This is an author provided manuscript version of an article that was officially published as: McCunn, L.J. & Wright, J. (2019). Hospital employees' perceptions of circadian lighting: A pharmacy department case study. *Journal of Facilities Management*, 17(5), 422-437. DOI: 10.1108/JFM-04-2019-0016

*Journal of Facilities Management* is published by Emerald Publishing Limited, and more information about the journal can be found at: https://www.emerald.com/insight/publication/issn/1472-5967. The official published version of this article can be found at: https://www.emerald.com/insight/content/doi/10.1108/JFM-04-2019-0016.

Copyright © 2019, Emerald Publishing Limited.


# Hospital Employees' Perceptions of Circadian Lighting: A Pharmacy Department Case Study

| | |
|---|---|
| Journal: | *Journal of Facilities Management* |
| Manuscript ID | JFM-04-2019-0016.R1 |
| Manuscript Type: | Research Paper |
| Keywords: | circadian lighting, productivity, affective organizational commitment, satisfaction, wellbeing, psychology |
| | |

SCHOLARONE™
Manuscripts

Running head: HOSPITAL LIGHTING

# Hospital Employees' Perceptions of Circadian Lighting: A Pharmacy Department Case Study

*Keywords.* circadian lighting, productivity, affective organizational commitment, satisfaction, well-being

Journal of Facilities Management

**Structured Abstract**

**Purpose:** An interdisciplinary body of literature has focused on the role of lighting in mitigating patient and employee stress and error-producing conditions in hospital settings. The purpose of this case study was to explore how a new circadian lighting system installed in a small pharmacy unit with no penetration of natural light is experienced by staff. Psychosocial variables, such as affective organizational commitment, perceived productivity, wellbeing, and satisfaction with the physical work environment were measured in order to further a line of enquiry that may help facilities managers and hospital administrators make optimal choices when purchasing lighting and commissioning retrofits.

**Design:** Post-occupancy evaluation; mixed-methods survey design.

**Findings:** While affective organizational commitment, perceived productivity, wellbeing, and satisfaction with the physical work environment were experienced, to some extent, by employees, low average responses about whether the setting had improved since circadian lighting had been installed suggest that the retrofit did not affect them as positively as expected. Counter to the intention of the installation, participants did not perceive the circadian lighting as a strong improvement to their levels of stress, concentration, mood, or fatigue at work.

**Originality/Value:** More research on simulated daylighting should be done to optimize occupant responses to lighting retrofits in hospitals. This case study supports recommendations to measure relevant psychosocial variables in occupants before and after a design change. Similarly-sized units within healthcare facilities that possess analogous dimensions and design constraints concerning a lack of daylight penetration will benefit from this case study's mixed methods, results, and interpretations.

Journal of Facilities Management

# Hospital Employees' Perceptions of Circadian Lighting: A Pharmacy Department Case Study

Light plays an important role in the ways in which hospital and health care designs affect people. As early as the mid-1800s, adequate interior lighting has been formally understood as critical to hospital environments, as has the notion that exposure to natural light (i.e., daylight) not only benefits patients, but hospital staff as well (Nightingale, 1859). Of course, patients, staff, and visitors experience healthcare settings differently — architects, engineers, and researchers interested in users' wellbeing in, and satisfaction with, these built environments are understanding and accounting for each type of experience though modern designs.

In a systematic meta-analysis of published studies about how the design of healthcare settings can influence the attitudes and behaviours of staff and patients, Ulrich, Quan, Zimring, Joeseph, and Choudhary (2004) found an association between insufficient lighting, especially on work surfaces, and the number of errors made in dispensing pharmaceuticals. Others (e.g., Harrison, 2004; McCarthy, 2004; Reiling, Breckbill, Murphy, McCullough, & Chernos, 2003; Rollins, 2004; Scott, 2004) have noted that lighting type (i.e., artificial; natural) and the degree of lighting in nurses' workspaces can lead to significant fatigue, as well as an increase in medication errors made by staff (e.g., misreading labels and orders, miscounting of pills, and so on). Chaudhury, Mahmood, and Valente (2009) point out that when nurses' exposure to daylight inside a hospital increases, they tend to report less stress and dissatisfaction with their jobs (as per Alimoglu & Donmez, 2005). Similarly, Mroczek, Mikitarian, Vieira, and Rotarius (2005) found that in a hospital retrofitted to have more lighting penetrate the interior through windows, the majority of staff felt that the increase in natural light had a positive impact on their work and

Journal of Facilities Management

wellbeing. Indeed, another study showed that when staff were exposed only to florescent lights during their shift, they reported feeling high levels of fatigue in the workplace (Scott, 2004).

Given a growing body of interdisciplinary literature concerning the effects of indoor lighting on mood, satisfaction, and task performance (e.g., Veitch & Newsham, 1998), and the negative effects of florescent lighting on employee experience in healthcare settings in particular, it is not surprising that innovative lighting models are being developed to improve these spaces for occupants. One example of such innovation is circadian lighting — a relatively new light distribution method that engineering and facilities management industries are labeling as 'circadian' because it varies, automatically or manually, in sky color temperature throughout the day to emulate a natural outdoor environment (International WELL Building Institute, 2018). Tunable LED fixtures are often used that allow for modulation of light intensity and duration without compromising the task or visual needs of individuals (US Department of Energy, 2017).

