

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► As each slide is presented, try to consciously think about how its color tone and brightness affect you.

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► Is an (the?) ultimate goal to provide lighting that mimics the temporal qualities of daylighting?

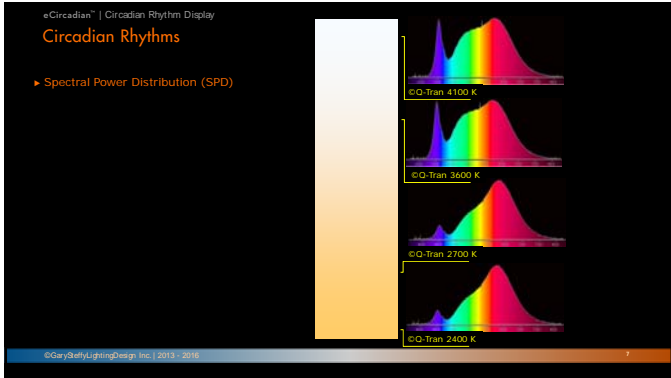
©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► Correlated Color Temperature (CCT)

©GaryBettyLightingDesign, Inc. | 2013 - 2016



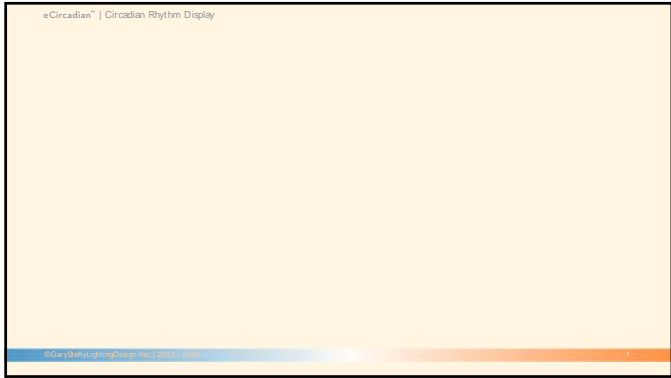
eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

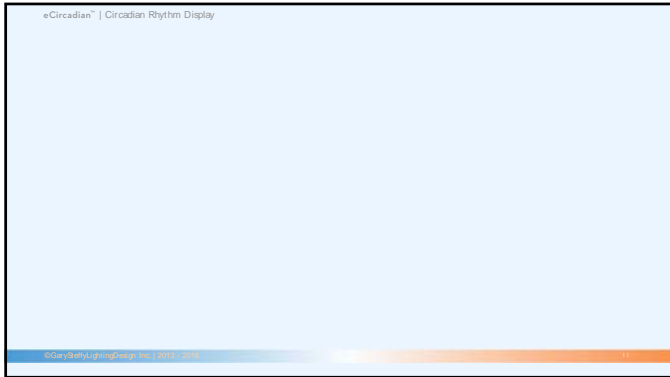
► Circadian Rhythms

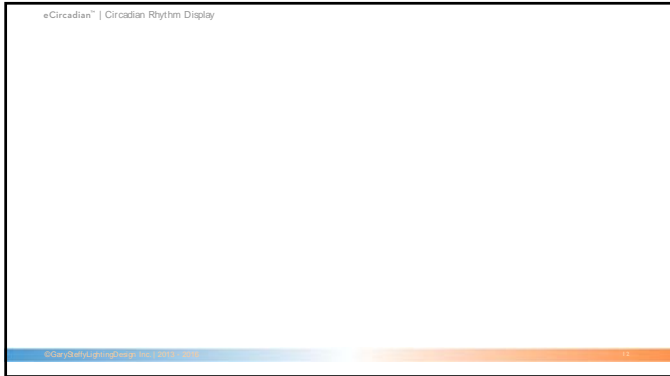
- Natural internal regulator of sleep/wake cycle
- Cycling on roughly a 24-hour period varies by individual
 - Sleep desire typically strongest at 1 to 3 p.m. and at 2 to 4 a.m.
- Controlled by area of brain responding to **light**

