Decoding Life Signals Lab: ECG Heart Rate Variability Challenge

Overview

In this lab exercise, you will analyze an ECG (Electrocardiogram) recording from the instructor that contains different breathing patterns. You'll explore how these breathing patterns affect heart rate variability (HRV) and learn to identify unique patterns across different visualizations.

Part 1: Loading the ECG Recording

Opening the Pre-recorded Data

1. Download the "ECG_sample_recording.txt" file from the course website
2. Launch the OpenBCI GUI application
3. In the System Control Panel (left side of the screen), select "PLAYBACK (from file)" from the DATA SOURCE options
4. In the PLAYBACK FILE section, click the text field to browse and select the ECG file
5. Click "START SESSION" at the bottom of the System Control Panel to load the recording

Configuring the Display

1. After starting the session, the GUI will display widgets for signal visualization
2. In the Time Series Widget, focus only on the ECG signal:
    - Click on the "Channels" dropdown at the top of the widget
    - Deselect channels 2-8 by clicking on their numbered buttons (keep only channel 1 selected)
3. Adjust the vertical scale to 1000 μV initially
4. Set the time window to display 5 seconds at a time
5. Use the playback controls to play, pause, or move through the recording

Part 2: Exploring the Recording

Understanding the Recording Structure

The instructor has recorded their ECG during different breathing patterns, each lasting approximately 1 minute:

1. Normal breathing (minutes 0-1)
2. Deep, slow breaths (6 breaths/minute) (minutes 1-2)
3. Rapid breathing (20 breaths/minute) (minutes 2-3)
4. Breath-holding for 10-15 seconds (minutes 3-4)
5. Return to normal breathing (minutes 4-5)

Adding Visualization Widgets

Add the following widgets by clicking the "+" button in the bottom left corner:

1. **Time Series Widget** (if not already present):
    - Shows the raw ECG signal
    - Look for the QRS complexes (the prominent spikes in the signal)
    - Note how the interval between heartbeats changes with different breathing patterns
2. **FFT Plot**:
    - Configure the Max Freq to 40 Hz
    - Set Max µV to 100 µV or adjust as needed
    - Select Log/Lin to "Log" for better visualization
    - Look for peaks that correspond to heart rate frequency
    - Compare the FFT during different breathing patterns
3. **Spectrogram**:
    - Set Max Freq to 40 Hz
    - Set Window to 3 Min or adjust to see more data
    - Set Log/Lin to "Log"
    - Look for patterns that change with breathing

Part 3: Data Analysis Tasks

Heart Rate Calculation

For each of the five breathing conditions, calculate the heart rate:

1. Position the playback marker in the middle of each breathing pattern segment
2. Count the number of QRS complexes (heart beats) in a 10-second window
3. Multiply by 6 to get beats per minute (BPM)
4. Record the BPM for each breathing pattern

Heart Rate Variability Analysis

1. For each breathing pattern, examine how consistent the intervals between heartbeats are:
    - During normal breathing, heartbeats should have moderate variability
    - During slow breathing, expect to see rhythmic changes in intervals (respiratory sinus arrhythmia)
    - During rapid breathing, check for shorter, more consistent intervals
    - During breath-holding, look for initial slowing followed by slight increase in heart rate
    - During return to normal, observe how quickly the pattern normalizes
2. Using the FFT Plot:
    - Identify the fundamental frequency peak corresponding to heart rate
    - Look for secondary peaks that might represent respiratory influences

    - Compare the frequency distribution across different breathing patterns
3. Using the Spectrogram:
    - Observe how the intensity of different frequencies changes over time
    - Identify transitions between breathing patterns
    - Note any harmonics or patterns that appear consistently

Questions to Answer

Data Interpretation Questions:

1. Which breathing pattern produced the highest average heart rate? Which produced the lowest?
2. During which breathing pattern did you observe the greatest heart rate variability?
3. How quickly did the heart rate return to normal after the breath-holding segment?
4. What changes did you observe in the FFT plot between slow breathing and rapid breathing?
5. Can you identify the respiratory influence on heart rate in the spectrogram? How does it appear?

Measurement Questions:

1. For each breathing pattern, report:
    - Estimated heart rate (BPM)
    - Dominant frequency shown in the FFT plot
    - Observable pattern in the spectrogram

Submission Guidelines

1. Answer the questions based on your data analysis
2. Summarize what you learned about the relationship between breathing and heart rate

Good luck with your heart rate variability analysis!