Daylight, manual sunshade use and occupant-centric circadian lighting stimulus in an open office

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ABSTRACT: Daylight is essential to human productivity. It has been shown that if we do not receive enough daylight, our health and well-being is negatively affected. However, an overabundance of daylight into the indoors can make performing with computer-based visual tasks difficult and uncomfortable due to glare. This study is a collaboration with SRG Partnership, an Architecture firm in Portland, OR, to analyze their own workspace in determining optimal amounts of daylight as an occupant-centric circadian resource in the office. The historic office space has large south-east-facing windows that can be a source of glare, which negatively affects productivity, and are controlled manually with motorized shades. Participating occupants were given a wearable light sensor to track the light levels received throughout the day over the course of one work week. Sunshade use was also monitored and recorded.

KEYWORDS: Circadian Rhythm, Equivalent Melanopic Lux, Glare, Sunshade Use, Open Office Lighting

INTRODUCTION

Daylight is critically important to the survival of human-kind and most all plants and animals. There have been recorded many benefits from being exposed to moderate amounts of sunlight and some obvious dangers are known when we receive too much radiation from the sun. We generally define light as the part of the electromagnetic spectrum (aprx. 380-780 nm) that we can perceive through our visual senses; in other words, what we can see (Webb, 2006).

For this study we will focus mainly on the impact of light on the circadian rhythm - our internal, biological clock. Light is key in setting and maintaining the circadian rhythm (Rea, 2002). As light enters our bodies through our eyes via intrinsically photosensitive retinal ganglion cells (ipRGSs), our bodies are able to regulate when to be awake and when to prepare to sleep, as well as influencing other bodily functions and hormones, (IWBI, v2). This light can be measured in Equivalent Melanopic Lux (EML).

CIRCADIAN RHYTHM

> “The Institute of Medicine (Health and Medicine Division) reports that about 50 to 70 million adults in the United States suffer from a chronic sleep or wakefulness disorder.” (IWBI, v2).

As societal behavior continues to keep us indoors, the need for innovative lighting techniques in the built environment is now more important than ever. The human body responds to a physiological process that keeps the body’s hormones and processes on a rhythmic cycle daily, called Circadian Rhythm. This cycle influences bodily systems (Digestion, Blood Pressure, Temperature Regulation, Metabolism). Many health risks can be attributed to the disruption of one's Circadian Rhythm (Diabetes, Obesity, Depression, Heart Attack, Hypertension, Stroke). In the morning the natural daylight is rich in Blue color that inhibits the release of melatonin, triggering the body's production of Cortisol and Ghrelin which causes one to be hungry and alert. As the day progresses the light begins to change from a blue-rich light in the morning to a Red light at night, which is when the bodily process releases melatonin, preparing the body for sleep.

Circadian Rhythm is controlled by light, natural and artificial. Too much direct sunlight can have negative effects on the human body and productivity. Sunlight is made up of other electromagnetic waves (Gamma, X-ray, Ultraviolet, Infrared, Microwave, and Radio). When designing for occupants Circadian Rhythm, the designer must understand that not all direct light is beneficial and that ultraviolet rays can cause damage to a person's skin and eyes; while direct light can cause glare lowering productivity.

ARTIFICIAL LIGHTING

Artificial lighting is used in place of natural sunlight in the built environment to supplement the adverse effects from UV light damaging materials and IR light raising the buildings temperature. There are many different options of artificial light being used in the built environment (Incandescent Lamps, Fluorescent, High-Intensity Discharge, Light-Emitting Diode). LED lights have the best efficiency and performance out of all the other options. These light sources also have a wider Correlated Color Temperature (relative color of light) range that can provide warm to cool color ranges. Candle light, incandescent, incandescent halogen light sources can only provide warm (red) shades of light. CFL and Fluorescent, and LED lights are able to produce light at a broader range from warm (red) to cool (blue).

METRIC

The International WELL Building Institute stipulates that for melanopic light intensity in a work environment, the following criteria 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.

“A well-designed lighting system that combines sufficient levels of natural artificial lighting can have a positive impact on the health and productivity of building occupants. Quality lighting can help alleviate fatigue increase concentration and increase productivity.” (IWBI, v2). We will be using the standards set by the IWBI as a ruler to measure light quality in SRG’s office space.

