HUMAN CENTRIC LIGHTING

STAN WALERCZYK, HCLPC, CLEP, LC

LIGHTING WIZARDS

NASA sunrise

STAN WALERCZYK'S BIO

- 25 years experience
  - Distribution, maintenance, installer, retrofit contractor, fixture designer, consultant, lighting designer, policy maker, researcher
- Often in unique position dealing with lighting designers and retrofitters
- 500+ projects
- 50+ published articles
- 700+ seminars, including
  - 4 Lightfairs
  - 3 IES Annual Conferences
  - Numerous IES Sections across the country
- IES Member 1995 - 2008
  - Served on several committees
  - Currently on Visual Effects of Lamp Spectral Distribution and Energy Management Committees
- Certified Lighting Energy Professional by AEE
  - CLEP Review Board
- Lighting Certified by NCQLP
- Human Centric Lighting Professional Certification
- Assisted on DOE spectrally enhanced lighting research
- Architectural SSL Magazine Product Innovation Awards Judge
- DOE CALiPER Guidance Committee
- Human Centric Lighting Committee Chair

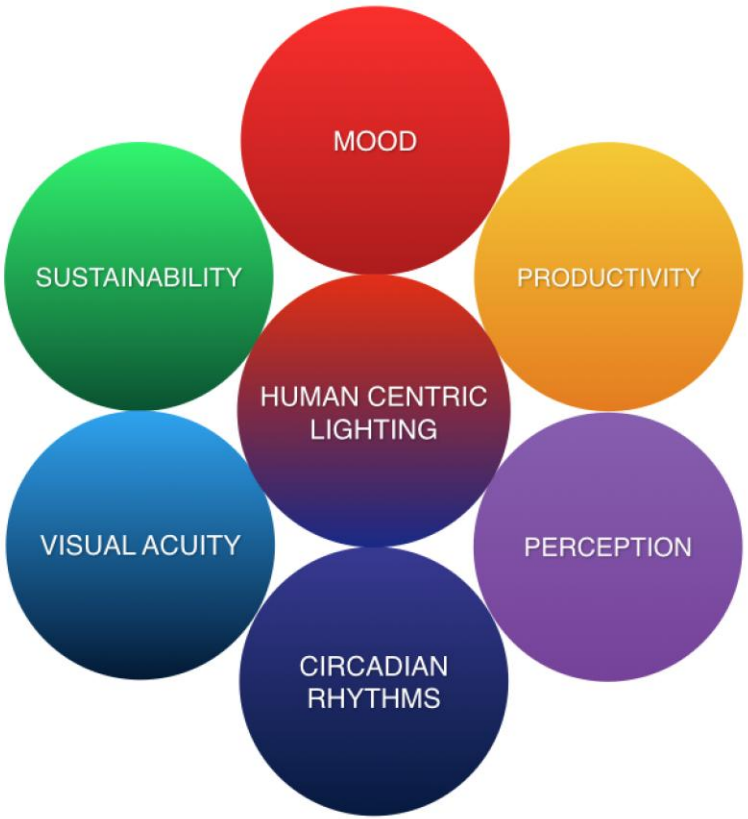
FORMAT

- Since I crammed a 4 hour class into a 90 minute one, please hold questions until the end

ALTHOUGH WE DO NOT HAVE TIME, YOU COULD WATCH THIS 9 MINUTE DR. GEORGE BRAINARD VIDEO, WHICH EXPLAINS THE VISUAL AND NONVISUAL PARTS OF VISION

https://www.youtube.com/watch?v=Pwg8s4B_Cyw

HUMAN CENTRIC LIGHTING



- This excites more than anything else has in my 24 years
- Architectural SSL Magazine published original version June of 2012
- Architectural Products Magazine published new version January of 2014

HUMAN CENTRIC LIGHTING

- Human Centric Lighting can also be called human factors in lighting, biophilia and other terms
- I firmly believe that Human Centric Lighting, including daylight and tunable LED systems will be the next big step in lighting
  - Maybe more significant than Edison Creating the light bulb

HUMAN CENTRIC LIGHTING

- Although the previous circle diagram has five separate outer circles, listed below, **they are interconnected**
  - Circadian rhythms
  - Mood
  - Visual acuity
  - Perception
  - Energy saving and sustainability
  - Productivity & performance

CIRCADIAN RHYTHMS

CIRCADIAN RHYTHMS

- Much of this circadian rhythm section is based on the work of
  - Dr. Steven Lockley at Harvard School of Medicine
    - His recent book, which is available at Amazon
      - Sleep: A Very Short Introduction
    - https://sleep.med.harvard.edu/people/faculty/163/

  - Dr. George Brainard at Thomas Jefferson University
    - We watched the video
    - http://www.jefferson.edu/facint/details.cfm?key=gxb116
  - And other prominent researchers

CIRCADIAN RHYTHMS

- International Space Station is switching to tunable LEDs
  - Lockley and Brainard worked together
  - 5000K most of the day
  - Higher Kelvin and light level boosts
  - 3000K before going to bed

CIRCADIAN RHYTHMS

- We developed a 24 hour body clock
  - Different light levels and CCT throughout the day, and changing throughout the year
  - Allowing being alert during the day and sleep at night
    - So we could survive
- People used to spend 90% of the daytime outside
- Now most people only spend about 10% outside
  - Thanks to electric lighting, which is basically one light level and one CCT all day long, day after day, year after year, decade after decade
  - Human Beings are not designed for this

CIRCADIAN RHYTHMS

- How is our clock set?
  - New photoreceptor discovered, ipRGC
  - Intrinsically photosensitive Retinal Ganglion Cells
- Particularly responsive to blue rich light
- Even some blind people are sensitive to this light through the ipRGC!

