

Background

Neurofeedback training (NFT) uses EEG to help people self-regulate their brain activity.

- Variability exists: some people show strong improvements while others show minimal change.
- There are different frequencies of brainwaves, each categorized into delta (less than 4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (30–100 Hz). Each frequency band represents a particular physiological function.



Methodology

- Participants: Healthy volunteers
- Equipment: EEG headset, OpenBCI software, Faraday cage, cognitive test, MATLAB
- Training Protocols:
 - Each participant trains each frequency band
 - Real-time visual feedback indicates successful modulation
- Procedure:
 - Baseline EEG recording (resting state)
- Neurofeedback session: Measure real-time EEG changes
- Cognitive test: Before and after each session.
- Analysis: Compare early EEG trend with later cognitive gains.



Investigating the Relationship Between Alpha, Beta and Gamma Neurofeedback and Cognitive Performance to Predict Training Outcomes



Rddhima Bora

Advisor: Dr. Kevin Crowthers



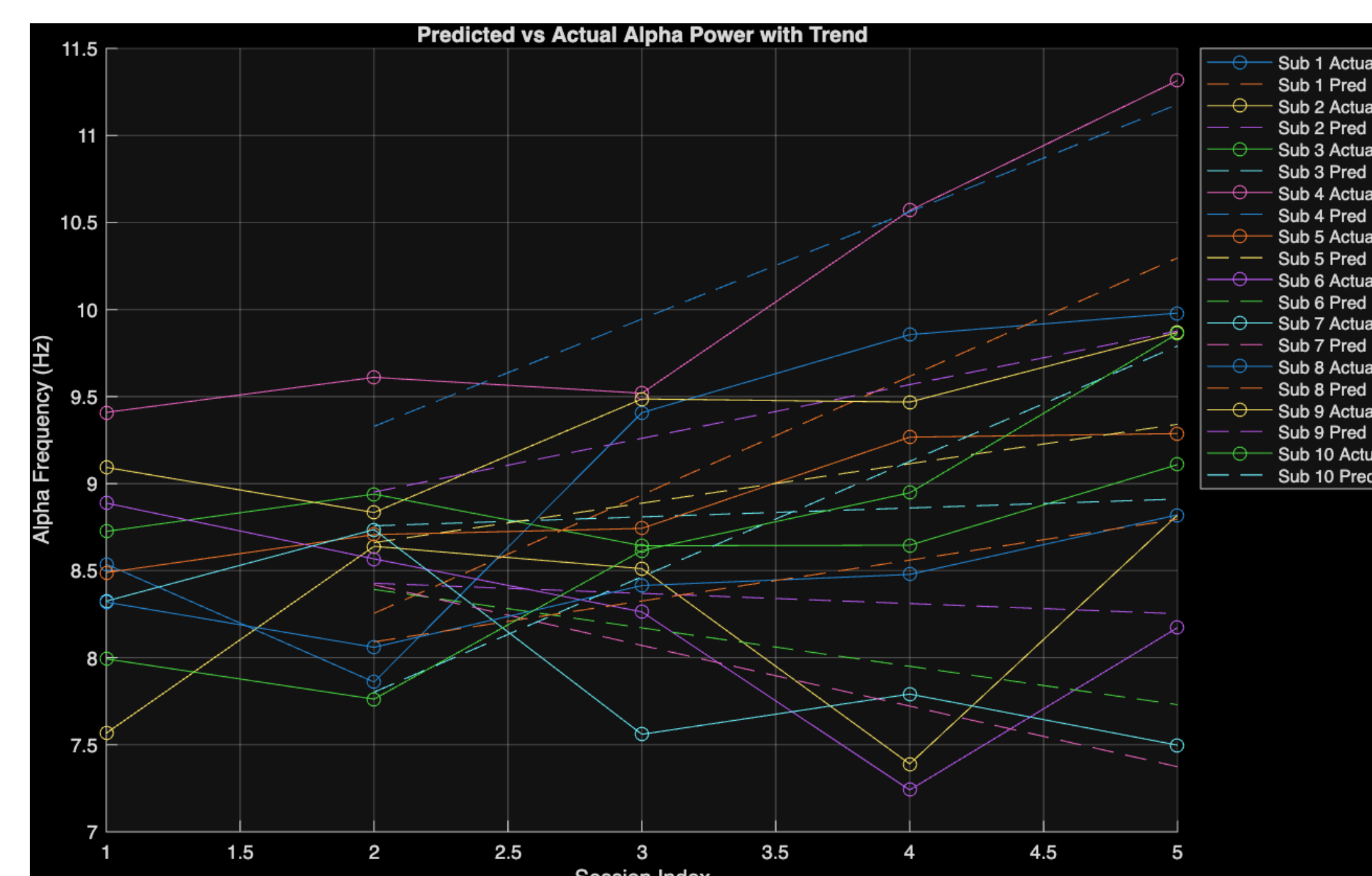
Research Question

Can early changes in alpha, beta, and gamma EEG activity during neurofeedback predict long-term improvements in cognitive performance?

