Project3_writeup
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This writeup is a detailed assessment of Heart Rate Variability (HRV) through the analysis of inter-beat intervals (IBIs) that are recorded during different types of activities. Using interpolation methods and a 0.1-second time step, we investigate the dynamics of autonomic nervous system reactions to various physiological and psychological conditions. This project explores the intricacies of HRV patterns, from the interpolation of IBIs to the computation of HRV measures, offering insight into possible consequences for stress assessment and general well-being. By carefully examining the data and providing insightful interpretations, we hope to make a significant contribution to our understanding of HRV as a physiological marker for a variety of activities.

Part 1

For the ANS Evaluation project we had a student perform the analysis by placing the ECG sparkfun sensor on the areas that were shown in an example we found that they should all be placed. The four activities that were chosen were all based on the instructions that were given to us for comparison. The first activity had the student just sitting in their seat and closing their eyes for five minutes. This activity was a bit harder to capture because of the noise in the classroom and the clothing being very close to the sensor would interfere with capturing the data as accurately as possible. The second activity had the student playing their favorite relaxing video game, fortnite. They play this game a lot and find it very relaxing. The third activity was performed by sitting for thirty minutes and playing online chess games. The fourth activity was the physically stressful activity where the student went on a elliptical bike in the gym for 15 minutes. These activities were all chosen by the student as they were the easiest way to record data for the amount of time left in class. The activities were mentioned because in the code of this project we defined the activities as the number according to the order given in the instructions.

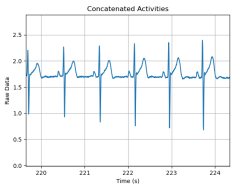

figure 1: The 4 activity recordings concatenated together

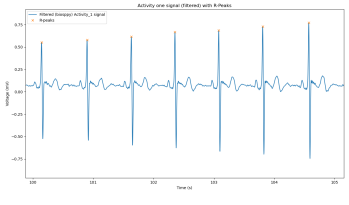

Figure 2: raw data for Sit and relax

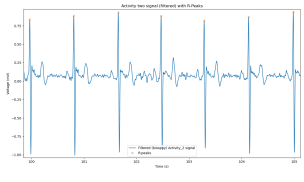

Figure 3: raw data for relaxing activity

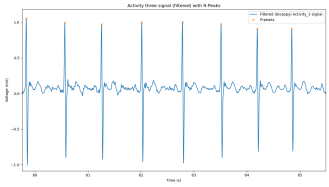

Figure 4: raw data for mentally stressful activity

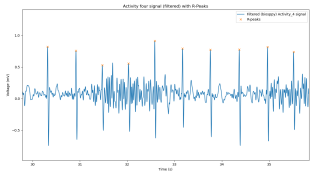

Figure 5: raw data for Physically stressful activity

The functions we used in this were load_data and load_x. Load_data can load recorded data of the different activities and can load them as 3 different types of data, which could be in, .txt, .npz, or .csv files. The load_x function chooses whether to load the data in the domain it's already in and also has an option to plot these sets or not.

Part 2

We chose to write a wrapper function to define the filtered data as filter_data, these filtered the data using 2 filters to call. In the wrapper function we defined notch_filter and butterworth_filter, for a notch filter and butterworth filter, which is used because these 2 filters remove any sounds or artifacts that disrupt the recording of the data, these are flexible because to run these filters the specific functions need to be called to run.

