LIGHT BEYOND VISION

AND ITS IMPACT ON HUMAN HEALTH

Light Beyond Vision

The science proven lighting solution that enables people to artificially illuminate places of work and rest while enhancing our biological response to our circadian cycle.

melagen®

Versalux

This brochure takes you through the reasons behind the MelaGen® initiative, and the research and science presented at the Alertness CRC Light Beyond Vision Roadshow, which underpins its development.

MONASH University

CRC ALERTNESS SAFETY AND PRODUCTIVITY

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Program

Contents

THE CIRCADIAN RHYTHM

Since the beginning of mankind, our species has existed in a natural lighting environment cycle between brightness and darkness as the Earth spins.

This 24-hour cycle programmed our body's internal clock that we call the Circadian Rhythm. Different systems of the body follow circadian rhythms that are synchronised with a master clock in the brain. The biggest impact to the body's master clock is the presence and absence of daylight, which is why our circadian rhythms are tied to the cycle of day and night.

Through the invention of artificial lighting (from fires, candles, oil & gas lamps, through to luminaires powered by electricity) humans have been able to control how long we stay awake for, which in turn manipulates this circadian rhythm. When this circadian rhythm is altered, it can disrupt our sleep / wake cycle, resulting in a wide range of physical and mental health problems.

MelaGen® is the result of focused scientific research into the impact of artificial lighting on our bodies; MelaGen® powered luminaires are designed to allow humans to enjoy the benefits of a more natural and healthy circadian rhythm whilst still providing the artificial light required in our modern world.

Led by the CRC for Alertness, Safety and Productivity (Alertness CRC), in partnership with Monash University and Versalux Lighting Systems, extensive feasibility studies and a review of the latest state-of-the-art scientific literature enabled the development of product specifications and guidance for the application of alertness promoting and sleep permissive/promoting capability into a single lighting fixture.

This innovative lighting initiative, known as MelaGen®, can be used in several industries to heighten alertness and improve sleep quality. The system has three variants for this purpose:

1. MelaGen® Blue luminaires, featuring specialised blue enriched LED chips with alertness promoting capability;

2. MelaGen® ReFresh luminaires, featuring specialised blue-depleted LED chips for sleep permissive/promoting capability; and

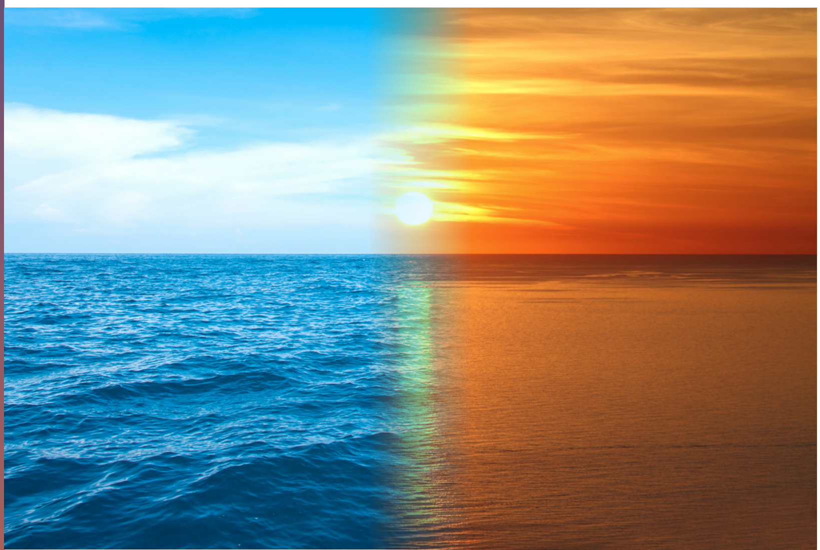
3. MelaGen® ReGen luminaires, featuring a combination of both MelaGen® Blue and MelaGen® ReFresh LED chips. This allows for transitions between alertness promoting and sleep promoting capability to suit environments commonly found in hospitality, military, healthcare, aged care, and correctional facilities.

melagen®

MelaGen® Blue for Alertness
30% more blue light

- Blue-Enriched LED chips
- High M/P ratio of 0.90
- CCT 4200K
- CRI Ra90

MelaGen® ReGen



- Combination of both MelaGen® Blue and MelaGen® ReFresh LED chips
- Transitions between 0.35-0.90 M/P ratios
- CCT 2200K-4200K
- CRI Ra90

MelaGen® ReFresh for Deeper Sleep
60% less blue light

- Blue-Depleted LED chips
- Low M/P ratio of 0.35
- CCT 2200K
- CRI Ra90

Associate Professor Clare Anderson

Clare Anderson was a Theme Leader with the Alertness CRC, and is an Associate Professor and sleep and circadian specialist at the Turner Institute for Brain and Mental Health at Monash University. Her research is focussed on the contribution of sleep and circadian timing on alertness and cognitive function, and the development of targeted sleep and circadian strategies to maximise alertness, enhance cognitive health, and promote occupational safety and productivity.

A/Prof Clare Anderson presented this research at the 2019 Alertness CRC Light Beyond Vision roadshow.

The **total cost of inadequate sleep** in Australia was estimated to be **$66.3 billion** in 2016-17

Being awake continuously for 21-24 hours is comparable to performance at a **blood alcohol level twice the legal driving limit**

There's almost **double the prevalence of type 2 diabetes in rotating shift workers,** as well as increased insulin resistance

It is estimated that inadequate sleep contributes to **23% of total motor vehicle accidents.**

FINANCIAL AND HEALTH COSTS

The direct cost of treating sleep disorders are small in comparison to the costs of treating the conditions associated with inadequate sleep. In 2016-17, in Australia, these costs were estimated to be:

- health system costs of $1.8 billion, or $246 per person with inadequate sleep;
- productivity losses of $17.9 billion, or $2,418 per person with inadequate sleep;
- informal care costs of $0.6 billion, or $82 per person with inadequate sleep; and
- other financial costs, including deadweight losses, of $5.9 billion, or $802 per person with inadequate sleep.[1]

In addition to financial costs, inadequate sleep was shown to reduce overall health, which can be measured using disability adjusted life years (DALY's). In 2016-17, it was estimated that, in Australia, there was $40.1 billion in the loss of wellbeing.[1]

