WINDOWS AND DAYLIGHT FOR HEALTHCARE WORK ENVIRONMENTS: AN EVALUATION OF OCCUPANTS' PERFORMANCE AND WELLBEING AND BUILDING ENERGY USE

A Dissertation

by

RANA SAGHA ZADEH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2012

Major Subject: Architecture

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Approved by:

Chair of Committee,	Mardelle McCuskey Shepley
Committee Members,	James W. Varni
	Glen Mills
	Charles H. Culp
	Zofia K. Rybkowski
Head of Department,	Ward V. Wells

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ABSTRACT

Windows and Daylight for Healthcare Work Environments: An Evaluation of Occupants' Performance and Wellbeing and Building Energy Use. (May 2012)

Rana Sagha Zadeh, M.ARCH, Azad University

Chair of Advisory Committee: Dr. Mardelle McCuskey Shepley

A growing body of evidence links quality and safety outcomes in healthcare to the physical environment. Research studies in the laboratory setting indicate appropriate environmental lighting can result in elevated mood, arousal and alertness, leading to increased productivity and reduced cognitive impairment. However, the effect of daylight and the impact of the presence of windows on healthcare employees' health and performance have not been adequately studied.

Multiple methods were used to investigate the role of lighting from both occupancy and energy perspectives in a healthcare setting. Study 1: Ethnographic Research. Staff members, in three facilities, completed surveys regarding the most important environmental characteristics of an ideal workplace. They selected the top three characteristics helping with their alertness and wakefulness. Study 2: Quasi-experimental Biological Study. measurements were gathered from 12 volunteer Registered Nurses, who provide patient care in both windowed (design case) and windowless nurse stations (reference case). In addition, the RNs' work-related and subsidiary behavior related to sleepiness and mood were recorded via behavioral mapping. Study 3: Energy Modeling. The impact of a window on energy consumption and cost was evaluated using computer modeling.

Study 1: The top five environmental factors for an ideal workplace were identified as temperature, appropriately sized workplace, low noise levels, privacy and comfortable furniture. Daylighting, temperature and comfort were identified as the top three most important environmental factors supporting staff in alertness and wakefulness. Study 2: The frequency of subsidiary behavior in the same individuals was reduced by 40% in the nurse station with a window and daylight compared to a similar windowless nurse station (p-value=0.001). The average daily heart rate was reduced by 3% in the windowed condition (design case) but not significantly (P=0.1000). The blood oxygen saturation increased (97.6 to 98.1) in the windowed location significantly (p-value= 0.0110). Study 3: Overall, energy consumption increased by 30%, however, this energy loss could be completely avoided using high performance glazing.

The present study concluded that ‘a window’ in healthcare environments may be linked to considerable benefits to occupant performance and wellbeing, and will not necessarily negatively impact building energy use.

DEDICATION

to

My parents

&

My grandparents

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

It should assist the care providers in maintaining high performance measures, while maintaining economic viability. Building design affects health outcomes. The design of an indoor space is a powerful component that can set a baseline for economic, social and health-related outcomes regarding healthcare environments and their occupants. One of the most frequently discussed attributes of healthcare settings, especially when it comes to quality and safety, is lighting. This study provides a literature review on the latest research on lighting in healthcare facilities and reports on a fresh set of studies regarding the role of lighting relative to the health and performance of staff and employees.

Healthcare facility owners and users require buildings that are durable, functional and energy efficient, in addition to being easy to maintain and beautiful enough to deliver the right first impression to visitors. Healthcare is a high stress, work-intensive and risky profession, and the facilities housing healthcare operations should be tailored to accommodate these conditions. Most importantly, the facilities should be designed to help prevent avoidable physical and psychological harm to their occupants. New construction or renovation of a health facility provides an opportunity to healthcare administrators, staff and patients for significantly raising the bottom-line in quality, performance and fiscal payback.

This dissertation follows the style of *Health Environments Research & Design Journal*.

