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Circadian Lighting:

To what extent can WELL certification standards be met by daylighting?

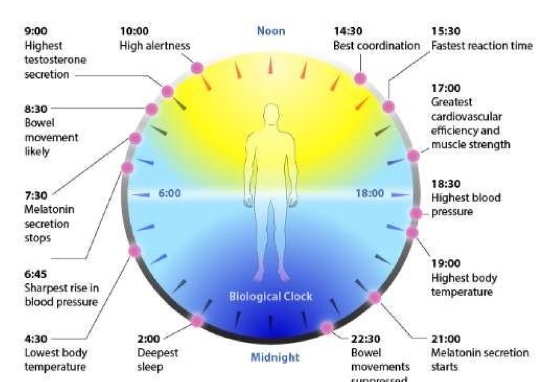
Kelly Light[1], Dr. Richard Mistrick[2]

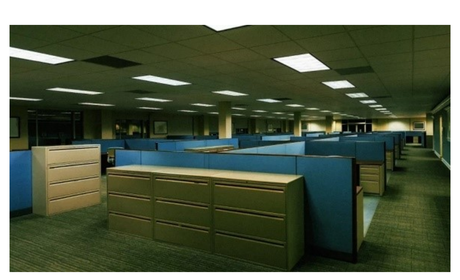
[1]Cedar Crest High School, [2]Department of Architectural Engineering, The Pennsylvania State University

Introduction

Light is a main factor in regulating the circadian rhythm of the human body through specialized light sensors within our eyes. These intrinsically photosensitive retinal ganglion cells (ipRGC's) are responsible for expressing the photopigment, melanopsin. Melanopsin expression suppresses melatonin, the hormone regulating the human sleep-wake cycle. A greater signal from the ipRGC's and melanopsin results in suppression of melatonin resulting in wakefulness and alertness while a weaker signal allows for higher levels of melatonin, resulting in sleepiness and a lack of concentration. In addition to signals from the ipRGC's, the timing of light exposure and a person's "photic" or light history contribute to the body's light sensitivity and amount of melatonin suppression.

Through lighting cues, our eyes detect the light-dark cycle of the environment and align our body's physiological rhythm to the environmental cycle associated with the rotation of the Earth. This alignment is called **circadian entrainment**.





Poor lighting during the day can have negative impacts on health

In the past, as an agricultural society, humans spent much of their time outdoors where the appropriate cues for the sleep-wake cycle were available with the positioning of the Sun in the Earth's sky. Today, human beings spend 90% of their time indoors and incorrect lighting cues are often given to the human body at incorrect times of the day causing a disruption in the sleep-wake cycle. This disruption in the sleep-wake cycle can result in negative short-term and long-term impacts on the health and well-being of humans, including stress, cardiovascular disease and cancer to name a few.

Launched in 2014, the **WELL Building Standard** is a certification system, based on scientific and medical research, concerning the features of a built environment that impact human health and well-being. Light is one of the seven concepts measured in the standards. The WELL standards for Circadian Lighting in a work space state that one of the following must be met:

- *At 75% or more of workstations, at least 200 equivalent melanopic lux is present, measured on the vertical plane facing forward, 1.2 m [4 ft.] above finished floor (to simulate the view of the occupant). This light level may incorporate daylight, and is present for at least the hours between 9:00 AM and 1:00 PM for every day of the year.*

or

- *For all workstations, electric lights provide maintained illuminance on the vertical plane facing forward (to simulate the view of the occupant) of 150 equivalent melanopic lux or greater.*

Equivalent Melanopic Lux (EML) is a metric that is weighted to the ipRGC's peak sensitivity at 480 nm. The amount of EML is measured on the vertical plane at eye level of the occupant.

The focus of this research was to study to what extent daylighting (using the Sun as the only source of light in the given space) meets the WELL certification standard for circadian lighting.