The total cost of inadequate sleep in Australia was estimated to be $66.3 billion in 2016-17 – approximately $8,968 per person affected in both financial and wellbeing costs.[1]

CAR ACCIDENTS

- It is estimated that inadequate sleep contributes to 23% of total motor vehicle accidents.
- Furthermore, just over one Australian each day will die from falling asleep at the wheel of a vehicle or from industrial accidents due to a lack of sleep.
- People can experience increased distractibility and difficulties staying in lane when driving drowsy.[2]
- Drivers who sleep <4 hours are 11 times more likely to crash than drivers who slept 7 hours.[1]

ALERTNESS AND ATTENTION WHEN SLEEP DEPRIVED

- Repeated nights of inadequate sleep lead to attention failures.[3]
- Being awake continuously for 21-24 hours is comparable to performance at a blood alcohol level of 0.08-0.1, twice the legal driving limit.[4]
- Sleep restriction increases distractibility and also compounds attention failures when distracted.[5]

EXECUTIVE FUNCTION WHEN SLEEP DEPRIVED

- Sleep restriction increases impulsive and inappropriate responses to negative situations.[6]
- Sleep loss impairs inhibitory control.[7]
- Working memory capacity is reduced during sleep restriction.[8]
- Cognitive flexibility to switch between goal-oriented tasks is impaired during sleep deprivation.[9]

EMOTIONAL REGULATION WHEN SLEEP DEPRIVED

- Sleep deprivation reduces trust, and increases selfish behaviour during social exchanges.[5]
- During sleep restriction there is a reduced functional connectivity between the emotion regulation centre and emotion processing centre, leading to enhanced reactivity to negative stimuli.[10]

MICROSLEEPS

- Involuntary brief short episodes (3-15 seconds) where the brain enters a sleep state.[11]

HEALTH, SHIFT WORK, AND SLEEP DEPRIVATION

- Almost double the prevalence of Type 2 diabetes is found in rotating shift workers, as well as increased insulin resistance.[12]
- There is an increased risk of cancer in long-term night workers and shift workers.[13]
- Shift work is associated with poorer mental health.[14]

Dr Andrew Phillips

Dr Andrew Phillips is a Senior Lecturer in the Turner Institute for Brain and Mental Health at Monash University. He has made fundamental discoveries about the human circadian system, including the existence of large differences in light sensitivity between individuals.

He has developed computational models for predicting an individual's circadian timing and their sleep/wake patterns. He has also developed metrics for quantifying healthy rhythms.

Dr Andrew Philips helped to collate this research for the 2019 Alertness CRC Light Beyond Vision Roadshow.

SENSITIVITY TO LIGHT

- Sensitivity to light varies according to age[15], sex[16], and genotype.[17]
- Individual differences in light sensitivity cover a greater than 50 fold range.[18]

Abnormal response of the circadian system to light

- Increased sensitivity of the circadian system to light is associated with:
  - Delayed sleep, leading to chronic sleep restriction and daytime dysfunction (delayed sleep-wake phase disorder; DSWPD)[19]; and
  - Bipolar disorder.[20]
- Decreased sensitivity of the circadian system to light is associated with:
  - Seasonal affective disorder[17]; and
  - Major depressive disorder.[21]

Pharmacologically altering light sensitivity

- The mood stabilising medication lithium (used to treat bipolar disorder) appears to decrease the sensitivity of the circadian system to light.[22]
- Conversely, selective serotonin reuptake inibitors (SSRIs) appear to increase the sensitivity of the circadian system to light.[23]

LIGHT QUALITIES AND THE EFFECT ON THE CIRCADIAN SYSTEM

- The effect that light has on the circadian system depends on the brightness, with brighter light eliciting a greater physiological response.[24]
- Additionally, the circadian system is most responsive to short wavelength (~480nm) blue light.[25]

DAYTIME LIGHT, COGNITION AND MOOD

- Blue-enriched lighting enhances processing speed and concentration.[26, 27]
- In the workplace (for daytime workers), daytime blue-enriched light can increase subjective alertness, increase concentration, enhance positive mood, increase performance, reduce fatigue, and the subjective quality of subsequent sleep.[28, 29]

LIGHT AND PHYSIOLOGICAL FUNCTION

- Evening blue-enriched light, such as light emitting digital devices, appears to delay sleep onset, can reduce or delay the onset of rapid eye movement (REM) sleep, and suppresses slow-wave sleep.[30]
- Bright daytime blue-enriched light can enhance the immunological response and reduce organ injury during an infection.[31]

Associate Professor Sean Cain

Sean W Cain is a circadian biologist with over 20 years of experience in the field. He is an Associate Professor at the Turner Institute for Brain and Mental Health at Monash University. He is the current President of the Australasian Chronobiology Society, the only circadian rhythms research society in the region. He worked in basic animal models of circadian rhythms at the University of Toronto for his PhD and in human circadian rhythms at Harvard Medical School.

His research focuses on the effects of light on the human circadian system and how our modern light environments and light-related behaviours affect our health.

Associate Professor Sean Cain presented this research at the 2019 Alertness CRC Light Beyond Vision roadshow.

EVOLUTION AND ADAPTATION

- Organisms responsive to light patterns can be traced as far back as ~2.5 billion years ago.[32]
- All organisms contain an internal timekeeper regulated by a cycling gene expression.[33]
- We call this circadian rhythms, which results in changes in physiology and behaviour over a 24-hour period.[34]
- To align specific biological functions to night and day¨ the circadian system continually uses light cues to synchronise the clock to external light-dark cycles.[35]
- Light input is transmitted to the circadian system via intrinsically photosensitive retinal ganglion cells (ipRGCs) and to a lesser extent rods and cones (the retinal cells responsive for vision).[36]
- IpRGCs contain a photopigment melanopsin, which has a peak spectral sensitivity to short wavelength (~480nm) blue light.[37]

CIRCADIAN RHYTHMS

- The ability to continually synchronise our biological clocks allows us to adjust to changes in light such as when moving to a new time-zone or moving to a new season.
- The effect that light has on the body clock depends on the timing of exposure[38]. Light delivered in the evening can delay the timing of our rhythms, shifting the times when we feel awake and tired later on subsequent days. Conversely, light delivered in the morning can advance our rhythms, resulting in us feeling awake and tired earlier on subsequent days.
- Although the effect of light on the circadian system is adaptive, it is hazardous in a modern industrial world where we can experience perpetual light[39]. Natural lighting has a consistent pattern, with high levels of blue light during the daytime, and low levels of light during the night. Conversely, being indoors during the day can result in a weaker daytime light signal, while the use of electronic devices and artificial light at night reduces the darkness signal. Together, the overall weak signal of day and night cycles to the circadian system can result in a disturbance of biological timing (circadian disruption).

