2017 US DOE SOLID-STATE LIGHTING R&D WORKSHOP
PLENARY PANEL | CREATING VALUE FROM HUMAN PHYSIOLOGICAL RESPONSES TO LIGHT

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

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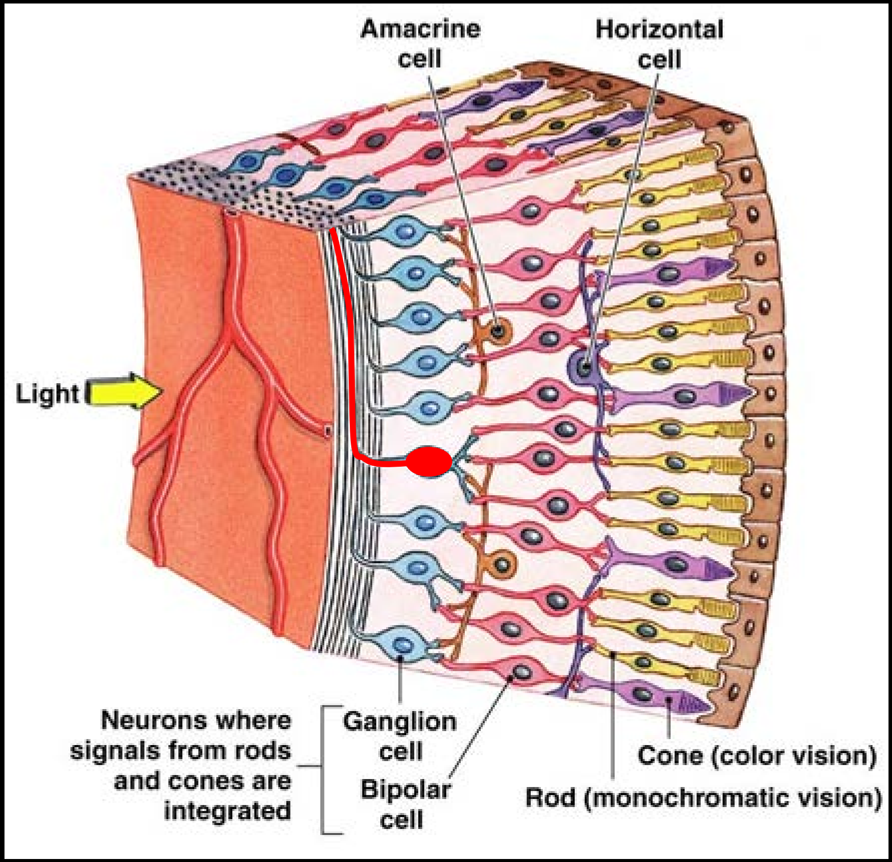
Non-image forming effects of light