SETTING

Located at the corner of SW 6 and Columbia St., Portland, OR, SRG’s office is housed inside a renovated commercial space. Along one side of the space are 6 ½ large, full-height windows which provide daylight to the two-story volume. The study is concentrated in the main space near the large windows, containing the majority of the employee work stations. There are deciduous trees outside all but one of the window bays, which provides some external shading during the warmer months. In the morning there is a lot of daylight in the space and is initially observed to be typically offset by the use of large motorized sunshades. The sunshades mitigate glare on the workstations. As the sun moves to the west the light is reflected off of the windows and cladding of the surrounding buildings, which are another source of glare. This glare, again, is offset by the use of sunshades. SRG has allowed us to use their open office space to perform this study to test lighting levels and circadian stimulus as it affects the employees.

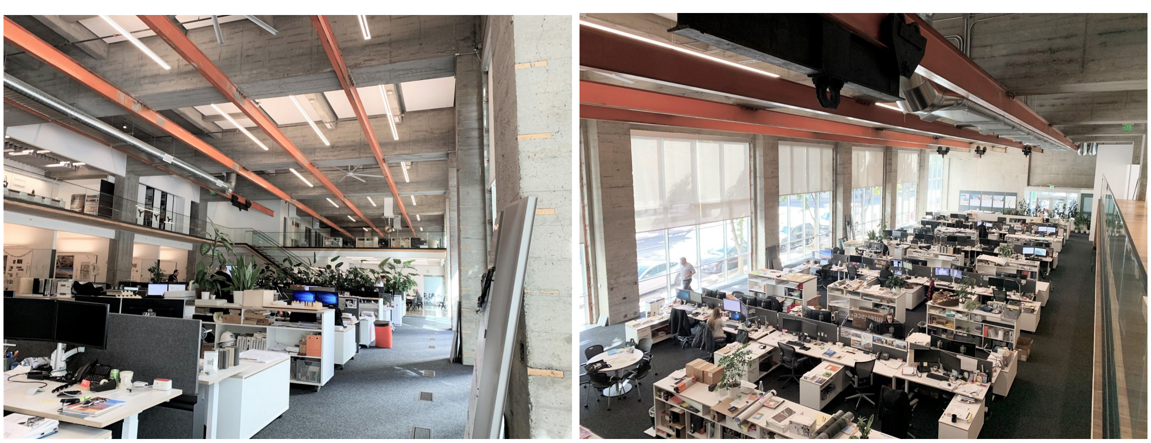


Image 1-2: SRG office space, LED lighting (left), large bay windows with sunshades (right).

HYPOTHESES

1. Because of sun shade use to control glare, individual employees in the SRG office do not receive adequate circadian stimulus, as defined by WELL Building Standards v2. (75% of workstations over 200 EML, between 9:00 am - 1:00 pm).

METHODS

In order to track the EML that each employee was exposed to throughout the day we deployed 20 HOBO MX2202 data loggers by Onset Computer Corp. that we fashioned to be wearable on the garment of the employees using a paper and binder clip. The HOBO sensors were distributed to twenty employees who volunteered and agreed to wear them on the front of their shirts or coats for the duration of the work day. The majority of the employees were seated within the main work area, however, two employees were located on the upper mezzanine level and two others were farther from the windows in smaller office spaces. Each employee's workstation was marked on a floor plan of the office and the sensor number was recorded to trace which employees had which sensor. Each wore these sensors for a full business week (5 days), the data was logged continuously, and compiled after the sensors were collected from all participants.