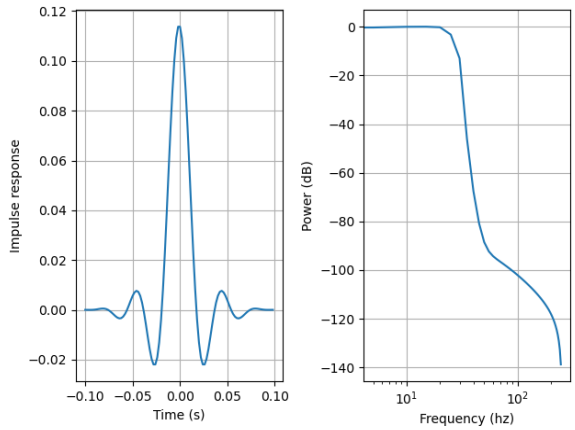

Figure 6: Filter impulse response and frequency response

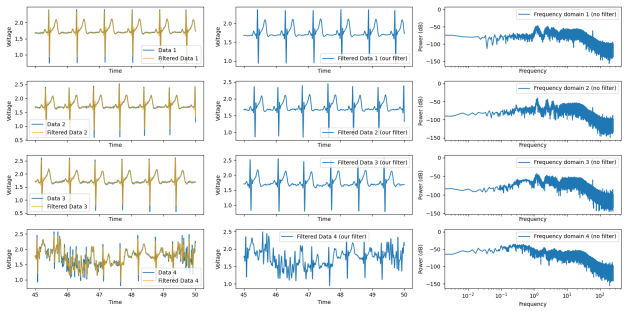

Figure 7: Data filtered comparisons

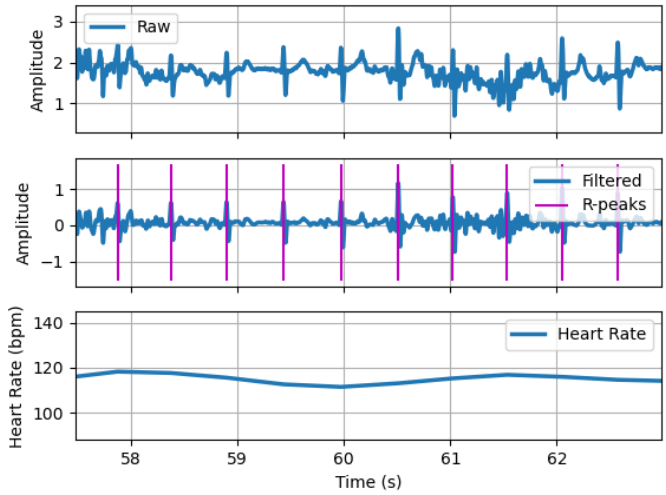

Figure 8: Biopsy library graph of the ECG data

Part 3

We used biosppy for the detection of heartbeats in our project. Biopsy uses a data filtration process employing templates, a method we had used to our approach in Project 2. To identify heartbeats, the algorithm assesses whether the preceding index is less than the subsequent one, thereby pinpointing the moment of a heartbeat.

Since we were using a Python module that was skilled at creating arguments on its based on the ECG data, we were able to make the code adaptable. This approach relied on using our detect_heartbeats function, which requires fs and ecg_data as inputs. This application illustrates how flexible and advanced biopsy is inside our framework of analysis.

Part 4

We anticipate that HRV values for physically demanding and stressful activities would correlate with an increased heart workload which would show higher levels.
On the other hand, we anticipate lower HRV values for peaceful and soothing activities, which correlate to times when physical effort is decreased.

The HRV values that were acquired are consistent with the expectations that were set before the analysis was carried out in our code. We ran the calculate_HRV function, which was created to take in r_peaks and fs as inputs and then output the required analysis. This feature makes it easier to calculate the analysis using biospy, a program that is used in this project to process data obtained from the ECG signal.

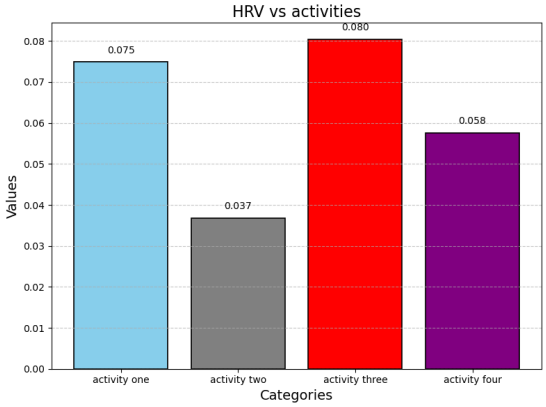

Figure 9: Bar plot for relative HRV values for each activity

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Part 5

For the importance of the ratio of low-frequency to high-frequency power in heart rate variability (HRV); The LF/HF ratio represents the equilibrium between sympathetic and parasympathetic activity. So with this knowledge we expected that the activities that didn't involve any physical movement would have a lower ratio compared to the activities when the person's body was at rest. Our LF/HF ratio values do match these expectations. We created a function that will plot the results from the previous part where we saved each event into a dictionary. These functions can plot a bar graph of any 4 floats with any specified title, y and x labels. The HRV LF/HF power functions can plot any power vs frequency data array, and calculate the average power of any two specified bands of frequencies.