CONSEQUENCES OF CIRCADIAN DISRUPTION

- Artificial light at night can delay our circadian timing, making it difficult to sleep until later at night. Compounding this effect is that blue light suppresses the sleep promoting hormone melatonin in humans, which further perpetuates difficulty sleeping.[40]
- Long-term exposure to sleep deprivation and circadian disruption such as shift work can increase risk of:
  - Rectal cancer [41];
  - Cardiovascular disease [42]; and
  - Metabolic conditions like diabetes.[43]

Organisms responsive to light patterns can be traced as far back as ~2.5 billion years ago

Using melatonin suppression as a proxy to relate outcomes, the following key outcomes have been extracted from the published literature.

Photopic Lux (vertical light)	M/P Ratio	Melanopic Lux (blue light)	Melatonin Delay (Minutes)	Reduction in Slow-Wave Sleep (1st Cycle)
80	0.6	48	39	10%*
160	0.6	96	46	22%*
300	0.6	180	56	32%*

**This table shows the impact of blue light at M/P of 0.6 on slow-wave sleep and melatonin release, when compared to an M/P of 0.35*

SLOW-WAVE SLEEP:

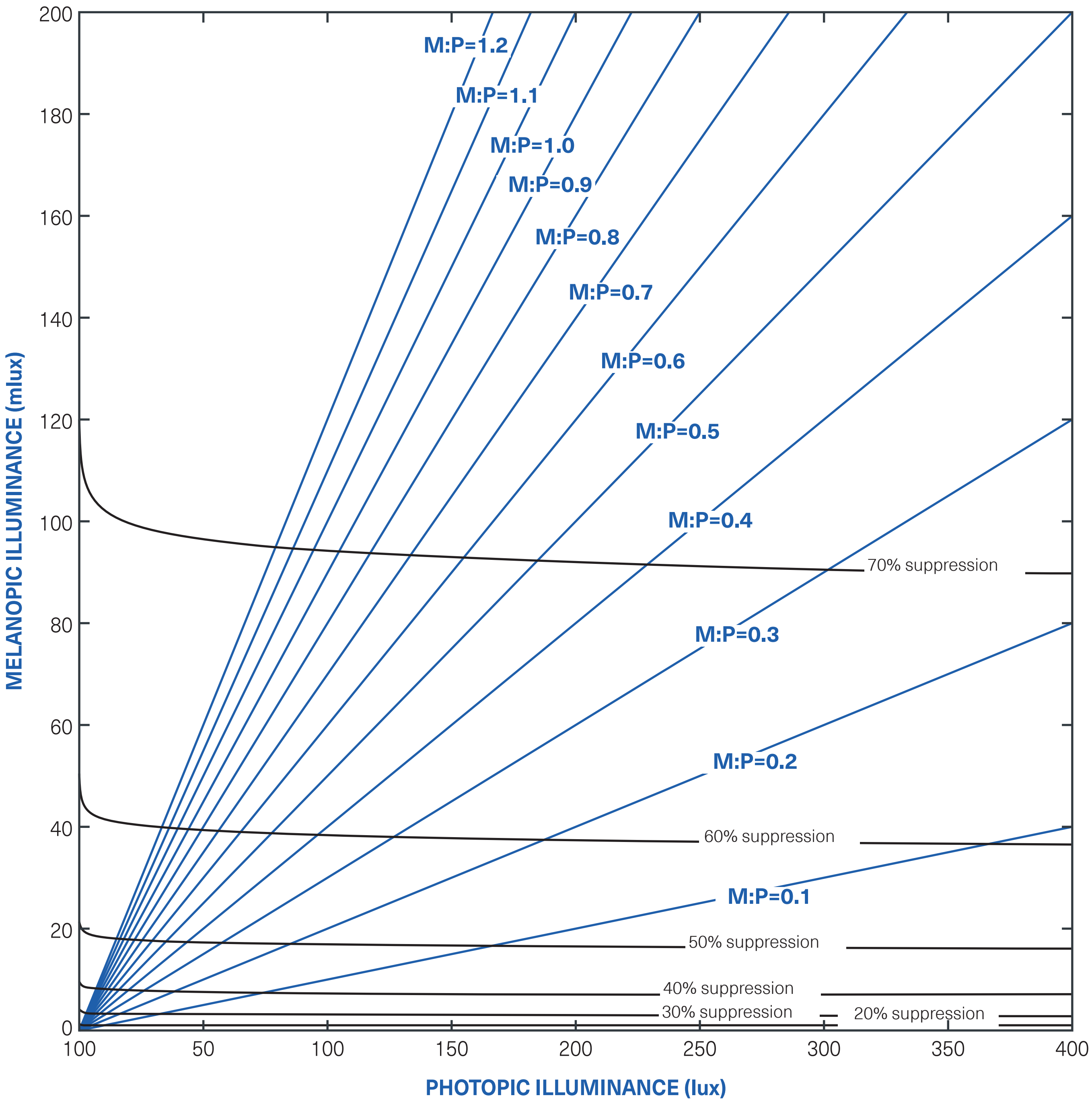
- Slow-wave sleep is the principal marker of sleep depth and restorative value of sleep.
- The amount of slow-wave sleep is highest early in the night.
- Evening exposure to blue-enriched light before bed decreases the amount of slow-wave activity.
- Based on published data[44], it is estimated that exposure in a hospital bed to 300 lux at a typical M/P of 0.6 would reduce slow-wave sleep by 32%, compared to 300 lux at an M/P of 0.35.

TIME OF MELATONIN RISE:

- The rise of melatonin signals the beginning of the biological night, as the body readies itself for sleep.
- Evening exposure to light causes the rise of melatonin to occur later.
- Based on published data[18], it is estimated that exposure in a typical hospital bedroom, the rise of melatonin in the evening would occur 56 minutes later when exposed to 300 lux at a typical at M/P of 0.6, compared to an M/P of 0.35.