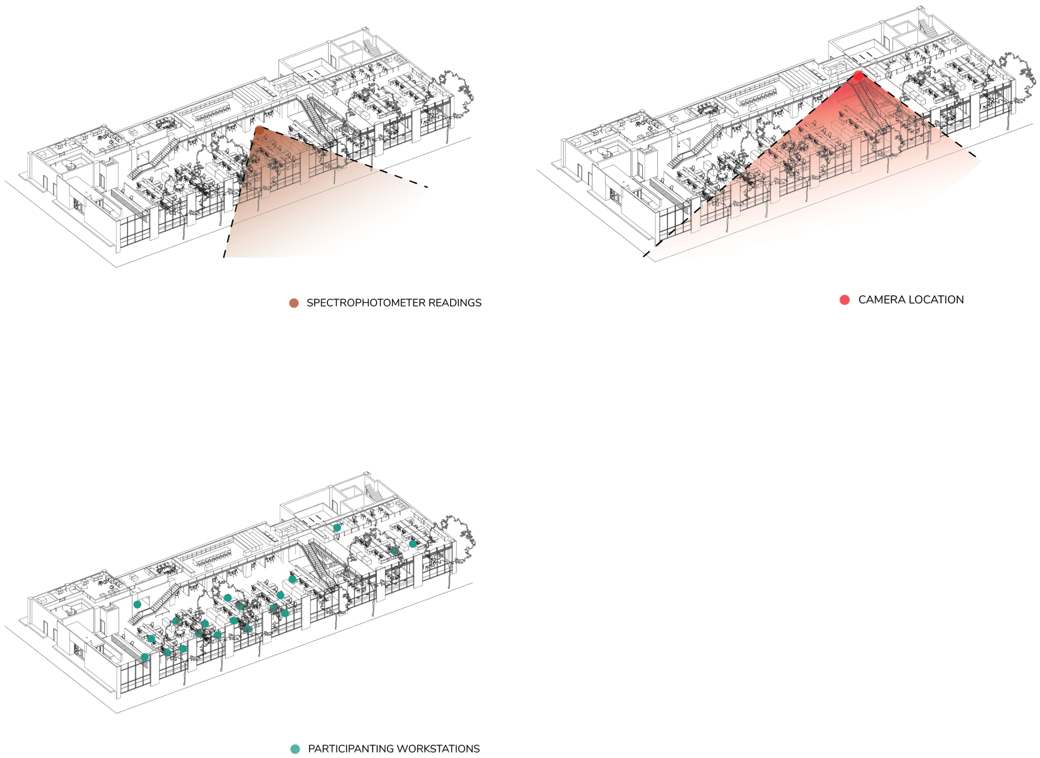


Image 3-5: The floorplans above show the location of where the spectrophotometer readings were taken, where the camera was located to monitor sunshade use, and the location of participants' workstations.

To separate levels of illuminance coming from daylight and artificial light, we used a spectrophotometer to measure the levels of the present light spectrum, or, in order to estimate EML by understanding the contribution of the biologically active component of light experienced by the occupants. Three readings were taken at a designated location in the office; one in the morning (8:00), one in the afternoon (13:00), and one in the evening (17:00).

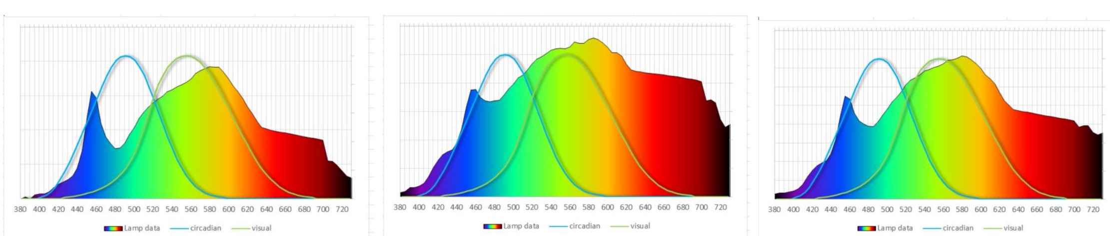
A camera was set up on the upper level overlooking the window bays to monitor sunshade use by the occupants. This was done using time-lapse technology to determine the time of day when the shades were up and when they were deployed. From the videos it was clear to pinpoint when the shades were being lowered because of excessive glare, which was affecting productivity. Comparing this data with the data collected from the recorded HOBO sensors we can determine if the use of the sunshades were causing a decrease in circadian stimulus from daylight.

Image 6-7: View from camera showing sunshades retracted (left) and deployed (right).

