THE EFFECT OF LIGHTING ON THE CIRCADIAN RHYTHM AND ITS APPLICATIONS IN A HEALTHCARE ENVIRONMENT

by

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B.S., Kansas State University, 2014

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Architectural Engineering
College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2014

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Abstract

The correlation between natural and artificial lighting and the human circadian rhythm was researched to determine how changing artificial lighting design could improve the working environment in healthcare facilities.

Research showed that human circadian rhythm is largely influenced by daylight and the accompanying light color (CCT) change in a day. Consequently, healthcare providers who are not exposed to daylight are isolated from this natural indicator. This can disjoint their circadian cycles from a normal rhythm and lead to physiological and psychological complications.

Daylighting and standard artificial lighting design conditions were observed at Mercy Regional Medical Center (MRMC) in Manhattan, Kansas,. Then, healthcare providers at MRMC were anonymously surveyed about their perceived alertness throughout a typical working shift[1]. The data was charted and plotted against a normal circadian rhythm to demonstrate whether a normal or disjointed cycle was experienced by healthcare providers. The comparison of this data to observed lighting conditions exhibited the necessary influence of daylight on achieving a normal circadian rhythm. This study reinforced the information available from many other sources connecting healthcare lighting and the circadian rhythm.

Working on this premise, research suggested two lighting designs that would improve the working environment in healthcare facilities. The first of these would be the inclusion of circadian rooms. Special rooms in a healthcare facility would be available to staff in order to provide light therapy. Short wavelength blue light, experienced at optimal times throughout a shift, would act as stimulants (similar to daylight cues), adjusting employees' circadian cycles to normal when daylight exposure was unattainable. Alternately, a healthcare facility working on set, not-staggered, shifts could incorporate a variable lighting system. This system would rely on specialized lights to alter light color (CCT) throughout a shift to mimic daylight rhythms. Accordingly, staff would be exposed to daylighting cues from artificial sources and experience normal circadian rhythms.

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[1] The responses from the staff of Mercy Regional Medical Center were offered voluntarily to assist in gathering personal experience of the circadian rhythm. The results, as presented in this report, are not meant to evaluate the state of alertness or competency of any employee, nor are they intended to express judgment on the working conditions of this facility.

Table of Contents

List of Figures

List of Tables

Acknowledgements

I would like to express my thanks to my major professors Fred Hasler and Russ Murdock. Their ideas, advice and continuous support have helped me to get the most out of my architectural engineering studies. Both in and out of the classroom, they have helped me to grow as a student and personalize my degree. I would also like to thank professor Kimberly Kramer, the final member of my masters committee, for her support.

Additionally, I owe special appreciation to Crystal Bryant-Kearns and the staff of Mercy Regional Medical Center. Without their participation in my survey, I couldn't have gathered the personal observations of healthcare providers to support my research. It was also invaluable to see the lighting conditions in a hospital space so that I could better understand my topic.

Finally, I have the deepest gratitude to my family and friends. They are the ones who have been by my side since I started school and who encouraged me in pursuing my graduate studies. Their love and unfailing support have always given me confidence and led me to achieve my dreams. For all this and so much more, I especially thank my mom Betsy, my Dad Mark, and my little sister Becky.

Chapter 1 - The Circadian Rhythm and How it Affects Us

The most valuable resource of any facility is its staff. In a healthcare environment, this is especially true. Healthcare employees are responsible for the patients they see and consequently, their tasks are of the utmost importance. To assist these individuals, working conditions must be conducive to achieving top performance of these tasks, especially patient care. Arguably one of the greatest advantages that a working environment can give a healthcare provider is quality lighting. Quality lighting not only provides proper task illumination, but it manipulates the circadian rhythm of those exposed to it to promote better health and performance.

What is the Circadian Rhythm?

"Circadian" derives from the Latin words "circa," meaning around, and "diēs," meaning day; in other words, "around a day" ("Circadian"). This revolution around a twenty four hour period is the defining characteristic of the circadian cycle. At essence, it is the daily human biological clock that synchronizes with the daylight. The circadian cycle, also known as the circadian rhythm, or circadian pacemaker, is medically explained as:

> "... an endogenous near-24-hour oscillator in the suprachiasmatic nuclei (SCN) of the hypothalamus. The cells in these nuclei spontaneously generate rhythms with close to, but not exactly, 24 hours, and are therefore synchronized to environmental time by the 24-hour light-dark cycle" (Pechacek).

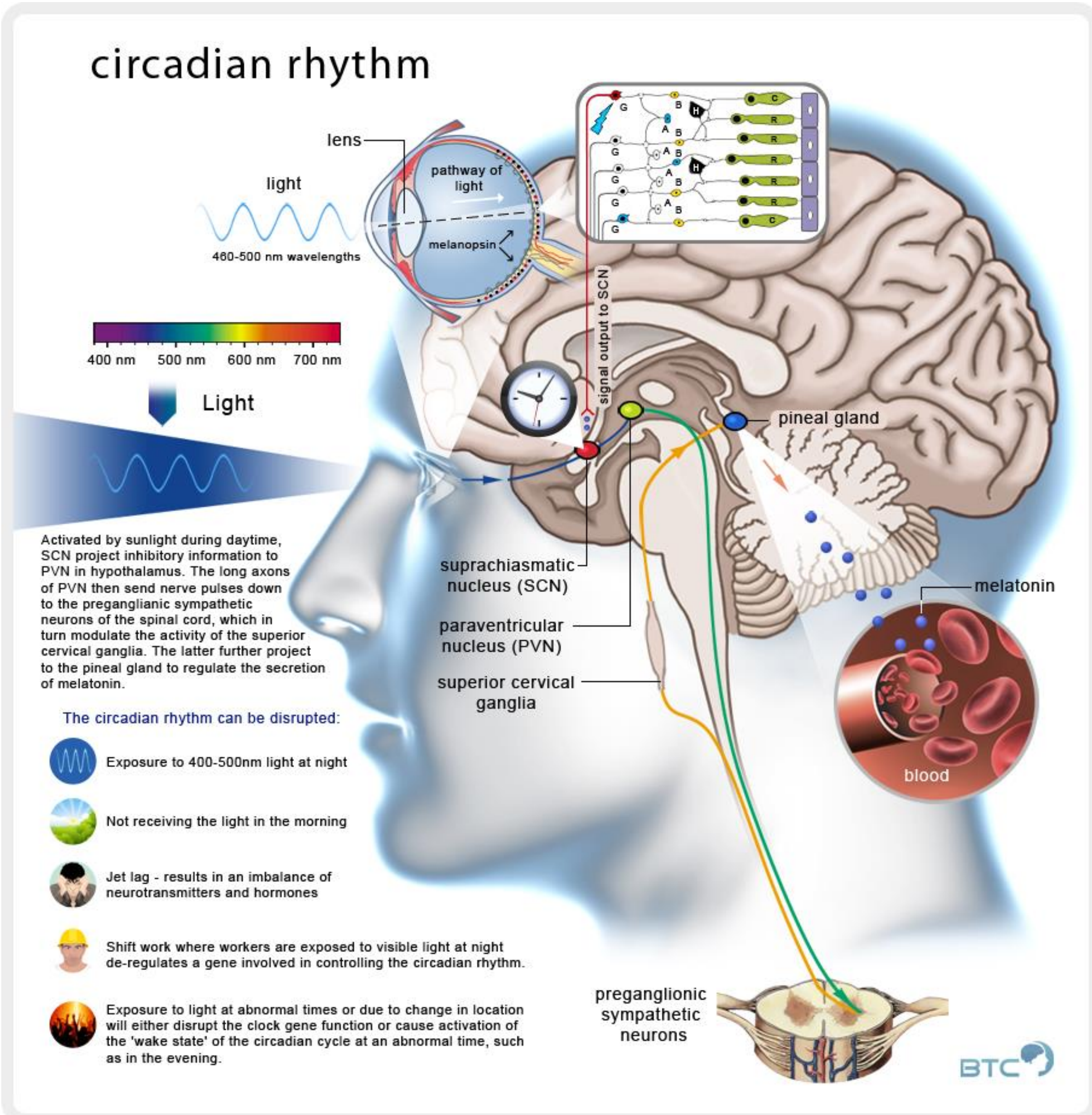
When natural daylight (approximate wavelength of 460nm to 500nm) is received through the eye, it activates an area of the brain known as the suprachiasmatic nuclei, or SCN. The SCN is a transmitter which then outputs a signal that daylight has been detected to another area of the brain known as the paraventricular nuclei, or PVN. Then, via nerve pulses, the PVN relays the signal again to the preganglanic sympathetic neurons of the spinal cord which control the activity of the superior cervical ganglia, or SCG. The SCG then transmits the command to the pineal gland to regulate secretion of the hormone melatonin into the blood ("Circadian Rhythm"). In the end, the secretion or suppression of melatonin controls human sleep/wake urges and impacts the alertness of humans. This process is shown in Figure 1.1 Circadian Rhythm.

Essentially, this is a process by which daylight controls how the human brain operates throughout a twenty-hour period. To explain it more simply, this process is governed by three separate components working together as shown in Figure 1.1 Circadian Rhythm: an internal oscillator, a transmitter, and external oscillators. First is the internal oscillator in the SCN. This is comparable to the pendulum in a grandfather clock; as the color temperature of daylight (discussed in Chapter 2) received by the SCN changes with passing time, the oscillator marks the shifting patterns of the body because the cells of the nuclei generate with a twenty-four hour period. Secondly, hormones are an important component of the circadian system, specifically melatonin which acts as a transmitter. As melatonin travels in the bloodstream throughout the body, it relays information provided by the daylight signals of the SCN about the time of day depending on whether it is being suppressed or secreted. This prompts bodily reaction to revolving circadian time; suppression prompts wake signals while secretion prompts sleep signals. Controlling these other two components is the final piece of the circadian system, external oscillators. External oscillators are factors outside the human body that act as stimuli to the SCN and describe the information to be transmitted by melatonin. The most important external oscillator is the light-dark cycle. As the color temperature of daylight changes from morning (high temperature, cool appearance) to evening (low temperature, warm appearance) and into night, signals are sent to the SCN. This continually resets the internal oscillator, the SCN, to its twenty four hour period and governs the proper suppression or secretion of melatonin for the time of day (Joseph). To conclude, the light in a twenty four hour period controls the body's reactions and operation (as described in the next section) at any given time. This natural cycle of daylight and darkness is approximately twenty four hours in length so the human circadian rhythm is also set to a twenty four hour cycle.

Figure 1.1 Circadian Rhythm

Electronically published by the Brain Treatment Center of Asia ("Circadian Rhythm").

Permission included in Appendix C – Permission 2.

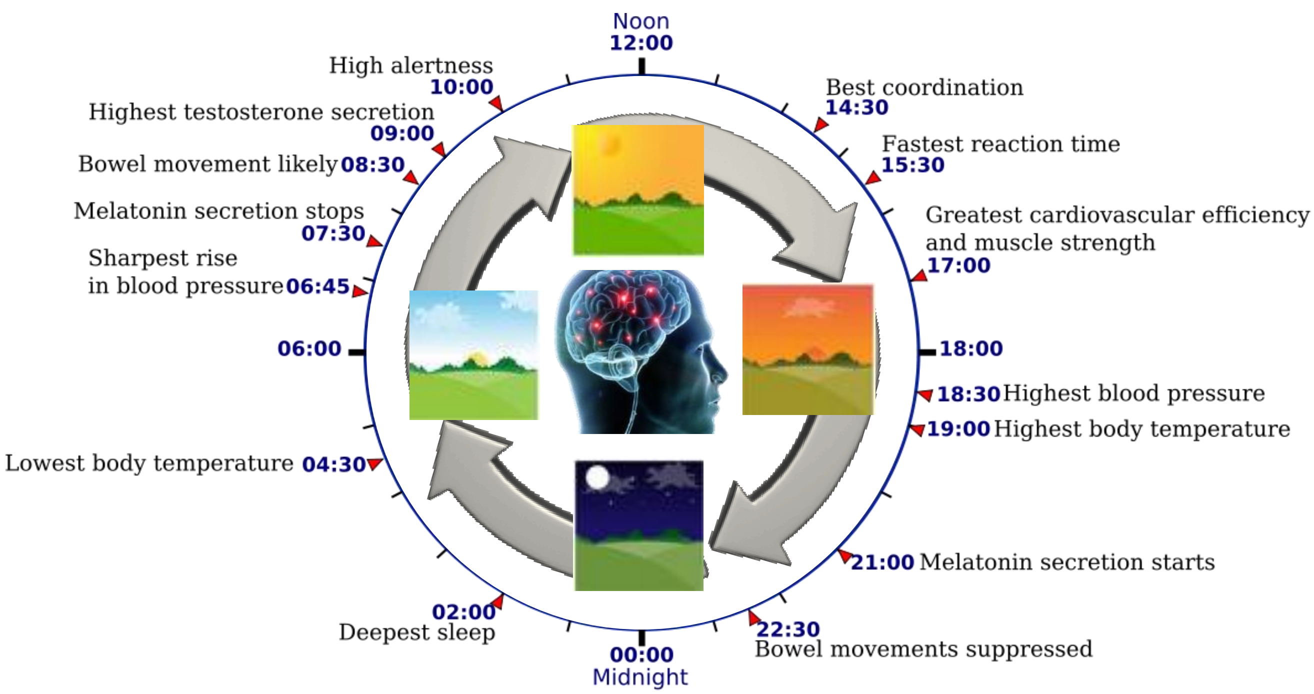


Physiological Impacts of the Circadian Rhythm

The most noticeable impact of the circadian rhythm is the control that it exerts over human physiological processes. Melatonin is the hormone that regulates energy and alertness. If melatonin is being suppressed, one will feel awake and alert; if melatonin is being secreted, one will feel the urge to sleep. As shown in Figure 1.2 Biological Clock Human, different times throughout a day are related to different levels of melatonin secretion or suppression in the body. The level of melatonin secretion or suppression prompts different physiological reactions that are linked to times. These include bowel movement likelihood and testosterone secretion in the morning, as well as improved coordination and reactions, increased cardiovascular efficiency and muscle strength, and heightened blood pressure in the afternoon (Ray).