For a given brightness, the amount of melanopsin-activating light (blue light) determines the effect of light on the circadian system. When modelling the effects of the amount of "melanopic" illuminance at a given visual brightness (M/P), it is shown that at lower M/P values, lights can be visually brighter while having less of an impact on melatonin levels.

For example, at an M/P of 0.3, lights can be at 300 photopic lux before suppressing melatonin by 70%. It only takes 150 photopic lux at an M/P of 0.6 (typical lights) to reach that level of suppression.



The blue curves correspond to different melanopic-to-photopic (M/P) ratios, ranging from 0.1 to 1.2.

LIGHT SCHEDULING BASED ON FINDINGS

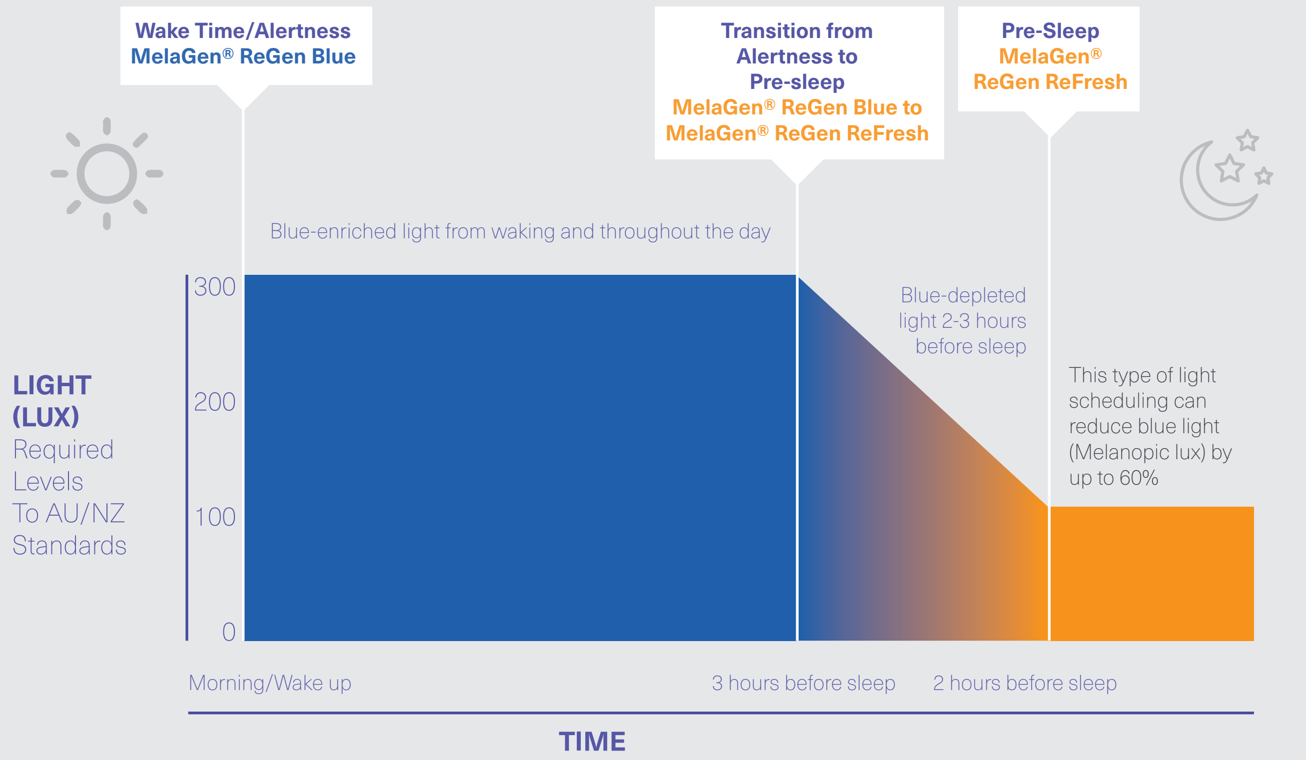
BEDROOMS AND PRE-SLEEP

The rise of melatonin signals night for the body and promotes sleep. In a healthy sleeper, the onset of melatonin is ~2-3 hours before typical bedtime.

Blue light suppresses the natural onset of melatonin. Blue-depleted light has far less of an effect on melatonin, thus allowing for room-level light to have less of a negative effect on melatonin, our clocks and sleep quality. To avoid disrupting melatonin, low-level blue-depleted light should be used 2-3 hours before bed.

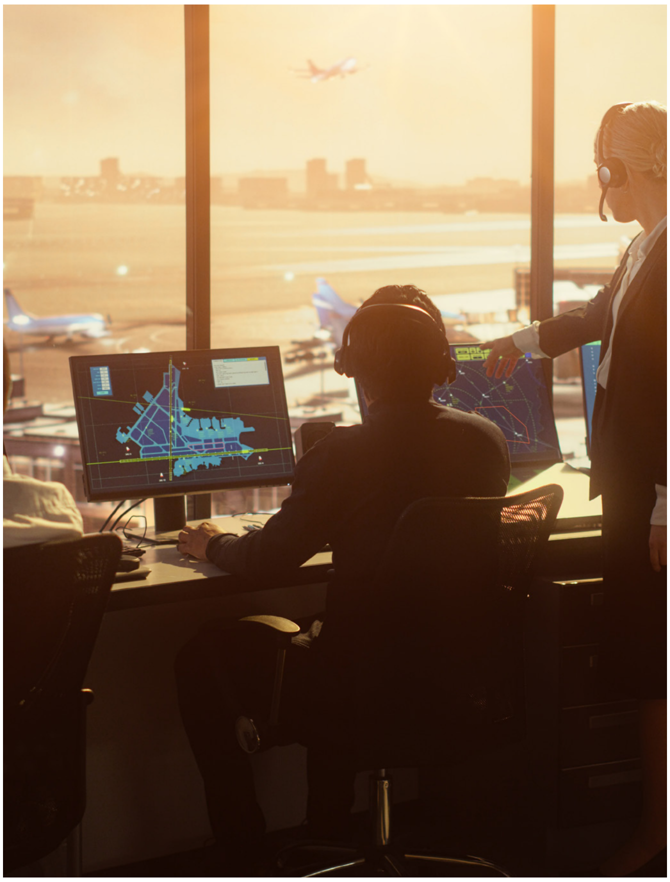
LIGHT SCHEDULING FOR BEDROOMS

For hospital, mental health, aged care, correctional, emergency service, and military bedrooms, blue-enriched light (a high M/P ratio) is ideal during the day, as it allows room-level light to have the highest circadian effect, producing greater alertness. To induce calmness and avoid disrupting melatonin, the blue-enriched light should transition 2-3 hours before sleep to low-level blue-depleted light.