RESULTS

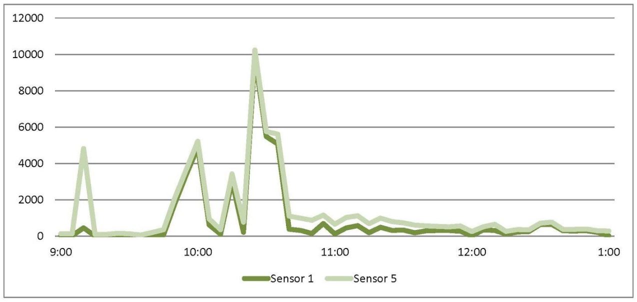
The data collected from the wearable HOBO sensors gave us readings in lumens, for every five minutes of the day, for 5 days. We took all this data and synthesized each HOBO (1-20) into daily averages. The WELL standard stipulates that 75% of workstations need at least 200 equivalent melanopic lux between the hours of 9:00am to 1:00 pm, so we also extracted data and analyzed it specifically for the WELL standard. After analyzing the HOBO data we needed to extract the data retrieved from the spectrophotometer readings we took to understand the light intensity that the space was receiving. This data from the spectrophotometer was also needed in tandem with the HOBO data to convert the lumens to EML to appropriately compare the data to the WELL standard.

After taking three readings with the spectrophotometer (8:00am, 12:00pm, and 5:00pm) we were able to calculate a photo melanopic ratio to help us find EML. When deciphering the data from the spectrophotometer, we can see that Graph 1 is displaying a spike of blue light with little arching to the graph. This means that the morning reading was picking up the electric lighting, which is the skinny blue spike. Natural daylight, has a broader spectrum than artificial light and displays more of a continuous arc. Graph 2 was a reading at noon, where you can see the broader levels of blue light that entered the office. Graph 3 was taken at the end of the work day where the light levels have noticeably dropped. Because we needed to combine the spectral reading with the data collected from the HOBO sensors we used Graph 2 as test data to calculate the EML since it was a good medium between the three.



Graph 1-3: from left to right

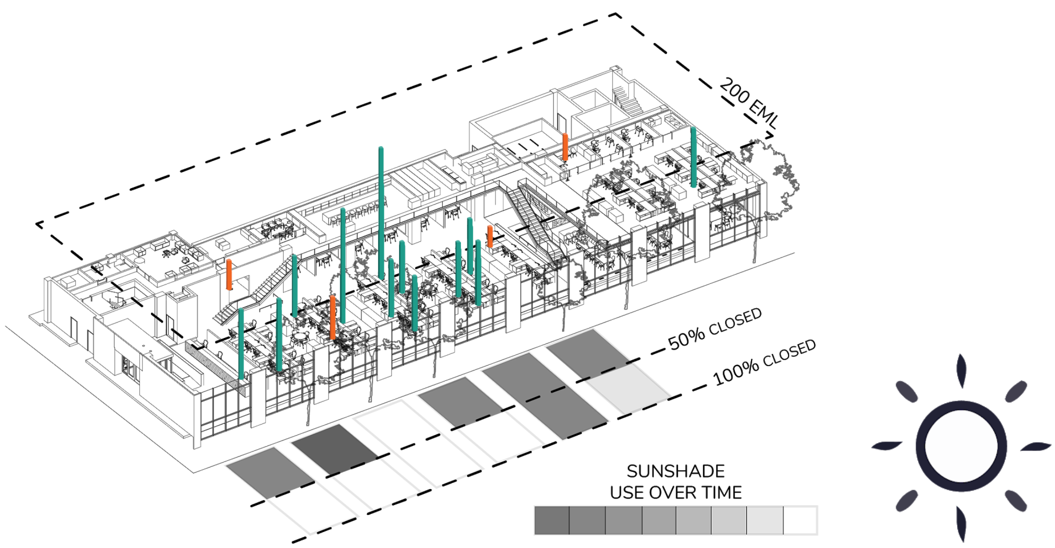
By combining the data from the HOBO sensors and the spectrophotometer we were able to determine the equivalent melanopic lux (EML) for each sensor. By applying the computed EML data to participant's location we were able to determine and analyze the individual data reading-outs. Graph 4 below shows sensor 1 and sensor 5; sensor 1 was located on the mezzanine level next to the window, and sensor 5 was next to the window on the first floor. The reading was taken on a sunny day where both occupants had similar exposure, resulting in satisfactory light expose in regards to the WELL standard. Conversely, in Graph 5, where the data was analyzed from an overcast day that sensor 5 which was located on the first floor next to the window had a much larger exposure compared to sensor 1 occupant on the mezzanine level. With this data for all 20 sensors we developed graphic charts for the three conditions: sunny, overcast, and partly cloudy. We chose these three conditions to determine whether occupants received enough stimuli from natural light exposure during these regular sky conditions.



