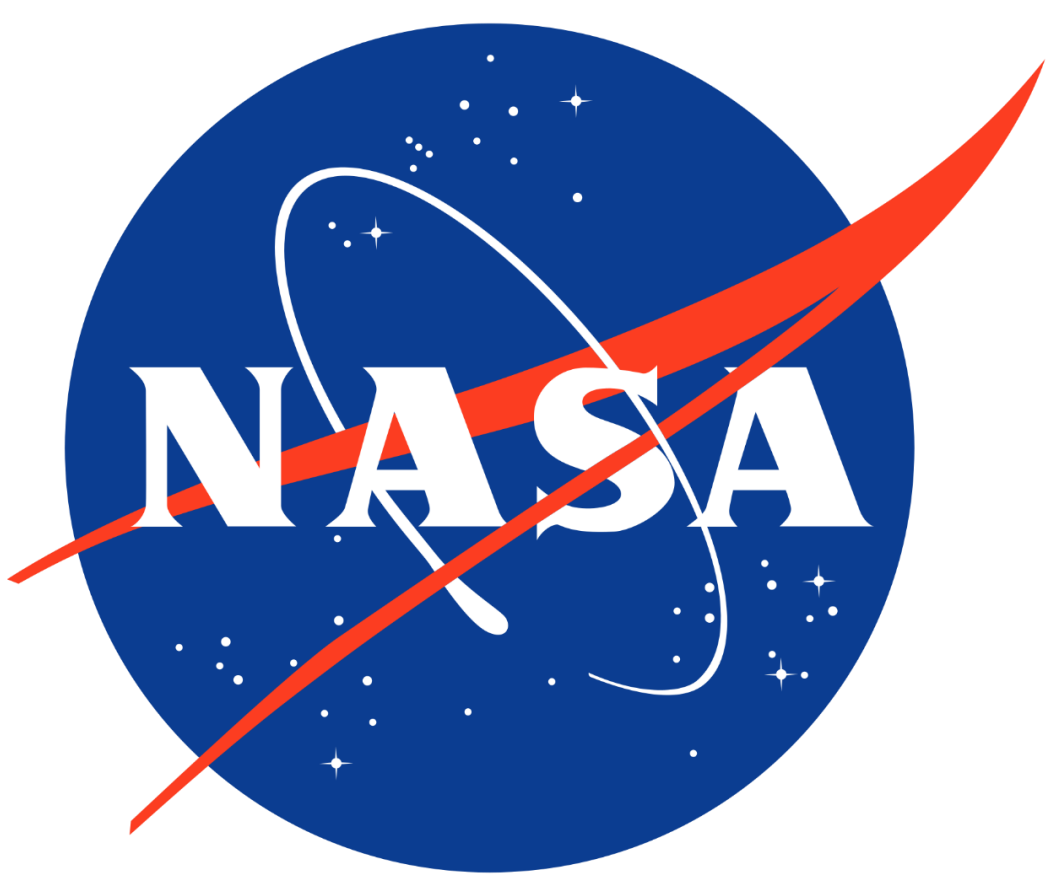
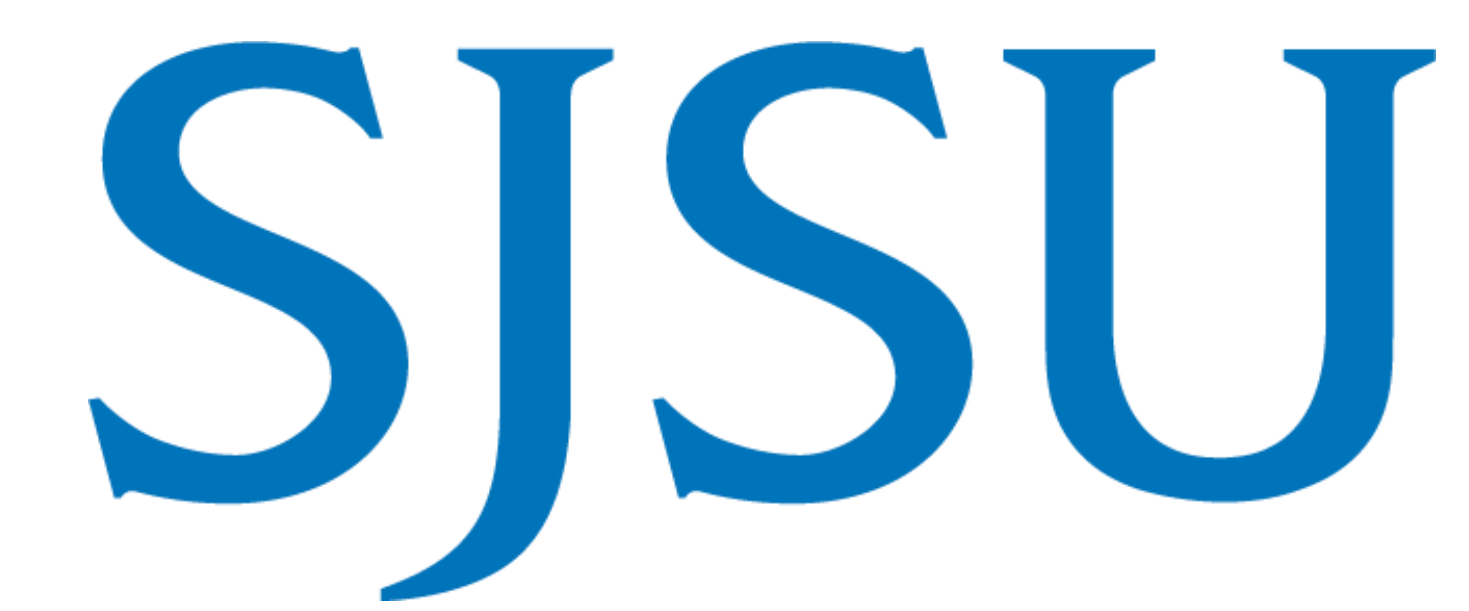