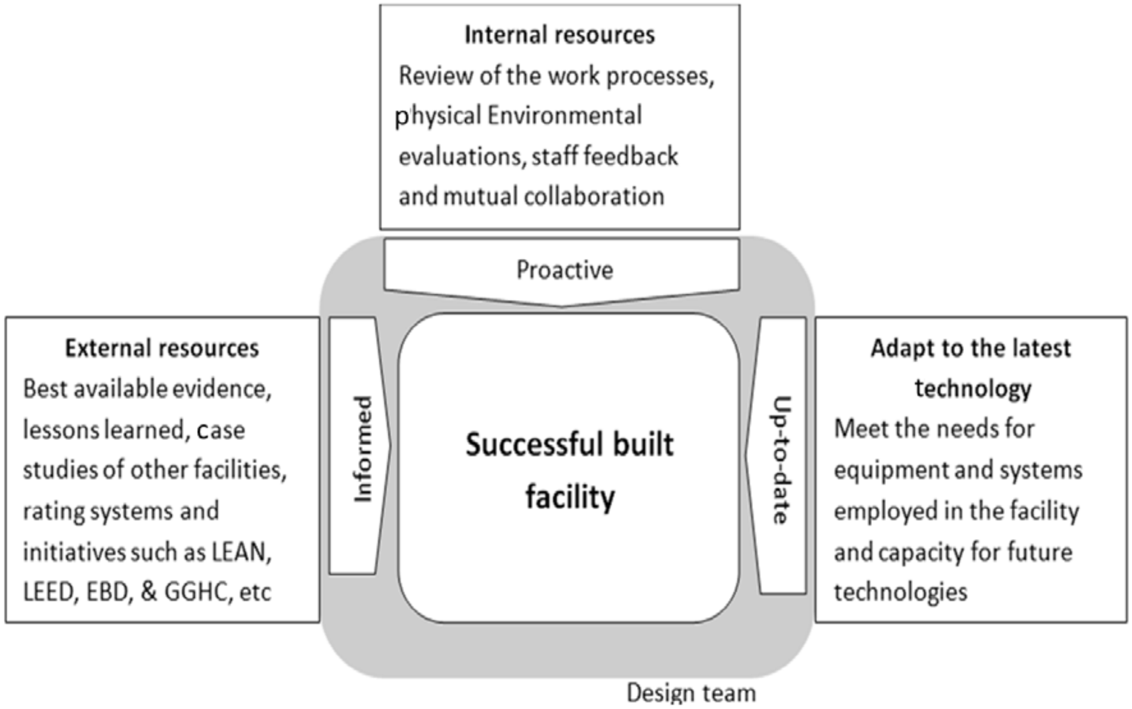
Meeting the Needs of Building Occupants

Federal, state and local building codes adapted from International Building Codes (by the International Code Council) in general, and Guidelines for Design and Construction of Healthcare Facilities (Facility Guidelines Institute, 2010) in particular, address minimum building safety and space requirements. A building that meets minimum quality is not the ultimate goal, because increasing quality to an optimum level assures maximum potential performance with minimal costs. This is why minimum quality, over the lifetime of a project, could become costly and dysfunctional. In contrast, high quality buildings will have better performance with lower costs over the project operation period (Dell'lsola & Kirk, 2003). On the other hand, an unnecessarily costly facility could consume more than its share of the budget, which would in turn limit opportunities for improved healthcare. A building does not have to be "expensive" in order to meet the needs of its occupants. The right design is a product of an informed joint effort between users and building professionals.

A successfully designed health facility must live up to the complex and risky nature of healthcare. It should assist the care providers in maintaining high performance measures, while maintaining economic viability.

The complexity of healthcare requires that building designers and planners absorb and understand the care delivery model, communicate the role of physical environment to the healthcare users and administrators, and translate the needs of care providers into building forms. In addition, the designers and planners should apply the best available external evidence regarding safety and quality. A smarter and less expensive approach to facility design is now available through the field of healthcare design research.

Recent design initiatives regarding buildings and equipment provide important directions for creating a thriving healthcare environment in which the resources are well spent on the main objectives (quality, efficiency and safety). New approaches, such as Evidence-Based Design (EBD), Green Guide for Healthcare (GGHC), or Leadership in Energy and Environmental Design (LEED), help professionals evaluate and check for efficiency, quality and life cycle costs. While these trends go beyond the minimum requirements for quality and safety in building codes, the ultimate success of the final project is guaranteed by a proactive shared effort among facility stakeholders, as shown in Figure 1.1.



Note. Successful design team translates the facility needs, the best available evidence and technology into building form.

Figure 1.1. Successful built facility framework (informed, proactive, and up-to-date).

