

Pupillometry and Eye Tracking for Cognitive workload measurement

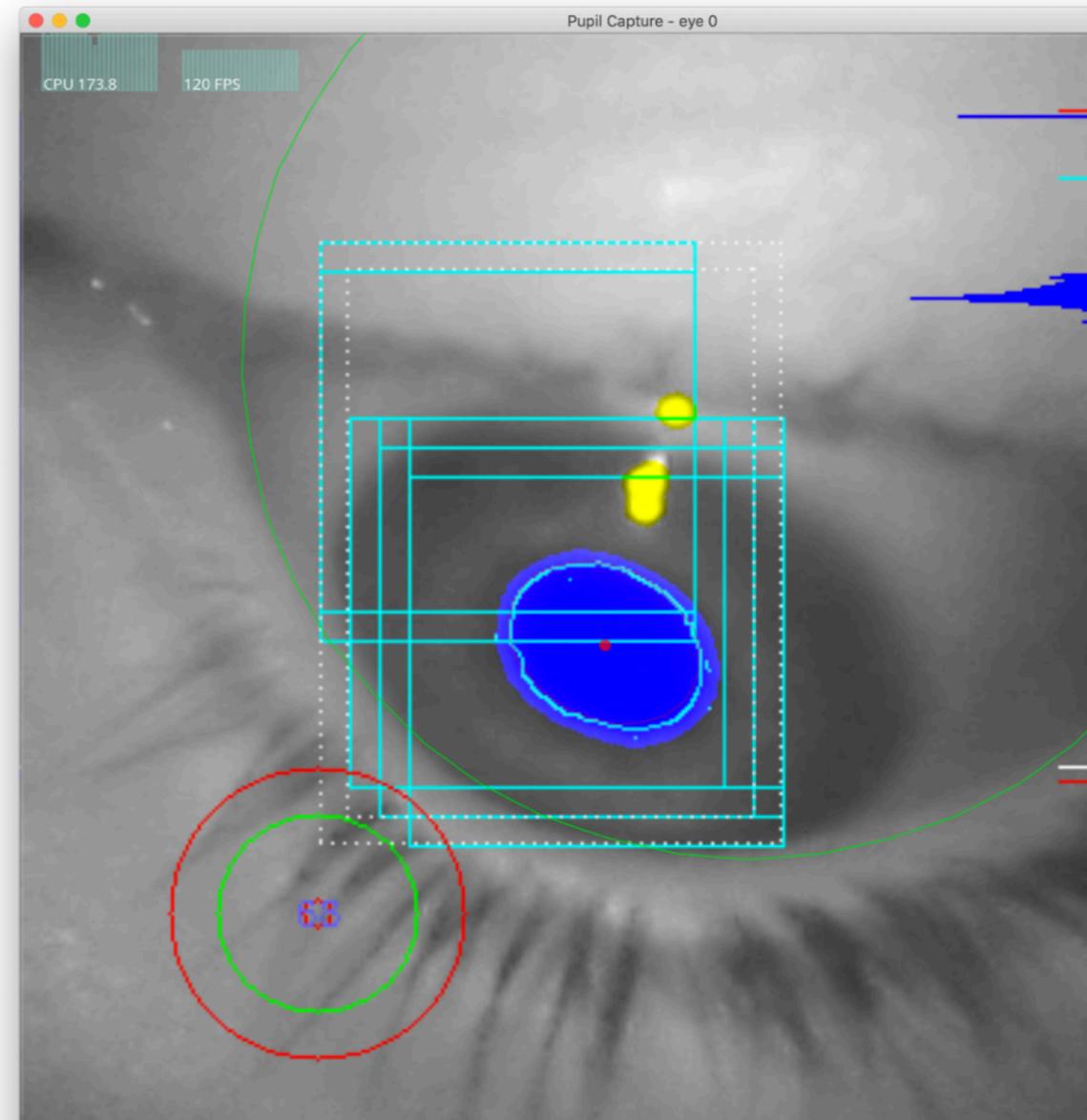
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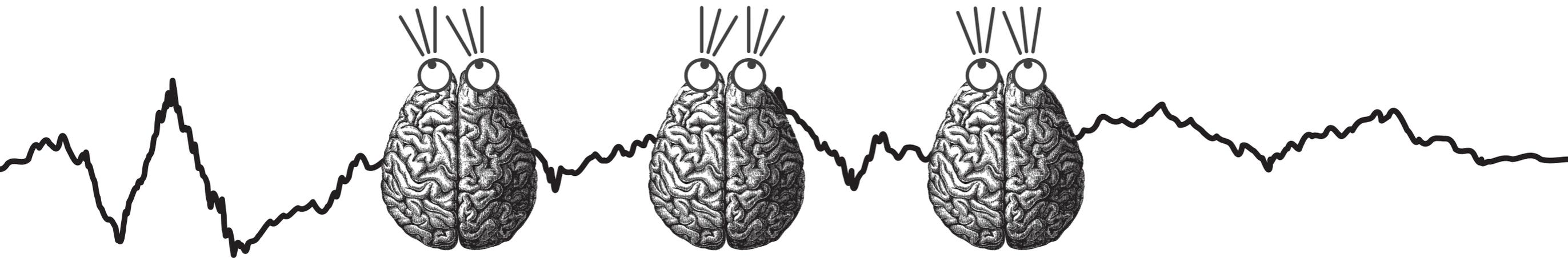


The Norwegian Defence University College - Forsvaret

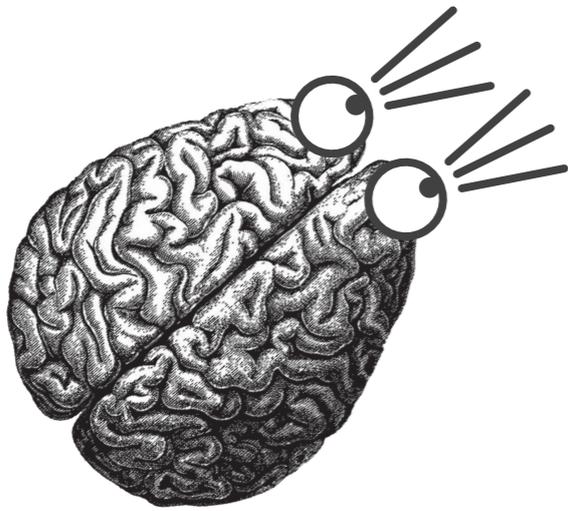


Cognitive Workload

- Measurable level of **mental effort** put forth by an **individual** in response to a **task**.
- Result of the **interaction** between a subject and a task.
- **Human-centred** rather than **task-centred**.



Scope



Development of a **field method** for the measure of **cognitive workload** in usability testing.

- **Accidents and Procedures** analysis in simulators.
- Optimise the **design** to fit the **human** component.
- Development of **reactive safety** countermeasures built inside the system.

Why C.W.?

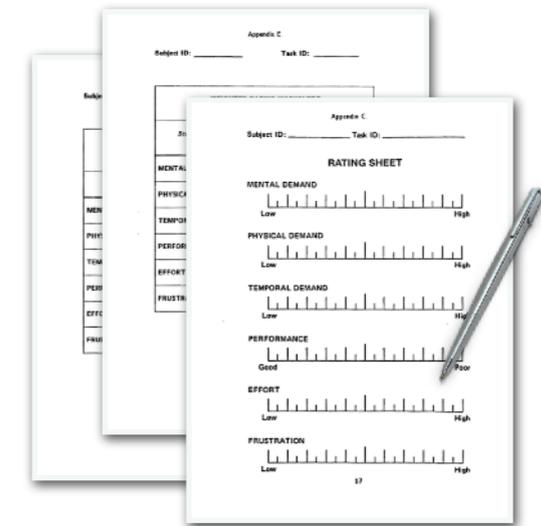
A tool in the interaction design and evaluation of **safety-critical systems**:

- Collect data about **physical** and **cognitive state**.
- Identify **mental over-load** and **under-load**.



