BEE

Tick Tock: An International Student Workshop Exploring Lighting Design Factors in the Hospitality Industry

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Abstract

Researchers conducted a lighting design methods workshop exploring circadian rhythm factors that may impact travelers staying in hotel rooms. Students attended separate workshops conducted in Mexico and the United States of America. During the workshop in each country students first attended a one-hour lecture about circadian rhythm lighting design considerations followed by a one-hour hands-on exploration of existing and retrofitted lighting designs in hotel rooms that included light bulbs designed to produce circadian entrainment effects. Spectrometers, surveys, spectrum actigraphy watches and light meters were used to teach students ways to measure traveler and hotel room lighting design factors. Placement of various types of light bulbs in specific areas of hotel rooms may contribute to sleep disruption and entrainment of circadian rhythms. Students gained knowledge of lighting design approaches that could influence travelers' hotel stay experiences. Students worked in small to teams to propose lighting design interventions that could influence the spectral profile within hotel rooms with the goal of entraining circadian rhythms. The workshop facilitators and students discussed their proposed lighting designs as a group.

Keywords: International, Empathic Design, Lighting, Chronobiology

1. Introduction

An empathic design lighting workshop was conducted in The United States and Mexico to increase student awareness of circadian rhythm design factors that may impact consumers in the travel and hospitality industry. The goal of the workshop was to provide students with a technology enhanced learning experience to measure and compare electric lighting effects in a field setting and ways to better understand lighting related effects that travelers may face in hotel rooms. First, students attended a one-hour lecture about the role of lighting to impact circadian rhythms and human health and ways lighting can be used to potentially improve the experience for travelers. After the classroom portion of the workshop, students participated in hands-on design workshop for hotel room lighting. Students used actigraphy watches, client surveys, light meters and a spectrometer to compare the lighting conditions in existing and retro-fitted hotel rooms. Hotel room lighting measurements and client survey data collected during the workshop helped to stimulate student discussions about how data driven lighting design approaches can be used to meet client needs in the hospitality industry. Student teams then proposed hotel room lighting design plans with the goal of reducing the potential for a traveler's sleep disruption based on the room specific lighting configurations in both the existing and retrofitted hotel rooms.

Circadian Rhythms Overview

Circadian rhythms are 24-hour body clock cycles, which are important for human health and are influenced by light, activity and other factors. Light is found to be the principal circadian synchronizer in humans and different light levels are capable of producing weak to strong effects on the human body [1] In fact, bright indoor light can suppress melatonin secretion [2] and reset circadian rhythm in humans [3]. Drifting or disrupted circadian rhythms create irregular sleep/wakefulness patterns, which are sometimes observed in travelers, shift workers, people of advanced age, or those suffering from chronic diseases [4-7]. Increasing light exposures throughout the day and during evening hours is known to result in improved sleep patterns and increased entrainment of circadian rhythms [8]. At the same time, light emitting electronic devices used for reading or for entertainment before bedtime have been shown to produce adverse effects on circadian rhythm and suppress the sleep promoting hormone melatonin [9]. Travelers travelling across time zones are at risk of disrupting circadian rhythm that may also cause circadian rhythm disorders [10, 11].

Travel Related Circadian Rhythm Disruption

Travelers are an at-risk group for circadian rhythm disruption because they must adapt to unusual travel times, distant geographic time zones and seasonal effects of natural light differences. Travel related stress may negatively influence travelers' circadian rhythms, health outcomes and have received some attention in the literature [12-17]. International air travel involving changes in time zones can cause disruption in circadian rhythm and also reduce physical performance of travelers [18, 19], affect sleep patterns [20-22], induce fatigue [23, 24] and also cause mood swings [25]. Extreme tiredness and other physical effects felt by travelers is often called jet lag, which is caused by misalignment between internal circadian rhythm and local time due to travel across time zones [26]. A planned and timed bright light exposure can be used to manage the effects of disrupted circadian rhythm in travelers [14]. Circadian rhythms can be reset through electric light exposure; Abbott and Zee [27] used exposure to bright light for 30-45 minutes on awakening together with melatonin to progressively advance the wake time until desired sleep window was reached. Light has been recognized as most important time cue that could be used to entrain the circadian rhythm pacemaker to normal 24-hour cycle after disruption [28-30].