Our circadian clocks expect bright light in the day and darkness at night. Modulating the amount of melanopsin-activating light can help produce better day/night signals for patients, military personnel, inmates, and staff on a standard working roster.

LIGHT SCHEDULING BASED ON FINDINGS



LIGHT SCHEDULING BASED ON FINDINGS

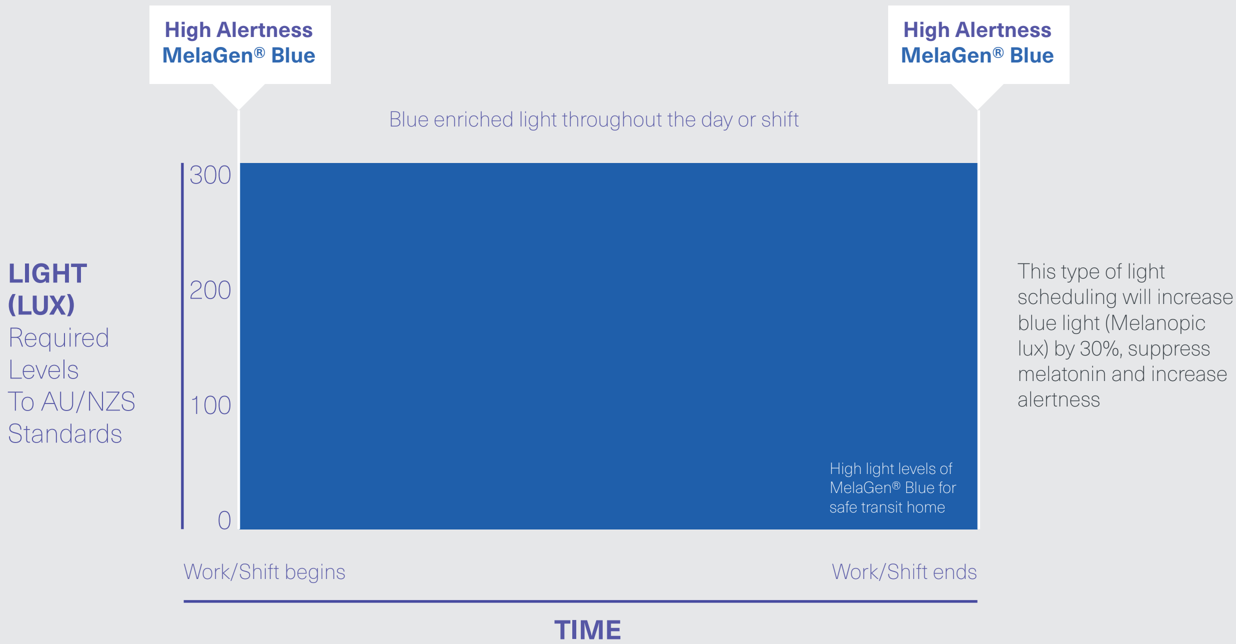
DAYTIME OR WORK

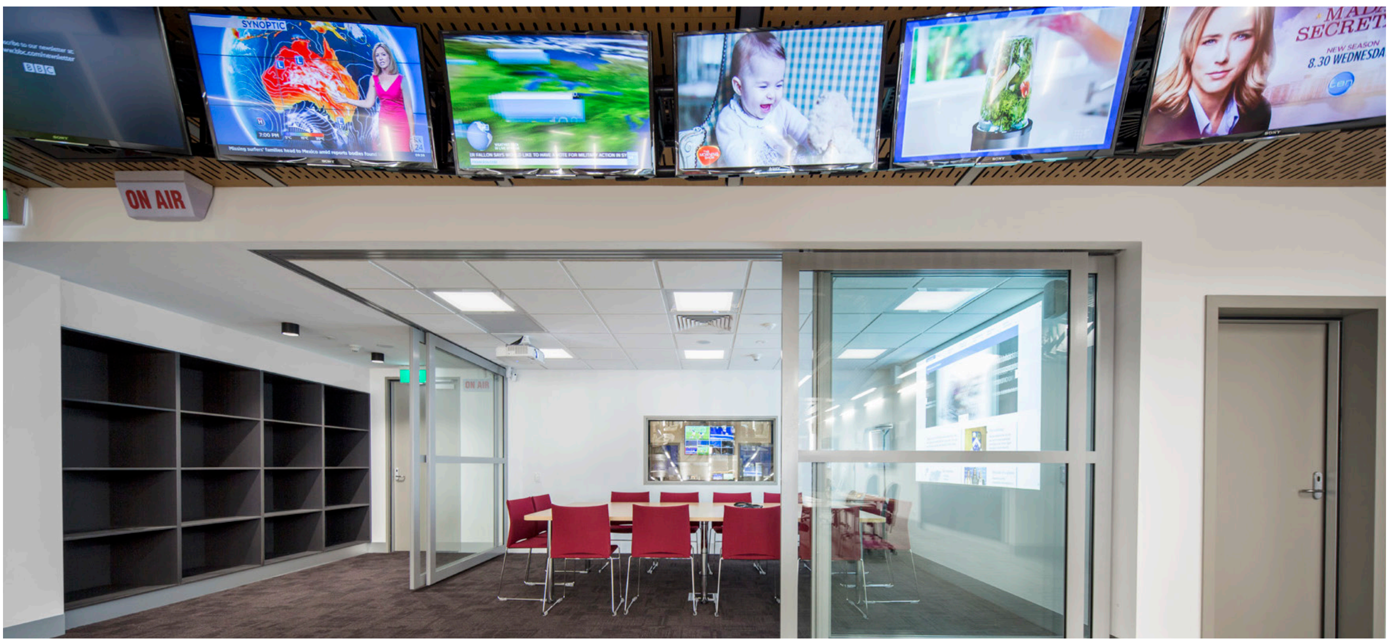
In the day, strong daytime signals are easiest with blue-enriched light.

