Nurses' Satisfaction with Patient Room Lighting Conditions: A Study of Nurses in Four Hospitals with Differences in the Environment of Care

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Abstract

Purpose: The present study aims to contribute to current knowledge about nurses' perceived importance of lighting in patient rooms, and to compare these perceptions across different ages, work shifts, (day and night), and environments of care (traditional and contemporary).

Background: Creating an environment of care in patient rooms that successfully balances energy efficiency concerns with the holistic needs of patients, families, and caregivers poses a major challenge for future lighting systems. This study adds to a growing evidence base on the effects of lighting on nurses' job performance, job satisfaction, and overall perceptions of the environment.

Methods: Survey responses from 138 participants working in medical-surgical units in four hospitals were analyzed using a mixed-methods approach, with three of the hospitals having lighting systems characterized as providing a traditional environment of care (TEC) and the other hospital having lighting systems characterized as providing a contemporary environment of care (CEC).

Results: No significant differences were found based on age or work shift, but several significant differences were found between participants working in the hospital with a CEC and those working in hospitals with a TEC. Participants from the hospital with a CEC lighting system consistently reported higher lighting quality, fewer patient complaints, and less need for supplemental lighting than the participants from the three hospitals with TEC lighting systems.

Conclusion: The results of this study provide evidence that innovative lighting approaches and technologies are worth considering as an investment by hospital administrators looking to improve perceptions of the patient room environment.

Introduction

The U.S. Department of Energy reported that the healthcare industry in the United States accounts for over 16% of the nation's gross domestic product, and 9% of the energy used in commercial buildings. U.S. healthcare facilities are estimated to spend nearly $9 billion on energy annually, which translates in a typical hospital to over $13,500 per bed spent on energy. Indeed, the energy use intensity (EUI) of hospitals exceeds most other types of buildings and is roughly three times that of office buildings. Lighting systems have been a critical part of the hospital energy story, with previous data indicating that over 40% of the electricity use in a hospital has been attributed to lighting (U.S. Department of Energy, 2013).

Reducing healthcare lighting energy use poses difficult challenges. Complex medical procedures require high light levels (DiLaura et al., 2011), in many cases beyond the levels afforded by older lighting systems. Further, a growing understanding of the effects of light on human biology, as well as the importance of light for helping to create pleasant, non-institutional environments, has created a desire for hospital lighting systems that provide flexibility in spectral output and control. However, such lighting systems may require higher power densities than the simpler systems of the past in order to meet the high light levels required, as well as to provide the desired flexibility. Thus, creating an environment of care with respect to lighting that balances energy efficiency concerns with the holistic needs of patients, families, and medical caregivers poses a challenge for designers and administrators of hospitals and other healthcare settings.

As defined by the Facilities Guidelines Institute (FGI), the term *environment of care* refers to "those physical environment features in a health care facility that are created, structured, and maintained to support and enhance the delivery of health care" (FGI, 2018, Glossary). As Nightingale (1859) noted in the 19th century, the physical environment of a medical facility can affect the psychological wellbeing and behaviors of every kind of building user—from patients and their visitors to medical staff. A century later, Nightingale's vision was largely neglected during the postwar economic boom of the mid-20th century when rapid advances in medical technology, and an increased focus on efficiency in the delivery of medical care, meant a decrease in attention on the human dimensions of hospital design. The environment of care during this period, referred to herein as the traditional environment of care (TEC), became a testament to technology and efficiency, resulting in dehumanized institutional spaces (Bates, 2018).

Since the mid-1980s, a renewal of Nightingale's perspective has characterized hospital design with a movement away from the traditional environment of care to one that is more welcoming to patients and visitors. As Nesmith (1995) explained, this movement goes beyond simply making spaces more attractive. The contemporary environment of care (CEC) recognizes that, while the physicality of hospitals must support the effective delivery of care, they are in and of themselves tools in the healing process, supporting wellness through psycho-physiological effects. These effects are important for all building users – patients, visitors, and staff – just as Nightingale observed.

For nursing staff in particular, environmental attributes such as air quality, acoustics, and lighting, can significantly impact their state of health and job efficiency (Ulrich et al., 2008, 2004). Evidence that hospital lighting can affect nurses' levels of fatigue and performance exists (CABE, 2004) and, in some cases, seems to lead to error-producing conditions (e.g., errors in dispensing medication) (Buchanan et al., 1991). The design of lighting systems in patient rooms can also impact nurses' job performance in

terms of their effectiveness in treating patients carefully and quickly, as well as their satisfaction at work. Lighting is a key environmental variable that is thought by nurses to contribute to errors made in acute care settings, along with issues with noise level, ergonomics, furniture, equipment, and layout (Chaudhury et. al, 2009; Mahmood et. al, 2011). Design recommendations made by Chaudhury et al. (2009) were supported in a case study focusing on an acute care unit in which a combination of daylighting and electric lighting was in place (McCunn & Gifford, 2013).

Other examples of how important patient room lighting can be for nurses are found in a multidisciplinary body of literature. In one study, 392 Australian critical care nurses identified that "adjustments to lighting" was one of the most common end-of-life care practices that they employed (Ranse, Yates, & Coyer, 2016). For each of the 51 items on the questionnaire, nurses rated how often they undertook practices for end-of-life patients using a five-point scale of "never," "rarely," "sometimes," "often," and "always." Factor analysis identified six domains of care and, for the environmental modification domain, the most important (i.e., highly loaded) item was "adjust (dim or turn off) the lighting around the patient's bed space."

In 2016, Hadi, DuBose, and Ryhard also investigated nurses' perceptions of lighting from a survey of 393 nurses working in medical-surgical (med-surg) units in the U.S. Their survey focused on five general locations inside med-surg units (as opposed to only patient rooms, as the present study does) where lighting might impact nurses' job performance and satisfaction. Nurses' perceptions of lighting conditions at patients' bedsides, and at decentralized nurse stations, were significantly less desirable than lighting conditions at centralized nurse stations, patient bathrooms, and unit corridors. In addition, at each of the five general locations within the units, nurses with access to lighting controls reported significantly higher satisfaction with the lighting than those who did not have access to lighting controls.

Another study investigated nurses' perceptions of light level at their workplace and found differences based on nurses' ages. Kamali and Abbas (2012) surveyed 120 nurses at a recently-built naturally-lit open ward healthcare center in Malaysia to determine their impressions of light levels on their job tasks, such as administering medications orally. All of the nurses who were 40 years or older selected "dark" or "vague" on a questionnaire which asked them to describe the lighting," while over 70% of nurses between the ages of 30-39 selected "comfortable" or "clear," as did 90% of nurses self-reporting to be in the 21-29 age category. While these age-related effects are consistent with the fact that the aging visual system requires more light stimulation for productive sight (DiLaura et al., 2011), Kamali and Abbas (2012) did not report photometric measurements of the lighting environment about which nurses were reporting, nor did they state the total number of nurses in each age group who responded to the survey. These and other methodological concerns limit the application of the results for more general purposes.

