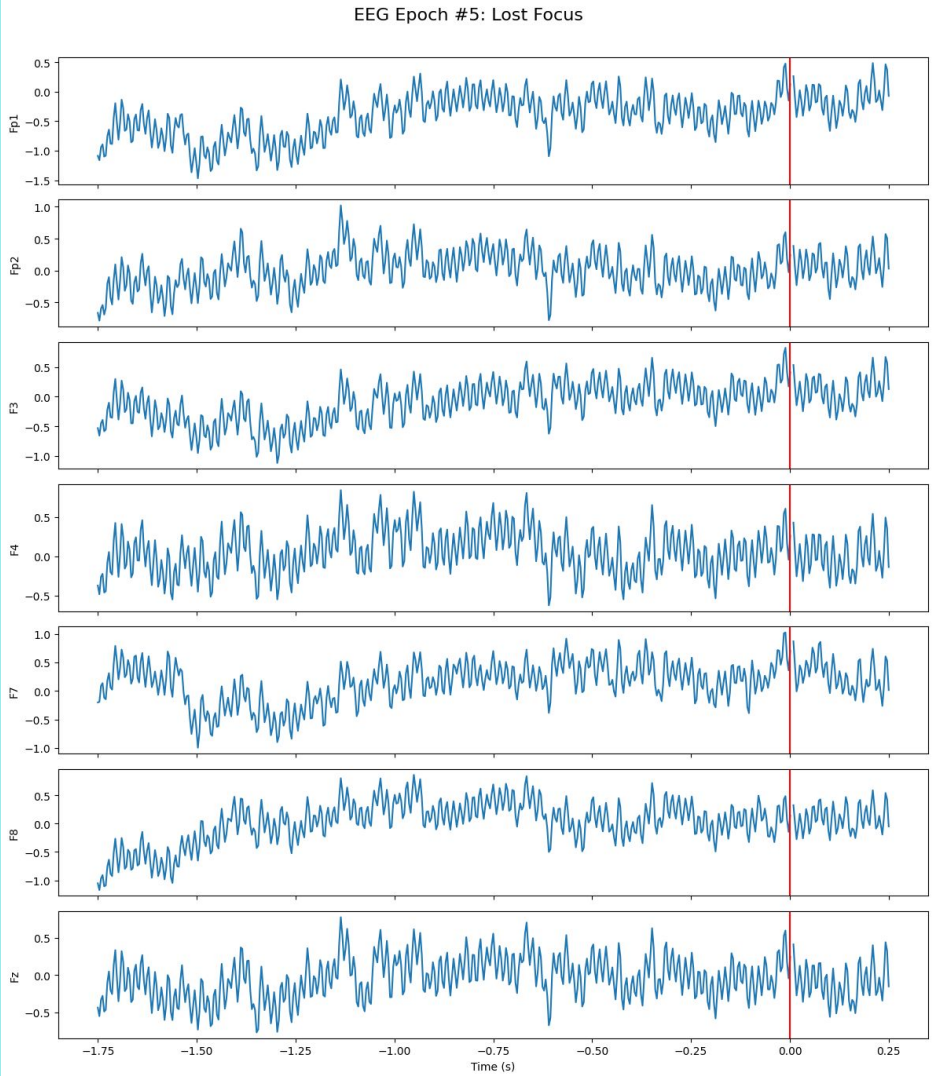
Epoching

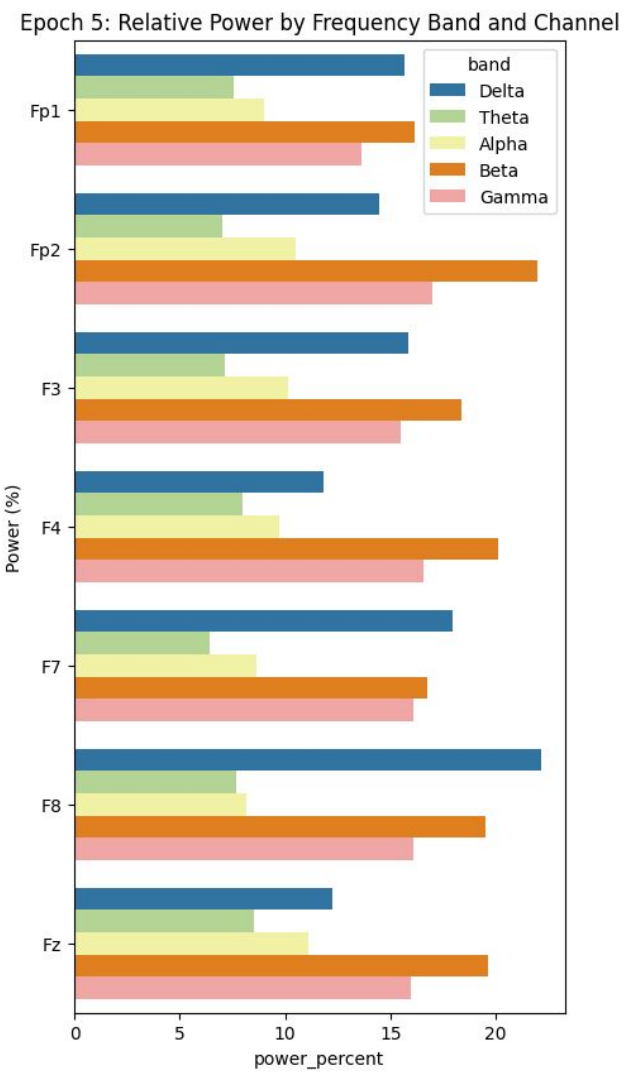
- 11 epochs - correspond to a event marker
- 7 channels
- 499 time samples per channel
- sampling rate = 250
- duration of each epoch is 2 seconds




