Non-image forming effects of light: Bridging the gap from the lab to the home

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Non-image forming effects of light

- Lateral Geniculate Nucleus – Intensity contrast
- Superior Colliculus – Cross-modal Integration
- **Hypothalamus** – Autonomic Effects, Alertness
- **Suprachiasmatic Nucleus** – Circadian Entrainment
- Pretectum – Pupil Constriction
- IGL – Integration of Light & Motor Information
Integrated Photoreception

Intrinsically photosensitive retinal ganglion cell (ipRGC)
## Integrated Photoreception

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**extrinsic**

**intrinsic**

![Diagram showing extrinsic and intrinsic connections]
Can we exploit differences between the systems?

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Can we exploit differences between the systems?

Give a sequence of flashes

Sustained firing of ipRGC… flashes “look” continuous

Time between flashes = recovery of rod/cone sensitivity
Sequence of flashes more potent than continuous light

5,000x less light yields 3x greater phase shift
Phase shift without impact on sleep

**SLEEP STAGES**

<table>
<thead>
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<th>Before</th>
<th>During</th>
<th>Paired t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wake (min)</td>
<td>5.3 ± 6.7</td>
<td>14.4 ± 21.6</td>
<td>n.s</td>
</tr>
<tr>
<td>S1 (min)</td>
<td>19.4 ± 6.3</td>
<td>20.3 ± 14.0</td>
<td>n.s</td>
</tr>
<tr>
<td>S2 (min)</td>
<td>26.1 ± 12.1</td>
<td>19.5 ± 16.6</td>
<td>n.s</td>
</tr>
<tr>
<td>S3/4 (min)</td>
<td>6.8 ± 10.9</td>
<td>4.5 ± 12.7</td>
<td>n.s</td>
</tr>
<tr>
<td>REM (min)</td>
<td>2.4 ± 5.6</td>
<td>1.6 ± 3.0</td>
<td>n.s</td>
</tr>
<tr>
<td># transitions</td>
<td>23.5 ± 8.1</td>
<td>21.3 ± 16.2</td>
<td>n.s</td>
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**POWER SPECTRUM**

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<tbody>
<tr>
<td>Delta</td>
<td>206000 ± 143000</td>
<td>148000 ± 190000</td>
<td>n.s</td>
</tr>
<tr>
<td>Theta</td>
<td>10400 ± 6040</td>
<td>8220 ± 5840</td>
<td>n.s</td>
</tr>
<tr>
<td>Alpha</td>
<td>5920 ± 4190</td>
<td>5000 ± 3210</td>
<td>n.s</td>
</tr>
<tr>
<td>Sigma</td>
<td>1100 ± 505</td>
<td>1220 ± 866</td>
<td>n.s</td>
</tr>
<tr>
<td>Beta</td>
<td>1760 ± 1370</td>
<td>1950 ± 1450</td>
<td>n.s</td>
</tr>
<tr>
<td>Gamma</td>
<td>147 ± 236</td>
<td>178 ± 240</td>
<td>n.s</td>
</tr>
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Clinical utility?

Phase shifting during sleep without disturbing sleep:

(Pre)Adaptation to jet lag
Delayed sleep in teens
Advanced sleep in elderly
Erratic sleep schedules
## Effective in Teens

