Circadian and fatigue effects on the dynamics of the pupillary light reflex

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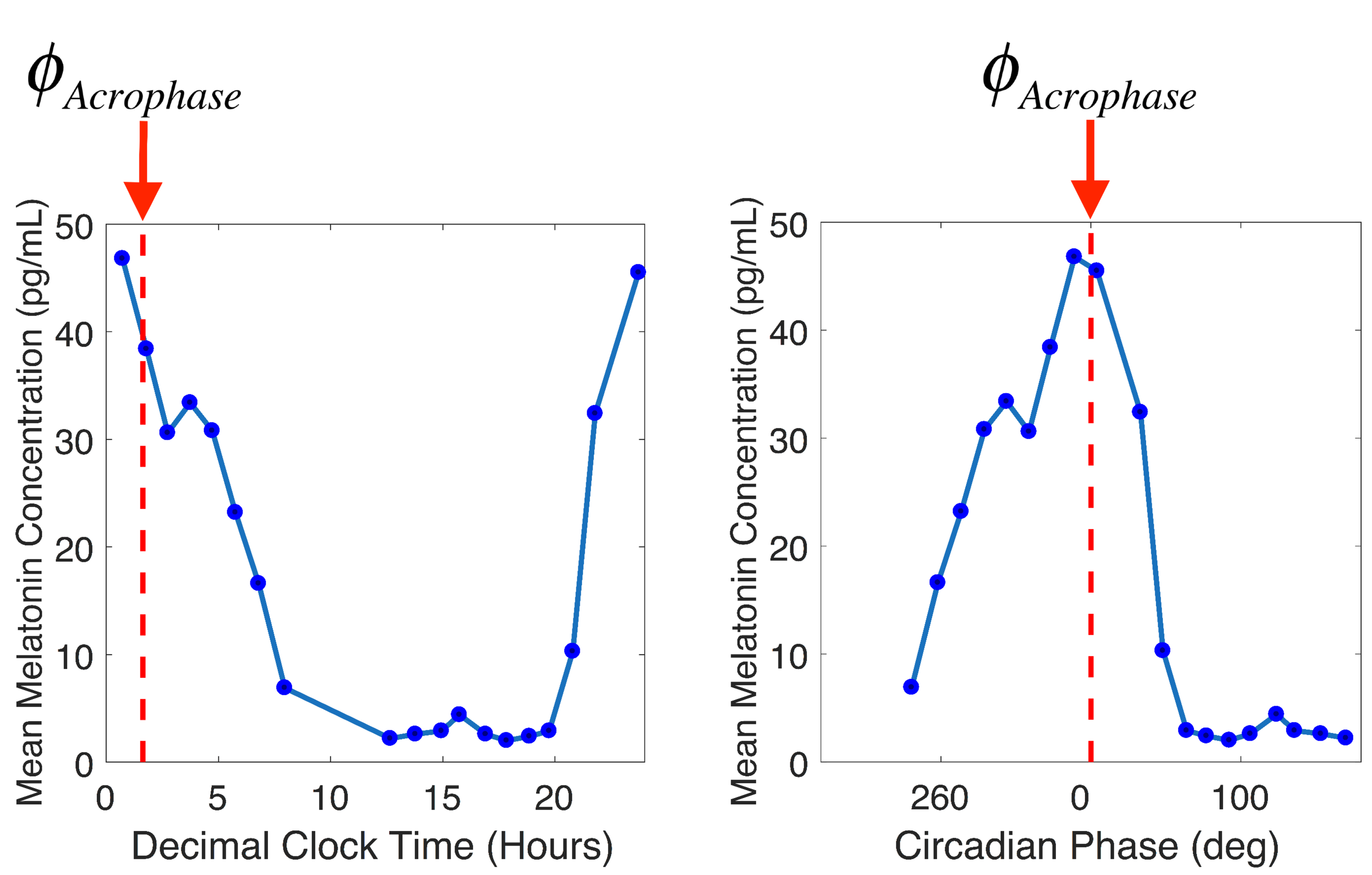
INTRODUCTION

The pupillary light reflex (PLR) is a negative feedback loop that adjusts the aperture of the eye (iris) to changes in ambient light. Given that visual pathways for the PLR are shared by those regulating circadian rhythm (REFS), it is not surprising that PLR magnitude shows circadian modulation of PLR amplitude (REF). In our study, we measured the PLR over a 24-hr period to examine if there are also changes in PLR dynamics related to time awake and circadian cycle.

