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Effect of motor imagery on pupil dilation

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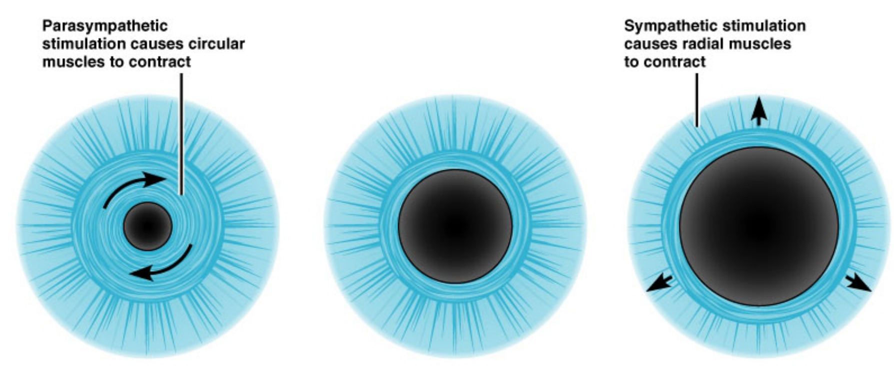
INTRODUCTION

One function of the pupil is to regulate the flux of light entering the eye in response to changes in illumination.



What does modulate pupil diameter?

1. Pupillary light reflex: From 1.5mm to 9mm, 200ms latency.

2. Emotions alter pupillary responses as well (C. Bernard; C. Darwin 1850)

   - Diameter increases: sexual arousal, pain, novelty, task difficulty
   - Diameter decreases: age, habituation, negative affect

Contriction: parasympathetic pathway (pretectal olivary nucleus, Edinger–Westphal nucleus, ciliary ganglion)

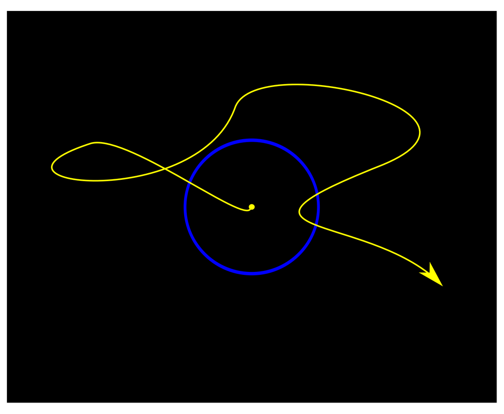
Dilation: sympathetic circuit (hypothalamus)

But what about 'non cognitive' real and imagined motor tasks?

METHODS

41 subjects participated in 3 experiments.

Goal: control the cursor such that its time spent within the circle was maximized during 25s.



