PSY 308
Cognition Of Motor Movements
Monsoon 2024

Assignment 2

Shamik Sinha - 2022468

Introduction

Pupillometry has emerged as an important area of study as it offers a non-invasive, objective window into cognitive and emotional processes. This way of measuring human cognitive processes, has numerous advantages over other cognitive measures, in response to various mental states, such as attention, arousal, and emotional intensity (Franzen et al., 2022). This information can be invaluable for understanding human behaviour, improving user experience design, and even diagnosing neurological disorders (Hsu & Kuo, 2023).

The primary aim of this assignment is to perform an analysis to investigate the relationship between pupil dilation and reaction time in response to different emotional stimuli (Happy, Angry, Neutral) and experimental conditions (Main vs Control). By comparing these measures, we seek to understand how emotional cues and experimental manipulations influence cognitive processes and attention allocation.

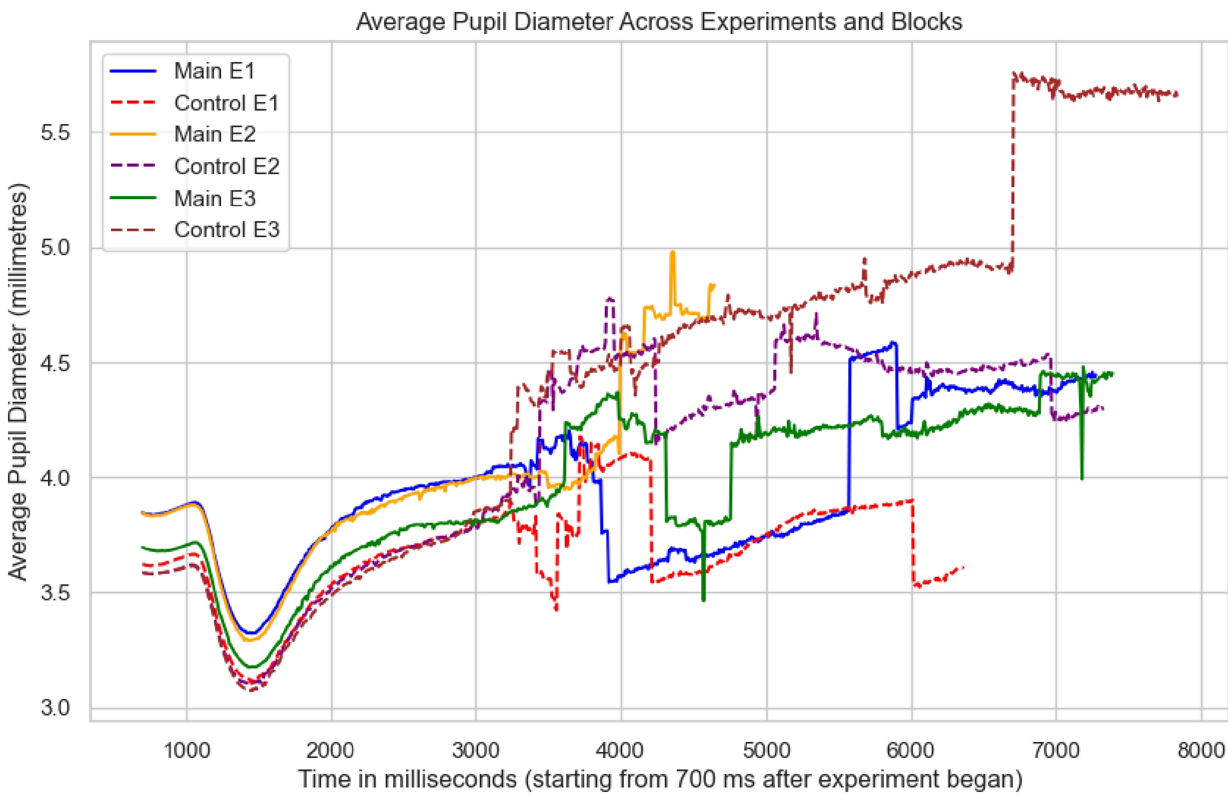
Methodology

The dataset used was collected from participants who were tasked with responding to facial expressions of Happy, Angry, and Neutral emotions. The participants completed two conditions: the Main Experiment, where they identified emotions, and the Control Experiment, where they identified the position of a red dot on the faces. The data consists of trials organised into three blocks (E1, E2, E3), corresponding to Happy, Angry, and Neutral expressions.