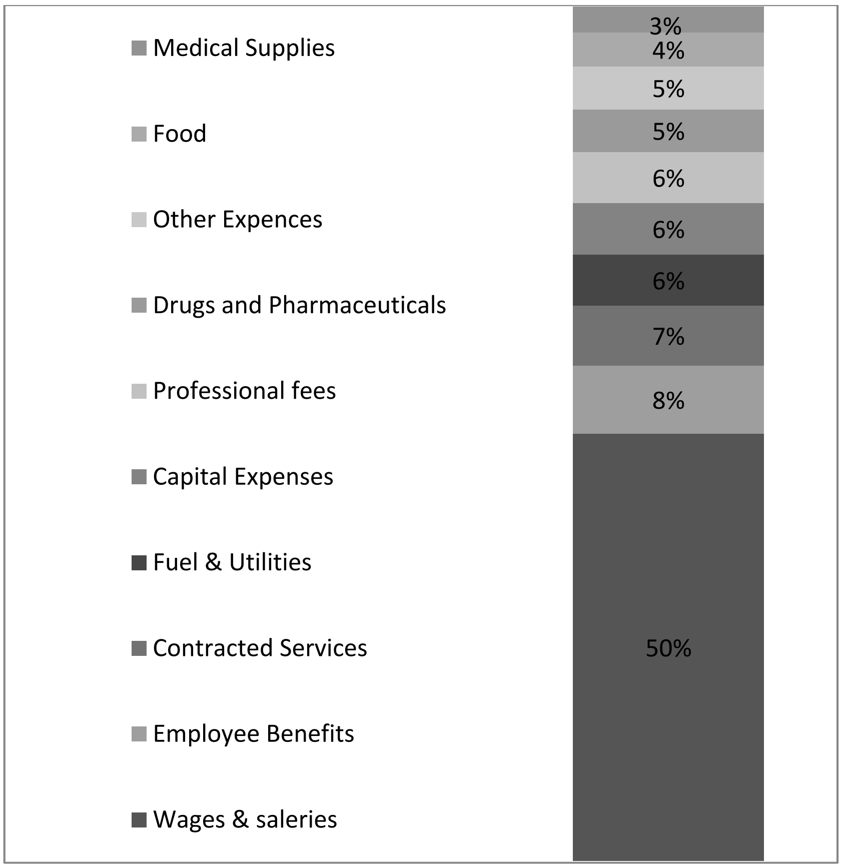
Research Background

This study addresses the role of daylighting in shaping high performance healthcare buildings by contributing to the safety, performance and wellbeing for the buildings' occupants, as well as improving energy efficiency. Both energy savings and occupant wellbeing have been addressed in definitions of sustainable buildings (LEED rating systems). The occupant outcome is a key component of high performance building codes and best practices. This is emphasized in EBD literature and the LEED Reference Guide for Green Building Design and Construction-Healthcare Supplement (U.S. Green Building Council, 2009).

A health facility building is actually the smallest share of financial investments affecting the largest portion of operational costs. Research shows capital costs, including building costs, represent only 6% of the total business operation costs in healthcare (Kirk & Dell'Isola, 1995). Despite representing a small portion of the total capital, such investment on built space plays an important role in revenue generation during the project life cycle because it sets the baseline for care efficiency and safety, including staff related costs and savings. Staff related costs are the largest portion of the total business operation costs, through efficiency, productivity and health. Research shows that the staff and their performance are key contributors to patient safety and satisfaction of care.

Staff related expenses (salaries, wages, benefits, recruitment, retention, etc.) are the costliest share of the healthcare business. According to Kirk and Dell'Isola (1995), staff expenses are about half of the total expenses during the life cycle of a project (see

Figure 1.2). This is also confirmed by cost reports from the Massachusetts Hospital Association (2010) that indicate 49% of the total annual expenses are spent on salaries and wages. In addition, the Arizona Department of Health Services (2010) found in 2009 that 39% of the total expenses were allocated to salaries and wages.



Note. Figure is based on data by Kirk and Dell'Isola (1995).

Figure 1.2. Business operation costs.

