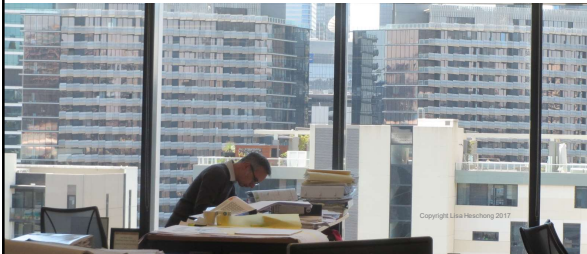


## Valuing Daylight and View

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NEMA Daylight Management Council  
California IOU Title 24 Development

April, 29 2019

## Standard Abrasives, 1995

New plant, built to recover from 1994 Earthquake in San Fernando Valley  
relocated 25 miles away

- Daylight from skylights
- Huge window views
- Happy, loyal employees





## Window serve many functions:

- Security
- Weather protection
  - Rain, wind, snow
- Heat Flows
  - Solar gains
  - Heat loss
- Ventilation
  - Filtration (insects, dust)
- Communication, egress
- Privacy
- Daylight
  - Modulation
- View




## The CEC Title 24/IOU rationale:

- Energy savings**
  - Yes, absolute value has declined...
  - But, relative value is the same!
    - Daylight can reduce lighting energy use by 50%
- Efficiency**
  - NO transmission losses
  - NO battery storage inefficiencies
- Reliability**
  - Daylight is there every day, no service interruptions
- Carbon reduction**
  - There is NO carbon use for daylight




## The CEC Title 24/IOU rationale:

- Cost Effectiveness**
  - Cost of controls is now almost trivial
    - Digital LED controls are sophisticated and pervasive
  - \*Non-energy benefits\* = win-win added value
- A Universal Application**
  - All occupied buildings have windows
  - 90% of all windows have blinds or shades
    - Let's improve them, not ignore them!
- A Key Retrofit Market**
  - Window blinds can be upgraded for improved performance
  - Daylight transmission and utilization can be enhanced, not reduced



## \*Non-Energy Benefits, value to owner and society

- Resiliency**
  - Daylight is there every day, rain or shine
    - After earthquakes, fires, floods, and black-outs
- Leasing rates**
  - Faster leasing turnover
  - Higher sales value
- \*Occupant performance and well-being\***
  - Productivity studies
  - Circadian stimulus
  - Other cognitive benefits



## CEC and IOU funded Productivity studies

2003

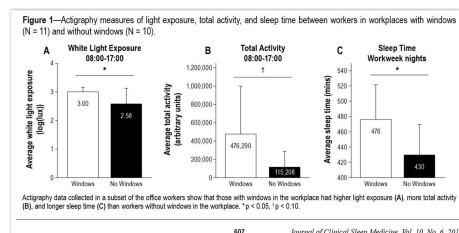
- **and More Daylight**
  - **PIER Retail Study:**
    - higher sales, more transactions in daylight stores
    - 20X the value of the energy savings
  - **PIER Schools Re-Analysis Report:**
    - 20% more progress/year on math and reading tests
- **and Bigger, Better Views**
  - **PIER Call Center Study:**
    - Workers handle 7% more calls
  - **PIER Desktop Study:**
    - Greater working memory capacity
    - Fewer health complaints in office workers
  - **PIER Classroom Study:**
    - Better test scores



## Impact of Windows and Daylight Exposure on Overall Health and Sleep Quality of Office Workers: A Case-Control Pilot Study

Boubekri, Cheung, Reid, Wang & Zee, *Journal of Clinical Sleep Medicine*, Vol 10, No 6, 2014

- **47 minutes more sleep per night for workers with windows**
- **More active movement per day, both workdays and weekends**
  - n = 49 subjects total SF & PSQI, 21 subjects w 8 days of actigraphy



