Assignment-2 Report

1. Problem Statement

The aim of this study was to find out the relationship between pupil diameter and emotions along with the effect of eccentricity, with valid and invalid trials condition.

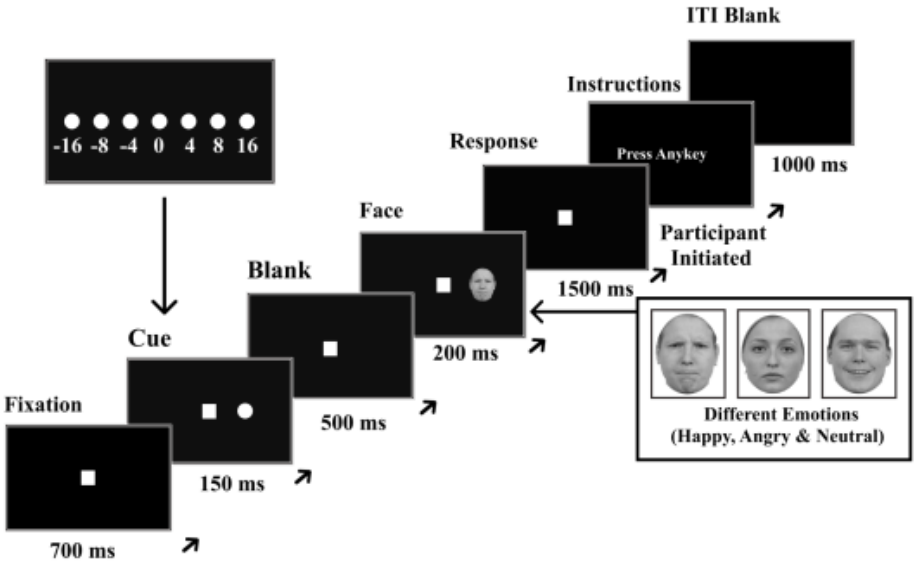

Figure 1: Setup for the experiment

2. Dataset Exploration

Firstly, I checked for missing files or missing data, and I found out that the below files were not present.

```
Missing csv files:
D3-6\ANT\E1\1\target_cued.csv
D3-6\ANT\E1\1\target_uncued.csv
D3-6\ANT\E1\2\target_cued.csv
D3-6\ANT\E1\2\target_uncued.csv
D3-6\ANT\E2\1\target_cued.csv
D3-6\ANT\E2\1\target_uncued.csv
D3-6\ANT\E2\2\target_cued.csv
D3-6\ANT\E2\2\target_uncued.csv
D3-6\ANT\E3\1\target_cued.csv
D3-6\ANT\E3\1\target_uncued.csv
D3-6\ANT\E3\2\target_cued.csv
D3-6\ANT\E3\2\target_uncued.csv
```

Figure 2: Missing Files in the Dataset

Next, I explored the number of rows/samples for each condition and for each emotion to account for the class distribution.

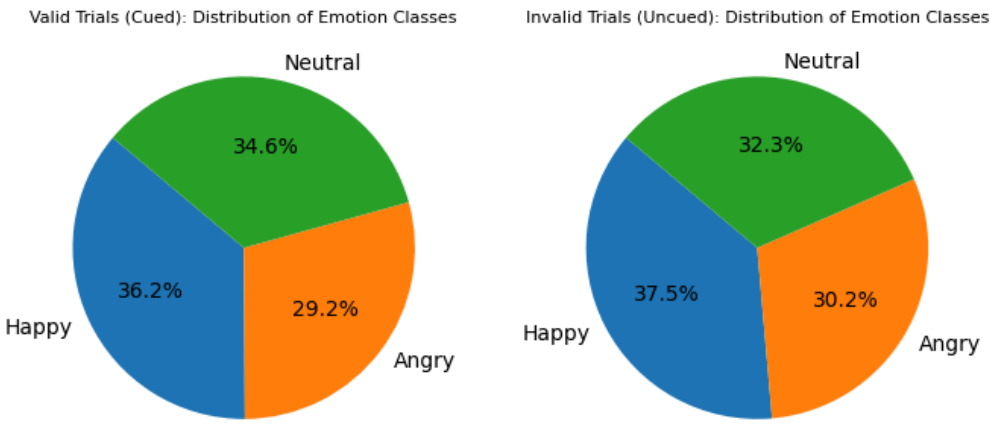

Figure 3: Class distributions

The above plot clearly shows that there are more imbalances present in the Uncued condition, where 37.5% of samples are for Happy, while Angry has only 30.2% of overall samples, with ~ 7.3% difference between them.
A similar pattern was observed in cued condition, where happy has 36.2% of samples and angry has 29.2%, ~ 7% difference across the two classes.

