Novel Lighting Strategies for Optimizing Circadian Health and Alertness in Shiftworkers

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Shiftwork

- 15 million individuals work outside regular 9-5 shift (U.S. Department of Labor)
- Increased risk of accident & injury (Folkard & Tucker, 2003)
- Myriad physiological & psychological consequences (Evans et al. 2013; Brown et al., 2009; Lawson et al., 2011)
- Compromised alertness, performance and health costs ~$200 billion annually (Kerin & Aguirre, 2005)
- Limited practical solutions
What causes the harm?

Three interconnected processes interact in the shiftworker:

• Circadian misalignment

• Sleep deprivation

• Light at night
Circadian Rhythms and Disturbances

**NORMAL**

- **Plasma Melatonin (pg/ml)**
- **Core body temperature (°C)**
- **Plasma cortisol (μg/100 ml)**

**SLEEP**

**WAKE**
Circadian Rhythms and Shift Work
Policy Resource and Education Paper (PREP), 2010

• “the single most important reason given for premature attrition from the field”

• Lack of guidance:
  “Shifts should be scheduled, whenever possible, in a manner consistent with circadian principles. For most settings, scheduling isolated night shifts or relatively long sequences of night shifts is recommended.”
Lighting Countermeasures for Shiftworkers

- Facilitate circadian adjustment
- Increase alertness/performance on-shift
- Increase sleep duration/quality
Elements Mediating the Effects of Light

• Timing

• Wavelength
Phase Response Curve

Subjective Day

Subjective Night

Advance

Phase Shift (h)

Delay

Circadian Time (h)

Phase advance

Phase delay
Spectral Sensitivity

\[ \lambda_{\text{max}} = 464 \text{ nm} \]

\[ R^2 = 0.91 \]
Responses to “Blue-Attenuated” Light

- Van der Werken et al., 2014
Proposed Intervention for Night Shiftworkers

Combines two evidence-based lighting interventions to address two different light responses:

- **Circadian Phase Resetting, architectural**
  - maximize input during subjective day
  - minimize input close to desired bedtime

- **Acute Alerting, individual**
  - light for alerting ONLY
  - only when KSS ≥6 and/or increased reaction time on PVT (need based*)
Study Light Sources

<table>
<thead>
<tr>
<th>Light Source</th>
<th>CCT (K)</th>
<th>Melanopic lux (m-lux)</th>
<th>Photopic lux (lux)</th>
<th>m-lux/lux</th>
<th>CRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA sky at 2 PM</td>
<td>5107</td>
<td>1.12e+3</td>
<td>662</td>
<td>1.69</td>
<td>100</td>
</tr>
<tr>
<td>3500K fluorescent</td>
<td>3562</td>
<td>50.4</td>
<td>100</td>
<td>0.504</td>
<td>75.2</td>
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<tr>
<td>Blue-enriched</td>
<td>3483</td>
<td>93</td>
<td>100</td>
<td>0.931</td>
<td>84.26</td>
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<tr>
<td>Alert ONLY</td>
<td>TBD</td>
<td>~30</td>
<td>100</td>
<td>~0.30</td>
<td>&gt;80</td>
</tr>
</tbody>
</table>
Shiftworker Intervention Protocol (N=30)

Baseline assessment (2 weeks)

Night shiftworker “day”

Night shiftworker “night”

KSS/PVT

Randomized, cross-over design

Blue-enriched (2 weeks)

Blue-enriched + Alert ONLY (2 weeks)
Measures

- Sleep and work diaries
- Continuous actigraphy
- Hormone profiles (melatonin and cortisol)
- Karolinska Sleepiness Scale (KSS)
- Psychomotor vigilance test (PVT)
- Subjective measures of health, quality of life, turnover communication
Conclusions

• Biological effects of light may be influenced via a variety of variables (timing, intensity, wavelength, photoperiod history)

• However, not all light responses are necessarily influenced in the same way

• Those disassociations may be utilized in the development of optimal treatment strategies

• Further, individualized and dynamic lighting environments have the potential to be particularly effective in populations with significant variability in circadian phase, such as shiftworkers
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