Circadian Rhythm Entrainment Using Electric Light

Electric light is important for synchronizing circadian rhythm in humans and has an effect on circadian pacemaker [29]. Light exposure in early night promotes delay in human circadian rhythms and light exposure in late night advances the shift. Thus, controlled exposure of light can reset human circadian rhythm [9, 28, 29]. A successfully entrained circadian pacemaker equalizes internal and external day lengths and the literature suggests a connection between the circadian clock and human health [31-33]. Travelers often experience jet lag due to travel across time zones. Several studies have shown that exposure of bright light (>3000 lux) during daytime for at least three hours in the day can reset the circadian clock [34-38] and also help in circadian rhythm entrainment to shifted sleep-wake pattern [30, 39-41]. Melatonin also has the ability to induce sleep and can be used to entrain circadian rhythm when treatment is appropriately timed [2, 3, 42]. Literature also demonstrates that exposure to indoor room light for at least six hours on an advancing schedule has led to circadian pacemaker adjustment to a new sleep wake cycle [29, 43]. This is relevant to modern day lives of travelers as they are mostly exposed to indoor room light of airports, airplanes, hotels or offices during travel.

Hotel Room Lighting

Hotel rooms and their potential impact on circadian rhythms including guests perceived well-being that is contingent on lighting design effects are not well understood. The increased use of LED circadian rhythm lighting products warrants the need for practitioners to consider the implications for traveler health and well-being within hotel rooms, which may be influenced by electric lighting. Hotel guests have reported sleep difficulties and disrupted sleep-wake patterns in hotels [11].

2. Research Methodology

International Lighting Workshop

The workshops in Mexico and the United States were designed to explore client needs in hotel rooms which could then be applied to lighting design practice with the goal of minimizing electric lighting effects on disrupting restful sleep and ways to improve traveler alertness in specific areas of hotel rooms. Students interacted with peers and faculty during the workshop to stimulate active learning and collaboration. Student pre-workshop surveys highlighted the participants desire to learn applied methods to specifically meet client needs as a desired outcome of the workshop. The workshop session included lecture, hands-on experience with technology, followed by reflection, problem solving and teamwork. The primary student-learning outcome was learning about technology-supported methods, which provide empirical evidence for circadian lighting design solutions to address client needs. The approaches presented to students for measuring the potential effects of hotel room lighting prior to and after lighting interventions could be integrated into the participants' work planning discussions and presentation with clients. The duration of the workshops was two hours including one hour of class time, and one hour of hands-on lighting measurements, discussion, and lighting design planning in the retrofitted hotel room in the U.S. and Mexico.

Classroom Session

Upon arriving at the workshop classroom in a hotel meeting room, students completed informed consent documentation, which was previously approved by the Institutional Review Board at a large Midwestern university in the United States. Participants received no compensation for attending the workshop and completing the workshop activities. The benefits for participants included increased knowledge of emerging LED lighting products and a greater understanding of the potential impact of electric lighting on travelers' health and perceived wellbeing in the hospitality industry. After students provided consent to participate in the study, each was issued an individually calibrated Philip's Actigraph Spectrum actigraphy watch. Actigraphy watches measure light levels (LUX), the visual spectrum (Red, Green, Blue light frequencies), activity levels, and various sleep performance indicators. Spectrum actigraphy watches can be used to measure the effects of natural and electric lighting for employees or guests during proactively or retroactively in facilities. Participants completed a paper survey, which included selected items from National Sleep Foundation Sleep Index (Knutson et al., 2017) to better understand factors, which can influence sleep performance in hotel rooms. The workshop presenters stressed the need for developing an understanding of client needs prior to beginning a lighting design.

Multiple approaches were used to expose students to research methods for designing lighting systems in hotel rooms during the classroom portion of the workshop. The advantages of introducing lighting design concepts in the classroom followed by hands-on measurement and proposed adaptation within real-world facilities is suspected to strengthen student learning outcomes from the workshop content. A combination of qualitative and quantitative techniques first presented in the classroom including the use of client questionnaires helped to reinforce the concepts of empathic design. Analysis of client survey data findings strengthened students understanding of the importance of discussing with clients' circadian rhythms factors which might affect real-world lighting solutions.