3. Data Preprocessing

As specified in the assignment, we need to eliminate columns from t1 to t86, which represent pupil diameter during the fixation period.
Also, along with this the first column representing “Image Name” is not useful for our analysis, hence, I deleted that as well and saved cleaned file as: “new_target_<condition>.csv”

4. Data Analysis
4.1 Reaction Time

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

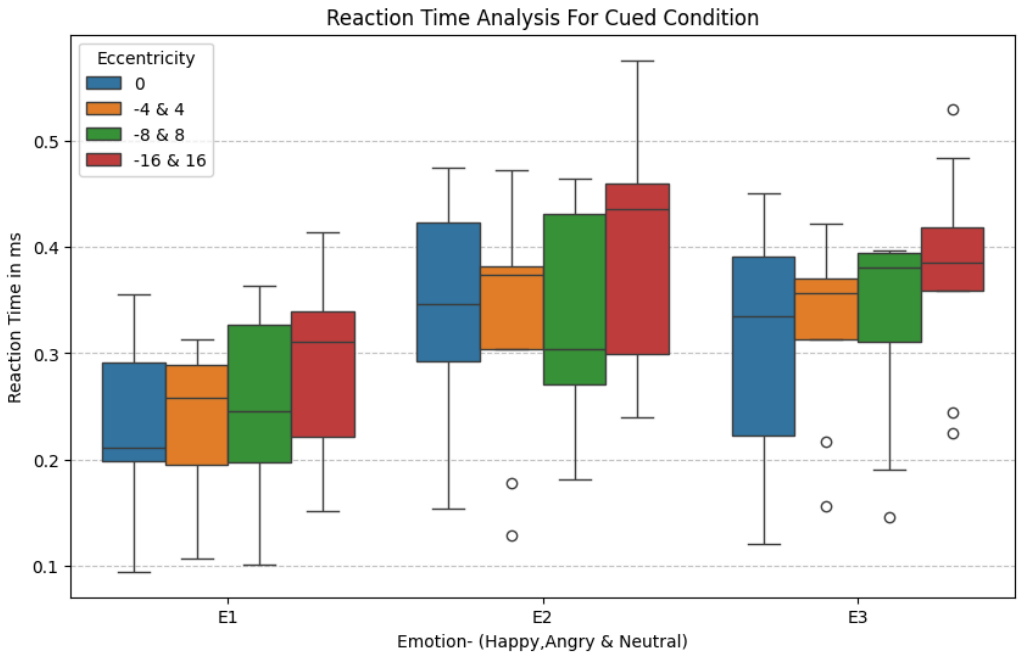

Figure 4: Reaction Time for cued condition, across each emotion & eccentricity

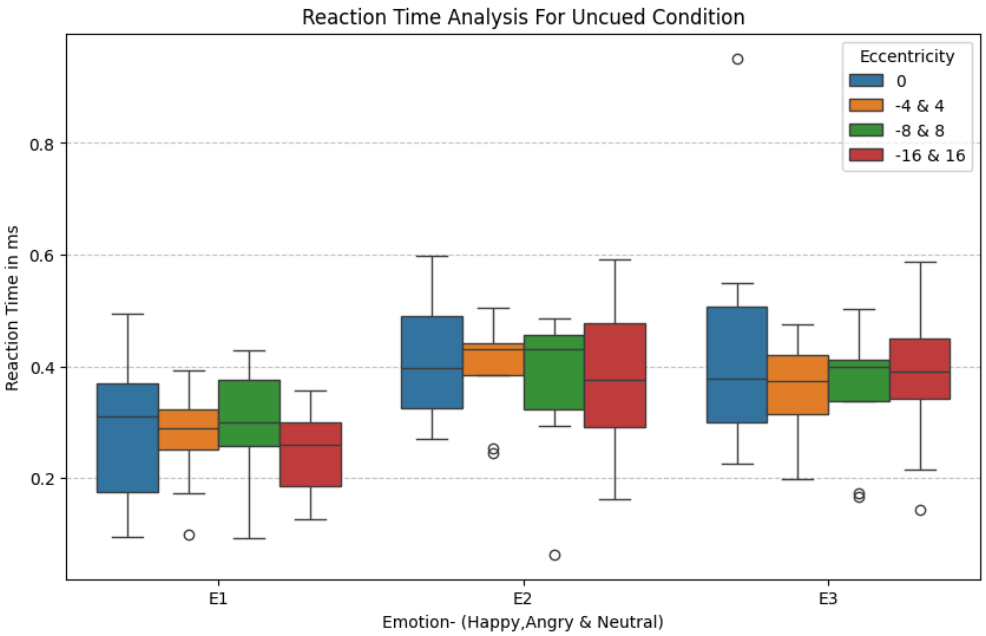

Figure 5: Reaction Time for uncued condition, across each emotion & eccentricity

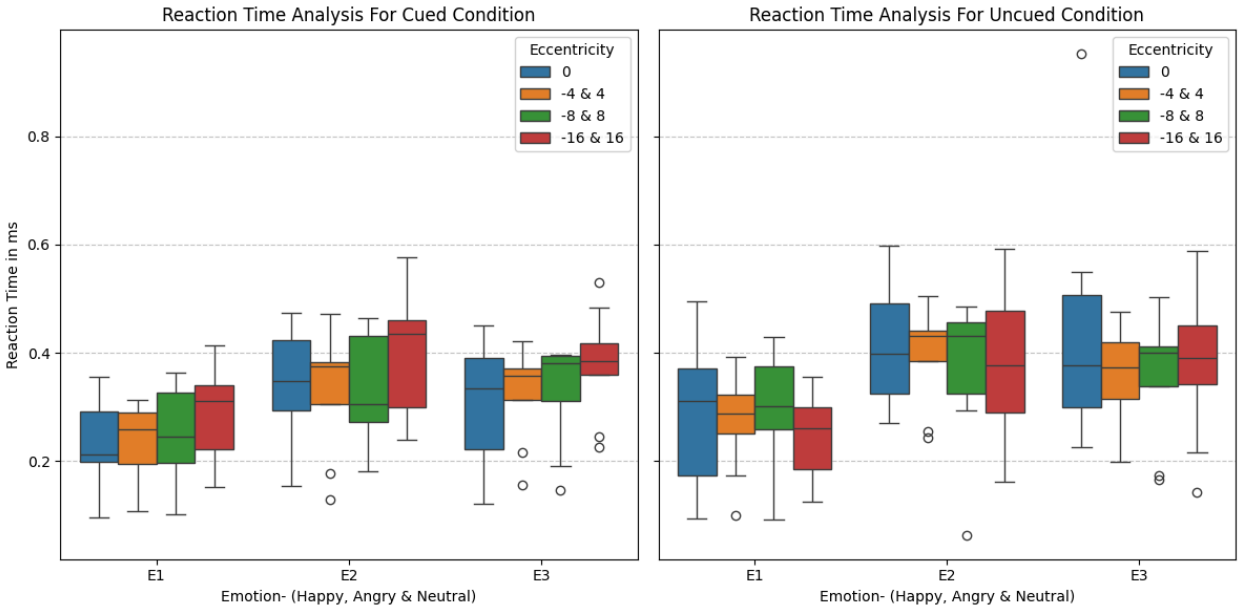

Figure 6: Reaction time for both conditions, for better comparison

From the above plots (figure-4,5,6), we can easily establish that, cued trials had a less reaction time across all the emotions, as compared to the uncued condition.
In the case of cued condition, reaction time increases as eccentricity increases, whereas the same is not evident for the uncued trials; reaction time remains almost same with increasing eccentricity, specifically for neutral emotion. Also, uncued trials have a higher variability, as indicated by the box height and whisker length. Thus uncued trials shows greater inconsistency as compared to the cued condition.
There are outliers for both the conditions, but uncued condition has are more frequent outliers for each of the emotion.
For emotions, E1 has the lowest reaction times, which suggests that E1 is detected more quickly. E2 on the other hand has the highest reaction time in case of cued condition, while E3 mostly has reaction time between E1 & E2, as indicated by the center of the box for each of the eccentricity.