Figure 1.2 Biological Clock Human

Adapted by Michelle Gutknecht from an image electronically published by the National School of Biological Sciences, Royal Holloway University of London (Ray).



For the average times of day shown in Figure 1.2, when melatonin secretion stops at 7:30 A.M., it is an indicator to wake up. In the following hours, the body prepares for the day and reaches its highest level of alertness at 10:00 A.M. Following this, the afternoon brings improved coordination and reaction time. Finally, at 21:00, melatonin secretion starts, telling the body that it is time for sleep. Then, throughout the night, processes are slowed or halted to promote rest. For most people who work a typical day shift, this circadian cycle meshes with the requirements of their work day. Their body "alerts" them to wake up in a timely manner, then improved function enables top performance throughout the shift. By the onset of night, the body's processes have slowed to encourage a full night's sleep (Pechacek). This is an idealized daily routine.

However, there are many individuals whose natural circadian rhythm is contrary to that imposed by a job or other responsibilities. For employees who work the night shift, it is impossible to mesh their daily routine with the natural cues being provided by their bodies and their surroundings. This can lead to any number of harmful side effects. One prime example of this is the mixed effects of wakefulness and drowsiness. Because the circadian cycle prompted by the external environment of night-shift workers is contrary to the requirements of their working shifts, the hormones that would typically keep a person awake during the day now act to prevent sleep when they return home from work each morning. Likewise, normal circadian rhythm that induces sleep at night would work to prevent night shift employees from being fully alert (Joseph). Though employees in the healthcare industry are especially susceptible to this because healthcare facilities require 24-hour staff, employees in any industry that requires a night shift can experience the same circadian disjoint and consequences.

Because the suppression and secretion of melatonin induced by the circadian system exerts so much control over the body's physiological processes, its disruption can lead to serious health issues. Some of these include gastrointestinal complications, heart disease, menstrual problems, infertility and loss of libido (Van Reeth). All of these are damaging enough in their own right, but they can also be coupled with psychological issues.

Psychological Impacts of the Circadian Rhythm

In addition to the physiological impacts that are controlled by the circadian rhythm, all night shift employees, regardless of industry, are very vulnerable to psychological impacts that can result from a disrupted circadian cycle. Some of these are direct relationships. For example, someone who works the night shift and suffers from a circadian disruption would be unable to enjoy a normal social life. Their work hours would prevent typical social interaction and the decreased alertness accompanying circadian mis-synchronization would inhibit other social occasions. This causes many individuals to feel dissatisfied in both their work and personal lives, often leading to depression (Van Reeth).

Just as the activity of the brain and production of hormone controls physiological reactions, the circadian cycle also controls other chemical stimuli that regulate mood. In the article "How Might Circadian Rhythms Control Mood? Let me Count the Ways..." Colleen A. McClung discusses several of these chemicals. The first are proinflammatory cytokines which are thought to be linked to depression, "...genetic or environmental disruptions of circadian rhythms lead to a proinflammatory response in the brain that alters monoamine signaling, SCN function and hippocampal neuroplasticity, ultimately leading to a depression-like state" (McClung). These chemicals, which are stimulated by a disrupted circadian cycle, trigger other disruptions throughout the body which leads to symptoms of depression. Additionally, plasma ghrelin and leptin both operate on a twenty-four hour circadian period. These are linked to the reward center in the brain so a disruption in the circadian rhythm, and therefore a disruption in ghrelin and leptin, are associated with increased stress and heightened anxiety.

When chemical stimuli in the body aren't properly aligned with the twenty four hour circadian cycle, depression and anxiety are two of the psychological impacts. However, daylight or artificial lighting that aids circadian synchronization can combat this. Participants in numerous studies have revealed that they are happiest in spaces that they perceive as being brightly lit and that daylight is the preferred source for this light. Different studies have included participants of widely varied backgrounds; all ages of males and females, from occupations ranging from students to businessmen. Specifically, one study of Turkish nurses showed that they were exposed to less stress and were more satisfied at work when exposed to daylight at least 3 hours per day. Further, when the extent of daylight in the facility was increased, forty-three percent reported that the change had a very positive impact on their work life and twentyseven percent reported a positive impact on their work life (Joseph). This demonstrates the important psychological connection that daylight has to mood. Staff who are regularly scheduled for night-shift duties do not have access to daylight. Therefore, they do not have the increased positive outlook on their work life that those with day lit work places do. Coupled with a disrupted circadian cycle, these workers are susceptible to psychological difficulties. It can further be concluded that artificial lighting able to mimic daylighting to promote circadian synchronization would have the same positive effect as real daylighting.

To further support the importance of daylighting to circadian and psychological well-being, Kevin Van Den Wymelenberg reports in his Architectural Lighting magazine article entitled *The Benefits of Natural Light* that "Overall, the available research suggests that a successful daylighting design – one that factors in taming glare and solar heat gain – is likely to improve worker satisfaction, mood and productivity" (Van Dem Wymelenberg). From these studies, the importance of daylight is apparent. If no daylight is available, the circadian rhythm becomes misaligned and employees are likely to experience less satisfaction, decreased morale and lower productivity than employees in a day lit environment. Though daylight cannot be made available to workers on the night-shift, it is thought that artificial lighting strategies that promote circadian health could reduce the physiological and psychological problems faced by these employees as a result of their disrupted circadian rhythms.

Chapter 2 - The Connection Between Lighting and the Circadian Rhythm

The circadian rhythm is governed by the brain's interpretation of light experienced throughout a day. The human body is programmed to respond to the light-dark cycle which thereby controls physiological and psychological reactions. Because they are so distinct, light color (CCT) and the time of day are two interrelated components that are especially important for the synchronization of the circadian rhythm to the natural environment.

In order to observe this impact of lighting on the circadian rhythm, and to supplement research with personal findings, healthcare providers were surveyed to investigate their perceived alertness throughout a typical working shift. The goal of this effort was to understand the differences between day shift employees and night shift employees and make a connection to the lighting available during these time periods.

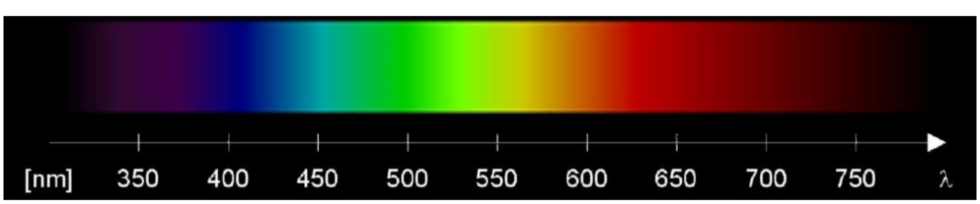
Light Color and Time of Day

Time of day is easy to quantify. It is accepted to be the number of hours that have passed since the acknowledged start of a day; midnight. Visible light color, however, is a little less straight forward. Light color deals with the perceived appearance of a spectral distribution of light. Light from any source is emitted as electromagnetic radiation in specific wavelengths, measured in nanometers. When these wavelengths are interpreted by the human eye, they are perceived as color (MacEvoy). Figure 2.1 Visible Continuous Spectrum 2, shows the relationship between wavelength and color.

Figure 2.1 Visible Continuous Spectrum 2

Adapted by Michelle Gutknecht from an image electronically published by Maite Lacarra and Ariel Majcher of the EU-HOU (Lacarra).

EU-HOU is the European Union Hands on Universe collaboration of teachers and scientists.



Different wavelengths, or different colors of light, are also perceived to be more or less bright than one another. In looking at Figure 2.1 Visible Continuous Spectrum 2, the eye is drawn to the area of the spectrum between about 500nm and 560nm that appears to be bright green. This is because the eye perceives these colors to be "brightest." As the eye travels to the edges of the visible spectrum through, at 350nm and 800nm, it is difficult to distinguish any difference between the color presented by the wavelength (violet or red) and the black border of the visual. This demonstrates the diminished brightness that is perceived from these wavelengths of light. The connection between wavelength, color, and brightness is therefore a very influential property to the human circadian rhythm.

In discussing the color of light, it is also important to understand the difference between the perceived color of light based on its wavelength and the color temperature or correlated color temperature (CCT) of light. Color temperature of light is a numerical measurement of its color appearance. From IES, "It is based on the principle that any object will emit light if it is heated to a high enough temperature and that, as the temperature increases, the color of the light will change along with the temperature" ("Color"). So, this is the temperature, in Kelvin (K), to which something must be heated to produce the thermal radiation and color that approximates the spectrum of radiation absorbed by a black body radiator at the same temperature. This measure is used for light sources, like incandescent, that are physically being heated, and for daylight which correlates to the thermal radiation of the sun. Correlated color temperature is a rating of a light source that is not being physically heated. It compares the perceived color of the source to the surface temperature (in Kelvin) to which an ideal black body radiator would have to be heated to emit the same color. This comparison then enables a light source to be identified by a temperature that corresponds to its perceived color. Light sources that have a correlated color temperature of over 5,000K are perceived as being a bluish-white color and are considered *cool* light sources (despite their high color temperature). On the other end of the spectrum, light sources with a correlated color temperature of 2,700K to 3,000K are perceived as being yellowish white to red and are considered *warm* light sources (despite their lower color temperature) ("Color"). In order to understand more fully understand Kelvin and correlated color temperature, Table 2.1 Color Temperature of Various Light Sources provides the color temperature of multiple common light sources.

Table 2.1 Color Temperature of Various Light Sources

Adapted by Michelle Gutknecht from an image electronically published by Bruce MacEvoy entitled "Correlated Color Temperature for Common Illuminants and Light Sources." (MacEvoy).

Temperature	Source
1,700 K	Match Flame
1,850 K	Candle Flame Sunset / Sunrise
2,000 K - 3,300 K	Incandescent Lamps
3,000 K	Soft (or Warm) White Compact Fluorescent Lamps
3,200 K	Studio lamps Photofloods
3,350 K	Studio "CP" Light
4,100 K - 4,150 K	Moonlight
5,000 K	Horizon Daylight
5,000 K	Tubular Fluorescent Lamps Cool White / Daylight Compact Fluorescent Lamps (CFL)
5,500 K - 6,000 K	Vertical Daylight Electronic Flash
6,200 K	Xenon Short-Arc Lamp
6,500 K	Daylight Overcast Sky
6,500 K - 10,500 K	LCD or CRT Screen
15,000 K - 27,000 K	Clear Blue Poleward Sky

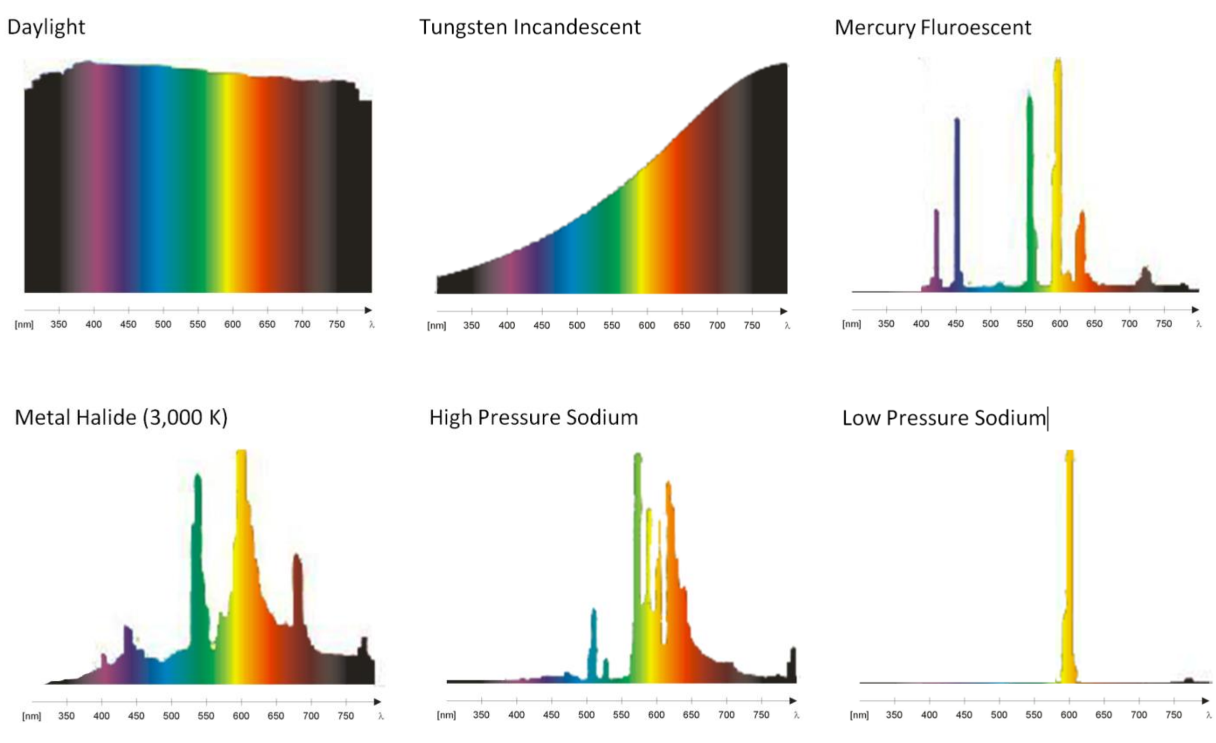
When the sun rises in the morning, it primarily emits short wavelength light in the blue spectrum. This is perceived as a 'cool' light color. Following sunrise, the Kelvin color temperature of sunlight shifts, changing from a 'cool', blue light to a 'warmer' amber light as the day progresses through afternoon and evening (Burpee). Though not prominently noticeable in a visual sense, this change can be perceived by the optical photo sensors that control the circadian rhythm. Inherently, the brain connects cool light to morning while is connects warmer light to later times in the day. Hence, cool light prompts physiological and psychological responses indicative of morning (as described in Chapter 1), while warm light promotes afternoon and evening responses