The purpose of the present study is to contribute to current knowledge about nurses' perceived importance of lighting in patient rooms, and to compare these perceptions across different ages, work shifts, (day and night), and environments of care (TEC and CEC). This knowledge is intended to help facility designers and managers incorporate nurses' perspectives in their decisions, as well as to inform technologists and engineers developing future generations of lighting systems for patient rooms. These future generations of patient room lighting provide new opportunities that surpass those provided by the TEC and CEC lighting systems studied in prior research. While TEC and CEC lighting have been characterized by the incandescent and fluorescent light sources of the past, future systems will utilize solid-state lighting technologies, such as LEDs, and will provide new opportunities for adapting the intensity, distribution, and spectrum of light to better satisfy the holistic needs of patients and caregivers at different times of day or night. The present study was initiated, in part, to provide a better

evidence base for informing the development and application of future LED lighting systems for patient rooms.

Study Site Details

In 2015, nursing staff working in four different hospital facilities in the U.S. Pacific Northwest were invited to participate in the present study. At the time of data collection, three of these hospitals (Hospitals A, B, and C) had lighting systems in their med-surg units typical of older hospitals with a traditional environment of care. These traditional environment-of-care lighting systems (TECL) have few luminaires (typically less than five) in each patient room, with simple switching controls and without dimming capabilities. The other hospital (Hospital D) had a more advanced lighting system in the med-surg patient rooms, consistent with the hospital's more recent construction and overall contemporary design. Typical of contemporary environment-of-care lighting systems (CECL), the patient rooms in this hospital utilized zones of luminaires with separate controls for each zone, with additional lighting for nighttime navigation. The luminaires in the patient rooms in Hospital D did not have dimming capability. Photographs of the patient room lighting in each hospital are provided in Appendix A.

In 2015, two of the authors toured units in each hospital during the month prior to the distribution of the questionnaire. At the time of distribution, a typical med-surg patient room in Hospital A included a headwall luminaire using 4 ft fluorescent lamps with separate uplight and downlight compartments controlled from a patient bed remote, and a hinged upper section for use as an examination light when flipped over to afford direct light along the bed. These rooms also had one or two recessed slot (6 in. by 4 ft) lensed luminaires using 4 ft fluorescent lamps for general room lighting and in-wall amber LED step-lights near the bathroom and exterior doors. Other than the patient control for the headwall luminaire, the recessed luminaires were controlled by a switch near the nurse monitor; step-lights were controlled by a switch near the door.

Patient rooms in Hospital B used a single multi-purpose recessed 2 ft by 4 ft luminaire over the bed, comprised of a 2 ft by 2 ft exam light section with four 2 ft fluorescent lamps, and a 2 ft by 2 ft section with two 2 ft fluorescent lamps for reading. The exam section was controlled by a wall switch located at the headwall and the reading section was controlled at the patient bed. Additionally, this luminaire had an integral small spotlight operated by a separate wall switch near the doors to provide for chart reading without turning on the full overhead lighting. This luminaire originally provided the entire lighting in the rooms, but additional luminaires and controls had been added during an update to the rooms that was completed shortly before the questionnaire. Additions included a recessed downlight using a compact fluorescent lamp (CFL) at the entry area, an in-wall LED step-light near the bathrooms that served as a night light, and a wall sconce using a CFL with a separate wall switch for guest control. A four-gang switch at the door with labels (e.g., sconce, bed, down, and night) controlled these luminaires. The upgrade only addressed lighting changes; the overall room décor and furnishings remained institutional in style, consistent with a TEC facility.

Patient rooms in Hospital C had only a multi-function headwall luminaire with 4 ft fluorescent lamps in separate uplight and downlight sections; the uplight section was hinged to serve as a flip-up examination light. These luminaires were like those described in Hospital A, although they were a different model made by a different manufacturer. The facility manager for Hospital C informed the researchers that, at the time of the questionnaire, some luminaires were more than 10 years old while others may have been over 30 years old.

In contrast to the TECL systems found in Hospitals A, B, and C, patient rooms in Hospital D were completed in 2010 as part of new construction; the lighting systems are consistent with the CECL category. These rooms typically had two recessed linear slot-style luminaires using 4 ft fluorescent lamps over the beds aligned with the sides of the beds, as well as a small-scale linear headwall luminaire with a 4 ft fluorescent lamp for patient reading. Two downlights using CFLs for general room lighting were located at the foot of the beds. A wall-mounted luminaire was located above the sink in the rooms and built-in lighting was installed in shelving incorporated into the wall across from the bed. A wall sconce in the guest area, with a separate wall switch located near the luminaire, provided lighting in this area. Step-lights were also present near bathroom doors.

Methods

Participants

The number of participants working in med-surg units who responded fully to the questionnaire was 138 (128 females, 10 males). An *a priori* power analysis was not done for this study because recruitment was limited by the number of nurses working in med-surg units in each hospital. However, based on a post-hoc power analysis using the program G*Power (see Faul et al., 2007), a sample size of 84 is needed to find large effect sizes using two-tailed independent samples *t*-tests with a *p* value set at 0.05.

Of the 138 respondents, 130 self-identified their position as a "nurse," and the remaining 8 self-identified as a "Certified Nursing Assistant." Thirty-nine participants worked in Hospital A, 39 worked in Hospital B, and 20 in Hospital C. Thus, 98 participants in the sample worked under a TECL lighting. Forty participants were working with a CECL system in Hospital D. The breakdown of reported ages for each hospital is shown in Table 1.

Table 1. Participants' reported age range by hospital.

Hospital	Under 25 years	25-40 years	41-55 years	Over 55 years	Total
A	2	22	9	6	39
B	3	19	7	9	39[a]
C	0	9	7	4	20
D	4	26	8	2	40

[a] One participant from Hospital B did not report their age.

Materials and Procedure

A link to an online questionnaire was distributed by email to nursing staff in August, 2015 from the executive nurse in each hospital. The questionnaire was created using the online survey platform SurveyMonkey (SurveyMonkey Inc. Palo Alto, California, USA). The first page of the questionnaire explained the study, and the voluntary nature of participation, including a statement of informed consent that was accepted when the participant clicked a button to continue. The research protocol was approved by the Pacific Northwest National Laboratory Institutional Review Board, scope number 22475.