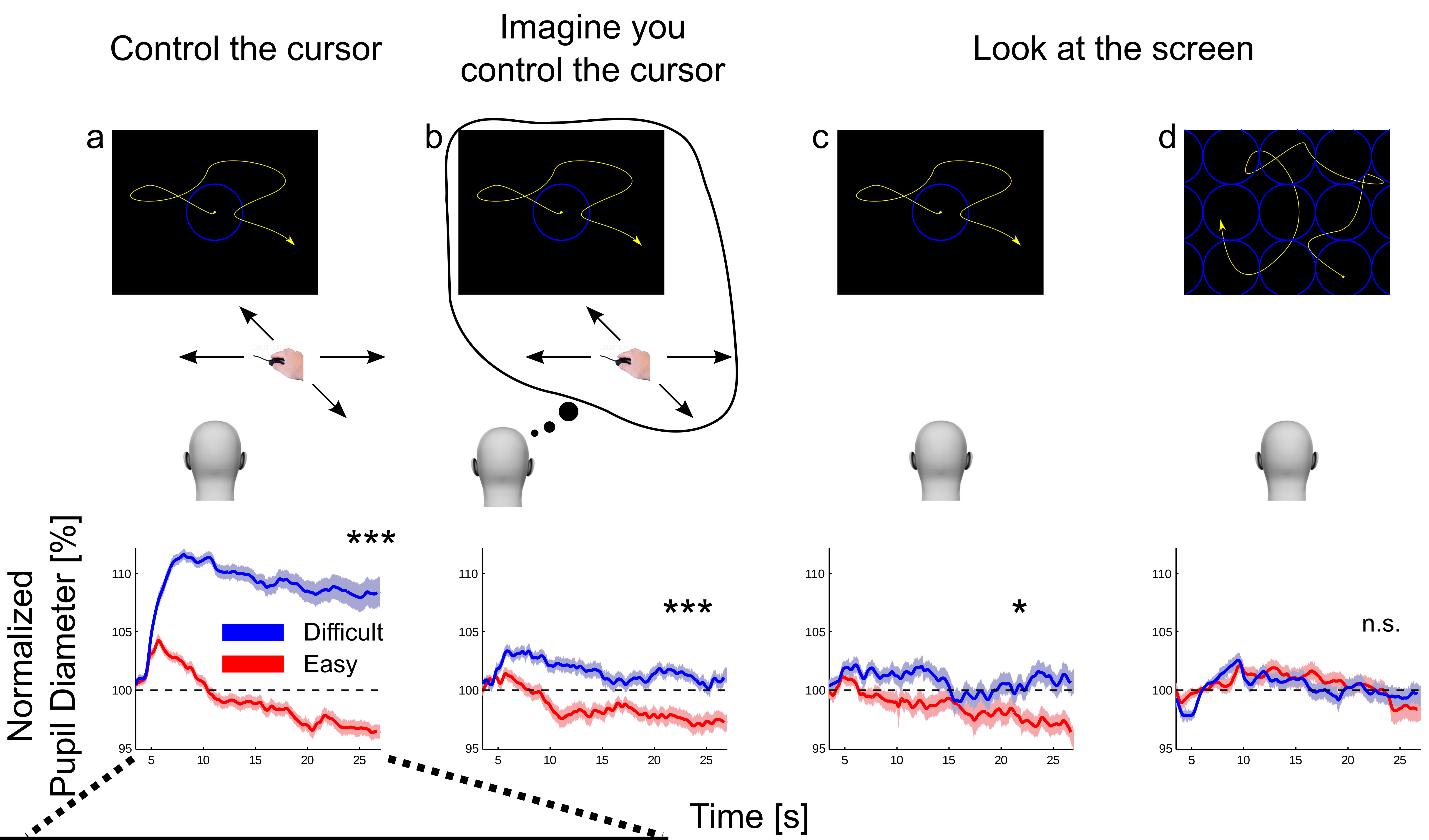
$$\begin{bmatrix}x\\y\end{bmatrix}_{t+1} = \begin{bmatrix}x\\y\end{bmatrix}_{t} + \begin{bmatrix}\theta_x\\\theta_y\end{bmatrix}, \theta_x, \theta_y \sim N(0,\sigma)$$