Common artificial lights, however, emit a static spectrum of light. Typical fluorescent or incandescent lamps that are the most common in commercial and healthcare settings are capable only of producing a set spectrum of light as shown in Figure 2.2 Spectral Distribution Curve of Various Light Sources. Unlike daylight, which fairly evenly encompasses the entire visual spectrum, a traditional fluorescent lamp has noticeable peaks in the blue and green wavelengths (cool) which combined are greater than its peak in the yellow wavelength. Current fluorescent technology is advancing the correlated color temperature of fluorescent to more closely mimic daylight, but new 3,000 or even 3,500K lamps still cannot capture the full spectral distribution of true daylight. Incandescent, as shown, has a steadily increasing distribution from short (cool) to long (warm) wavelength light ("Color"). Though fluorescent and incandescent are both generally perceived as 'normal' light (because of long experience and acceptance), neither provides a strong impersonation of daylight's spectral distribution.

Figure 2.2 Spectral Distribution Curve of Various Light Sources

Adapted by Michelle Gutknecht from an image electronically published by by IES entitled "Spectral Power Distribution Curve" ("Color").

IES is the Illuminating Engineering Society of North America.



Fluorescent lights, whose color is traditionally perceived to be cool based on its peaks in the blue and green spectrum, approximates the warmth of horizon daylight at 5,000K, as demonstrated in Table 2.1 Color Temperature of Various Light Sources above. Also, incandescent lights are much warmer when compared to vertical daylight, being 3,000K rather than 6,500K. Therefore, each of these sources can be perceived as day light, or evening light. For a night shift employee who had no exposure to daylight, a fluorescent or incandescent working environment would therefore suspend their circadian pacemaker in "evening." As shown in Figure 1.2 Biological Clock Human, the evening is the time at which the circadian system begins to send sleep signals to the body. This is contrary to the demands of a night shift employee's work. When they begin and continue through a working shift, it is imperative to be awake and receiving alerting signals from the circadian rhythm. In a natural progression of morning through afternoon, the circadian cycle would improve reactions, coordination and alertness as discussed in Chapter 1, all of which are important in job performance. Unfortunately, without natural light to reset this rhythm , night shift employees are stuck with a circadian cycle that is contrary to their work requirements, which can lead to difficulties in optimum task performance.

The natural world would contradict the circadian system after leaving a shift as well. A night shift employee who started their shift in the evening would have experienced "natural evening," then worked through "perpetual evening." At the conclusion of the night shift, they would exit the artificially lit environment to morning daylight. Theoretically, the circadian system would then trigger alerting signals which would be contradictory to the sleep need that an employee would need after working a night shift. The employee would never transition naturally from morning to evening and into night with synchronization between their circadian system and the outdoor environment because they worked in an artificially lit space with no access to daylight. This lack of synchronization is what prompts many of the physiological and psychological difficulties discussed in Chapter 1.

The static spectrum emitted by traditional lamps in artificial lighting design fail to reproduce daylight. In this regard, the lack of color change over time (from cool blue morning light to steadily warmer afternoon and evening light) is the most unnatural aspect. Consequently, employees who work without the influence of natural daylight experience disjointed circadian rhythms. The circadian system cannot be synchronized to its twenty-four hour rhythm under traditional artificial lighting designs.

Survey Results

Employees at Mercy Regional Medical Center in Manhattan, Kansas were asked to complete anonymous surveys (as shown in Appendix A) rating their perceived alertness throughout a typical shift. The time periods in question were established for hours 1-4, 5-8, and 9-12 of the shift in addition to the time periods during and directly after breaks and lunch. These time periods were chosen to correlate with benchmarks in a normal circadian rhythm. A typical day shift at MRMC started between 7am and 8am and lasted between eight and twelve hours. The night shift started at 6pm in the evening and continued for twelve hours until 6am the following morning. Assuming that appropriate exposure to the light-dark cycles was available to day shift employees who worked in a day lit environment, it was anticipated that survey participants' responses would reflect normal circadian rhythms. For night shift employees, however, who were not exposed to daylighting cues (or artificial light cues to mimic and reset the circadian rhythm), it was hypothesized that a disrupted pattern of alertness would be established. Surveys were provided and returned voluntarily and results and participation were completely anonymous[2].

Thirty responses were received from the staff of Mercy Regional Medical Center. These included surveys from different areas of the hospital and varied, but similar, working shifts of the day and night staff. The completed surveys were documented and the perceived alertness values tabulated as shown in Table 2.2 and Table 2.3. Following this, a graph was created of both the day staff and night staff responses showing the fluctuation of alertness throughout a working shift. Trend lines of the graphical results were plotted to demonstrate the typical changes in employee alertness throughout an established time period. As described in Chapter 1, changes in alertness should correspond to changes in typical circadian cycle. As shown in Figure 2.3 as compared to Figure 2.5, the healthcare providers working during the daytime shifts at MRMC

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[2] The responses from the staff of Mercy Regional Medical Center were offered voluntarily to assist in gathering personal experience of the circadian rhythm. The results, as presented in this report, are not meant to evaluate the state of alertness or competency of any employee, nor are they intended to express judgment on the working conditions of this facility.

demonstrated a typical rhythm that closely matches an established normal circadian cycle. Conversely, as shown in Figure 2.4 as compared to Figure 2.5, the healthcare providers working during the nighttime shifts demonstrated circadian rhythms that were disjointed from normal.

The survey was used as a tool to establish trends among day and night shift employees. The primary component was the section that asked employees to define perceived alertness as they worked their typical shift. Perceived alertness was rated on a 10 point scale with 10 being defined as "fully alert" while 1 was defined as "not at all." For a twelve hour working shift to be accurately synchronized to a normal circadian cycle, hours 1-4 should demonstrate increasing alertness from the benchmark start of shift alertness as the body suppresses melatonin production. Following, hours 5-8 would indicate a period of declining alertness at the onset of afternoon. Finally, alertness would again increase between hours 9-12 to the final benchmark at end of shift. In this idealized rhythm, a pattern is established. In Tables 2.2 and 2.3 Survey Responses, the section "Alertness by Time (per respondent) indicates the numerical value of perceived alertness that was reported by each employee. By following the increases and decreases established by each individual's responses, it was possible to create a line that would follow the normal circadian curve (if the circadian rhythm was in sync with the natural environment). The averages in this section of the tables indicate the average of all reported alertness values for day or night shift employees at a given time in their shift. Averaging all responses allowed a trend line to be created which showed the overall alertness progression of all employees during the day or night shift. These graphs are included in Figures 2.3 and 2.4.

Additionally, employees were asked to rate their alertness both during and after a break in their shift. Survey responses and discussion with an employee at MRMC confirmed that many employees spend their break time in the restaurant within the facility. Personal observation of this space (included in Appendix B) revealed excellent daylight infiltration both in the restaurant and in the corridors that would lead an employee to this place during break. Based on this observation and circadian theory, it was thought that an employee with a normal circadian rhythm should be more alert following their break than before or during because the body would receive natural daylighting cues to reset the circadian rhythm. Change in alertness is given to see whether each person had become more alert (as anticipated), stayed the same, or become less alert over break. Then the total number of employees who experienced the same change on break was counted and shown to the left of the break time perceived alertness responses.

Next, the reported working shift of each employee is provided to show the time of day that corresponds to their alertness responses for each period of time during the working shift.

Employees were surveyed about their alertness in several different places so that a comparison could be investigated between daylight and artificial lighting in the space to employee alertness in that space. Responses were again rated on a 1-10 scale as described above and compared to the personal observations of space conditions provided in Appendix B. The results of this comparison were not strongly conclusive as the average alertness of all respondents was approximately 8 for each shift during the day shift. However, it is notable that the two spaces to average alertness over 8, the public spaces and patient rooms, are also the two spaces where the most natural daylight was observed. This conclusion cannot be verified by the night shift, however, because the average alertness seemed to be linked to task performance rather than lighting. The three spaces with higher average levels of alertness reported by the night shift employees were patient rooms, procedure rooms, and exam rooms. Each of these spaces would require attention to patients as compared to public spaces and the nurse's station (with lower reported average alertness) which would require attention to transitioning between spaces or paperwork, respectively.

Finally, employees were asked which of multiple factors they thought most affected their perceived alertness at any time. This was included in the survey to find out if employees are aware of the connection between daylight, artificial light and their perceived alertness. The total number of employees who responded affirmatively to each factor was tallied. It was interesting to note that for a number of employees, lighting was not thought to affect alertness as much as other factors. Specifically, day and night shift employees both noted that their type of work and the temperature of their workspace were the top two factors that they believed to impact their alertness. Exposure to natural light was only considered by about half the respondents to be a factor, while brightness was considered by slightly more. Changes in space lighting and light color of the workspace were only thought by about one quarter of the respondents to affect their perceived alertness. As these are some of the most important factors for circadian synchronization, it can be concluded that the average worker does not understand the connection that lighting has to their circadian rhythm nor the ways in which lighting and the circadian rhythm can affect their alertness.

Table 2.2 Day Shift Survey Responses

Provided by the staff of Mercy Regional Medical Center, compiled by Michelle Gutknecht. All alertness is reported on a 1-10 scale with 10 being described as "fully alert" and 1 being described as "not at all." Averages and totaled changes in alertness are provided to demonstrate trends and commonalities between respondents.

Alertness by Time (per respondant)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Average
Start of Shift	3	9	9	10	9	6	7	5	8	7	10	9	6	10	8		10	8	7	8	10	8	7.95
Hour 1-4	9	9	8	10	8	9	8.5	5	10	8	10	9	8	10	9		8	10	8	9	9.5	7	8.67
Hour 5-8	9	9			8	6	8.5	6	8	5	9	8	7	10	6		8	8	8	7	6	6	7.50
Hour 9-12		9				4	6		5			7		10								5	6.57
End of Shift	9	9	7	10	8		9	7	5	6		7	7	10	5		8	8	8	9	6	7	7.63
Average	7.5	9	8	10	8.25	6.25	7.8	5.75	7.2	6.5	9.67	8	7	10	7		8.5	8.5	7.75	8.25	7.88	6.6	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
During Break		9					8	6	7	6		6	7	10	6		9	8		9	7	7	7.50
After Break		9					8	5	9	6		6	7	10	7		10	8	9	9	10	8	8.07
Change in Alertness	None	None	None	None	None	None	None	Less	More	None	None	None	None	None	More	None	More	None	More	None	More	More	More
Shift	8-17	745-20	12-16	12-16	8-1630	7-17	7-19	7-1530	5-1730		9-17		8-1630	8-1130	5-1330	7-13	8-15	8-1630	8-1630	8-1630	8-17	7-17	

Change in Alertness	
None	15
More	6
Less	1

Alertness by Place (per resondant)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Average
Nurse's Station					7	10	8	6		8												9	8.00
Patient Rooms						10	10	6		9												9	8.80
Procedure Rooms							10	5		8												9	8.00
Exam Rooms							10	5		8												9	8.00
Public Spaces	9		9		7		8	6	10	9	9	9	7	10	7	5	9	8	10	9	10	8	8.37

Factors Thought to Affect Alertness	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
Type of Work	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	17
Location of Work	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	7
Consumed Food and Beverages	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	0	1	0	1	1	1	1	12
Brightness of Your Workspace	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	0	1	1	12
Break Time	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	3
Fatigue	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	0	1	0	1	1	1	1	14
Use of Electronics	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	1	1	0	0	1	1	1	8
Changes in Space Lighting	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5
Recent Events	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	3
Weather	0	0	0	0	1	0	1	1	1	0	0	1	0	0	1	0	1	0	0	1	1	0	9
Light Color of Your Workspace	0	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	6
Future Events	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	3
Temperature of Workspace	0	0	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1	0	1	1	14
Exposure to Natural Light	0	0	0	0	1	0	1	1	0	1	0	0	0	0	1	1	1	1	1	0	1	1	11

Table 2.3 Night Shift Survey Responses

Provided by the staff of Mercy Regional Medical Center, compiled by Michelle Gutknecht. All alertness is reported on a 1-10 scale with 10 being described as "fully alert" and 1 being described as "not alert at all." Averages and totaled changes in alertness are provided to demonstrate trends and commonalities between respondents.

