Assignment-2 Report

1. Problem Statement

The aim of this study was to find out the relationship between pupil diameter and emotions. To be more specific, we need to analyze the dataset and make inferences about how pupil diameter and reaction time vary when participants are presented with different emotions (Happy, Angry, Neutral). For this study, two experiments were conducted - Main, where participants had to detect emotions, and Control, identification of the spatial location of a dot presented on the emotional face.

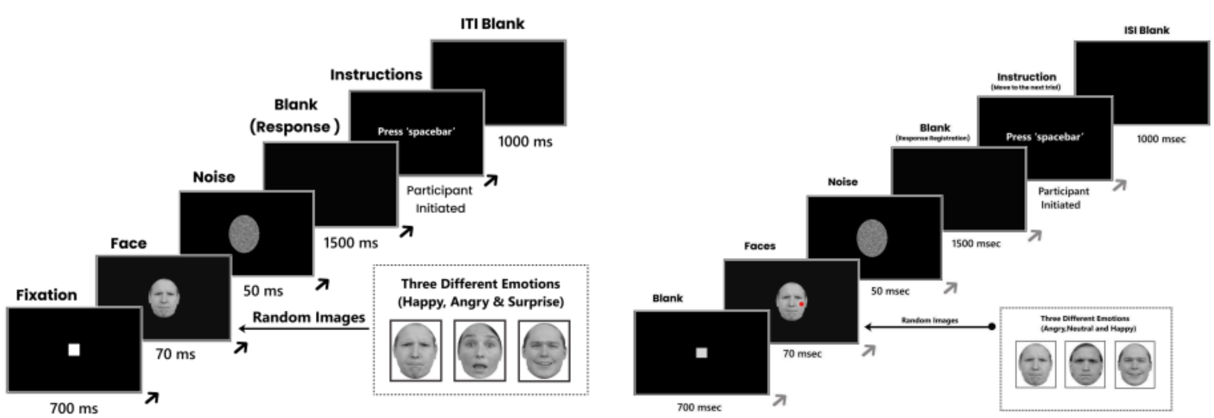

Figure 1: Setup for the Main experiment (LHS) and Control experiment (RHS)

2. Dataset Exploration

For both experiments, the csv files had a similar structure of columns. Mainly, there were 3 columns representing “Stimulus Name,” “Reaction Time,” and “Reaction Key,” respectively, and from column 4 onwards, there was a time series representing pupil diameter. Hence number of columns across csv files varied, which is shown in the figure below.

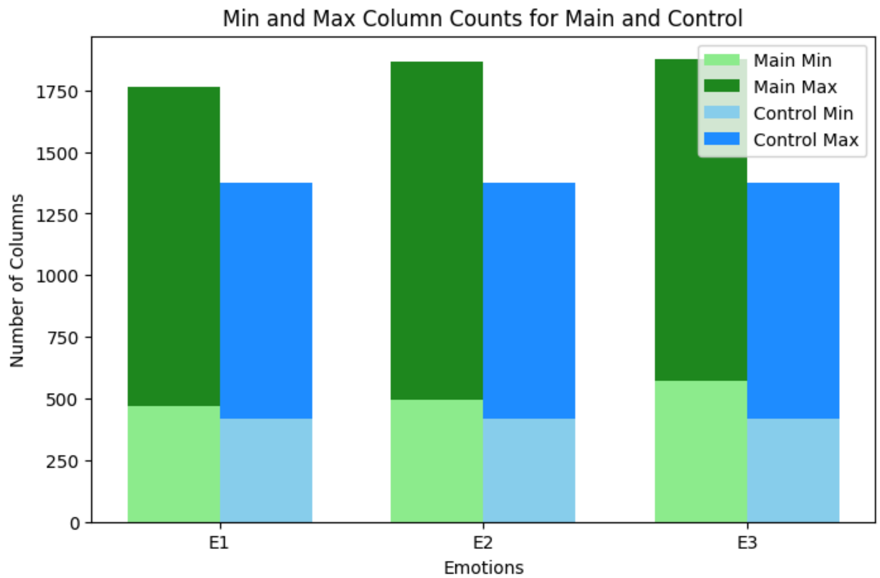

Figure 2: Min and Max number of columns

It is clear from this graph that the Main had variable columns, which indicates more pupil diameter data, while the control experiment had a consistent number of columns.
Next, I explored the number of rows/samples for each experiment and for each emotion to account for the class distribution.