- 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

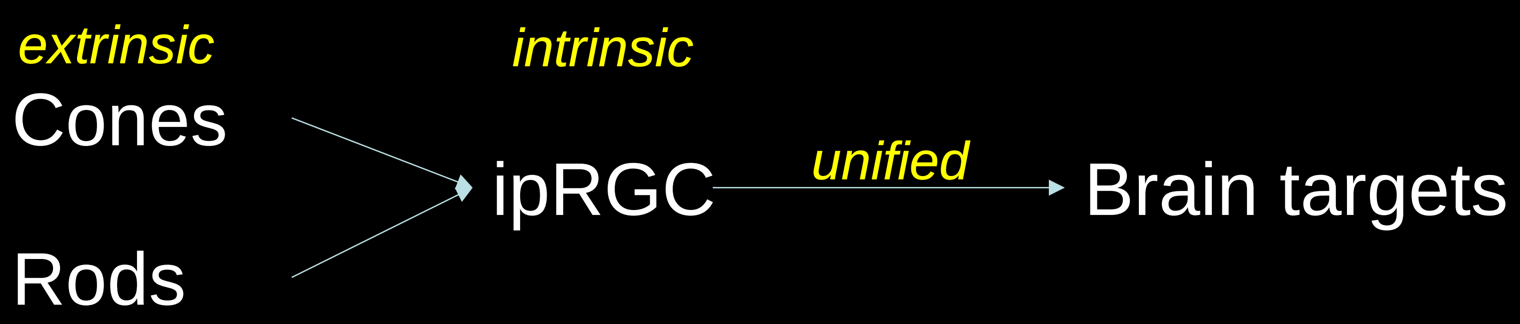
Integrated Photoreception



Intrinsically photosensitive retinal ganglion cell (ipRGC)

Integrated Photoreception

	Rods	Cones	Melanopsin
Spectrum	505 nm	555 nm	480 nm
Intensity	Very low	Medium → High	High
Duration	On/Off	On/Off	Sustained, integrative
History	Very short (seconds)	Very short (seconds)	Very long (hours?)
Spatial	Low	High	Very low



Can we exploit differences between the systems?

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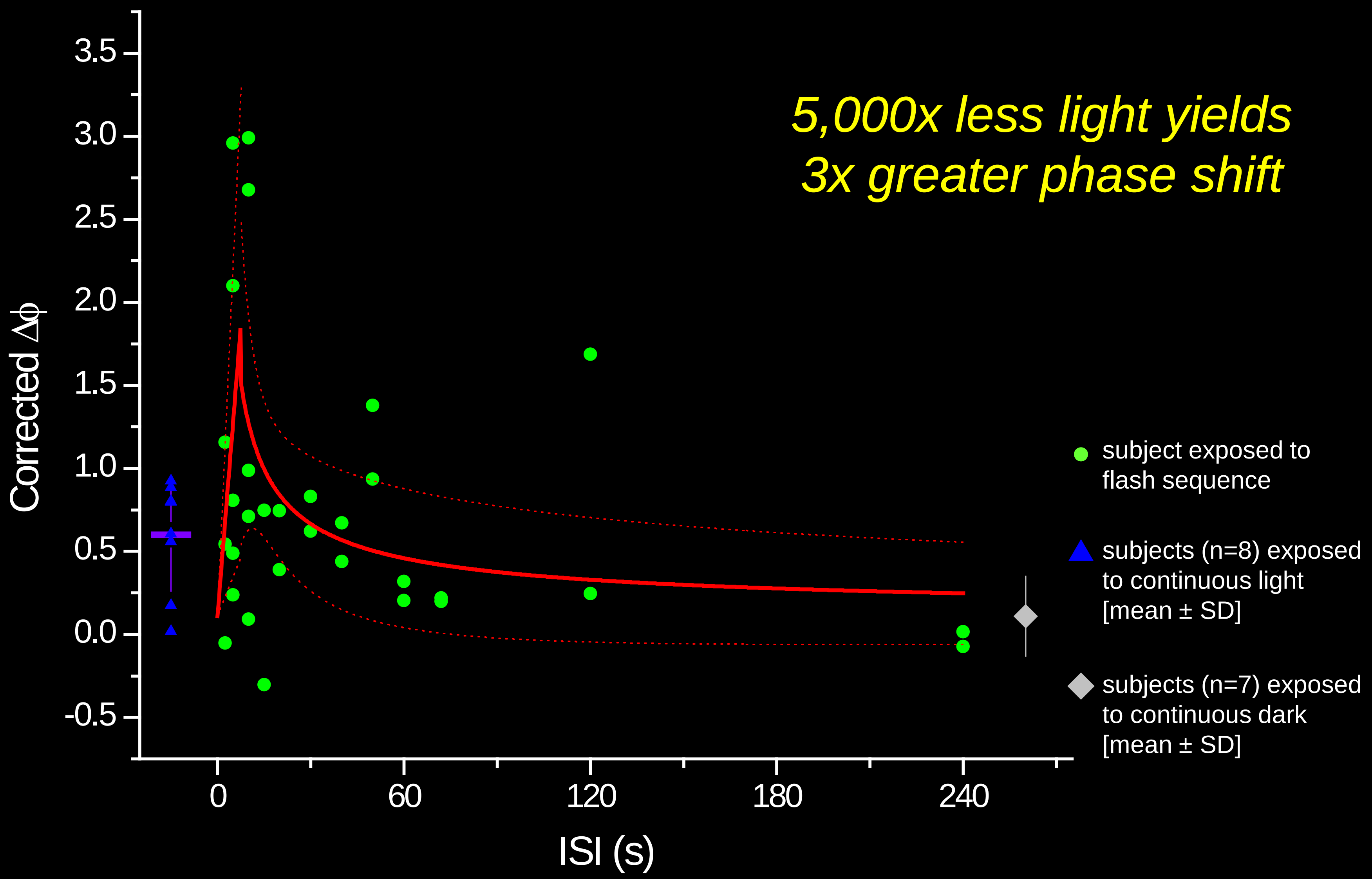
Can we exploit differences between the systems?