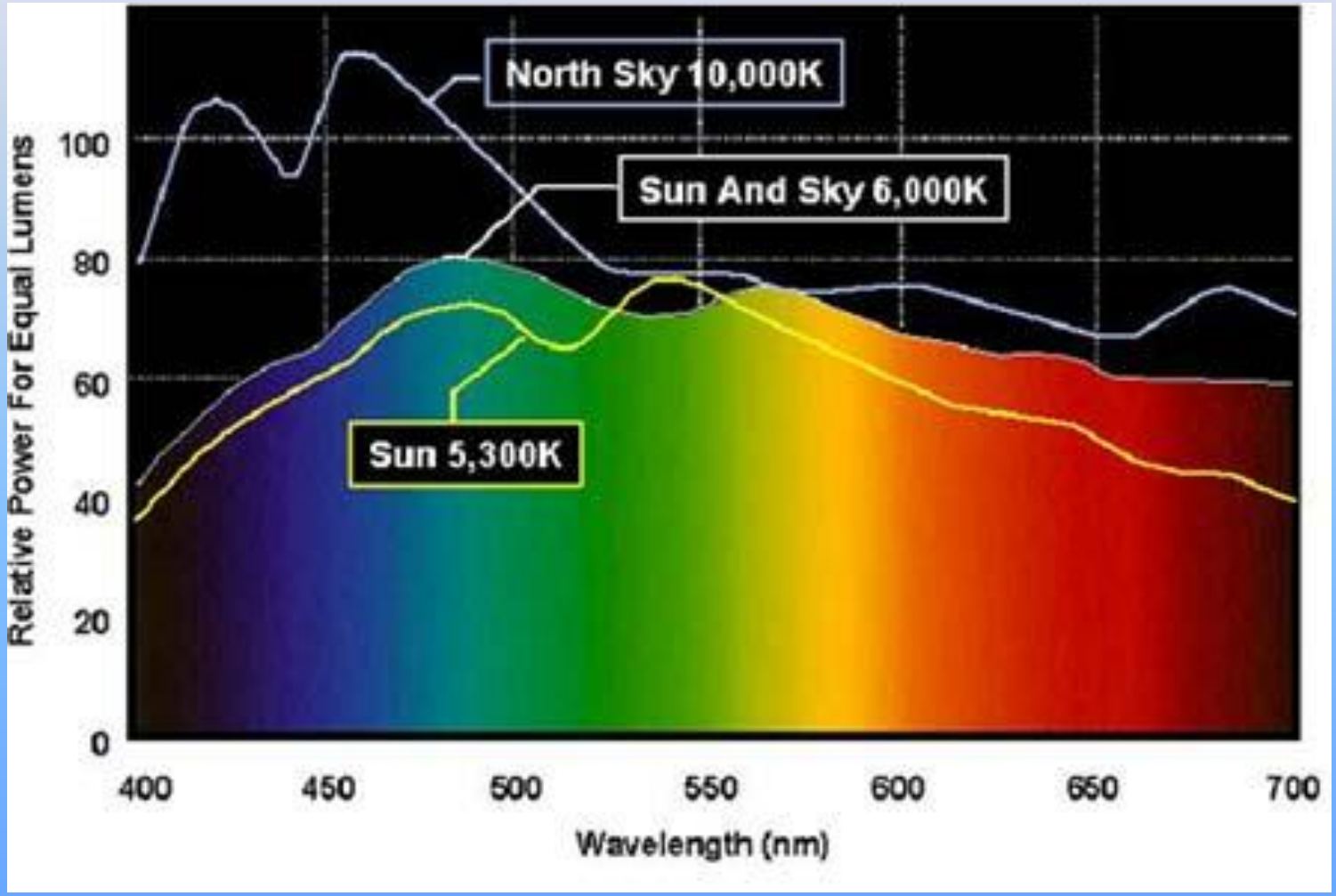
CIRCADIAN RHYTHMS

- Morning and evening are relatively warm color temperature, but they are not exactly the same
- Light at noon has high blue content
  - 5000K direct sun; up to over 14,000K blue sky
- Night just moon and stars

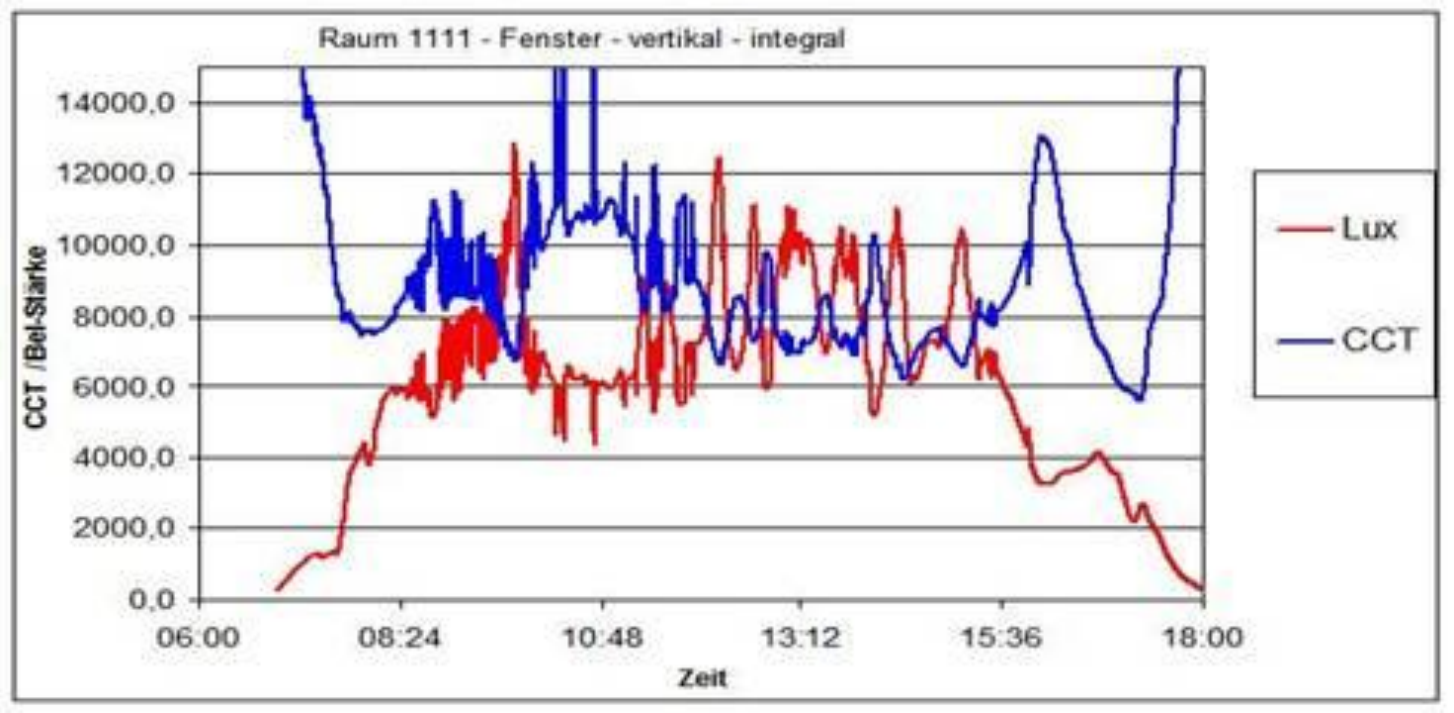
CIRCADIAN RHYTHMS

- We have developed under day/night cycle
- Good research has found that blue region has the greatest impact for the non visual side of vision
  - Somewhere between 460 & 500 nm
- A properly functioning circadian rhythm will maximize production of serotonin and dopamine at midday

DAYLIGHT


North Sky 10,000K
Sun And Sky 6,000K
Sun 5,300K
Relative Power For Equal Lumens
100
80
60
40
20
0
400
450
500
550
600
650
700
Wavelength (nm)

DAYLIGHT



courtesy of Osram Sylvania

AMA ADOPTS NEW POLICIES AT ANNUAL MEETING

- **June 19, 2012**
- CHICAGO – The American Medical Association (AMA), the nation's largest physician organization, voted today during its annual policy-making meeting to adopt the following new policies:
- **Adverse Health Effects of Nighttime Lighting**
- The AMA today adopted policy recognizing that exposure to excessive light at night can disrupt sleep, exacerbate sleep disorders and cause unsafe driving conditions. **The policy also supports the need for developing lighting technologies that minimize circadian disruption and encourages further research on the risks and benefits of occupational and environmental exposure to light at night.**
- "The natural 24-hour cycle of light and dark helps maintain alignment of circadian biological rhythms along with basic processes that help our bodies to function normally," said AMA board member Alexander Ding, M.D. "Excessive exposure to nighttime lighting disrupts these essential processes and can create potentially harmful health effects and hazardous situations."
- "This type of disruption especially impacts those employed by industries requiring a 24-hour workforce as well those faced with unsafe driving conditions caused by artificial lights on cars and roadway illumination. By supporting new technologies that will reduce glare and minimize circadian disruption, the AMA is taking steps to improve both public health and public safety."

HUMAN BIOLOGICAL TRIGGERS

- Intensity and CCT of Light may trigger
  - Light/dark cycle
  - Temperature
  - Feeding
- Light is the switch that turns everything on and off

HOW DOES LIGHT & DARKNESS AFFECT OUR BODY?