©GaryBettyLightingDesign, Inc. | 2013 - 2016



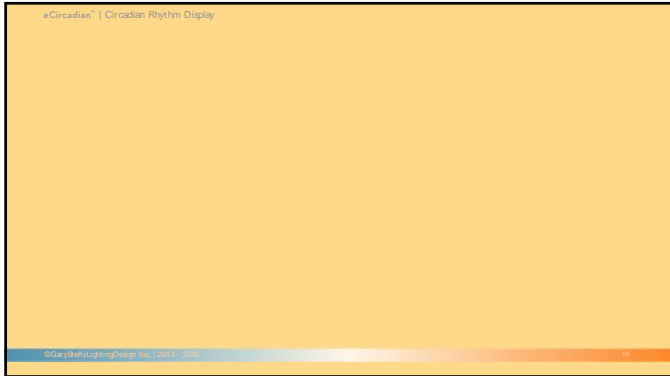


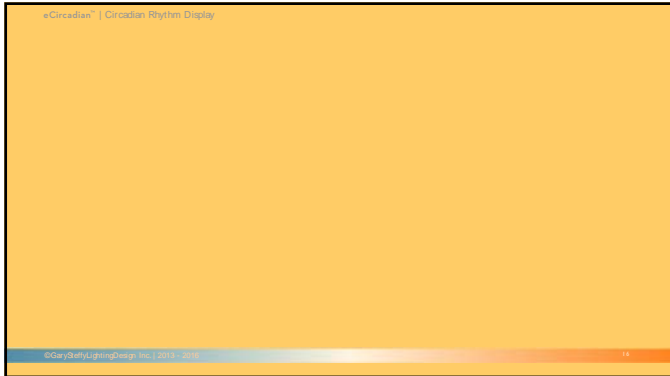


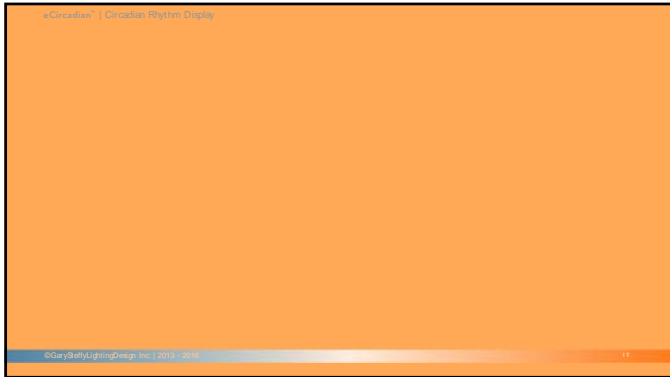




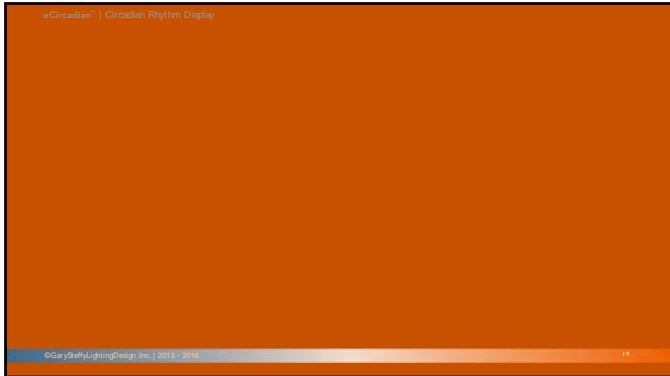


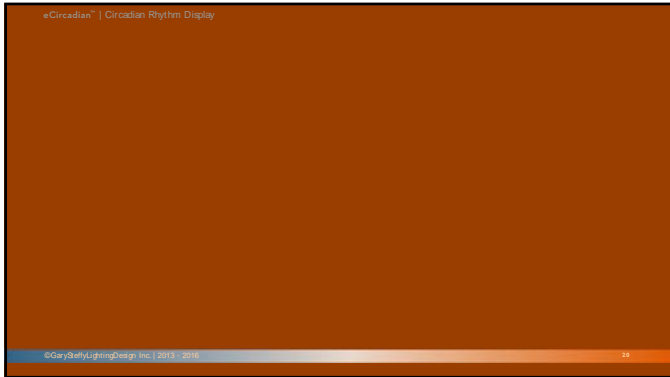


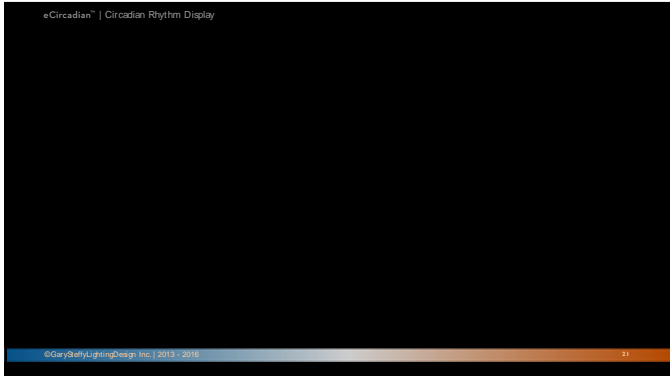












eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► **Why Now**

- Research converges on lighting's influence on circadian rhythms and health and wellbeing consequences

©GaryBettyLightingDesign, Inc. | 2013 - 2016 12

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► **Why Now**

- Research converges on lighting's influence on circadian rhythms and health and wellbeing consequences
- Emergence of low-cost commercial-grade potent light emitting diodes
 - Brighter
 - Blue "baseline" SPD
 - High efficacy

©GaryBettyLightingDesign, Inc. | 2013 - 2016 13

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► **Why Now**

- Research converges on lighting's influence on circadian rhythms and health and wellbeing consequences
- Emergence of low-cost commercial-grade potent light emitting diodes
 - Brighter
 - Blue "baseline" SPD
 - High efficacy
- Emergence of lower-cost digital controls

©GaryBettyLightingDesign, Inc. | 2013 - 2016 14

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► **Why Now**

- Research converges on lighting's influence on circadian rhythms and health and wellbeing consequences
- Emergence of low-cost commercial-grade potent light emitting diodes
 - Brighter
 - Blue "baseline" SPD
 - High efficacy
- Emergence of lower-cost digital controls
- **Surge in uses of backlit device displays**
 - Brighter
 - Larger

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► **Why Now**

- Research converges on lighting's influence on circadian rhythms and health and wellbeing consequences
- Emergence of low-cost commercial-grade potent light emitting diodes
 - Brighter
 - Blue "baseline" SPD
 - High efficacy
- Emergence of lower-cost digital controls
- Surge in uses of backlit device displays
 - Brighter
 - Larger
- **Negative health implications for people exposed to backlit device displays and lighting in the built environment appear to be serious and escalating**

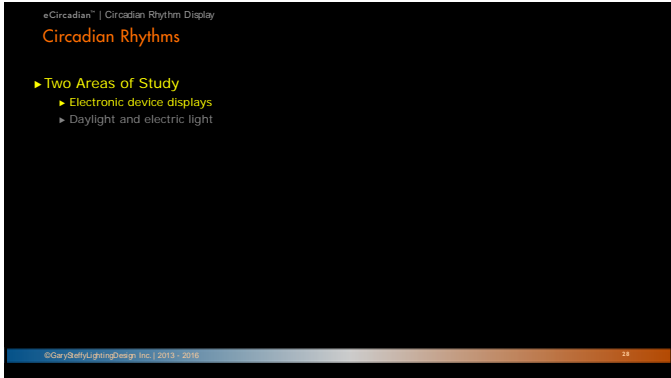
©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