How is C.W. measured?

- **Subjective Ratings** > Subjective measures of perceived effort as rated by the subject.



- **Performance observation** > Performance of the subject in a controlled task.
Workload \neq performance.



- **Physiological Measures** > Physiological indices of cognitive state, nonintrusive data over time.

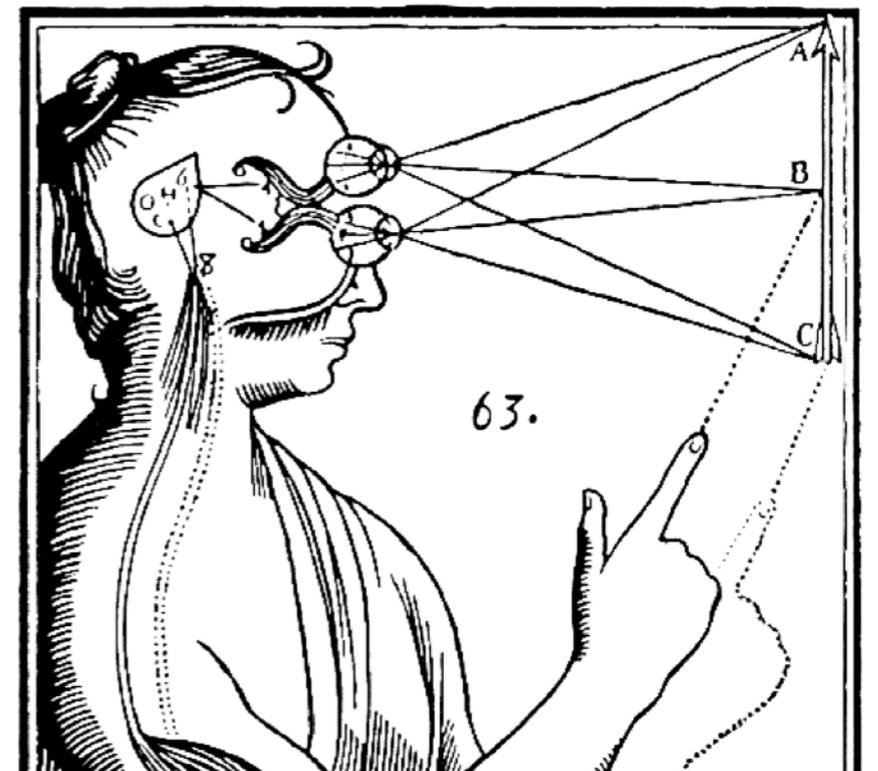


A by-product of Eye Tracking

Eye Tracking **enables** a variety of measurements with a single device:

- Visual attention.
- Parameters of eye movement (saccades and fixations).
- **Pupil size.**

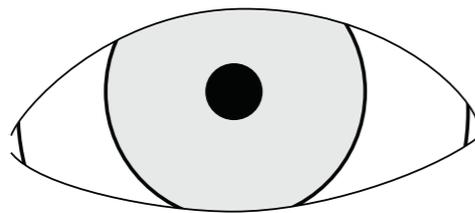
It is Portable, Unobtrusive and Affordable.