In 2017, a US Department of Energy report on the tuning of LED lighting in hospitals stated that a base of evidence predicting optimal settings for variable lighting systems, such as circadian lighting, has not been reliably established (US Department of Energy, 2017). More recently, in a 2019 Research for Development series, Maurizio Rossi re-iterated that "there is no internationally accepted standard that establishes rules for designing a circadian lighting system for interior spaces." (p. xi). Today, evidence highlighting the benefits that variable lighting sources in hospitals can have on both patient and staff populations is emerging, but is not yet abundant. In their review of relevant design literature, Ulrich et al. (2004) found that bright light at appropriate daytimes decreased patients' length of hospital stay and rates of diagnosed seasonal affective disorder. Another study reviewed by Ulrich et al. (2004) involved a dementia ward fitted with lights tuned to shine brighter during daylight hours; this lighting scheme

Journal of Facilities Management

improved rest-activity rhythms of the patients who lived there. Walch et al. (2004) also found that patients exposed to an increase of sunlight intensity during their hospital stay experienced lower perceived stress, less pain, and took 22 percent less analgesic medication per hour.

Taken together, the studies reviewed by Ulrich et al. (2004) establishes compelling suggestions that daylight exposure for patients should be adequately bright and, if afforded by an artificial lighting framework, aligned with natural daylight cycles to improve experiences of the setting. Ulrich et al. (2004) note that these recommendations hold for improving the work environment for, and performance of, hospital staff. Arguably, appropriately-designed lighting in all units within a hospital, and perhaps especially in a unit dedicated to the measuring, compounding, and dispensing of pharmaceuticals, is ideal. Indeed, one study highlights the influence of different illumination levels on the dispensing errors of pharmacists by showing that errors were reduced when lighting levels were high (Buchanan, Barker, Gibson, Jiang, & Pearson, 1991).

While a number of studies in the bodies of design and environmental psychology literature focus on the role of lighting in mitigating patient and employee stress and error-producing conditions in hospital settings, the key aim of the present case study is to explore how the combination of florescent and circadian lighting installed in a small pharmacy unit with no penetration of natural light is experienced by staff. We measure a number of psychosocial variables, such as affective organizational commitment, perceived productivity, wellbeing at work, and satisfaction with the physical work environment in order to further a line of enquiry that may help facilities managers and designers make optimal choices when purchasing lighting and commissioning retrofits.

Journal of Facilities Management

Organizational commitment is understood in the industrial/organizational psychology literature as an attitude based on the degree of identification with, or attachment to, the organization for which one works (Allen & Meyer, 1987). This attitude has been shown to correlate with job satisfaction and perceived productivity (Schultz & Schultz, 1998). The emotional facet of this construct, affective organizational commitment, occurs when one's values align with those communicated by one's organization (Allen & Meyer, 1987; Allen & Meyer, 1990). Understanding the extent to which hospital staff feel affective organizational commitment toward the hospital, as an organization, in relation to a circadian lighting installation intended to enhance their experience at work, may be beneficial for hospital administrators, as well as to the body of research on how human-centered lighting models affect building occupants. Self-reported levels of perceived productivity, wellbeing at work, and satisfaction with the physical work environment were also explored to understand more about whether they relate to each other in a hospital unit without natural daylighting. Results may be comparable to analogous facilities and departments with similar design constraints.

**Site Details**

In 2016, Philips linear interior LED wall grazing fixtures with intelligent white light were installed inside a ceiling alcove around the perimeter of some of the rooms (i.e., the main working room, a small office, and the sterile mixing room) within the pharmacy unit in an urban hospital in a medium-sized city located in British Columbia, Canada (see Figures 1, 2, and 3). The unit (also known as the “hub”) is located in the basement of the building and is not publicly accessible because of the controlled nature of the pharmacological substances housed within the area. The hub is operational from 7:30am to 4:30pm, seven days a week. The space is connected to a Centralized Intravenous Additive (CIVA) that uses the same DMX controller as the other

Journal of Facilities Management

areas in the hub. In the CIVA, the circadian lighting is used as the main lighting source for the entire space.

The hub lacks any source of natural light. Thus, the installation of circadian lighting was purposive on the part of the hospital's facilities managers to improve the physical work environment for employees spending lengthy periods of time in an area with no penetration of daylight. The lights are designed to mimic diurnal patterns of illumination in order to afford a sense of time passage and a connection to natural rhythms. In fact, the way the lights look when reflected on wall surfaces seems to represent glimpses of sky.

The lights were commissioned with a factory pre-set DMX controller using a time clock for scenes to be set at varying color temperatures throughout the day (e.g., 2700K at dawn, 6500K at noon, 3250K at dusk, and so on). Sunrise and sunset are determined internally by the controller's astronomical clock. A daylight sensor was installed on the outside of the building to tie into the controller to dim the lights when outdoor lighting levels change. For example, if outdoor conditions become cloudy, daylight sensors can dim the lights inside the hub to mimic outdoor color intensity (Philips Color Kinetics, 2011-2012).