The questionnaire included 17 numbered items, some of which had multiple prompts. Eight items requested demographic information. The remaining nine items all directed the participants to provide a response based on the typical patient room where the nurse worked. Of the other nine items, three were open-ended response questions addressing what participants felt were the best attributes about the patient room lighting, what attributes would they change about the lighting to improve their working environment, and what attributes would they change about the lighting to improve the patients' experience. Another item inquired about the use of supplemental lighting, such as flashlights or mobile phones, for performing tasks in patient rooms. One item provided a word list for participants to indicate their overall impressions of the lighting in patient rooms.

Three items had 5-point Likert scales. One of these items asked participants to rate (from excellent to poor) the quality of the lighting for eight different task areas in the patient room. Another asked participants to rate the frequency (from very frequently to never) of eight patient complaints about lighting. One item asked the participants to rate seven lighting characteristics in terms of how they helped or hindered their work; the following item asked participants to then rank order the same seven lighting attributes in terms of the impact of each on participants' ability to perform their professional duties in patient rooms. The order of the qualities being rated was randomized for the lighting attributes and task area Likert items, to counterbalance any order effects. Each variable met the criteria 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).

All items included open-ended comment boxes after the question, except the rank order item, and were subject to a systematic content analysis to quantify the most common words and phrases. Content analysis is a technique for describing systematically the form and content of written (or spoken) material (Sommer & Sommer, 1997). This qualitative data was divided among three raters who identified emerging themes, sub-categories, and valences (negative, neutral, positive) based on the content in each distinct comment. Categorized comments were then exchanged among raters to determine if there were any significant disagreements in the initial interpretation. Disagreements were recorded and ultimately resolved by the raters to establish a final content analysis of all comments.

This paper focuses on analyses of the three Likert-scale items, the rank order item, and the supplemental lighting item, with a mixed-methods approach that uses results from content analysis of the open-ended responses to interpret the results from the quantitative items.

Results

Participants' Perceptions of Lighting System Attributes in Med-Surg Patient Rooms

Participants across all four hospitals responded neutrally to many of the items asking about whether seven specific lighting system attributes helped or hindered their ability to perform professional duties in patient rooms (see Table 2 for a full list of attributes). No significant statistical mean differences were found between those working day and night shifts (all *p*s > 0.05). Similarly, no significant differences were found between responses for six of the seven lighting attributes among hospitals (all *p*s > 0.05).

Table 2. Mean ranks of the importance of different lighting characteristics for all participants and by hospital.

Attribute	Overall Mean Rank[a]	HOSPITAL			
		A	B	C	D
Light level in work area	2.60	2.23	2.95	2.85	2.5
Control of lights[b]	3.06	2.72	3.23	3.05	3.23
Color of light[c]	3.54	3.10	3.97	3.20	3.63
Glare from light fixtures	4.40	4.31	4.15	4.80	4.53
Flicker of light fixtures	4.56	4.92	4.03	4.35	4.83
Pattern of light and dark areas	4.86	5.13	4.82	4.80	4.65
Shadows from people and objects	4.99	5.51	4.85	4.95	4.65

[a] A ranking of 1 meant most important while a ranking of 7 meant least important.
[b] "ability to control the lighting through switches, dimmers, and other devices."
[c] "how the lighting affects your ability to evaluate skin tones and other colors in the room."

Two significant differences were found in participants' mean responses to the prompt concerning the attribute "control of lights" in the patient room. The mean response to this item in Hospital D (M = 3.88, SD = 1.20) was significantly higher than the mean response in Hospital B (M = 2.87, SD = 1.26, $t(77)$ = -3.62, p = 0.001, d = 0.82). Hospital D's mean of 3.88 was also significantly higher than the mean response in Hospital C (M = 2.80, SD = 1.44, $t(58)$ = -3.06, $p < 0.01$, d = 0.84). The higher mean score for Hospital D indicates that participants found the control of lights more helpful in Hospital D, with a CECL system, than in the other two hospitals, which both had TECL systems.

Participants' greater satisfaction with control in Hospital D was also supported by the systematic content analyses done to words and phrases offered in response to the open-ended prompt placed after items about lighting attributes. Only two disagreements occurred between the raters, yielding moderate inter-rater reliability (kappa value of 0.49; see Altman, 1991). At Hospital D, nine distinct, usable comments were written by participants in response to this item; most (6 of 9) concerned controllability over the brightness of the lighting, whereas other comments had to with glare, flicker, and lighting maintenance (one comment each).

The theme of controllability was also revealed to be important in content analyses performed on the open-ended responses made by those working in Hospital A, where 4 of the 9 comments related to control, and in Hospital B, where 8 of the 20 comments received related to control. Participants in Hospital A commented equally frequently about brightness levels and controls, which both received 4 comments. Sixteen comments were offered by those in Hospital C, 5 related to glare, followed by brightness and directional light (three comments each).

More comments from participants working at Hospital D (CECL) were positive compared to the number of positive comments made by participants at the three TECL hospitals (3 of 9 comments at Hospital D compared to 0 positive comments at Hospitals A and C, and 1 of 20 at Hospital B). See Appendix B for frequencies of all themes emerging from this item.

The other item concerning lighting attributes asked participants to rank the same seven lighting attributes from the previous item in order of impact on their ability to perform their professional duties. Table 2 shows the results. Overall, the top two lighting attributes selected by participants as having the greatest impact on their professional duties in patient rooms were "light level in work area" (mean rank = 2.60, median IQR = 2.00), followed by "control of lights (ability to control the lighting through switches, dimmers, and other devices)" (mean rank = 3.06, median IQR = 2.00). Color of light was ranked third at each hospital (mean rank = 3.54). In contrast, the two attributes reported to have the least impact on participants' duties were "shadows from people and objects" (mean rank = 4.99, median IQR = 5.00) and "pattern of light and dark areas" (mean rank = 4.86, median IQR = 5.00).