Changes in oculomotor behavior and PVT reaction time during one night of sleep deprivation



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Introduction

- The Psychomotor Vigilance Test (PVT) is a widely used objective measure of sustained attention and alertness. In addition, visual motion processing and eye movements have been found to be affected time awake and circadian phase [1].
- Here, we use Linear Mixed-Effects Models (LMM) to characterized the contribution of homeostatic sleep pressure (time awake) and circadian phase (with respect to acrophase) on oculomotor behavior captured by multiple COBRA (Comprehensive Oculomotor Behavioral Response Assessment) oculometrics and PVT reaction time, and to investigate whether there is a relationship between PVT reaction time and oculomotor behavior.

Methods

Procedure (Fig. 1):

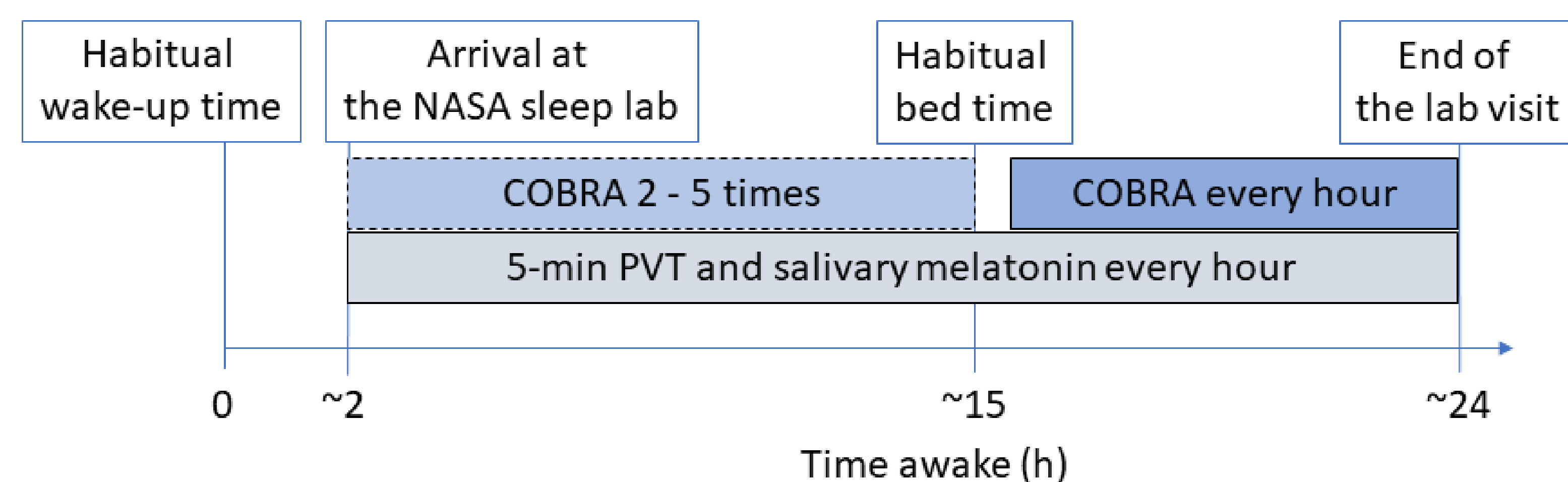


Fig. 1. Study protocol, n=12 (age 24.8 ±5.4, six males) [1]

