

# The effects of lighting on autonomic control of the heart

Eve Edelstein<sup>1</sup>

Robert J. Ellis<sup>2\*</sup>

John J. Sollers, III<sup>2</sup>

Julian F. Thayer<sup>2</sup>

<sup>1</sup> *New School of Architecture & Design  
San Diego, California*

<sup>2</sup> *The Ohio State University  
Columbus, Ohio*

\* [ellis.306@osu.edu](mailto:ellis.306@osu.edu)



# Introduction

---

- Vagally-mediated heart rate variability (HRV) is an independent risk factor for morbidity and mortality<sup>1,2</sup>
- Higher resting HRV associated with better health, self-regulation of behavior, and control of attention<sup>3,4,5</sup>

# Introduction

---

- HRV influenced by changes in lighting
  - normal circadian fluctuations in HRV attenuated in office environments with minimal natural light<sup>6</sup>
- Non-cycled lighting environment harmful to organism health
  - linked with increased error rates in hospital pharmacies<sup>7</sup>
  - linked with increased cancer rates in nighttime nursing staff<sup>8</sup>

# Experiment

---

- Purpose: investigate changes in HRV while performing a mental task (“auditory two-back”) in two lighting conditions (red vs. white)
  - red light: 638 nm; 20 lux @ 20” distance
  - white light: 463 nm; 576 lux @ 20” distance

# Task: Auditory two-back

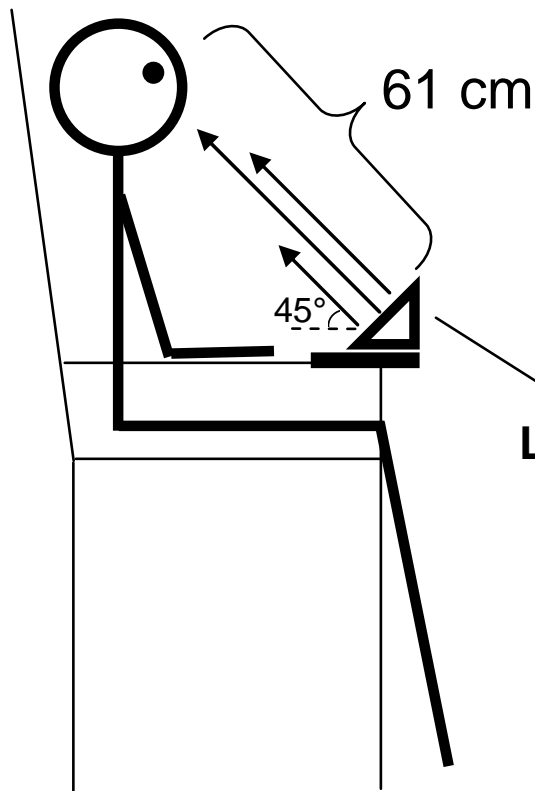
---

- test of working memory<sup>9</sup>
- 80 Consonants presented once every three seconds: “... C ... D ... B ... D ...”  
↑  
target
- Two possible responses
  - “target”: consonant identical to the one presented two earlier (prob  $\approx$  .33)
  - “non-target”: all other consonants