Methods

Using the Rhinoceros 3D computer-aided design (CAD) application and Grasshopper programming language, a 34 ft. x28 ft. x 10 ft. room was created, containing three 8 ft. x 6 ft. windows along the same wall. The room contained the following specifications:

Item	Specification
Ceiling	80% reflectance
Floor	20% reflectance
Interior Walls	60% reflectance
Window Glass	60% Transparency
Exterior Walls	50% Reflectance
Ground outside windows	18% Reflectance

Melanopic Ratio by Light Source

CCT (K)	Light Source	Ratio
2700	LED	0.45
3000	Fluorescent	0.45
2800	Incandescent	0.54
4000	Fluorescent	0.58
4000	LED	0.76
5450	CIE E (Equal Energy)	1.00
6500	Fluorescent	1.02
6500	Daylight	1.10
7500	Fluorescent	1.11

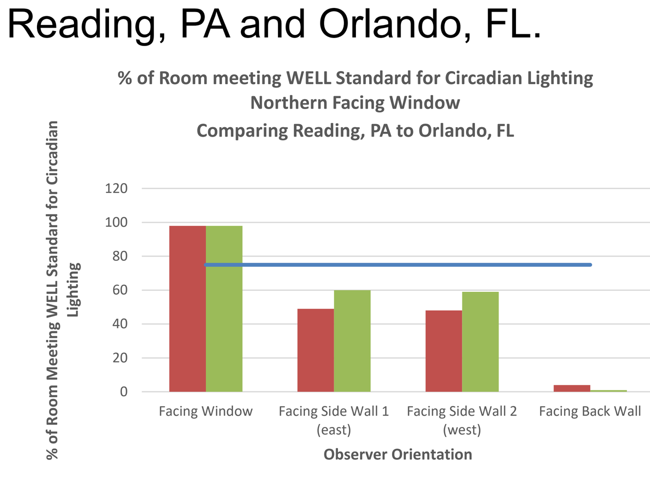
* Source: WELL Building Standard

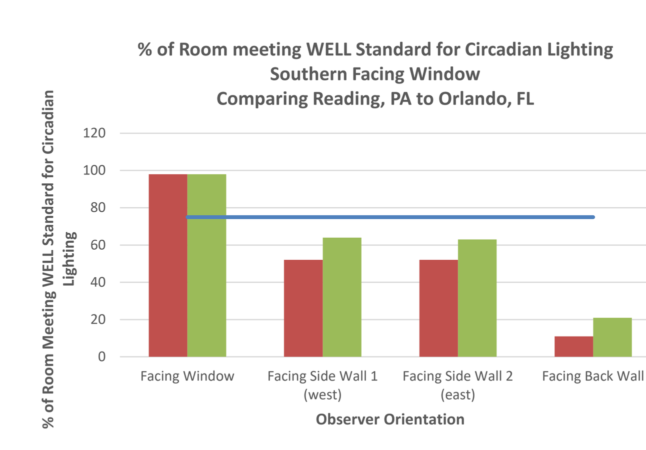
Since 182 lux is equal to 200 EML using the 1.1 melanopic to photopic ratio for daylighting, the program was set to measure the percentage of points in the room meeting 182 lux, 100% of the time, between the hours of 9 AM and 1 PM, during the course of a year.

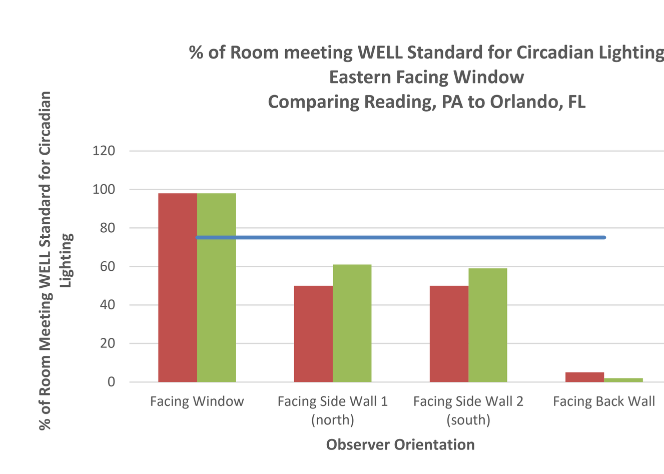
Data was collected for the windows facing north, south, east and west. Within each of the window orientations, data was collected for the observer perspective inside the room facing the windows, facing each of the side walls, and facing the back wall. To compare the effect of location and sun angle, two locations were chosen: Reading, PA (which is close to the researcher's home and work locations) and Orlando, FL. After data was collected, other studies were performed to gather more information concerning how changing the guidelines would affect the success rate of meeting the standards using daylighting.