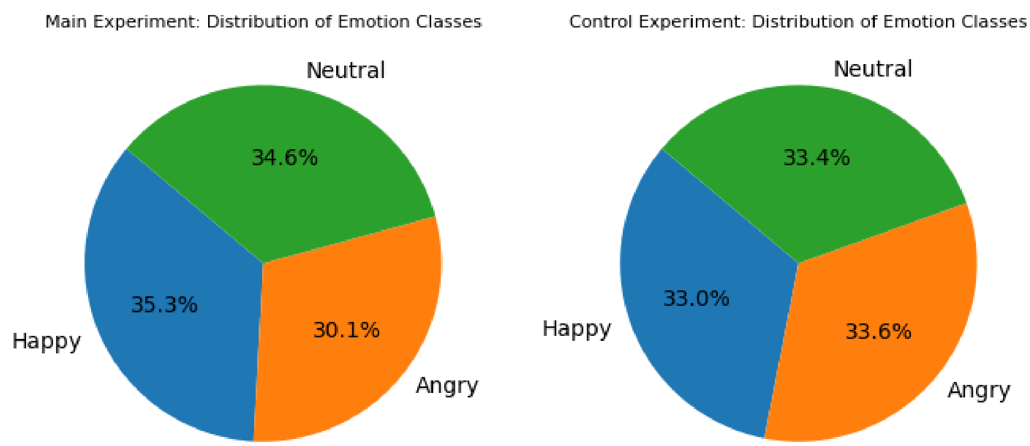

Figure 3: Class distributions

The above plot shows that there are nearly equal samples in the control experiment, but for the Main experiment it varied, with E2 (Angry) having 5% fewer samples as compared to E1.

3. Data Preprocessing

I started out by checking whether all the csv files were present for those 10 individuals for each emotion and each experiment. Now, while performing data exploration, I found out that in each of the csv file, the last column was unnecessary, and it had values as names of earlier columns.
Also, column 1, which represents “Stimulus Name,” is also not needed for our analysis.
Also, as specified in the assignment, we need to eliminate columns from t1 to t86, which represent pupil diameter during the fixation period.
After deleting all these columns, I created a new csv file as “new.csv” with the above columns deleted.

4. Data Analysis
4.1 Reaction Time

For aggregating the overall data for reaction time, I took the median across each participant, experiment, and emotion and got a scalar value.
Taking median rather than average ensures that it is robust to skewness and outliers.

Figure 4: Plot for Reaction Time across experiments and emotions

In the plot, we can easily see the differences across the experiments and can easily infer that reaction time was almost constant for the control experiments, and emotion didn't seem to have any impact on the reaction time, whereas, for the main experiment reaction time for E1 (Happy) is 0.37374 ms which then increases to a peak value of 0.5568 for E2 (Angry), and then decreases to 0.5025 for E3 (Neutral). This means that participants take the longest reaction time to respond to angry stimuli, followed by a slight decrease in neutral emotion.

Overall, the plot suggests that emotions have a relationship with reaction times only when the participants focus on recognizing emotions, while the other experiment remain unaffected.

4.2 Pupil Diameter

For aggregating data for pupil diameter, we take the average values across each column while ignoring rows with "NULL" values. The following graph represents the trends for pupil diameter.