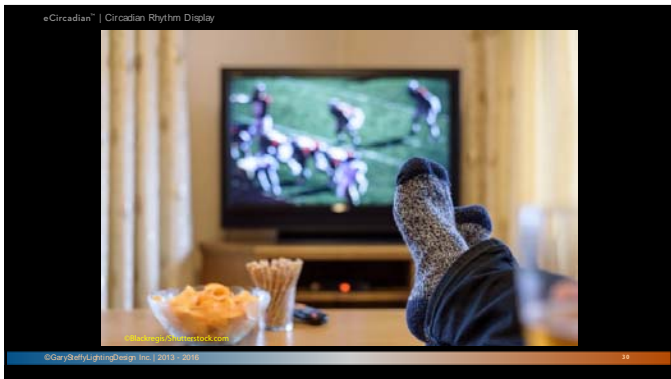
Circadian Rhythms

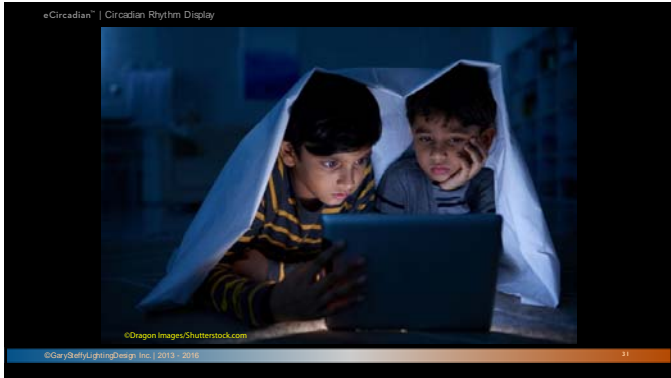
► **Time to Recalibrate How, When, and What Light is Dispensed**

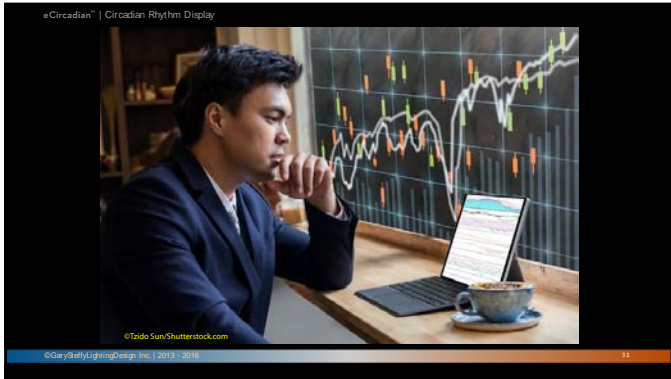
©GaryBettyLightingDesign, Inc. | 2013 - 2016