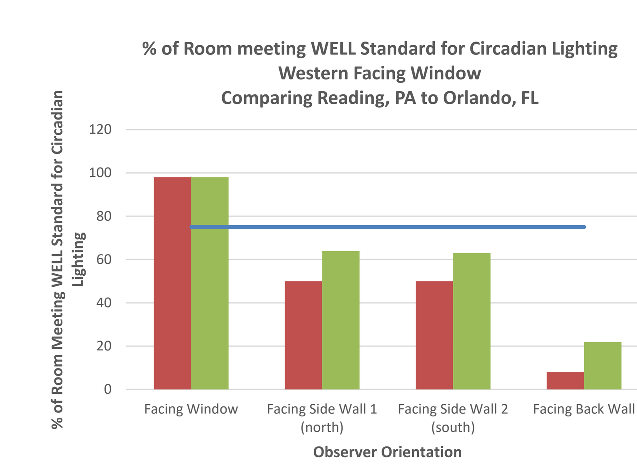
Results

The following graphs compare to what extent the WELL standard for circadian lighting is met based on window orientation and observer perspective for both Reading, PA and Orlando, FL.

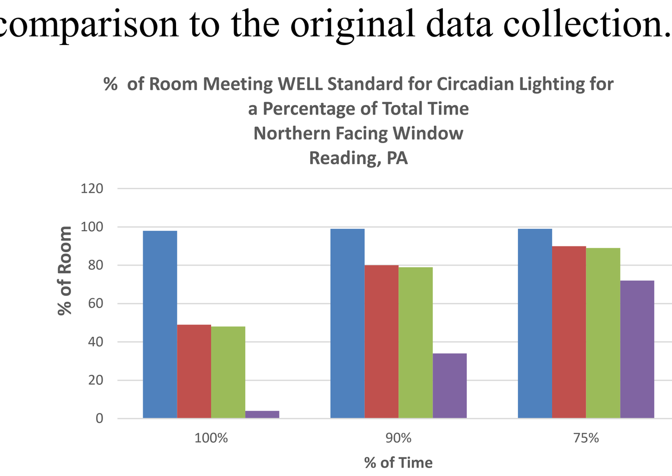


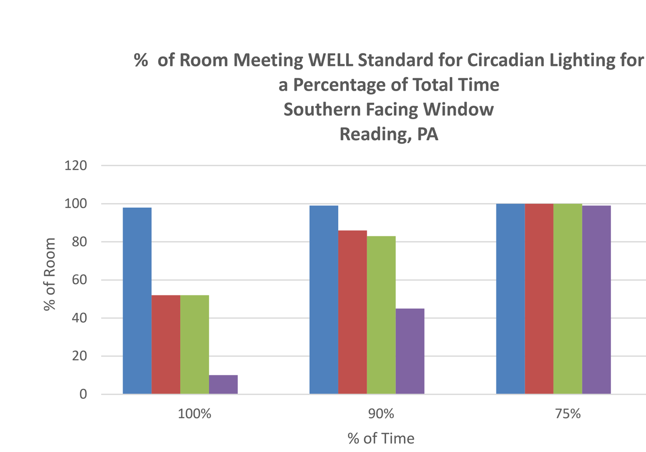




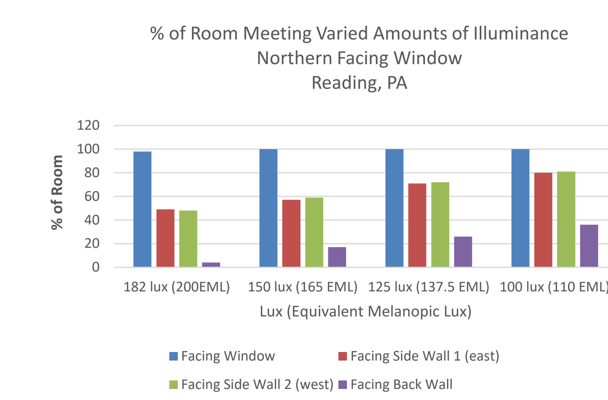


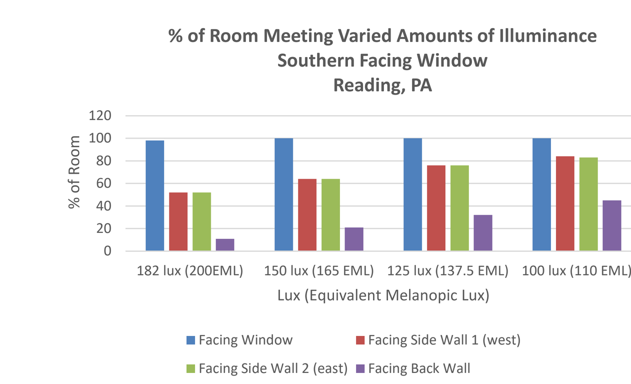
Following the initial study, additional studies were performed to gather data concerning to what extent lower standards could be met. The first additional study looked at lowering the percentage of time to meet the WELL standards from 100% to 90% to 75% of the time during the course of a full year. This study was only performed for Reading, PA and only for northern and southern facing windows (giving the lowest and highest values) as a comparison to the original data collection.