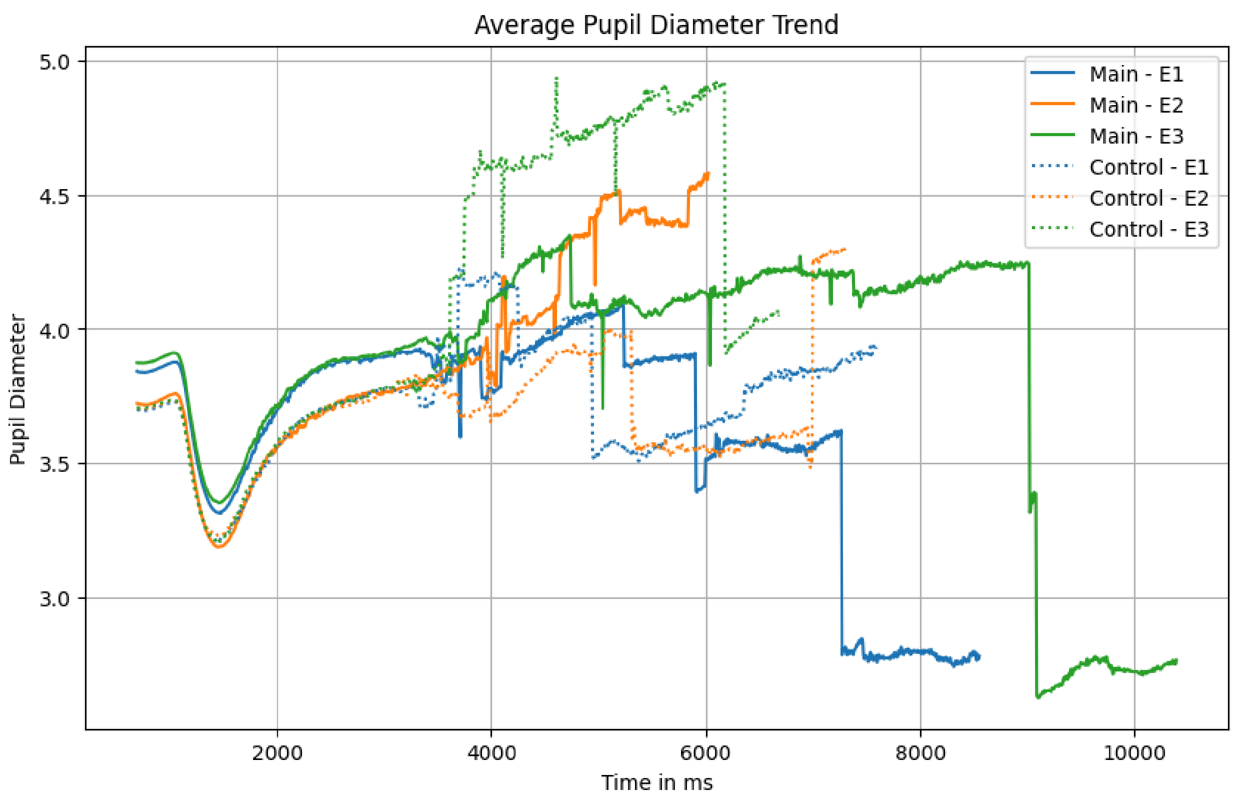

Figure 5: Pupil diameter trends with time

First of all, the right side of the graph has variability and sudden drops for each curve due to fewer participants having data beyond 3000 ms. After 7000 ms, some points only represent 1 participant; hence, our main analysis will be for 696 ms to 3000 ms, representing the region after fixation and until the response time window.
The graph starts from 696 ms, with Main’s E1 and E3 pupil diameters being more than Control's, and Main’s E2 follows a similar pattern to those for Control.
Around 1000 ms, pupil diameter starts to decrease for all experiments and emotions, and around 1450 ms, the pupil diameter reaches a minimum, with values ranging from 3.18 (Main E2) to 3.45 (Main E3). The control experiments have almost the same values for this region, while Main E1 and E2 converge.
Around 2500 ms, pupil diameter returns back to initial levels, and this results in the formation of a “V” shaped curve.
Up to 3000 ms, Main E1 and E3 follow a similar pattern, as do Control and Main E3. Beyond 3000 ms, the trends diverge significantly: Main E2 rises sharply, Main E1 and E3 decrease, and Control E3 peaks at around 4.9.

4.3 Supporting Plot- Rate of change of pupil diameter with time

To further infer and inspect the “V” shaped region I decided to plot the rate of change of pupil diameter with time, from 1000 ms to 2500 ms.