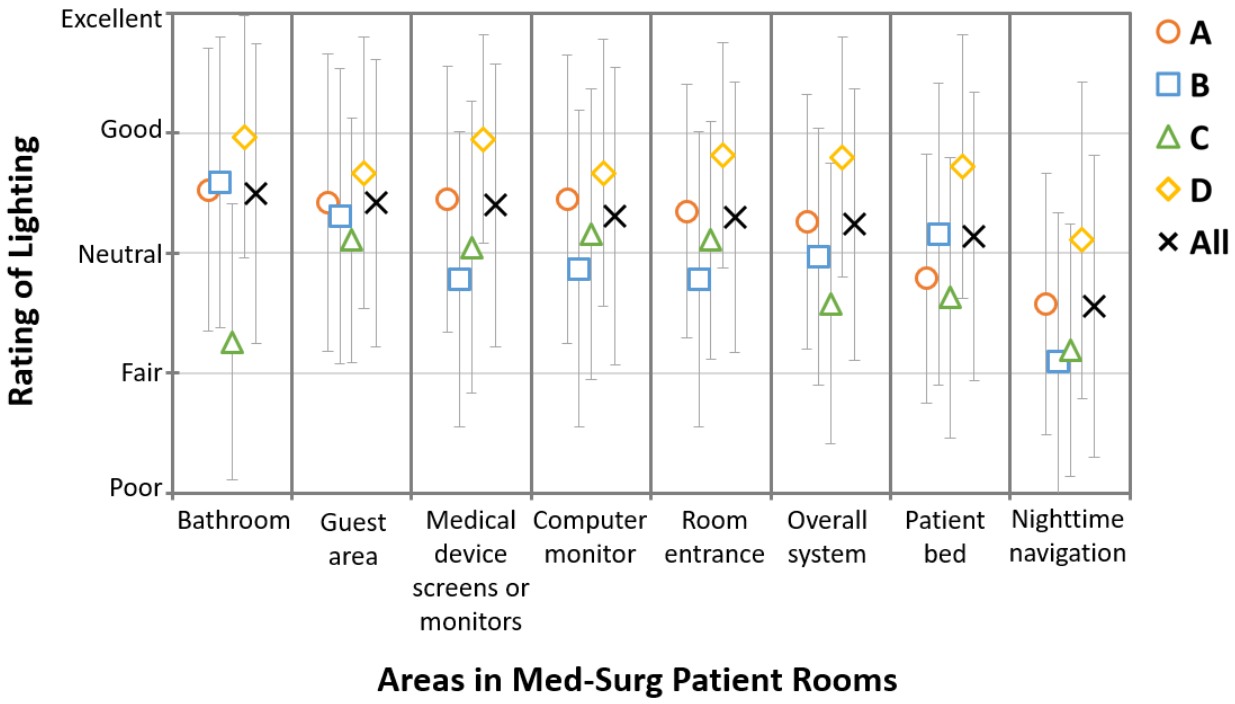
A Friedman's test revealed significant differences between the rankings of these seven items ($\chi 2(6) = 155.12$, $p < 0.001$) but post hoc analyses with Wilcoxon signed-rank tests were conducted only between the top two ranks, and the bottom two ranks. A Bonferroni correction was applied, resulting in a significance level set at $p < 0.025$, and no significant differences were found between the two lighting attributes ranked to have the least impact on participants' job performance ($Z = -0.711$, $p = 0.48$), or between the two lighting attributes rated to have the greatest impact on participants' job performance ($Z = -2.013$, $p = 0.044$). When the mean ranks of each lighting attribute were analyzed by hospital, similar patterns to the omnibus test were revealed; in all four hospitals, the same two attributes (i.e., "light level in work area," and "control of lights") were ranked to have the greatest impact on participants' job performance.

An analysis between participants' ages and the lighting attributes they reported to be the most and least impactful to their job performance in patient rooms revealed a similar pattern to other analyses in that "light level in work area" had the greatest perceived impact for all age categories, followed by "control of lights." One interesting finding was noted in the rank orderings based on age. Whereas participants under the age of 25 thought that "glare from light fixtures" had the least impact (ranked seventh), glare was ranked fourth in importance by those participants in the 41-55 and over 55 age categories. Because the most impactful lighting attribute was the same for all age groups, and because a Bonferroni adjustment to the alpha level would be quite strict because of the number of comparisons, no further significance testing was done between lighting attributes between or among age groups.

Participants' Perceptions of Lighting in Specific Areas of Med-Surg Patient Rooms

One item asked participants to report their perceptions of lighting in specific areas of typical patient rooms in their hospital; results are shown in Figure 1. The specific area with the highest overall mean rating was "bathroom" ($M = 3.50$, $SD = 1.25$), and the area with the lowest overall mean rating was "nighttime navigation lighting" ($M = 2.56$, $SD = 1.26$). Of the responses to nighttime navigation lighting, 17.4% were identified as not applicable to participants' experiences with lighting in their hospital's patient rooms (i.e., "N/A" response, which mostly came from day shift participants), or were missing.

Participants working under a CECL system in Hospital D reported higher ratings, on average, for all areas compared to hospitals operating under a TECL system (i.e., Hospitals A, B, and C). Independent samples *t*-tests revealed significantly higher ratings of the "overall system" of lighting by those working in Hospital D compared to Hospital A ($t(75) = -2.26$, $p < 0.05$, $d = 0.52$), Hospital B, ($t(74) = -3.46$, $p < 0.01$, $d = 0.80$), and Hospital C ($t(56) = -4.10$, $p < 0.01$, $d = 1.15$).