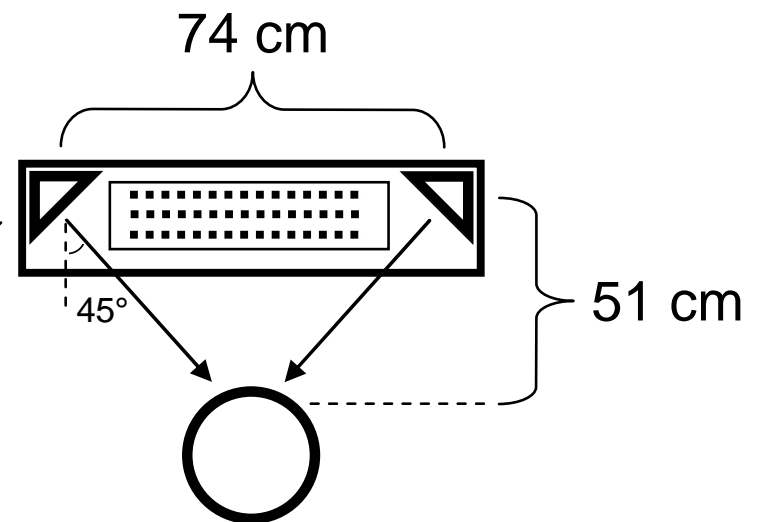
# Experimental Set-up

---

side view

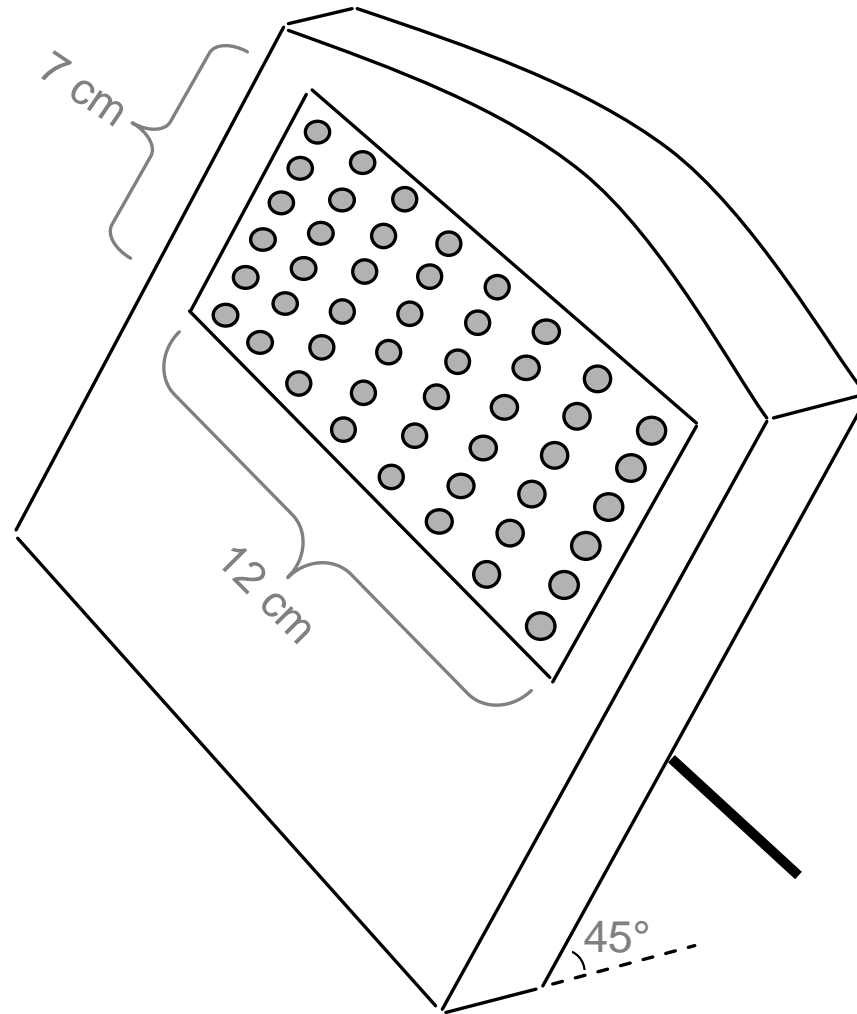


top view



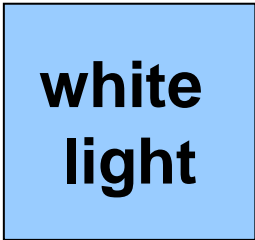
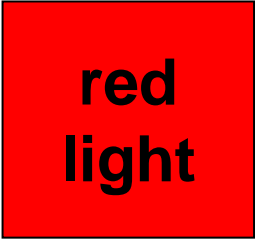
# Illustration of a Lightbook<sup>10</sup>

---



# Experimental Procedure

---

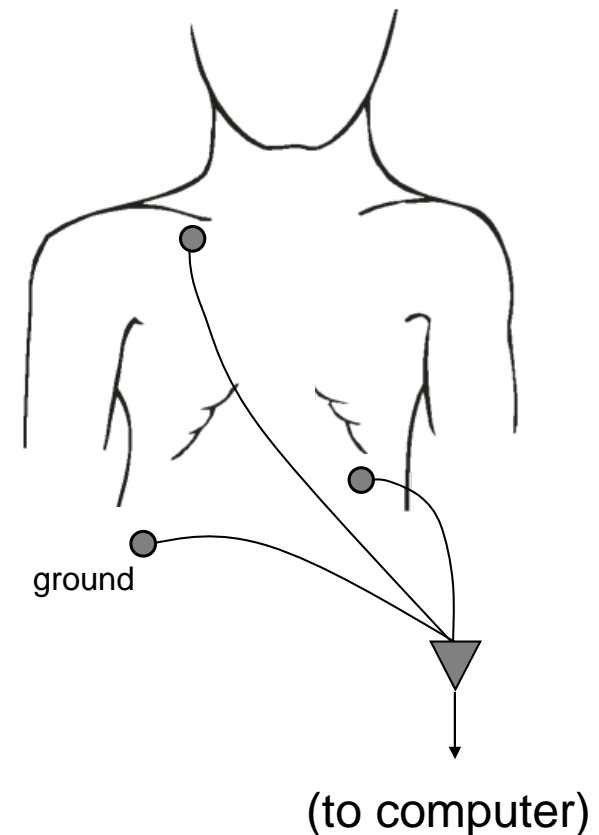
	light condition	duration (mins.)	description
		5	baseline: fluorescent
		1	2-back practice
		15	dark adaptation
counterbalanced		6	light A on
		4	2-back
		5	recovery
		15	dark adaptation
		6	light B on
		4	2-back
		5	recovery
		5	fluorescent
		3	final questionnaire



