

Spontaneous fluctuations of pupil size and brain rhythms co-vary at rest

Objective

Cortical brain activity underlies a number of varying **non-cortical authorities**. These can act to **regulate cortical excitability** and therefore bias our momentary perception, cognition, and behavioural performance¹. Here, we measured **pupil size to explore links** of the reticular activating system, specifically the locus-coeruleus-norepinephrine (LC-NE) circuit **with cortical rhythms**.

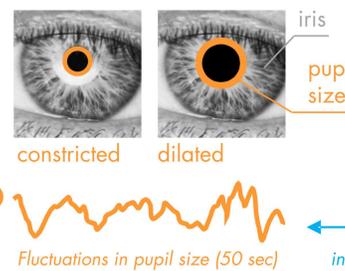
Approach

We recorded 248-channel **MEG** and simultaneous eye-tracking in 24 participants at rest and fixating (7 min). In a source-level whole-brain analysis of a subset of **22** participants we correlated local power envelopes of rhythmic activity in canonical frequency bands (2 – 128 Hz) with slow-varying (< 2 Hz) spontaneous fluctuations in pupil size.

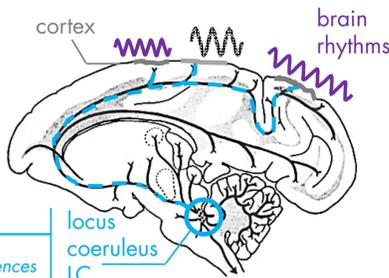
Findings & Conclusions

- Pupil engages in ~0.2 Hz resting rhythm, the **Hippus**²
- Co-variations with **theta**, **alpha** and **gamma** rhythms
- Different patterns for pupil size and pupil 'speed'
- **Positive correlation of alpha power and pupil**
- Basis of co-variance remains to be characterised ...
- Findings replicated in two other datasets⁵ (both N > 20)

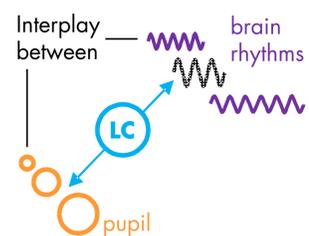
Pupil



Brain



Research question



Pupil preprocessing³

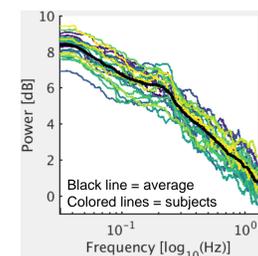
EyeLink 1000 (SR research) tracked pupil area, Blinks interpolated (linear) in ~7min traces, Canonical blink responses regressed out.

Brain preprocessing⁴

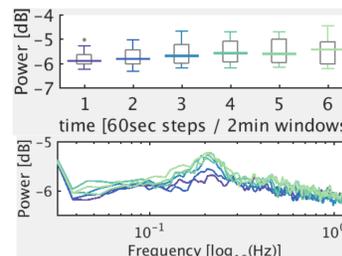
MEG denoised and blinks removed via ICA, Myogenic artifacts excluded by inspection, Frequency-specific spatial filters derived using DICS beamformer, applied to MEG time series, voxel-wise Hilbert transform to obtain amplitude envelopes

Pupil analysis

Pupils show Hippus and 1/f characteristic in loglog spectra

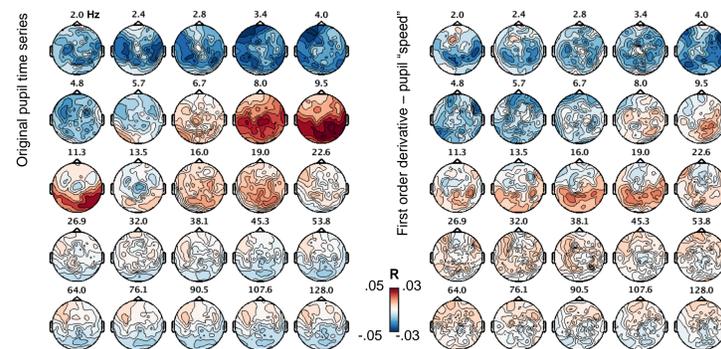


Hippus (~0.2 Hz) magnitude increases over time during rest



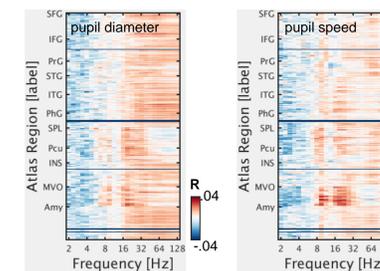
Pupil-brain links – sensor space

Rank correlations of pupil time series and amplitude envelopes



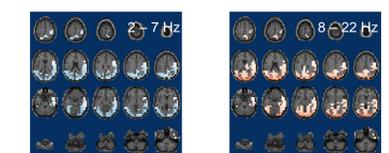
Pupil-brain links – source

Rank correlations of pupil time series and amplitude envelopes by cortex region*



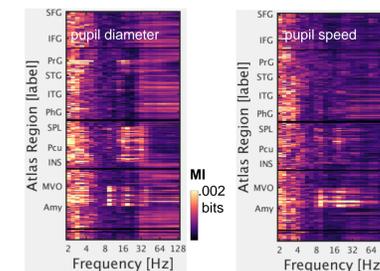
Cortical sources

Rank correlations, tested against correlations with reversed pupil time series, cluster-corrected*



*weighted cluster mass, N=1000, neighbourhood of 12 (avg: 6 – 30) regions

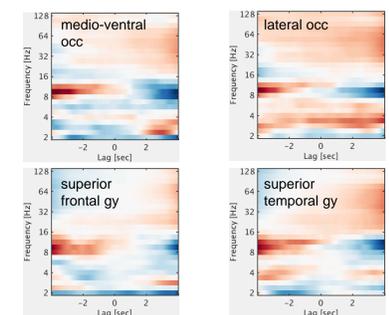
Mutual information between pupil time series and amplitude envelopes*



*Pupil time series/amplitude envelopes bandpass-filtered to range of [0.005,2] Hz

Temporal relationships

Cross-correlation of pupil time series and amplitude envelopes [neg lag = pupil leads]



References

- [1] Aston-Jones & Cohen (2002) Annu Rev Neurosci
- [2] Bouma & Baghuis (1971) Vision Res
- [3] Anne Urai: github.com/anne-urai/pupil_preprocessing_tutorial
- [4] Oostenveld et al. (2011) FieldTrip ... Comp Int Neurosci

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