4.2 Pupil Diameter

For aggregating data for pupil diameter, we take the average values across each column, below are the trends for the same.

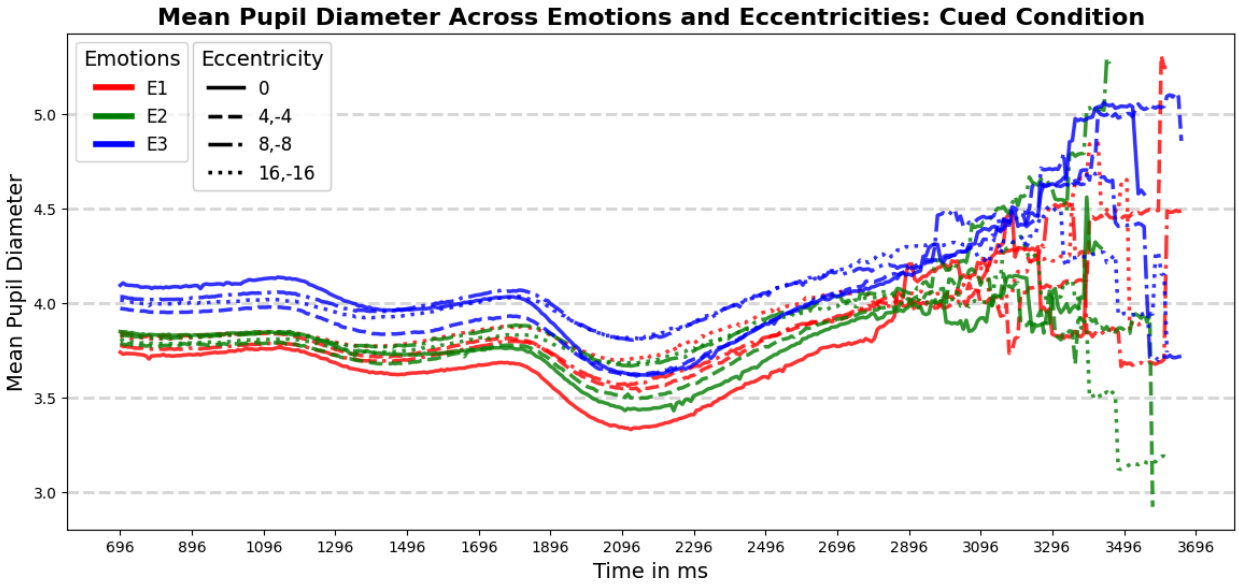

Figure 7: Pupil diameter trends for Cued Condition

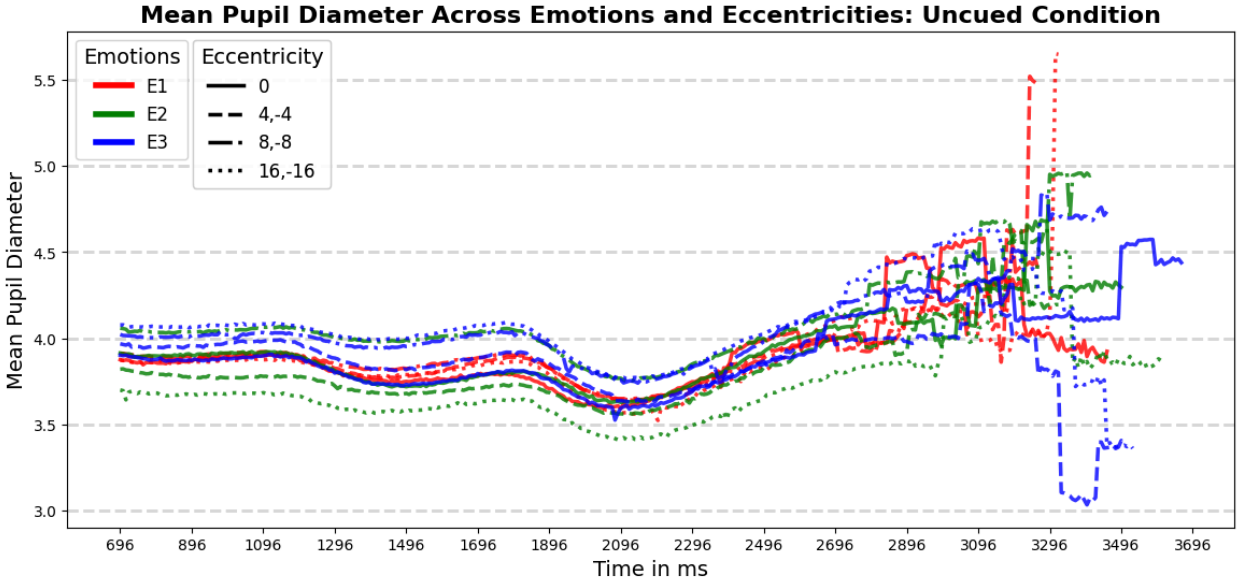

Figure 8: Pupil diameter trends for Uncued Condition

First of all, the right side of each graph has sudden variability for each curve due to fewer participants having data beyond 2600 ms.; hence, our main analysis will be from 1800 ms to 2600 ms, representing the region after stimulus presentation and till the response window.
Across both plots, there is a clear dip in pupil diameter after the presentation of the stimuli. And then a gradual increase after 2000 ms, indicating pupil dilation. Now, for cued condition, curves have a more structured and smooth increase and less overlapping regions, as compared to the uncued condition.
For emotions, E3, has highest pupil dilation than E1 & E2 across both the conditions, while E1 consistently has smallest dilation for cued trials, whereas E2 has intermediate dilation, as indicated by the color regions, first blue(E3), then green(E2) in between then, E1(red). Now, for greater eccentricities (±16, ±8), there is higher pupil dilation as compared to near eccentricities (0, ±4), as dotted curves are in upper region which shows pupil constricts less for them.
In case of Uncued condition, E2&E3, have more broader ranges of pupil dilation, while E1 has narrow regions for each of eccentricity.

4.3 Supporting Plot- Rate of change of pupil diameter with time for Cued Condition

To further inspect the region from 1800 ms to 2600 ms, I decided to plot the rate of change of pupil diameter with time for Cued Condition.