[INSERT FIGURES 1, 2, and 3 HERE]

Rather than helping employees achieve a sense of variable natural lighting during times when they would normally be asleep, or preparing for sleep, the circadian lighting was installed to afford employees with a sense of daylight during the work day and break up their experience of solid-state overhead lighting. No participatory planning was done with employees by hospital administrators before installation. Employees working in all rooms, except the pharmacy stores room, are exposed to the lighting.

Journal of Facilities Management

## Methods

### Participants

Only 6-10 employees typically work in the hub. Eight individuals completed the questionnaire for this case study (all were female). The mean age of the seven participants who chose to report their demographic information was 43.29 (*SD* = 10.21). These seven participants also had spent, on average, 7.86 years (*SD* = 10.65) working in the hub before the lighting retrofit was completed in 2016, and, on average, 1.28 years (*SD* = 0.69) working in the hub after the retrofit. In addition, 57.1% of the seven participants who reported their demographics stated that they were aware of the circadian lighting installation in the hub. They also reported to spend an average of 203.58 minutes (*SD* = 222.84; 3.93 hours) in a typical work day in an area of the hub affected by the circadian lighting.

### Materials

An online questionnaire consisting of standardized and unstandardized scales and open-ended items was used. Demographic items (i.e., age, gender, length of time participants had worked in the hub before the circadian lighting had been installed, and the length of time they had worked in the hub after installation) were asked, along with a question about the number of minutes during a typical work day that participants feel they spend in the area affected by circadian lighting, as well as an item asking whether participants had been aware that new lighting had been installed in the hub.

The first standardized scale was the 8-item affective commitment scale (ACS) often utilized in industrial/organizational psychology literature, as well as in environmental psychological literature (Allen & Meyer, 1990; Solinger, van Olffen, & Row, 2008; BLINDED, 2017; BLINDED, 2012). The ACS was used in the present study to assess employees' emotional

Journal of Facilities Management

attachment to, identification with, and involvement in the hospital. Some items in the ACS were revised slightly to reflect the context of a health facility (e.g., the word "organization" was replaced with "hospital, where relevant). One item was changed to focus on the physical environment rather than the social environment (i.e., "I enjoy discussing things about this unit with other people" was changed to "I enjoy discussing the way this hospital looks with other people").

Four items of the ACS are reverse-coded; all scale items were asked on a Likert scale where 0 represented a very low level of agreement and 7 represented a very high level as per Allen and Meyer (1990). One item was added to the end of the ACS to ask participants to compare their current perception of affective organizational commitment to a time before the circadian lighting was installed. Because this item is not part of the standardized ACS, it was not included in the reliability analysis of the scale which revealed very strong internal consistency (as per DeVellis, 2012) ($\alpha = .93$; see Table 1 for exact item wording).

Next, eight items measuring participants' perceived productivity were revised from a scale developed and used in previous research by BLINDED (2017). Again, a retroactively-worded item was added to the end of the scale to measure participants' sense of productivity before the lighting installation. This item was not included in the reliability analysis of the scale; Cronbach's alpha for the scale was good, $\alpha = .80$; see Table 2.

Similarly, three items measuring participants' perceived wellbeing in the workplace, in relation to the circadian lighting, were revised from a scale developed by one of the authors (LM) for unpublished field research in an office building. Its internal consistency was good, $\alpha = .87$ (see Table 3). Four retroactively-worded items relating participants' perceptions of wellbeing to the new lighting were added to the end of the scale and analyzed independently (see Table 3).

Journal of Facilities Management

Finally, participants' levels of satisfaction with the physical work environment were measured by four items on the same Likert scale. These questions were created specifically for this case study and, as a scale, were shown to be reliable (α = .85; see Table 4). We also asked two open-ended items after this scale in order to perform thematic content analysis of words and phrases (e.g., "please use the open-ended space below to describe the physical design attributes of the pharmacy department that contribute/do not contribute to your satisfaction at work").

**Procedure**

This research was approved by the authors' institutional ethics board (Protocol: 2018-062-BLINDED), as well as by the region's health authority's ethics board (H2018-050). An introductory email was sent by the hub's manager, on behalf of the Director of sustainability for all hospitals in the region, to an employee listserv to explain the nature of the study. The email was sent one week before a follow-up email was sent, in the same manner, containing a link to the questionnaire created using an online tool (i.e., REDCap) approved by the Research and Capacity Building Department that manages research undertaken in the region's hospitals. Once the link was clicked, participants could read information about informed consent and decide whether to participate by clicking a button to advance to the next page of the online questionnaire. The survey was open for four weeks in the fall of 2018.

## Results

Each continuous item was tested for normality based on recommendations by Kline (1997). All items met the criteria for acceptable skewness (values between +3 and -3) and acceptable kurtosis (values between +8 and -8). Because of a lack of data from before the circadian lighting was installed, no 'before and after' between-groups or repeated measures statistical comparisons could be performed. However, descriptive statistics could be calculated

Journal of Facilities Management

and interpreted for all scales and items in the questionnaire to understand average levels of agreement with particular psychosocial variables after the retrofit.

