Assignment: Visual Evoked Potentials Analysis

Introduction

In this assignment, you will analyze the visual stimulation data from the MNE sample dataset. This dataset contains recordings of a participant who was presented with visual stimuli (checkerboard patterns) in the left and right visual fields. You will follow a similar analysis workflow to what we explored with auditory stimuli, but focusing on visual processing pathways. This assignment will help you understand the retinotopic organization of the visual system and the contralateral dominance pattern in visual processing.

Background

Visual processing in the brain follows key organizational principles:

- Visual information from the left visual field is initially processed in the right hemisphere, and vice versa
- Early visual responses (P100, ~100ms) show strong contralateral organization
- Later components (N170, ~170ms; P300, ~300ms) reflect more distributed processing
- Primary visual processing occurs in the occipital lobe (back of the head)

Dataset Details

The visual experiment in the MNE sample dataset includes:

- **Stimulus type**: Black and white checkerboard pattern
- **Presentation conditions**:
    - Left visual field (Event code: '3' or 'Visual/Left')
    - Right visual field (Event code: '4' or 'Visual/Right')
- **Duration**: 50 ms
- **Visual angle**: Approximately 4 degrees, presented about 5 degrees to the left or right of fixation
- **Expected neural response**:
    - Left visual field stimuli primarily activate the right occipital cortex
    - Right visual field stimuli primarily activate the left occipital cortex
    - Key components include P100 (~100ms) and N170 (~170ms)

Assignment Tasks

Part 1: Data Preparation and Preprocessing

1. Load the MNE sample dataset and extract EEG data.
2. Apply a bandpass filter (1-30 Hz) to the raw data.
3. Create epochs for visual stimuli (left and right visual field conditions).
4. Inspect the epochs and remove any bad trials if necessary.

Part 2: Basic Evoked Response Analysis

5. Calculate and plot the evoked responses (ERPs) for both left and right visual field conditions.
6. Create topographic maps at key time points (e.g., 100ms, 170ms, 250ms) for both conditions.
7. Generate joint plots (combined ERPs and topographies) for visual comprehension.

Part 3: In-depth Analysis and Comparison

8. Create image plots showing channel × time activity for both conditions.
9. Compare the evoked responses between left and right visual field conditions using mean and Global Field Power (GFP) plots.
10. Identify and annotate key components (P100, N170, etc.) in your plots, noting their latencies and amplitudes.

Part 4: Interpretation and Questions

Answer the following questions based on your analysis:

1. **Lateralization**: How does the topographic distribution of activity differ between left and right visual field stimulation at the P100 timepoint? Explain the neurophysiological basis for these differences.
2. **Component Analysis**: Compare the latency and amplitude of the P100 and N170 components between left and right visual field stimulation. Are there notable differences? What might these differences indicate about visual processing?
3. **Comparison with Auditory**: Compare your findings from the visual analysis with the auditory analysis we did in class. What are the key similarities and differences in terms of:
    - Lateralization patterns
    - Component timing
    - Spatial distribution of activity
4. **Processing Sequence**: Based on the timing and distribution of the visual ERP components, describe the sequence of visual information processing in the brain. How does the spatial distribution of activity change over time?
5. **Electrode Selection**: Which electrodes show the strongest responses to visual stimuli? How does this compare to the electrodes that were most responsive to auditory stimuli?

Part 5: Advanced Analysis (Bonus)

If you have time and are interested in exploring further:

1. Calculate and plot the difference topography (Left visual field - Right visual field) at key time points to highlight lateralization effects.
2. Perform a time-frequency analysis to examine oscillatory responses to visual stimuli in different frequency bands (alpha, beta, gamma).
3. Investigate the relationship between pre-stimulus alpha activity and post-stimulus visual response amplitude.

Submission Guidelines

Your submission should include:

1. A well-commented Python notebook with all your analysis code.
2. Clear visualizations with proper labels and titles.
3. Written answers to the questions in Part 4.
4. A brief summary (max 500 words) of your findings and their significance for understanding visual processing.

Evaluation Criteria

Your assignment will be evaluated based on:

1. Correctness and completeness of the analysis pipeline
2. Quality and clarity of visualizations
3. Depth of interpretation and understanding demonstrated in your answers
4. Critical thinking and connections made to neurophysiological principles
5. Code quality and documentation

Resources

- MNE-Python documentation: https://mne.tools/stable/index.html
- Sample dataset description: https://mne.tools/stable/overview/datasets_index.html#sample
- Visual evoked potentials review: Di Russo, F., Martínez, A., Sereno, M. I., Pitzalis, S., & Hillyard, S. A. (2002). Cortical sources of the early components of the visual evoked potential. Human brain mapping, 15(2), 95-111.

Hints

- Focus particularly on occipital and parietal electrodes for visual responses
- The retinotopic organization should be clearly visible in early components
- Consider how the contralateral activation pattern evolves over time
- Pay attention to both the timing and spatial distribution of components