One major goal of building a successful healthcare facility is helping the staff stay healthy and happy, as well as enabling them to do their job better. The staff is the frontline of care, and increasing their efficiency and effectiveness plays a considerable role in creating a high quality healthcare system (Hendrich, Chow, Skierczynski, & Lu, 2008). Despite their demanding workload, medical staff strive to create patient safety in the presence of multiple system inefficiencies (Ebright, Patterson, Chalko, & Render, 2003). They must not be overburdened by nonclinical inefficiencies (Robert Wood Johnson Foundation and Institute for Healthcare Improvement, 2006) and they must be supported by the built environment.

According to Shojania, Duncan, McDonald, Wachter, Markowitz (2001, p. 2), "Improving patient safety is a team effort, and the playbook is often drawn from fields outside of health care. Most medical errors cannot be prevented by perfecting the technical work of individual doctors, nurses, or pharmacists. Improving patient safety often involves the coordinated efforts of multiple members of the health care team, who may adopt strategies from outside healthcare."

It is necessary for healthcare designers to join this trend. Despite representing the smallest portion of the total project capital, the built environment strongly affects staff performance and wellbeing (the largest portion of the total expenses) because the potential for the staff to create safe, high quality healthcare is limited by the quality of the environment in which they work. In addition, providing work environments that empower effective nursing care which results in better clinical outcomes is important for healthcare systems. Effective work processes could help alleviate the 400,000-person shortage of registered nurses anticipated in the year 2020 (Buerhaus, Staiger, & Auerbach, 2000).

The built environment can adjust human-related operating outcomes and costs by improving satisfaction and efficiency among the staff. As a result, intelligently built facilities should be envisioned early in the design process in order to minimize conflict with occupant comfort, as well as enhancing safety, productivity and support for occupant wellbeing.

Research Purpose

To date, approximately 1,200 credible research studies have been identified that discuss the connection between environmental characteristics and operational outcomes, including reduction of "infections, falls, medication errors and unnecessary in-hospital transfers and staff injuries" (Marberry, 2011). This evidence helps coherent decision making in the renovation and construction phase. The field is young, but the body of knowledge regarding the relationship between building life cycles and better environments is swiftly expanding. Organizations such as the Center for Health Design, Academy for Design and Health, the Robert Wood Johnson Foundation, the Texas A&M University's Center for Health Systems & Design, the University of Clemson and several other centers around the world are at the forefront of this research. Yet, numerous areas need further clarification, research and investigation; one of these major areas is lighting.

Evidence has shown that natural light can result in improved mood (Benedetti, Colombo, Pontiggia, Bernasconi, Florita, & Smeraldi, 2003), reduced stress (Walch, Rabin, Day, Williams, Choi, & Kang, 2005), perceived pain (Ulrich, 1984), improved pain medication consumption (Walch et al., 2005) and reduction in length of stay for patients (Beauchemin & Hays, 1996). Research has also indicated that manipulation of lighting, including the quality of natural light, can directly alter biological rhythms, sleepiness and alertness, and can affect cognitive function. Daylight, compared to electric light, has higher intensity and fulfills human eye spectral sensitivity. While several studies exist on the effect of lighting on fatigue and sleepiness, field studies are needed to understand the effects of bright light on "objective measures of performance in health care workers and medical errors" (Jha, Duncan & Bates, 2001), as well as the impact of natural light on these measures. Further study is also needed on the different effects of artificial versus natural light.

Establishing lighting conditions for healthcare workspaces to achieve the body's optimum performance state has not yet been addressed. The main challenge to lighting research is its multidisciplinary nature which involves architecture, environmental psychology, environmental design and sustainability, human biology and sleep medicine. People who have the skills to evaluate built environments are not always well-equipped to measure occupant outcomes appropriately, while those who have scientific knowledge of behavioral studies generally lack the knowledge of built environments (Rubin, 1987; Wyon, 1996; cited by Veitch, Charles, Farley, & Newsham, 2007). However, considerable research potential exists in this field for those who have access to knowledge in both psychology and architecture.

Researchers in many countries have addressed the physiological and psychological benefits of lighting, including the quality of natural light in codes and guidelines. For example, in Europe many countries require employee work areas to be within a “certain distance from a window” (Rashid & Zimring, 2008, p. 161). Building codes in Norway, Sweden and Denmark have adapted this rule (Roger Ulrich, personal communication, 2010). Hospitals in Germany have banned the use of cool-white fluorescent light (Walker 1998; cited by Edwards & Torcellini, 2002).