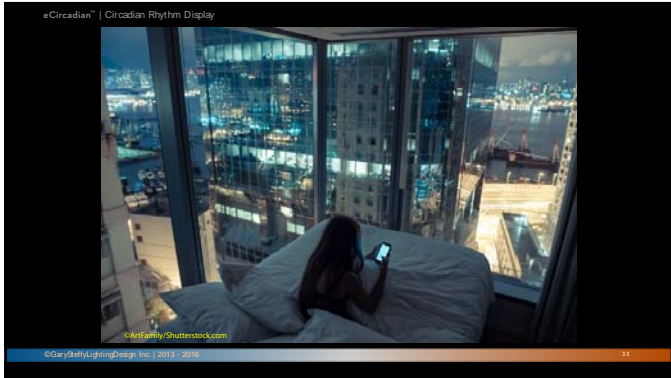


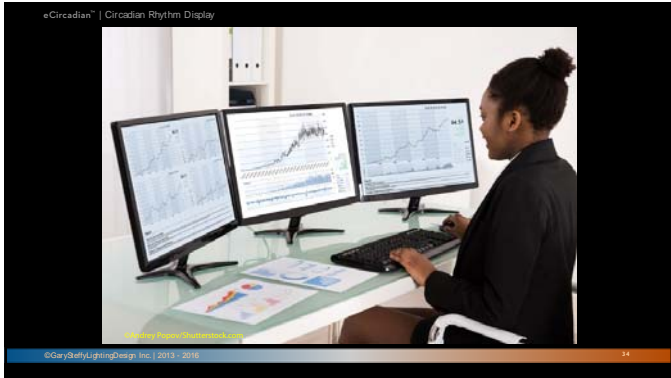


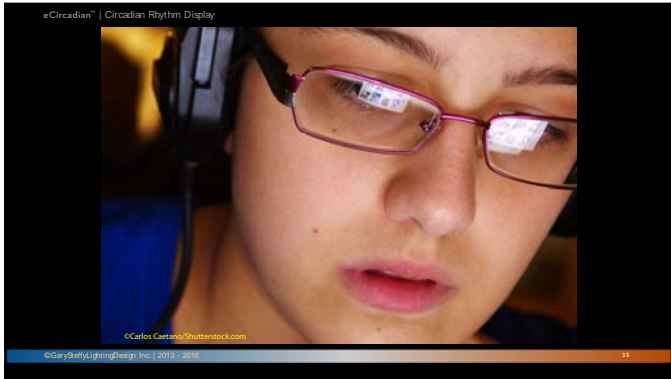


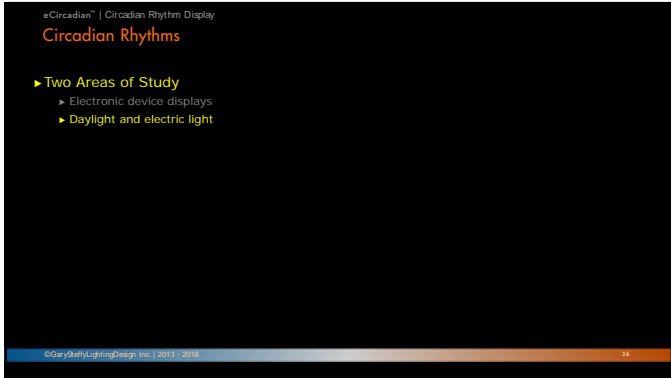


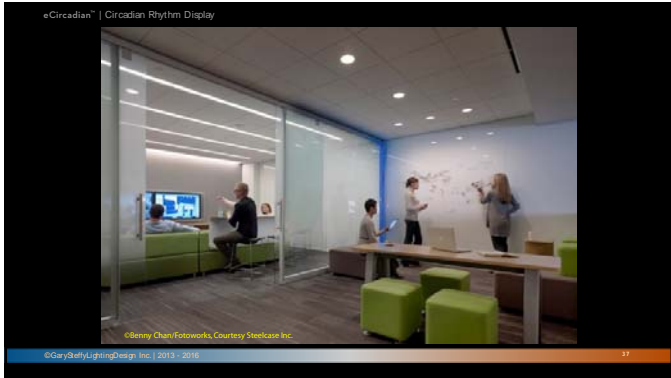


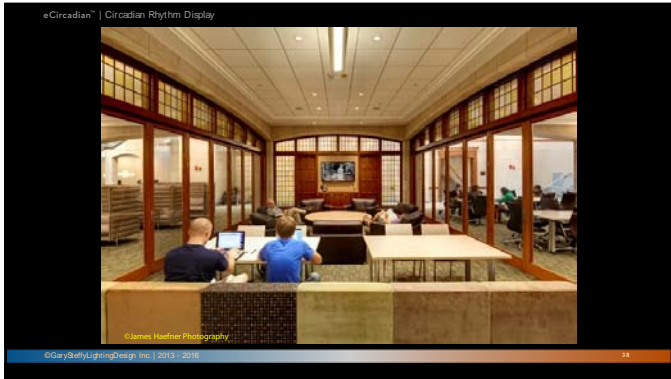


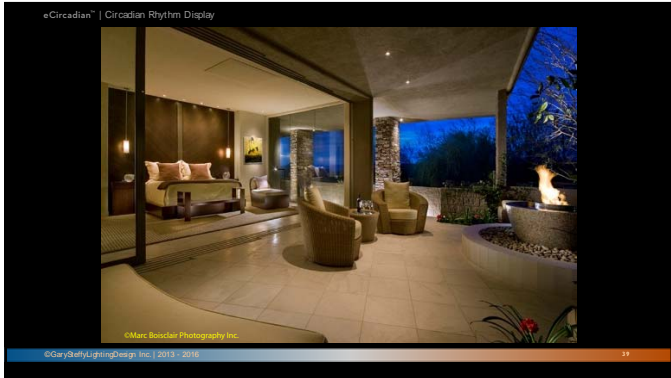


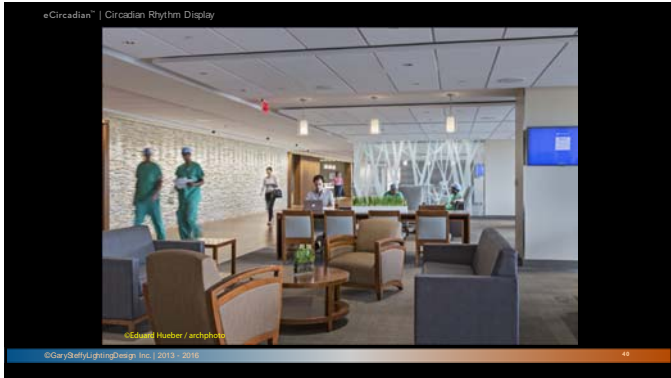


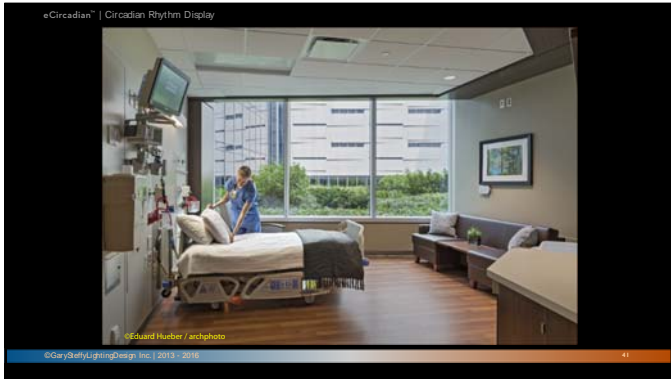


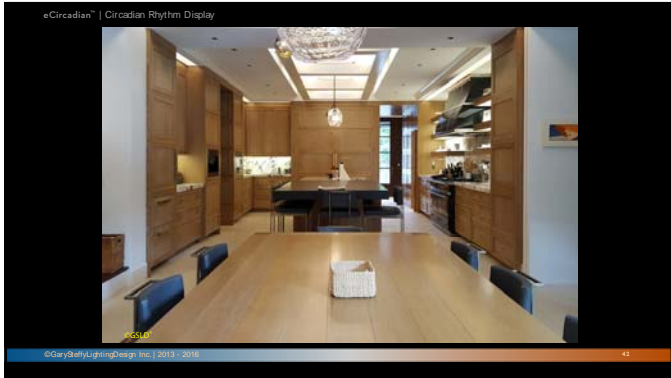


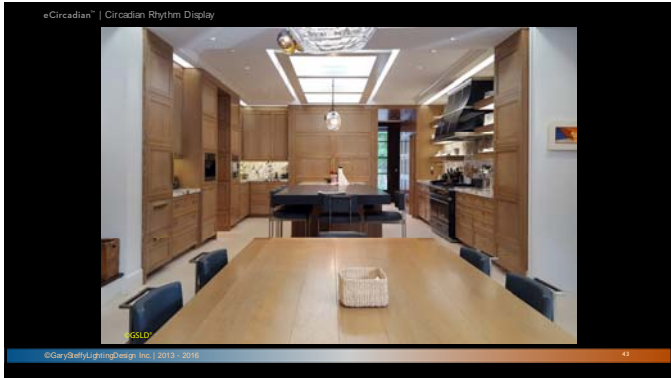


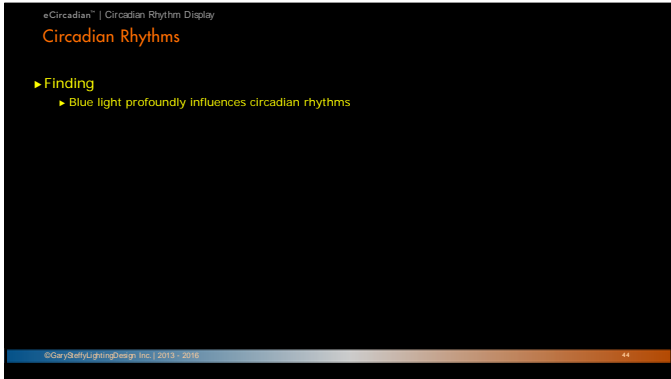


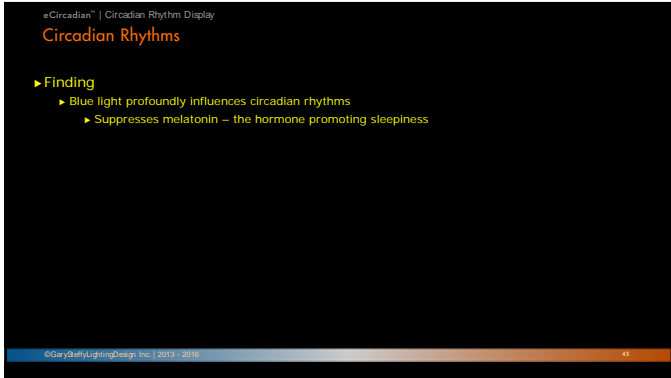












eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

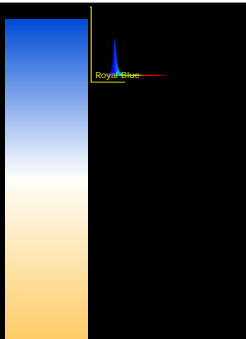
- ▶ Finding
 - ▶ Blue light profoundly influences circadian rhythms
 - ▶ Suppresses melatonin – the hormone promoting sleepiness
 - ▶ Relatively significant variables:
 - ▶ Timing
 - ▶ Good
 - ▶ Wake-up to mid-to-late afternoon
 - ▶ Bad
 - ▶ Mid-to-late afternoon to wake-up
 - ▶ Duration
 - ▶ Age
 - ▶ Young
 - ▶ Elderly

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Blue Light
 - ▶ Monochromatic
 - ▶ Narrow-band of visible spectrum
 - ▶ 440 to 480 nm exclusively (looks blue)

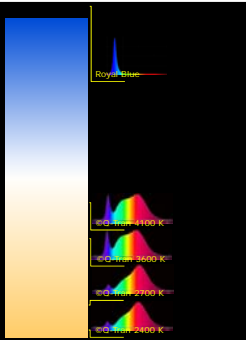


©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Blue Light
 - ▶ Monochromatic
 - ▶ Narrow-band of visible spectrum
 - ▶ 440 to 480 nm exclusively (looks blue)
 - ▶ Polychromatic
 - ▶ Broad-band of visible spectrum
 - ▶ 440 to 480 nm inclusively (looks "white")




©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Blue Light
 - ▶ Beneficial
 - ▶ Wake-up through mid afternoon




©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Blue Light