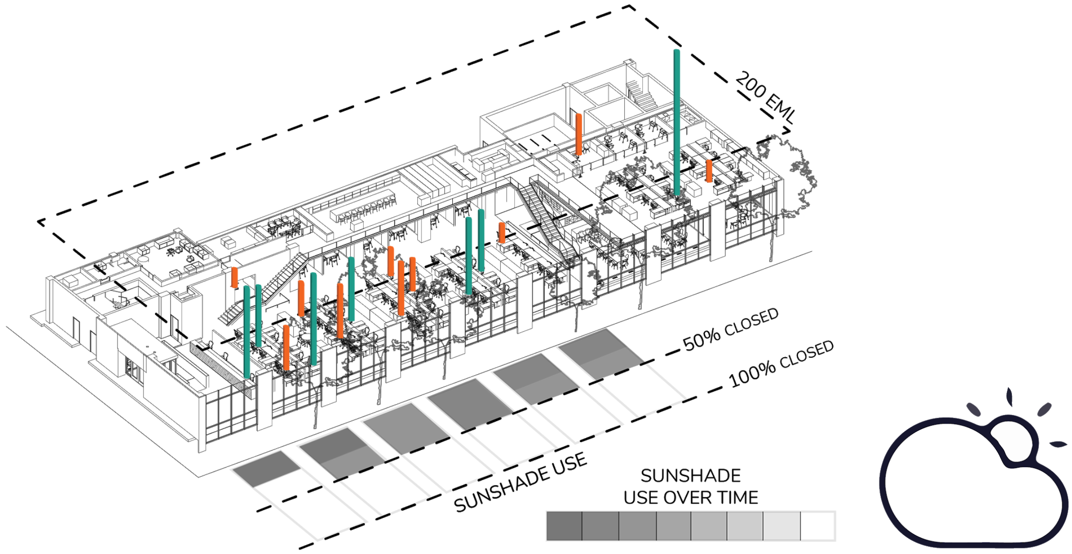
Graph 4: Lux levels for two occupants on a sunny day.

Graph 5: Lux levels for two occupants on an overcast day.

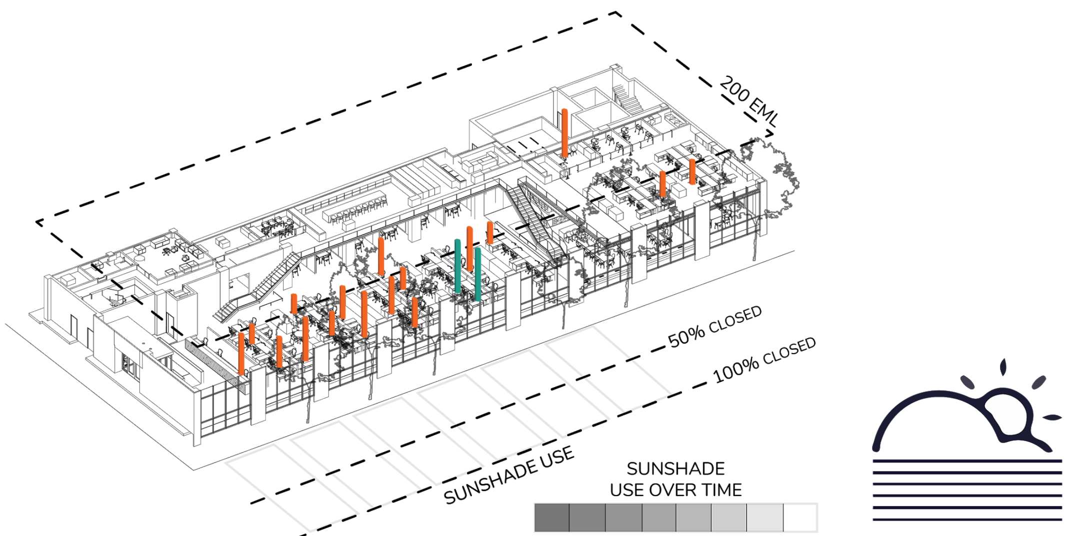
The graphic for the three sky conditions uncovered that during sunny days more than 80% of workstations had reached 200+ EML, meeting the WELL standard. The other two sky conditions, overcast and partly cloudy did not meet the requirements for acceptable circadian lighting. Overcast sky conditions only had 10% of the occupants' workstations meeting acceptable levels of lighting and the day with a partly cloudy sky condition had 41%.