## 20 years later: Original v New LEED Schools in Ohio

154 LEED schools, followed for 4 years

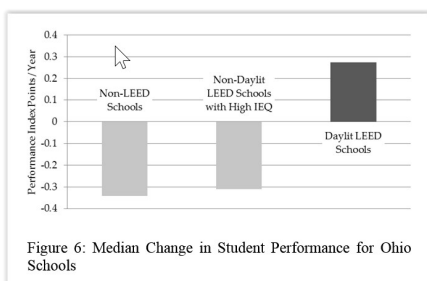
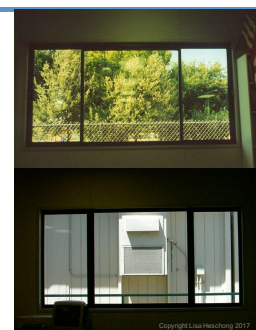


Figure 6: Median Change in Student Performance for Ohio Schools

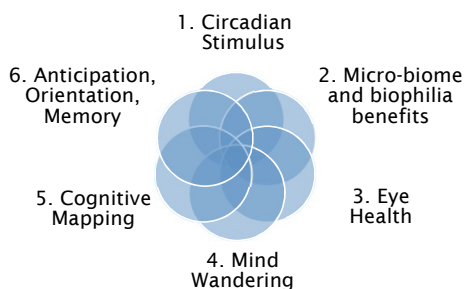
Heller, C and Sharag-Eldin, A, Kent State University, Dept of Architecture, 2016

## View was the big winner in PIER studies ! In three populations, 7 outcomes

- **Call Center** (n = 105 workers)
  - +7% to +12%
  - Worker speed
- **Desktop study** (n = 201 professionals)
  - +10% to +25%
  - 3 mental acuity tests
  - Less fatigue
- **Schools study** (n = 309 cl's/rms, 9000 students)
  - +7% to +30%
  - Faster math and reading learning



## Health and Cognitive Benefits of Window Views:



## Americans spend 95% of their lives indoors

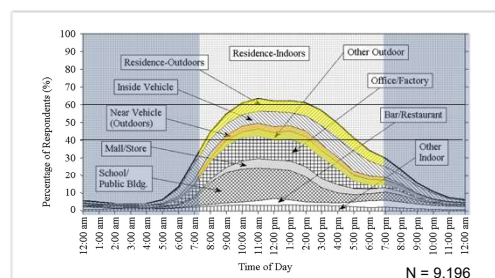


Figure 4: Stacked plot showing the weighted percentage of NHAPS respondents in each of ten different locations according to the time-of-day. The original minute-by-minute diary data have been smoothed for clarification.

The National Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants, by N. Klepeis et al, published by LBNL 2001.



**Americans spend 95% of their lives INDOORS**

*"We are an indoor species"*

Photo: George Hodan



Don't Get Too Comfortable at That Desk **The New York Times**

By ERIN LUNN OCT. 6, 2017



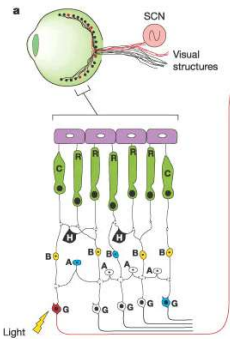
Renovated Microsoft offices have a variety of work spaces for employees. Left, a phone booth style room for privacy, and right, an isolation room. (Left: Justin Tanaka/The New York Times)

**Eyes, and photo receptors, are more complicated than we thought...**

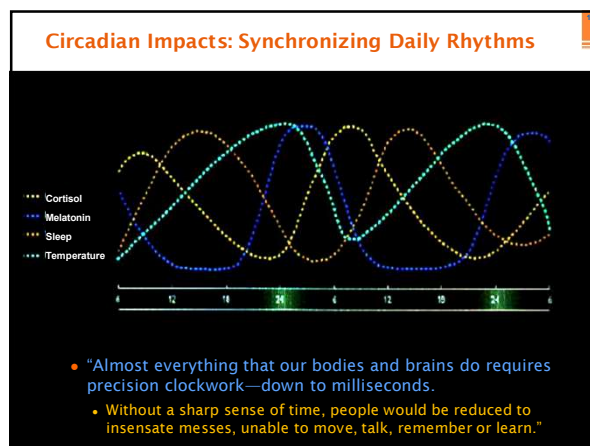
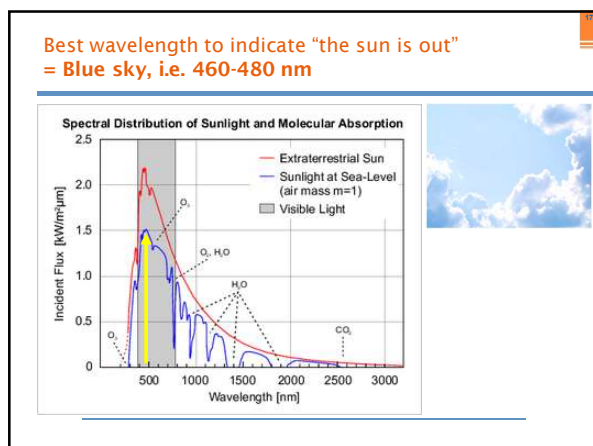