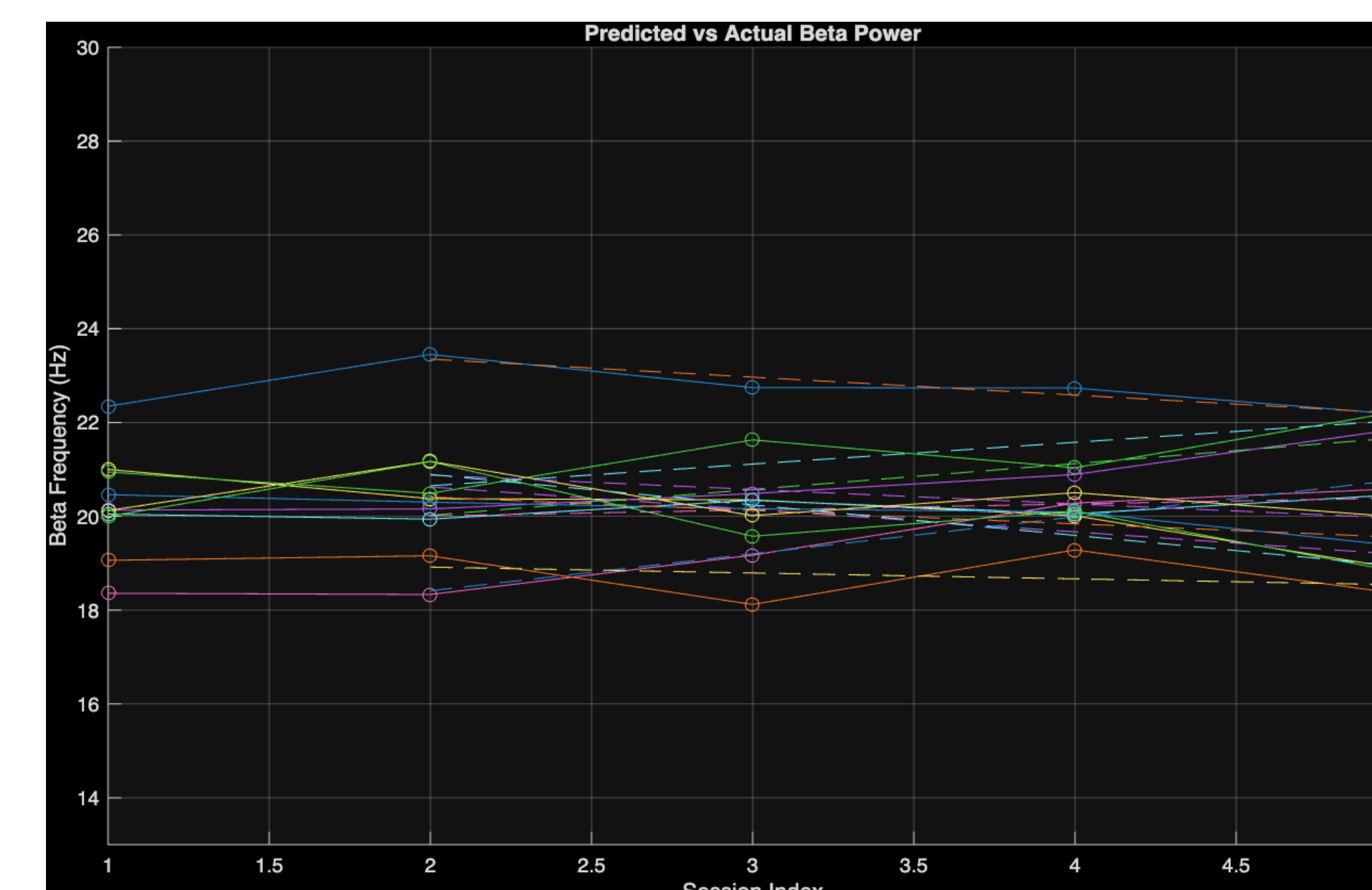
Hypothesis

Individuals who show early increases in the trained frequency band will demonstrate greater cognitive gains across training sessions.