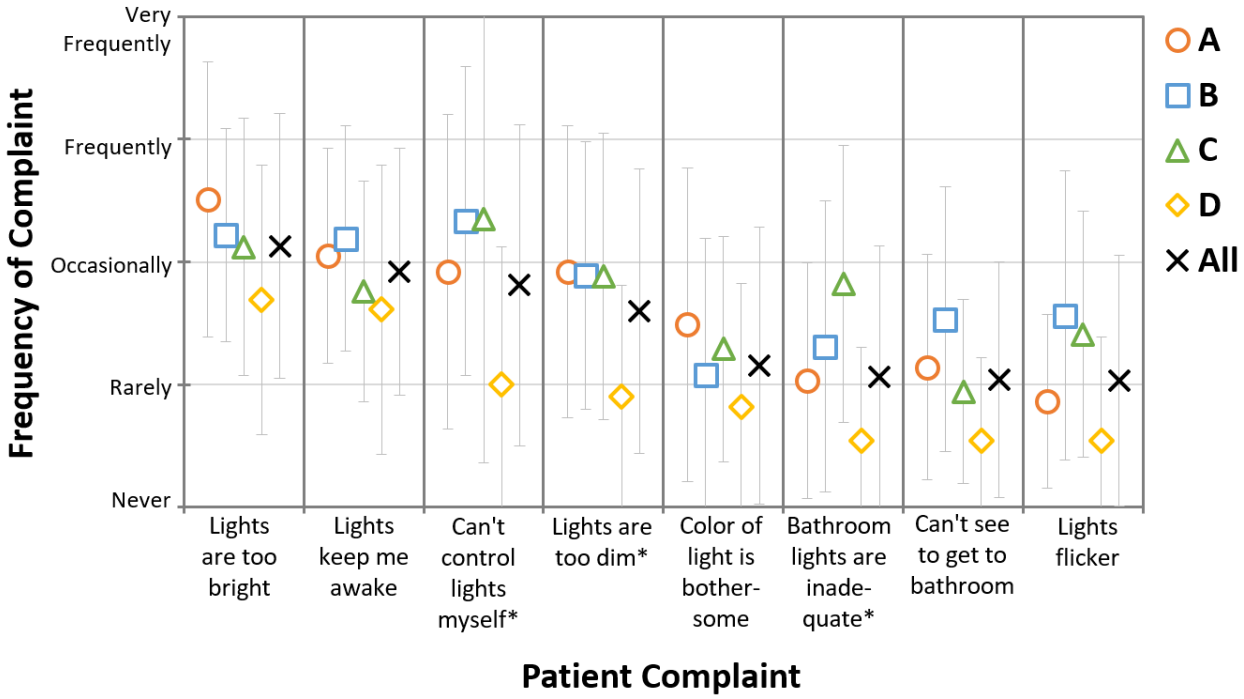


Notes: For each room area, the geometric colored symbols represent the means for each hospital while the "X" represents the overall mean response for all hospitals. Error bars shown represent the mean value ± the standard deviation. For the overall system ratings, the mean response from Hospital D was significantly higher than the mean responses for Hospital A, Hospital B, and Hospital C.

Figure 1. Results from questionnaire items related to participant ratings of the lighting in different room areas.

Participants' Reports of Patient Complaints with Respect to Lighting

When averaged across the four hospitals, participants' responses to items asking them to rate the frequency with which patients complain about eight specific aspects to do with lighting fell between 2 and 3.2 on a 5-point Likert scale where 2 represented 'rarely' and 3 represented 'occasionally' (see Figure 2). When these data were analyzed by shift type, lower responses from participants working night shifts were revealed and one difference was found to be statistically significant. Not surprisingly, on average, participants working night shifts perceived more patient complaints related to lights keeping patients awake than participants who worked day shifts, $t(127) = -2.34$, $p < 0.05$, $d = 0.42$ (ps > 0.05 for all other comparisons).



Notes: For each complaint, the geometric colored symbols represent the means for each hospital while the "X" represents the overall mean response for all hospitals. Error bars shown represent the mean value ± the standard deviation. For the three items with an * shown, the difference between the mean response for Hospital D and the other three hospitals was statistically significant.

Figure 2. Results from questionnaire items related to participant reports of the frequency of patient complaints about aspects of the patient room lighting.

When data were compared by hospital type, a similar pattern was revealed whereby most mean responses fell between 1 ('never') and 3 ('occasionally') on the Likert scale; Figure 2 shows that for a few items, individual hospital means fell between 3 and 4 ('frequently'). Several significant differences existed between Hospital D and the other three hospitals. Participants working under a CECL system in Hospital D perceived significantly fewer patient complaints than participants working under a TECL system at Hospitals A, B, and C concerning the dimness of lighting in patient rooms, patients' controllability of lights for themselves, and the adequacy of bathroom lighting (see Table 3).

Table 3. Mean ratings, standard deviations (SD), t-statistic and degrees of freedom (df) values for differences in participants' perceptions of patient complaints for those items where statistically significant differences were found.

Complaint	Hospital	Mean	*SD*	*t*-value [a] (df)
Lights are too dim	A	2.92	1.19	-4.22(74)*
	B	2.89	1.09	-4.29(73)*
	C	2.88	1.17	-3.41(54)*
	D	1.90	0.91	N/A
Can't control lights myself	A	2.92	1.28	-3.33(74)*
	B	3.33	1.26	-4.83(73)*
	C	3.35	1.00	-4.28(54)*
	D	2.00	1.12	N/A
Bathroom lights are inadequate	A	2.03	0.96	-2.48(74)*
	B	2.31	1.19	-3.36(73)*
	C	2.82	1.13	-5.00(54)*
	D	1.54	0.76	N/A

[a] when compared to Hospital D. The *t* value is shown as not applicable (N/A) for Hospital D.
Note: Likert-type scale ranged from 1 = Never to 5 = Very Frequently. * indicates statistical significance ($p < 0.01$).

Participants' Use of Supplemental Lighting

One questionnaire item asked whether the participants required supplemental lighting when performing their duties, and provided examples such as a task light, flashlight, or mobile phone light. Response options were no, sometimes, and yes. Results revealed that 68% of participants responded either "yes" (40%) or "sometimes" (28%), while 32% of participants responded that they did not require the use of additional lighting beyond what is supplied in a typical patient room. Of participants from Hospital D, 51% responded that they did not require additional lighting, while participants from Hospitals A, B, and C responded "no" just 24%, 24%, and 26% of the time respectively. Figure 3 shows these results.

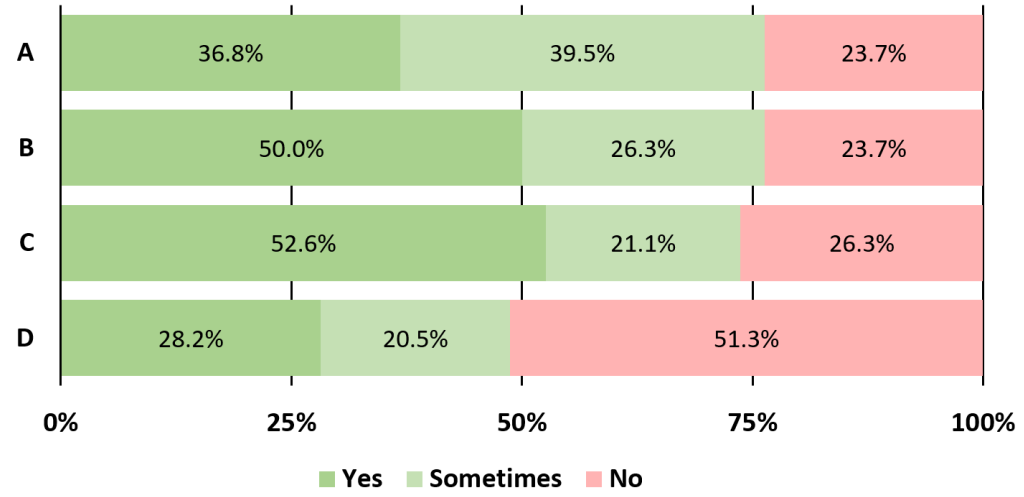


Figure 3. Percentage of participants who responded for each of the three response options when asked whether supplemental lighting was required when performing their duties. Results are shown by hospital.