Data preprocessing was performed before performing any form of analysis. Firstly, We defined dictionaries to store pupil data and reaction times for each block (E1, E2, E3) and experiment type (Main and Control). Then from the CSV files containing pupil data, we extract pupil diameter measurements from columns 87 onward (after the stimulus presentation). These measurements are converted to numeric values and averaged across time points for each trial. Reaction times are also extracted, converted to numeric values, and stored for each block. The data is then organised by experiment type and block. Finally, we calculate the weighted averages of pupil diameter data across participants for each block, as well as the median reaction times for each condition. This aggregation allows for a comprehensive analysis of the pupil and reaction time responses across the experimental conditions.

We used line plots to illustrate average pupil diameter changes over time for each emotional block (Happy, Angry, Neutral) in both Main and Control conditions. Bar plots are used to display average reaction times across these blocks, comparing Main and Control conditions. Additionally, we used scatter plots to depict experiment duration variations across blocks and plot relationships between reaction time and pupil diameter. We also used violin plots to visualise the distribution of reaction times by stimulus type and condition among other things.

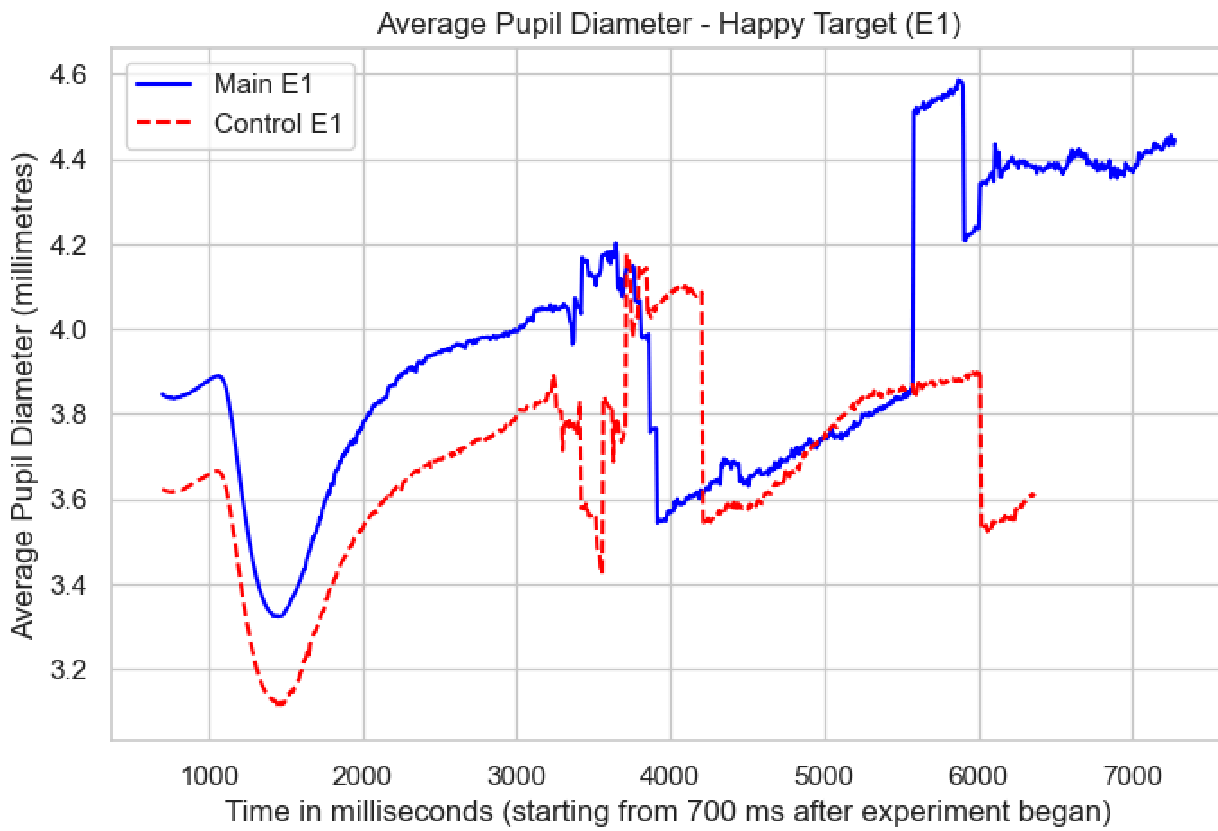
Results, Analysis & Inferences

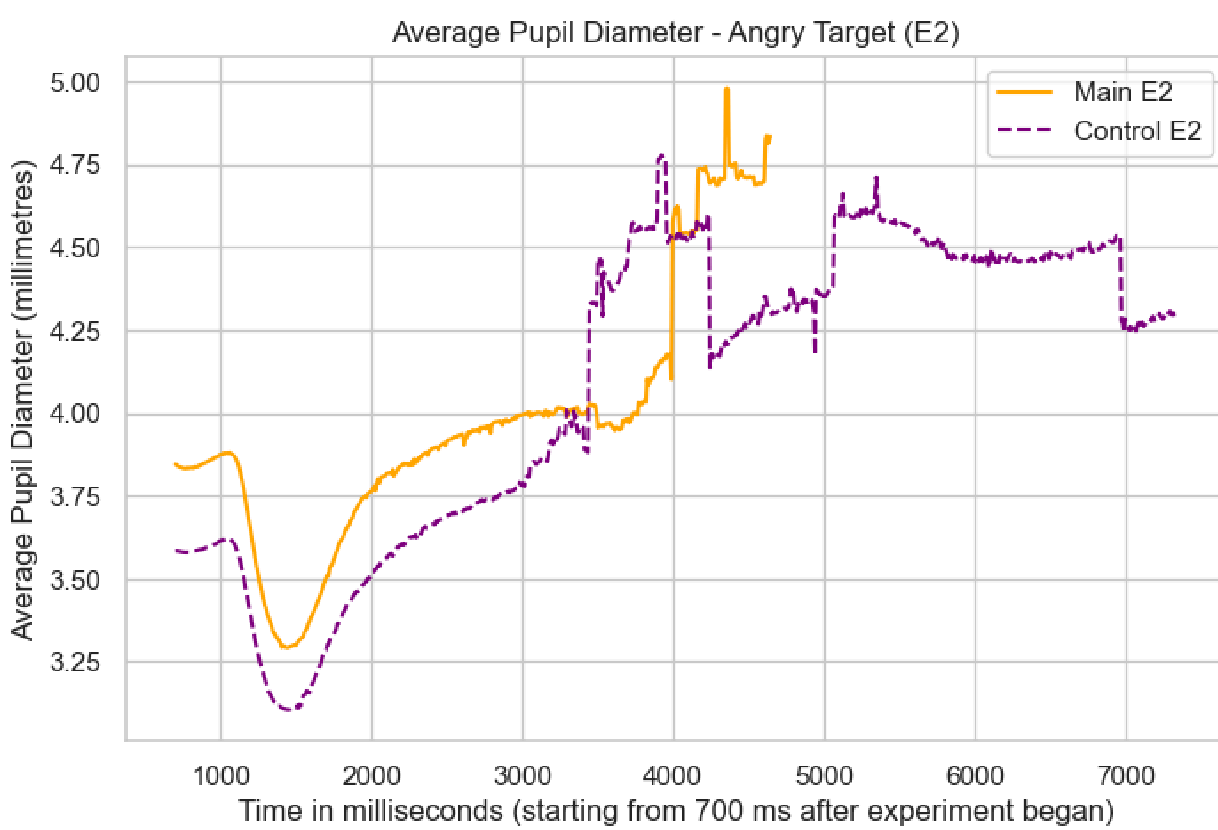


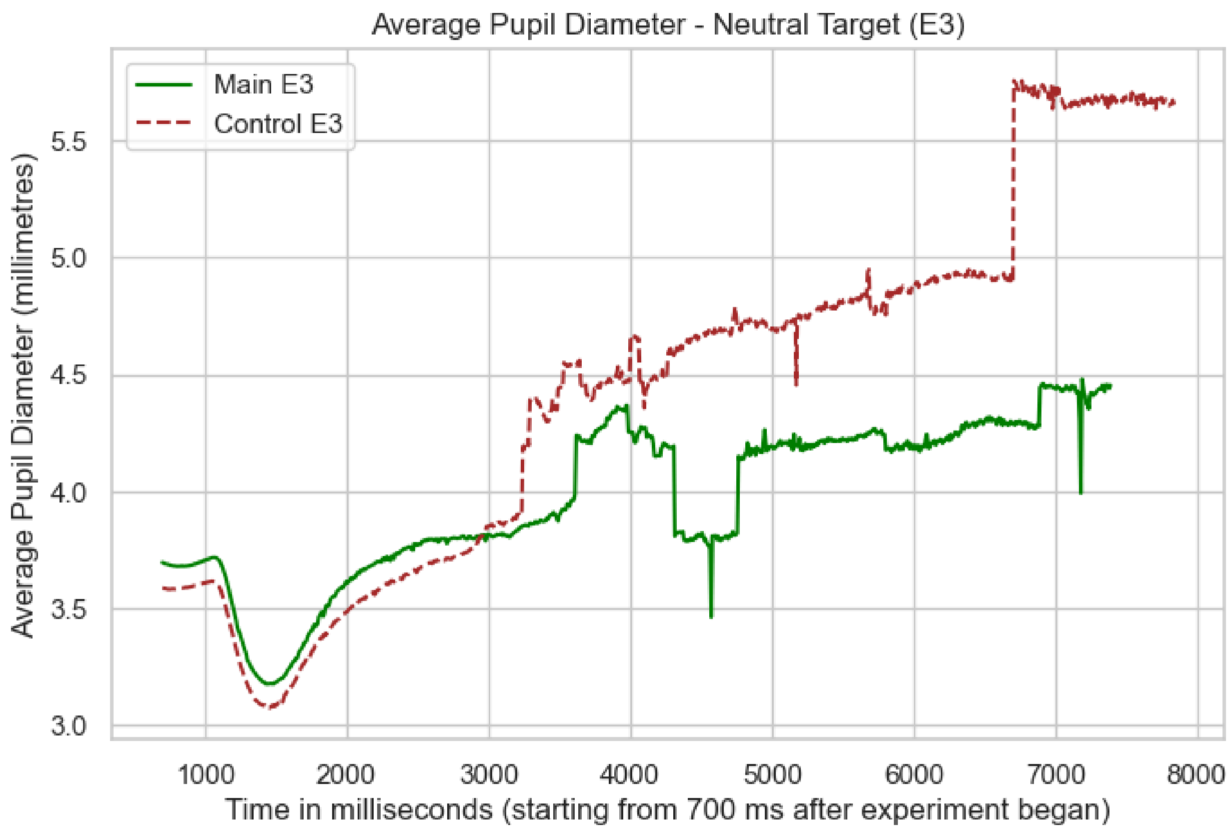
A single plot showing how average pupil diameter varies over time for different experimental conditions and emotional stimuli. The x-axis represents time in milliseconds, and the y-axis represents pupil diameter in millimetres. Different coloured lines are used to represent different conditions and blocks.

Observation: All conditions exhibit an initial dip in pupil diameter shortly after the experiment begins and the stimuli are presented.

Inference & references: This dip likely represents a phenomenon known as the "pupillary light reflex", where pupils constrict in response to visual stimuli or a sudden increase in brightness (Barrionuevo et al., 2023; Binda et al., 2013). Even though the stimulus here is likely emotional rather than simply visual, this reflex can still occur as an involuntary response to attention-grabbing stimuli (Barbur et al., 1992).