 - ▶ Beneficial
 - ▶ Wake-up through mid afternoon
 - ▶ Detrimental
 - ▶ Mid-to-late afternoon through wake-up




©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Blue Light
 - ▶ Beneficial
 - ▶ Wake-up through mid afternoon
 - ▶ Detrimental
 - ▶ Mid-to-late afternoon through wake-up
 - ▶ Extends wake time



©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ **Blue Light**
 - ▶ Beneficial
 - ▶ Wake-up through mid afternoon
 - ▶ Detrimental
 - ▶ Mid-to-late afternoon through wake-up
 - ▶ Extends wake time
 - ▶ Manifests sleeplessness




©GaryBettyLightingDesign, Inc. | 2013 - 2016 12

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ **Blue Light**
 - ▶ Beneficial
 - ▶ Wake-up through mid afternoon
 - ▶ Detrimental
 - ▶ Mid-to-late afternoon through wake-up
 - ▶ Extends wake time
 - ▶ Manifests sleeplessness
 - ▶ Perpetuates ever-longer wake cycles/shorter sleep cycles




©GaryBettyLightingDesign, Inc. | 2013 - 2016 13

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ **Blue Light**
 - ▶ Beneficial
 - ▶ Wake-up through mid afternoon
 - ▶ Detrimental
 - ▶ Mid-to-late afternoon through wake-up
 - ▶ Extends wake time
 - ▶ Manifests sleeplessness
 - ▶ Perpetuates ever-longer wake cycles/shorter sleep cycles
 - ▶ Unhealthy



©GaryBettyLightingDesign, Inc. | 2013 - 2016 14

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ The Blue Appeal
 - ▶ Cool (hip, chic, modern, edgy, new)

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ The Blue Appeal
 - ▶ Cool (hip, chic, modern, edgy, new)
 - ▶ Cool (crisp, bright, dazzling, evocative of sky and water)