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



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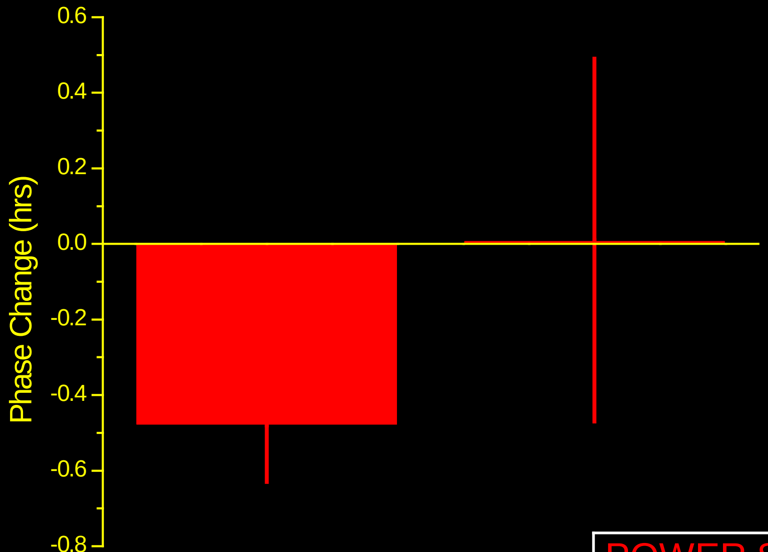
Phase shift without impact on sleep



SLEEP STAGES	Before	During	Paired *t*-test
Wake (min)	5.3 ± 6.7	14.4 ± 21.6	n.s
S1 (min)	19.4 ± 6.3	20.3 ± 14.0	n.s
S2 (min)	26.1 ± 12.1	19.5 ± 16.6	n.s
S3/4 (min)	6.8 ± 10.9	4.5 ± 12.7	n.s
REM (min)	2.4 ± 5.6	1.6 ± 3.0	n.s
# transitions	23.5 ± 8.1	21.3 ± 16.2	n.s

POWER SPECTRUM (µV/cm²)	Before	During	Paired *t*-test
Delta	206000 ± 143000	148000 ± 190000	n.s
Theta	10400 ± 6040	8220 ± 5840	n.s
Alpha	5920 ± 4190	5000 ± 3210	n.s
Sigma	1100 ± 505	1220 ± 866	n.s
Beta	1760 ± 1370	1950 ± 1450	n.s
Gamma	147 ± 236	178 ± 240	n.s