METHODS

11 healthy subjects (6 females, mean age = XXX) participated in a within-subject repeated-measures design. Prior to the laboratory study, subjects adhered to a strict two-week at-home sleep schedule and diet, maintaining a sleep log, and monitoring their activity using an actiwatch.

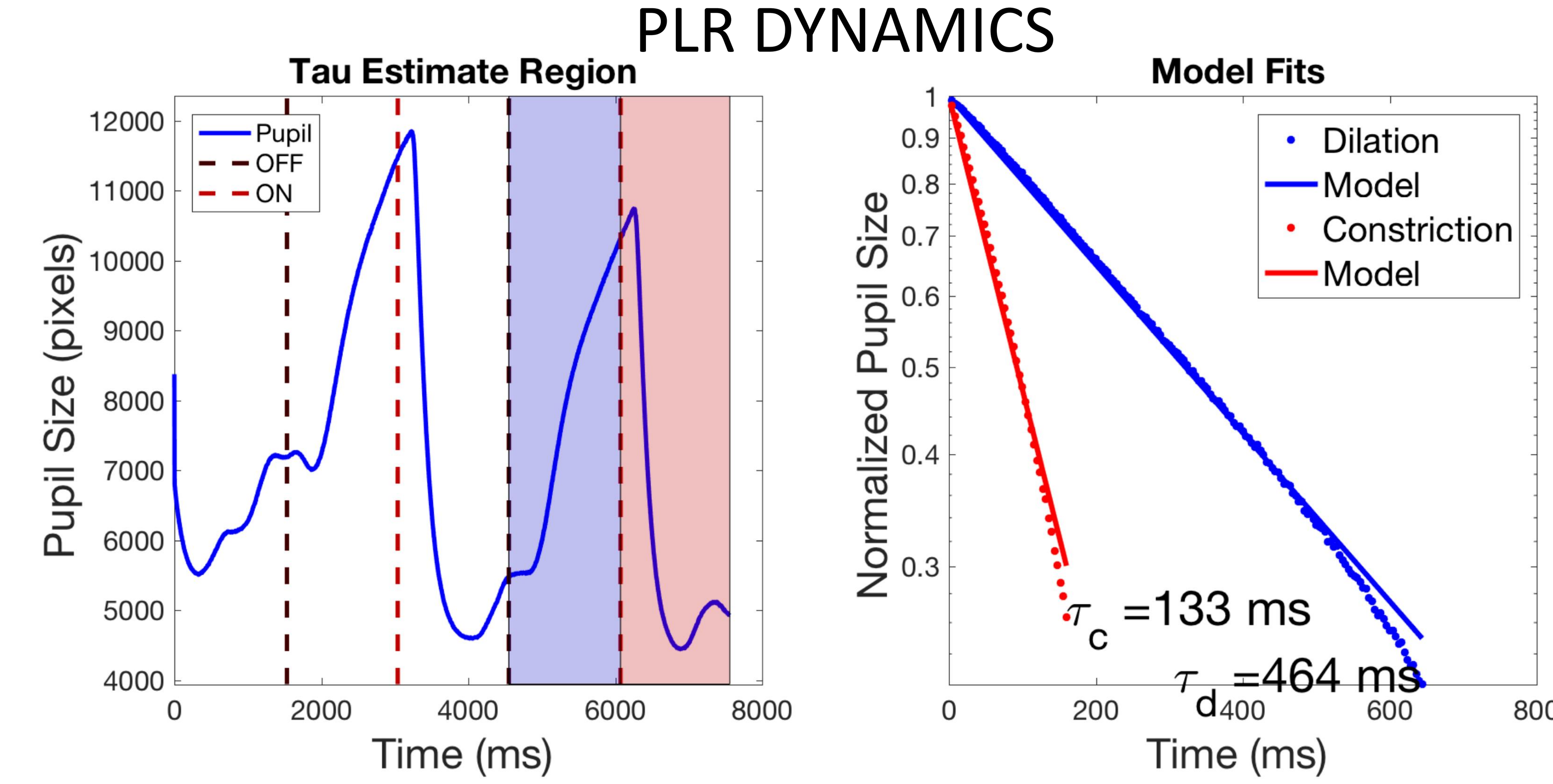
Subjects then followed a constant-routine protocol (REF) in our laboratory where they were kept awake for 24 hrs. To test PLRs, we presented two square-wave pulses of background white light (params) and monitored pupil size using a video-based eye-tracker (Liston et al., 2016). Three baseline day-time and 7-9 hourly night-time PLR measurements were taken. Hourly salivary melatonin samples were also taken.