For day workers and shift workers, blue-enriched light (a high M/P ratio) is ideal, as it allows room-level light to have the highest circadian effect, producing greater alertness and suppression of melatonin. For night workers, blue-enriched light can promote wakefulness when the body is promoting sleep.

LIGHT SCHEDULING FOR THE WORKPLACE

Blue-enriched light for day and shift workers (e.g. nurses, aged care staff, prison guards, teachers, fire fighters, military personnel, commercial office workers) can be implemented in worker areas to help maintain alertness.





Lighting featuring MelaGen® technology can be applied with the following products from Versalux Lighting Systems:

NICO MELAGEN

COMO MELAGEN

LUCCA MELAGEN

ASTI MELAGEN

INFINITI MELAGEN

PROTECTALUX MELAGEN

ENDURALUX MELAGEN

VANTAGE BLUE MELAGEN

melagen Blue

MELAGEN® BLUE

MelaGen® Blue luminaires feature specialised blue-enriched LED chips with a high M/P ratio of 0.95, and nominal colour characteristics of 4000K, CRI90, for instances where an alerting effect is desired through suppression of melatonin release.

melagen Refresh

MELAGEN® REFRESH

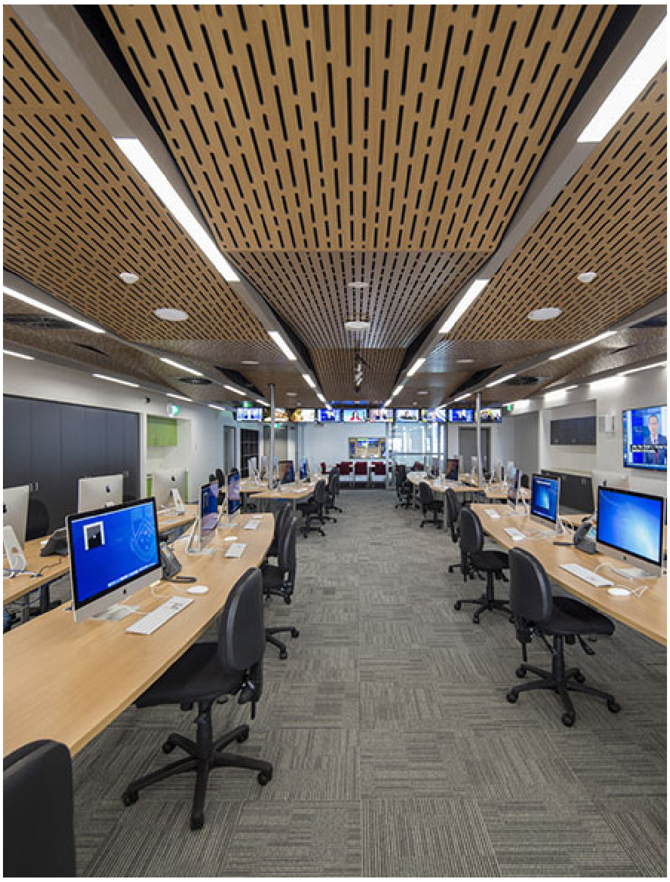
MelaGen® ReFresh luminaires feature specialised blue-depleted LED chips with low M/P ratio of 0.35, and nominal colour characteristics of 2200K, CRI90, for instances where melatonin release is desired to prepare for sleep and deep rest.

melagen Regen

MELAGEN® REGEN

MelaGen® ReGen luminaires feature a combination of both MelaGen® Blue and MelaGen® ReFresh LED chips allowing for transitions between the 0.35-0.95 M/P ratio modes of illumination (from nominal 2200-4000K), CRI90, for promotion of optimal sleep cycles within permanently occupied spaces such as those that exist in hospitality, military, healthcare, aged-care, and correctional facilities.

USING LUMINAIRES POWERED BY MELAGEN® FOR SUPPORTING ALERTNESS AND REST



REFERENCES

[1] Sleep Health Foundation (2017). Asleep on the job: Costs of inadequate sleep in Australia, Deloitte. https://www.sleephealthfoundationÆorgÆauØfilesØAsleep_on_the_job/Asleep_on_the_Job_SHF_report-WEB_small.pdf.

[2]Anderson & Horne, 2013

[3] Van Dongen, Maislin, Mullington, & Dinges, 2003

[4] Dawson & Reid, 1997

[5] Anderson & Dickinson, 2010

[6] Anderson & Platten, 2011

[7] Collet et al., 2020

[8] McMahon et al., 2018

[9] Slama et al., 2018

[10] Yoo, Gujar, Hu, Jolesz, & Walker, 2007

[11] Hertig-Godeschalk et al., 2019

[12] Morikawa et al., 2005

[13] See review by Haus & Smolensky, 2013

[14] Zhao et al., 2019

[15] Crowley, Cain, Burns, Acebo, & Carskadon, 2015

[16] Monteleone, Esposito, Rocca, & Maj, 1995

[17] Roecklein et al., 2013

[18] Phillips et al., 2019

[19] Watson et al., 2018

[20] Bullock, McGlashan, Burns, Lu, & Cain, 2019

[21] McGlashan, Coleman, Vidafar, Phillips, & Cain, 2019

[22] Hallam, Olver, Horgan, McGrath, & Norman, 2005

[23] McGlashan et al., 2018

[24] Zeitzer, Ruby, Fisicaro, & Heller, 2011

[25] Bailes & Lucas, 2013

[26] Keis, Helbig, Streb, & Hille, 2014; Sleegers et al., 2013

[27] Mills, Tomkins, & Schlangen, 2007

[28] Viola, James, Schlangen, & Dijk, 2008

[29] Chang, Aeschbach, Duffy, & Czeisler, 2015

[30] Chellappa et al., 2013

[31] Lewis et al., 2018

[32] Edgar et al., 2012

[33] Andreani, Itoh, Yildirim, Hwangbo, & Allada, 2015

[34] Daan & Pittendrigh, 1976

[35] Pittendrigh & Minis, 1964

[36] Gooley, Lu, Fischer, & Saper, 2003

[37] Bailes & Lucas, 2013

[38] St Hilaire et al., 2012

[39] Gaston, Visser, & Hölker, 2015

[40] Prayag¨†Najjar¨†&†Gronfier¨†2019

[41] Papantoniou et al., 2018

[42] Portaluppi et al., 2012

[43] Gan et al., 2015

[44] Chellappa et al. 2015

PAPERS

The Cost of Inadequate Sleep

Anderson, C., & Dickinson, D. L. (2010). Bargaining and trust: the effects of 36-h total sleep deprivation on socially interactive decisions. Journal of Sleep Research, 19(1-Part-I), 54-63. doi:10.1111/j.1365-2869.2009.00767.x