- Controls hormone production
  - Dopamine: Day - Pleasure, Alertness, Muscle Coordination
  - Serotonin: Day - Impulse Control, Carbohydrate Cravings
  - Cortisol: Day – Stress Response
  - Melatonin: Night - Sleep

EXAMPLES OF DISRUPTED CIRCADIAN RHYTHM

- Most medical errors occur on 3rd shift
- Accident rate dramatically higher
  - Truck drivers
  - Manufacturing errors
- WHO classifies 3rd shift work as a class III carcinogen

courtesy of Rodney Heller at Energy Performance Lighting

PHILIPS HEALWELL

- High Kelvin and high lumens morning to mid afternoon
- Lower Kelvin and lower lumens during evening
- Sleep better, so recover faster
- Now fluorescent, but color changing LED will be better
- Google search ‘Philips HealWell’ for videos

A ROOM WITH A VIEW

- Several studies have shown that for many hospital patients, that a view of the outside, even if there is not substantial daylight coming in through the window, can allow pain and other medication to be cut in half

A KEY PERSON REGARDING GOOD HOSPITAL DESIGN

- Rosalyn Cama, FASID, EDAC
  - President and Principal Interior Designer of CAMA, Inc.
    - http://www.camainc.com/home.html
  - Latest book
    - Evidence-Based Health Design
  - Board member of The Center for Health Design
    - www.healthdesign.org/chd/about/board-directors/rosalyn-cama-fasid-edac

TYPICAL WORK LIGHTING

- **Most work lighting today is 3500 or 4100K**
- **Some health disorders may be linked to improper amounts of blue rich light during correct parts of the day**
- **We spend 5 out of 7 days working days indoors**
- **We need more daylight**
- **If we cannot get natural, get manmade daylight**

courtesy of Rodney Heller at Energy Performance Lighting

HEALTHY LIGHTING

- Healthy lighting and healthy darkness are inextricably linked – must have both
  - Most people in western countries do not get enough outdoor light
- Need to have that normal 24 hour Circadian Cycle
- Base your light choices on science

courtesy of Rodney Heller at Energy Performance Lighting

JET LAG

- Circadian Shifting
- You are pushing your normal day/night either forward or backward
- Solve this by entraining your circadian rhythm
  - More blue later at night for going west
  - More blue earlier in morning for going east

courtesy of Rodney Heller at Energy Performance Lighting

BASEBALL TEAMS BEATEN BY JET LAG

- Nature, Vol 377, October 19, 1995
- Lawrence D. Recht, Robert A. Lew & William J. Schwartz
- “Whether due to jet lag or some other aetiology, our finds are of practical importance for the west coast teams, because they face the double handicap of playing away games after eastward trips. The result is that these teams are giving up more than one additional run in every game played after such travel.”

SEATTLE MARINERS

- Home team locker room
- Here is a 4 minute video
  - http://planled.com/?portfolio=mariners-project-introduction
  - http://www.youtube.com/watch?v=r5C7cujp5GQ&feature=youtu.be

AT HOME

- Potential causes of sleep and/or health disorders
  - Computer work or play late evening and/or early night
  - TV on all night in bedroom
  - Blue alarm clock lights
  - Blue night light
- Blue at night disrupts our natural hormone flow
- “Daylight” type light at home causes 30-45 minute sleep onset delay
- Recommend 2700K, like the sun going down

courtesy of Rodney Heller at Energy Performance Lighting

SLEEP

- Important not to have high light levels and high CCT at least one hour , sometimes longer, before going to bed
  - Light with significant 460 - 500 nm content should be avoided before going to bed
  - Some studies have shown even relative high light levels with warm color tone lighting can make it harder for people to go to sleep
  - Some people can get used to high light levels and high Kelvin before going to bed

HELP WITH VIDEO DISPLAYS

- f.lux
  - It makes the color of your computer, tablet and cell phone displays adapt to the time of the day, like sunlight during the day and warm at night
  - Free download
    - http://stereopsis.com/flux/

AS WE AGE

- Over 50
  - Need more visible light due to yellowing of lens
  - 25-50% more, can use task light
  - No blue rich light in evening
- Elderly & Alzheimer's
  - More rich blue light in morning to midday
  - Convert hallway lights to red at night
  - Higher success of sleeping all night
  - Spectrum tuning for more healthy living

AS WE AGE

- Eunice Noell-Waggoner is the President of the Center of Design for an Aging Society and has done of good work for lighting for the aged
  - http://www.centerofdesign.org/pages/aboutus.htm

ELEDERY & LOW VISION

- Robert Dupuy
  - National Chair of the IES Lighting for the Elderly and Vision Impaired Committee
  - Co-author of ANSI/IES Recommended Practice 28, which is lighting and the Visual Environments for Senior Living
  - He will create his consulting business in early 2014

DAYLIGHTING

- Including daylight is usually great
  - Walks outside during breaks
  - Windows
  - Skylights
- But there are concerns with daylight harvesting
  - From east, south and west windows can be glare and contrast ratio problems
- Just a view can be helpful

EXTERIOR NIGHT LIGHTING

- Maybe could have lower CCT and lower light levels in the middle of residential and other types of blocks and higher CCT and higher light levels in intersections
- Maybe could have higher light levels and higher CCT up to 9, 10 or 11 PM, and then reduce not only light level, but also CCT, which may be good for humans and animals

ULTRAVIOLET LIGHT

- 450 nm and below is UV light and can be damaging from electric and day light
- Dr. Joan Roberts at Fordham University is an expert on this, macular degeneration and other vision ailments
  - http://faculty.fordham.edu/jroberts/

DOSING

- Wrapping up this circadian cycle section, it is important to mention dosing specifically, which has been discussed indirectly
- Dosing
  - Light level
  - Nanometers of light
  - Time of day
  - Length of exposure
- At this time not all experts and quasi-experts agree on what is the best dosing

HUMAN CENTRIC LIGHTING MOOD

(INCLUDING PERSONAL PREFERENCES)

MOOD

- Gilles Vandewalle, etal have found that certain colors or light can affect emotions, mood and cognition
- Here are two
  - Light as a modulator of cognitive function
  - Spectral quality of light modulates emotional responses in humans

MOOD

- As shown before, and repeated here, circadian rhythms also affects mood

HOW DOES LIGHT & DARKNESS AFFECT OUR BODY?

- Controls hormone production
  - Dopamine: Day - Pleasure, Alertness, Muscle Coordination
  - Serotonin: Day - Impulse Control, Carbohydrate Cravings
  - Cortisol: Day – Stress Response
  - Melatonin: Night - Sleep

MOOD

- Giving people options can improve mood
  - For example
    - Many office workers, especially in cubicles do not have that much control in their space
    - Being able to turn on and off, aim, adjust light level and CCT in task lighting could improve mood, sense of control, satisfaction and productivity

MOOD

- Sitting in a dentist chair or lying down on a doctor’s exam table, would you rather look up at a typical fluorescent troffer with clear prismatic lens or a troffer with a blue sky with some clouds nature scene lens?