Table 1: ***Workshop Participant Demographics***

The Characteristics of the Workshop Participants section has been expanded to describe the diversity of the attendees.

Gender	n	%
Male	4	10%
Female	38	88%
Ethnicity (Multi-Report)		
White	33	77%
African American	2	5%
Hispanic	2	5%
Asian	1	2%
Native American	5	12%
Other Race	3	7%
Education		
High School/GED	5	12%
Some College	20	46%
2 Year College	3	7%
4 Year College	10	23%
Master's Degree	2	5%
Income		
Below $20,000	17	40%
$20,000-$29,999	1	2%
$30,000-$39,999	2	5%
$40,000-$49,999	2	5%
$50,000-$59,999	3	7%
$60,000-$69,999	1	2%
$70,000-$79,999	2	5%
$80,000-$89,999	2	5%
$90,000 and more	9	21%

The survey research portion of the workshop was followed by a PowerPoint presentation by the researchers, which discussed the implications of circadian rhythm factors, which might affect travelers. The lecture also discussed ways in which spectrometers, light meters, and spectrum actigraphy devices can be used independently or in combination to capture traveler behaviors and environmental lighting exposures. For example, actigraphy data can be captured during predetermined and scheduled periods to assess illuminance and diverse spectral exposure trends over time for either individuals or groups as they navigate the natural and built environment during travel. The differences between how light may affect hospitality industry employees and travelers and the similarity of difference of these lighting impacts on each group can also be explored through spectrum actigraphy studies.

Hotel Room Lighting Demonstration

Images or diagrams of rooms and lighting configurations could be added to give. After the lecture portion of the workshop concluded, the researchers escorted students to an existing and retrofitted hotel room to complete a hands-on lighting design workshop. For this purpose, two hotel rooms at hotel properties in the U.S. and Mexico were used for the study: students measured the existing lighting design in one room at each hotel and a second room was used to evaluate lighting designs with circadian entrainment lighting modifications. Outlet plug configurations in the rooms in both the U.S. and Mexico were identical and did not require adaptors or voltage regulators to conduct the hotel room retrofits.

Contrary to the researchers' original retrofit plans for the workshop, Philip's Hue networked lighting devices could not be retrofitted in the U.S. or Mexico hotels since they required dedicated data switches and IP addresses which were not supported by each hotel's network restrictions. Hotel rooms in the U.S. and MX were retrofitted with selected LED circadian rhythm enhancing room light bulb interventions compared to the in situ LED lighting. The hotels in which the workshops were conducted in the U.S. and Mexico had strict rules about permissible modifications to the hotel rooms that included no items adhered or attached to wall surfaces but each hotel allowed the use of independent lighting fixtures (i.e. gooseneck lamps within the rooms. The existing lighting designs provided comparative data for students of the rooms illuminance levels and spectral profiles in key areas such as the bathroom, hallways, sleeping and work areas.

The researchers transported the planned retrofit lighting fixtures, bulbs and instruments in carry-on luggage during airline travel. The customs inspections required documentation of the location, duration, and purpose of the lighting workshop in Mexico to ensure goods intended for resale were not being transported across the border.

The retrofitted hotel room included the Lighting Science "Good Night" (FG-02263-A19-9 W 2231K 70CRI and "Aware and Awake" (LS-75WE BR40 9W 2349K 80 CRI); GE "Link Smart" (22604-A19-12 W 2849K 80 CRI) and GE "Brightstick" (63857-5403K 80 CRI) LED light bulbs. Clip-on gooseneck lamps allowed students to quickly move proposed hotel room lighting design changes and then take comparative readings to measure the effects of the changes during the workshop. A total of six gooseneck lamps were provided in the U.S. and MX to make modifications to the hotel rooms lighting designs using the bulbs discussed above. Students used Extech HD450 data logging light meter readings, and a Lighting Passport ALP-01 spectrometer to measure and compare illuminance and spectral profiles between the hotel rooms.