Pupil Size

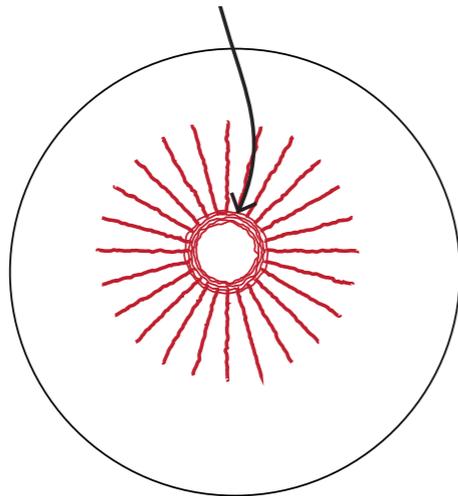
Bright Light

Fast Light Reflex



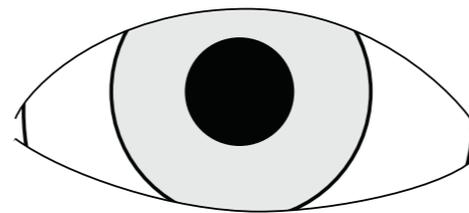
Parasympathetic system

Circular muscles
Contracting



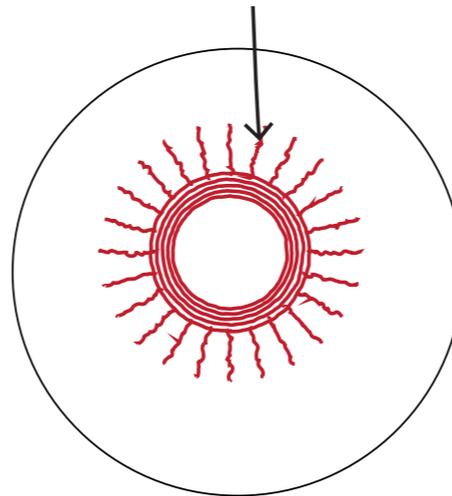
Dim Light

Slow Light Adaptation



Sympathetic system

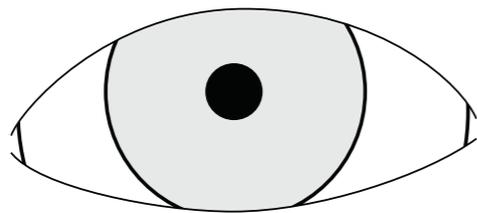
Radial muscles
Contracting



Pupil Size

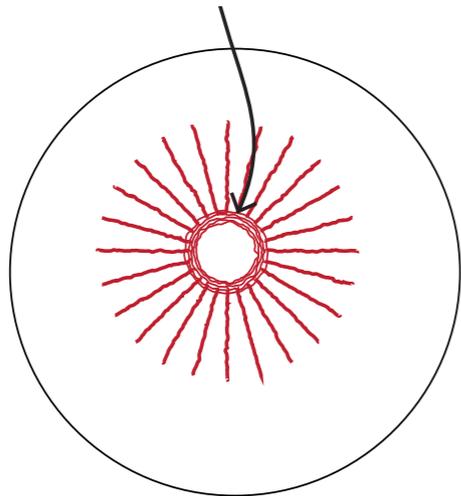
Bright Light

Fast Light Reflex



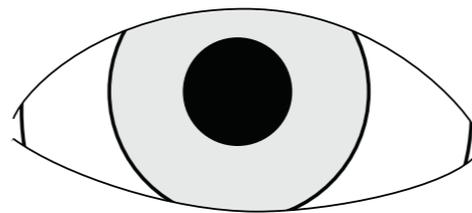
Parasympathetic system

Circular muscles
Contracting



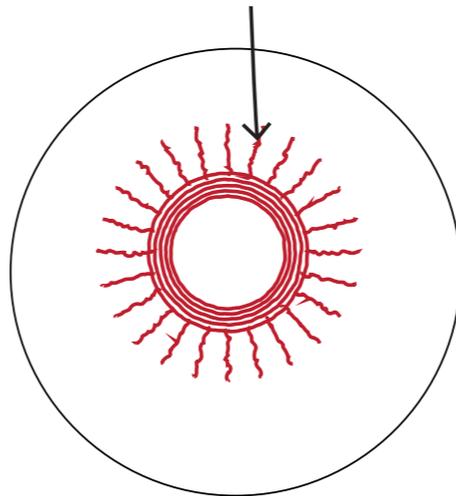
Dim Light

Slow Light Adaptation



Sympathetic system

Radial muscles
Contracting



Brain Activity

Fast Dilation Reflex



Pupil Size

As more **electrical impulses** are received by the brainstem



more **reflex impulses** are sent to the pupils

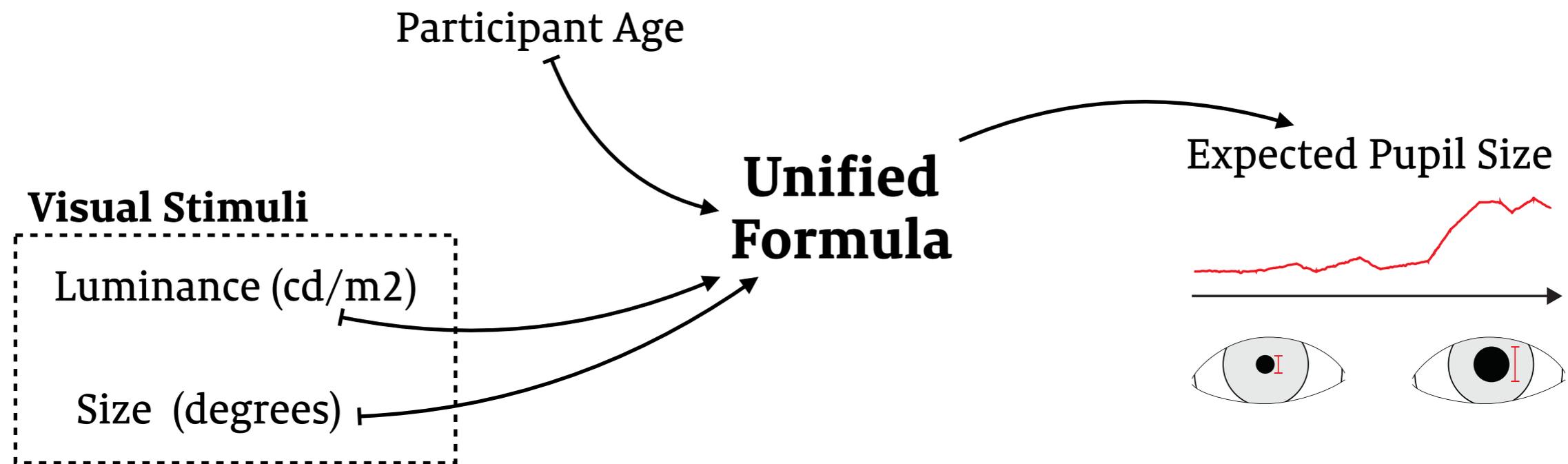


greater the **pupil dilatation** becomes.

In stable lighting conditions, changes in pupil diameter reflects changes in cognitive workload.

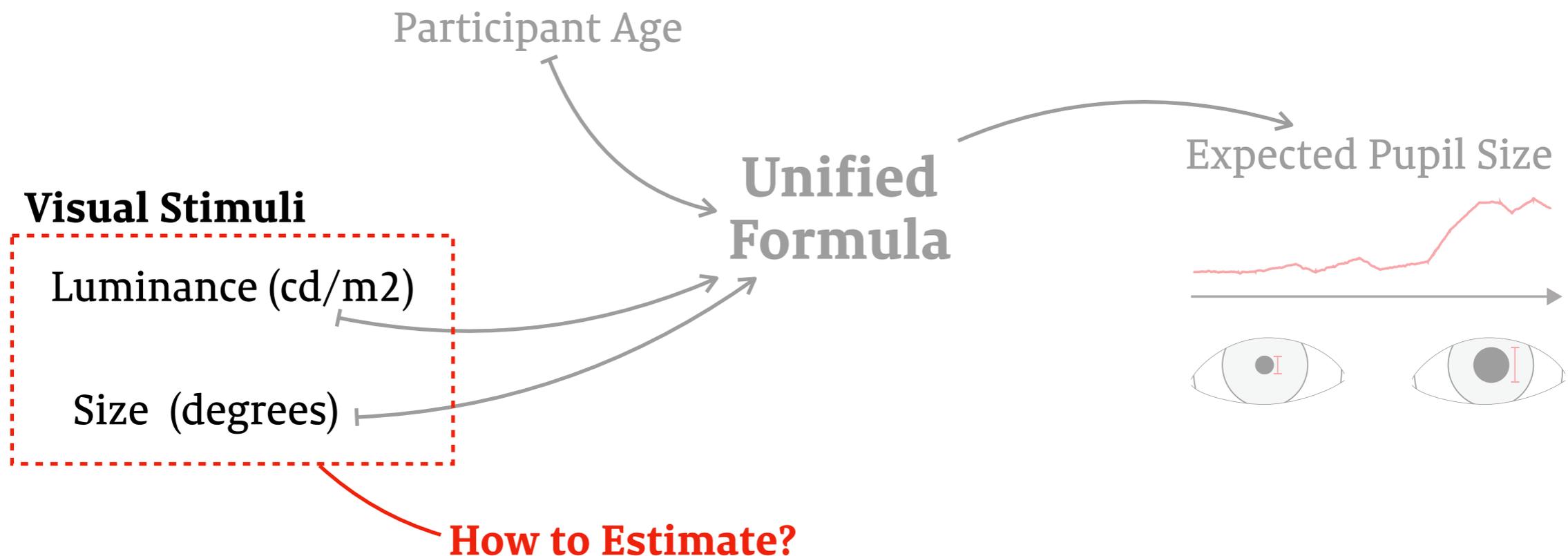
Estimate the pupil size

Implementing the **unified formula** for light-adapted **pupil size**
by Andrew B. Watson and John I. Yellott.



Estimate the pupil size

Implementing the **unified formula** for light-adapted **pupil size**
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Affordable Eye Tracker (Pupil Labs)



Estimate the visual stimuli

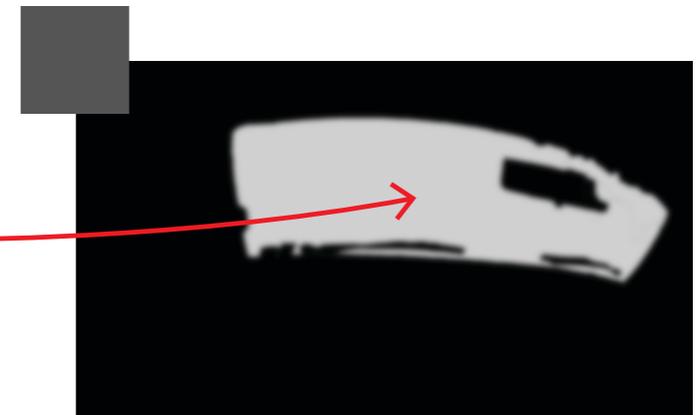
Calculate the average relative luminance.



Video + Gaze data



Isolate the area surrounding the gaze.



Relative luminance around the gaze.

Estimate the visual stimuli

Relative luminance
from the video.

Absolute luminance
from the sensor.