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

	Light + CBT (n=15)	Time d
Sleep Onset Latency (min)		
Baseline	19.91 ± 18.67	-0.71***
End-Treatment	11.25 ± 6.81	
Sleep Onset Time (hh:mm)		
Baseline	24:21 ± 0:47	-0.96***
End-Treatment	23:31 ± 0:47	
Total Sleep Time (min)		
Baseline	438.9 ± 29.99	1.07***
End-Treatment	482.1 ± 37.08	
Sleep Efficiency (%)		
Baseline	0.91 ± 0.05	0.91***
End-Treatment	0.95 ± 0.03	
Out of Bed (hh:mm)		
Baseline	8:02 ± 0:34	-0.31
End-Treatment	7:22 ± 0:37	
Sleep Quality (1-5)		
Baseline	3.35 ± 0.60	0.65***
End-Treatment	3.86 ± 0.59	

faster to fall asleep

50 min earlier bedtime

43 min more sleep

more efficient

better quality

Critical component: passive therapy

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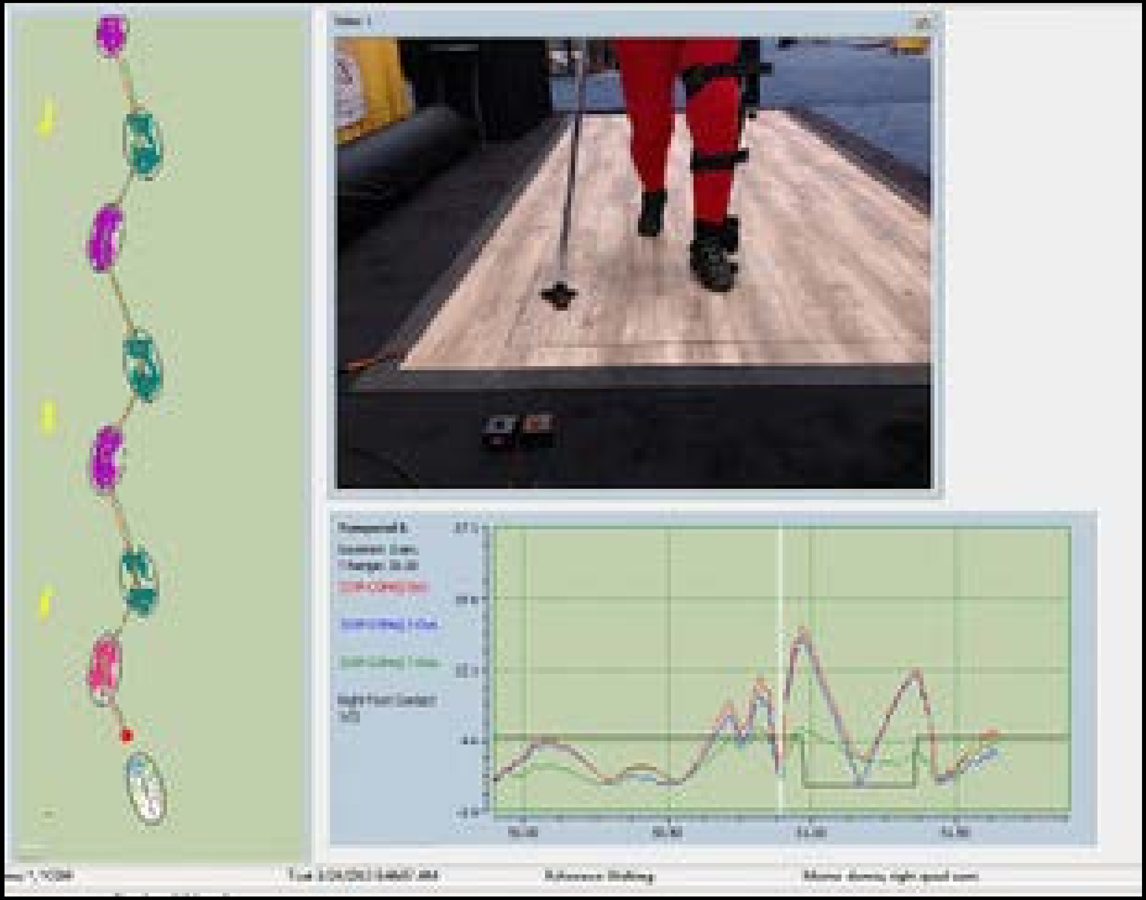
When might it be beneficial to activate vision and not non-image forming circuits?