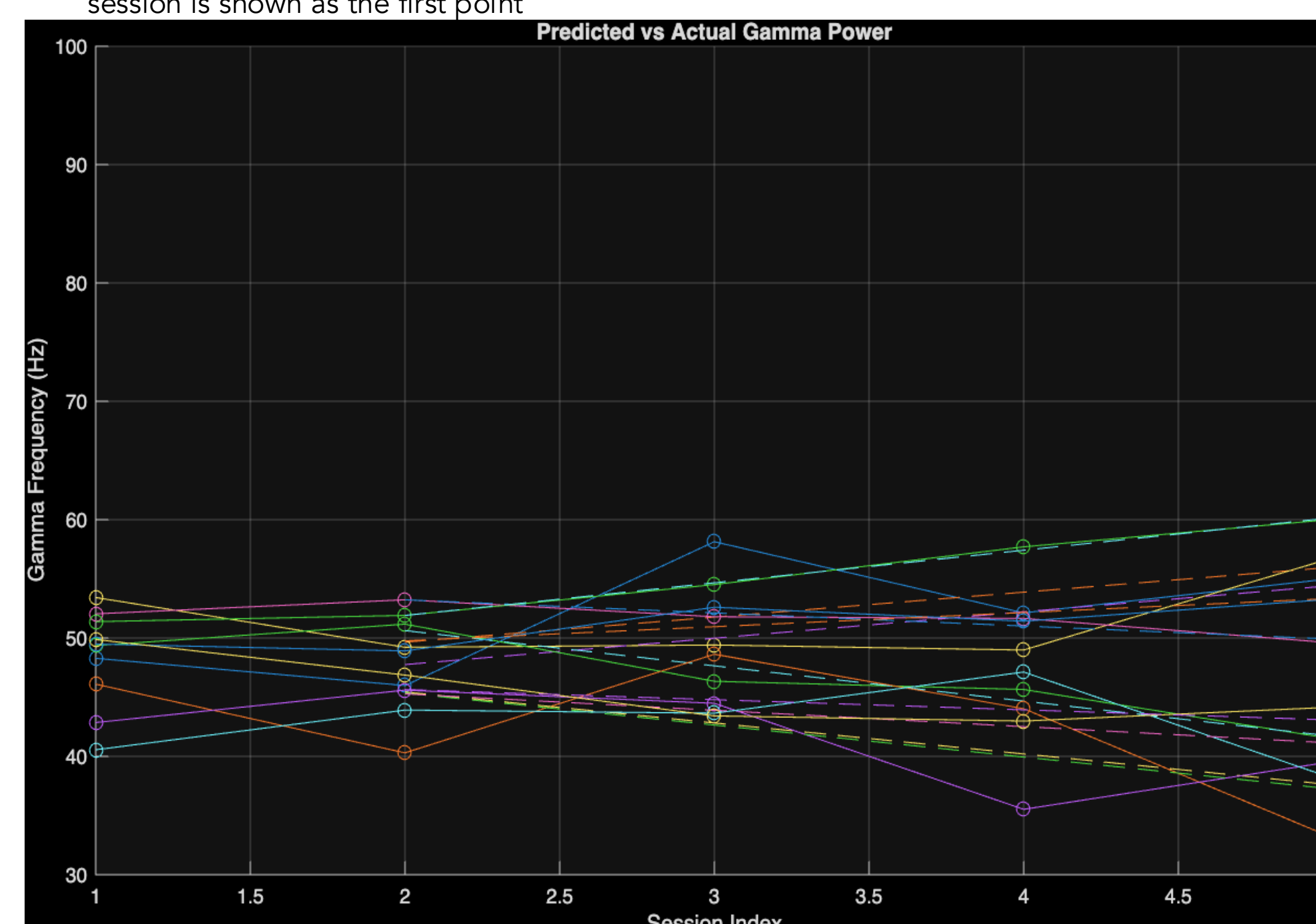
Results



Graph 1: This plot shows simulated alpha-band power across multiple sessions for each subject. Actual measurements are solid lines, while predicted values from the OLS linear model are dashed. The y-axis corresponds to the alpha band (8–13 Hz), and the early session is shown as the first point



Graph 2: This plot shows the simulated beta-band power across multiple sessions for each subject. The solid lines represent actual values, while dashed lines indicate predicted values from a linear model based on run index. The early session is included as the first point on the x-axis, and the y-axis is constrained to the beta frequency band (13–30 Hz).