Average Relative
Luminance



Gaze Relative
Luminance

334cd/m²

Average
Luminance

Combined luminance

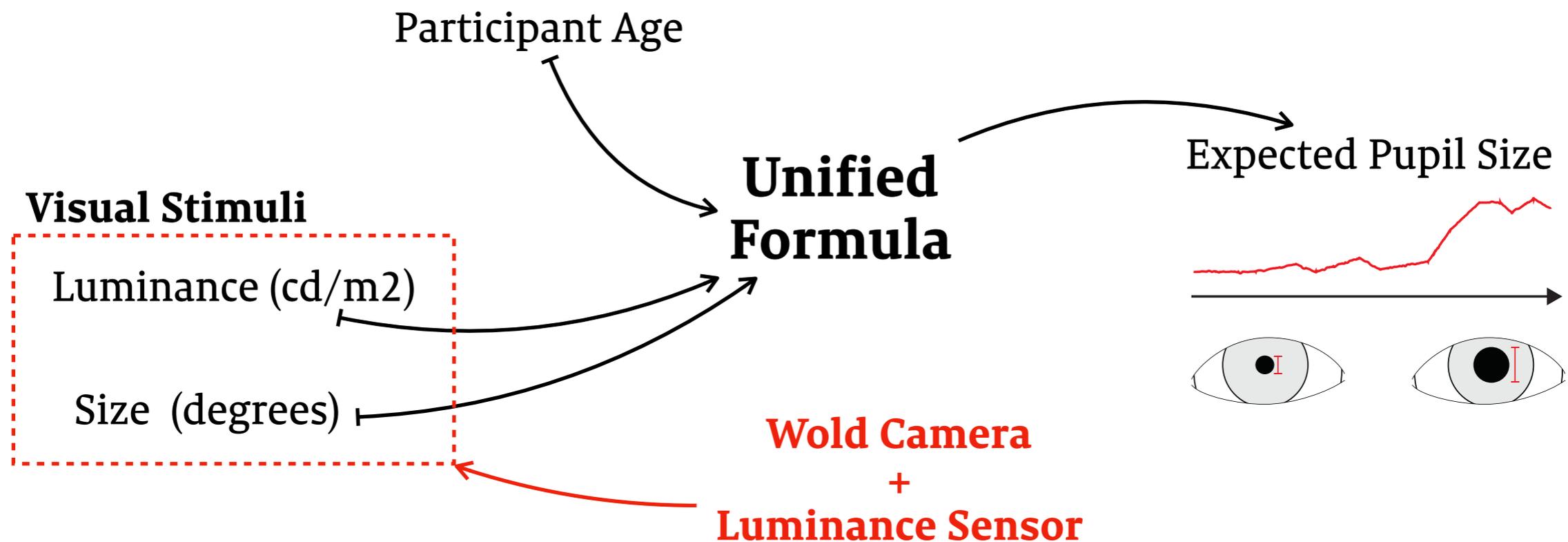
540cd/m²

Gaze
Luminance

**Dependant on
exposure**

Estimate the visual stimuli

Using the **unified formula** for light-adapted **pupil size** by Andrew B. Watson and John I. Yellott.



Cognitive workload

As the **difference** between the **expected pupil size** and the **measured pupil size**.

Light



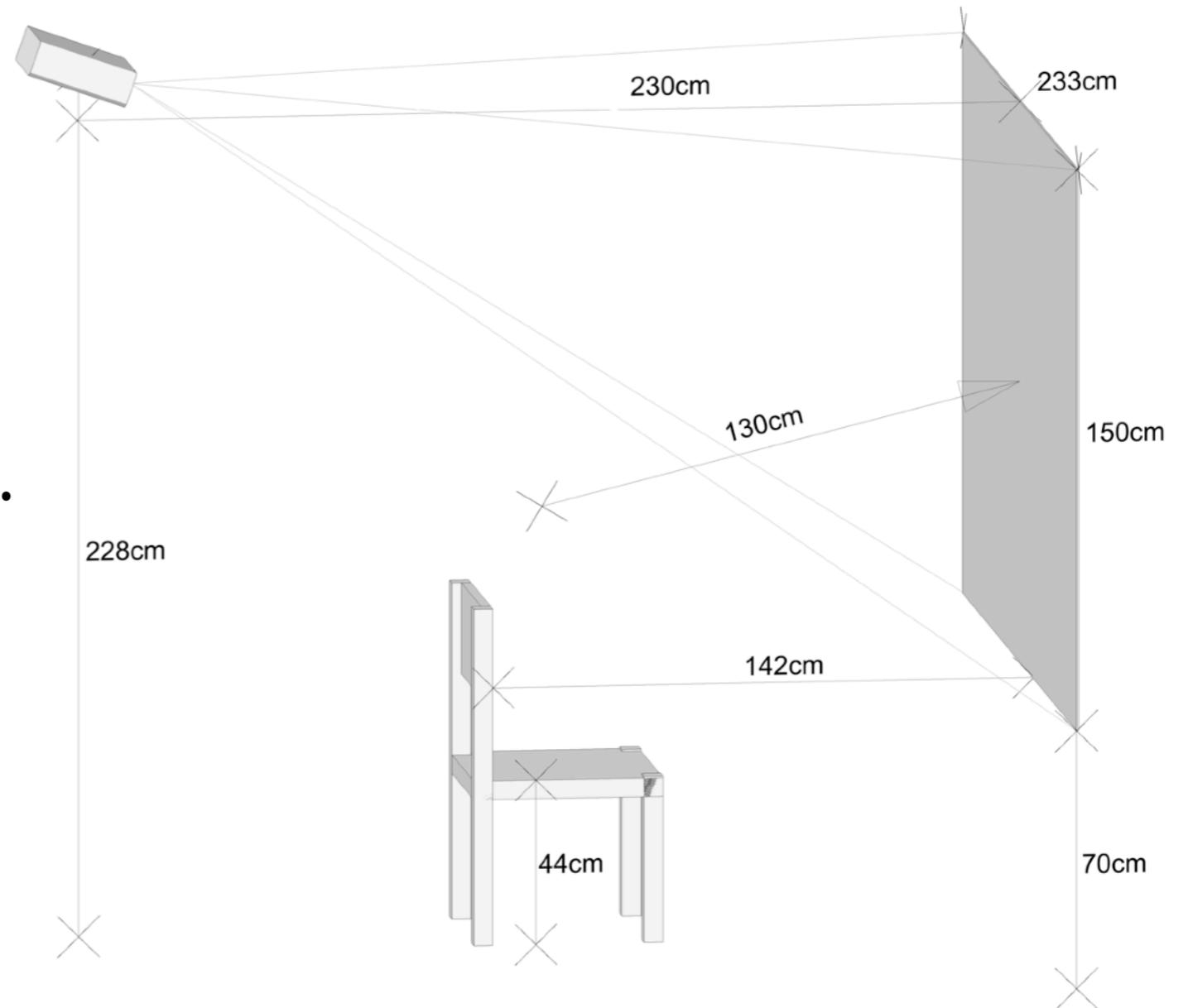
Cognitive Workload



Measured Pupil = Expected Pupil + Effect of CW + Noise

Laboratory test

- Controlled visual stimuli.
- Sequence of cognitive tasks.