Average Pupil Diameter - Happy Target (E1)
Main E1
Control E1
Average Pupil Diameter (millimetres)
Time in milliseconds (starting from 700 ms after experiment began)
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
1000
2000
3000
4000
5000
6000
7000

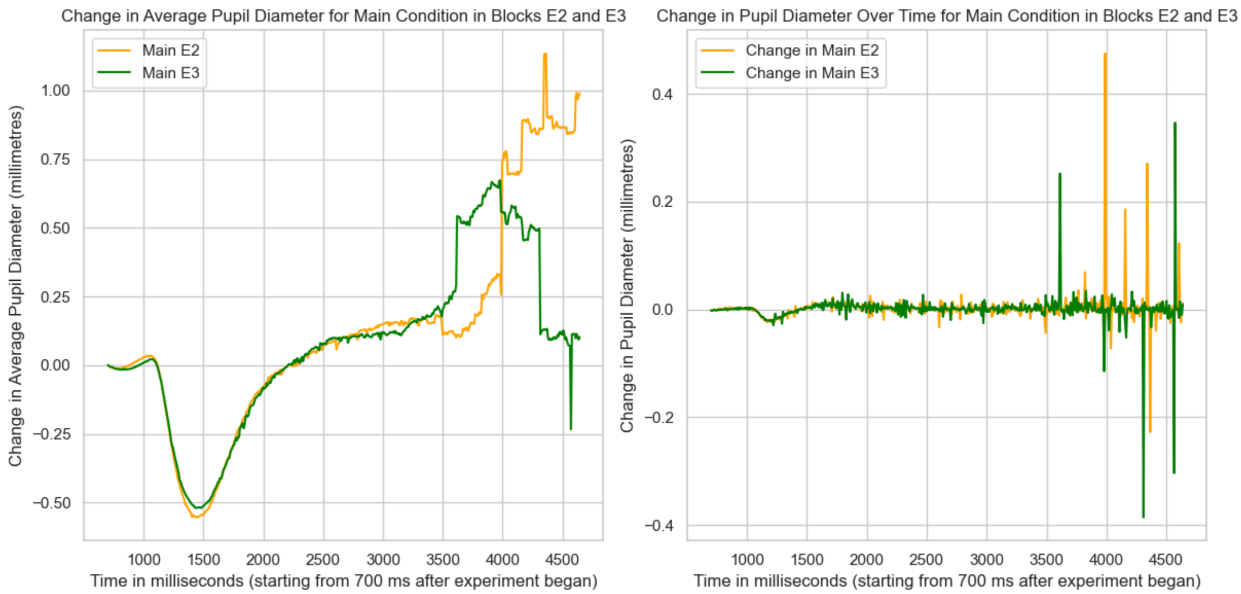

Average Pupil Diameter - Angry Target (E2)
Main E2
Control E2
Average Pupil Diameter (millimetres)
Time in milliseconds (starting from 700 ms after experiment began)
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
1000
2000
3000
4000
5000
6000
7000



The three graphs above illustrate changes in average pupil diameter over time for different emotional stimuli (Happy, Angry, Neutral) and experimental conditions (Main, Control). Each graph shows the time course of pupil dilation, with the x-axis representing time in milliseconds and the y-axis representing pupil diameter. Different coloured lines represent the Main and Control conditions for each emotional stimulus.

Observation: Across all three emotional conditions, following the initial dip, the pupil starts to expand significantly, particularly after 2000 milliseconds.

Inference: This dilation is linked to increased cognitive load, specifically when people are processing any sort of stimuli. The pupil diameter increase in “response to increased cognitive activity”, like “increased levels of arousal or mental effort”. This aligns with research findings on the relationship between cognitive load and pupil size (Mathôt, 2018).



The graphs show changes in pupil diameter over time for two conditions (E2 and E3). The left graph shows average change, while the right graph shows individual changes in average pupil diameter over time for Angry and Neutral emotions, only for the main experimental condition. The x-axis represents time in milliseconds, and the y-axis represents pupil diameter.

Observation: The average change in pupil diameter spike more in the positive direction and average pupil diameter subsequently higher for the Angry condition than the Neutral condition.

Inference & references: This increased pupil diameter for the Angry condition suggests heightened arousal and attentional engagement. Negative emotions, such as anger, increase arousal and attentional engagement, leading to larger pupil size as was also observed by Kinner et al. (2017). Heightened pupil dilation observed for angry stimuli also reflects an evolutionary response, where increased attention is directed towards potential threats (Sørensen & Barratt, 2014). Pupils dilate more when greater attention is allocated to a phenomenon (Kang et al., 2014). These studies, therefore validate our inference.