Analyses:

- Acrophase was from estimated salivary melatonin levels
- PVTs performed within an hour from COBRA sessions were included and binned with COBRA.
- LMM models used to assess the contribution of:
 - 1) time awake (sleep pressure) or acrophase-locked measurement time (circadian phase) to changes in mean Reciprocal Reaction time (RRT) from PVT and in four COBRA parameters (saccadic velocity slope, saccade rate, proportion smooth, and steady-state gain [1]), and
 - 2) the mean RRT and time awake, or circadian phase, to changes in COBRA parameters.
- We treated time awake, circadian phase, and mean RRT as fixed effects, and participant as a random effect.
- Models were computed using the 'lmer' function from the 'lme4' package in R [2] and compared with Analysis of Variance (ANOVA). LMM p-values were determined using Satterthwaite's method [3].

Results

1) Relationship of time awake and circadian phase to PVT and COBRA

ANOVA indicated the models, including either time awake or circadian phase as a fixed effect, provided a significantly better fit for the mean RRTs as well as all for four oculomotor parameters compared to the null model. See Table 1 for the model comparison and estimates.

2) Relationship between COBRA and PVT

The model with both circadian phase and mean RRT as main effects provided a better fit for steady-state gain and proportion smooth parameters compared to the model with circadian phase alone ($\chi^2(1) = 18.2$, $p < 0.001$ and $\chi^2(1) = 8.8$, $p < 0.01$, respectively). In addition, the model with time awake and mean RRT as main effects explained more changes in steady-state gain than the model with time awake alone ($\chi^2(1) = 4.0$, $p < 0.05$). See Table 2 for the model summaries.

Table 1 LMM model comparison and estimates			Mean RRT	Saccade rate	Saccade velocity slope	Proportion smooth	Steady-state gain
Time awake	ANOVA	$\chi^2(1)$	34.2	26.8	54.2	56.9	49.7
		p	<0.001	<0.001	<0.001	<0.001	<0.001
	Estimate	$\hat{\beta}$ (SE)	2.9e-03 (5e-04)	2.8e-02 (5e-03)	-0.342 (0.04)	-5e-03 (5e-04)	-7.5e-03 (9e-04)
Circadian phase	ANOVA	$\chi^2(1)$	6.0	16.6	18.6	19.6	14.1
		p	<0.05	<0.001	<0.001	<0.001	<0.001
	Estimate	$\hat{\beta}$ (SE)	-9.1e-05 (4e-05)	-1.6e-03 (4e-04)	3.0e-04 (3.4e-03)	1.8e-04 (4e-05)	-1.6e-03 (1e-04)

Table 2. LMM model summaries		$\hat{\beta}$ (SE)	t (df)	p
Steady-state gain	Circadian p.	2.3e-04 (7e-05)	3.1 (113)	<0.01
	Mean RRT	-0.8 (0.2)	-4.4 (115)	<0.001
	Time awake	-6e-03 (1e-03)	-5.9 (113)	<0.001
	Mean RRT	-0.4 (0.02)	-2.0 (115)	<0.05
Proportion smooth	Circadian p.	1.6e-04 (4e-05)	4.0 (113)	<0.001
	Mean RRT	-0.3 (0.1)	-3.0 (116)	<0.01

Conclusion

- We confirmed that both time awake and circadian phase each contribute to performance reductions as reflected in the PVT reaction time and multiple COBRA oculometrics.
- As a novel finding, we demonstrated here that is a significant relationship between PVT and oculomotor behavior. Moreover, the PVT-COBRA link appears to vary depending on the specific oculometric.
- Future analyses will explore more systematically the link between PVT and COBRA oculometrics to shed light on the relationship between general alertness and visuomotor performance.

References

- [1] Stone, L.S., Tyson, T.L., Cravalho, P.F., Feick, N.H. and Flynn-Evans, E.E. (2019), Distinct pattern of oculomotor impairment associated with acute sleep loss and circadian misalignment. J Physiol, 597: 4643-4660.
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