Mean responses to ACS items were quite low (see Table 1) and the mean response to the ACS scale was neutral 3.67 (*SD* = 1.67). The strongest mean response was on the item concerning participants' agreement that they would be happy to spend the rest of their careers at the hospital (*M* = 5.00, *SD* = 2.14) while the lowest concerned the retroactive item asking whether participants felt as though their organization had improved since the lighting installation (*M* = 2.63, *SD* = 1.51).

[INSERT TABLE 1 HERE]

In contrast, average responses on the perceived productivity scale were higher (see Table 2); the scale mean was also higher than that of the ACS, *M* = 5.69, *SD* = 1.12). The strongest mean responses were on items concerning participants' general consideration of their own productivity at work, and whether they felt motivated to create a positive atmosphere at work (*M* = 6.50, *SD* = 1.07; *M* = 6.50, *SD* = 1.07, respectively). The lowest mean was in response to the item about participants' willingness to take on a leadership role during a time of crisis in the workplace (*M* = 4.50, *SD* = 2.62). However, similar to the retroactive item posed after the ACS, the retroactive item relating to perceived productivity after the lighting retrofit was neutral (*M* = 3.63, *SD* = 2.07).

[INSERT TABLE 2 HERE]

Next, the three items in the perceived wellbeing at work scale were analyzed to reveal positive perceptions (scale mean = 1.25, *SD* = 1.28; note that all items in this scale were worded in reverse). Mean responses to all three items indicated strong disagreement with negatively-worded items concerning how the new lighting program affects levels of fatigue, general stress

Journal of Facilities Management

level, and concentration at work (see Table 3). However, the other four items in this section of the questionnaire were each worded to capture participants' retroactive perceptions of the hub in relation to their wellbeing at work; average responses to these items were neutral (see Table 3).

[INSERT TABLE 3 HERE]

Mean responses on items in the workplace satisfaction with the physical environment scale were also quite neutral (scale $M = 4.78$, $SD = 1.47$). The highest average response on this scale was on the item concerning general satisfaction with the workplace ($M = 5.75$, $SD = 1.75$); the lowest concerned satisfaction with the physical work environment of the hospital ($M = 3.75$, $SD = 1.49$). Items to do with the physicality of the pharmacy hub itself, and its lighting environment in particular, elicited strong positive responses (see Table 4).

[INSERT TABLE 4 HERE]

Participants were also asked to describe, in their own words, design attributes of the hub that contribute to their satisfaction at work, as well as attributes that do not. Five participants chose to type in the textbox to respond to the first item, yielding six distinct and relevant comments. Only three individuals offered comments on the second item, yielding six distinct comments.

When content analyzed by two independent raters, words and phrases offered for the first question concerning the physical attributes that contribute to satisfaction were categorized mostly to do with lighting (50% of the data), while the remainder of the data had to do with air quality, visual interest (i.e., preference for a large-scale abstract mural in the hub), and cleanliness. No disagreements occurred between raters ($\kappa = 1.00$). Words and phrases offered for the second items concerning physical attributes that do not contribute to satisfaction were content analyzed into themes such as layout (50%), space (33%), and visual interest (17%). No

Journal of Facilities Management

disagreements occurred between raters ($\kappa = 1.00$). Comments concerning lay out and space discussed a lack of space and crowding, as well as a lack of natural efficient pathways in the hub. As in the previous open-ended item, the theme of visual interest had to do with a large abstract mural in the hub, except that it was depicted as a hinderance to satisfaction for the individual responding to this item, rather than a contribution. No comments were made indicating that the lighting in the hub did not contribute to satisfaction.

## Discussion

This small but descriptive case study asked hospital employees working in a pharmacy hub with no direct source of natural light about their perceptions of a recently-installed circadian lighting system around the perimeter of most of the rooms in the unit. While employees working in the hub did not experience strong affective organizational commitment overall, they did feel mildly satisfied with the notion of working at the hospital for the rest of their careers. Given the lowest average response concerning the construct of affective organizational commitment was toward the item asking whether the organization had improved since the lighting installation, the circadian lighting retrofit does not seem to have positively affected employees' levels of affective organizational commitment, despite the reason for the installation being to improve the work setting for occupants. It may be that this intention was not communicated clearly enough to occupants by hospital administrators or facilities managers, and that in order for a connection to be made between a new lighting installation and affective organizational commitment, organizations must ensure that occupants understand links between design change and their experience with the physical work environment. Indeed, BLINDED (2017) note the importance of an informative and communicative commissioning process to office building occupants during and after a retrofit.

Journal of Facilities Management

In contrast, participants perceived their levels of productivity to be fairly high but, similar to the retroactive item concerning affective organizational commitment, the average response to the retroactive item concerning perceived productivity since the lighting retrofit had been completed was neutral. It seems that, for this case study, occupants do not associate attributes of a circadian lighting program with productivity. This may be because the lighting was installed around the perimeter of the unit's rooms and, thus, does not serve as task lighting or a main source of overhead lighting that may be expected to impact productivity at work. It seems as though the circadian lighting installation in this particular setting is perceived to be ambient rather than as a stimuli that is directly useful for completing work tasks. Interestingly, the item on the workplace satisfaction with the physical environment scale that asked participants how they felt about the pharmacy hub's lighting environment elicited strong positive responses on average. This result suggests that although the lighting in the hub may not be understood by occupants to associate with psychosocial variables, it is not unsatisfactory to them in general.