- Melatonin acrophase was estimated for each subject using a cosinor analysis (Nelson et al., 1979) and used to convert from Clock Time to Circadian Phase.

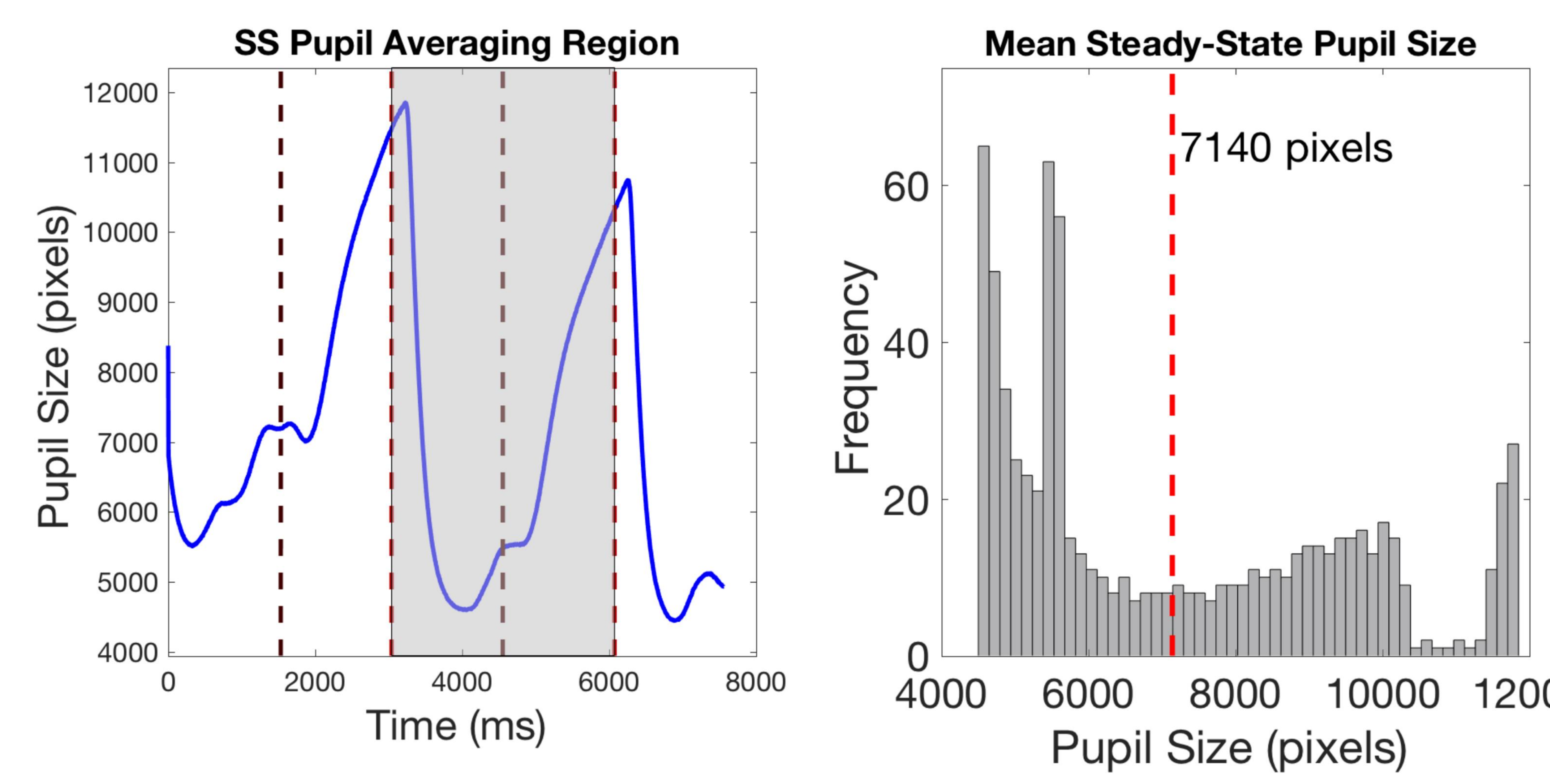
ANALYSIS

PLR DYNAMICS



- PLR dilation and contraction time constants were independently estimated using an exponential model (Longtin & Milton, 1988).