# HRV Recording

---

- seven 225-s windows
- inter-beat interval (IBI) time series analyzed using a fast Fourier transform
- examined spectral power in high-frequency (HF) band (.15 to .4 Hz)
  - vagal influences on HRV maximal in this band



# Data Analysis

---

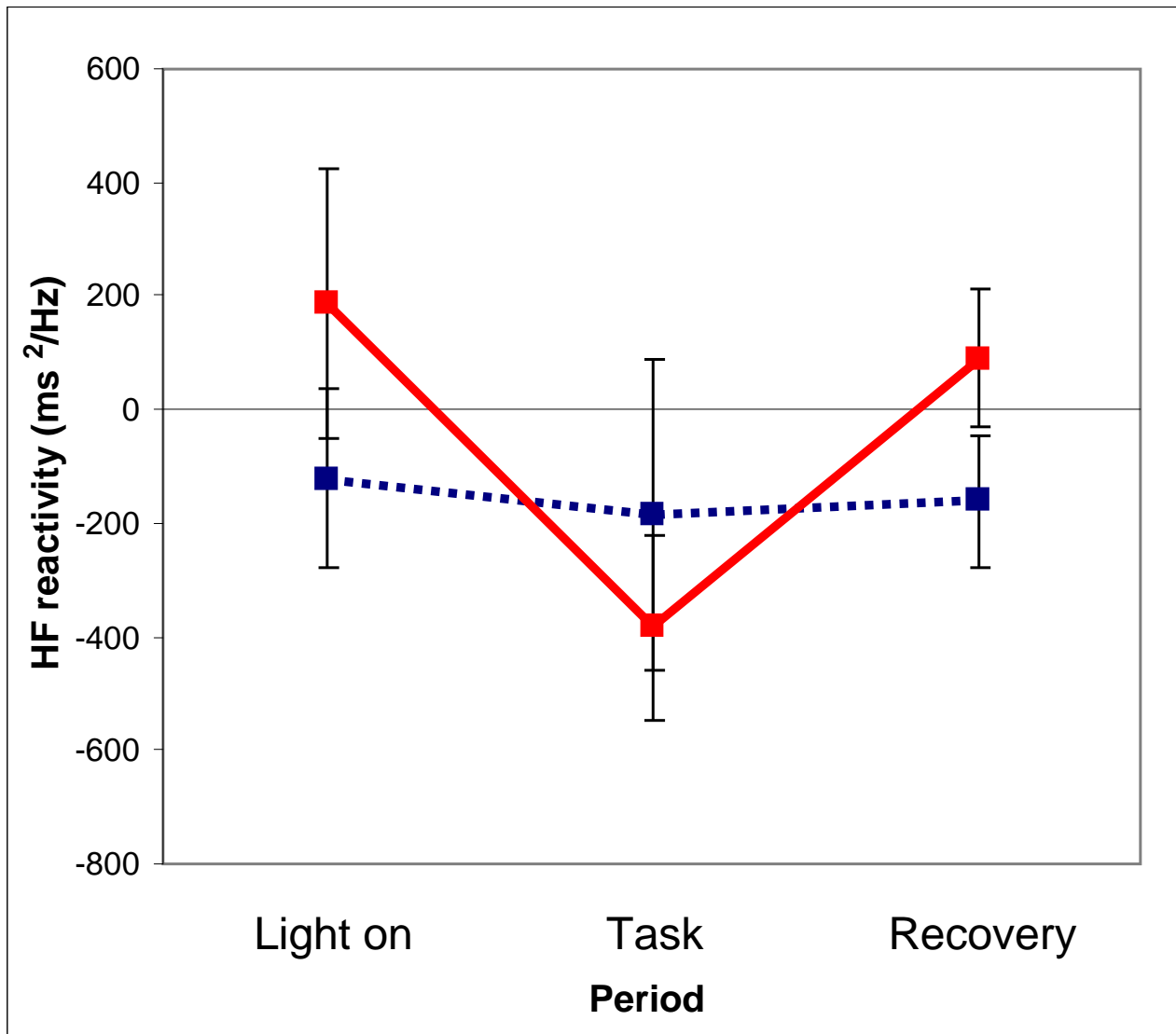
- $n = 16$
- 3 periods of interest in each light cond.:
  - “Light on”: Ss rest while light is on
  - “Task”: Ss perform task
  - “Recovery”: Ss rest while light is on
- ANOVA Design:  
2 (Light Cond.) x 3 (Period)