Alertness by Time (per respondant)	1	2	3	4	5	6	7	8	Average
Start of Shift	10	10	10	10	10	9	10	8	9.63
Hour 1-4	9	9	10	10	10	9	10	7	9.25
Hour 5-8	8	9	10	9	7	8	9	6	8.25
Hour 9-12	5		9	8	5	4	7	5	6.14
End of Shift	4	7	9	8	5	3	10	4	6.25
Average	7.2	8.8	9.6	9.0	7.4	6.6	9.2	6.0	

During Break	4	6	9	8	9	6	8.0	7.0	7.125
After Break	2	7	9	10	7	6	9.0	7.0	7.13
Change in Alertness	Less	More	None	More	Less	None	More	None	None
Shift	18-6	18-24	18-6	18-6	18-6	18-6	18-6	18-6	

Change in Alertness	
None	3
More	3
Less	2

Alertness by Place (per respondant)	1	2	3	4	5	6	7	8	Average
Nurse's Station	8	9	10	9	9	5	8	7	8.13
Patient Rooms	10	7	10	10	8	9	10		9.14
Procedure Rooms	10	10	10	10	9	9	10	10	9.75
Exam Rooms	10	7		10		9	10	9	9.17
Public Spaces	6	7	9	9	9	9	7	7	7.88

Factors Thought to Affect Alertness	1	2	3	4	5	6	7	8	Total
Type of Work	1	0	0	1	1	1	1	1	6
Location of Work	0	1	0	1	1	0	1	1	5
Consumed Food and Beverages	1	0	0	1	1	1	1	1	6
Brightness of Your Workspace	1	0	0	0	1	0	1	0	3
Break Time	1	1	0	0	1	0	1	1	5
Fatigue	1	0	0	1	1	1	1	0	5
Use of Electronics	0	0	0	0	0	0	0	1	1
Changes in Space Lighting	0	0	0	0	1	0	1	0	2
Recent Events	1	0	0	1	1	0	0	0	3
Weather	1	1	0	0	1	0	0	0	3
Light Color of Your Workspace	0	1	0	0	1	0	1	0	3
Future Events	0	0	0	1	0	0	1	0	2
Temperature of Workspace	1	1	0	1	1	1	1	0	6
Exposure to Natural Light	0	1	0	0	1	0	1	0	3

Figure 2.3 Day Shift Alertness Trends

Provided by the staff of Mercy Regional Medical Center, analyzed by Michelle Gutknecht.

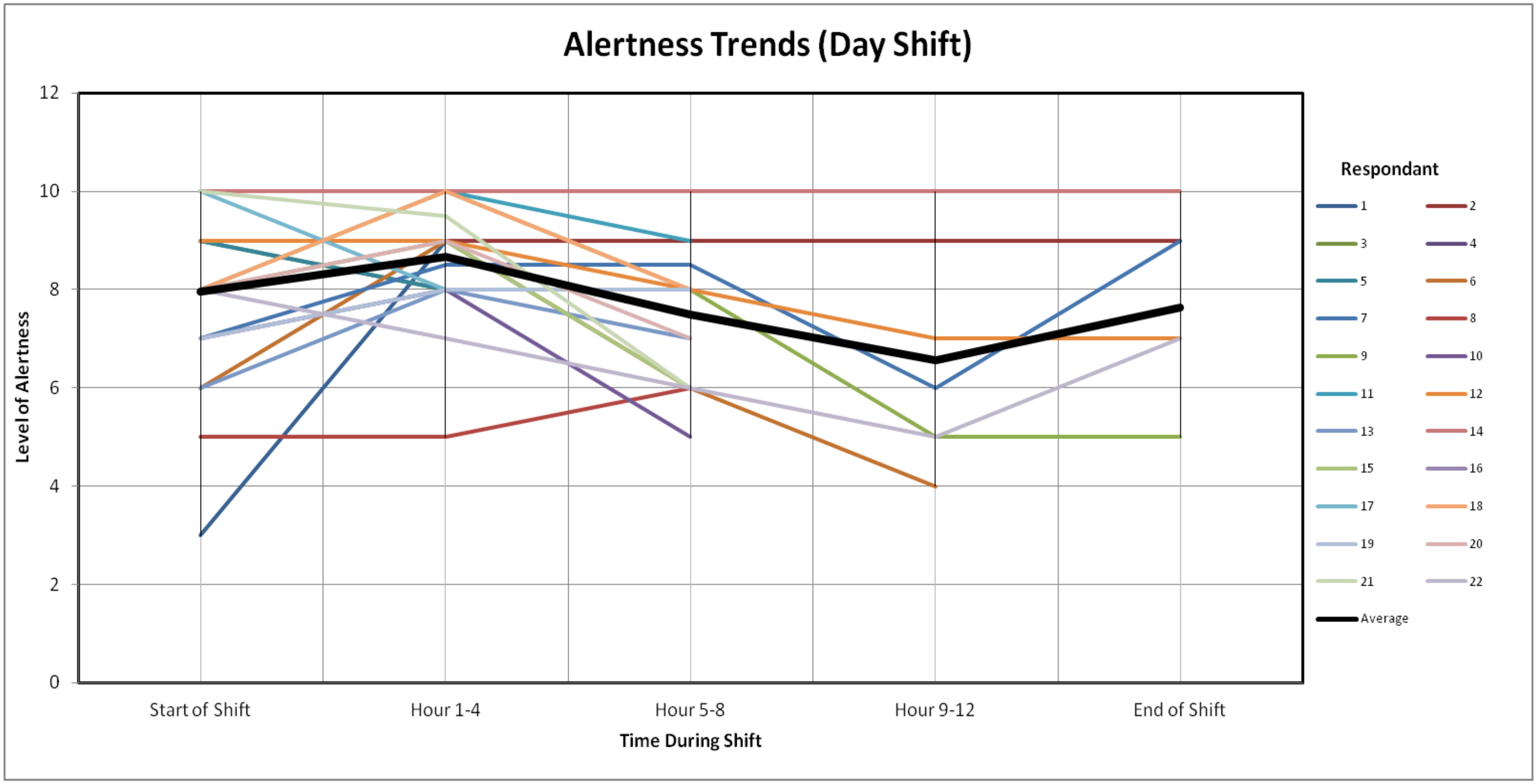


Figure 2.4 Night Shift Alertness Trends

Provided by the staff of Mercy Regional Medical Center, analyzed by Michelle Gutknecht.

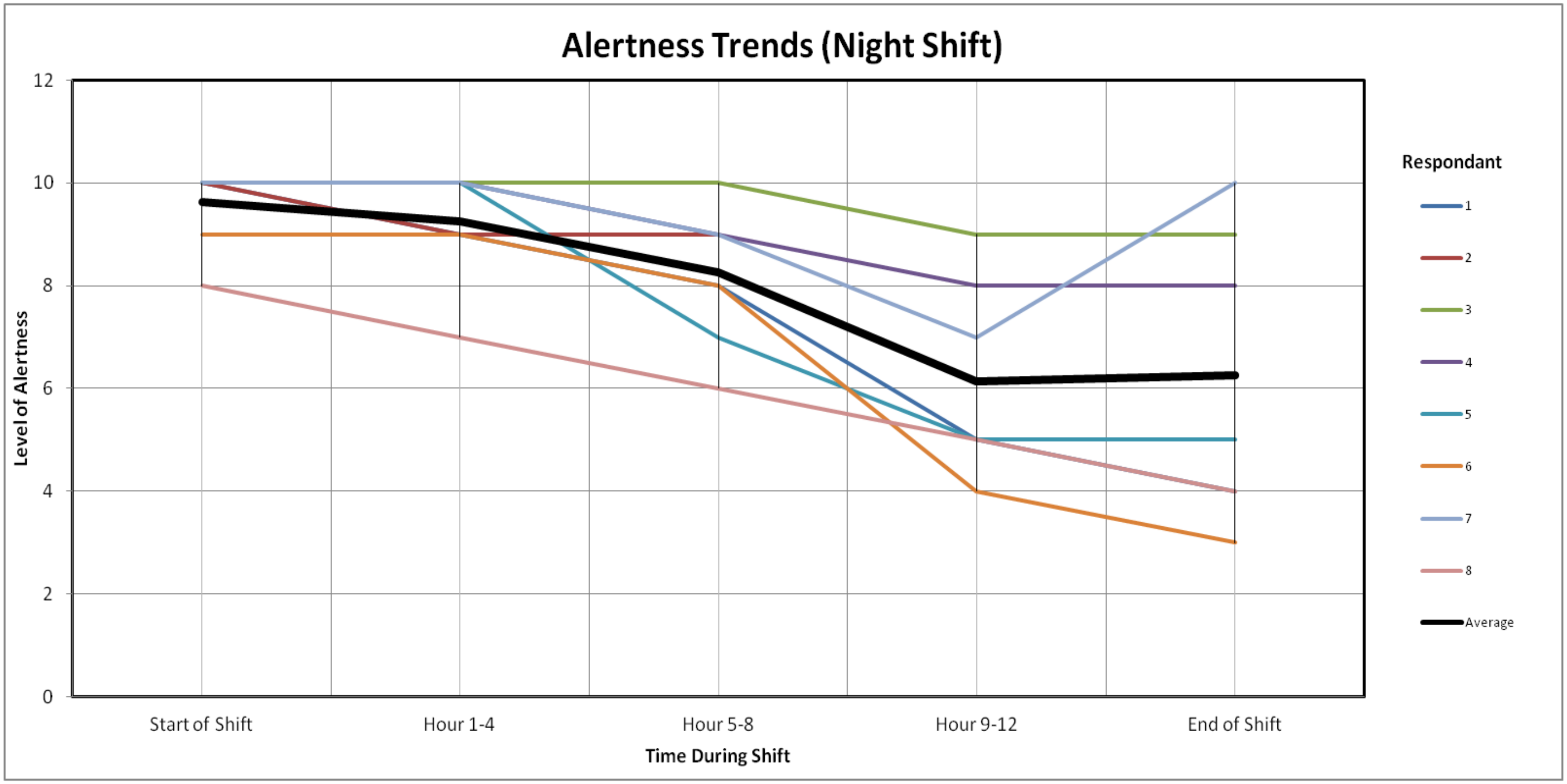
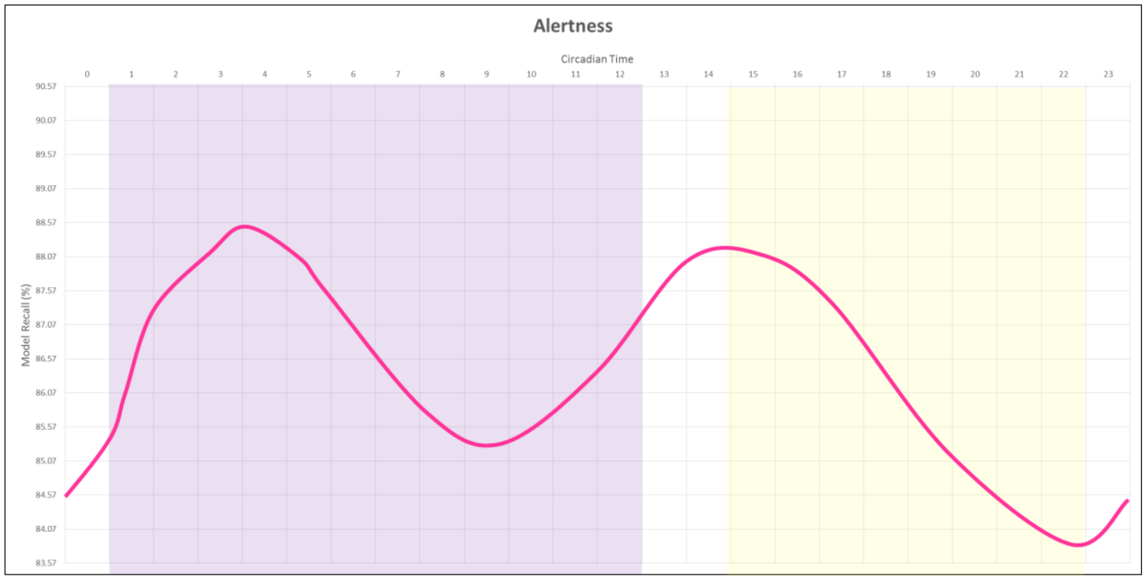


Figure 2.5 Comparison to Normal Circadian Rhythm

Graphic adapted by Michelle Gutknecht from an image electronically published by by SuperMemo ("Sleep Chart"). Comparison by Michelle Gutknecht.



- The continuous pink line represents the trend of model recall percentages and indicates a normal, twenty-four hour circadian rhythm.
- Circadian time 0 corresponds to an individual's wake-up time.
- The purple highlighted box indicates the period of time (circadian hours 1-13) that should correspond to a 12-hour working shift. Hence, the highlighted line within this box shows the circadian cycle that should be followed if an individual's 12 hour work shift is synchronized to circadian time. This matches the circadian rhythm established by alertness survey responses of day shift employees at MRMC.
- The yellow highlighted box represents the time period (circadian hours 15-23) that most closely resembles the circadian cycles established by alertness survey responses of the night shift employees at MRMC.