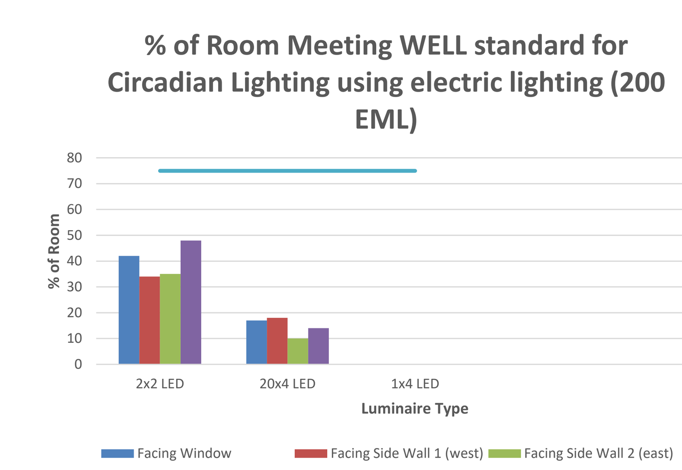
The second additional study looked at how well daylighting could meet lower amounts of EML 100% of the time during the course of a full year. Again, only Reading, PA, northern and southern facing windows were used for this study.

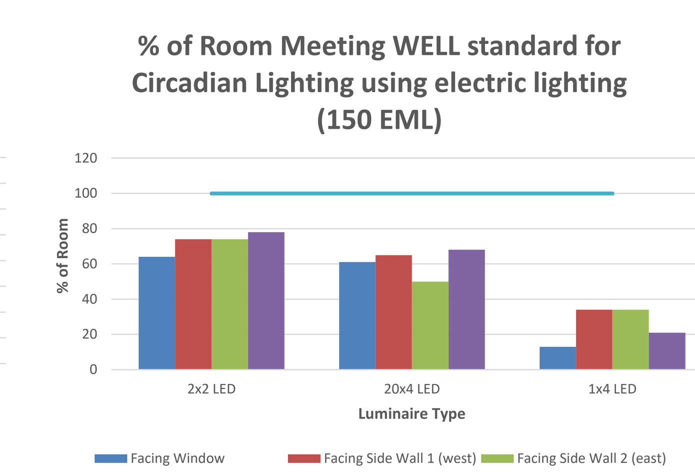




As a comparison study, data was collected for three different types of luminaires using AGI32 lighting simulation software

- 2 ft. x 2ft. BLT Tunable White LED
- 20 in x 4 ft. Low Profile LED Wraparound
- 4 ft. x 1 ft. Suspended Nera LED 40/60 Distribution, 750 lm/ft.





Discussion

The initial study of to what extent the WELL standard for circadian lighting could be met by daylighting alone showed that no matter which way the window faced – north, south, east, west – the standard of 200 EML, between 9 AM and 1 PM, 100% of the time could only be met when the observer faced the window while working. If the observer faced the side walls or the back wall, the standard could not be met in Reading, PA nor in Orlando, FL.

When lowering the standard to 200 EML, between 9 AM and 1PM 90% and then 75% of the time, the Northern and Southern facing window scenarios were both able to meet the new lower 75% standard for all observer orientations.

Lowering the standard from 200 lux to 150 lux to 125 lux to 100 lux being met 100% of the time did not result in meeting the new standard for all orientations for either southern or northern facing windows. While the observer facing the side walls did improve to meet the new standard, an observer facing the back wall of the room still did not meet the new criteria.

The current WELL standards for circadian lighting in a given workspace could not be met with daylighting alone. In comparison, the three scenarios involving only electric lighting also did not meet the requirement. In order to meet the WELL criteria, a combination of daylighting and electric lighting must be used. The next step in this research would be to find the optimal combination of both light sources for meeting the WELL criteria for circadian lighting.

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Acknowledgements

A special thank you to Dr. Richard Mistrick for his guidance during this research project. Also, thank you to Dr. Kathleen Hill, Dr. Matthew Johnson, Amber Cesare, Tiffany Lewis, and Kyle Simon from the Center for Science and the Schools for the opportunity to participate in the Research Experience for Teachers Program

The RET for Teachers is funded by NSF Building Education Research Experience for Teachers Grant EEC 1855256.