# Data Analysis


---

- Dependent Measures
  - HF-HRV and IBI reactivity scores
    - baseline levels subtracted from each Period
    - Also used baseline HF-HRV as a independent variable (median split)
- Planned comparisons: quadratic trends
  - Tests whether HRV is lower during “task” than during “light on” and “recovery”
  - effect size:  $\eta^2 = (SS_{\text{effect}}) / (SS_{\text{effect}} + SS_{\text{error}})$

# HF-HRV reactivity



Quadratic trends:

  $\eta^2 = .50$

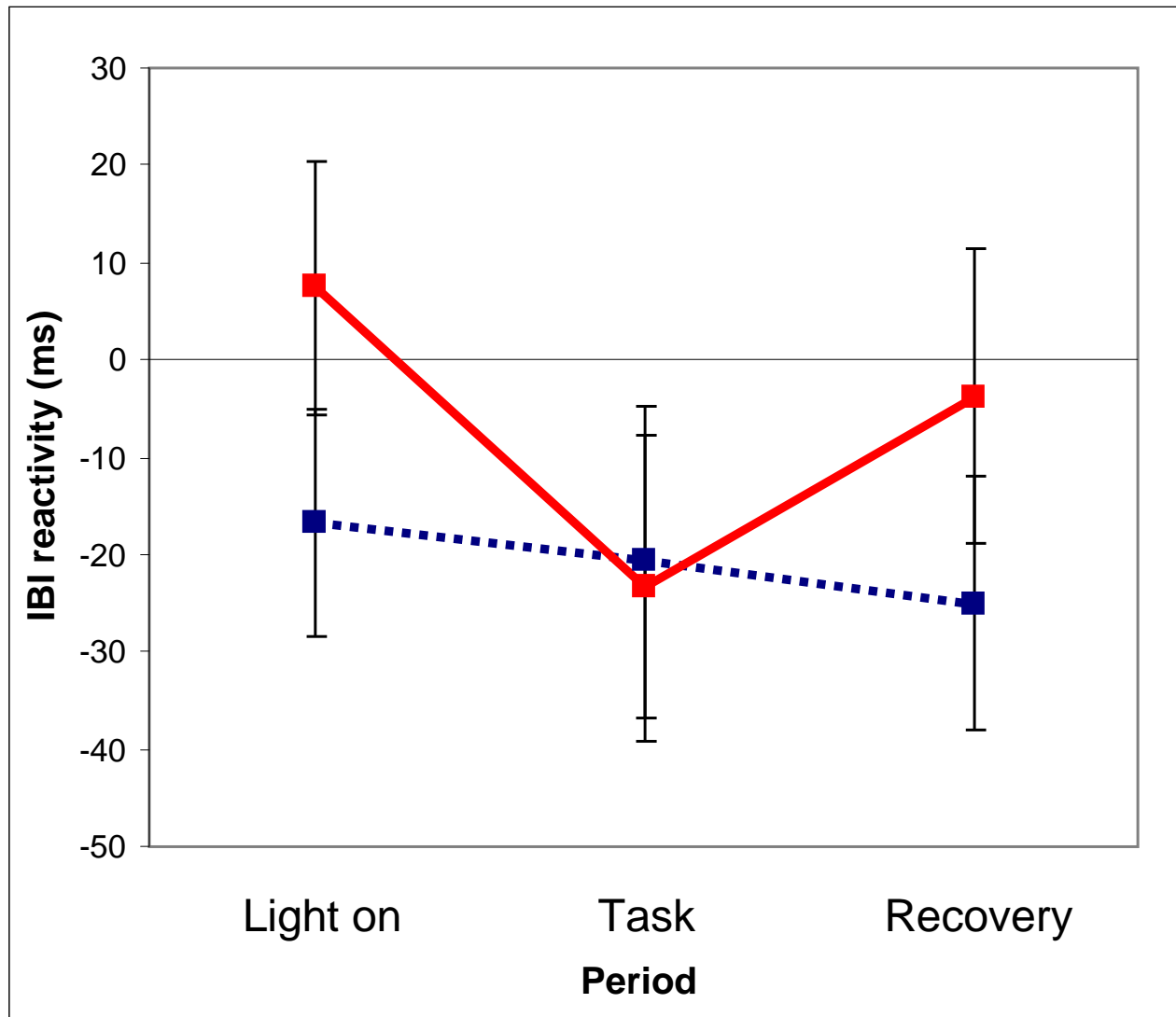
$F(1,15) = 14.85, p = .002$

  $\eta^2 < .01$

$F(1,15) = .02, p = .88$

$n = 16$

# IBI reactivity



Quadratic trends:

$$\eta^2 = .31$$

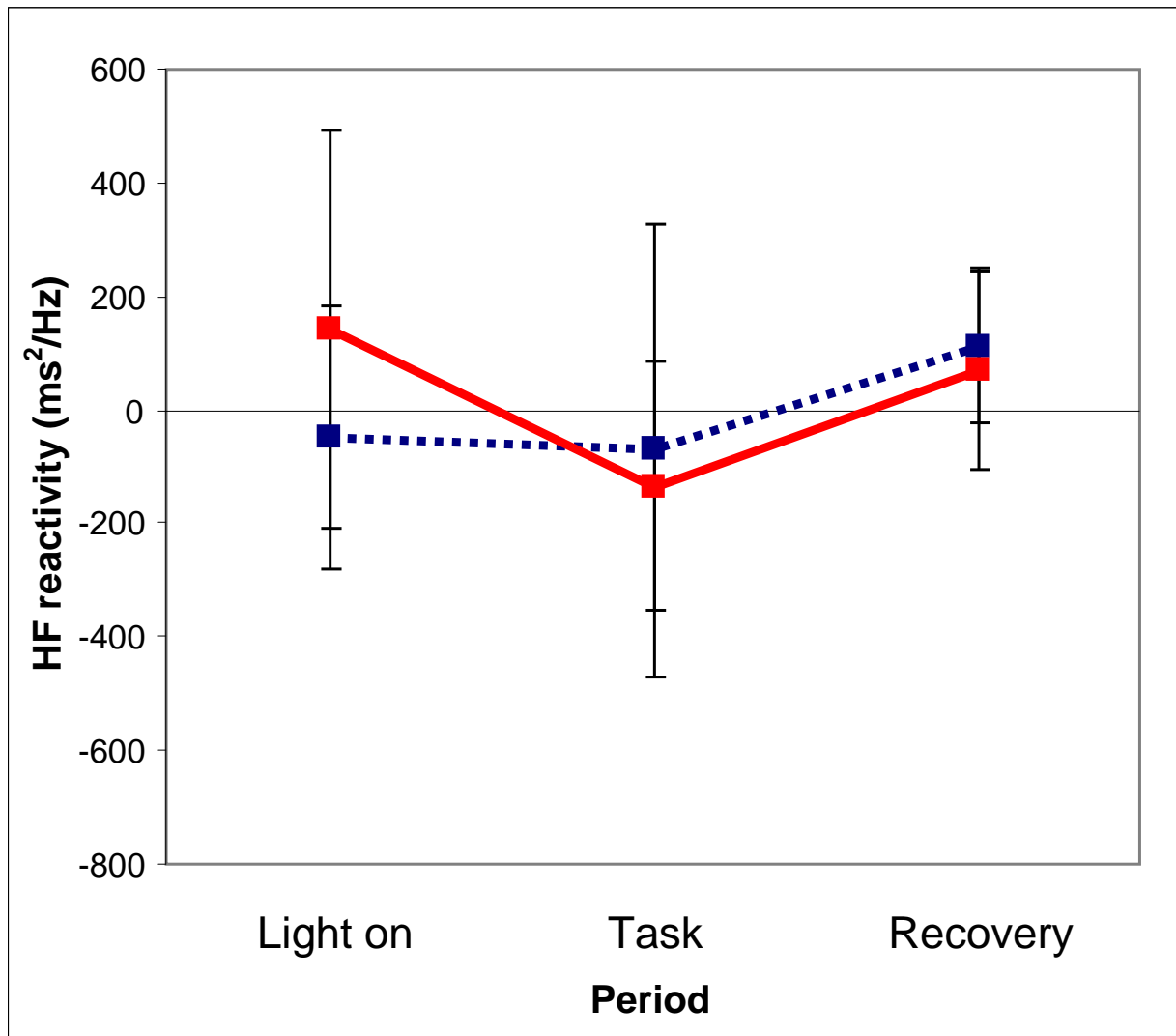
$$F(1,15) = 6.69, p = .02$$

$$\eta^2 \approx 0$$

$$F(1,15) < .01, p = .98$$

$n = 16$

# HF-HRV: low baseline HRV group



Quadratic trends:

$\eta^2 = .13$

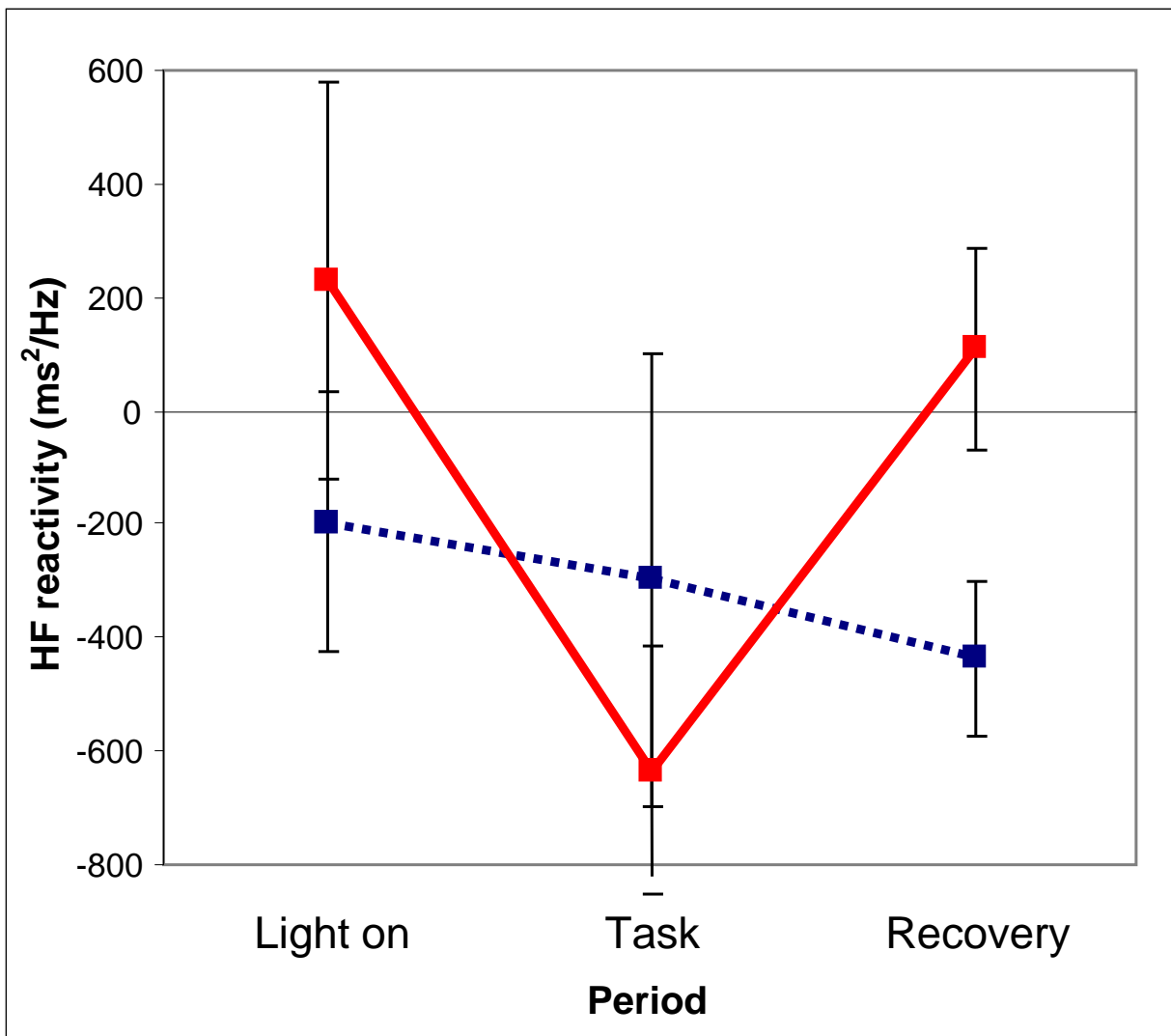
$F(1,14) = 2.06, p = .17$

$\eta^2 < .01$


$F(1,14) = .07, p = .80$


$n = 8$

# HF-HRV: high baseline HRV group



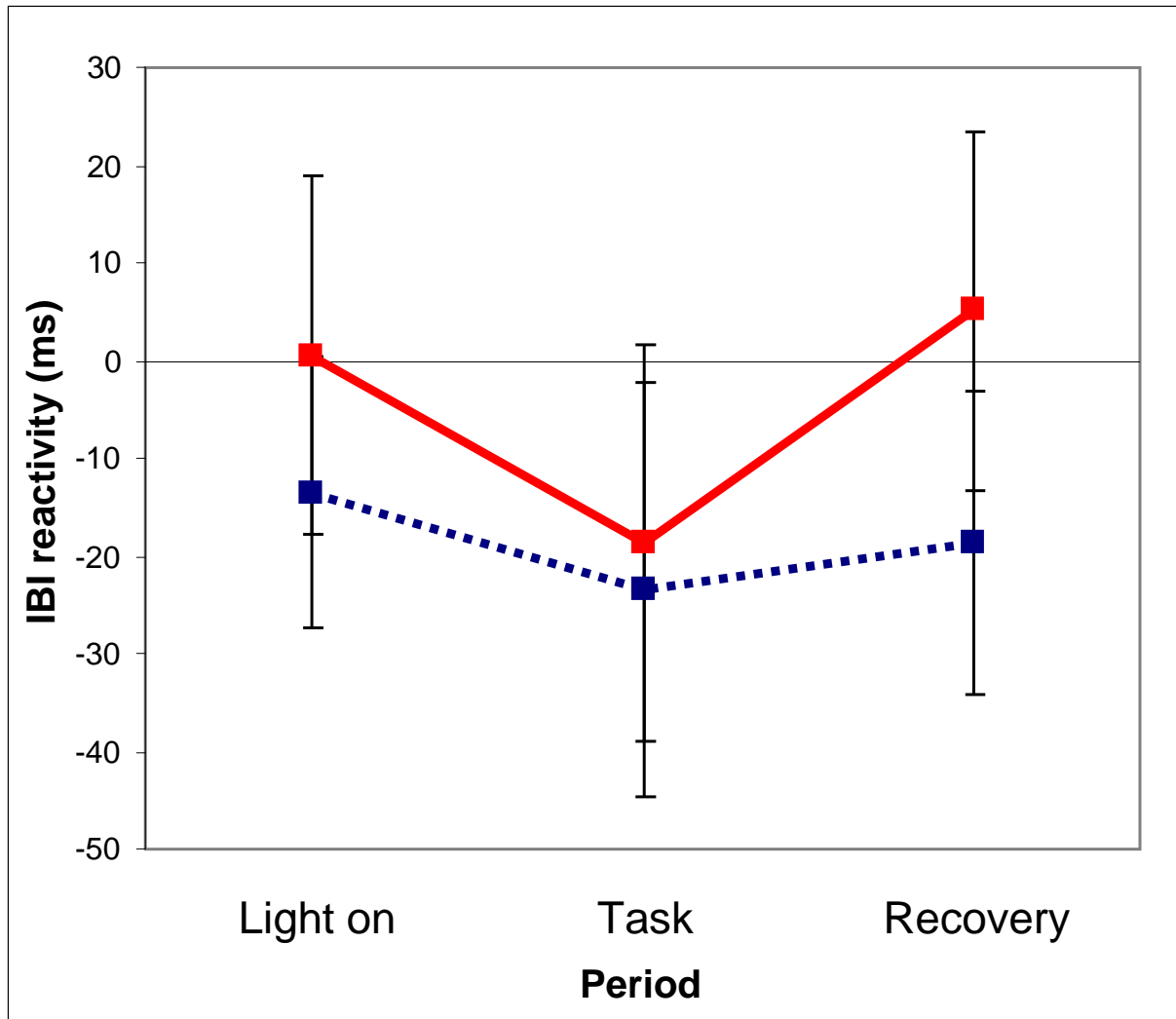
Quadratic trends:

  $\eta^2 = .62$   
 $F(1,14) = 23.11, p < .001$

  $\eta^2 \approx 0$   
 $F(1,15) < .01, p = .96$

$n = 8$

# IBI: low baseline HRV group



Quadratic trends:

$$\eta^2 = .14$$

$$F(1,14) = 2.27, p = .15$$

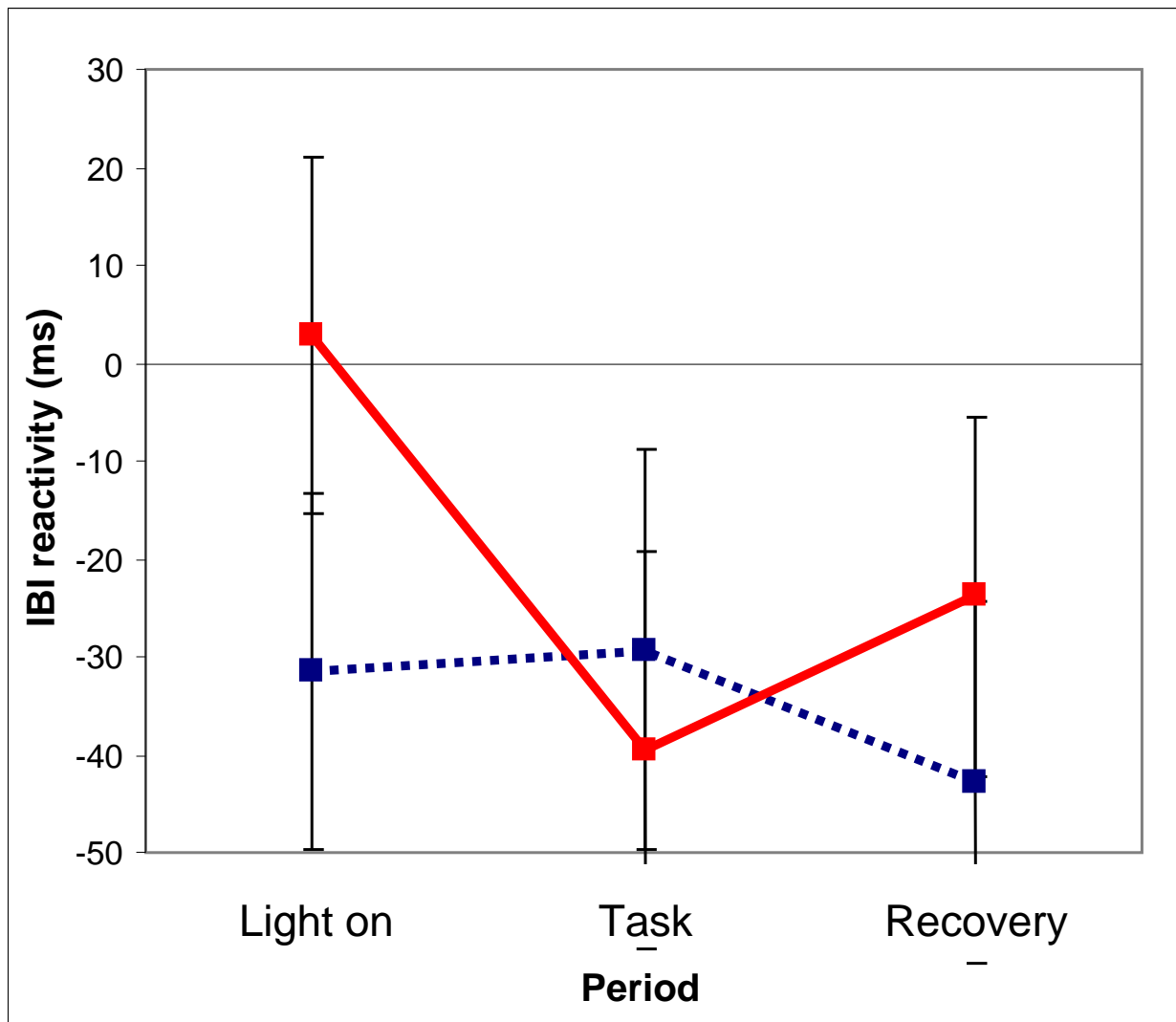
$$\eta^2 = .01$$

$$F(1,14) = .16, p = .69$$

$$n = 8$$



# IBI: high baseline HRV group



Quadratic trends:


$$\eta^2 = .23$$

$$F(1,14) = 4.18, p = .06$$


$$\eta^2 = .01$$

$$F(1,14) = .18, p = .67$$

$n = 8$

# Discussion

---

- Significant quadratic trends were found in the red light condition but not the white light condition
- A quadratic trend indicates a context-appropriate physiological response
  - lower HRV while attention is engaged; higher HRV during periods of rest
  - indicates conservation of energy and flexible adapting

# Discussion

---

- Subjects found red light condition more pleasant than white light condition
  - Rated pleasantness on scale of 1 to 5
  - [ $F(1,14) = 18.44, p < .001, \eta^2 = .57$ ]
- Pleasantness of lighting condition can thus be linked to an individual's ability to mount a context-appropriate physiological response

# Discussion: baseline HRV

---

- For both HF-HRV and IBI, quadratic trends were more pronounced in subjects who had high (vs. low) baseline HF-HRV
- This agrees with previous findings: high resting HRV is associated with greater potential for behavioral and physiological flexibility

# Conclusion

---

- These data have implications for architectural design and health care facilities where constant levels of illumination are implicated as stressors related to increased health risk.

# References

---

- 1. Thayer, J., & Lane, R. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *J. of Affective Disorders*, 61, 201–216.
- 2. Thayer, J., & Lane, R. (2007). The role of vagal function in the risk for cardiovascular disease and mortality. *Biological Psychology*, 74, 224–42.
- 3. Friedman, B.H., & Thayer, J.F. (1998). Autonomic balance revisited: Panic anxiety and heart rate variability. *Journal of Psychosomatic Research*, 44, 133–151.
- 4. Backs, R., & Seljos, K. (1994). Metabolic and cardiorespiratory measures of mental effort: the effects of level of difficulty in a working memory task. *International Journal of Psychophysiology*, 16, 57–68.
- 5. Hansen, A., Johnsen, B., & Thayer, J. (2003). Vagal influence on working memory and attention. *International J. of Psychophysiology*, 48, 263–74.

# References

---

- 6. Thayer, J. F., Christie, I. West, A. Sterling, C. Abernethy, D. Cizza, G., et al. (2006) The Effects of the Physical Work Environment on Day/Night Differences in Heart Rate Variability. *Psychophysiology*, 43, S97-S98. Research 46th Annual Meeting. session III number 98. Oct. 25, 2006. Vancouver.
- 7. Buchanan TL, Barker KN, Gibson JT, Jiang BC, Pearson RE. (1991) Illumination and errors in dispensing. *Am J Hosp Pharm.*, 48, 2137–45.
- 8. Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP (2003). The role of actigraphy in the study of sleep and circadian rhythms. *Sleep*, 26, 342–92.
- 9. Jonides, J., Schumacher, E., Smith, E., Lauber, E., Awh, E., & Minoshima, S. (1997). Verbal working memory load affects regional brain activation as measured by PET. *J. Cog. Neuroscience*, 9, 462–475.
- 10. [www.litebook.com/products/litebook-prodinfo.asp](http://www.litebook.com/products/litebook-prodinfo.asp)