NATURE SCENE LED TROFFERS

- Available from several manufacturers
- Here is a video from one
  - www.youtube.com/watch?v=rYDW7rvbpTY&feature=channel

VIRTUAL SKY

- Each 50 centimeter square panel has 288 red, blue, green and white LEDs
- Current price is about $1000 per square yard, but pricing should come down dramatically over time
- www.fastcoexist.com/1679095/can-natural-light-make-employees-more-productive

MY FAVORITE PRODUCT AT LIGHTFAIR

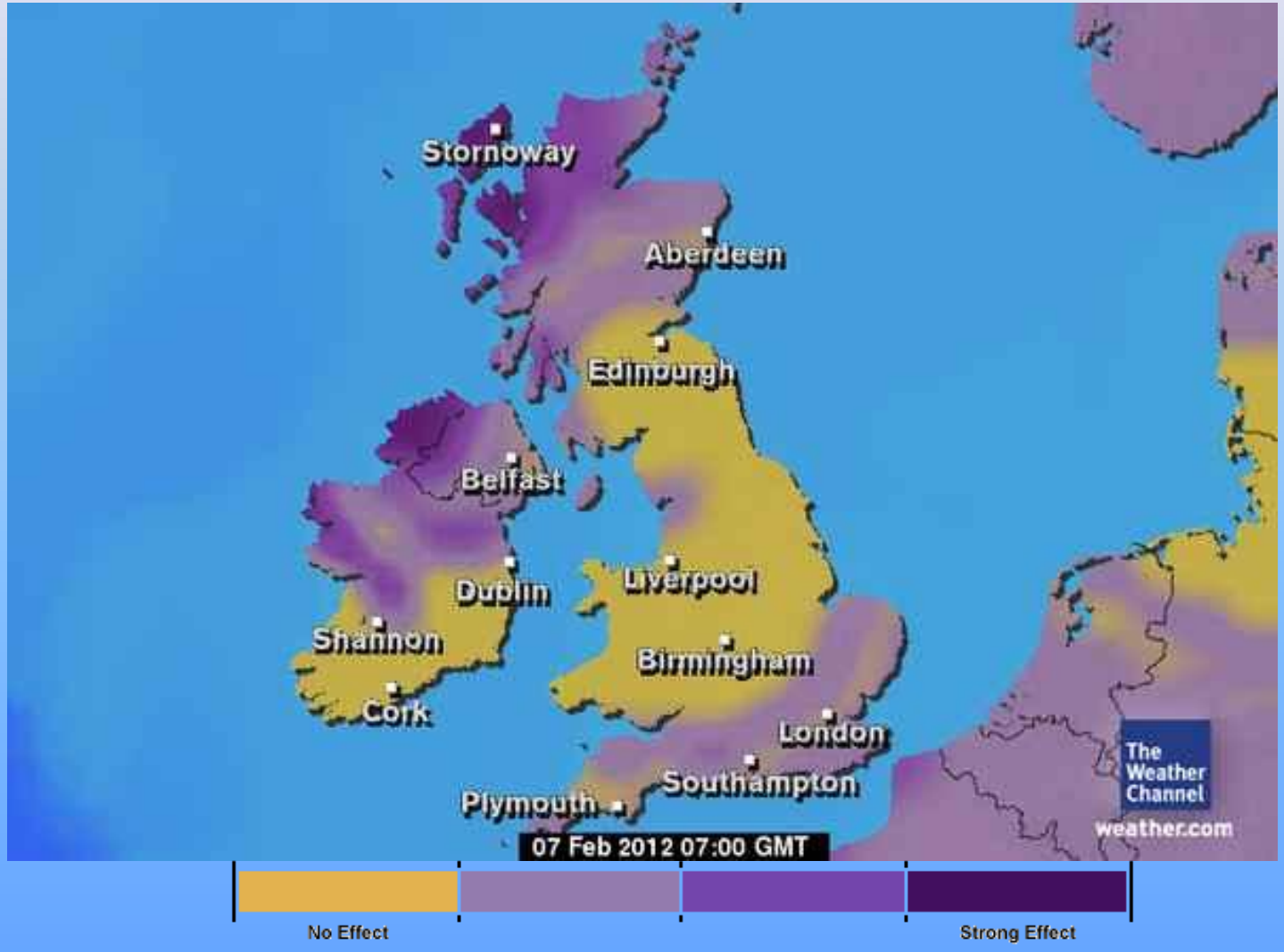
Acuity Group's Winona Lighting's Aera

SEASONAL AFFECTIVE DISORDER (SAD)

- We were built to hibernate in the winter!
- Caused by shorter days and cloudy days
- Intermittent and blue rich light has positive affect in curing this disorder, particularly in the morning
- Increases the happy hormones
- Whose responsibility is this to get the lighting?

courtesy of Rodney Heller at Energy Performance Lighting

SAD

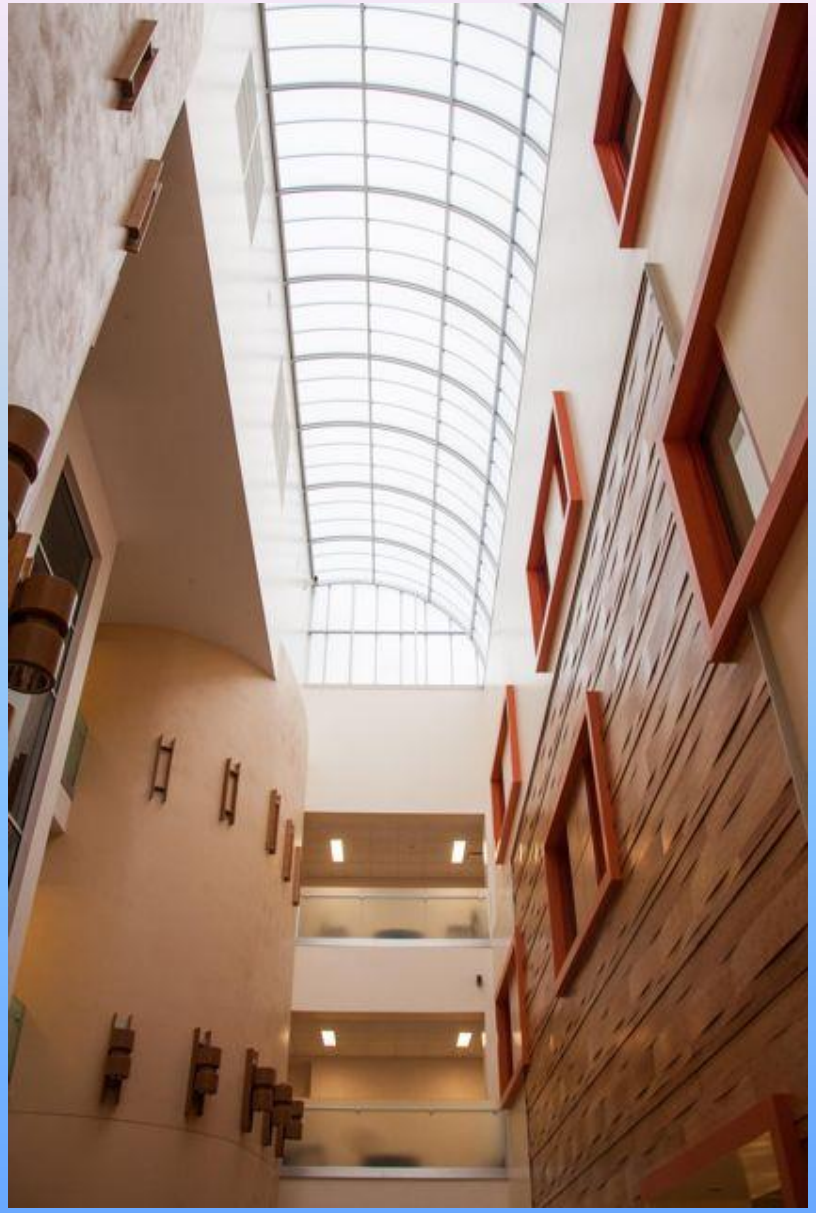

Stornoway
Aberdeen
Edinburgh
Belfast
Dublin
Liverpool
Shannon
Birmingham
Cork
London
Southampton
Plymouth
The Weather Channel
weather.com
07 Feb 2012 07:00 GMT
No Effect
Strong Effect

SAD

- Now there are some blue LED lights
  - Such as Philips goLITE BLU Energy Light series
- But be careful to avoid 450 nm and below

LIGHT LOUNGE

- University of Northern Iowa
- The Northern Iowa, March 5, 2012
- Sabin Hall’s “light lounge” works to offset SAD
  - When the University of Northern Iowa's Sabin Hall was renovated last year, ways to offset Seasonal Affective Disorder were incorporated into the design. The upper atrium of the building was converted into a "light lounge," allowing more natural light into the hall and helping to combat the effects of SAD and darker weather.
  - "This was something that the designers came up with — they realized that we spend much of our time indoors during low sunlight days, particularly during the fall and spring semesters" said Gowri Gulwadi, associate professor of applied human sciences. "Part of the inspiration behind it is green design. This is something that could positively affect people's health from an environmental perspective."