Graph 3: This plot shows the simulated gamma-band power across multiple sessions for each subject. Solid lines show actual values, and dashed lines show predictions from a linear model using run index. Early sessions are included on the x-axis, with the y-axis reflecting the gamma frequency band (30–100 Hz).

Predictions were generated using ordinary least squares (OLS) linear regression. Run index was used as the predictor variable to model changes in EEG band frequency (alpha, beta, gamma) across sessions. The model estimates a best-fit line that minimizes squared error between actual and predicted values.

Prediction Accuracy Metrics:

- Alpha Band:
 - $R^2 = 0.942$
 - $RMSE = 0.189$ Hz
- Beta Band:
 - $R^2 = 0.820$
 - $RMSE = 0.338$ Hz
- Gamma Band:
 - $R^2 = 0.547$
 - $RMSE = 2.263$ Hz

Highlights

- Early-session EEG power can provide a rough prediction of later session trends.
- Linear models using run index capture trends across runs for each frequency band.
- Predicted values closely follow actual trends, showing the model's usefulness.
- Beta (13–30 Hz) and Gamma (30–100 Hz) bands show variability across subjects and runs.
- Early sessions are important as baseline points for tracking changes over time.
- Simulations highlight that higher-frequency bands (gamma) tend to have more variability than lower-frequency bands.

Future Steps

- Collect real EEG data for all sessions.
- Compute actual band power for alpha, beta, gamma.
- Test different prediction models (linear, nonlinear).
- Explore time-based x-axis instead of run index.
- Compare subject-level variability across bands.
- Extend to cross-band correlations (e.g., alpha–gamma).

References

- Egner, T., & Gruber, J. H. (2004). EEG biofeedback of low-beta band components: Frequency-specific effects on variables of attention and event-related brain potentials. *Clinical Neurophysiology*, *115*(1), 131–139. <https://doi.org/10.1097/00001756-200112101-00058>
- Engel, A. K., & Fries, P. (2010). Beta-band oscillations—Signalling the status quo? *Current Opinion in Neurobiology*, *20*(2), 156–165. <https://doi.org/10.1016/j.conb.2010.02.015>
- Gruber, J. (2009). A theory of alpha/theta neurofeedback, creative performance enhancement, long distance functional connectivity and psychological integration. *Cogn Process* *10* (Suppl 1), 101–109. <https://doi.org/10.1007/s10339-008-0248-5>
- Hanslmayr, S., Sauseng, P., Doppelmayr, M. et al. (2005). Increasing Individual Upper Alpha Power by Neurofeedback Improves Cognitive Performance in Human Subjects. *Appl Psychophysiol Biofeedback* *30*, 1–10. <https://doi.org/10.1007/s10484-005-2169-8>
- Jensen, O., Kaiser, J., & Lachaux, J.-P. (2007). Human gamma-frequency oscillations associated with attention and memory. *Trends in Neurosciences*, *30*(7), 317–324. <https://doi.org/10.1016/j.tins.2007.05.001>
- Marzbani, H., Marateh, H. R., & Mansourian, M. (2016). Neurofeedback: A Comprehensive Review on System Design, Methodology and Clinical Applications. *Basic and clinical neuroscience*, *7*(2), 143–158. <https://doi.org/10.15412/J.BCN.03070208>
- Spitzer, B., & Haegens, S. (2017). Beyond the status quo: A role for beta oscillations in endogenous content (re)activation. *eNeuro*, *4*(4), 1–15. <https://doi.org/10.1523/ENEURO.0170-17.2017>
- Vernon, D. J., Egner, T., Cooper, N., Compton, T., Neillands, C., Sheri, A., & Gruber, J. (2003). The effect of training distinct neurofeedback protocols on aspects of cognitive performance. *International Journal of Psychophysiology*, *47*(1), 75–85. [https://doi.org/10.1016/S0167-8760\(02\)00091-0](https://doi.org/10.1016/S0167-8760(02)00091-0)
- Zocfel, B., Huster, R. J., & Herrmann, C. S. (2011). Neurofeedback training of the upper alpha frequency band in EEG improves cognitive performance. *NeuroImage*, *54*(2), 1427–1431. <https://doi.org/10.1016/j.neuroimage.2010.08.078>