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ The Blue Appeal
 - ▶ Cool (hip, chic, modern, edgy, new)
 - ▶ Cool (crisp, bright, dazzling, evocative of sky and water)
 - ▶ Cheap

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ The Blue Appeal
 - ▶ Cool (hip, chic, modern, edgy, new)
 - ▶ Cool (crisp, bright, dazzling, evocative of sky and water)
 - ▶ Cheap
 - ▶ High efficacy

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ The Blue Problem
 - ▶ Ubiquitous

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ The Blue Problem
 - ▶ Ubiquitous
 - ▶ Electronic device displays
 - ▶ 5000 K to 6500 K common
 - ▶ Long-duration exposure morning to night
 - ▶ Field of focused, attentive view (Ev @eyes)

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ **The Blue Problem**
 - ▶ **Ubiquitous**
 - ▶ Electronic device displays
 - ▶ 5000 K to 6500 K common
 - ▶ Long-duration exposure morning to night
 - ▶ Field of focused, attentive view (Ev @eyes)
 - ▶ **Electric light**
 - ▶ 2700 K to 6000 K common
 - ▶ Potential long-duration exposure morning to night/night to morning
 - ▶ Potential field of focused, attentive view (Ev @eyes)

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ **The Blue Problem**
 - ▶ **Ubiquitous**
 - ▶ Electronic device displays
 - ▶ 5000 K to 6500 K common
 - ▶ Long-duration exposure morning to night
 - ▶ Field of focused, attentive view (Ev @eyes)
 - ▶ **Electric light**
 - ▶ 2700 K to 6000 K common
 - ▶ Potential long-duration exposure morning to night/night to morning
 - ▶ Potential field of focused, attentive view (Ev @eyes)
 - ▶ **Daylight**

©GaryBettyLightingDesign, Inc. | 2013 - 2016

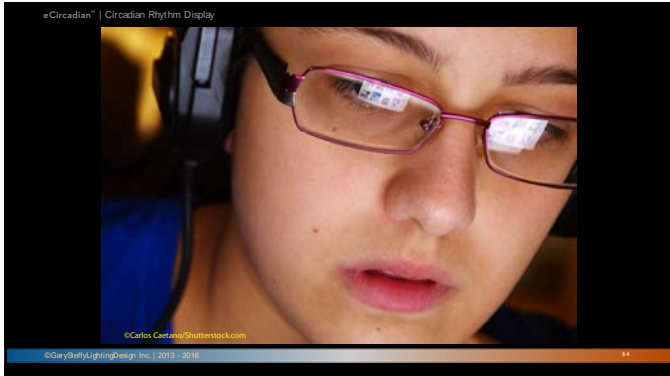
eCircadian™ | Circadian Rhythm Display

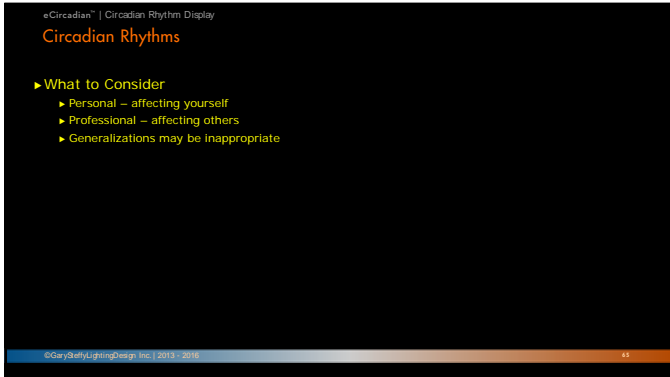
Circadian Rhythms

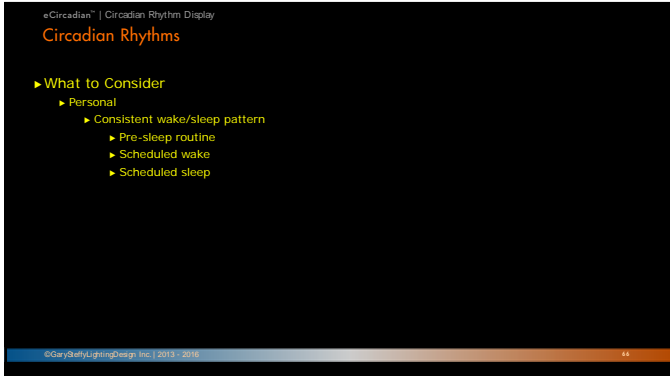
- ▶ **The Blue Problem**
 - ▶ **Ubiquitous**
 - ▶ Electronic device displays
 - ▶ 5000 K to 6500 K common
 - ▶ Long-duration exposure morning to night
 - ▶ Field of focused, attentive view (Ev @eyes)
 - ▶ **Electric light**
 - ▶ 2700 K to 6000 K common
 - ▶ Potential long-duration exposure morning to night/night to morning
 - ▶ Potential field of focused, attentive view (Ev @eyes)
 - ▶ **Daylight** (naturally entrains circadian rhythms)

[lowest] [Likelihood of Disruption (highest)]

©GaryBettyLightingDesign, Inc. | 2013 - 2016







eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► What to Consider

- Personal
 - Consistent wake/sleep pattern
 - Pre-sleep routine
 - Scheduled wake
 - Scheduled sleep
 - Sleep blackout
 - Blackout drapes
 - No display devices
 - 617 nm or 2200 K nightlighting

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► What to Consider

- Personal
 - Consistent wake/sleep pattern
 - Pre-sleep routine
 - Scheduled wake
 - Scheduled sleep
 - Sleep blackout
 - Blackout drapes
 - No display devices
 - 617 nm or 2200 K nightlighting
 - Light exposure during wake phase – regardless of instrument
 - SPD
 - Quantity
 - Duration
 - Timing