Anderson, C., & Horne, J. A. (2013). Driving drowsy also worsens driver distraction. Sleep Medicine, 14(5), 466-468. doi:10.1016/j.sleep.2012.11.014

Anderson, C., & Platten, C. R. (2011). Sleep deprivation lowers inhibition and enhances impulsivity to negative stimuli. Behavioural Brain Research, 217(2), 463-466. doi:10.1016/j.bbr.2010.09.020

Collet, J., Ftouni, S., Clough, M., Cain, S. W., Fielding, J., & Anderson, C. (2020). Differential Impact of Sleep Deprivation†and†Circadian†Timing†on†Reflexive†Versus Inhibitory Control of Attention. Sci Rep, 10(1). doi:10.1038/s41598-020-63144-y

Dawson, D., & Reid, K. (1997). Fatigue, alcohol and performance impairment. Nature, 388(6639), 235-235. doi:10.1038/40775

Haus, E. L., & Smolensky, M. H. (2013). Shift work and cancer risk: Potential mechanistic roles of circadian disruption, light at night, and sleep deprivation. Sleep Medicine Reviews, 17(4), 273-284. doi:10.1016/j.smrv.2012.08.003

Hertig-Godeschalk, A., Skorucak, J., Malafeev, A., Achermann, P., Mathis, J., & Schreier, D. R. (2019). Microsleep episodes in the borderland between wakefulness and sleep. Sleep. doi:10.1093/sleep/zsz163

McMahon, W. R., Ftouni, S., Drummond, S. P. A., Maruff, P., Lockley, S. W., Rajaratnam, S. M. W., & Anderson, C. (2018). The wake maintenance zone shows task dependent changes in cognitive function following one night without sleep. Sleep, 41(10). doi:10.1093/sleep/zsy148

Morikawa, Y., Nakagawa, H., Miura, K., Soyama, Y., Ishizaki, M., Kido, T., . . . Nogawa, K. (2005). Shift work and the risk of diabetes mellitus among Japanese male factory workers. Scandinavian Journal of Work, Environment & Health, 31(3), 179-183. doi:10.5271/sjweh.867

Slama, H., Chylinski, D. O., Deliens, G., Leproult, R., Schmitz, R., & Peigneux, P. (2018). Sleep Deprivation Triggers Cognitive Control Impairments in Task-Goal Switching. Sleep, 41(2). doi:10.1093/sleep/zsx200

Van Dongen, H. P. A., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The Cumulative Cost of Additional Wakefulness: Dose-Response Effects on Neurobehavioral Functions and Sleep Physiology From Chronic Sleep Restriction and Total Sleep Deprivation. Sleep, 26(2), 117-126. doi:10.1093/sleep/26.2.117

Yoo, S.-S., Gujar, N., Hu, P., Jolesz, F. A., & Walker, M. P. (2007). The human emotional brain without sleep — a prefrontal amygdala disconnect. Current Biology, 17(20), R877-R878. doi:10.1016/j.cub.2007.08.007

Zhao, Y., Richardson, A., Poyser, C., Butterworth, P., Strazdins, L., & Leach, L. S. (2019). Shift work and mental health: a systematic review and meta-analysis. International Archives of Occupational and Environmental Health, 92(6), 763-793. doi:10.1007/s00420-019-01434-3

The Research

Bailes, H. J., & Lucas, R. J. (2013). Human melanopsin forms a pigment maximally sensitive to blue light (λ max ≈ 479 nm) supporting activation of G q /11 and G i/o signalling cascades. Proceedings of the Royal Society B: Biological Sciences, 280(1759), 20122987. doi:10.1098/rspb.2012.2987

Bullock, B., McGlashan, E. M., Burns, A. C., Lu, B. S., & Cain, S. W. (2019). Traits related to bipolar disorder are associated with an increased post-illumination pupil response. Psychiatry Research, 278, 35-41. doi:10.1016/j.psychres.2019.05.025

PAPERS

Chang, A.-M., Aeschbach, D., Duffy, J. F., & Czeisler, C. A. (2015). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proceedings of the National Academy of Sciences, 112(4), 1232-1237. doi:10.1073/pnas.1418490112

Chellappa, S. L., Steiner, R., Oelhafen, P., Lang, D., Götz, T., Krebs, J., & Cajochen, C. (2013). Acute exposure to evening blue-enriched light impacts on human sleep. Journal of Sleep Research, 22(5), 573-580. doi:10.1111/jsr.12050

Crowley, S. J., Cain, S. W., Burns, A. C., Acebo, C., & Carskadon, M. A. (2015). Increased Sensitivity of the Circadian System to Light in Early/Mid-Puberty. The Journal of Clinical Endocrinology & Metabolism, 100(11), 4067-4073. doi:10.1210/jc.2015-2775

Hallam, K. T., Olver, J. S., Horgan, J. E., McGrath, C., & Norman, T. R. (2005). Low doses of lithium carbonate reduce melatonin light sensitivity in healthy volunteers. The International Journal of Neuropsychopharmacology, 8(2), 255-259. doi:10.1017/s1461145704004894

Keis, O., Helbig, H., Streb, J., & Hille, K. (2014). Influence of blue-enriched classroom lighting on students cognitive performance. Trends in Neuroscience and Education, 3(3-4), 86-92. doi:10.1016/j.tine.2014.09.001

Lewis, A. J., Zhang, X., Griepentrog, J. E., Yuan, D., Collage, R. D., Waltz, P. K., . . . Rosengart, M. R. (2018). Blue Light Enhances Bacterial Clearance and Reduces Organ Injury During Sepsis*. Critical Care Medicine, 46(8), e779-e787. doi:10.1097/ccm.0000000000003190