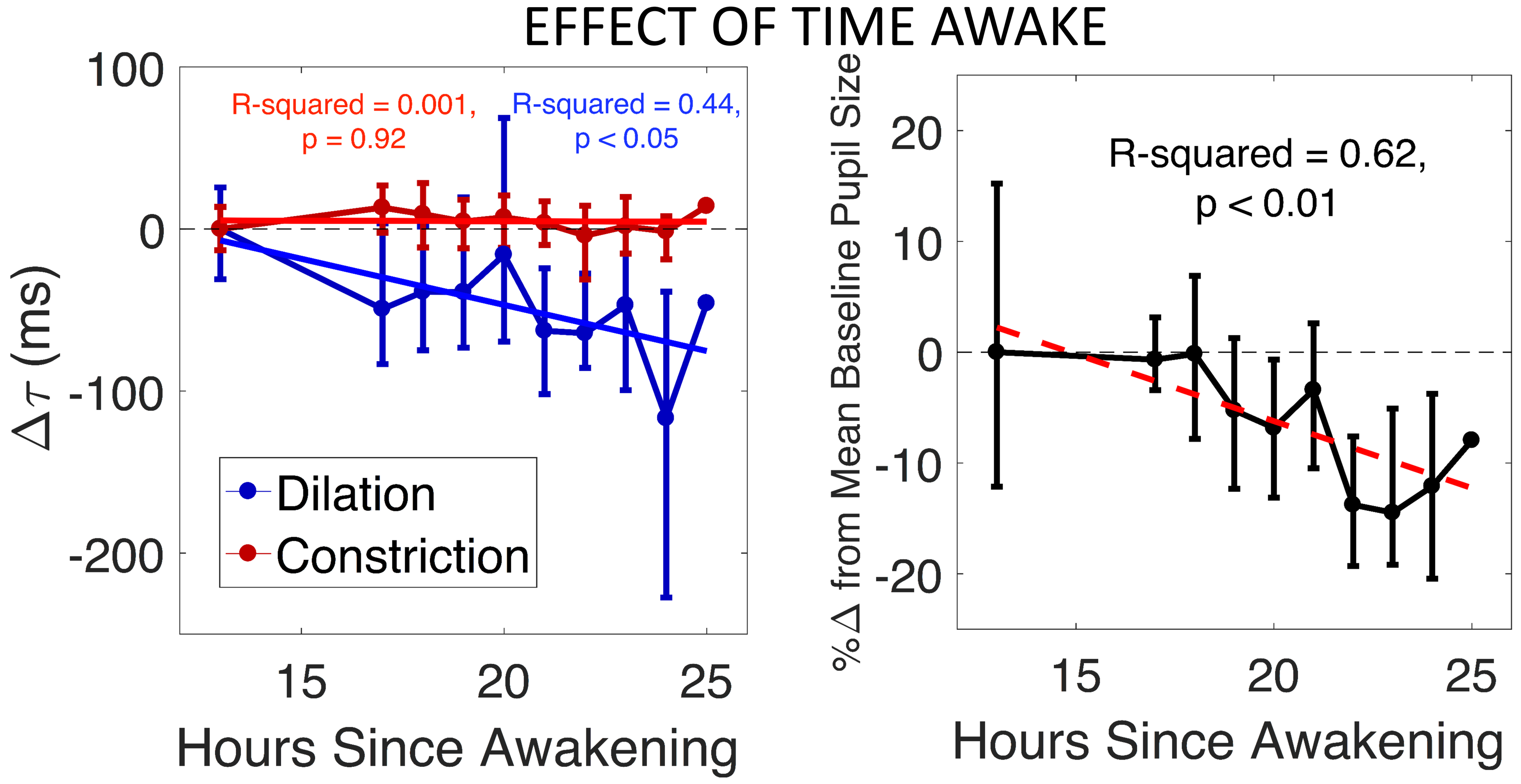
STEADY-STATE PUPIL SIZE



- We defined steady-state pupil size as the mean pupil size during a single light-dark cycle of light (highlighted in grey).

