# Oculomotor Behavior Metrics Change According to Circadian Phase and Time Awake

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## INTRODUCTION

- Non-invasive, objective measures of sleep loss and circadian misalignment are needed in operational environments
- Eye-tracking devices utilizing slow eye-movements and eye blinks can be used to detect sleepiness and have been used in operational settings (Johns *et al.* 2005)
- We hypothesized that an expanded suite of oculomotor behavioral metrics, collected using an appropriately randomized visual tracking task, would change according to circadian phase and time awake

## METHODS

- 11 healthy participants (6 females, mean age = 25.0, ±5.6)
- Two-week at-home pre-study schedule including 8.5 hours in bed with regular timing verified by actigraphy, call ins, sleep logs
- Constant Routine (Mills *et al*. 1978)
  - Participants remained in the lab in a semi-recumbent posture in < 4 lux of light for at least ~24 hours
  - Hourly snacks to diminish influence of metabolism,
  - Saliva sampled hourly for measurement of melatonin and cortisol
- Comprehensive Oculomotor Behavioral Response Assessment (COBRA; Liston *et al.* 2016; Figure 1)
  - Target displayed at unpredictable time and location on fast LCD display
  - Participant required to locate target and track its motion across the screen for ~1 second
  - All directions covered in 2° steps
  - Speeds of 16, 18, 20, 22, & 24 deg/s
  - COBRA administered 2-4 times during the day and hourly from habitual bedtime until morning
  - High-speed eye-tracker data used to compute >15 oculomotor metrics per trial with 180 trials per session

**Figure 1**. COBRA device

### *Analysis Methods*

- Melatonin acrophase estimated for each subject using a cosinor analysis (Nelson *et al*., 1979) and used to convert from clock time to circadian phase in degrees

## RESULTS

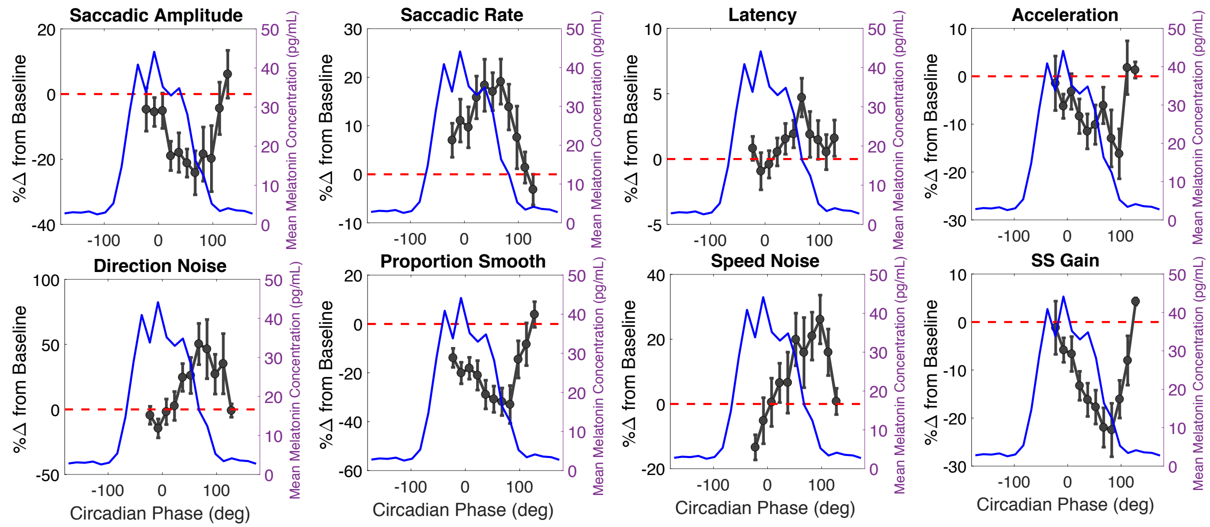


**Figure 2**. *Each panel represents the deviation from baseline (red line, average of daytime measurements) each oculomotor metric outcome in 15 degree bins (error bars, ± SEM). The blue line represents the average melatonin profile for the group. deg = degrees, SS = steady state, %Δ = percentage change from daytime baseline*

## CONCLUSIONS

- Several oculomotor behavioral metrics show large, systematic modulation with circadian phase
- Many metrics also show significant linear decline from baseline with time awake (not shown)
- Such metrics may be valuable in identifying fatigue-specific impairment in operational settings
- Future work should characterize how such metrics change with chronic sleep loss, sleep inertia, and in operational settings

## REFERENCES

1. Johns, M., Tucker, A., Chapman, R. (2005). A new method for monitoring the drowsiness of drivers. *Proceedings of the 2005 International Conference on Fatigue Management in Transportation Operations.*
2. Mills, J.N., Minors, D.S., Waterhouse, J.M. (1978). Adaptation to abrupt time shifts of the oscillator(s) controlling human circadian rhythms. *J Physiol*, 285:455-470.
3. 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.
4. Nelson, W., Tong, Y.L., Lee, .J., Halberg, F. (1979). Methods for cosinor-rhythmometry. *Chronobiologia*, 6(4):305-323.

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