With respect to participants' perceptions of their wellbeing at work, the new circadian lighting in the hub seems to be understood as not harming their feelings of wellbeing on the job. This interpretation is based on low means reported for the reverse-coded items (e.g., "I believe that the circadian lighting program in my work area negatively impacts my general stress level"). In other words, participants strongly disagreed with items asking whether the new lighting in the hub *negatively* affected their levels of fatigue, general stress level, and concentration. However, responses offered for the four retroactively-worded items about employees' perceived wellbeing at work were not as strong — they were, instead, quite neutral. Employees do not appear to feel strongly that the circadian lighting in their workspace has improved (or diminished, given the neutrality of average responses) their levels of stress, concentration, mood, or fatigue. Although

Journal of Facilities Management

this result contrasts with Alimoglu and Donmez's (2005) findings that access to daylight can improve levels of stress, the present case study's independent variable of simulated daylight may make comparisons to this and other studies in the body of literature difficult.

One aspect not measured in the present case study is employees' level of control (either actual or perceived) over the new circadian lighting system in the hub. Environmental control has been shown to be one of the most important factors in improving perceptions of light quality, as well as occupant mood and satisfaction with a work setting (Newsham et al. 2004; Boyce et al. 2006; Veitch et al. 2008). Moreover, significant relations between lighting control, affective organizational commitment, and perceived productivity have been found in other research (e.g., BLINDED, 2017). However, Veitch (2001) notes that while perceived control has a strong basis in the body of psychological literature, installing complex controls for individual occupants to learn to use to obtain a sense of control over their work environment can sometimes lead to less productive outcomes. It may be that occupants' perceptions of control (or lack thereof) may have affected their responses to some of the psychosocial scales included in this study. As noted in the Site Details section, employees are not able to directly control the circadian lighting system. Focusing future research on measuring occupants' perceptions of control over modern lighting installations that operate via external sensors to illuminate interior spaces based on outdoor conditions (especially during seasons in which it is darker during typical work hours, i.e., between 8:30am-5:00pm) may be prudent. Küller et al., (2006) found that those working in indoor settings in locales farther north of the equator experienced variations in mood over the year that did not occur for those living in countries closer to the equator. Although the tuning of circadian lighting systems can be automated for seasonal differences in color temperature, it may be worth investigating ways in which occupants perceive the lighting environment at work

Journal of Facilities Management

during these seasons and when they are aware of a circadian lighting system in their area and have, perhaps, formed expectations about what it should look (and feel) like inside during working hours indoors.

Finally, to better understand which features of the physical environment participants understood to help or hinder their satisfaction while working in the hub, qualitative research methods were used to analyze words and phrases offered by some employees. Themes that emerged from the item asking about which design attributes contribute to satisfaction mostly concerned lighting. Some specific comments were that the lighting is "enjoyable," and that "I can see what I am doing." However, knowing whether comments to do with lighting are about the circadian lighting in particular, as opposed to other forms of lighting in the hub, is difficult. In addition, for the item asking about which attributes did not contribute to their satisfaction, participants' comments mostly communicated issues with poor layout, space conflicts, and an issue with visual interest concerning a large-scale abstract mural in the unit.

Because the theme of lighting was most frequent in response to the item concerning physical attributes that contribute to employee satisfaction, and because no comments to do with lighting were offered in response to the item about which attributes do not contribute to employee satisfaction, the circadian lighting retrofit in the pharmacy hub seems to have been successful in affording employees a sense of satisfaction at the workplace. Taken together, findings indicate that employee perceptions of a circadian lighting system in a pharmacy unit in a medium-sized urban hospital with minimal daylight penetration are generally positive but that such an installation may not improve some psychosocial constructs for employees working under these conditions, such as affective organizational commitment, perceived productivity, and wellbeing on the job.

Journal of Facilities Management

Hospital administrators must weigh the neutrality of some of the responses made by employees with the cost of circadian lighting retrofit projects. More research on the extent to which building users perceive simulated daylight, in the form of circadian lighting, as resembling natural light is needed to understand better whether the benefits of natural light can be experienced with circadian lighting. In our effort to find literature that describes the psychological benefits of artificial daylighting in work settings, we were able to find one study that examined mood state for individuals working in two office types: windowless or one that included an artificial skylight affording a view of a cloudless, sunny sky (Canazei et al., 2017). Participants' moods, and their connectedness to nature, were reported to be better in the office with the artificial skylight. However, this experiment is not entirely analogous to the present study (i.e., direct sky views were not a factor in the present work). Undoubtedly, more interdisciplinary research is required as designers and facilities managers move forward in planning and managing high-performance, sustainable buildings that afford physical and psychological health and wellbeing for occupants.