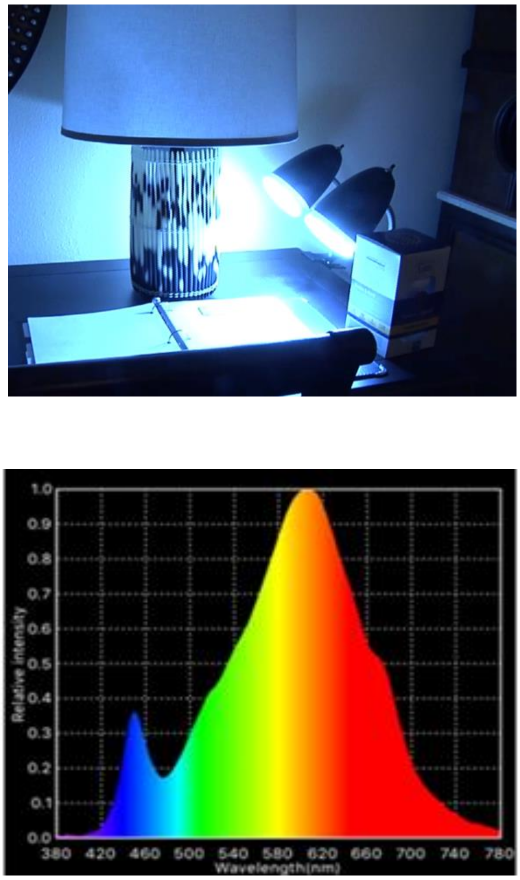

Figure 1. Image of Retrofitted Hotel Room Desk Area with Lighting Science 'Aware and Awake' lightbulb and Spectrometer profile.

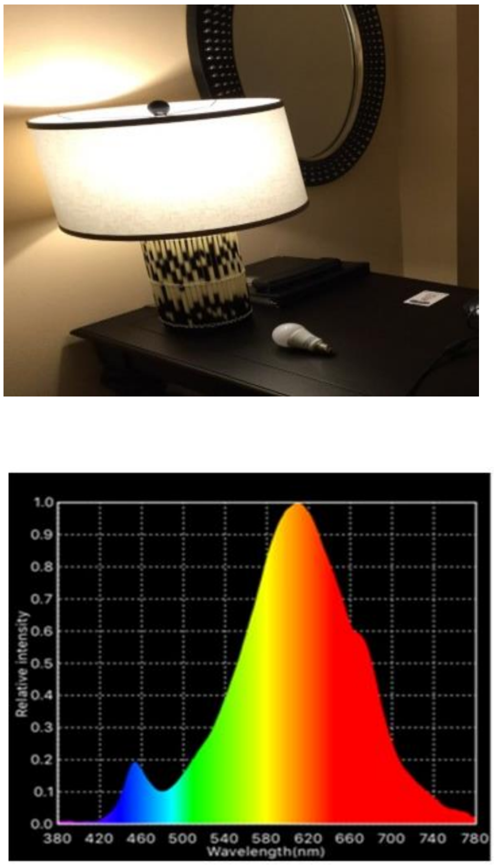

Figure 2. Image of Existing Desk Area Lighting Configuration and Spectrometer profile.

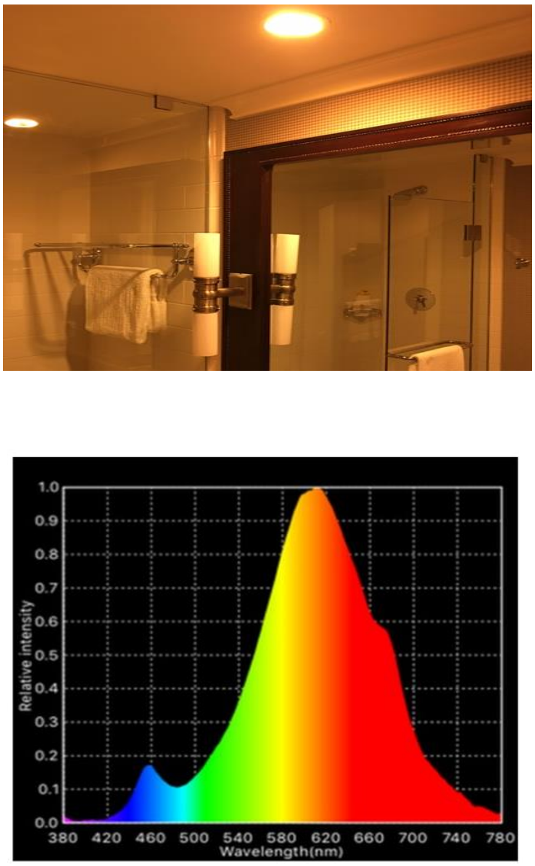

Figure 3. Image of Retrofitted Bathroom with Lighting Science 'Good Night' lightbulb and Spectrometer profile.