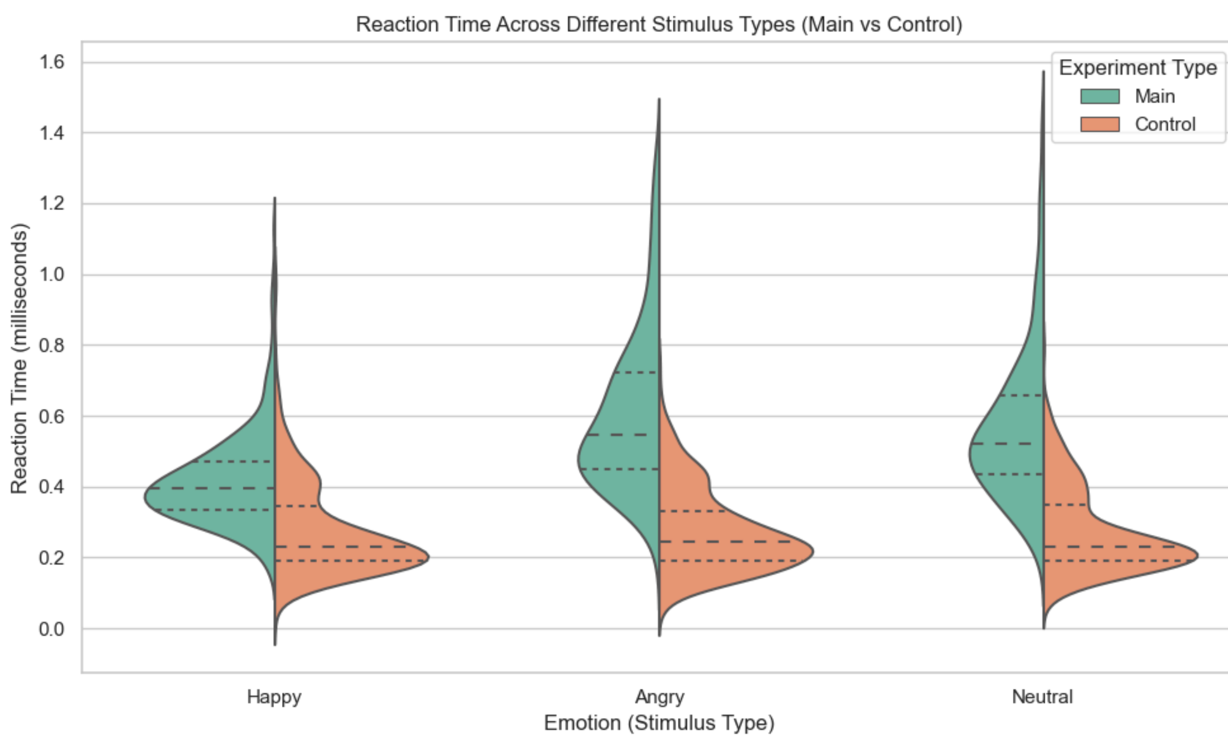
The Bar Plot displays the average reaction times for the Main and Control conditions across three different emotional blocks (E1, E2, E3). It compares the time participants take to respond to the stimuli in each condition.

Observation: The Main condition consistently exhibits higher reaction times than the Control condition across all three emotional blocks. Reaction time was significantly affected by the presentation of emotional stimuli.

Inference and references: This suggests that the task of identifying the target emotion in the Main condition was more cognitively demanding than the task of detecting the red dot in the Control condition. The significant effect of emotional stimuli on reaction time suggests that emotions can influence cognitive-motor performance, potentially by affecting attention and decision-making (Lu et al., 2017).

Observation: The average reaction time for the "Happy" emotion condition is consistently lower compared to the "Angry" and "Neutral" emotion conditions across all three blocks (E1, E2, E3).