LIGHT LOUNGE

- Mike Lambert, currently at KCL Engineering, was the senior lighting designer on this project

A CLOSED-LOOP FEEDBACK SYSTEM FOR A CONTEXT-AWARE TUNABLE ARCHITECTURAL LIGHTING APPLICATION

- Jason Nawyn, Maria Thompson, Nancy Chen, Kent Larson, Massachusetts Institute of Technology, Media Laboratory, OSRAM SYLVANIA, Central Research and Services Laboratory
- PROCEEDINGS of the HUMAN FACTORS and ERGONOMICS SOCIETY 56th ANNUAL MEETING - 2012
- You can obtain this excellent report at
  - http://www.hfes.org//Publications/

A CLOSED-LOOP FEEDBACK SYSTEM FOR A CONTEXT-AWARE TUNABLE ARCHITECTURAL LIGHTING APPLICATION

- This does not just include warm to cool white Kelvin changing, but also colors, such as green and blue, in the periphery
  - Colored LEDs may consume one tenth the wattage of white LED lighting
- Controls, including occupancy sensors and digital cameras, can help automatically adjust light levels, CCT and color depending the task
  - For, example lower light levels for computer work than for paper tasks

EXPLORATION OF GESTURE-BASED CONTROL FOR TUNABLE SOLID STATE LIGHTING APPLICATIONS

- Jeremy M. Spaulding and Jeffrey Holt, OSRAM SYLVANIA
- PROCEEDINGS of the HUMAN FACTORS and ERGONOMICS SOCIETY 56th ANNUAL MEETING - 2012
- You can obtain this report at
  - http://www.hfes.org//Publications/

EXPLORATION OF GESTURE-BASED CONTROL FOR TUNABLE SOLID STATE LIGHTING APPLICATIONS

- Just like some of the newest electronic games are no longer using hand-held devices, but have cameras to detect body movements
- Osram Sylvania is experimenting the same way to control tunable lights in a space
- I experienced this at their Beverly, MA facility and was impressed

HUMAN CENTRIC LIGHTING
VISUAL ACUITY

VISUAL ACUITY

- Much of this section is based on the work of
  - Dr. Sam Berman
    - Senior Scientist Emeritus at Lawrence Berkley National Laboratory
    - Developed spectrally enhanced lighting, formerly known as scotopically enhanced lighting
  - Brian Liebel
    - Directed the DOE research of spectrally enhanced lighting
    - Chair of the IES Visual Effects of Lamp Spectral Distribution Committee wrote TM-24

which

  - (I assisted on the DOE research and am a member of this committee)

VISUAL ACUITY

- The more blue in light, the better your visual acuity
- Shrinks size of pupil, so more light from targets reaches the fovea, so can more clearly
- Can either improve acuity at same wattage or maintain acuity while saving wattage

VISUAL ACUITY

- The way that humans really perceive light, visual acuity can be improved with higher CCT lighting keeping existing wattage in many applications or maintained using lower wattage
  - Usually the latter is done to save energy
- Equivalent Visual Efficiency (EVE)
- IES Board approved TM-24 and accompanying white paper, and it should be published by now

SPECTRALLY ENHANCED LIGHTING COMPARED TO IMPROVED CIRCADIAN LIGHTING

- Spectrally enhanced lighting
  - 5000K fluorescent may be the best choice for spectrally enhanced lighting for visual acuity and brightness
    - Not too blue
    - Loosing little or no photopic lumens
    - No added lamp pricing
- Human Centric lighting
  - This is where up to 17,000K may be applied for specific applications at certain times of the day
  - I had 8000K in my California office
  - Others can use lower and higher CCT

GENERAL RULE OF THUMB

- 5000K can usually save 10% than equivalent 4100K and 20% compared to 3500K
  - Often turns out to be one lower BF ballast model
- For example
  - 2 F32T8 835 & 1.15 BF (appr. 72W)
  - 2 F32T8 841 & 1.00 BF (appr. 64W)
  - 2 F32T8 850 & .88 BF (appr. 54W)
- Another example
  - 2 F32T8 835 & .71- .77 BF (appr. 47 - 48W)
  - 1 F32T8 850 & 1.15 BF (appr. 38W)

HUMAN CENTRIC LIGHTING PERCEPTION

PERCEPTION

- I learned some of this from Milena Simeonova, Lighting Coordinator at Pacific Gas & Electric's Pacific Energy Center
  - www.pge.com/pec
- This seems quite plausible for some people for some applications, but I would love to see some good research documentation

PERCEPTION

- These factors may help people perceive the time of the day, how much energy they should have at that time of day, time of the year, etc., in addition to amount of light and spectral distributions for circadian rhythms
  - Sunrise and sunset time and how far North or South
  - Position of sun in the sky throughout the day and throughout the year
  - Sunlight coming through certain windows and lighting opposite walls
  - Length and direction of shadows
  - Perceived amount of light
  - Roosters crowing
  - Birds singing
  - Amount of traffic noise
- Maybe it would be to electrically light certain walls at various times of the year

PERCEPTION

- Many people work in offices with no or little exposure to the daily and yearly sun cycles
- Maybe it would be to electrically light certain walls at various times of the year

HUMAN CENTRIC LIGHTING PRODUCTIVITY

PRODUCTIVITY

- Productivity, which can also be called performance, may be improved with
  - Being more alert
  - Feeling good
  - Being able to see better

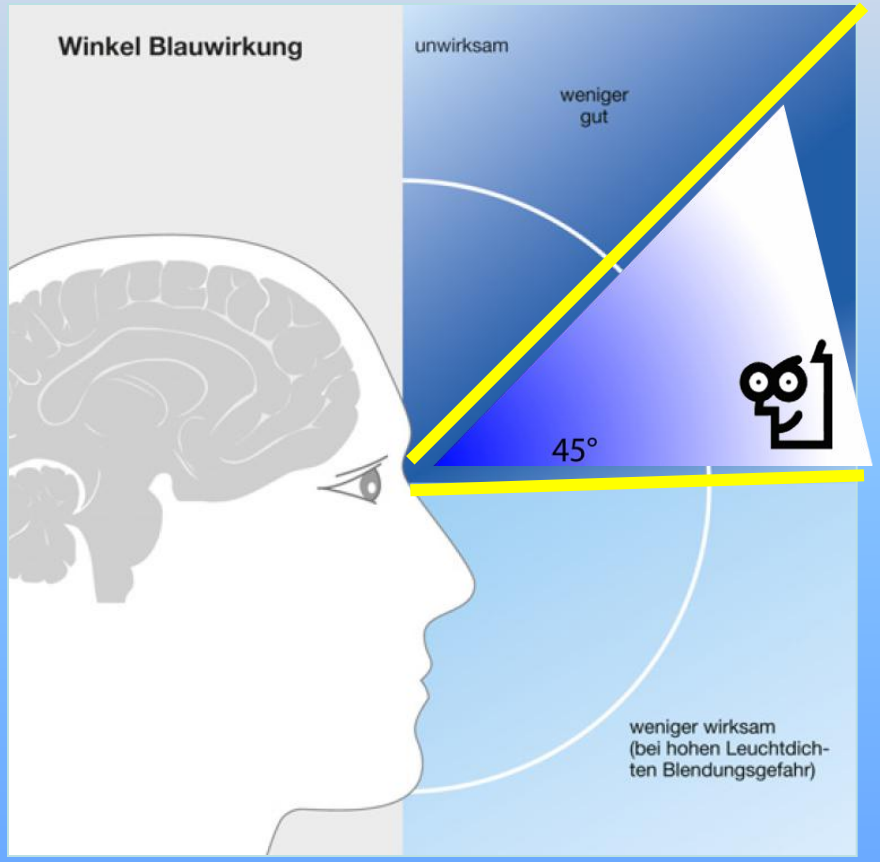
THE EFFECT OF HIGH CORRELATED COLOUR TEMPERATURE OFFICE LIGHTING ON EMPLOYEE AND WORK PERFORMANCE

- J. Circadian Rhythms, 2007
- 17,000K fluorescent in English office building
- Conclusion
  - High correlated colour temperature fluorescent lights could provide a useful intervention to improve wellbeing and productivity in the corporate setting, although **further work is necessary in quantifying the magnitude** of likely benefits.