SuperMemo is a company that was founded in Poland in 1991 and develops software that is "devoted to improving memory, self-growth, creativity, time-management, and speed learning" ("Sleep Chart"). In the course of developing and using this software, SuperMemo has conducted many surveys on the patterns of alertness that correspond to changes in time. This data has further been compared to the circadian cycle so that conclusions could be drawn regarding the effect of the circadian system on alertness and its implications to sleep and memory. One such study is the The Sleep Chart published by SuperMemo which is shown in Figure 2.5 Comparison to Normal Circadian Rhythm and explained as follows:

> "***Alertness (C)*** *graph showing the powerfully biphasic nature of the human circadian cycle. The horizontal axis shows the circadian time, i.e. the time that elapses from phase 0, i.e. the predicted "end of the night" time. The prediction comes from the circadian model employed in SleepChart, and is derived from the sleep log collected in SuperMemo. The pink line is the predicted alertness derived from the same sleep log data using the two-process model of sleep developed for the purpose of sleep optimization in SuperMemo (the model is inspired by similar work by Alexander A. Borbely and Peter Achermann). The alertness is the resultant of the status of the two sleep drive processes: the homeostatic process and the circadian process. The blue dots are recall data taken from an actual learning process in SuperMemo* ("Sleep Chart").

This graph demonstrates the changes in alertness over time for a person experiencing a normal circadian rhythm. From the explanation given by SuperMemo, circadian time 0 on the graph is the time at which a person wakes up in the morning. The blue dots represent responses while the pink line represents the averages attained to create a normal circadian cycle.

In comparing SleepChart to an average work schedule, it can be assumed that an employee's work shift would begin at approximately circadian time 1. Then, as healthcare facilities are structured around a 12 work day, the work shift would end at circadian time 13. This is highlighted in purple on Figure 2.5. For a person experiencing a normal circadian rhythm, their cycle should follow the pink line in Figure 2.5 highlighted within the purple box.

The first section of Table 2.2 Day Shift Survey Responses titled Alertness by Time (per respondent) shows the data collected from day shift employees at Mercy Regional Medical

Center. These reported values of perceived alertness, as provided by MRMC employees for various times during their working shift, were plotted in Figure 2.3 Day Shift Alertness Trends. Each respondent's perceived alertness was plotted as an individual line and an average of all responses for the shift was plotted as a black trend line. Respondents acknowledged that they were exposed to daylight during the course of their working shifts and personal observation of the facility (as described more fully in Appendix B) confirmed the availability of daylight in the spaces mentioned. During the day, patient rooms and public spaces have daylight available through many windows in MRMC. Nurse stations are also exposed to natural light that comes into the interior of the building from windows in patient and public spaces. The plotted curve of surveyed respondents' alertness levels very closely matched that of the normal circadian rhythm. Starting at "Start of Shift" in Figure 2.3 and continuing through hours 1-4, 5-8, 9-12 and concluding with end of shift, employees cited increasing, then decreasing, and then increasing levels of alertness as shown by the black 'Average' line on Figure 2.3. This corresponds accurately to a normal circadian curve defined in SleepChart shown in Figure 2.5.

The results from the night shift, however, were much different. The night shift employees each reported a shift that started at 6pm and ended at 6am (with one exception who ended the shift at midnight). As the normal circadian rhythm graph is structured with circadian time 0 being the time of wake up (5pm based on the reported shift), a night shift employee should still follow the same pink curve highlighted in purple from hours 1-13 on SleepChart that the day shift employee experienced. The survey respondents should have cited increasing, then decreasing, then again increasing levels of alertness (like the day shift employees reported) as their shift progressed from 6pm through the night to 6am. The survey responses provided by the employees of MRMC are shown in the section of Table 2.3 Night Shift Survey Responses titled Alertness by Time (per respondent) and plotted in Figure 2.4 Night Shift Alertness Trends. Each individual's reported perceived alertness and corresponding alertness graph failed to match the normal circadian curve. For night-shift employees, alertness was highest at the start of shift and declined through hours 1-4, 5-8, 9-12 to the end of shift. This does not at all resemble the purple highlighted curve in SleepChart that should be experienced for people with a normal circadian cycle. It more closely resembles the downward slope highlighted in yellow on Figure 2.5 that represents the circadian cycle at circadian hours 15-23. During these hours (considering a wake up time of circadian hour 0), the person should conceivably be sleeping at the end of the night.

This demonstrates the contradiction that is faced by night shift employees. While their circadian system is triggering sleep urges, the demands of their work require wakefulness and task attention.

For employees working the night shift, daylight is not available during their working hours. Survey respondents acknowledged no daylight exposure during their overnight shift or admitted only seeing daylight during sunrise or sunset (sunrise and sunset were disregarded as daylight exposure because it was only available for such a time period within the 12 hour shift). As demonstrated by the survey responses that showed disjointed circadian curves for night shift more indicative of nocturnal sleep than work alertness, research linking daylight and the circadian system is strongly supported. This is enhanced by the responses of the day shift employees who received natural daylight exposure during their working shifts and showed changes in alertness over time that corresponded to circadian rhythms well synchronized to their natural environment. From this survey of MRMC, it was shown that working only in traditional artificial lighting conditions without daylight exposure (as the night shift did), is a cause of circadian disjoint.

Furthermore, circadian philosophy dictates that most people tend to feel revived and therefore more alert after taking a break from their work day. As shown in Table 2.4 and graphed in Figure 2.6, this trend was true for day shift workers, a majority of whom claimed to feel more alert after their break. As most of these employees also stated that they were exposed to daylight over their break, whether through windows or by going outside, it again can be supported that daylight enables synchronization of the circadian rhythm.

On the other hand, night shift employees who were asked the same question, mostly responded that they felt the same, or even less alert after taking a break during their shift. As shown in Table 2.5 and graphed in Figure 2.7, this trend is contrary to what was experienced by the day shift. Without the stimulus of daylight acting during break time, the circadian cycle was unable to be affected. Employees continued in the same downward alertness trend as shown in Figure 2.4. Because the artificial lighting conditions experienced during their break were the same as those during their work shift, their alertness trends did not change. This is in strong support of the theory that daylight, or artificial light with the ability to mimic the changing color temperature of daylight, is necessary for circadian stimulus.

Table 2.4 Day Shift Change in Alertness Over Break

Provided by the staff of Mercy Regional Medical Center, compiled by Michelle Gutknecht.

Respondant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Avg.
During Break		9					8	6	7	6		6	7	10	6		9	8		9	7	7	7.50
After Break		9					8	5	9	6		6	7	10	7		10	8	9	9	10	8	8.07

Figure 2.6 Day Shift Break Trends

Provided by the staff of Mercy Regional Medical Center, analyzed by Michelle Gutknecht.

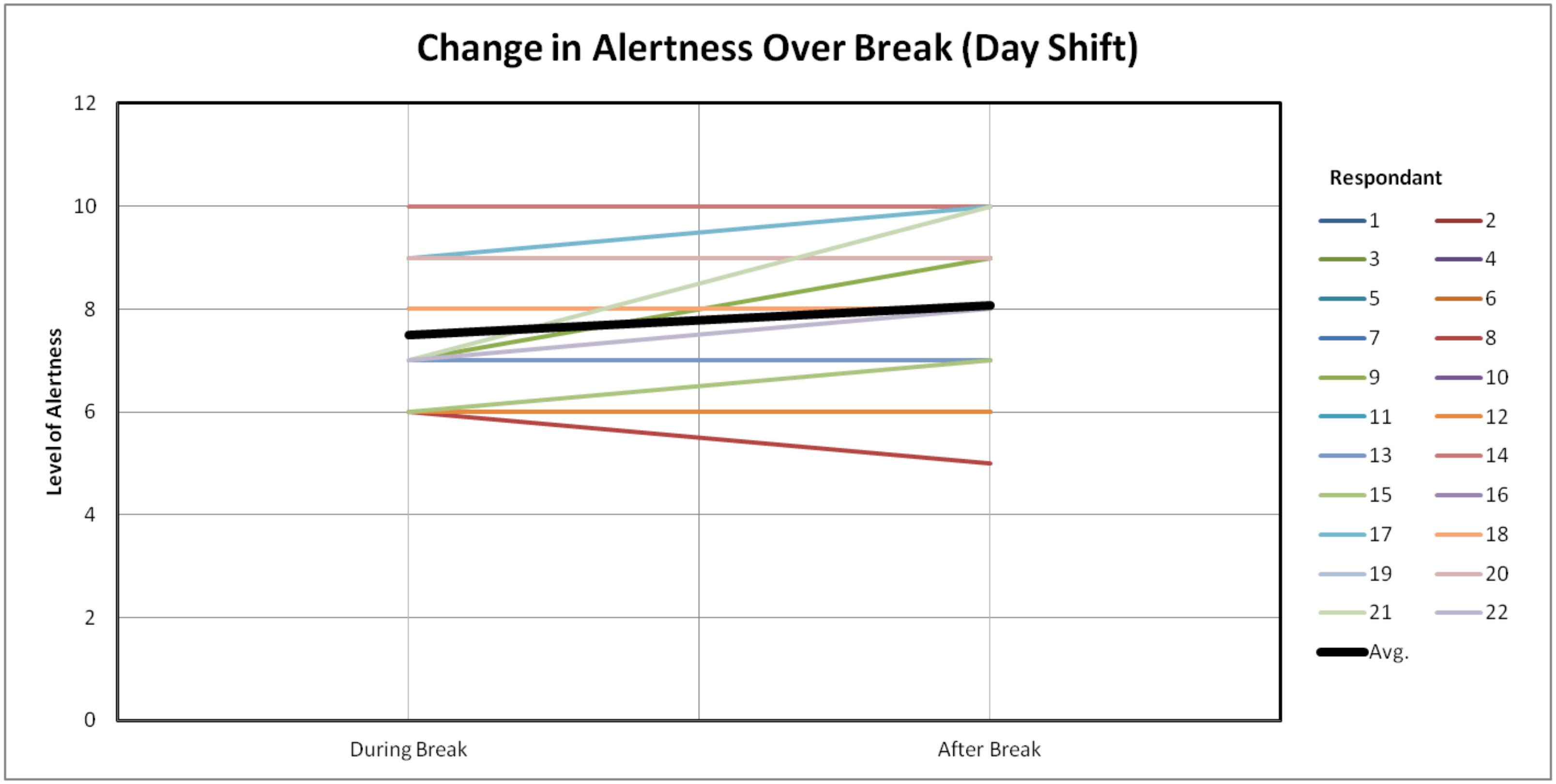


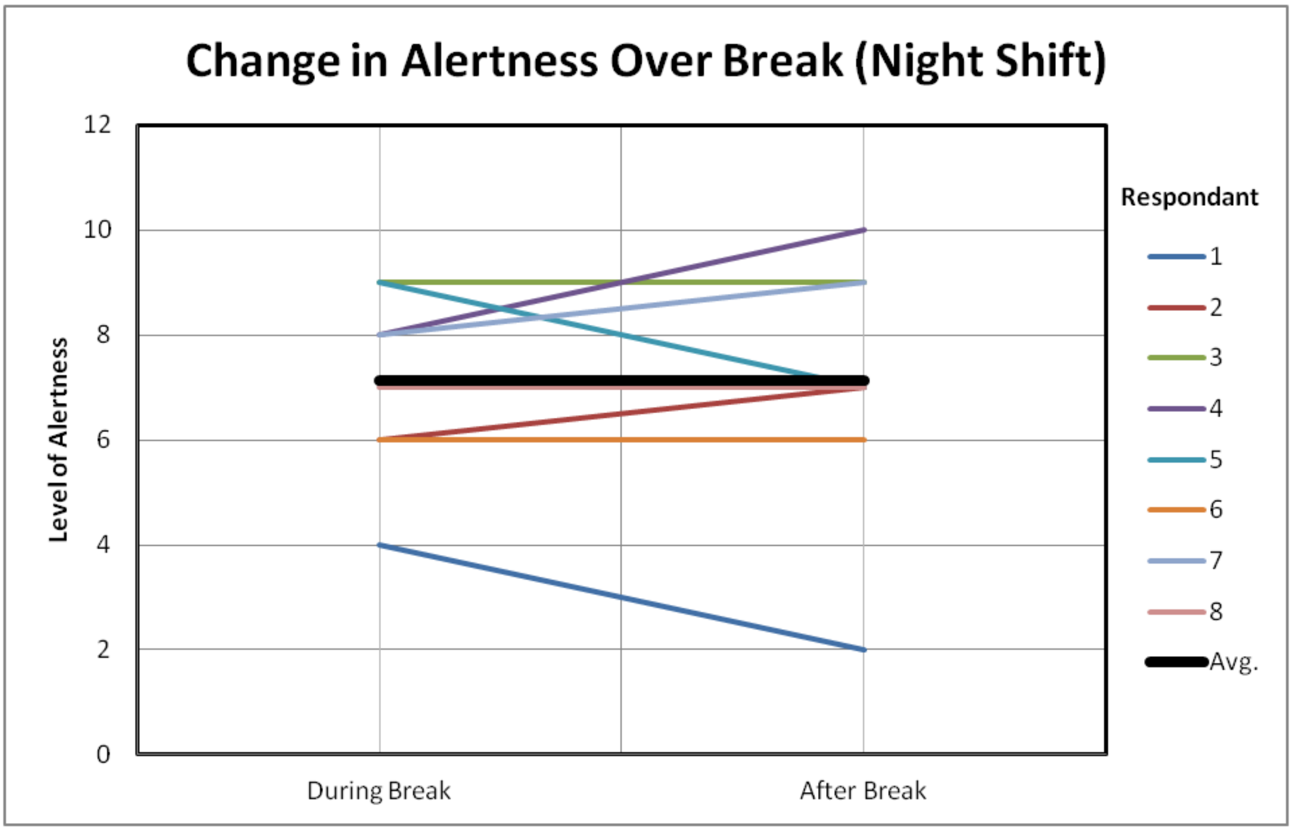
Table 2.5 Night Shift Changes in Alertness Over Break

Provided by the staff of Mercy Regional Medical Center, compiled by Michelle Gutknecht.