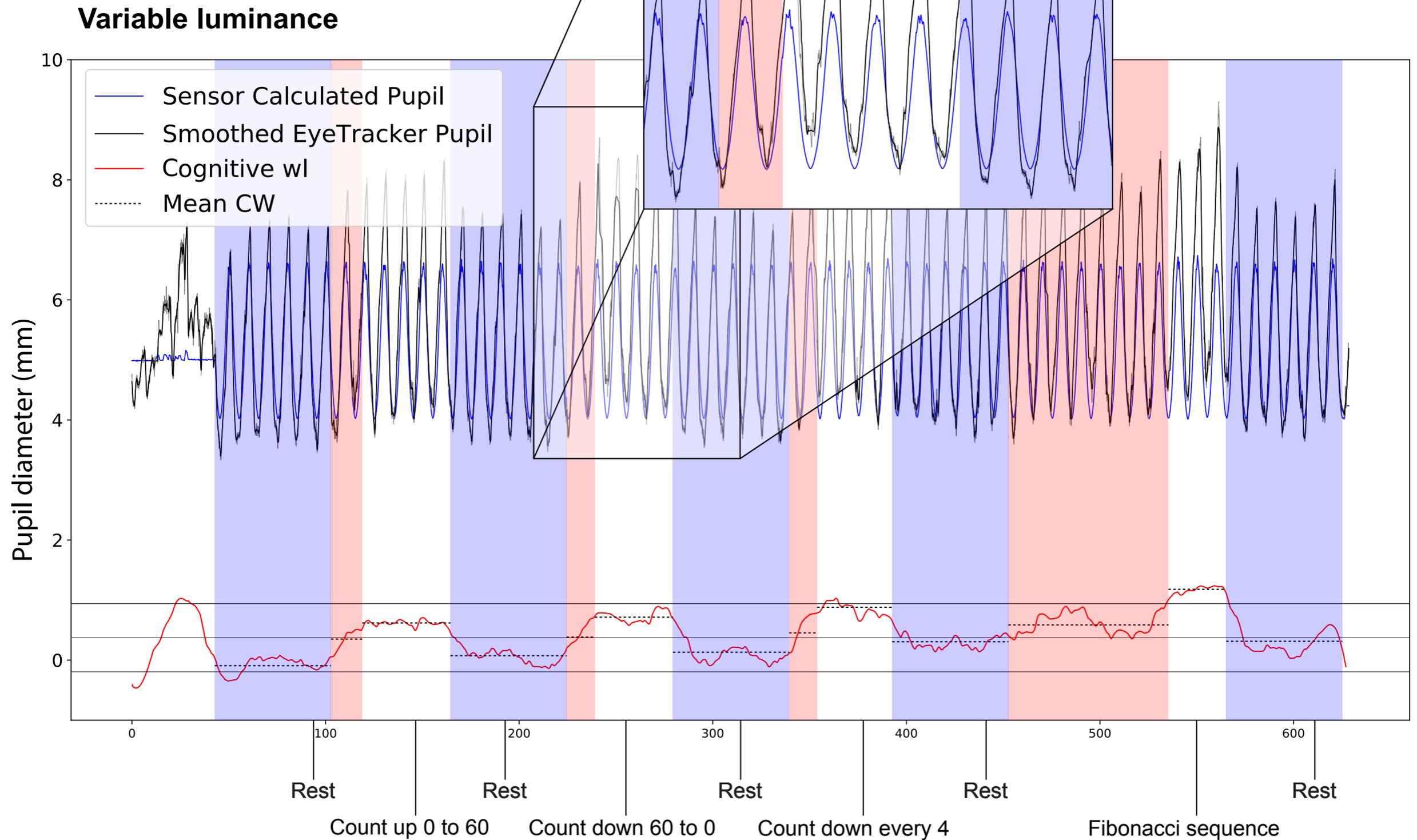


Laboratory test

Please keep focus on the dot

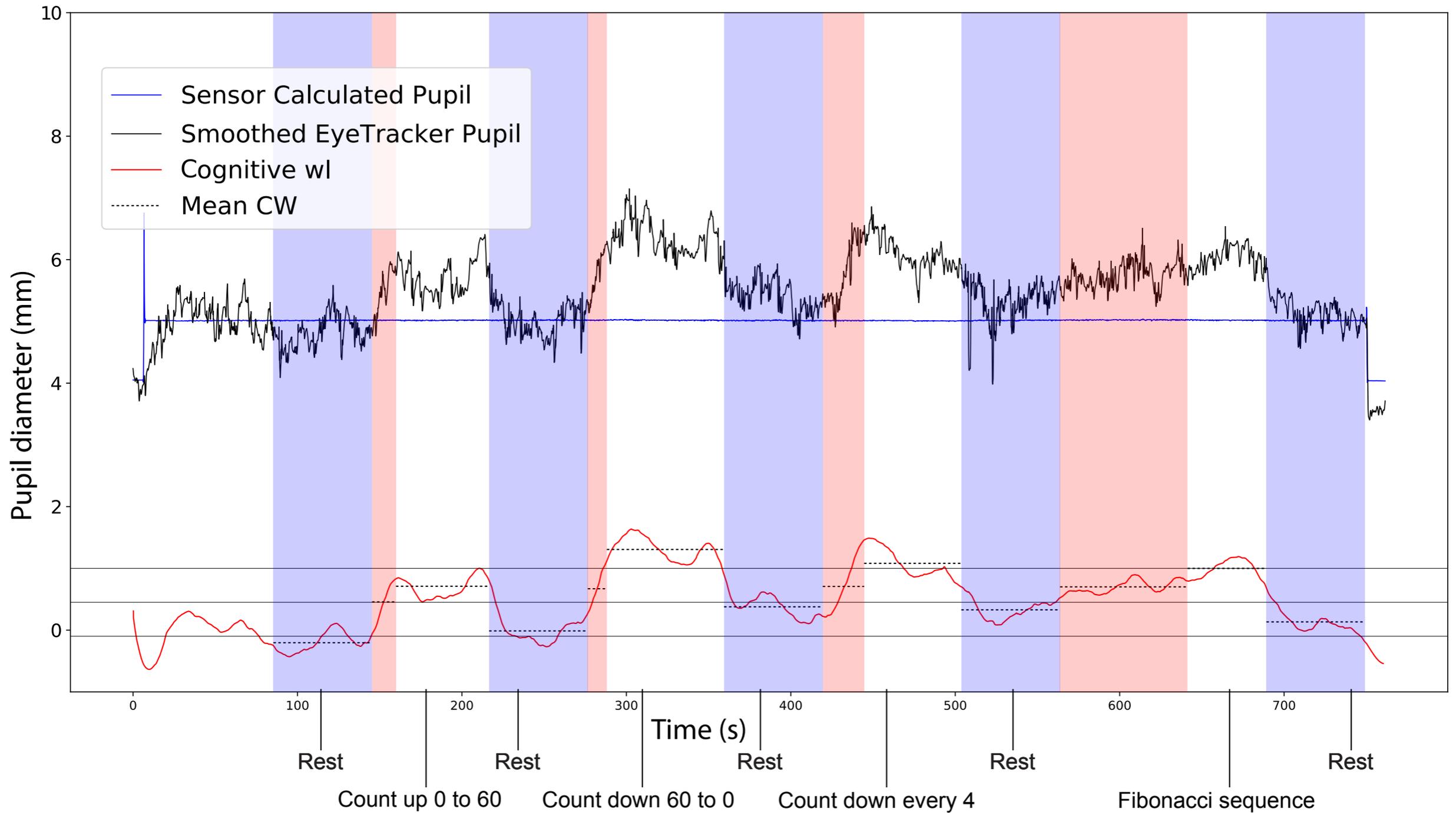


Laboratory



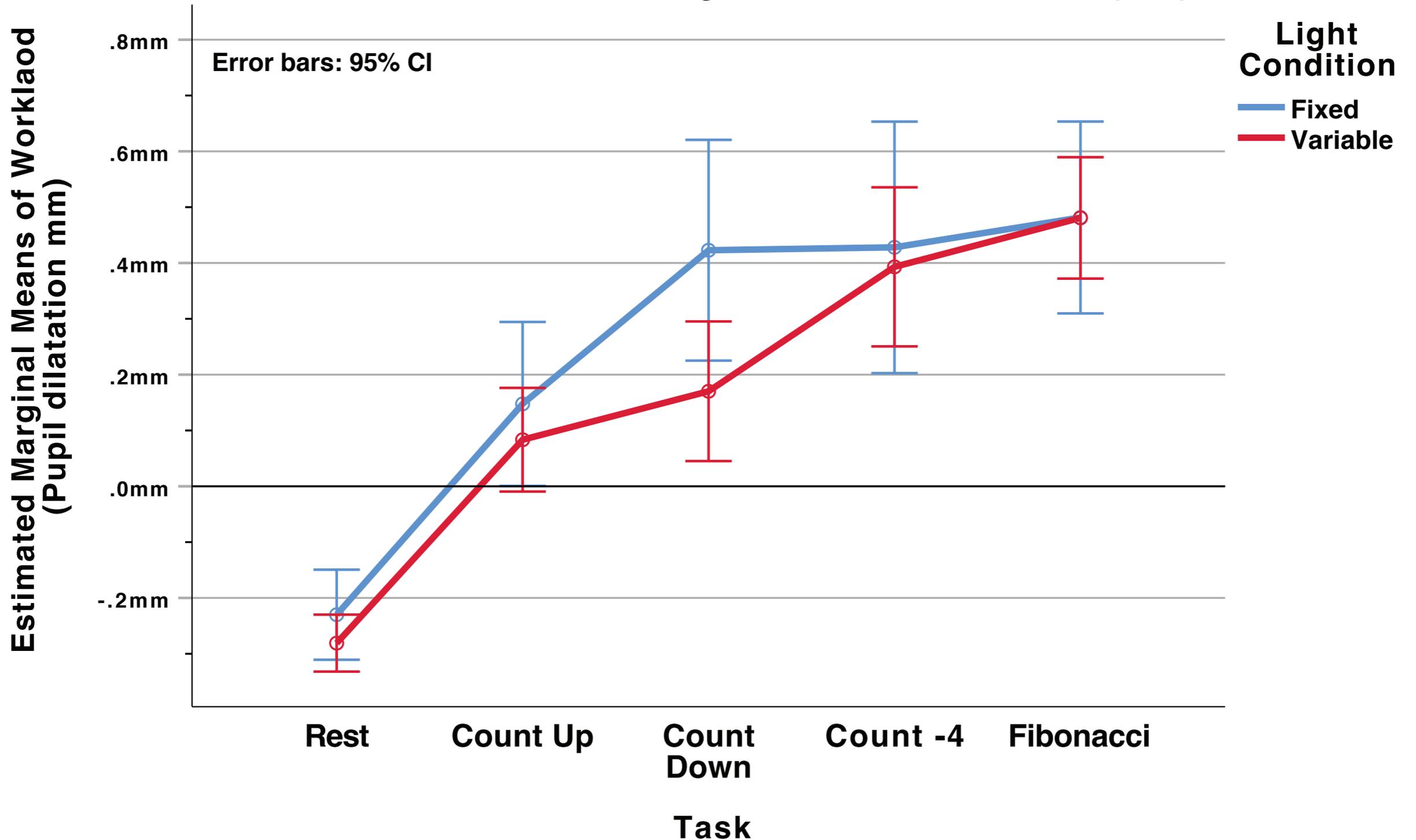
Laboratory test

Fixed luminance



Laboratory test

Estimated Marginal Means of Workload (mm)



Field Test



Field Test

Vessel (Kvarven)



Subjective

NASA TLX

Appendix E.