Inference: Participants were quicker to identify and respond to happy facial expressions compared to angry or sad expressions. This difference in reaction times could be attributed to the inherent salience and positive valence of happy emotions. Happy faces may be more easily processed due to their association with positive experiences and rewards, leading to faster cognitive processing and quicker responses. This finding aligns with research suggesting that positive emotions can enhance cognitive performance and attentional focus (Leppänen et al., 2003; Fox et al., 2000).



The violin plot visually represents the distribution of reaction times for different emotions, revealing that happy faces are recognized faster than angry or neutral expressions. The wider the violin, the more variability in reaction times. The less overlap between violins, the more significant the difference between conditions. This plot strengthens the conclusion from the previous bar plot, indicating that happy faces are indeed processed more quickly.

Conclusion

The results highlight that pupil diameter significantly changes in response to emotional stimuli, with larger dilation for angry faces, indicating heightened arousal and attentional engagement. The Main experiment (emotion recognition) elicited greater pupil dilation and longer reaction times compared to the Control experiment (dot detection), suggesting that emotional processing demands more cognitive resources. Reaction times were quicker for happy faces, supporting the idea that positive stimuli are processed more efficiently. Overall, emotional cues, particularly negative ones like anger, require more cognitive effort, with pupil dilation serving as a reliable indicator of cognitive load and attentional engagement in emotional processing.

Bibliography

Franzen, L., Cabugao, A., Grohmann, B., Elalouf, K., & Johnson, A. P. (2022). Individual pupil size changes as a robust indicator of cognitive familiarity differences. *PloS One*, *17*(1), e0262753. https://doi.org/10.1371/journal.pone.0262753

Hsu, C.-H., & Kuo, L.-T. (2023). Application of Pupillometry in Neurocritical Patients. *Journal of Personalized Medicine*, *13*(7), 1100. https://doi.org/10.3390/jpm13071100

Barrionuevo, P. A., Issolio, L. A., & Tripolone, C. (2023). Photoreceptor contributions to the human pupil light reflex. *Journal of Photochemistry and Photobiology*, *15*, 100178. https://doi.org/10.1016/j.jpap.2023.100178

Binda, P., Pereverzeva, M., & Murray, S. O. (2013). Attention to Bright Surfaces Enhances the Pupillary Light Reflex. *Journal of Neuroscience*, *33*(5), 2199–2204. https://doi.org/10.1523/JNEUROSCI.3440-12.2013

Barbur, J. L., Harlow, A. J., & Sahraie, A. (1992). Pupillary responses to stimulus structure, colour and movement. *Ophthalmic and Physiological Optics*, *12*(2), 137–141. https://doi.org/10.1111/j.1475-1313.1992.tb00276.x

Mathôt, S. (2018). Pupillometry: Psychology, Physiology, and Function. *Journal of Cognition*, *1*(1), 16. https://doi.org/10.5334/joc.18

Kang, O. E., Huffer, K. E., & Wheatley, T. P. (2014). Pupil Dilation Dynamics Track Attention to High-Level Information. *PLOS ONE*, *9*(8), e102463. https://doi.org/10.1371/journal.pone.0102463

Kinner, V. L., Kuchinke, L., Dierolf, A. M., Merz, C. J., Otto, T., & Wolf, O. T. (2017). What our eyes tell us about feelings: Tracking pupillary responses during emotion regulation processes. *Psychophysiology*, *54*(4), 508–518. https://doi.org/10.1111/psyp.12816

Sørensen, T. A., & Barratt, D. (2014). Is threat the only modulator of attentional selectivity? Redefining the Easterbrook hypothesis. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.01020

Lu, Y., Jaquess, K. J., Hatfield, B. D., Zhou, C., & Li, H. (2017). Valence and arousal of emotional stimuli impact cognitive-motor performance in an oddball task. *Biological Psychology*, *125*, 105–114. https://doi.org/10.1016/j.biopsycho.2017.02.010

Leppänen, J., Tenhunen, M., & Hietanen, J. (2003). Faster Choice-Reaction Times to Positive than to Negative Facial Expressions. *Journal of Psychophysiology*, *17*, 113–123. https://doi.org/10.1027//0269-8803.17.3.113

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial Expressions of Emotion: Are Angry Faces Detected More Efficiently? *Cognition & Emotion*, *14*(1), 61. https://doi.org/10.1080/026999300378996