**ipRGC**  
*intrinsically photosensitive Retinal Ganglion Cells*

- There are non-visual light receptors in the retina
  - especially sensitive to blue light
  - similar to the blue sky
- That signal a separate neural and hormonal pathway
  - orchestrating circadian response
    - for all body functions
- Thus, light at the eye effects:
  - alertness, sleep quality
  - mood, emotional resilience
  - learning and memory
  - metabolic health



From: Reppert, S.M. & Weaver, D.R. *Nature* 418, 935 - 941 (2002)



### Neurotransmitters are circadian and interdependent

- Turned on by DARK
  - Melatonin – sleep, mood, puberty, activity
  - Norepinephrine – mood, intelligence, insulin resistance
  - Acetylcholine – learning, memory formation
- Turned on by LIGHT
  - Serotonin – impulse control, carbohydrate cravings
  - Dopamine – motivation, muscle coordination, working memory, tanning, visual adaptation
  - GABA (Gamma-Aminobutyric Acid) – calm, focus, inhibition

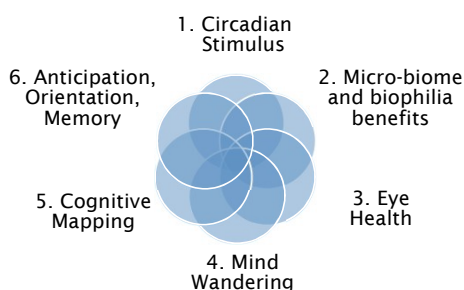
#### • “Light is a Drug”\*

- \*i.e. “Light has biological effects equivalent to some drugs”

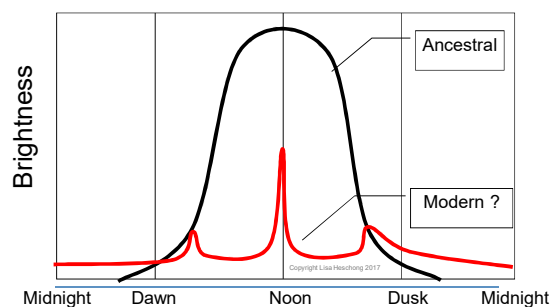
### There is much that we don’t know about vision and photo-receptive opsins

- 5 Classical Opsins, found in the retina:
  - Four cone opsins (a.k.a. photopsins) – expressed in cone cells, used in color vision
    - Long Wavelength Sensitive (LWS) Opsin –  $\lambda_{max}$  in the red region of the electromagnetic spectrum (two forms)
    - Middle Wavelength Sensitive (RH2 or MWS) Opsin –  $\lambda_{max}$  in the green region
    - Short Wavelength Sensitive 2 (SWS2) Opsin –  $\lambda_{max}$  in the blue region
    - Short Wavelength Sensitive 1 (SWS1) Opsin –  $\lambda_{max}$  in the violet/UV region
  - Rhodopsin (Rh1) – expressed in rod cells, used in night vision (more recent in evolution?)
- 9+ Novel Opsin Groups, with the function poorly understood, or unknown:
  1. Melanopsin – Best studied novel opsin involved in circadian rhythms and pupillary reflex.
  2. Pineal Opsin (Pinopsin) – Wide range of expression in the brain, most notably in the pineal region
  3. Vertebrate Ancient (VA) opsin – Has three isoforms VA short (VAS), VA medium (VAM), and VA long (VAL). It is expressed in the inner retina, within the horizontal and amacrine cells, as well as the pineal organ and habenular region of the brain. Not found in mammals.
  4. Parapinopsin (PPi) Opsin
  5. Extraretinal Rhodopsin-Like Opsins (Exo-Rh) – Rhodopsin-like protein expressed in the pineal region
  6. Encephalopsin or Panopsin – Originally found in human and mice tissue with a very wide range of expression (brain, testes, heart, liver, kidney, skeletal muscle, lung, pancreas and retina)
  7. Teleost Multiple Tissue (TMT) Opsin – Teleost fish opsin with a wide range of expression
  8. Peropsin – Expressed in the retinal pigment epithelium (RPE) cells
  9. RGR-opsin – Expressed in the retinal pigment epithelium (RPE) and Müller cells