OSRAM's 'BIOLOGICALLY OPTIMIZED LIGHTING' FOR SCHOOL STUDY

- Provided by Dr. Hannah Helbig, Osram, 2012
- ZNL Transfer Centre for Neuorscience and Learning and Osram did research at 2 European schools
- Siteco's indirect and LED fixtures
  - Direct 4000K
  - Indirect tunable 6500 - 14,000K
    - 14,000K during study
- Measurements close to students' eyes were 6500K horizontal and 5500K vertically
- Spatial, spectral and temporal properties
  - Higher Kelvin for up light to be like outside

MORE ON OSRAM
Designing biologically effective lighting: Spatial properties.



OSRAM'S BIOLOGICALLY OPTIMIZED LIGHTING FOR SCHOOL STUDY

OSRAM’S BIOLOGICALLY OPTIMIZED LIGHTING FOR SCHOOL STUDY

- Osram ‘s press release “New Light Creates Bright Sparks”
- "Even though it has been recognised for a long time that light with a specific colour temperature and illumination intensity has a positive effect on people's performance and well-being, the fact that the students with the biologically optimised lighting had up to a third fewer errors in the concentration test is impressive", said Dr. Katrin Hille (head of research at ZNL), who was in charge of the light study. Contributing to the positive results also was the fact that biologically optimised light provides stimulation to the body as if the person was outdoors. That is, the students' circadian rhythms shift forward and the young people became fit earlier. Therefore, this light can counteract social jetlag - tiredness in the mornings frequently observed in young people particularly. Many participants in the study are enthusiastic about the new lighting: **"My concentration is actually better. In normal light, however, I sometimes have to keep myself awake in the classroom"**, as one student described the experience.

PHILIPS SCHOOLVISION

- 12,000K first 30 minutes in morning
  - Help wake up
- 5000 to 6500K during normal work
  - Calm work type light
- Double the work light intensity for tests
  - Increases focus for demanding tasks
- 2700K after recess (and before nap time)
  - Calming affect
- Now fluorescent, but will be much better with LED
- http://www.youtube.com/watch?v=3lfc1y8q5l4&feature=related

OSRAM’S BIOLOGICALLY OPTIMIZED LIGHTING FOR SCHOOL STUDY

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ORF

- Dr. Michael Mott
  - University of Mississippi, www.olemiss,edu
  - Has done School Vision research in Europe, United States and Asia
  - Illuminating the Effects of Dynamic Lighting on Student Learning
  - Oral Reading Fluency (ORF) is very important and was measured

Abstract

Light is universally understood as essential to the human condition. Yet light quality varies substantially in nature and in controlled environments leading to questions of which artificial light characteristics facilitate maximum learning. Recent research has examined lighting variables of color temperature, and illumination for affecting sleep, mood, focus, motivation, concentration, and work and school performance. This has resulted in artificial light systems intended to support human beings in their actualization through dynamic lighting technology allowing for different lighting conditions per task. A total of 84 third graders were exposed to either focus (6000K-100fc average maintained) or normal lighting. Focus lighting led to a higher percentage increase in oral reading fluency performance (36%) than did control lighting (17%). No lighting effects were found for motivation or concentration, possibly attributable to the younger age level of respondents as compared with European studies. These findings illuminate the need for further research on artificial light and learning.

ORF & BOTTLENECK

- Reading faster can allow more time for comprehension, which is usually the main benefit of reading
- Let's look at the bottleneck
  - There are three elements
  - Brain can receive 700 million to 1 billion neuro firings per second
  - Cerebral cortex supplies the brain at 3 – 5 million neuro firings per second
  - Eyes supplies cerebral cortex at 30 million neuro firings per second
- That is why there are size charts at the door of 7/11 stores
  - You think the thief was 5'2", but he was 6'6"

ORF & BOTTLENECK

- High Kelvin lighting can improve lighting two ways
  - –Spectrally enhanced lighting
  - –Alertness

CONSIDER THIS

- Let’s say you
  - Eat too much at lunch and come back to the office groggy
  - Or you have to do some work late evening or during the night
- You could drink coffee, cola or another stimulant drink
  - 4 hour half life
- Or **maybe** you could jack up the light level and Kelvin
  - 2 hour effect
- With the evening or night work, you would may be awake for an hour or so after you finish

HUMAN CENTRIC LIGHTING ENERGY SAVINGS (INCLUDING SUSTAINABILITY)

ENERGY SAVINGS

- Good LED products can usually reduce significant wattage and electric bills
  - At least some of the Kelvin changing LED troffers and task lights have about the same LPW as fixed Kelvin LED products
- Saving energy also reduces carbon footprint, which is good for people and the planet

SUSTAINABILITY

- Dimming and Kelvin changing LED systems can save significant energy, which reduces carbon footprint, etc.
- Many end-customers already think that is very important
- This will probably become more important
- But we really do not know if LED is less toxic than other high performance lighting technologies
- Maybe better lighting will help workers to be more sustainable, with less medical time off and insurance payments

SUSTAINABILITY

- Numerous corporations and organizations have sustainability groups, that lower carbon footprint and less toxic chemicals are more important than payback or other hard finicial returns
  - Warner Bros is one example

IT SURE LOOKS LIKE DIMMING AND COLOR CHANGING LEDs WILL BE THE FUTURE

KELVIN CHANGING AND DIMMABLE LED PRODUCTS

- Two ways
  - RGB or RGB+
    - Expensive
    - Not that that good LPW
      - But lime green instead of traditional green LEDs help
      - Also at least Osram Sylvania's ceramic converted blue LEDs help
    - RGB+ can be the best for colors and certain nanometers of light
    - Long term color consistency issues if no feedback loop
  - Just warm-white and cool-white LEDs
    - An example is 3000K and 6500K
    - Can get anything between by dimming one more than the other
    - Maximum light output in the middle, around 4750K
    - With spectrally enhanced lighting, often half maximum wattage at 6500K
    - Same LPW as high performance fixed Kelvin products
    - Can be about same price as fixed Kelvin products

TROFFERS & TROFFER KITS

- Next Generation Luminaires 2013 Indoor Competition Recognized the PlanLED - Samjin - Pure brand color tunable 2x2 panel

KELVIN CHANGING AND DIMMABLE LED TROFFERS

- Some lighting options that may work well and could be tested
  - Could match the exterior CCT throughout much of the day
  - Open offices and classrooms
    - Could set all of the fixtures with the same light output and Kelvin
      - Could change for different tasks
    - Could have higher light level for people that need more light
  - Private offices
    - Worker could have a remote control to adjust light level and CCT whenever he or she wanted to