The participant's age also seemed to affect the self-reported response to the need for additional light. Those over the age of 55 had the highest percentage of "yes" responses and the lowest percentage of "no" responses; conversely, those under the age of 25 had the lowest percentage of "yes" responses and the highest percentage of "no" responses (see Figure 4). While this finding is not surprising based on people's general need for more light as they age, the number of participants in each age group is not balanced across the age groups, or across the four hospitals (see Table 1); further research is needed to better understand the differential effects of the type of lighting and the age of participants on the need for supplemental lighting.

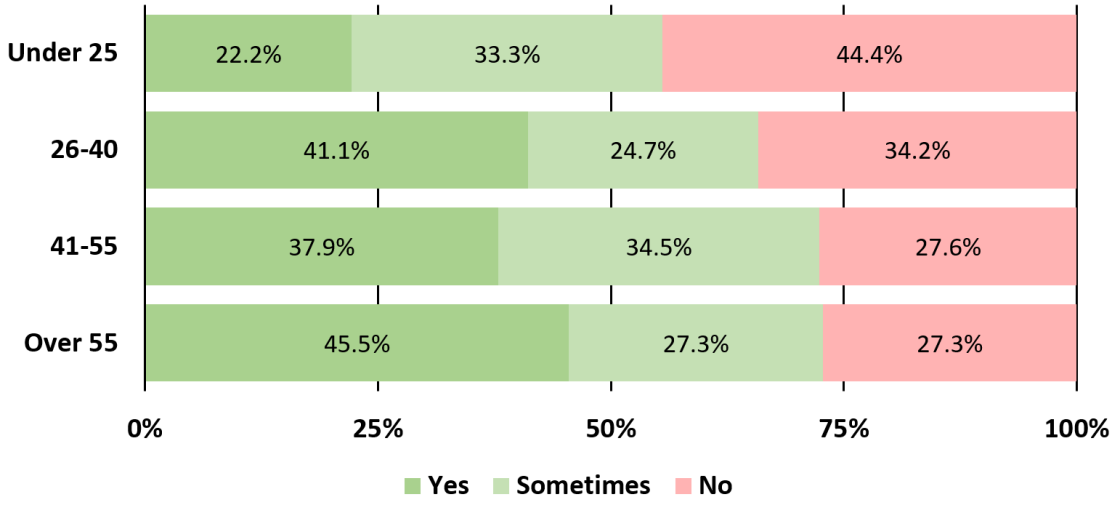


Figure 4. Percentage of participants who responded for each of the three response options when asked if supplemental lighting was required when performing their duties. Results are shown by reported age range. Two participants in the 26-40 category and one in the 41-55 category did not respond to this item.

Those participants who responded with either “yes” or “sometimes” were asked to explain their response in a textbox. This yielded 115 distinct comments across the four hospitals. No disagreements among the raters occurred, indicating strong agreement on, and reliability of, the themes. See Appendix C for frequencies of all themes emerging from this item.

Of the 37 comments made by participants in Hospital A, 15 had to do with “supplemental light” and 12 of those comments mentioned having to use a flashlight or penlight to navigate patient rooms. Similarly, of the 40 comments from participants in Hospital B, the most frequent response had to do with issues concerning supplemental light (17 comments), with most of those mentioning having to use a flashlight or penlight to do their jobs. The same pattern of responses was found in the 21 responses from those working at Hospital D under a contemporary lighting system. Finally, although 6 of the 17 comments coming about Hospital C had to do with “general duties,” 5 comments fell within each of the themes of “supplemental light” and “insufficient light.”

Discussion

Comparing Lighting Systems Based on the Environment of Care

Results from the present study indicate that participants' perceptions of CECL systems are more positive than those of TECL systems. Mean ratings of the quality of the lighting for each of the seven patient room areas rated were higher for the hospital with a CECL system than for the three hospitals with TECL systems, as shown in Figure 1. Individual comparisons for the overall ratings showed that the mean rating for the overall system in Hospital D with a CECL system was significantly higher than those for each of the three hospitals with TECL systems.

The advantages of a CECL system were also demonstrated in the participants' reports of patient complaints as shown in Figure 2. Participants working at the hospital with a CECL systems reported fewer patient complaints about all eight lighting issues included on the questionnaire compared to the three hospitals with TECL systems. In three cases (e.g., dimness of lighting in patient rooms, patients' controllability of lights for themselves, adequacy of bathroom lighting) these differences between the CECL and TECL systems were statistically significant.

In addition, a higher percentage of participants from the hospital using a CECL system thought that additional lighting was not necessary compared to those working in the hospitals with a TECL system; see Figure 3. However, similar themes emerged from participants' comments about supplemental lighting in patient rooms across hospitals, regardless of lighting system, focusing mostly on the need to use flashlights or penlights in patient rooms to do their jobs safely and efficiently. It seems that whenever additional lighting is required by nurses working in patient rooms, similar solutions may be implemented, even with a CECL system. It also seems that those working in a hospital with a CECL system are still making use of supplemental sources of light to do their work inside patient rooms, although those sources are needed less often.

While the results of this study demonstrate that CECL systems are rated more favorably than TECL systems by medical staff, they also show areas where future lighting systems can make further improvements in patient room lighting. The LED lighting systems that will be used for future hospitals provide inherently better control over light output than CECL or TECL systems, so that the ability to provide higher light levels in specific areas of the patient room when needed may reduce the need for supplemental lighting as reported by the participants in this study. Furthermore, the two patient complaints with the highest reported overall mean frequency across all four hospitals were, "lights are too bright" and "lights keep me awake" (see Figure 2).

The ability of future lighting systems to provide better control over light output and to address the emerging evidence about lighting's effects on sleep disruption and circadian alignment provide opportunities to reduce the frequency of these complaints. Research on future patient room lighting systems can inform the development and optimization of technology solutions for addressing these issues. Based on the results of this study, future patient room lighting systems that address the concerns of nurses and patients may lead to improvements in the medical staff's job satisfaction. While the role of patient room lighting and the environment of care on job satisfaction has not been explored, connections have been made between nurses' job satisfaction and job retention (Erenstein and McCaffrey 2007, Hairr et al. 2014, Lu et al. 2005). Future research that investigates the relationships between the capabilities of advanced lighting systems and nurses' job satisfaction would provide an important contribution to our understanding.

The Importance of Lighting Controls

Hadi et al.'s (2016) conclusion that access to lighting controls is related to med-surg nurses' feelings of satisfaction at work is mirrored in the present study—participants working in the hospital with a CECL system were significantly more satisfied with their ability to control lighting in patient rooms than participants working in the hospitals with TECL systems. Indeed, controllability was ranked by participants across all four hospitals, as well as all age categories and shift types, as being one of the most important lighting attributes affecting job performance in med-surg patient rooms. Controllability is also directly related to the other top-rated attribute, light level. This emphasis on lighting controllability in patient rooms emerged from both quantitative and qualitative analyses: content analyses of words and phrases offered by participants at each hospital revealed the theme of control to be important overall and was considered more positively by those working in Hospital D with a CECL system. The importance placed on lighting controls by participants in these studies indicates the priority of this topic for future research on patient room lighting. Research findings related to desirable control options, intuitive user interfaces, and appropriate levels of automatic and manual control will enable more comprehensive technology and application solutions for future patient room lighting systems.