Respondant	1	2	3	4	5	6	7	8	Avg.
During Break	4	6	9	8	9	6	8	7	7.13
After Break	2	7	9	10	7	6	9	7	7.13

Figure 2.7 Night Shift Break Trends

Provided by the staff of Mercy Regional Medical Center, analyzed by Michelle Gutknecht.



Chapter 3 - Implementation of Circadian Lighting Design in Healthcare

In any working environment, lighting is particularly important. Sufficient illumination levels enable task performance and promote productivity and mood amongst employees. In a healthcare environment, this is especially true. As presented in Chapters 1 and 2, lighting is the most important stimulus for the circadian rhythm, which, in turn, is a primary influence in the physiological and psychological responses of individuals.

Lighting, especially that provided by natural daylight, is the influence that regulates the circadian rhythm to a set twenty four hour cycle and enables the body to function as normal. For people who are unable to experience natural daylighting in their normal routine, it becomes necessary to synchronize their circadian cycle in other ways. Traditional artificial lighting strategies are unable to reset the circadian rhythm but there are other lighting techniques that can be applied. Circadian rooms and variable lighting systems are two strategies that have been used to promote better circadian synchronization among night shift employees.

Circadian Rooms

As light is the primary factor that regulates the circadian cycle, light is also the most important tool to re-synchronize the circadian rhythms of those who are disjointed from normal. Unfortunately, for night shift employees in healthcare, it is impossible to accomplish this with daylight alone. Because the work schedules of these individuals aren't scheduled to allow daylight access during their shift, it becomes important to provide circadian stimulus in another fashion. One way to do this is to incorporate circadian rooms into the design of healthcare facilities.

A circadian room is a space that is designed to provide specific, circadian influencing lighting to its occupants. As presented by Rick Morrison in his speech *Circadian Rhythm and Lighting Design Case Study in the Queensland Children's Hospital,*

> "In 2001, Dr. George Brainard's team at Thomas Jefferson Medical University discovered a photo receptor in the human eye, responsible for reacting to light and controlling the production of melatonin. Their research showed that light in the range of

447-484 nm (nanometers) is responsible for suppressing melatonin production and shifting circadian rhythms" (Morrison).

These findings showed that a specific band of cool, blue light could be used to suppress melatonin production, a key chemical that regulates sleep signals. Hence, by exposing healthcare employees to this specific light, the circadian cycle of night shift workers can be reset.

This was supported in a study by Dr. Jeanne F. Duffy and Dr. Charles A. Czeisler. In their publication "Effect of Light on Human Circadian Physiology," Duffy and Czeisler explained that they exposed individuals to monochromatic light of either 460nm or 555nm. After 6.5 hours, the individuals who had received 460nm light rated themselves as more alert than those who had received 555nm light. This was backed up by the researchers who noted "faster reaction times and fewer lapses of attention" in the group that had been exposed to short wavelength light (Czeisler).

Taking the results of these studies, it could be concluded that short wavelength blue light will help to synchronize healthcare night shift workers to a normal circadian rhythm. By designing a healthcare facility with specific "circadian rooms" that are lit with short wavelength blue lamps, night shift employees could benefit from blue light exposure and reset their circadian systems. A circadian room would be used just as a break room. When a night shift employee went on break, they would sit in the circadian room and the ambient short wavelength blue light would re-synchronize their circadian system. Research cited by Rick Morrison shows that even the short exposure (approximately 20 minutes) that would be available to an employee on break, would be a major benefit to proper circadian health.

What makes a circadian room effective is the same concept that lies behind bright light therapy. Bright light therapy is often used to treat circadian disorders including delayed sleep phase syndrome (DSPS), non-24-hour sleep-wake syndrome, and advanced sleep phase syndrome (ASPS). All are conditions that shift a person's sleep cycle away from what is considered socially normal. Often, people with DSPS are unable to fall asleep until long after midnight and are then unable to rise in the morning for school or work. Though this sounds like the life of a college student, it is considered a circadian disorder when the delayed sleep phase negatively affects a persons' ability to function in society. ASPS is the opposite. People with ASPS are unable to stay awake in the evening but are awakened extremely early by their circadian cues. In order to treat these conditions, bright light of up to 10,000 lux is directed at a person's eyes for 30-90 minutes; in the morning for DSPS and non-24-hour sleep-wake syndrome, and in the evening for ASPS. Each treatment of bright light gradually shifts an individual's sleeping pattern until it matches the societal norm ("Bright Light Therapy"). Similar to this treatment, each exposure of short wavelength blue light administered to healthcare facility employees during their break time in a circadian room would gradually shift their circadian cycle until it matched a normal rhythm. This would allow their body's circadian system to match, rather than fight, the requirements of their night shift work.

Though this strategy has yet to be universally employed, Rick Morrison discussed its implications on a project being designed for the Queensland Children's Hospital. Using the concept of room specific lighting, the facility will incorporate 5 different rooms on separate floors for night shift employees. These rooms will be incorporated with the staff lounges. Theoretically, combining a circadian room with a space that is already comfortable and well-known to employees, like a staff lounge, it is highly likely that it will be used.

As previously discussed, research has proven that light in the 447-484nm wavelength is most impactful in resetting circadian rhythm. This is known as the circadian stimulus wavelength. Furthermore, it was important to determine what intensity of light would be most effective in resetting the circadian system. Morrison showed that the illuminance of daylight can vary greatly depending on conditions as shown in Table 3.1 Light Level Variations in Daylight. So, even though the team knew that providing light with the same illuminance as daylight would be most effective, they still had to decide which daylight illuminance to use.

Table 3.1 Light Level Variations in Daylight

Published electronically in Rick Morrison's "Circadian Rhythm and Lighting Design Case Study in the Queensland Children's Hospital" (Morrison).

Illuminance	Example
120,000 lux	Brightest sunlight
110,000 lux	Bright sunlight
20,000 lux	Shade illuminated by entire clear blue sky, midday
10,000 - 25,000 lux	Typical overcast day, midday
<200 lux	Extreme of darkest storm clouds, midday
400 lux	Sunrise or sunset on a clear day (ambient illumination).
40 lux	Fully overcast, sunset/sunrise
<1 lux	Extreme of darkest storm clouds, sunset/rise

40 lux was determined to be the effective illuminance that would reset the circadian system with 80 minutes of exposure. This exposure time, however, was too long to be practical for a night shift employee. After further calculation , the team designing Queensland Children's Hospital doubled the light level to 80 lux so that only 20 minutes of exposure would be sufficient for realignment purposes. The team decided that "The reason for developing circadian spaces in the hospital was to provide the correct conditions described in research in which the eye would receive the blue wavelength of 447-484nm. In particular, the ability to provide about 40 lux of blue light to the eye was desirable" (Morrison).

The lighting design for these circadian spaces involves a mix of linear recessed wall washers and recessed downlights. Each wall washer is to be fitted with dual purpose LED chips to provide white light and alternately switched blue light. The recessed downlights are to be fitted with white LEDs so that the space may be used comfortably by employees even when the blue LED wall washers are switched on for circadian benefit. Morrison further describes the circadian spaces:

> "To effectively reflect different colours – the interior walls and ceiling must be finished in a highly reflective but neutrally white colour to prevent color bleed and distortion [either of which could negatively impact the effectiveness of circadian treatment]. This reflection should also be 'lambertian,' or diffusing, to encourage ambient scatter and reduce specular reflections.
>
> Lighting Specifics – Calculations
>
> - Table – 34 lux
> - Walls – 90-160 lux
> - Ambient (short wavelength blue light) – 70-87 lux
>
> Equipment and Controls
>
> - LEDs are Cree® XLamp® XR-C LED.
>   - These have a radiant flux of 300mW, which translates into 18.1 lumens per blue chip. The light fitting has 33 blue chips per metre which provides 597.3 lumens per metre [just slightly less than a 60W incandescent lamp].
> - Recessed LED lighting made in Melbourne.
> - Control is by DALI interface from a simple wall panel push button display

- Two scenes –
    - Blue Light [for circadian benefit or night shift employees]
    - White Light [for general use by day shift employees]" (Morrison).

The intent is that this space will be used by staff during the day as a normal lounge (with all white lighting) and as a lounge with circadian benefit (ambient short wavelength blue light with white task lighting) for night shift employees. For night shift employees, use of a circadian room on break time will resynchronize their circadian cycles to a twenty four hour rhythm that compliments, rather than contradicts their imposed working routine. Figures 3.1 and 3.2 show the rendered views of the space in both white light and blue light (without the white task lighting) conditions.

Figure 3.1 Circadian Room Under White Light

Published electronically in Rick Morrison's "Circadian Rhythm and Lighting Design Case Study in the Queensland Children's Hospital" (Morrison). Permission included in Appendix C – Permission 1.

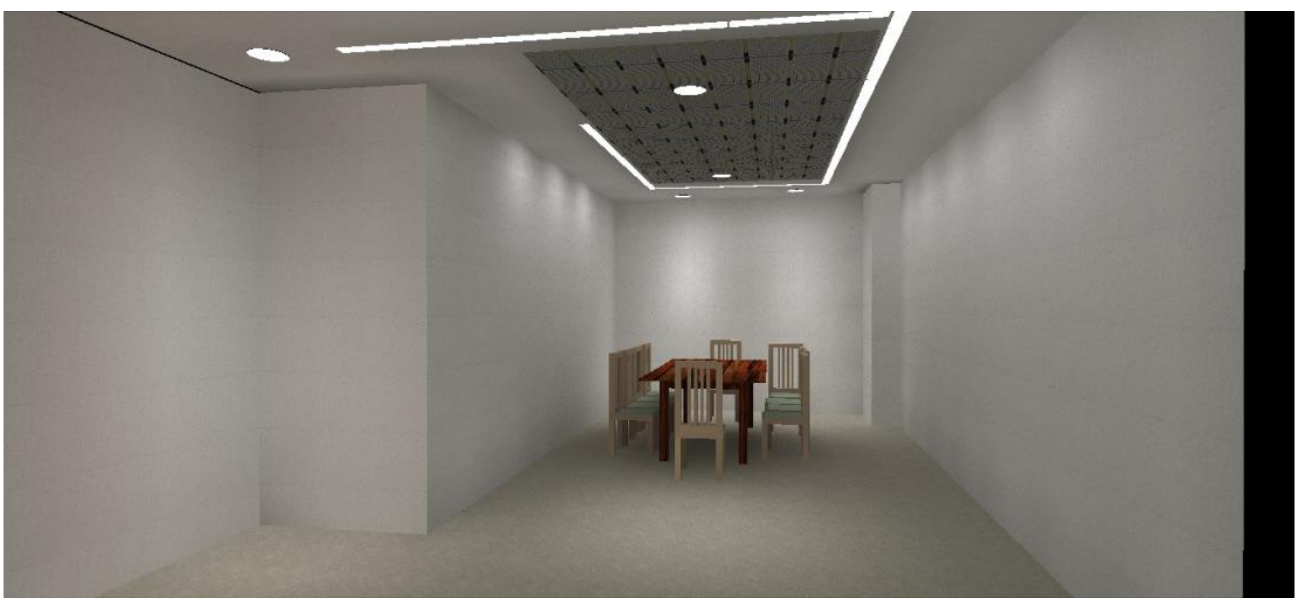


Figure 3.2 Circadian Room Under Blue Light

Published electronically in Rick Morrison's "Circadian Rhythm and Lighting Design Case Study in the Queensland Children's Hospital" (Morrison). Permission included in Appendix C – Permission 1.

The new Queensland Children's Hospital is set to open in 2014 and at that time, facility occupants will be asked to review the circadian spaces on a weekly basis. These responses are to be collected and reviewed to advance the knowledge of circadian lighting design in healthcare facilities. Though the results of this study are yet to be seen, the willingness of Queensland Children's Hospital to undertake this design is indicative of its expected benefit to employees.