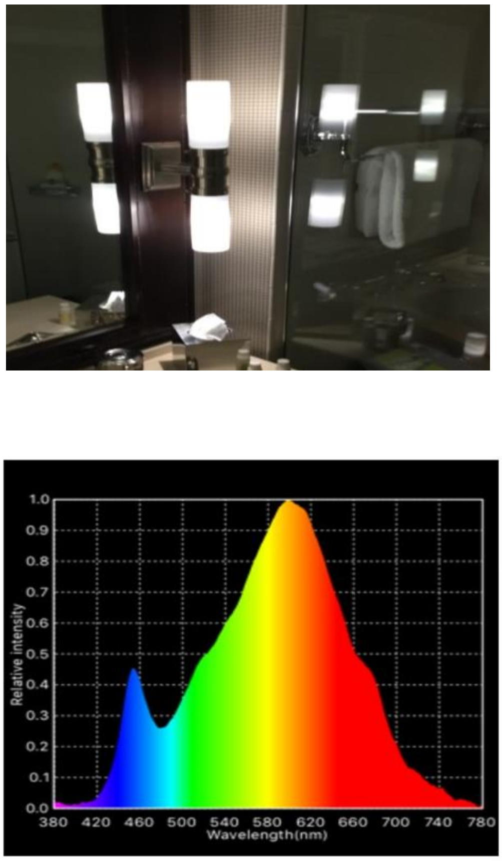

Figure 4. Image of Existing Bathroom Lighting Configuration and Spectrometer profile.

Prior to starting the hotel room demonstration, students were provided with light meters, a spectrometer, measuring tapes, paper pads and pencils to facilitate data collection, analysis, and recommendations. The students measured the parameters of the existing space including the intensity and spectral profile of both the existing lights and modified rooms, which they documented in field research notes controlling for measurements taken at 2'6" on the vertical plane. Students drew informal sketches of the hotel room configuration including furniture and light fixtures on provided paper pads to document their measurements and observations about the existing lighting design. Students then created a proposed lighting design sketches in which they outlined how they might change the lighting design to best influence circadian rhythm entrainment in critical areas of the hotel room. For additional reflection after the workshop concluded, students were provided with printed reports summarizing their spectrum actigraphy results via email to help them better understand the potential of technology for informing client co-created lighting designs.

Students worked in teams of two to sketch a proposed circadian rhythm entrainment lighting design based on their measurements and reflection on the prior workshop activities. The researchers asked students questions about their proposed lighting designs like those that might be asked by clients. Questions explored design solutions for both the existing and retrofitted hotel rooms designs produced during the workshop.

Figure 5. Student measurements of hotel room lighting parameters and documenting proposed changes in sketches for design variants

3. Research Results

Today's students are exposed to technology at an early age and adapt quickly to the use of tools such as adaptable lighting systems and instruments for measuring their potential effects on clients with spectrometers. The use of instruments to inform design decision making in the lighting design field will continue to increase in importance in the future and academic institutions should consider ways to apply technologies like spectrophotometry skills training in field settings as part of the lighting design curriculum. Likewise, today's students are comfortable with interacting with their peers and developing collaborative solutions to lighting design challenges which integrate diverse lighting designer opinions and technical lighting design expertise. Working together in small groups supported the students learning process through peer interactions while increasing the value of the proposed evidence based lighting design modifications for hotel rooms through formulation of collaborative solutions. Using hands- on field learning experiences also helped students better understand real- world design challenges when attempting to measure client environments and addressing client goals for the finished environment.