### Health and Cognitive Benefits of Window Views:



### Our ancestral pattern of light and dark



### Window Views and Occupant Well-being

- Circadian stimulus
  - A view out a window provides about 10x the stimulus of a daylight space
    - Which provides about 10x the stimulus of an electrically lit space
  - The stimulus is always locally appropriate
- Children especially benefit from morning daylight
  - Helps to alert them
  - Helps to synchronize their rhythms
  - Helps them to get better sleep
  - Helps them to be more active, and reduces obesity
  - Improves their memory



### We’d all like to work in a “Healthy Building”

- Do we want simulated health?
- Or the real thing?





### Simulated Views: SkyFactory, a Kansas corp



Helpful?  
Creepy?



### Digital technology competes for eyeball time

- "Can't we just simulate that?"
- We are ever hungrier for visual stimulus....
  - Artificial skylights, video images of beaches and waterfalls, webcams of bird nests,

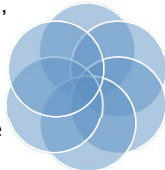


VIRTUAL REALITY



Coelux artificial skylights – a new Italian company

### Health and Cognitive Benefits of Window Views:



1. Circadian Stimulus
2. Micro-biome and biophilia benefits
3. Eye Health
4. Mind Wandering
5. Cognitive Mapping
6. Anticipation, Orientation, Memory

### "WE" are part of an intricate ecology, indoors and out:

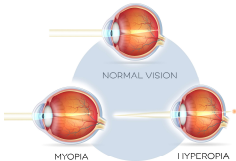
A Cautionary tale of HVAC engineering hubris, and human health



"Ventilation", by Morgan Maiolie

### Myopia: An Urban Malady

- Some Asian countries
  - now have 95% of children developing myopia
- Eskimos went from
  - 2% to 25% in one generation
- Light at night
  - Causes myopia in chickens
  - Likely children too....
- After childhood
  - Myopia becomes permanent
- Current hypothesis:
  - 3 hours+ playing outside per day, with exposure to UVB and blue light
  - Prevents myopia development



MYOPIA      NORMAL VISION      HYPEROPIA

### Recent studies have shown Americans spend 47% of their waking hours "Mind Wandering"



Killingworth and Gilbert, Harvard U. Science, Nov 11, 2010 N = 2250

Glancing, up and usually to the right...  
Preferably out a window...

## Daydreaming with computers



## 'Mind Wandering' and Creativity:

43% more creative after "low-load mental activity"



### Inspired by Distraction: Mind Wandering Facilitates Creative Incubation

- Baird et al., UC Santa Barbara, Dept of Psychology, 2012
- Psychological Science 23(10) 1117-1122
- N=135
- 'Unusual uses test' before and after interruption
- 12 minutes between tests
- Four conditions

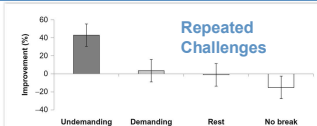


Figure 1.3 Improvement in unusual uses task (UUT) uniqueness scores (postincubation performance relative to baseline performance) for repeated exposure problems as a function of incubation condition. Error bars indicate standard errors of the mean. Reprinted with permission from SAGE Publications, Baird et al. (2012).