Ch 0
1
0
−1
−2


Ch 0
0.5
0.0
−0.5
−1.0
−1.5

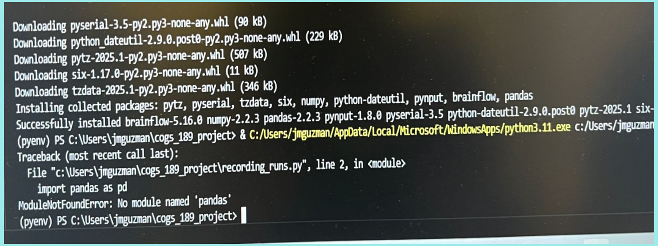

EEG Epoch #5: Lost Focus
Fp1
Fp2
F3
F4
F7
F8
Fz
Time (s)

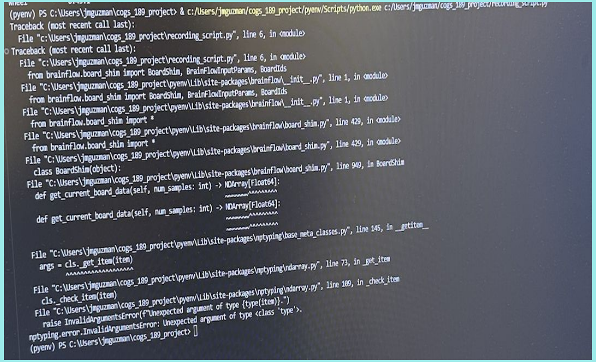

Epoch 5: Relative Power by Frequency Band and Channel
band
Delta
Theta
Alpha
Beta
Gamma
Fp1
Fp2
F3
F4
F7
F8
Fz
Power (%)
power_percent

Discussion

What we learned

- Software skills
  - Writing recording script incorporated with our experimental paradigm
  - Troubleshooting (virtual environments, terminal debugging, package installation issues)
  - Data preprocessing and filtering
  - Feature extraction
- Hardware
  - EEG System Setup & Configuration - Placing electrodes, checking impedance
- Other skills
  - EEG compliant experiment design
- Difficulties of implementing a real-time feedback system





Discussion

What could be done better given more time:

- **More trials and testing**
  - Testing could be expanded to a larger number of subjects to improve reliability.
  - Extending the recording duration and ensuring better-controlled conditions
  - Content that students know vs. don't know
- **Better definition of attention states**
  - With more data and time, we would be able to analyze and define what focus and unfocused states look like with greater reliability, as well as being able to compare more datasets with each other to recognize similarities in these states.
- **Predefined labels vs. user-defined labels**
  - Refining attention labels, whether based in established EEG thresholds or self-reported attention levels could improve the accuracy and adaptability of the system.

Discussion

What could be explored in the future:

- **Incorporating Machine Learning for Personalized Models:** In using techniques such as r-LDA, SVM, or KNN to build subject-specific classifiers to predict focus or lapses, could lead to higher precision than what threshold-based approaches are capable of. Unlike simpler approaches, machine learning will be able to adapt to individual differences given time and training.
- **Include Modality-Specific tasks:** Including sessions where participants study with visual or auditory materials, examining how modality affect attention, and examining if Pomodoro timing should differ depending on the sensory input could lead to a modality-sensitive Pomodoro system that adjusts session lengths based upon what type of content is being utilized.
- **Add a Baseline and Dual-Task Condition:** In including baseline EEG recordings and comparing attention metrics during unfocused vs focused tasks, focus detection accuracy would be refined. In adding dual-task conditions, it would help to test if the neurofeedback system is capable of adapting to real-world multitasking situations.
- **Deeper Analysis of Regional Brain Activity:** better visualize what each region of the brain corresponds with what type of activity/focus

Thank You!