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► Entrainment

- Light Exposure
 - Device displays
 - Lighting

Circadian Phase	Wavelengths	Quantity	Duration	Timing
Wake	~380 – 780	High to moderate	Hours	Wake to ~3 p.m.
Late-wake to Pre-sleep	~550 – 780	Moderate to low	Hours	~3 p.m. to bed
Sleep	~617 if any	Zero	Hours	Bed to wake

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Entrainment
 - ▶ Blue's effect
 - ▶ Device displays
 - ▶ Lighting

Circadian Phase	Wavelengths	Blue's Effect	Duration	Timing
Wake	~380 – 780	Enchains	Hours	Morning
Late-wake to Pre-sleep	~550 – 780	Disrupts	Hour +	Evening
Sleep	~617 if any	Disrupts	Minutes	Bed – wake

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Disruptive
 - ▶ Pre-sleep
 - ▶ Sleep

©All-stock-photos/Shutterstock.com

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

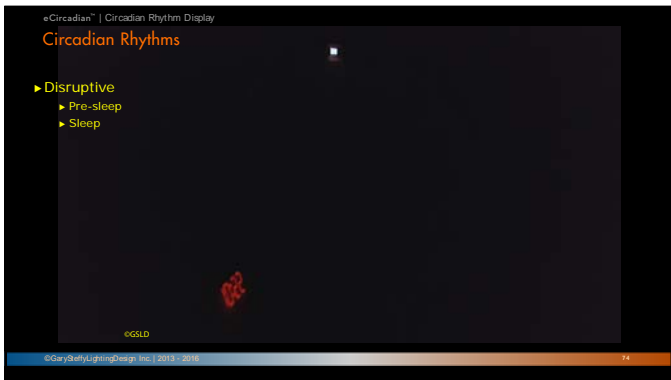
Circadian Rhythms

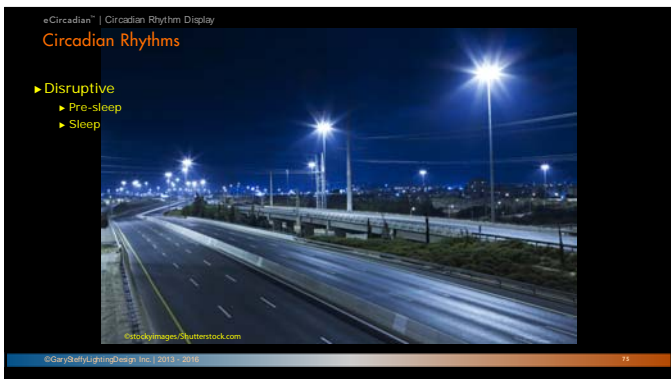
- ▶ Disruptive
 - ▶ Pre-sleep
 - ▶ Sleep

©kakaku/Shutterstock.com

©GaryBettyLightingDesign, Inc. | 2013 - 2016







eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ System permanence
 - ▶ Users' ages
 - ▶ Applications
 - ▶ Surrounding zones
 - ▶ Circadian footprint
 - ▶ Criteria

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ System permanence
 - ▶ LED endurance
 - ▶ Dedicated lamping
 - ▶ Long lamp life
 - ▶ L90, L80, L70
 - ▶ LLD implications
 - ▶ Initial costs
 - ▶ Discourage "throw-away" mentality
 - ▶ Increase replacement cycle

©GaryBettyLightingDesign, Inc. | 2013 - 2016

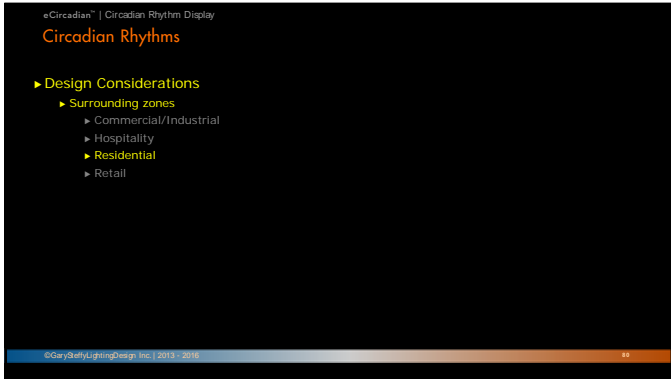
eCircadian™ | Circadian Rhythm Display

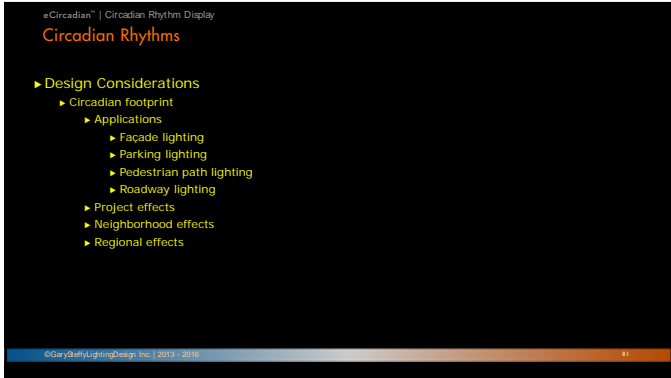
Circadian Rhythms

- ▶ Design Considerations
 - ▶ Users' ages
 - ▶ Now
 - ▶ Future

©GaryBettyLightingDesign, Inc. | 2013 - 2016







eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Illuminances
 - ▶ Luminances
 - ▶ Lamps
 - ▶ Controls
 - ▶ Products
 - ▶ Predictions

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Priorities
 - ▶ Rationale
 - ▶ Documentation

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Illuminances
 - ▶ Eh
 - ▶ Ev
 - ▶ EV at eyes

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Illuminances
 - ▶ Luminances
 - ▶ Reflectances
 - ▶ Surface Illuminances