Subject ID: _____ Task ID: _____

WEIGHTED RATING WORKSHEET

Appendix C.
Subject ID: _____ Task ID: _____

RATING SHEET

MENTAL DEMAND
Low High

PHYSICAL DEMAND
Low High

TEMPORAL DEMAND
Low High

PERFORMANCE
Good Poor

EFFORT
Low High

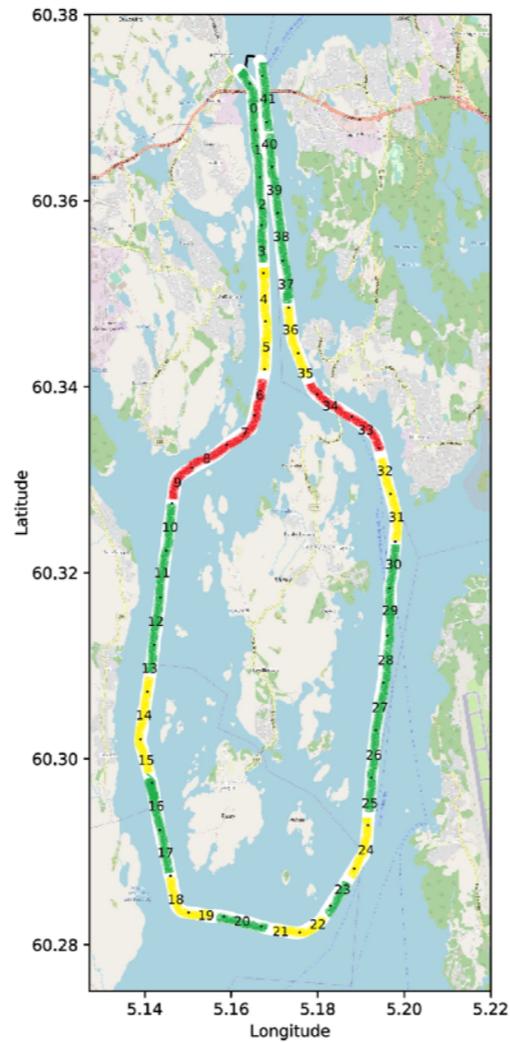
FRUSTRATION
Low High

17

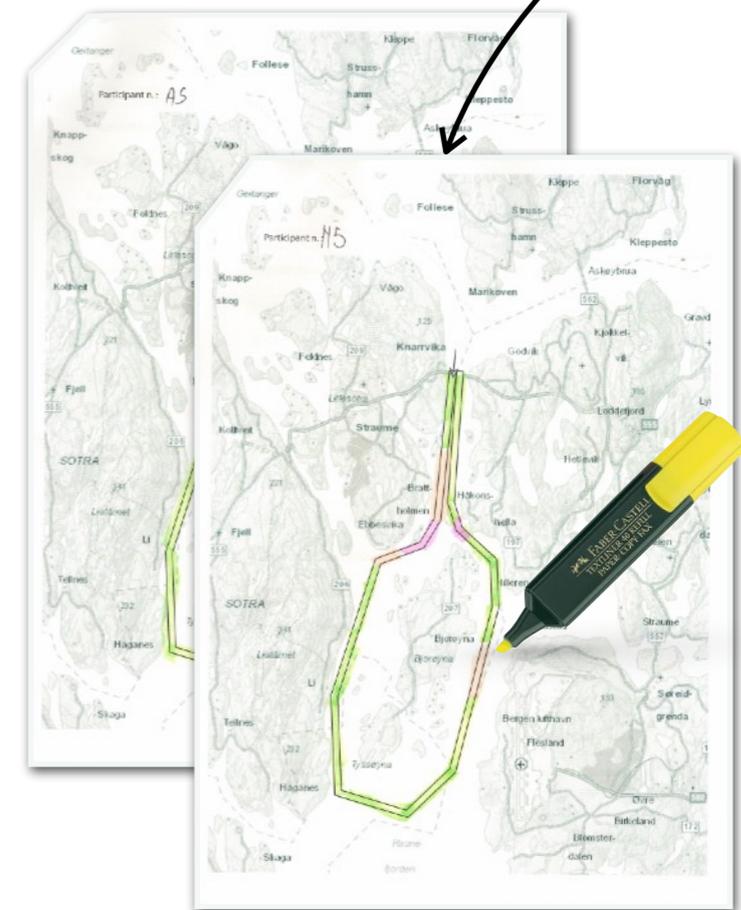
(NOTE - The total count is not to be greater than 5.)