For the current hotel room student workshop, participants were particularly concerned about areas close to the bed such as the nightstand lamps and how the lighting in sleeping areas of hotel rooms might influence restful sleep as important factors to consider when designing lighting. Lighting solutions identified by students for use near the bed area included the Lighting Science "Good Night" bulb which may support restful sleep by limiting blue wavelength light exposure. The lighting within the hotel room bathrooms was also identified as a key design consideration for lighting to reduce potential sleep disruption since travelers may use the restroom during the nighttime hours. Students preferred the use of Lighting Science "Good Night" bulb in the hotel bathroom to minimize the effects of awakening and returning to sleep after using the bathroom. The entry, hallway, desk and seating areas were identified as areas in hotel rooms where guests might be less concerned about the potential for lighting induced sleep disruption circadian effects since these areas are commonly used for providing incidental light while moving, organizing, preparing, reading, working, or socializing within the hotel room. Students preferred the use of the Lighting Science "Aware and Awake", or G.E. "Link Smart" or "Brightstick" light bulbs to support hallways, closets, and work/seating spaces within the retrofitted hotel room which had higher blue light profiles.

Student workshop survey data findings further supported the workshop lighting design considerations by reinforcing that the student participants experience common seasonal sleep disturbances similar to the general population which could be exacerbated during travel (Figure 2). The student survey data aligns with circadian types research that suggests the common onset of seasonal sleep problems for people in the fall and which end in the spring. Students learned the value of client surveys measuring sleep factors can be used to support empathic design planning [44]. Workshop participants similarly reported physical factors such as perceived alertness, tiredness, and energy which may impact travelers perceived health and wellbeing. Data reinforced to the students that approaches to lighting design to help mitigate sleep disruption effects or increase alertness should be considered in project scope lighting design meetings (Figure 3.) The role of electric lighting in influencing perceived physical status has support in the literature [44-46].

Figure 1: Light workshop instrumentation

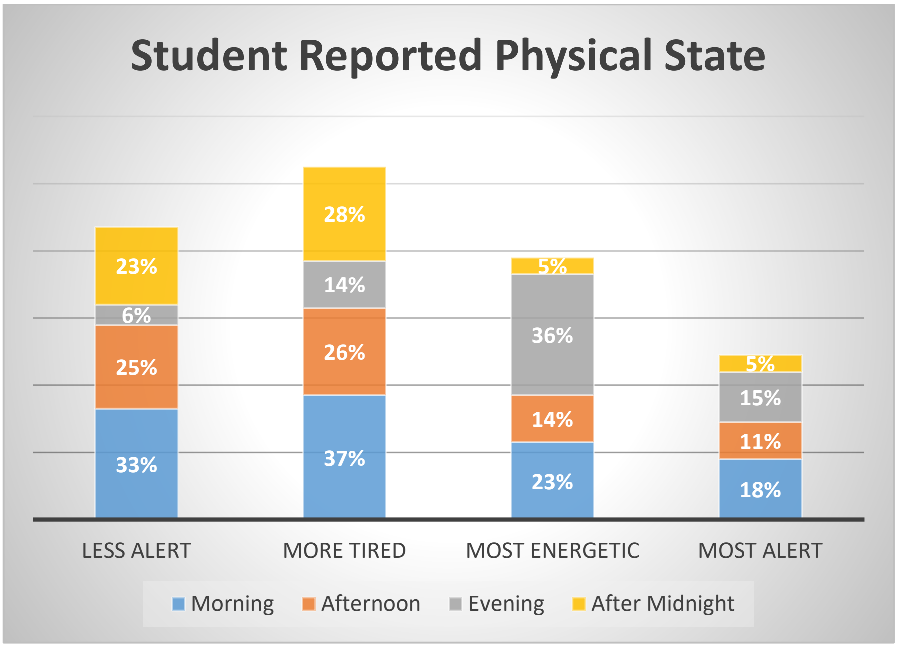

Figure 2: The surveys were used prior to the classroom-workshop to demonstrate ways that circadian lighting design consultations can be used to support circadian lighting designs by helping clients understand employee and customer self-reported sleep performance and diurnal shifts to physiological status