Current recommendations about lighting in workspaces are limited to light intensity and do not explore spectrum and quality. The Illuminating Engineering Society of North America (IESNA/ANSI) puts moderate emphasis on the application of natural light in the staff areas (Illuminating Engineering Society of North America [IESNA] Health Care Facilities Committee, 2006). The recommended illuminance for nurse stations in task lighting (and horizontal illuminance) has been established at 200 lx at the desk level, and 500 lx, 300 lx and 500 lx respectively, for the general areas, desk and medication stations (IESNA, Health Care Facilities Committee, 2006). These levels have been found to affect the performance of visual tasks of high contrast. Although these levels may be sufficient for visual aspects of a task performance, further research is needed to understand whether these values meet the needs of a human’s natural optimum performance.

Evidence suggests that beyond the benefits of lighting for visual access to tasks, the presence of bright natural light may be necessary for optimum health and performance (Rea, Figueiro & Bullough, 2002). According to Joseph (2006), light is essential for good performance on visual tasks: "More research is needed to understand the optimal lighting requirements for supporting the complex tasks performed” (Joseph, 2006, p. 4). Thus, field research on the impact of natural light on the hospital staff provides an excellent opportunity to translate laboratory research findings into everyday practice so that the healthcare staff can benefit from better designed and healthier environments.

Research Organization

This study provides an overview of the impact of the physical environment on healthcare outcomes. Chapter I provides an overview of the problem and the need for specific research on lighting in health facilities. Chapter II contains a review of the current literature about the overall impacts of the physical environment on occupants in addition to the impacts of environmental lighting performance and wellbeing and building energy use. Chapter III presents the multiple methods used in the research to further investigate the impacts of lighting in healthcare environments. Chapter IV discusses the results of the research and the discussion. Chapter V offers the conclusions and limitations of the research, as well as suggestions for future research.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

This chapter provides an overview of the literature on healing environments and environmental lighting, including day lighting. The first section of this chapter is an overview of the benefits and characteristics of the design of healthcare environments, especially as it relates to the reduction of stress and the improvement of health, efficiency and safety. The second section of the chapter focuses specifically on environmental lighting and the related literature, including the physiological and psychological impacts of lighting. Finally, the characteristics of natural and electric lighting are compared and contrasted, including information about the relationship between building energy consumption and the presence of natural light.

Overall Impacts of Physical Environments

The physical environment is a powerful component that sets a baseline for economic, social and health-related outcomes for occupants. Evidence has shown that the built environment, hand in hand with organizational factors, influences satisfaction, physiological wellbeing and psychological health, which in turn affects turnover, efficiency, absenteeism and burnout. Improving mental and physical health, as well as satisfaction of healthcare staff, will also improve patient satisfaction and perception of care. Figure 2.1 summarizes the documented impacts of both organizational and environmental factors on caregivers and receivers based on available peer-reviewed research.