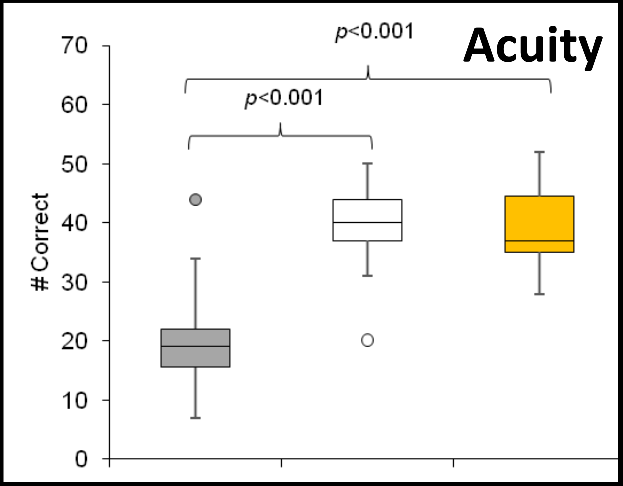
Nocturnal Ambulation in Elderly

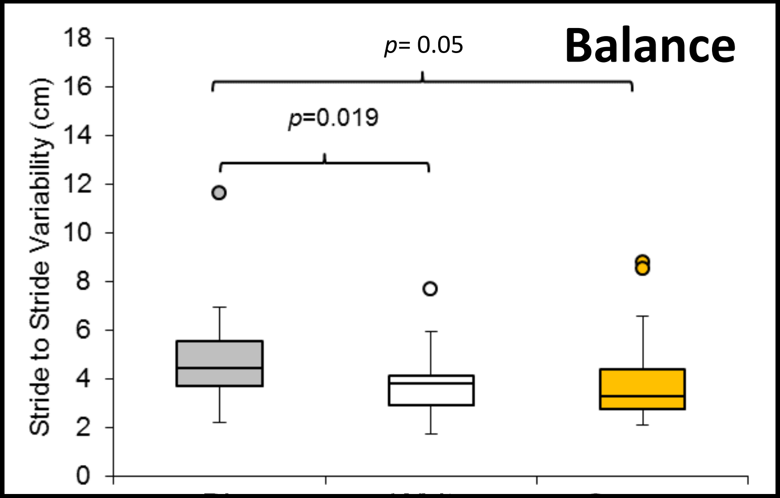


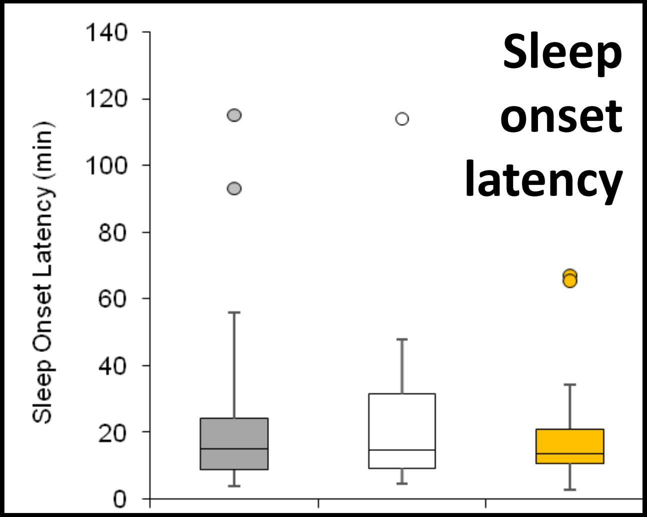
Light exposure during nocturia increases insomnia