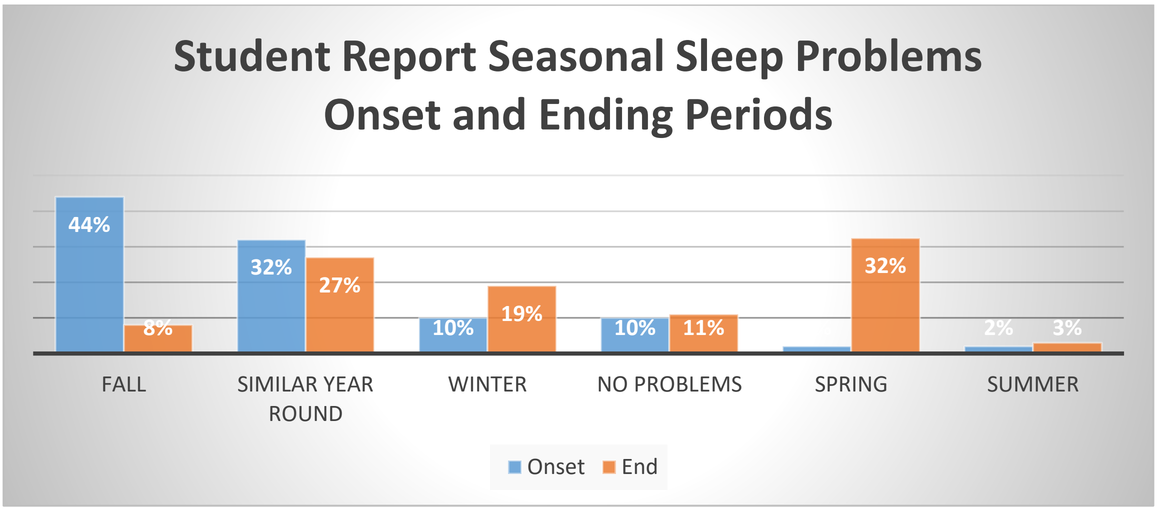

Figure 3: Student self-reported physical status during different times of day

4. Conclusion and Discussion

The workshop helped students better understand how diverse client circadian rhythms factors might influence a traveler's hotel experience and perceived well-being. The linkage of self-reported survey data to potentially improve client lighting design outcomes increased the students' empathy for clients during the design process. The workshop further demonstrated how low-cost light bulbs interventions selectively integrated into hotel rooms might influence circadian entrainment.

The goal for hospitality industry lighting designs to maximize guest health, well-being, and physical status for travelers will continue to increase in importance. Future biometric devices (e.g. Fit Bit) linked to tunable lighting systems (e.g. Philips Hue) to influence human health outcomes will combine the benefits of both new technologies in the near future by integrating biofeedback mechanisms into the separate systems. Marketing which highlights the purported advantages of circadian lighting designs integrated into hotel rooms may provide comparative advantages to industry competitors. Tunable LED lighting systems with modifiable lighting profiles on a per guest basis are the logical extension of user centric lighting design. The students who participated in the workshop will invariably encounter wearable devices that control tunable LED lighting systems in the future. The workshop strengthened the participants' knowledge about how emerging technologies might be integrated into their lighting design practice with the goal of improving client health outcomes.

Limitations and Future Research Directions

The students participating in the lighting workshops in the United States and Mexico are not representative of all travelers in the general population including those traveling to diverse geographic locations globally and experiencing seasonal variations of diurnal light. The workshops were both conducted in the fall of the year and did not allow for the measurement of seasonal available light variations inherent during travel throughout the year. Participants socio-economic status and other demographic considerations similarly did not represent the general population of travelers. Knowledge of the effects of lighting on human health and perceived well-being of the student participants may differ from travelers in the general population including knowledge about lighting design considerations that could influence hotel room guest experiences.

Further field research is needed to measure the perceived advantages of electric and natural light effects on human health including generalizable samples of travelers in hotel settings. Students reported their current physical status when they attended the workshop. Since the students traveled to the workshop, the field experience within a hotel may have influenced perceptions about environmental and physiological factors like sleep deprivation, crossing time zones, fatigue, seasonal, physical or emotional states common among travelers. Since the students traveled to attend the workshops it is likely that their empathy and understanding for the need of evidence based lighting design increased. An example of participating students survey responses that measured perceived physical status during a typical day is provided in Figure 3. The data highlighted to students that hotel room lighting designs could be used to better meet travelers' physical needs through targeted interventions. Since the workshop attendees wore actigraphy watches for short periods of time (2 hours), comparison of actigraphy based physiological data, spectral profiles and self-reported survey measure findings was not possible during the workshop. Larger scale studies of travelers' physical status and how hotel room lights can entrain circadian rhythms are needed. The workshop was successful in exposing students to the need for empathic design and importance of linking evidence based solutions supporting human health within the built environment.

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