Figure 1.4 Improvement in unusual uses task (UUT) uniqueness scores (postincubation performance relative to baseline performance) for new exposure problems as a function of incubation condition. Error bars indicate standard errors of the mean. Reprinted with permission from SAGE Publications, Baird et al. (2012).

## "Mind Wandering" studies have found:

- The more people 'daydreamed':
  - Larger working memory
  - Better long term 'memory consolidation'
  - More planning for future actions
  - Better incubation for creative problem solving

"Your brain is working for you  
even while you are resting..."

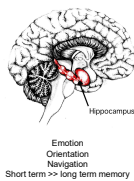


## Vantage Points and Cognitive Maps



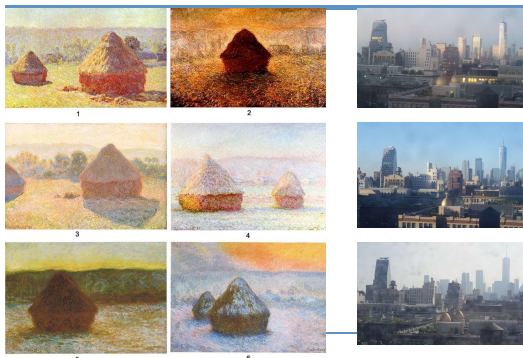
## Cognitive Mapping

- Is a primal evolutionary need for all animals
  - To get back home
  - To find the mate, the food, the water we remember
- Mapping is processed in the Hippocampus
  - Part of ancient limbic (emotional) core of the brain
    - London Taxi Drivers have an enlarged hippocampus
    - Rats without a hippocampus cannot orient in a maze
    - Circadian sensors connect to the hippocampus
  - Also the center of long term memory formation
    - Sacajawea could remember her way home, 10 years later
    - 5 yr old Indian boy, in "Lion" movie, finds his village, 1000 miles and 25 years later
  - Alzheimer's early disruption of the hippocampus
    - = disorientation in TIME and SPACE

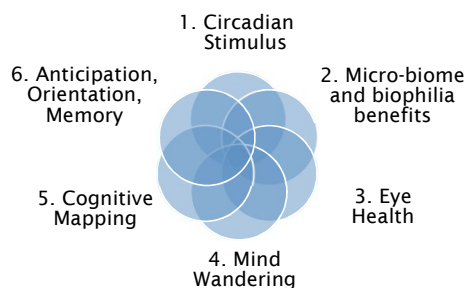


## Temporal Orientation:

Subtle trends in time, weather and season



### Health and Cognitive Benefits of Window Views:

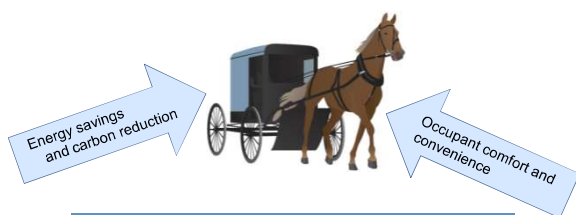


### What are the challenges?

- Understanding View Needs
  - *View is the primary task of a window !*
- Understanding Visual Comfort
  - Balanced daylight illumination inside of space
  - Access to circadian stimulus
  - Glare prediction >> for real people working in real places...
    - *View is the task !*
- Proper Energy Prediction
  - Standardized simulation and metrics (IES LM-83)
  - Credible baseline condition

### What is the goal ?

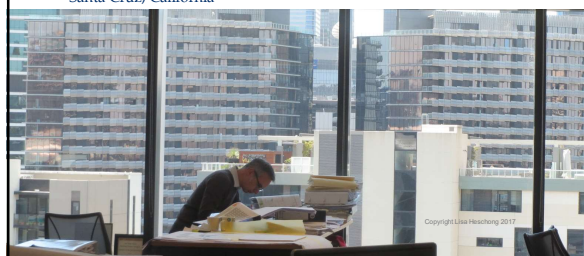
- Programs that move the market toward greater social benefits
  - **Occupant comfort first**
    - Then energy and carbon reduction



### Thank you!

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California IOU Title 24 Development

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