Variable Lighting Systems

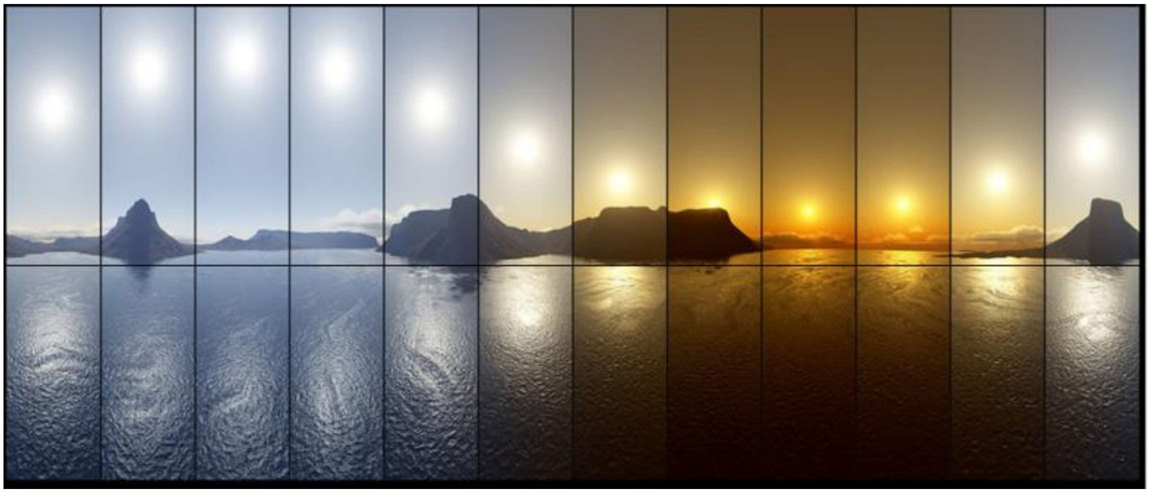
Another concept for promoting normal circadian rhythm amongst night shift employees in healthcare facilities is to design a variable lighting system. As discussed in Chapter 2, the main properties that are influential to the circadian rhythm are time of day and associated color temperature and illuminace of daylight. The main concept behind this influence is that color temperature and illuminance of daylight changes throughout a twenty four hour period, thus alerting the body to react appropriately to a certain time of day. However, without exposure to natural daylight, the body's circadian system can become unsynchronized with the natural environment. As Kevin Van Den Wymelenberg cites in his article *The Benefit of Natural Lighting,* "According to the US Environmental Protection Agency, humans spend upwards of 90 percent of their lives indoors. If they are occupying statically, perhaps stagnantly, lit environments, they can become disassociated with the natural outdoor cycles and variation of illuminance levels" (Van Dem Wymelenberg). For employees who are unable to experience daylight because of working demands, another option to reset the circadian rhythm is to design a lighting system that can mimic the changes of daylight. This is known as variable, smart, or dynamic lighting.

The basic concept of a variable lighting system is that luminaires are designed with LED lamps to change color temperature during a period of time. An LED lamp is typically composed of numerous, individual LED chips. Each LED chip then has the unique ability to be programmed to a desired color temperature of light. Then, as a day progresses, the LEDs in a luminaire can be programmed to activate different chips so that the desired color is emitted from the lamp. This is ideal in creating a dynamic lighting concept.

While day shift employees are exposed to natural daylight and don't have the need of a specialized lighting concept, the goal of dynamic lighting is to recreate the changing light of day for employees of the night shift. In doing so, each luminaire in a dynamic system is lamped with LEDs, then these are programmed to mimic the changing rhythms of daylight. Figure 3.3 shows an artistic rendition of color temperature change throughout a day. As described more in depth in Chapter 2, a day begins at sunrise with cool temperature light perceived as blue. Hence, the LEDs in this system would be programmed to match this at the commencement of the night shift. Then, as the night progressed, (the circadian day for night shift workers), the LEDs would slowly transition to produce warmer color temperature light perceived as yellow. This change would essentially recreate a day lit space within the artificially lit environment of a healthcare facility at night.

Figure 3.3 Light Color Change Throughout a Day

Published electronically in Rick Morrison's "Circadian Rhythm and Lighting Design Case Study in the Queensland Children's Hospital" (Morrison). Permission included in Appendix C – Permission 1.



Philips is one company that has embraced this concept in manufacturing smart luminaires for patient rooms in healthcare facilities. Philips' healthcare line includes the 'HealWell' luminaire. As described in their brochure,

> "HealWell is a new light solution for patient rooms, developed specifically to address people's natural responses to light, it provides light that is tuned to support the biological clock and creates a pleasant ambience for patients and visitors, thus supporting the healing environment... [and also] HealWell is designed to improve the healing environment by supporting patient comfort and staff performance with light that adapts to individual needs. Dynamic shades of warm and cool light support patient's diorhythms during the day. Coloured light and accents create a pleasant atmosphere in the patient rooms. HealWell also provides right levels of working light for staff, resulting in a complete room lighting system that is designed around the needs of patients and staff" ("HealWell").

This luminaire is specifically designed for patient rooms rather than staff areas, however, the concept could be replicated easily. The LED lamps in each luminaire provide a daylight like rhythm with varying illuminaces and changing cool to warm color temperature light output coordinated to the time of day. The same concept could be applied to the luminaires in employee areas, such as the nurse's station, to promote circadian health in night shift workers.

If a variable light system were incorporated, staff areas would consequently be lit differently than the patient areas during the night. Though this isn't perfect, it would still benefit the employees. Just as people aren't exposed to daylight full time during a day, staff wouldn't be exposed to their artificial "daylight" full time during the night. However, much of a night shift employee's time is spent in staff areas (because patients tend to be asleep and in less need of constant check up) during the night. As such, the time spent at the nurse's station in artificial daylight could be sufficient to correctly synchronize the circadian system.

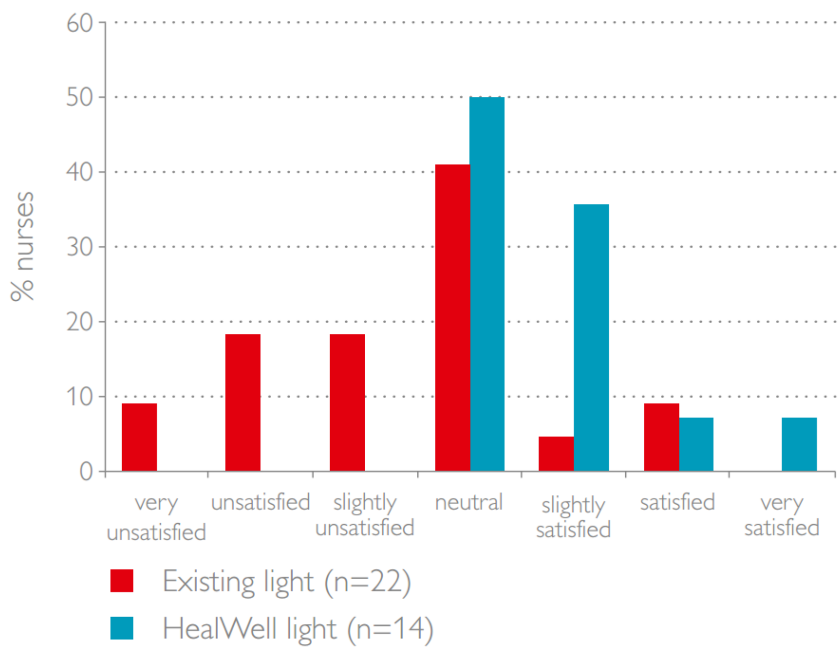
As presented in Figures 3.4 and 3.5 showing the application and results of HealWell, staff and patients of the Cardiology Department of Maastricht UMC in the Netherlands both expressed increased satisfaction with the lighting conditions of HealWell lit spaces. Another application of HealWell in The German Heart Institute in Berlin, Germany concluded that the simulation of natural daylight supported the sleep-wake cycles of patients and enhanced the healing environment. This also prompted better well-being for employees along with positively affected sleep-wake rhythm, mood and satisfaction ("HealWell)".

Figure 3.4 HealWell at Maastricht UMC

Published electronically by Koninklijke Philips ("HealWell"). Permission included in Appendix C – Permission 3.

Figure 3.5 Increased Staff Satisfaction at Maastrich UMC

Published electronically by Koninklijke Philips ("HealWell"). Permission included in Appendix C – Permission 3.



Even though this luminaire and its associated case studies are patient room based, it is reasonable to expand the concept to staff areas of the healthcare facility. Healthcare providers spend much time at the nurses' station throughout a typical night shift, so circadian based lighting strategies would be centered there. Staff areas could thus be designed with luminaires similar to the HealWell that would change light color temperature and illuminance over time, thereby mimicking the circadian progression of daylight. For night shift employees, the artificial lighting would provide the same circadian benefits of daylight; then they could enjoy synchronized circadian rhythms that complimented rather than contradicted their working routine. Expounding on the results of HealWell trials in the Netherlands and Germany, it is likely that staff satisfaction with the lighting design would increase. Most importantly though, by matching a normal circadian rhythm, night shift employees would also exhibit a traditional pattern of alertness and benefit from breaks as did their daytime colleagues (as described in Chapter 2.)

Chapter 4 - Further Research

As described in this paper, the circadian rhythm has been researched extensively. However, the implications of artificial lighting design to the circadian rhythm and especially its role in health care facilities are not so well known. Queensland Children's Hospital is the first health care institution (with available information) that has designed its artificial lighting to promote the circadian health of its employees. For further examination of this topic, it will be important to monitor the circadian rhythms of the employees at this facility. By compiling survey results of the staff alertness, it will be possible to determine the effectiveness of blue light therapy. In addition, it would be informative to look at how many shifts (using this therapy) it takes to realign the circadian cycles of night shift employees, how much exposure to blue light is required and how often to maintain circadian synchronization and if there are any downsides when the employees leave the night shift and enter the normal light of day. Hopefully, other health care institutions will follow the path that Queensland Children's Hospital has taken and design their facilities to advance circadian synchronization for night shift employees. As more health care facilities become willing to include circadian lighting in their artificial lighting design, night shift employees will benefit from circadian cycles that compliment, rather than contradict their work schedules.

Also as discussed in the previous chapter, Philips has designed special luminaires for patient rooms that change CCT to better follow the patterns of daylight. These luminaires are meant to promote the healing environment and have been shown to improve patient recovery. In the future, these luminaires can be adapted for staff spaces. By mimicking the correlated color temperature change of daylight in staff spaces during the night shift, employees will be able to synchronize their circadian rhythms to their working routine. Like blue light therapy, the impact that this change has on employees would need to be studied. Surveys of staff alertness trends could demonstrate the connection of artificial lighting change to improved circadian rhythm synchronization. Ultimately, it will be important to find the optimum CCT at each point in a shift and the rate of change that will be most beneficial to staff. Again, like blue light therapy, it would be necessary to learn how long an employee would work in these conditions before achieving circadian synchronization and if there are any drawbacks when night shift employees leave the space. With this system, it would also be necessary to monitor if there were any negative impacts to others who experienced the circadian lighting system for less than a full shift length of time.

Additionally, it would be informative to compare this research with other industries. Police forces, military, and 24-hour industrial workers are just a few examples of employees who are required to work during the night shift. These are similarly critical duties which require the individuals to be fully alert and exhibiting top performance. Though I was unable to find information concerning their incorporation of circadian strategies, it would further this research to discover what comparable employees in other industries do to promote circadian health. Are there any lighting strategies or techniques that are employed for these workers to improve their circadian synchronization?

Overall, the most important impact that research into circadian lighting will have will be its inclusion in the future of health care facility design. As more institutions become aware of the connection between artificial lighting and the circadian health of their employees, they should be more willing to design facilities that will aid circadian synchronization. This will improve the working environment for night shift employees and prevent the negative implications of working contrary to one's natural circadian cycle.

Chapter 5 - Conclusions

The circadian rhythm is a twenty-four hour cycle, regulated by the changing illuminance and color temperature of daylight, that helps to control human function and allows synchronization with the natural environment. Whether through windows or time spent outdoors, most people experience daylight at various times from morning to night to maintain this synchronization. For night shift employees who are only exposed to artificial lighting during their shift, there are no daylight cues to synchronize their internal circadian rhythm with the natural environment. As a result, many night shift employees experience physiological and psychological complications. One effect of this condition is that their natural cues and working requirements are in constant struggle. Circadian cues to sleep are triggered during the start of a night shift, leading to decreased alertness. Then, circadian cues to wake up in the morning prevent sleep when an employee returns home. Further studies have shown that gastrointestinal complications, heart disease, menstrual problems, infertility and loss of libido are all also side-effects of circadian disjoint. All of this can inhibit a normal life and lead to dissatisfaction and depression.

While it is not possible for night shift employees to be exposed to daylight during their shift, there are several artificial lighting strategies that may be designed into a healthcare facility to improve the circadian synchronization of night shift employees. Incorporating circadian rooms is one technique. A circadian room is a space that exposes employees to short wavelength blue light for short periods of time in order to reset their circadian cycle. This light exposure for as little as 20 minutes at a time will shift the circadian rhythm and re-align it to an employee's work schedule. Another strategy is to design a variable lighting system. This system uses luminaires with lamps that will mimic the changing wavelengths of daylight. During a night shift, these lamps would transition through a typical revolution of daylight from cool color temperature light perceived as blue in the "morning" (start of shift) to warm color temperature light perceived as yellow in the "evening" (end of shift). Thus, the imposed circadian cycle of the working environment would match the circadian rhythm of a working shift.

In designing a lighting strategy for a healthcare facility, the goal is to create an environment that will be beneficial to employee health and well-being. Day shift employees receive daylight exposure throughout the duration of their shift and are thus able to maintain a synchronized circadian rhythm that matches their working life with their natural environment. In creating a circadian based lighting design, the goal is to enable night shift employees to likewise experience a synchronized circadian rhythm. By incorporating circadian rooms, night shift employees can have a space in which to experience short wavelength blue light. This can shift their circadian rhythm, resulting in a synchronized twenty-four hour cycle. Similarly, if a variable lighting system is designed, the goal is again to match a night shift employees natural circadian cues to his or her working environment. Lighting employee spaces with lamps that mimic the changing patterns of daylight could set the circadian rhythms of employees to a normal twenty-four hour cycle that was synchronized to their working routine.