18

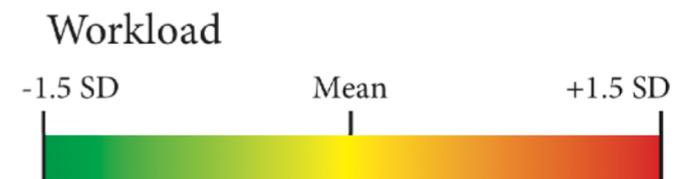
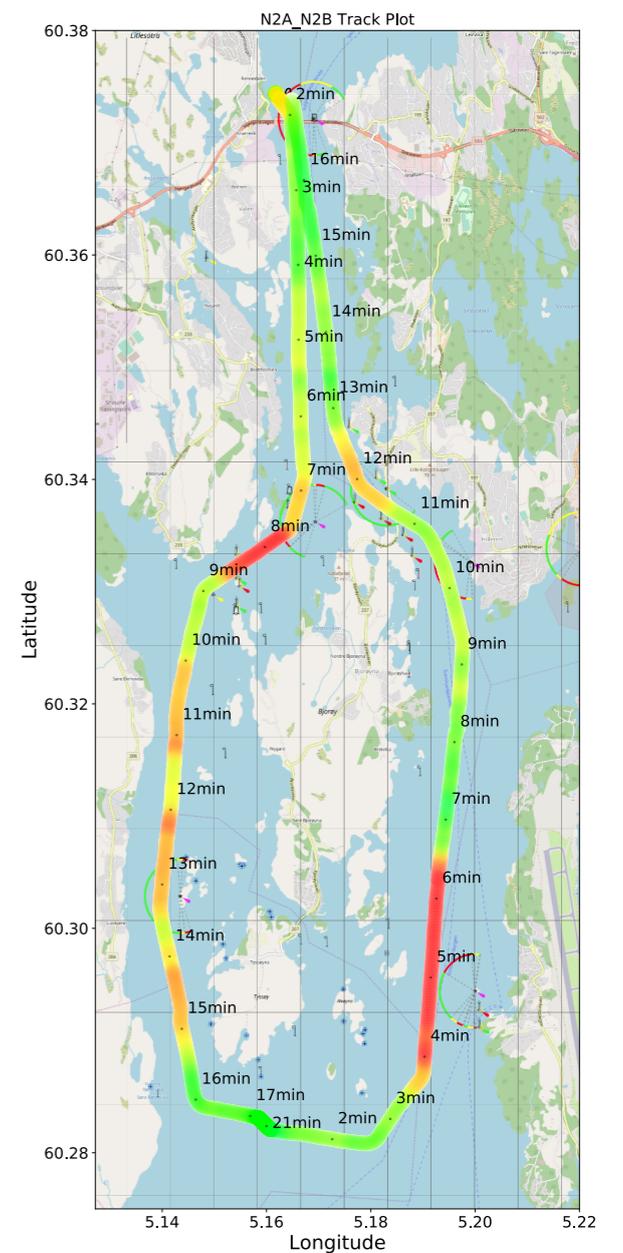
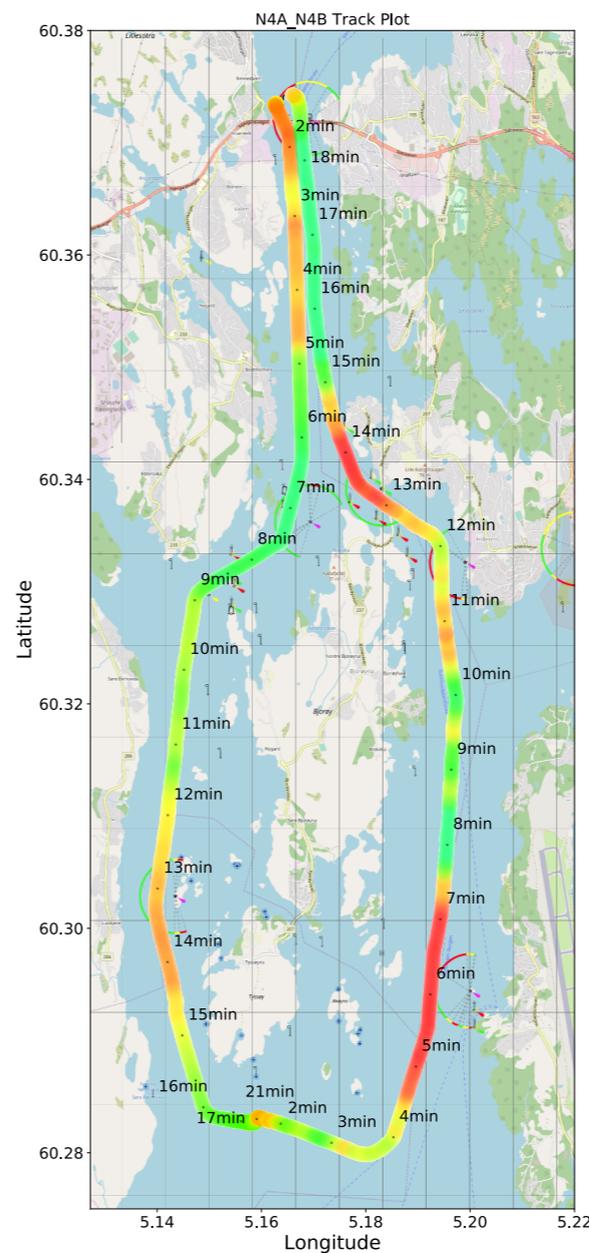
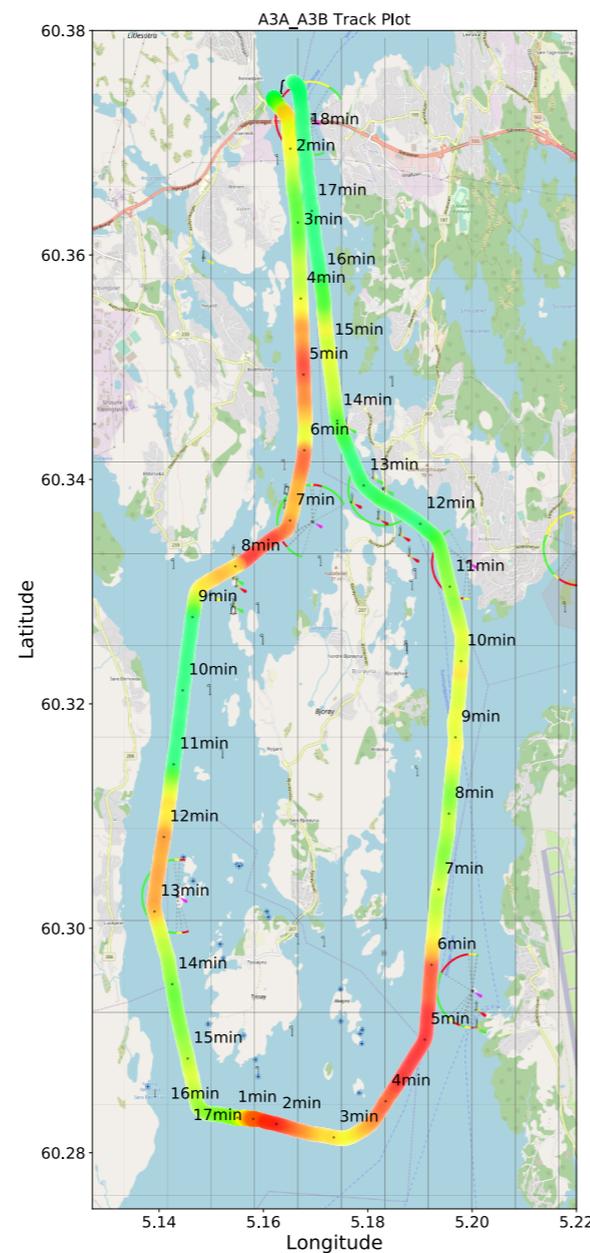
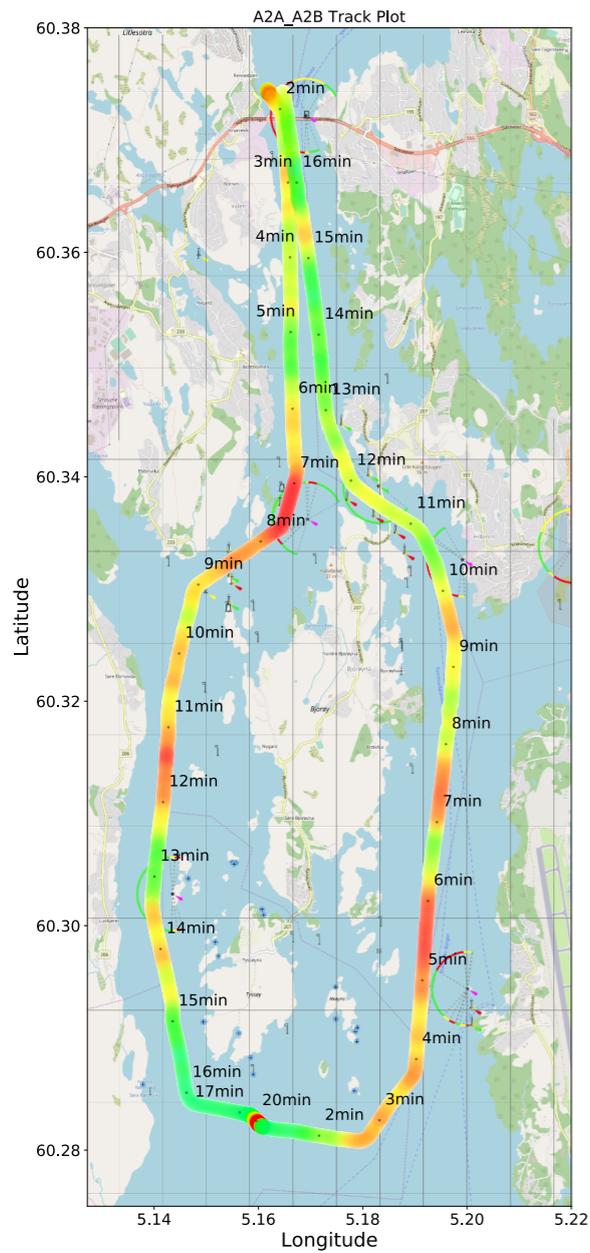
Expert Evaluation