The Need for Improved Nighttime Navigation Lighting

Of the seven items related to lighting for specific purposes in patient rooms, nighttime navigation lighting was consistently rated poorest, regardless of hospital or participants' age. This finding highlights a specific need for more attention toward lighting design strategies to help nurses perceive that they are working more effectively inside patient rooms during nighttime hours. Incidents at work, such as employee and patient falls, and a general disruption of patients' sleep patterns as nurses navigate rooms without adequate light (or as they employ other forms of lighting to work safely, such as flashlights or penlights) are common and noted in the body of literature. The present study offers further evidence of the role lighting plays for night shift nurses' ability to work effectively. Most patient rooms today, whether they have a TECL or a CECL system, do not adequately address the fact that night shift nurses need to enter patient rooms and perform important visual tasks while patients are sleeping. Future lighting systems need to be developed to provide the appropriate intensity, spectrum, and distribution of light that can satisfy the needs of both nurses and patients at night.

Lighting Considerations Based on Age

Although Hadi et al. (2016) did not demonstrate any influence of age on the overall satisfaction with lighting, the quantity of light, or complaints about glare, shadows, or flickering, the present study found that participants over the age of 55 believed that additional lighting was needed in patient rooms more often than younger participants did. This finding is consistent with published light level guidelines recommending that people over the age of 65 need two to four times the amount of light that people of younger ages require (DiLaura et al., 2011). However, this need for more light is balanced by an increasing sensitivity to glare for older adults (IES, 2016). The results of the present study aligned with what is known about vision, with the finding that participants under the age of 25 ranked glare as the least impactful lighting factor, while older participants considered glare to be a more important factor. Glare is related to both the intensity and the directionality of light; future patient room lighting systems that provide a greater ability to adapt these lighting characteristics may better serve nurses of all ages in performing their duties.

Conclusion

Analysis of the responses from the questionnaire of nursing staff revealed no significant findings based on the age or work shift of the respondents. However, several significant differences in responses were observed based on the hospital at which the participants worked, and the differences found were consistent with a priori expectations based on whether the patient room lighting systems best matched a traditional or a contemporary standard. Participants from the hospital with a CECL system consistently reported higher lighting quality, fewer patient complaints, and less need for supplemental lighting than the participants from the three hospitals with TECL systems.

As described earlier, patient rooms with CECL systems typically utilize zones of luminaires with separate controls for each zone, with additional lighting for nighttime navigation, and they sometimes include dimming capabilities. Undoubtedly, these CECL systems are more costly to purchase and install than the TECL systems of the past, such as those found in three of the hospitals in this study. **But the results of this study provide evidence that innovative lighting approaches and technologies are worth considering as an investment by hospital administrators looking to improve perceptions of the patient room environment.** As the underlying technologies for future lighting systems continue to evolve – LED luminaires, sensors, and control elements – the ability to provide greater localization and better adaptability of lighting in patient rooms promises to continue to increase, while the system costs should decrease with increasing adoption. Hopefully, evidence from ongoing research on patient room lighting will merge with these technology advancements to enable future lighting systems that far surpass the capabilities of CECL systems in satisfying a holistic set of patient and caregiver needs.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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Appendix A: Photographs of Patient Rooms

Figure A1: Hospital A patient room showing the wall-mounted luminaire at the headwall. The luminaire is hinged so that the light from the upper section (shown directed upwards here) can be directed towards the bed during an examination.

Figure A2: Hospital A patient room showing the recessed linear luminaires providing general room lighting.

Figure A3: Hospital A patient room showing the step-light style wall-recessed amber nightlight near the door to the patient bathroom.

Figure A4: Hospital B patient room showing the multi-function recessed luminaire above the bed. This was the only luminaire in the rooms originally. A later upgrade added the wall sconce luminaire for the guest area, a recessed downlight in the doorway entry area, and a step-light-style nightlight recessed into the wall.

Figure A5: Hospital B wall controller located near the entry door.

Figure A6: Hospital C patient room showing the wall-mounted luminaire with a hinged uplight section. The uplight section is in the examination position, directing its light toward the patient bed. The wall-mounted luminaire is the only electric lighting in the room.

Figure A7: Hospital D patient room showing the recessed round downlight luminaires for general room lighting, the recessed linear luminaires over the bed, the wall-mounted linear luminaire for patient reading, and the wall sconce luminaire in the guest area.

Figure A8: Hospital D patient room showing the entry area with separate sink light and push-button controller near the door.

Figure A9: Hospital D patient room push-button lighting controller. HOB refers to the "head of bed" wall-mounted luminaire while "BED" refers to the recessed ceiling lighting over the bed. "CEILING" refers to the recessed downlight luminaires providing general room lighting.

Appendix B: Content analysis details for comments related to lighting attributes

This table shows the emerging themes and sub-categories per hospital for comments made by participants responding to the item: "For a typical patient room in which you work during the day/night, please indicate whether each attribute hinders, is neutral or helps your ability to perform your professional duties."

Hospital	Theme	Freq.	%	Sub-Category	Freq.	%
A	Accessibility	0	0.00%			
	Brightness	4	44.44%	Additional Lighting	1	100.00%
	Color	0	0.00%			
	Controls	4	44.44%	Brightness	2	100.00%
				Accessibility	0	0.00%
				Directional Lighting	0	0.00%
	Directional Light	0	0.00%			
	Flicker	0	0.00%			
	General Negative	0	0.00%			
	Glare	0	0.00%			
	Lighting Source	1	11.11%	Fluorescent Lighting	0	0.00%
				Task Lighting	1	100.00%
				Overhead Lighting	0	0.00%
	Maintenance	0	0.00%			

Hospital	Theme	Freq.	%	Sub-Category	Freq.	%
B	Accessibility	3	15.00%			
	Brightness	2	10.00%	Additional Lighting	0	0.00%
	Color	1	5.00%			
	Controls	8	40.00%	Brightness	4	100.00%
				Accessibility	0	0.00%
				Directional Lighting	0	0.00%
	Directional Light	0	0.00%			
	Flicker	2	10.00%			
	General Negative	1	5.00%			
	Glare	0	0.00%			
	Lighting Source	1	5.00%	Fluorescent Lighting	0	0.00%
				Task Lighting	1	100.00%
				Overhead Lighting	0	0.00%
	Maintenance	2	10.00%			