With either of the recommended techniques, healthcare employees would benefit from circadian lighting. Synchronization of the working routine and circadian rhythm could prevent disjoint and result in better health and well-being for night shift workers. These individuals would no longer struggle between working environment and circadian stimuli as the two would be in agreement. Ideally, this would result in greater alertness on shift, more satisfaction in the workplace and a better personal life outside of the workplace. If correctly implemented, a study of healthcare facility employees (like that conducted at Mercy Regional Medical Center) would reveal that there was no notable difference between the circadian rhythms of day and night shift employees as judged by alertness throughout their shift. Employees would exhibit a normal rhythm, in sync with a twenty-four hour light dark cycle and would benefit from the associated improved physiological and psychological well-being.

Though the research provided in this report represents only a focused look at the impact lighting has on the circadian rhythm, it is important to note that other space conditions such as temperature or location as well as personal conditions such as fatigue, food/beverage consumption, and weather can all markedly effect a person's alertness on the job. Circadian studies that look at these other factors separately and on a larger scale will be able to provide stronger conclusions on the circadian based strategies in healthcare.

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Appendix A - Healthcare Provider Surveys

Shown in Figure A.1 is a copy of the survey that was provided to employees of Mercy Regional Medical Center. In addition to alertness, employees were asked about their exposure to daylight during their shift and standard lighting conditions in their workspace. To help identify patterns, participants were further asked to provide their working hours and locations along with their perceived level of alertness (from 1-10 with 10 being completely alert and 1 being not alert at all) in various locations and additional factors they felt might impact their alertness[3].

[3] The responses from the staff of Mercy Regional Medical Center were offered voluntarily to assist in gathering personal experience of the circadian rhythm. The results, as presented in this report, are not meant to evaluate the state of alertness or competency of any employee, nor are they intended to express judgment on the working conditions of this facility.

Created by Michelle Gutknecht.

Figure A.1 Lighting Conditions and Alertness Survey (Sample)

All responses are completely anonymous and your identity will be remain unknown.

Date ______________________________

Healthcare Facility and Position ______________________________

Working Shift (Start and End Time) ______________________________

Location of Work (nurse station, patient rooms, public spaces, other – please list multiple if applicable)

____

1. **How would you describe the current lighting conditions in your workspace?**

   ____

   ____

2. **Have you ever noticed any changes in the lighting of your workspace (increased/decreased brightness, color variation, etc.) throughout your shift?**

   Yes　　　　No

   If yes, please describe ______________________________

3. **If you could, how would you improve the lighting of your workspace during your shift?**

   ____

   ____

4. **How often are you exposed to natural light (sunlight through windows/skylights or spending time outdoors) during your shift?**

   a. Never
   b. Only during breaks
   c. Rarely
   d. About half the time
   e. Most of the time
   f. Always

   Please explain where this occurs: ______________________________

5. **What factors do you think affect your alertness during your shift? (Please select all that apply in reference to questions 6 and 7 on the reverse of this page).**

   a. Type of work
   b. Location of work
   c. Consumed food and beverages
   d. Brightness of your workspace
   e. Break time
   f. Fatigue
   g. Use of electronics
   h. Changes in space lighting
   i. Recent events
   j. Weather
   k. Light color of your workspace
   l. Future events
   m. Temperature of workspace
   n. Exposure to natural light

Michelle Gutknecht - Kansas State University – Architectural Engineering

All responses are completely anonymous and your identity will be remain unknown.

6. **Please rate your alertness during your shift at various times (10 is fully alert, 1 is not at all). Please note your location during these times and explain any changes you experience during the indicated time periods.**

   a. **Start of shift** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
   Location/Changes ____________________

   b. **Hours 1-4** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
   Location/Changes ____________________

   c. **Hours 4-8** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
   Location/Changes ____________________

   d. **Hours 9-12** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
   Location/Changes ____________________

   e. **During Break** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
   Location/Changes ____________________

   f. **After Break** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
   Location/Changes ____________________

   a. **End of Shift** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
   Location/Changes ____________________

7. **Please rate your alertness during your shift while working in various spaces (10 is fully alert, 1 is not at all).**

   a. **Nurse's Station** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

   b. **Patient Rooms** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

   c. **Procedure Rooms** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

   d. **Exam Rooms** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

   e. **Public Spaces** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Thank you very much for your participation! Your assistance is greatly appreciated in providing research data for my Masters Report.

Michelle Gutknecht - Kansas State University – Architectural Engineering

Appendix B - Observations of Healthcare Facility Lighting Conditions

A personal observation of the current lighting conditions at Mercy Regional Medical Center was conducted and the results are described here[4]. The observation was conducted at 9am on a very bright sunny day.

Nurse's Station

- Fluorescent fixtures.
- Overhead and task lighting.
- 760 lux at the working plane.
- Centered between multiple patient rooms.
- No direct windows to the space but daylight available through windows in adjoining patient rooms and waiting area.

Public Spaces (Corridors, Lobbies and Waiting Areas)

- Fluorescent fixtures.
- 620 lux at the working plane in the Corridor
- Abundant daylight in all spaces provided by large windows – special emphasis.
- Excellent views of central courtyard.
- Occupancy sensors.

Patient Rooms

- Fluorescent fixture over bed.
- Incandescent fixture over sink.
- 832 lux with only artificial lighting (shades drawn).
- 740 lux of only daylight (all artificial sources switched off).
- 1050 lux with combination of overhead and daylight.

[4] The opportunity to view the lighting within Mercy Regional Medical Center was given voluntarily and the observations, as described in this report, are in no way intended to judge the working conditions of the facility.

- Exterior of building.
- Large windows to provide daylight.
- Excellent views – central courtyard or away from facility.
- No direct windows to the space but daylight available through windows in adjoining patient rooms and waiting area.

Restaurant

The on-site restaurant is frequented by staff during their break times.

- Fluorescent fixtures overhead.
- Incandescent task lighting over the tables.
- 420 lux.
- Windows all around for infusion of daylight.

Appendix C - Image Permissions

The following are correspondence with the individuals or companies from whom images in this report were used. They are provided to show that permission has been received for every graphic that was not self-created.

Permission 1: Rick Morrison

RE: Use of Graphics from Presentation "Lighting design to support circadian rhythm in a public hospital"

Rick Morrison <rick.morrison@ndylight.com>

Wed 5/28/2014 6:12 PM

To Michelle Gutknecht <mgutk@ksu.edu>;

yes
as long as they are appropriately cited and credited
and
if you could send me a copy of your completed report – for my technical Library

cheers

Rick Morrison MLighting Grad Dip Illum Assoc IALD MIES RLP
Senior Lighting Designer/Manager

NDYLIGHT LIGHTING DESIGN

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E rick.morrison@ndylight.com | **www.ndylight.com**

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From: Michelle Gutknecht [mailto:mgutk@ksu.edu]
Sent: Thursday, 29 May 2014 9:09 AM
To: Rick Morrison
Subject: Use of Graphics from Presentation "Lighting design to support circadian rhythm in a public hospital"

Hello,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "The Effect of Lighting on the Circadian Rhythm and Its Applications in a Healthcare Environment," I would like to use graphics that I found from your presentation entitled "Lighting design to support circadian rhythm in a public hospital".

The cycle showing the sun's movement throughout the day and also the renderings of the circadian rooms in Queensland Children's Hospital are both highly relevant to my topic and integral to the support within my paper.

May I please have permission to use these graphics? They will be appropriately cited and credited to you and your presentation.

Please contact me if you have any questions regarding my use of these graphics or anything else.

Thank you,

Michelle Gutknecht
Architectural Engineering
Kansas State University
720.219.8480 | mgutk@ksu.edu

Permission 2: Brain Treatment Center

RE: Legal Department Artwork Approval

Brain Treatment Center <info@braintreatmentcenter.com>

Thu 6/5/2014 5:02 PM

To:Michelle Gutknecht <mgutk@ksu.edu>;

You are approved to use the image in the context in which you provided. Good luck on your project.

Regards,
Kevin Walshe
BTC Staff

-----Original Message-----
From: "Michelle Gutknecht" <mgutk@ksu.edu>
Sent: Wednesday, June 4, 2014 7:59pm
To: "info@braintreatmentcenter.com" <info@braintreatmentcenter.com>
Subject: RE: Legal Department Artwork Approval

Hello,

I contacted the brain treatment center last week and have yet to receive a decision about using an image that I found on your webpage in my Masters Report.

The image and the context in which it will be used is included as the attachment to this email. I look forward to hearing from you soon.

Thank you,

Michelle Gutknecht
Architectural Engineering
Kansas State University
720.219.8480 | mgutk@ksu.edu

From: info@braintreatmentcenter.com <info@braintreatmentcenter.com>
Sent: Tuesday, May 27, 2014 11:48 PM
To: Michelle Gutknecht
Subject: Re: Legal Department Artwork Approval

Thank you for your interest in our therapy!

Due to high volume, please allow us 3-5 business days to respond to your inquiries. Thank you for your patience and understanding.

BTC Team

From: Michelle Gutknecht <mgutk@ksu.edu>
Sent: Tuesday, May 27, 2014 11:48 PM
To: info@braintreatmentcenter.com <info@braintreatmentcenter.com>
Subject: Re: Legal Department Artwork Approval

Hello,

I am a graduate student at Kansas State University studying Architectural Engineering. I would like to request permission to use an image that I found on the Brain Treatment Center webpage in my Masters Report entitled "The Effect of Lighting on the Circadian Rhythm and Its Application in a Healthcare Environment." I have attached the Abstract of my report as well as the image (in context) and its included citation in my report. If there is any other information you need in making your decision, please don't hesitate to ask.

Thank you,

Michelle Gutknecht
Architectural Engineering
Kansas State University
720.219.8480 | mgutk@ksu.edu

From: Brain Treatment Center <info@braintreatmentcenter.com>
Sent: Tuesday, May 27, 2014 9:23 PM
To: Michelle Gutknecht
Subject: RE: A message from your contact form

Greetings Michelle,

As long as the Brain Treatment Center is displayed on the artwork and credited, please send us how it will be displayed and what context it will be used for our approval. Please send it here info@braintreatmentcenter.com with "Legal department Artwork approval" on the subject line and we will reply within 72 hours with either approval or not-approved.

Regards,

BTC Legal Department

-----Original Message-----
From: service@foxyform.com
Sent: Tuesday, May 27, 2014 3:40pm
To: Info@braintreatmentcenter.com
Subject: A message from your contact form

Name: Michelle Gutknecht
E-Mail: mgutk@ksu.edu
Message: Hello,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled \"The Effect of Lighting on the Circadian Rhythm and Its Applications in a Healthcare Environment,\" I would like to use a graphic found on the Brain Treatment Center webpage depicting the Circadian cycle\'s interaction with the brain.
http://braintreatmentcenter.asia/english/sleep/

May I please have permission to use this graphic? It will be appropriate cited and credited to the Brain Treatment Center.

Please contact me if you have any questions regarding my use of these graphics or anything else.

Thank you,
Michelle Gutknecht
Architectural Engineering
Kansas State University
720.219.8480 | mgutk@ksu.edu

Sender IP: 64.208.44.18 - Referer: www.foxyform.com

You are receiving this e-mail message because you have registered a contact form at www.foxyform.com

Permission 3: Koninklijke Philips

RE: Philips Permission to Use Image

Kerr, Carolyn <carolyn.kerr@philips.com>

Sun 6/15/2014 9:29 PM

To:Michelle Gutknecht <mgutk@ksu.edu>;

Hi Michelle,
Yes. This is approved.
Thanks.

Carolyn Kerr
Director, Marketing Communications and Brand
Lighting

200 Franklin Square Drive, Somerset, NJ 08873
Phone: 732-563-3236
Email: carolyn.kerr@philips.com

www.philips.com

Connect with Philips

From: Michelle Gutknecht [mailto:mgutk@ksu.edu]
Sent: Friday, June 13, 2014 3:23 PM
To: Kerr, Carolyn
Subject: RE: Philips Permission to Use Image

Carolyn,

Do you know when you might be able to provide final approval of the piece? I provided the context in which the Philips HealWell images will be used on Monday, June 9 and am interested to know how soon you might be able to look it over and give approval. I'm hoping to finalize my report as soon as possible and really appreciate your help with the Philips permission.

Thank you,

Michelle

From: Kerr, Carolyn <carolyn.kerr@philips.com>
Sent: Monday, June 09, 2014 1:00 PM
To: Michelle Gutknecht
Subject: RE: Philips Permission to Use Image

Hello Michelle,
You may use the images, but I do require final approval of the piece.
You must use them directly from the website, as I will not be able to pull higher resolution images for you.

Thanks.

Carolyn Kerr
Director, Marketing Communications and Brand
Lighting

200 Franklin Square Drive, Somerset, NJ 08873
Phone: 732-563-3236
Email: carolyn.kerr@philips.com

www.philips.com

PHILIPS

Connect with Philips

From: Michelle Gutknecht [mailto:mgutk@ksu.edu]
Sent: Friday, June 06, 2014 12:28 AM
To: Kerr, Carolyn
Subject: Philips Permission to Use Image

Hi Carolyn,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "The Effect of Lighting on the Circadian Rhythm and Its Applications in a Healthcare Environment," I would like to use graphics found on the Philips webpage describing the Philips HealWell fixture.

May I please have permission to use these graphics? They will be cited and credited to Philips. I have attached the official Image Permission Request form to this email. If possible, could you please reply with the form attached to email because I do not have a fax number?

Please contact me if you have any questions regarding my use of these graphics or anything else.

Thank you,
Michelle Gutknecht
Architectural Engineering
Kansas State University
720.219.8480 | mgutk@ksu.edu

Michelle Gutknecht
Architectural Engineering
Kansas State University
720.219.8480 | mgutk@ksu.edu