Self Report Maps



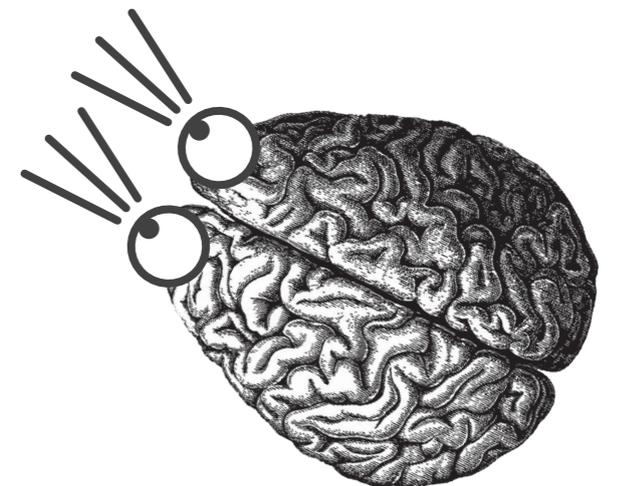
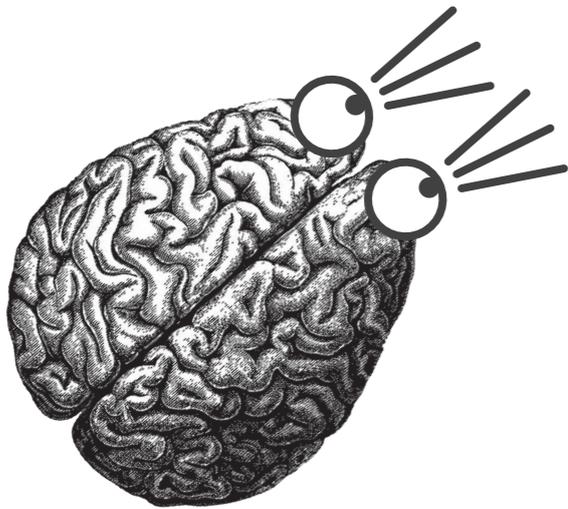
Objective



- High correlation between subjectively reported workload and measured workload.

- Eye tracking is **usable** in field conditions but still an involving process.

- Will be repeated in **Controlled conditions.**

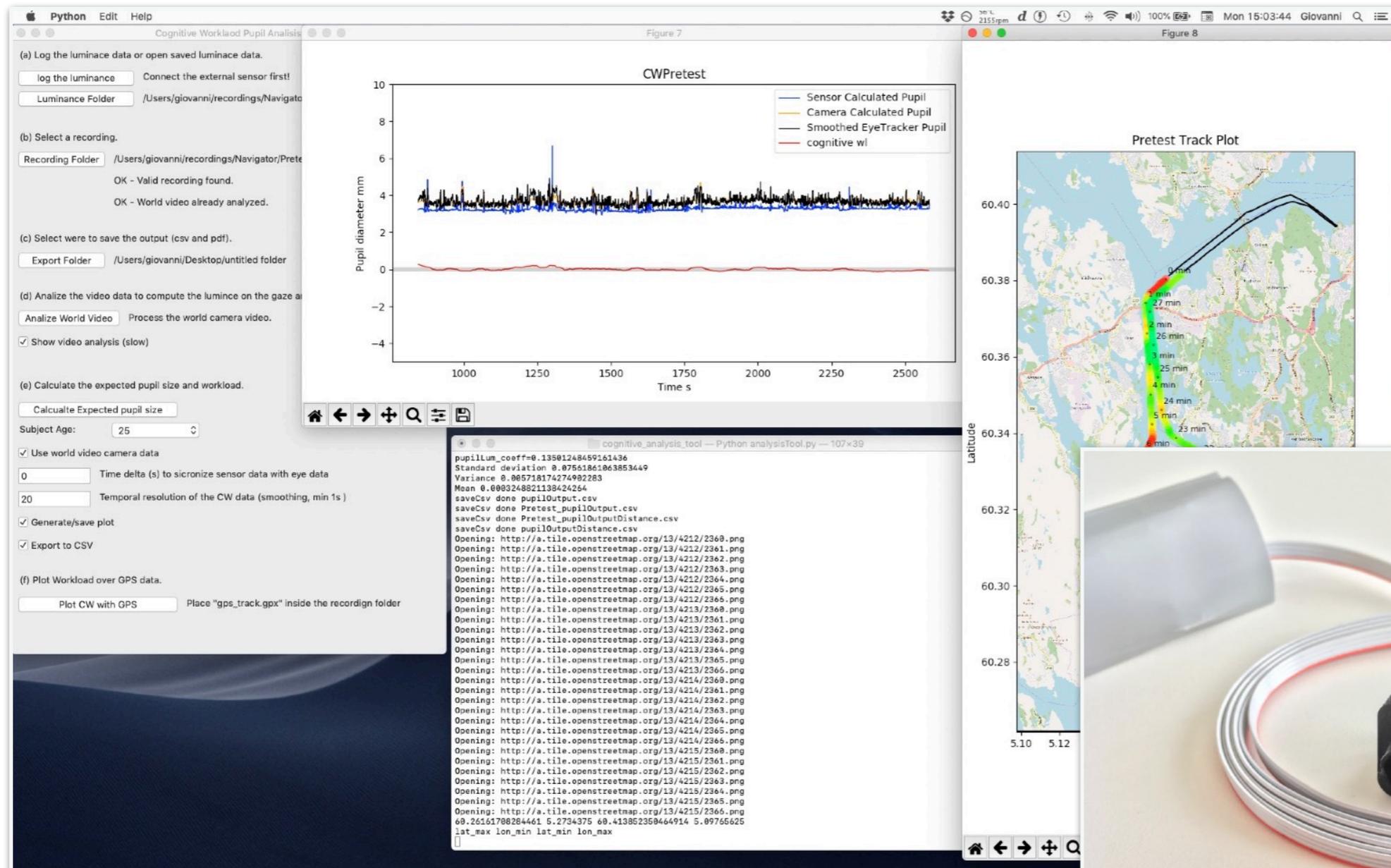


A second test session at the Norwegian Naval Academy is planned for late February.



Open Source

https://github.com/pignoniG/cognitive_analysis_tool



Github Rep. and Documentation

Sensor Kit 3D files and B.O.M.



Thanks