KELVIN CHANGING AND DIMMABLE LED TROFFER KITS

- There are some available at about $100 - $150, which is the same as standard LED ones
  - Controls are extra

KELVIN CHANGING AND DIMMABLE LED TROFFERS & KITS

- As you know, high performance T8 and T5 systems are quite good and relatively inexpensive
- I firmly believe that dimming and Kelvin changing will be necessary in many applications for many people to understand that LED is really better

KELVIN CHANGING AND DIMMABLE LED TROFFERS & KITS

- I have had more than one end-customer tell me that one reason that they are very interested in Kelvin changing and dimmable LED troffers or troffer kits is to make sure that the light go with the colors of
  - Walls, drapes, artwork, etc.
  - Other lighting fixtures, such as LED recessed cans

TASK LIGHTS

- PlanLED - Envirobrite have several tunable desk mount task
  - PlanLED - Prism's TL-8200 won a 2012 Lighting For Tomorrow Award
  - My favorite is the PlanLED TL-7000
    - Three light levels
    - Three color tones
    - Tall enough so can
      - Mimic undercabient task light
      - Provide light in front and back of computer monitor for low contrast
    - Long reach
    - Swivel
    - Low glare
    - Minimum shadowing
    - Up to 130 footcandles
    - 50 minute Timer
    - Black or white

TASK LIGHTS

PlanLED recently introduced the CTU tunable undercabinet task lights

DIMMING & KELVIN CHANGING VIDEOS

- www.youtube.com/watch?v=8ccaNHv3f2o&feature=youtube_gdata_player
- www.youtube.com/watch?v=XMM66hdD168&feature=youtube_gdata_player
- www.youtube.com/watch?v=ULc50FSMCPE&feature=em-share_video_user
- www.youtube.com/watch?v=OPaKuOeuMg8&feature=channel

TASK AMBIENT LIGHTING

- Task ambient lighting is one of the best ways to save energy and provide good lighting
  - But well designed task ambient lighting is under-utilized
  - Inverse square law
- I recently wrote a white on task ambient lighting, which is downloadable for free on my website
  - www.lightingwizards.com

TASK AMBIENT LIGHTING AT DIGNITY HEALTH CRE OFFICE

Life-changing Impact of human centric lighting

Before Retrofit	Solution
Glare on Monitor	20-25 FC Reduced Ambience
Contrast	2 Sets of Tunable Task Lights
3500K FL	Customized Work Station
Computer Glasses	No Longer Necessary

DRUM

- PlanLED 2’ diameter drum with remote control
  - Let me tell you about our kitchen remodel

SCREW IN

- Philips Hue
  - Residential division of Philips
  - http://forummedia.us/hue/
  - http://phys.org/news/2012-10-bulb-enables-wireless-personalized-smartphone.html

SCREW IN

- Lighting Science Group Definitely Digital

Introducing the

AWAKE & ALERT BULB™

Wouldn't it be great to wake up refreshed and alert? No caffeine. No energy shots. Using just a light bulb. But not just any light bulb. Originally designed to help NASA astronauts on the International Space Station be more alert naturally. The Awake & Alert LED light bulb really works. Oh, and it can help improve your focus too. So when you are ready to take on the day, so is your body.

SCREW IN

- Lighting Science Group Definitely Digital

Introducing the

GOOD NIGHT BULB™

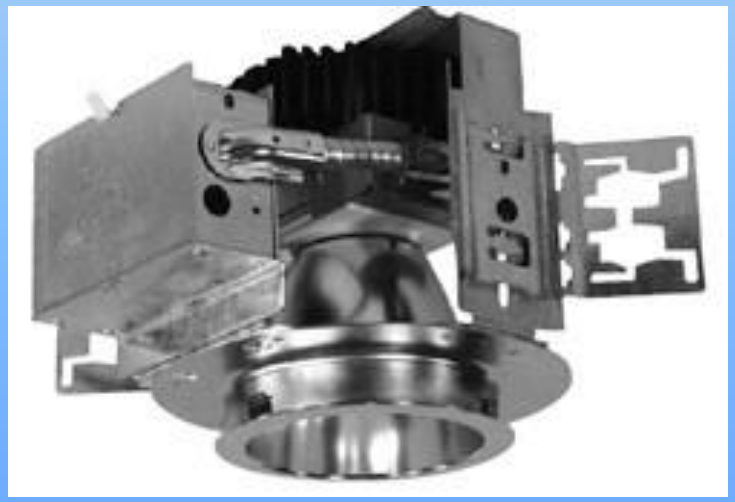
Want a better night's sleep? Did you know the light bulb that's been in your bedroom lamp since…well…forever just might be getting in the way of your body making melatonin – the hormone that helps you fall asleep? Many people spend $200 a year on sleeping pills, or up to $1200 on sleep therapy. It's time for a better solution. The Good Night LED light bulb originally developed for NASA astronauts on the International Space Station, lets melatonin do its thing. So when you're ready to sleep, your body is too.

RECESSED CAN OR TRACK HEAD

- Lumenetix Araya
  - The araya Color Tuning Module and Light Commissioning Tool introduce new levels of precision, performance and consistency by accurately tuning LED light over a wide range of color temperatures (CCT). Integral to this system is patented software models and Closed Loop Control that provides accurate color points, exact color matching between luminaires and calibration to maintain color temperature over the life of the color tuning module.
  - The complete araya system is available with Lumenetix designed reflectors for demanding LED lighting tasks and is also compatible with readily available reflectors.
  - Up to 97 CRI, but only 32 - 56 LPW
  - http://www.lumenetix.com/araya-color-tuning-led-light-module-led-light-engine

RECESSED CAN

- Pathway Lighting's Coventry Series 4VTW recessed can
  - 2700 - 6500K
  - 1000 and 2000 lumen
  - Interfaces with DMX and DALI control systems



CIRCADIAN ALARM CLOCK

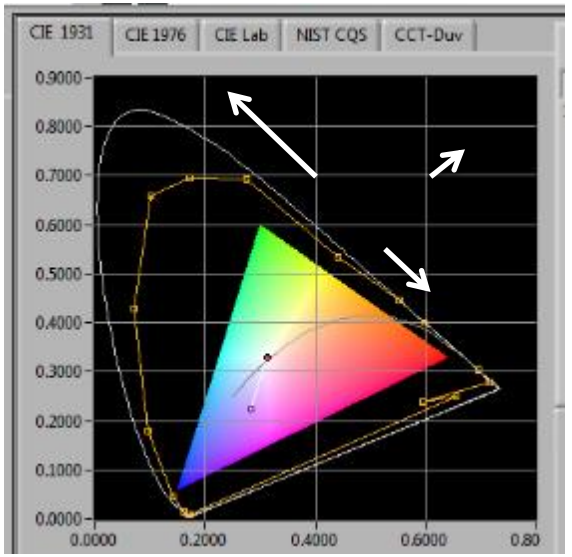
- Philips Wake-up Light
  - Coloured Sunrise Simulation

REALLY NEAT STUFF

- Telelumen
  - http://telelumen.com/
  - Following are some Telelumen slides with approval from Telelumen

Telelumen Range

- Color Temp: 1,000K – 100,000K
- Extended colors stimulate more of the visual range
- Enhance or remove individua colors to “pop” or “drop” room elements
- Control bio-relevant colors to influence occupant behavior