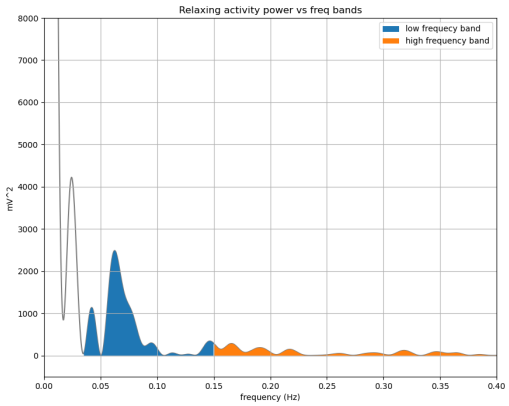

Figure 9: HRV frequency domain magnitude plot for Relaxing activity.

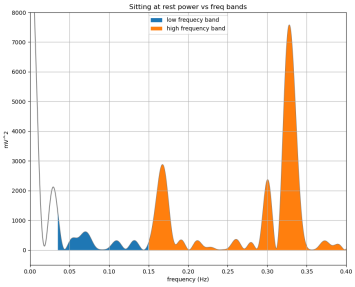

Figure 10: HRV frequency domain magnitude plot for Sitting at rest

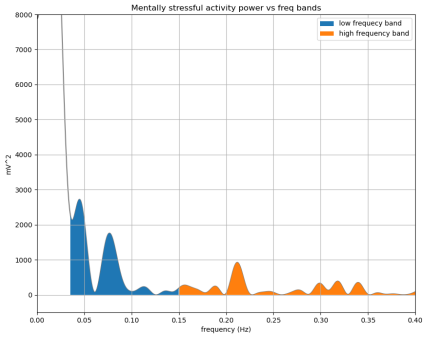

Figure 11: HRV frequency domain magnitude plot for Mentally stressful activity

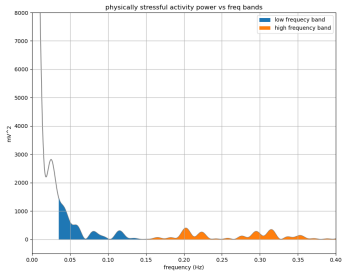

Figure 12: HRV frequency domain magnitude plot for Physically stressful activity

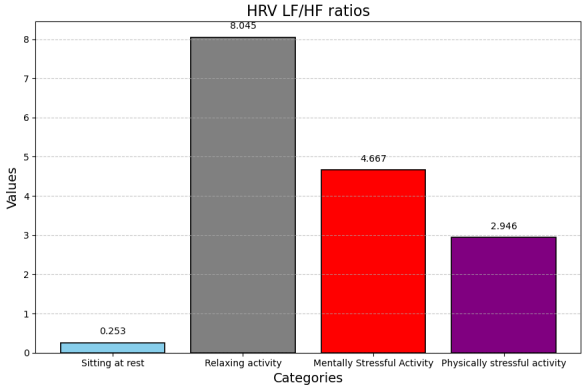

Figure 13: Bar graph Values for the HRV LF/HF ratios

Part 6

Our LF/HF ratio does support this idea, even though there are many more variables to consider when assessing someone's stress levels. There is a larger ratio and relationship between the physical activities and the less physical activities. The physically stressful activity had the 2nd lower LF/HF ratio, which is quite the opposite of the hypothesis and supporting research. This is without a doubt certainly due to the nature of that data collection and the substantial presence of

noise and artifacts due to the movement of wires. The fact that we saw these activities take place and knew which data to examine, so we knew there wouldn't be any errors, are the aspects that do restrict our certainty when it comes to this source. It may be possible to increase the sample size and diversity in order to strengthen the conclusions. This could also include, grouping the data according to personal traits or medical problems, providing a more narrow insight to the connection between stress and the LF/HF ratio. Also, since this was done in class, it could have been in a quieter setting, but we did our best to eliminate artifacts and selected the most appropriate time interval for the graphed signal. Other ways we could collect better data:

1. Have some sort of strap that attaches to the areas where the electrodes should be connected, to ensure a proper connection.
2. Soldered boards to again, not insure loose wiring, which causes a crap ton of noise. This noise became particularly hard to deal with in the more physical activities.
3. Design a filter into the arduino circuit to filter the incoming data, before it comes back to the arduino. Possibly a capacitive circuit to reduce dc gain.

Artifacts?

- Artifacts can cause false peaks, or heartbeats in the data. Artifacts can also change the shape and magnitude of any other wave in the qrst complex, which can cause misdiagnosis of murmers, fibrillation etc.

Research study?

- A few factors that limit our certainty about this conclusion are artifacts. Artifacts and noise caused quite a bit of either false positives or false negatives. This was seen particularly impactful with our physically stressful activity. Another limitation would be the simple 3-lead ecg we used. In a fully-fledged research study, we would set up a 12 lead ecg and a strap to consistently get a solid connection with the heart.