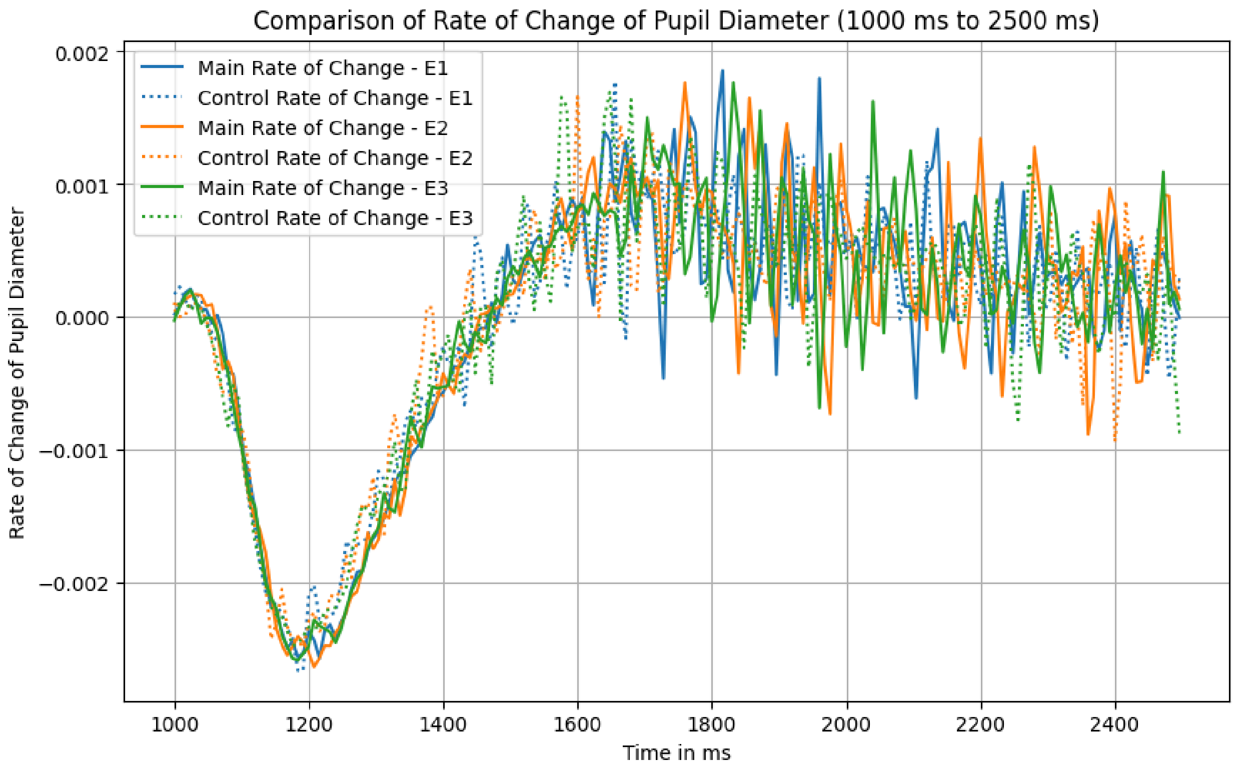

Figure 6: Rate of change of pupil diameter with time

From 1000 ms to 1200 ms, there's a sharp decrease in the rate of change, which is indicated by the dip below 0 for both experiments. This means that the pupil rapidly constricts as the rate of change is negative for this region.
Now, after 1300 ms, the rate of change starts to oscillate between positive and negative values, this suggests that pupil diameter is adjusting to get stable after the initial changes and cognition load.

5. Inferences

From the graphs, it is evident that there are notable fluctuations in pupil diameter over time. When a stimulus is presented, which refers to the region after 700 ms, the pupil

diameter starts to decrease and constricts more for Main's E2 (Angry), and during the response time window (around 1200 ms), it starts dilating, which clearly indicates that pupil diameter increases in response to cognition load, as in this region participant are using memory and cognition.
Now, pupil diameter doesn't seem to vary significantly across the control experiment, as it was a spatial detection task and hence required lower emotional engagement. For the Main experiment, emotion like anger (E2) causes more pupil constriction likely due to increased arousal, while neutral (E3) and positive emotions - happy (E1) caused relatively less pupil constriction.
Reaction time shows a gradual increase from Main's E1 to E2 and then drops for Main's E3. Main's E2 (Angry) has more reaction time, possibly due to the nature and complexity of stimuli, while the control experiment has consistent and lower reaction times, which indicates that red dot detection required less cognitive load as compared to the main.
For the Main experiment, participants had longer reaction times, and their pupils had more variation, reflecting the mental effort needed to recognize emotions. This task was more complex and emotionally engaging compared to the Control experiment, where participants simply detected a red dot. The Control task had quicker, more stable responses and minimal pupil changes, suggesting it required less emotional processing.

6. Conclusion

From the graphs and data, we can conclude that emotional recognition has greater physiological arousal, mainly for angry stimuli, due to slower reaction times and lower pupil diameters. This further suggests that negative emotions are processed with heightened sensitivity due to the perceived threat.
In contrast, the Control experiment had similar pupil responses, which indicates that it required lower cognitive demand and doesn't seem to vary with emotions. This further suggests that emotion-based tasks are more cognitively and physiologically demanding than simple visual tasks. Negative emotions, particularly anger, amplify these effects.

7. References

1. O'Sullivan, T., & Ibbotson, P. (2008). Matplotlib for Python Developers. *Packt Publishing*.
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   https://matplotlib.org/stable/contents.html
2. Pandas API :
   https://pandas.pydata.org/docs/reference/index.html#api
3. Henderson, R. R., Bradley, M. M., & Lang, P. J. (2018). Emotional imagery and pupil diameter. Psychophysiology, 55(6), e13050.
   https://doi.org/10.1111/psyp.13050