

Oculomotor Behavior Metrics Change According to Circadian Phase and Time Awake



Erin E. Flynn-Evans PhD MPH,¹ Terence L. Tyson,² Patrick Cravalho PhD,² Nathan Feick,² Leland S. Stone PhD³

¹Fatigue Countermeasures Laboratory, Human Systems Integration Division, NASA Ames Research Center, ²San Jose State University Foundation, NASA Ames Research Center, ³Visuomotor Control Laboratory, Human Systems Integration Division, NASA Ames Research Center.

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

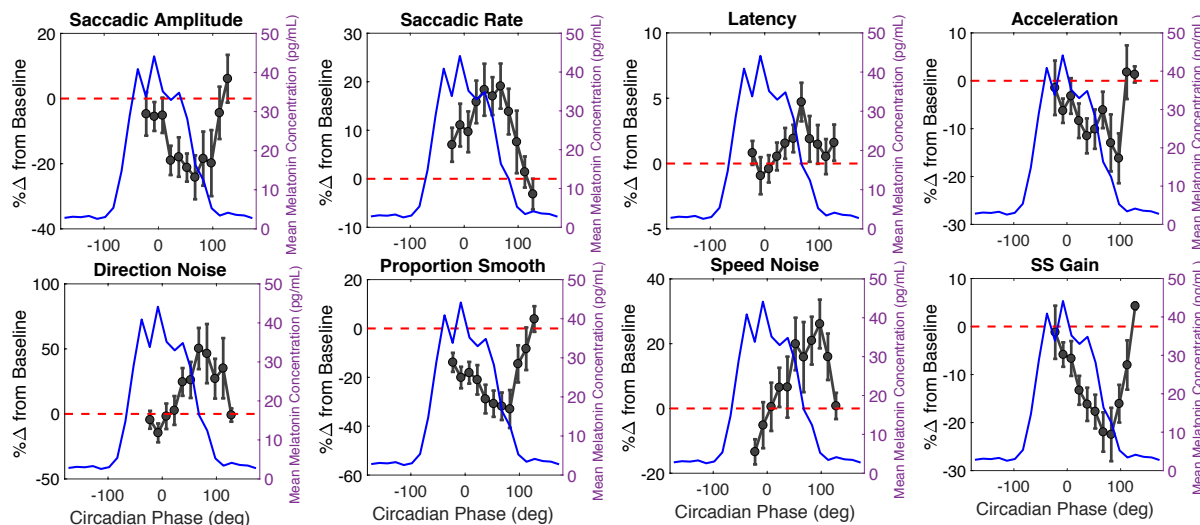


Figure 2. Each panel represents the deviation from baseline (red line, average of daytime measurements) each oculomotor metric outcome in 15 degree bins (error bars, ± SEM). The blue line represents the average melatonin profile for the group. deg = degrees, SS = steady state, %Δ = percentage change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