McGlashan, E. M., Coleman, M. Y., Vidafar, P., Phillips, A. J. K., & Cain, S. W. (2019). Decreased sensitivity of the circadian system to light in current, but not remitted depression. J Affect Disord, 256, 386-392. doi:10.1016/j.jad.2019.05.076

McGlashan, E. M., Nandam, L. S., Vidafar, P., Mansfield, D. R., Rajaratnam, S. M. W., & Cain, S. W. (2018). The SSRI citalopram increases the sensitivity of the human circadian system to light in an acute dose. Psychopharmacology, 235(11), 3201-3209. doi:10.1007/s00213-018-5019-0

Mills, P. R., Tomkins, S. C., & Schlangen, L. J. (2007). The effect of high correlated colour temperature office lighting on employee wellbeing and work performance. Journal of Circadian Rhythms, 5(0), 2. doi:10.1186/1740-3391-5-2

Monteleone, P., Esposito, G., Rocca, A., & Maj, M. (1995). Does bright light suppress nocturnal melatonin secretion more in women than men? Journal of neural transmission, 102(1), 75-80. doi:10.1007/bf01276567

Phillips, A. J. K., Vidafar, P., Burns, A. C., McGlashan, E. M., Anderson, C., Rajaratnam, S. M. W., . . . Cain, S. W. (2019). High sensitivity and interindividual variability in the response of the human circadian system to evening light. Proceedings of the National Academy of Sciences, 201901824. doi:10.1073/pnas.1901824116

Roecklein, K., Wong, P., Ernecoff, N., Miller, M., Donofry, S., Kamarck, M., . . . Franzen, P. (2013). The post illumination pupil response is reduced in seasonal affective disorder. Psychiatry Res, 210(1), 150-158. doi:10.1016/j.psychres.2013.05.023

Sleegers, P., Moolenaar, N., Galetzka, M., Pruyn, A., Sarroukh, B., & Van Der Zande, B. (2013). Lighting affects students' concentration positively: Findings from three Dutch studies. Lighting Research & Technology, 45(2), 159-175. doi:10.1177/1477153512446099

Viola, A. U., James, L. M., Schlangen, L. J., & Dijk, D.-J. (2008). Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. Scandinavian Journal of Work, Environment & Health, 34(4), 297-306. doi:10.5271/sjweh.1268

Watson, L. A., Phillips, A. J. K., Hosken, I. T., McGlashan, E. M., Anderson, C., Lack, L. C., . . . Cain, S. W. (2018). Increased sensitivity of the circadian system to light in delayed sleep–wake phase disorder. The Journal of Physiology, 596(24), 6249-6261. doi:10.1113/jp275917

Zeitzer, J. M., Ruby, N. F., Fisicaro, R. A., & Heller, H. C. (2011). Response of the Human Circadian System to Millisecond Flashes of Light. PLOS ONE, 6(7), e22078. doi:10.1371/journal.pone.0022078

The Science

Andreani, T. S., Itoh, T. Q., Yildirim, E., Hwangbo, D.-S., & Allada, R. (2015). Genetics of Circadian Rhythms. Sleep Medicine Clinics, 10(4), 413-421. doi:10.1016/j.jsmc.2015.08.007

Bailes, H. J., & Lucas, R. J. (2013). Human melanopsin forms a pigment maximally sensitive to blue light (λ max ≈ 479 nm) supporting activation of G q /11 and G i/o signalling cascades. Proceedings of the Royal Society B: Biological Sciences, 280(1759), 20122987. doi:10.1098/rspb.2012.2987

Daan, S., & Pittendrigh, C. S. (1976). A functional analysis of circadian pacemakers in nocturnal rodents. Journal of Comparative Physiology ? A, 106(3), 267-290. doi:10.1007/bf01417858

Edgar, R. S., Green, E. W., Zhao, Y., Van Ooijen, G., Olmedo, M., Qin, X., . . . Reddy, A. B. (2012). Peroxiredoxins are conserved markers of circadian rhythms. Nature, 485(7399), 459-464. doi:10.1038/nature11088

Gan, Y., Yang, C., Tong, X., Sun, H., Cong, Y., Yin, X., . . . Lu, Z. (2015). Shift work and diabetes mellitus: a meta-analysis of observational studies. Occupational and Environmental Medicine, 72(1), 72-78. doi:10.1136/oemed-2014-102150

Gaston, K. J., Visser, M. E., & Hölker, F. (2015). The biological impacts of artificial light at night: the research challenge. Philosophical Transactions of the Royal Society B: Biological Sciences, 370(1667), 20140133. doi:10.1098/rstb.2014.0133

Gooley, J. J., Lu, J., Fischer, D., & Saper, C. B. (2003). A Broad Role for Melanopsin in Nonvisual Photoreception. The Journal of Neuroscience, 23(18), 7093-7106. doi:10.1523/jneurosci.23-18-07093.2003

Papantoniou, K., Devore, E. E., Massa, J., Strohmaier, S., Vetter, C., Yang, L., . . . Schernhammer, E. S. (2018). Rotating night shift work and colorectal cancer risk in the nurses' health studies. International Journal of Cancer, 143(11), 2709-2717. doi:10.1002/ijc.31655

Pittendrigh, C. S., & Minis, D. H. (1964). The entrainment of circadian oscillations by light and their role as photoperiodic clocks. The American Naturalist, 98(902), 261-294.

Portaluppi, F., Tiseo, R., Smolensky, M. H., Hermida, R. C., Ayala, D. E., & Fabbian, F. (2012). Circadian rhythms and cardiovascular health. Sleep Medicine Reviews, 16(2), 151-166. doi:https://doi.org/10.1016/j.smrv.2011.04.003

Prayag, A. S., Najjar, R. P., & Gronfier, C. (2019). Melatonin suppression is exquisitely sensitive to light and primarily driven by melanopsin in humans. Journal of Pineal Research, 66(4), e12562. doi:10.1111/jpi.12562

St Hilaire, M. A., Gooley, J. J., Khalsa, S. B. S., Kronauer, R. E., Czeisler, C. A., & Lockley, S. W. (2012). Human phase response curve to a 1 h pulse of bright white light. The Journal of Physiology, 590(13), 3035-3045. doi:10.1113/jphysiol.2012.227892

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