Hospital	Theme	Freq.	%	Sub-Category	Freq.	%
C	Accessibility	0	0.00%			
	Brightness	3	18.75%	Additional Lighting	0	0.00%
	Color	1	6.25%			
	Controls	2	12.50%	Brightness	1	100.00%
				Accessibility	0	0.00%
				Directional Lighting	0	0.00%
	Directional Light	3	18.75%			

	Flicker	0	0.00%			
	General Negative	0	0.00%			
	Glare	5	31.25%			
	Lighting Source	2	12.50%	Fluorescent Lighting	0	0.00%
				Task Lighting	0	0.00%
				Overhead Lighting	2	100.00%
	Maintenance	0	0.00%			
Hospital	**Theme**	**Freq.**	**%**	**Sub-Category**	**Freq.**	**%**
D	Accessibility	0	0.00%			
	Brightness	0	0.00%	Additional Lighting	0	0.00%
	Color	0	0.00%			
	Controls	6	66.67%	Brightness	1	50.00%
				Accessibility	1	50.00%
				Directional Lighting	0	0.00%
	Directional Light	0	0.00%			
	Flicker	0	0.00%			
	General Negative	0	0.00%			
	Glare	1	11.11%			
	Lighting Source	1	11.11%	Fluorescent Lighting	0	0.00%
				Task Lighting	1	100.00%
				Overhead Lighting	0	0.00%
	Maintenance	1	11.11%			

Note: Freq. = Frequency count

Appendix C: Content analysis details for comments related to supplemental lighting

This table shows the emerging themes and sub-categories per hospital for comments made by participants responding to the item: "For a typical patient room in which you work during the day/night, do your professional duties require additional lighting beyond what is provided by the built-in patient room lighting? (If yes or sometimes, please explain the supplemental lighting below. Examples include a task light that you bring into the room, or a flashlight / mobile phone light.)

Hospital	Theme	Freq.	%	Sub-Category	Freq.	%
A	Control	1	2.70%	Dimming	1	50.00%
				Patient Bed	1	50.00%
	General Duties	14	37.84%	Examination	6	42.86%
				Procedures	8	57.14%
	Insufficient Light	6	16.22%	Equipment	1	16.67%
				Foot of Bed	1	16.67%
				Direct Light	0	0.00%
				Nighttime	0	0.00%
				Nightlight	1	16.67%
				Nurse Work Area	0	0.00%
				Overhead Lighting	1	16.67%
				Patient Bed	2	33.33%
				Wall Base	0	0.00%
	Nighttime Duties	1	2.70%			
	Room Lights	0	0.00%			
	Supplemental Light	15	40.54%	Flashlight	10	50.00%
				Penlight	6	30.00%
				Task Light	1	5.00%
				Spot Light	1	5.00%
				Bathroom Light	1	5.00%
				Mobile	1	5.00%
				Adjustable Light	0	0.00%
				Scammer	0	0.00%
				Gooseneck	0	0.00%
				Exam Light	0	0.00%
				Equipment	0	0.00%
Hospital	**Theme**	**Freq.**	**%**	**Sub-Category**	**Freq.**	**%**
B	Control	0	0.00%	Dimming	0	0.00%
				Patient Bed	0	0.00%
	General Duties	16	40.00%	Examination	6	30.00%
				Procedures	14	70.00%
	Insufficient Light	5	12.50%	Equipment	1	20.00%
				Foot of Bed	2	40.00%
				Direct Light	0	0.00%
				Nighttime	0	0.00%
				Nightlight	0	0.00%
				Nurse Work Area	0	0.00%

				Overhead Lighting	1	20.00%
				Patient Bed	0	0.00%
				Wall Base	1	20.00%
	Nighttime Duties	1	2.50%			
	Room Lights	1	2.50%			
	Supplemental Light	17	42.50%	Flashlight	9	56.25%
				Penlight	3	18.75%
				Task Light	0	0.00%
				Spot Light	0	0.00%
				Bathroom Light	0	0.00%
				Mobile	0	0.00%
				Adjustable Light	1	6.25%
				Scanner	0	0.00%
				Gooseneck	1	6.25%
				Exam Light	2	12.50%
				Equipment	0	0.00%
Hospital	**Theme**	**Freq.**	**%**	**Sub-Category**	**Freq.**	**%**
C	Control	0	0.00%	Dimming	0	0.00%
				Patient Bed	0	0.00%
	General Duties	6	35.29%	Examination	3	33.33%
				Procedures	6	66.67%
	Insufficient Light	5	29.41%	Equipment	1	25.00%
				Foot of Bed	0	0.00%
				Direct Light	1	25.00%
				Nighttime	0	0.00%
				Nightlight	0	0.00%
				Nurse Work Area	0	0.00%
				Overhead Lighting	2	50.00%
				Patient Bed	0	0.00%
				Wall Base	0	0.00%
	Nighttime Duties	1	5.88%			
	Room Lights	0	0.00%			
	Supplemental Light	5	29.41%	Flashlight	4	57.14%
				Penlight	2	28.57%
				Task Light	0	0.00%
				Spot Light	0	0.00%
				Bathroom Light	0	0.00%
				Mobile	0	0.00%
				Adjustable Light	0	0.00%
				Scanner	1	14.29%
				Gooseneck	0	0.00%
				Exam Light	0	0.00%
				Equipment	0	0.00%

Hospital	Theme	Freq.	%	Sub-Category	Freq.	%
D	Control	0	0.00%	Dimming	0	0.00%
				Patient Bed	0	0.00%
	General Duties	4	19.05%	Examination	2	40.00%
				Procedures	3	60.00%
	Insufficient Light	3	14.29%	Equipment	0	0.00%
				Foot of Bed	0	0.00%
				Direct Light	0	0.00%
				Nighttime	1	33.33%
				Nightlight	0	0.00%
				Nurse Work Area	1	33.33%
				Overhead Lighting	1	33.33%
				Patient Bed	0	0.00%
				Wall Base	0	0.00%
	Nighttime Duties	5	23.81%			
	Room Lights	0	0.00%			
	Supplemental Light	9	42.86%	Flashlight	7	58.33%
				Penlight	4	33.33%
				Task Light	0	0.00%
				Spot Light	0	0.00%
				Bathroom Light	0	0.00%
				Mobile	0	0.00%
				Adjustable Light	0	0.00%
				Scanner	0	0.00%
				Gooseneck	0	0.00%
				Exam Light	0	0.00%
				Equipment	1	8.33%

Note: Freq. = Frequency count