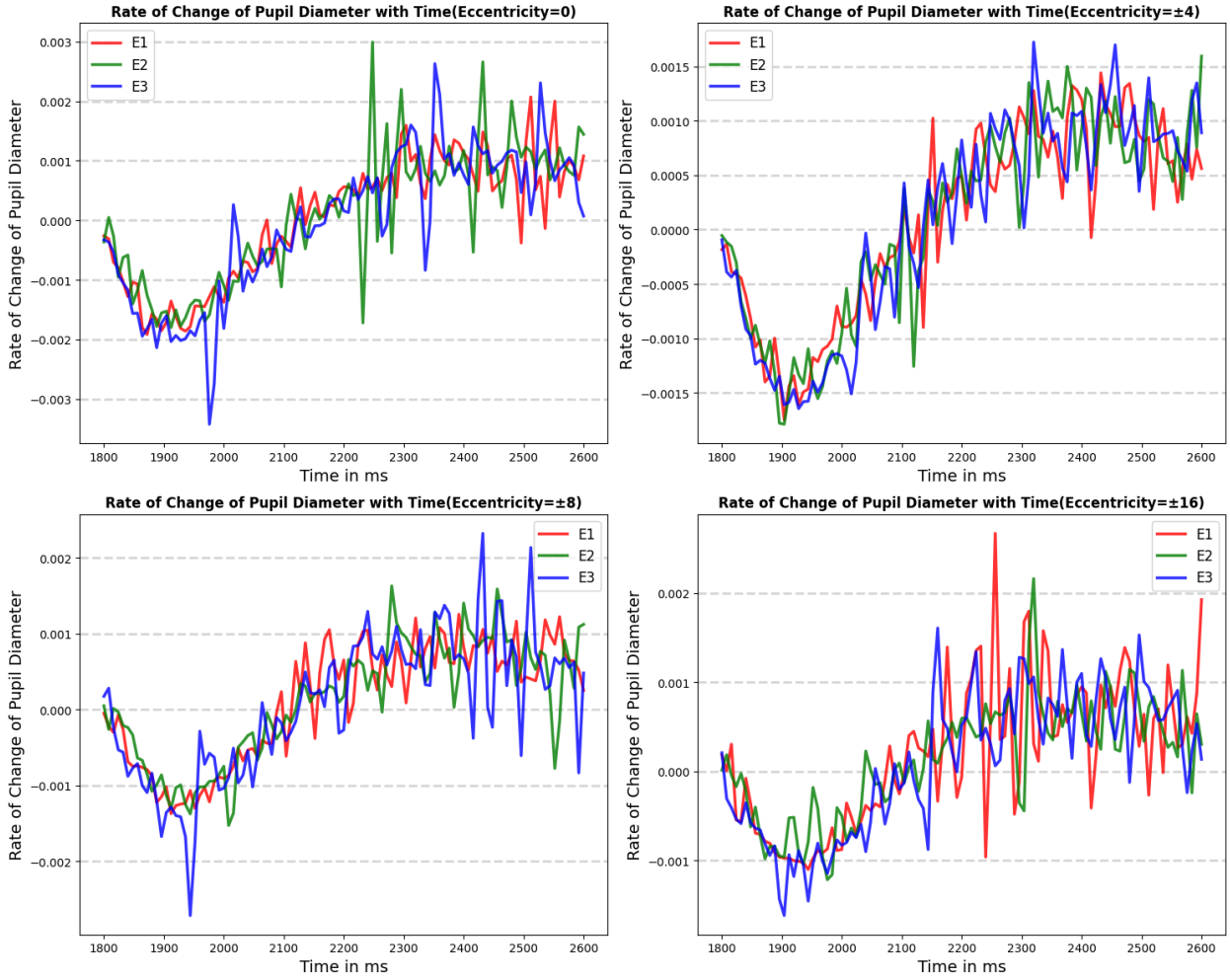

Figure 9: Rate of change of pupil diameter with time For Cued Condition

Initially the rate is negative, which leads to constriction phase and around 2200-2600 ms, the rate gets stabilized near to zero (positive). For eccentricity = 0, lowest negative rate is observed ~ -0.02, and the change has a linear fit till 2000ms. There are less fluctuations for ecc=0, now at eccentricity = ±4 it has less rate of change as compared to ecc=0, and after ~ 2100 ms, pupil dilation gets accelerated. And both the ±8 and ±16, have similar trends, but for ecc= ±16, a lot of fluctuations can be observed after 2200ms, across each emotion.

5. Inferences

Based on graphs from figures: 4,5&6, reaction time is faster for cued trials, with the cueing benefit more for E1, this aligns with Posner's cueing paradigm. Without the cues, reaction time are higher for more far locations (eccentricity = ±8,±16). Also happy faces are detected fast; this could be due to the evolutionary reasons, as happy represents a positive stimuli and it is more recognizable due to its social and pleasant nature. While, the angry emotion had a long reaction time, the possible reasons could be high cognition load & threat detection systems, as this emotion has a negative arousal. Whereas, the neutral faces had intermediate reaction times, as this doesn't provide strong emotional cues, thus makes them less recognizable.
As for pupil diameters, the higher dilations for neutral emotion means that neutral emotion requires more attentional load as it inherently doesn't have any emotional

arousal. Similarly, for happy emotion, it had lowest pupil dilation meaning which means that positive emotions are processed without that much load. While angry emotion requires some attention which may be is due to perceived threat from that emotion.
Also, larger eccentricities lead to greater pupil dilation, as processing emotional stimuli in peripheral vision requires greater effort, as compared to processing in near foveal regions: (0,±4).

6. Conclusion

From the graphs and data, we can conclude that if a valid cue is given, then it helps in processing and thus improves reaction time, this clearly aligns with Posner's cue paradigm. Also, emotional recognition has greater physiological arousal, mainly for angry stimuli, due to slower reaction times and intermediate pupil diameters. This further suggests that negative emotions are processed with heightened sensitivity due to the perceived threat.
Far eccentrities, lead to greater dilation, as stimuli in peripheral areas need more attentional resources so as to process them efficiently.

7. References

1. O'Sullivan, T., & Ibbotson, P. (2008). Matplotlib for Python Developers. *Packt Publishing*. Documentation: 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