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Illuminances
 - ▶ Luminances
 - ▶ Lamps
 - ▶ CCT
 - ▶ CRI
 - ▶ R9
 - ▶ SPD

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Illuminances
 - ▶ Luminances
 - ▶ Lamps
 - ▶ Controls
 - ▶ On/Off
 - ▶ Timed dimming
 - ▶ Continuous imperceptible dimming
 - ▶ Occupancy-sensed

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Illuminances
 - ▶ Luminances
 - ▶ Lamps
 - ▶ Controls
 - ▶ Products
 - ▶ Color qualities
 - ▶ Control protocols
 - ▶ Optical qualities

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Considerations
 - ▶ Criteria
 - ▶ Deliberate and careful selections
 - ▶ Illuminances
 - ▶ Luminances
 - ▶ Lamps
 - ▶ Controls
 - ▶ Products
 - ▶ Predictions
 - ▶ LLD
 - ▶ L90/L80/L70
 - ▶ LDD
 - ▶ Point-by-point analyses

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Strategies
 - ▶ Static
 - ▶ Dynamic

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Strategies
 - ▶ Static
 - ▶ Electric lighting/displays
 - ▶ Least disruptive throughout the duration of application?
 - ▶ 2700 K – 3000 K mid-afternoon to night?
 - ▶ CRI >90/R9 >60
 - ▶ Historic precedent for electric lighting
 - ▶ 4000 K – 6500 K morning to mid-afternoon?
 - ▶ Historic precedent for device displays
 - ▶ Glazing selection
 - ▶ Neutral?
 - ▶ Blue?
 - ▶ Dynamic

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ Design Strategies
 - ▶ Static
 - ▶ Dynamic
 - ▶ Electric lighting/displays
 - ▶ Cycle?
 - ▶ 3500 K – 6500 K – 3500 K morning to mid-afternoon?
 - ▶ CRI >90/R9 >60
 - ▶ Fade relatively dim to brightest to relatively dim
 - ▶ 3500 K – 2200 K mid-afternoon to bedtime?
 - ▶ Fade relatively dim to dimmest
 - ▶ Glazing selection
 - ▶ Neutral
 - ▶ Blue

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

- ▶ AMA Policy Statement
- ▶ American Academy of Pediatricians Suggestions

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► **AMA Policy Statement**

- A short-term detriment in sleep quality has been observed after exposure to short wavelength light before bedtime.
- Some evidence supports a long-term increase in the risk for cancer, diabetes, cardiovascular disease and obesity from chronic sleep disruption or shiftwork and associated with exposure to brighter light sources in the evening or night.
- Use 3000 K or lower CCT LED lighting for outdoor installations such as roadways.
- Consider dimming at off-peak time periods.

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

► **American Academy of Pediatricians Suggestions**


- Children and teens who spend more time with social media or who sleep with mobile devices in their rooms are at greater risk for sleep problems. Exposure to light (particularly blue light) and stimulating content from screens can delay or disrupt sleep, and have a negative effect on school.
- The AAP recommends keeping all screens—TVs, computers, phones, tablets—out of kids' bedrooms and turning all screens off 30 minutes before bedtime
- Dim the lights prior to bedtime.

©GaryBettyLightingDesign, Inc. | 2013 - 2016

eCircadian™ | Circadian Rhythm Display

► **circadian™ <25/Automated/Low Entrainment/Early Morning Start Sequence Example**

©GaryBettyLightingDesign, Inc. | 2013 - 2016



eCircadian™ | Circadian Rhythm Display

eCircadian™ -25/Automated/Low Entrainment/Morning Start Sequence Example

1200 pm on 10/31/2016

This is a morning start of an automated sequence. The video and photos illustrate the sequence of events in a virtual office space. The sequence starts with a dimly lit office space. The lights gradually increase in intensity, and the color temperature shifts from warm to cool. The sequence ends with a bright, clear office space.

©Gary/ReillyLightingDesign, Inc. | 2013 - 2016



eCircadian™ | Circadian Rhythm Display

eCircadian™ -25/Automated/Low Entrainment/Noon Start Sequence Example

1200 pm on 10/31/2016

This is a morning start of an automated sequence. The video and photos illustrate the sequence of events in a virtual office space. The sequence starts with a dimly lit office space. The lights gradually increase in intensity, and the color temperature shifts from warm to cool. The sequence ends with a bright, clear office space.

©Gary/ReillyLightingDesign, Inc. | 2013 - 2016



eCircadian™ | Circadian Rhythm Display

eCircadian™ -25/Automated/Low Entrainment/Mid Afternoon Start Sequence Example

1200 pm on 10/31/2016

This is a morning start of an automated sequence. The video and photos illustrate the sequence of events in a virtual office space. The sequence starts with a dimly lit office space. The lights gradually increase in intensity, and the color temperature shifts from warm to cool. The sequence ends with a bright, clear office space.

©Gary/ReillyLightingDesign, Inc. | 2013 - 2016



eCircadian™ | Circadian Rhythm Display

eCircadian™ -25/Automated/Low Entrainment/Night Start Sequence Example

143

eCircadian™ | Circadian Rhythm Display

eCircadian™ -25/Automated/Low Entrainment/Nightlight (manual selection) Example

144

eCircadian™ | Circadian Rhythm Display

Circadian Rhythms

Recent Examples

- State parking lot
 - 2700K/80 + CRI
 - Eh = 0.4 min
- Commercial parking lot
 - 2700K/90 + CRI
 - Eh = 0.4 min
- University campus pedestrian paths (distant from roadways)
 - 2200K/80 + CRI
 - Eh = 0.5 avg and 5:1 avg-to-min uniformity
 - Ev = 0.5 avg @standing face height and 5:1 avg-to-min uniformity

145