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<tr>
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<th>Light + CBT (n=15)</th>
<th>Time d</th>
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<tr>
<td><strong>Sleep Onset Latency (min)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>19.91 ± 18.67</td>
<td>-0.71***</td>
</tr>
<tr>
<td>End-Treatment</td>
<td>11.25 ± 6.81</td>
<td></td>
</tr>
<tr>
<td><strong>Sleep Onset Time (hh:mm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>24:21 ± 0:47</td>
<td>-0.96***</td>
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<tr>
<td>End-Treatment</td>
<td>23:31 ± 0:47</td>
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<td><strong>Total Sleep Time (min)</strong></td>
<td></td>
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<tr>
<td>Baseline</td>
<td>438.9 ± 29.99</td>
<td>1.07***</td>
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<td>End-Treatment</td>
<td>482.1 ± 37.08</td>
<td></td>
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<td><strong>Sleep Efficiency (%)</strong></td>
<td></td>
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<tr>
<td>Baseline</td>
<td>0.91 ± 0.05</td>
<td>0.91***</td>
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<tr>
<td>End-Treatment</td>
<td>0.95 ± 0.03</td>
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<td><strong>Out of Bed (hh:mm)</strong></td>
<td></td>
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<td>Baseline</td>
<td>8:02 ± 0:34</td>
<td>-0.31</td>
</tr>
<tr>
<td>End-Treatment</td>
<td>7:22 ± 0:37</td>
<td></td>
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<td><strong>Sleep Quality (1-5)</strong></td>
<td></td>
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<tr>
<td>Baseline</td>
<td>3.35 ± 0.60</td>
<td>0.65***</td>
</tr>
<tr>
<td>End-Treatment</td>
<td>3.86 ± 0.59</td>
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- Faster to fall asleep
- 50 min earlier bedtime
- 43 min more sleep
- More efficient
- Better quality

**Critical component: passive therapy**
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When might it be beneficial to activate vision and not non-image forming circuits?
Nocturnal Ambulation in Elderly

Light exposure during nocturia increases insomnia
Nominal impact on ambulation

Orange/red light (28 lux) vs. White light (28 lux) vs. Dim white light (<0.5 lux)

**Balance**

- Orange/red light: 18 ± 2 cm
- White light: 16 ± 2 cm
- Dim white light: 14 ± 2 cm

**Acuity**

- Orange/red light: 70 ± 10
- White light: 50 ± 10
- Dim white light: 30 ± 10

**Sleep Onset Latency**

- Orange/red light: 140 ± 20 minutes
- White light: 120 ± 20 minutes
- Dim white light: 100 ± 20 minutes

*p* values:
- Balance: *p* = 0.05
- Acuity: *p* < 0.001
- Sleep onset latency: *p* < 0.001
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Daytime light exposure modifies evening light responses.

**Morning light**

**Evening light**
Daytime light exposure modifies evening light responses

Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness
Anne-Marie Chang, Daniel Aeschbach, Jeanne F. Duffy, and Charles A. Czeisler

In the past 50 years, there has been a decline in average sleep duration and quality, with adverse consequences on general health. A representative survey of 1,508 American adults recently revealed that 90% of Americans used some type of electronics at least a few nights per week within 1 h before bedtime. Mounting scientific evidence from countries around the world shows the negative impact of such technology use on sleep. This negative impact of eReaders may be due to the short-wavelength-enriched light emitted from these devices, given that artificial light exposure has been shown experimentally to produce alerting effects, suppress melatonin, and phase-shift the biological clock. A few reports have shown that these effects suppress melatonin levels, but little is known about the effects on circadian phase or the following sleep.

Real life trumps laboratory in matters of public health

The recent article by Chang et al. (1) adds to the growing literature that exposure to even seemingly dim light at night can have a negative impact on sleep. There have been several articles published in recent years indicating that the seemingly innocuous light emitted from consumer electronics devices has the capacity to increase alertness at night, thereby making it more difficult to initiate sleep (2). One of the problems that we have in judging the light emitted from these devices is that our conscious perception of light is mediated by a circuity that both overlaps and yet is distinct from the circuity amount of light one receives during the daytime (3, 4). In the current study, subjects were exposed to ~90 lx for 12 h before a 4-h session in which they were exposed to the light from a light-emitting eReader. The 12 h of 90 lx (equivalent to spending the entire day in dim room lighting that is well below workplace standards for adequate lighting) would be quite abnormal for most people. Although institutionalized older individuals could be exposed to this lighting schedule, most individuals, even those of us bound to indoor jobs, are normally exposed to greater illuminance throughbedtime. Thus, the question still remains as to whether the light being emitted from an eReader, or any other type of electronic device, would actually impact nocturnal alertness and sleep in normally behaving individuals.

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Lab members and collaborators (selected)
Raymond Najjar (flash frequency)
Kate Kaplan (teen study)
Amanda McBean (balance study)
Norman Ruby (flash during sleep)
Leah Friedman (relative light)

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National Institute of Child Health and Human Development (NIH)
National Institute on Aging (NIH)
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