Nominal impact on ambulation

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







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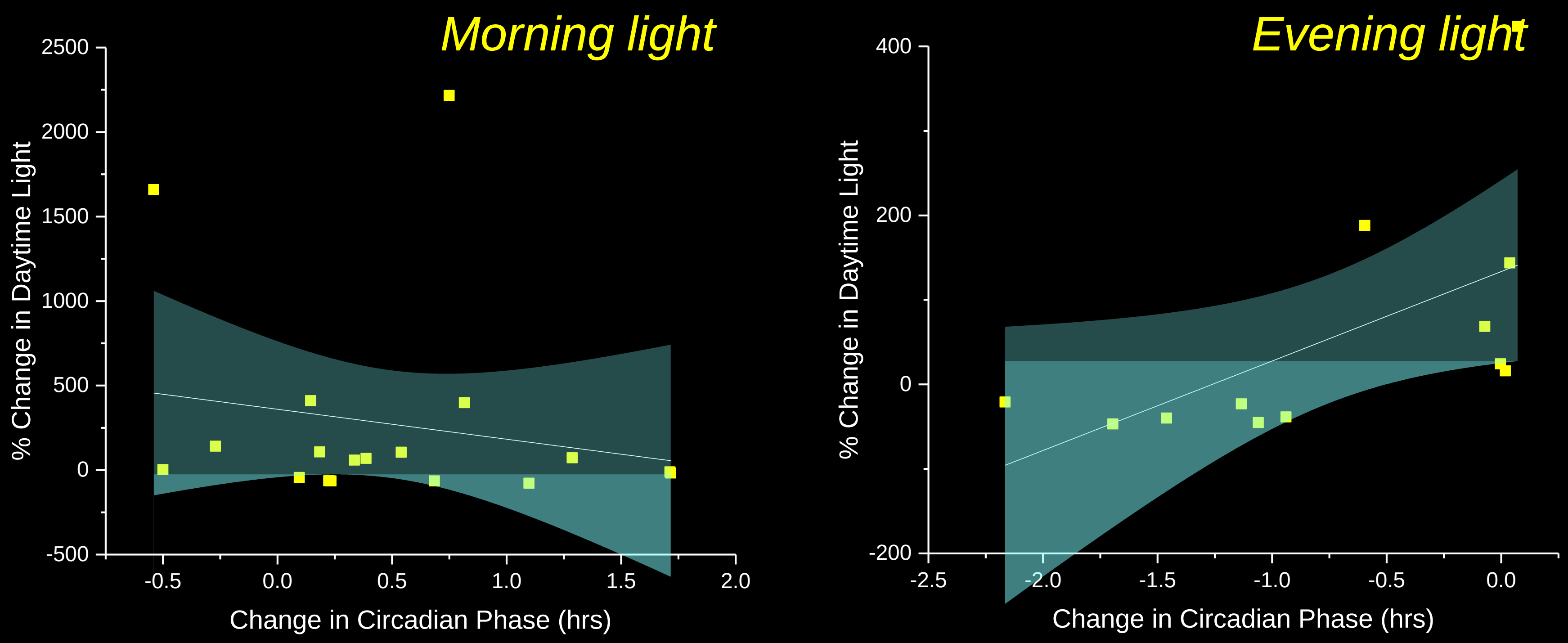
Daytime light exposure modifies evening light responses



Daytime light exposure modifies evening light responses

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Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness

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In the past 50 y, 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 evidence from countries around the world shows the negative impact of such technology use on sleep. This negative impact on sleep may be due to the short-wavelength–enriched light emitted by these electronic 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 devices suppress melatonin levels, but little is known about the effects on circadian phase or the following sleep episode, exposing a substantial gap in our knowledge of how this

sleep, and subjective and objective measures of sleepiness both in the evening while reading and the following morning.

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LETTER

LETTER

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 circuitry that both overlaps and yet is distinct from the circuitry

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 through-

bedtime. 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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