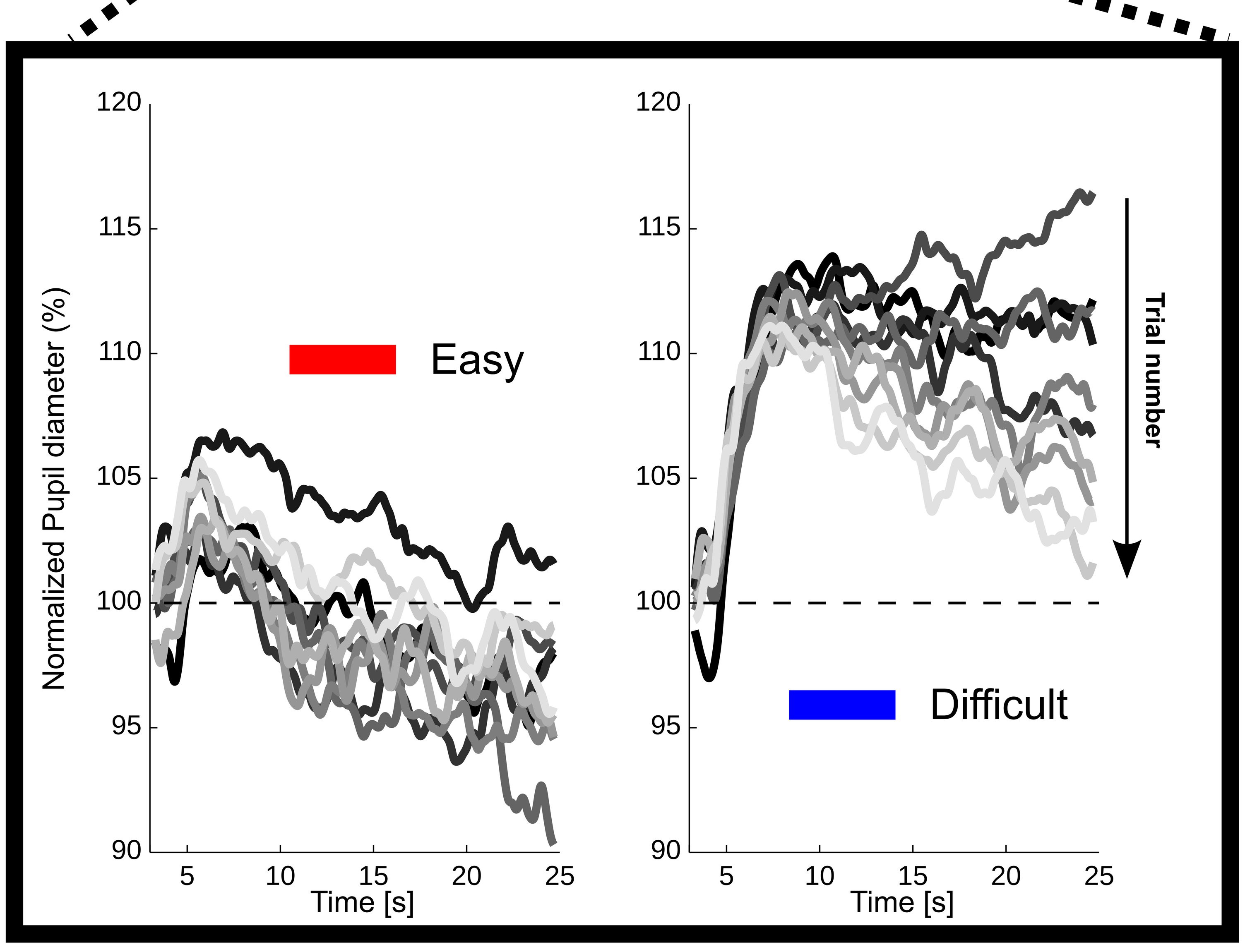
Easy: small sigma (10mm)
Difficult: large sigma (35mm)

Experiment 1: real and imagined movements (n=20)
- Real then Imagined
- 10 Easy + 10 Difficult, randomized

Experiments 2-3: watch the screen (n=10 & 11)
- 10 Easy + 10 Difficult, randomized

RESULTS





(a) Largest normalized pupil diameters in the difficult real condition.

(b) Still true when participants imagined the motor commands required to maintain the cursor in the circle.

(c) Without prior instruction, pupil diameters were closer in both conditions but still larger in the most challenging trials.

(d) When there was no "natural" place to move the cursor, pupil diameters became undistinguishable across conditions.

When performing real movements, pupil diameters decreased over time from the first trial in the **Easy** condition.

In contrast, the **Difficult** condition required learning as indicated by increasing or sustained pupil diameters over time in the early trials.

CONCLUSION

The present study is unique in its attempt to eliminate factors related to cognitive workload and arousal and to focus on the effects of motor activity on pupil dilation. Motor imagery by itself is sufficient to induce differences in pupillometry, although the engagement of additional computational processes when an actual motor output is required increases pupil dilation.
This finding has important methodological implication as it provides a reliable indirect real time measurement of resources required by motor imagery and has a much better time resolution than chronometry, widely used in the motor imagery literature.

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