**Limitations**

Because the authors did not have the opportunity to begin this case study until 2018, one limitation to the research is a lack of data about how employees felt, and what they perceived, about the setting before the circadian lighting was installed in the hub in 2016. Although retroactively-worded items were used in the questionnaire to understand participants' appraisals of their work environment before the retrofit (compared to the way it currently is), statistical comparisons before and after the design change would have been optimal. In addition, the small sample size limits this case study in its power and generalizability. However, we hope that similarly-sized units within hospitals and other health care facilities that possess analogous

Journal of Facilities Management

dimensions and design constraints concerning a lack of daylight penetration will benefit from this study's mixed methods, results, and interpretations.

## Conclusion

An interdisciplinary body of literature exists in which positive associations are shown between daylighting and a number of psychosocial variables. However, research on how a new form of lighting that mimics patterns daylighting—circadian lighting—may affect hospital staff members' perceptions of their physical work environment is not yet abundant. We expected that circadian lighting would be understood positively by pharmacy employees working in a hospital space without daylight penetration where circadian lighting had been recently installed. Using a mixed-methods design, we found that affective organizational commitment, perceived productivity, wellbeing at work, and satisfaction with the work environment were experienced, to some extent, by employees post-retrofit. However, low average responses about whether the work environment had improved since the lighting installation suggest that the retrofit did not positively affect employees as strongly as may have been hoped for by facilities managers and hospital administrators. In particular, results concerning wellbeing at work indicate that participants do not perceive the lighting retrofit as having strongly improved (or diminished) their levels of stress, concentration, mood, or fatigue. These findings contrast others noting that having access to daylight at work can improve some psychosocial factors. More research on simulated daylight sources in the workplace should done to afford effective, productive outcomes of lighting retrofits that involve new technologies. Along with augmenting a growing body of literature that merges design, environmental psychology, ergonomics, and health, this case study highlights that obtaining systematic measurements of building occupants'

Journal of Facilities Management

psychosocial experiences with the physical environment before and after a lighting retrofit is optimal.

Journal of Facilities Management

## References

Alimoglu, M. K., & Donmez, L. (2005). Daylight exposure and the other predictors of burnout among nurses in a university hospital. *International Journal of Nursing Studies, 42,* 549-555.

Allen, N. J. & Meyer, J. P. (1990). The measurement and antecedents of affective, continuance and normative commitment to the organization. *Journal of Occupational Psychology*, *63*, 1–18.

Allen, N. J. & Meyer, J. P. (1987, June). Paper presented at the Canadian Psychological Association. An investigation of 'extra-role' behaviors within organizations, Vancouver, BC, Canada.

Buchanan, T. L., Barker, K. N., Gibson, J. T., Jiang, B. C., & Pearson, R. e. (1991). Illumination and errors in dispensing. *American Journal of Hospital Pharmacy, 48,* 2137-2145.

Boyce, P. R., Veitch, J. R., Newsham, G.R., Jones, C. C., Heerwagen, J., Myer, M., & Hunter, C. M. (2006). Occupant use of switching and dimming controls in offices. *Lighting Research & Technology, 38,* 358–376.

Canazei, M., Pohl, W., Bliem, H. R., Martini, M., & Weiss, E. M. (2017). Artificial skylight effects in a windowless office environment. *Building and Environment, 124,* 69-77.

Chaudhury, H., Mahmood, A., & Valente, M. (2009). The effect of environmental design on reducing nursing errors and increasing efficiency in acute care settings. *Environment and Behavior, 41,* 755-786.

DeVellis, R. F. (2012). *Scale development: Theory and applications.* Los Angeles, CA: Sage.

Harrison, S. (2004). Bad hospital design leads to poor staff performance. *Nursing Standard, 18,* 7.

Journal of Facilities Management

International WELL Building Institute. (2018). Circadian lighting design. Retrieved from: https://standard.wellcertified.com/light/circadian-lighting-design

BLINDED (2017).

Kline, R. B. (1997). *Principles and practice of structural equation modeling.* New York, NY: Guilford.

Küller, R., Ballal, S., Laike, T., Mikellides, B., & Tonello, G. (2006). The impact of light and colour on psychological mood: A cross-cultural study of indoor work environments. *Ergonomics, 49,* 1496-1507.

McCarthy, M. (2004). Healthy design. *Lancet, 364,* 405-406.

BLINDED. (2012).

BLINDED. (2017).

Mroczek, J., Mikitarian, G., Vieira, E. K., & Rotarius, T. (2005). Hospital design and staff perceptions: An exploratory analysis. *Health Care Manager, 24,* 233-244.

Newsham, G., Veitch, J. R., Arsenault, C., & Duval, C. (2004). Effect of dimming control on office worker satisfaction and performance. In *Proceedings of the IESNA Annual Conference.* Tampa, New York: Illuminating Engineering Society of North America.

Nightingale, F. (1859). *Notes on nursing: What it is and what it is not.* London: John W. Parker.