Graph 6: Graphic illustration of the combined data on a sunny day



Graph 7: Graphic illustration of the combined data on a partly cloudy day



Graph 8: Graphic illustration of the combined data on an overcast day

CONCLUSION

We hypothesized that because of sunshade use, the occupants would not reach WELL building standards of 200 EML between the hours of 9:00 am and 1:00 pm. What we found was the factor that had the highest impact on the amount of EML levels in the office was the sky condition. For example, on a sunny day (10/29/19) the office received an average of 380 EML, whereas on an overcast day (11/4/19), the office only received an average of 134 EML. Even with the sunshades being retracted all day on Nov. 4th, only 10% of the office received sufficient levels of circadian stimulus.

The sun shades also played a large role in limiting the amount of daylight to the occupants. On a relatively clear day the sunshades were deployed 25% in window bay 5 at 9:30 am. The occupant seated directly adjacent to this bay recorded lux levels of 3,670 at this time. By 10:00, however, the sunshades dropped to 50% and the occupant's light levels received dropped also to 732 lux. From this data we can see that the amount of light blocked by the sunshades is quite significant. The occupant is still attaining the WELL standard, but when we consider those at workstations farther into the office, the light levels become more crucial to their attaining the WELL standard and a healthy circadian stimulus.

Several solutions to help the occupants who are not receiving sufficient levels of EML for their circadian rhythms would include more efficient sunshades, increased artificial light, and seeking small opportunities throughout the day to get outside. Possible sunshade solutions include task shading to prevent glare. This would be deployed on an individual basis to meet the need of the workstations affected. Another sun shading solution is to use bottom-up shades to block glare at the workstations' height down low, but still leaving the majority of the upper window open to let in lots of daylight for the occupants further from the windows. The LED lights in the SRG office are two stories up in the main part of the office and are on a timer to dim as the day goes on. It could be recommended to leave the lights on at maximum brightness throughout the entirety of the day. Lamps at desks can also supply needed EML levels if they give off the right spectrum. A simple solution, and what humans have always done, is to simply be outside. Going on a short walk around the block, eating lunch outdoors or in a sunny location in the building, and taking time to be in some sun may give you the light that your body needs.

Today it is easy for us to become distracted and we end up spending so much time indoors or on our computers that we can forget how important it is to feed our circadian stomach. Daylight is essential to managing our circadian rhythms. For SRG, and any other office, it is important for the overall health and productivity of their employees. These design solutions may be thoughtfully applied to any similar office where there needs to be an increase in circadian stimulus.

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Keywords Defined Appendix

Circadian Rhythm - is a physiological process of the human body that keeps the body's hormones and processes on a rhythmic cycle daily. Influences bodily systems (Digestion, Blood Pressure, Temperature Regulation, Metabolism)

Color-rendering Index - a measure of light that is used to quantify how much a light source will stimulate the light response of melanopsin.

Equivalent Melanopic Lux (EML) - a measure of light that is used to quantify how much a light source will stimulate the light response of melanopsin.

Glare - the excessive brightness, excessive brightness contrast, and excessive quantity of light from a light source.

Illuminance - The amount of light incident on a given surface. Measured in lux or footcandles.

Light-emitting Diode (LED) - A lamp with semiconductor devices that produce visible light when an electrical current passes through them.

Lumens - is the total quantity of visible light emitted by a source per unit of time.

Luminare - A complete lighting unit that includes all the components that distribute light.

Luminance - A measurement of how bright a surface or light source will appear to the eye. Measured in candela per square meter or footlamberts.

Luminous Flux - is the total output of a light source. Measured in Lumens. (Total perceived amount of light in all directions)

Luminous Intensity - is a radiant power. Light in a particular Direction. Measured by candela.

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