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ECONOMICS

TYPICAL OFFICE 12' long x 10' wide x 9' high

$0.15	blended KWH rate			1.05	additional air conditioning savings (1.00 is none)	$0.05	/KWH saved first year rebate							10	years of long term benefit						
existing				proposed																	
application and fixture type	watts	annual hours	annual electric cost	option	retrofit option description	rated lamp life hours @ 3 hour cycles	watts (some aver-aged)	watts per square foot	watts reduc-tion	% watts reduc-tion	annual unit electric cost savings	appr instal-led cost	rebate	per year mainten-ance savings benefit for compre-hensive long term benefit and payback	per year improved worker productivity from improved lighting quality benefit for compre-hensive long term benefit and payback	per year combined maintenance savings and improved worker productivity benenfit for long term benefit and payback	payback in years just electricty	payback in years electricity & maint-enance	payback in years compre-hensive	long term benefit just electricity	Long term benefit electricity & maint-enance	**long term benefit compre-hensive**
12 x 10 x 9 office area with 2 2x4 18 cell parabolic troffers, each with 3 32W 735 20,000 hour rated F32T8s and generic .88 BF ballasting (1.51 watts per square foot)	180	3000	$81.00	A	Retrofit each troffer with 3 25W F32T8 5000K lamps & .71 BF extra efficient program start parallel wired ballast	30,000 - 36,000	112	0.93	68	38%	$32	$120	$10	$2	$2	$4	3.4	3.2	3.0	$212	$221	**$241**
				B	Retrofit each troffer with upscale kit which eliminates parabolic louvers, 1 high lumen F32T8 5000K lamp & 1.15 BF extra efficient program start ballast	30,000 - 36,000	78	0.65	102	57%	$48	$230	$15	$6	$250	$256	4.5	4.0	0.7	$267	$312	**$2,812**
				B1	Retrofit each troffer with upscale kit which eliminates parabolic louvers, 1 high lumen F32T8 5000K lamp & .89 BF extra efficient program start ballast. Also include 8W dimming & Kelvin changing LED task light.	30,000 - 36,000 for T8s	67	0.56	113	63%	$53	$310	$17	$6	$400	$406	5.5	4.9	0.6	$241	$284	**$4,284**
				B2	Retrofit each troffer with upscale kit which eliminates parabolic louvers, 1 high lumen F32T8 5000K lamp & .71 BF extra efficient program start ballast. Also include 2 8W dimming & Kelvin changing LED task lights.	30,000 - 36,000 for T8s	62	0.52	118	66%	$56	$380	$18	$6	$450	$456	6.5	5.9	0.7	$195	$238	**$4,738**
				C	Remove both troffers. Install 8' suspended indirect/direct fixture that has 2 high lumen F32T8 5000K lamps & 1.15 BF extra efficient program start ballast.	30,000 - 36,000	70	0.58	110	61%	$52	$410	$17	$6	$350	$356	7.6	6.8	1.0	$126	$170	**$3,670**
				C1	Remove both troffers. Install 8' suspended direct/indirect fixture that has 2 high lumen F32T8 5000K lamps & .89 BF extra efficient program start ballast. Also include 8Wdimming & Kelvin changing LED task light.	30,000 - 36,000 for T8s	63	0.53	117	65%	$55	$490	$18	$6	$500	$506	8.5	7.7	0.8	$80	$123	**$5,123**
				C2	Remove both troffers. Install 8' suspended direct/indirect fixture that has 2 high lumen F32T8 5000K lamps & .71 BF extra efficient program start ballast. Also include 2 8W dimming & Kelvin changing LED task lights.	30,000 - 36,000 for T8s	60	0.50	120	67%	$57	$560	$18	$6	$550	$556	9.6	8.6	0.9	$25	$67	**$5,567**
				G	Retrofit each troffer with high performance hardwired LED troffer kit with batwing distribution, set at 35W, so sufficient light at end of life.	50,000+	70	0.58	110	61%	$52	$270	$17	$12	$250	$262	4.9	4.0	0.8	$266	$370	**$2,870**
				G1	Retrofit each troffer with high performance hardwired LED troffer kit with batwing distribution, set at 30W. Also include 8W dimming & Kelvin changing LED task light.	50,000+	60	0.50	120	67%	$57	$340	$18	$12	$400	$412	5.7	4.7	0.7	$245	$347	**$4,347**
				G2	Retrofit each troffer with high performance hardwired LED troffer kit with batwing distribution, set at 25W. Also include 2 8W dimming & Kelvin changing LED task lights.	50,000+	55	0.46	125	69%	$59	$420	$19	$12	$450	$462	6.8	5.6	0.8	$189	$291	**$4,791**
				GH	Retrofit each troffer with high performance dimming & Kelvin changing hardwired LED troffer kit with batwing distribution, set at 35W, so sufficient light at end of life.	50,000+	70	0.58	110	61%	$52	$370	$17	$12	$350	$362	6.8	5.5	0.9	$166	$270	**$3,770**
				GH1	Retrofit each troffer with high performance dimming & Kelvin changing hardwired LED troffer kit with batwing distribution, set at 30W. Also include 8W dimming & Kelvin changing LED task light.	50,000+	60	0.50	120	67%	$57	$440	$18	$12	$500	$512	7.4	6.1	0.7	$145	$247	**$5,247**
				GH2	Retrofit each troffer with high performance dimming & Kelvin changing hardwired LED troffer kit with batwing distribution, set at 25W. Also include 2 8W dimming & Kelvin changing LED task lights.	50,000+	55	0.46	125	69%	$59	$520	$19	$12	$550	$562	8.5	7.1	0.8	$89	$191	**$5,691**

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HUMAN CENTRIC LIGHTING WEBSITE, COMMITTEE, ETC.

HUMAN CENTRIC LIGHTING WEBSITE, COMMITTEE, ETC.

- Please check out the Human Centric Lighting website
  - Lots of good and free information
  - Some of the committee presentations are available to the public
  - http://humancentriclighting.com/

HUMAN CENTRIC LIGHTING WEBSITE, COMMITTEE, ETC.

- Human Centric Lighting Committee
  - Officers
    - Chair is Stan Walerczyk
    - Vice Chair is Mike Lambert
    - Executive Director is John Hwang
  - Researchers include
    - Dr. Steve Lockley at Harvard School of Medicine, Dr. Joan Roberts at Fordham University, Dr. Venkat Venkataramanan at Institute for Optical Sciences at University of Toronto, Dr. Michael Mott at University of Mississippi, Dr. Doug Steel at PhotoKinetics, Dr. Josep Carreras at Catalonia Institute for Energy Research in Spain and Dr. Marjukka Puolakka at Aalto University in Finland
  - Manufacturers include
    - Lumenetix, Osram Sylvania, Philips, PlanLED and Telelumen
  - Specialists, lighting designers, consultants, contractors, ESCOs, utility people and others include
    - Eunice Noell-Waggoner, Robert Dupuy, Rosalyn Cama, Brian Liebel, Doug Steel, Milena Simeonova, Rod Heller, Connie Samla, Mark Whitney, Jeremy Spaulding, Rachelle Nono Winningham, Jeff Hirsch and numerous others

HUMAN CENTRIC LIGHTING WEBSITE, COMMITTEE, ETC.

- Human Centric Lighting Professional (HCLP)
  - Need to have CLEP, LC, LEED AP or another good certification first
  - It is so important not to have botched projects, which could give HCL a black eye
- Human Centric Lighting Approved Products
  - Need to DLC, Energy Star or Lighting Design Lab approved first
  - Then will need certain requirements for
    - Dimming
      - With no or limited flicker
    - Kelvin changing
    - R9
    - S/P ratios
      - Especially since IES recently approved TM-24, which is on spectrally enhanced lighting

HUMAN CENTRIC LIGHTING CASE STUDIES

hopefully we can get some in this area

IF WE HAVE TIME, WE CAN DISCUSS THE HALF LIFE OF CAFFEINE

THAT'S ALL FOLKS

- Questions
- Please fill out any evaluation forms
- Contact information
  - 808-344-9685
  - stan@lightingwizards.com
  - www.lightingwizards.com

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Maui sunset