Philips Color Kinetics. (2011-2012). Philips solid-state lighting solutions specifications. Burlington, MA. DAS-000080-01 r03 10-12

U.S. Department of Energy (2017, August). *Tuning hospital lighting: Evaluating tunable LED lighting at the Swedish hospital behavioural health unit in Seattle.* Technical report prepared for the U.S. Department of Energy Solid-State Lighting Program by Pacific Northwest National Labs.

Journal of Facilities Management

Reiling, J., Breckbill, C., Murphy, M., McCullough, S., & Chernos, S. (2003). Facility designing around patient safety and its effect on nursing. *Nursing Economics, 21,* 143-147.

Rollins, J. A. (2004). evidence-based hospital design improves health care outcomes for patients, families, and staff. *Pediatric Nursing, 30,* 338-339.

Rossi, M. (2019). *Circadian Lighting Design in the LED Era.* Switzerland: Springer.

Schultz, D. & Schultz, S. E. 1998. *Psychology and work today*, Upper Saddle River, NJ: Prentice Hall.

Scott, H. (2004). Working environments have a direct impact on care. *British Journal of Nursing, 13,* 893.

Ulrich, R., Quan X., Zimring, C., Joseph, A., & Choudhary, R. (September, 2004). *The role of the physical environment in the hospital of the 21st century: A once-in-a-lifetime opportunity.* The Center for Health Design. Technical Report.

Veitch, J. A., & Newsham, G. R. (1998). Lighting quality and energy-efficiency effects on task performance, mood, health, satisfaction, and comfort. *Journal of the Illuminating Engineering Society, 27,* 107–129.

Veitch, J. A. (2001) Psychological processes influencing lighting quality. *Journal of the Illuminating Engineering Society, 30,* 124-140.

Veitch, J. A., Newsham, G. R., Boyce, P. R., & Jones, C. C. (2008). Lighting appraisal, well being and performance in open-plan offices: A linked mechanisms approach. *Lighting Research & Technology, 40,* 133–151.

Walch, J. M., Rabin, B. S., Day, R., Williams, J. N., Choi, K., & Kang, J. D. (2004). The effect of sunlight on post-operative analgesic medication usage: A prospective study of spinal surgery patients. *Psychosomatic Medicine, 67,* 156-163.

Journal of Facilities Management

Table 1. *Means and Standard Deviations for the ACS (Items 1-8) and an Additional Retroactive Item (Item 9).*

| Item | *n* | Mean | *SD* |
|---|---|---|---|
| I would be very happy to spend the rest of my career working at this hospital | 8 | 5.00 | 2.14 |
| I enjoy discussing things about this hospital with other people | 8 | 3.75 | 2.66 |
| I could easily become as attached to another hospital as I am to this one *(reverse coded)* | 8 | 3.38 | 1.19 |
| I do not feel like 'part of the family' at this hospital *(reverse coded)* | 8 | 4.75 | 2.44 |
| I do not feel emotionally attached to this hospital *(reverse coded)* | 8 | 3.50 | 1.60 |
| This hospital has a great deal of personal meaning for me | 8 | 3.00 | 1.77 |
| I do not feel a strong sense of belonging to this hospital *(reverse coded)* | 8 | 3.63 | 1.51 |
| I feel as if this hospital's problems are my own | 8 | 2.38 | 2.50 |
| I feel as though my commitment to this hospital as an organization has improved since the circadian lighting retrofit | 8 | 2.63 | 1.51 |

Journal of Facilities Management

Table 2. *Means and Standard Deviations for the Perceived Productivity Scale (Items 1-8) and an Additional Retroactive Item (Item 9).*

| Item | *n* | Mean | SD |
|---|---|---|---|
| I consider myself to be productive at work | 8 | 6.50 | 1.07 |
| The lighting environment in the pharmacy department allows me to be as productive as I would like | 8 | 5.00 | 1.77 |
| I feel engaged in my work while I am in the pharmacy department | 8 | 6.13 | 1.13 |
| I do not believe that I could be any more productive than I already am at work | 8 | 5.50 | 2.07 |
| I am motivated to create a positive atmosphere at work | 8 | 6.50 | 1.07 |
| I assist my colleagues in doing their jobs in more efficient ways | 8 | 6.13 | 1.64 |
| I am willing take on more of a leadership role during a time of crisis at work | 8 | 4.50 | 2.62 |
| My colleagues look to me for setting a good standard for organization at work | 8 | 5.25 | 1.91 |
| I feel as though my productivity at this hospital has improved since the circadian lighting retrofit | 8 | 3.63 | 2.07 |

Journal of Facilities Management

Table 3. *Means and Standard Deviations for the Perceived Wellbeing at Work Scale (Items 1-4) and Additional Retroactive Items (Items 5-8).*

| **Item** | ***n*** | **Mean** | ***SD*** |
|---|---|---|---|
| The new circadian lighting program in my work area makes me feel physically fatigued | 8 | 1.75 | 1.49 |
| I believe that the circadian lighting program in my work area negatively impacts my general stress level | 8 | 1.00 | 1.41 |
| I believe that the circadian lighting program in my work area negatively impacts my ability to concentrate at work | 8 | 1.00 | 1.41 |
| In general, my level of fatigue at work has improved since the lighting retrofit | 8 | 3.00 | 1.69 |
| In general, my mood at work has improved since the circadian lighting retrofit | 8 | 3.25 | 1.98 |
| In general, my general stress level has improved since the circadian lighting retrofit | 8 | 3.25 | 1.98 |
| In general, my level of concentration has improved since the circadian lighting retrofit | 8 | 3.25 | 1.98 |