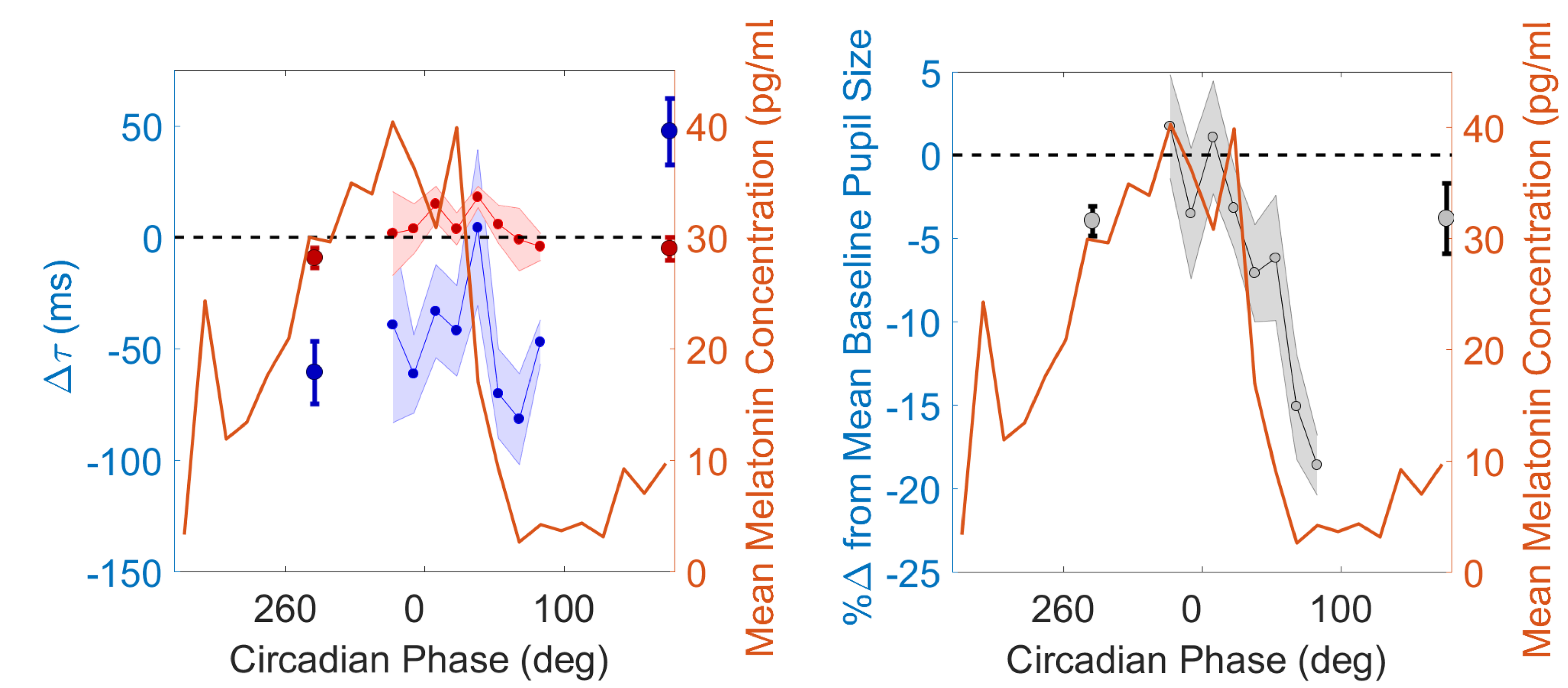
RESULTS

EFFECT OF TIME AWAKE



- PLR dilation is faster and pupil size smaller as hours awake increase.

EFFECT OF CIRCADIAN CYCLE



- PLR dilation dynamics and mean pupil size modulate across the 24-hour cycle.

SUMMARY

- PLR dilation time constant and steady-state pupil size showed linear decreases as a function of time awake.
- PLR dilation time constant showed modulation over the circadian cycle out-of-phase with melatonin.
- Mean pupil size showed modulation over the circadian cycle in-phase with melatonin.
- PLR constriction dynamics did not show any changes.

CONCLUSIONS

Under a constant routine protocol, PLR dynamics showed significant changes as a function of time awake and circadian phase.

REFERENCES

1. Liston, D.B., Wong, L.R., Stone, L.S. (2016). Oculometric Assessment of Sensorimotor Impairment Associated with TBI. *Optom Vis Sci*, 94(1): 51-59.
2. Longtin, A., Milton, J.G. (1988). Complex Oscillations in the Human Pupil Light Reflex with "Mixed" and Delayed Feedback. *Mathematical Biosciences*, 90:183-199.
3. Nelson, W., Tong, Y.L., Lee, J., Halberg, F. (1979). Methods for cosinor-rhythmometry. *Chronobiologia*, 6:305-323.

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