Alpha–Gamma Oscillatory Dynamics as Neural Markers of Predictive Processing: Investigating feedback and feedforward processes in a social inference task

Jakob Radmilovič

University of Ljubljana, University of
Vienna and Charlotte Fresenius
Privatuniversitat
Kardeljeva ploščad 16, Universitatsring 1,
Seestadtstrase 27
ronald.sladky@univie.ac.at

1.Introduction

This thesis investigates whether EEG oscillations, particularly in the alpha and gamma frequency bands, can serve as reliable neural markers for cognitive mechanisms as explained by Predictive Processing (PP). Despite strong theoretical support for PP, identifying consistent physiological markers of these processes in noninvasive human recordings remains an open challenge.

Building on insights from sensory neuroscience, experimental findings evoking predictive cognitive mechanisms, and evidence from information flow within laminar cortical organization, this thesis develops a theoretical synthesis of oscillatory dynamics in predictive cognition (Bastos et al., 2012). Additionally, an EEG experiment was performed to investigate predictive behavior during inference-based processing. The task allowed participants to naturally choose whether to rely more strongly on prior information or sensory evidence, enabling the investigation of neural activity in relatively unconstrained predictive settings.

2.Methods

The thesis combines a theoretical synthesis from existing literature with empirical EEG analysis. The literature review integrates partially incompatible frameworks to establish a coherent account of oscillatory dynamics in predictive processing. Empirically, EEG data was collected during a social inference task. In the task, participants viewed scenarios of social interactions, formed expectations and made inferences about relationships between the two individuals in the interaction. The precision of given prior information was manipulated through probabilistic cues (likely/positive, unlikely/negative, neutral), while sensory information was revealed via a gradual unblurring of the target scenario. Participants had to balance prior information and the gradual incoming sensory data to make inferences. Additionally, reaction times associated with the participants inferences were recorded.

EEG data will be analyzed to extract oscillatory markers, including the behavior of alpha and gamma oscillatory power throughout the trial. Data processing is going to be conducted using Brain Vision Analyzer, MATLAB, and MNE-Python.

3.Results

Results are expected to clarify the relationship between oscillatory dynamics and cognitive mechanisms as explained by PP. The literature review should yield a framework for consistent alpha-gamma behavior across tasks. Based on the literature we can expect that participants in the empirical task will show increased alpha power during the prior condition compared to the neutral condition before stimulus processing, reflecting top-down preparation. Gamma power is expected to increase during neutral conditions where prior information is absent and reliance on sensory evidence is higher. Faster reaction times in the prior condition are expected to be associated with stronger alpha activity and relatively reduced gamma activity, reflecting greater reliance on prior information over sensory evidence.

4.Discussion

Ultimately, the goal of this thesis is to evaluate the reliability of alpha and gamma oscillations as physiological markers of predictive processing mechanisms. This question has broader relevance because predictive processing frameworks are increasingly used to model cognitive function and dysfunction in different psychiatric conditions (Strube et al., 2021). Establishing robust neural signatures of predictive inference could therefore support the development of biomarkers for understanding variability in perception, cognition, and psychopathology.

References

-Bastos, A. M., Usrey, W. M., Adams, R. A., Mangun, G. R., Fries, P., & Friston, K. J. (2012). Canonical microcircuits for predictive coding. Neuron, 76(4), 695–711. https://doi.org/10.1016/j.neuron.2012.10.038

-Jensen, O. Mazaheri, A. (2010). Shaping functional architecture by oscillatory alpha activity: Gating by inhibition. Frontiers in Human Neuroscience, 4. https://doi.org/10.3389/fnhum.2010.00186

-Strube, A., Rose, M., Fazeli, S., Buchel, C. (2021).¨ Alpha-to-beta- and gamma-band activity reflect predictive coding in affective visual processing. Scientific Reports, 11(1), 23492. https://doi.org/10.1038/s41598021-02939-z