Journal of Facilities Management

Table 4. *Means and Standard Deviations for the Workplace Satisfaction with the Physical Environment Scale.*

| **Item** | ***n*** | **Mean** | ***SD*** |
|---|---|---|---|
| I am satisfied with the physical work environment at this hospital | 8 | 3.75 | 1.49 |
| I am satisfied with the physical work environment in the pharmacy department | 8 | 4.75 | 1.98 |
| I am satisfied with the lighting environment in the pharmacy department | 8 | 4.88 | 1.80 |
| I am generally satisfied with my workplace | 8 | 5.75 | 1.75 |

Journal of Facilities Management

*Figure 1.* Circadian lighting installed in a recessed crevasse along a perimeter wall.

Journal of Facilities Management

*Figure 2.* The impression of sky lighting given by circadian lighting installed around a room's perimeter.

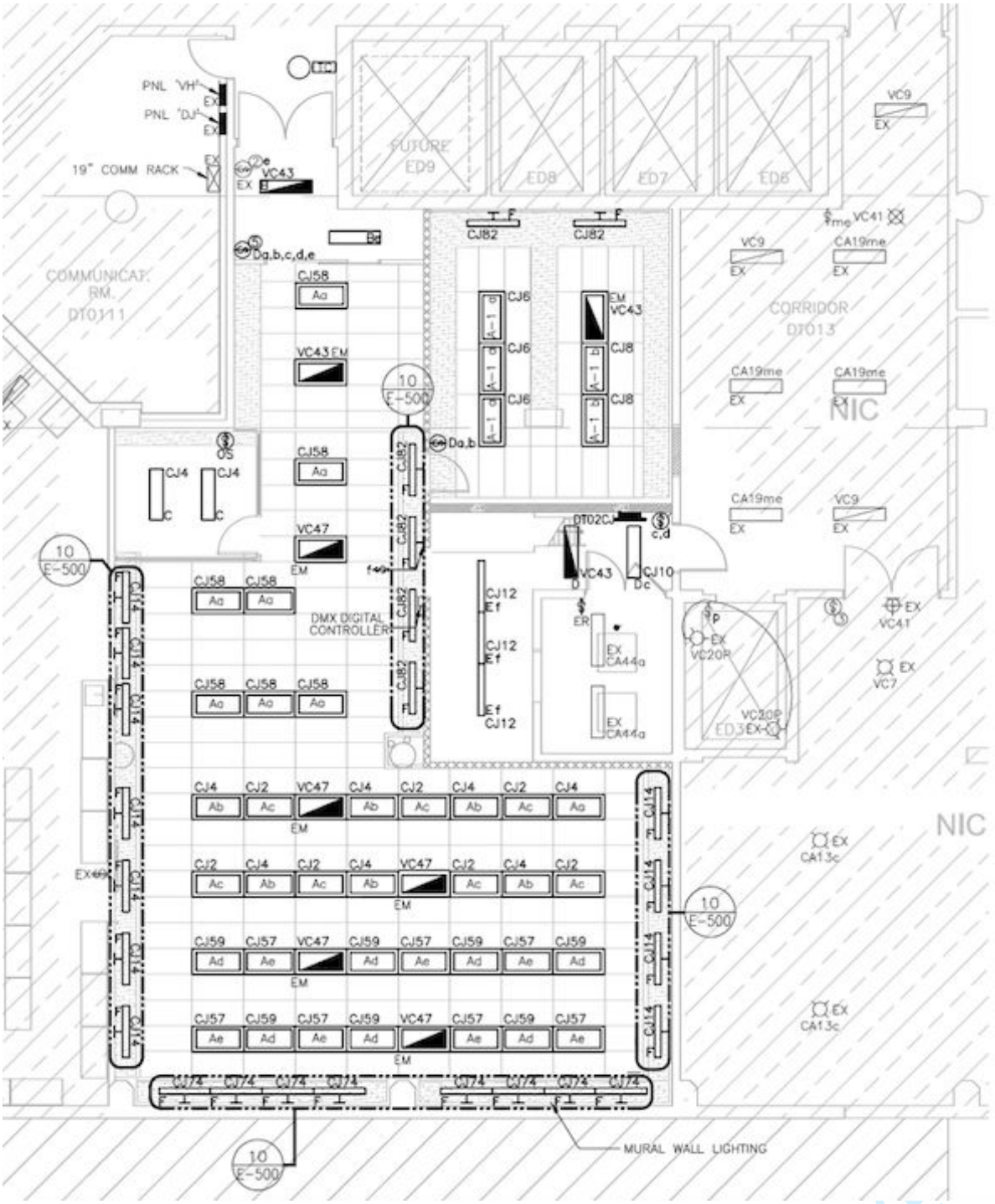


*Figure 3.* Floor plan of "the hub."