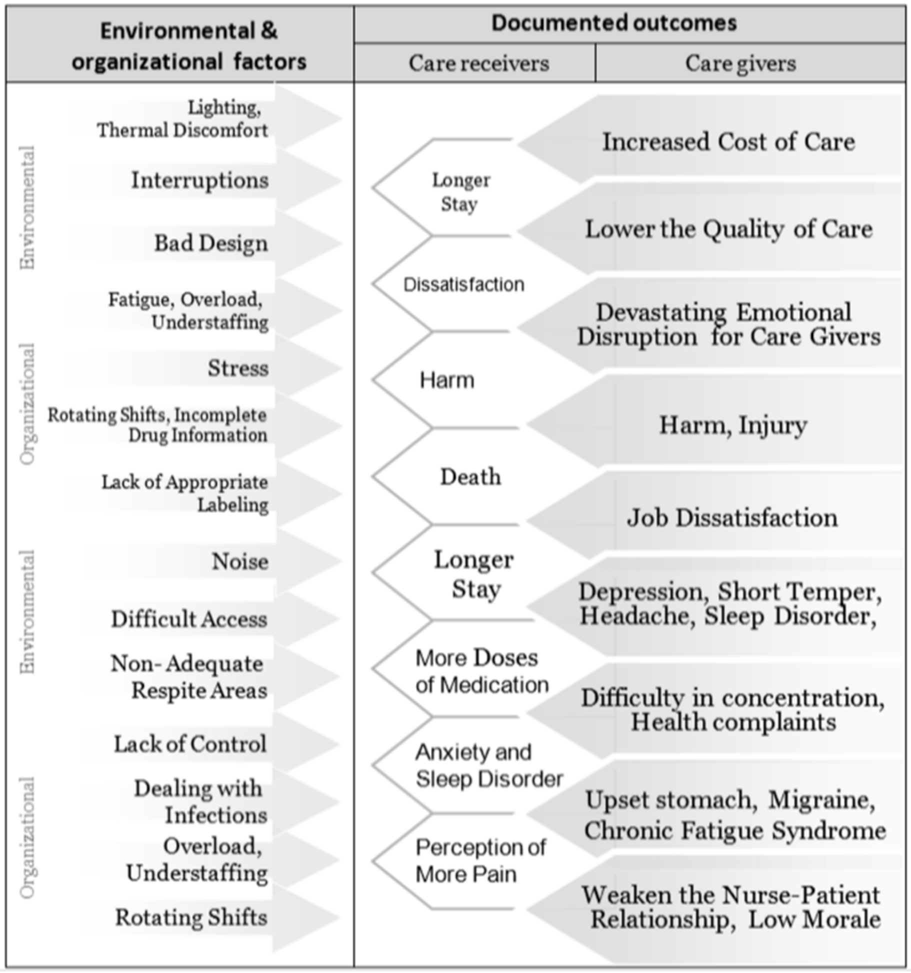


Figure 2.1. Organizational and environmental factors, general causes and impacts.

What is a Healing Environment?

Hospitals are similar to garages in the sense that diagnosis and treatment are both obtained by both technical machines and human knowledge (Hosking & Haggard, 1999). However, cars can be "diagnosed and treated" in a chaotic, dark and unattractive space (a garage), whereas humans needing care can potentially be harmed by such an environment. According to Ulrich, the concept of the healing environment today is a set of both physical and organizational factors that contribute to healthcare outcomes (Healthcare design and research lectures, 2009).

The surrounding environment is a stimulus and input that the human body receives, stores and processes (Huelet, 2007). These inputs translate into various physiological responses such as immune system modulation, wellbeing, ease and convenience (Hosking & Haggard, 1999; Huelet, 2007). Psychological, spiritual and intellectual reactions such as relaxation, joy, pleasure, hope, contentment, peace, humor, play, interest, enrichment and contemplative delight are also influenced by the built environment (Hosking and Haggard, 1999; Varni, Burwinkle, Sherman, Dixon, Ervice, Leyden, & Sadler, 2004; Huelet, 2007). "The healing environment is the physical and cultural atmosphere created to support families through hospitalization, medical visits, healing and bereavement" (Whitehouse, Varni, Seid, Cooper-Marcus, Ensberg, Jacobs, & Mehlenbeck, 2001, p. 303). Thus, the physical setting, similar to the clinical setting, can heal or harm (Huelet, 2007).

Today we know that "curing" is different from "healing" (Huelet, 2007). Huelet explains this in an excellent example. A stent reduced the heart blockage of a certain patient; however, after surgery, the patient's blood pressure and stress rose to a dangerous level as he witnessed the bereavement of family members for a roommate who had died. Even after the body was removed, the healing process, according to Huelet, did not really begin until the patient was dismissed from the hospital.

Benefits of Healing Environments

Healing environments -- healthcare settings designed to promote health and healing -- can improve physical health and overall health-related quality of life (Sherman, Eisen, Burwinkle, & Varni, 2006). In the competitive consumer-centered healthcare industry, user-friendly and pleasant facilities attract more patients and increase their satisfaction (Varni et al., 2004). Healing environments improve the bottom-line by improving efficiency and safety. Sufficient evidence exists that the physical environment can reduce employees' anxiety and fatigue, increase efficiency, improve safety and improve overall quality (Ulrich, Zimring, Joseph, Quan, & Choudhary, 2004). Today, healthcare systems tend to evaluate overall health outcomes rather than simply looking at morbidity (Sullivan, 2003). Ensuring that the characteristics of a healing environment are met is becoming a prominent goal for facility administrators.

Stress is a major component of healthcare environments. Stress can be either controlled or aggravated by environmental design. According to a publication by the National Institute for Occupational Safety (NIOSH) (Sauter, Murphy, Colligan, Swanson, Hurrell, Scharf, & Tisdale, 1998, p. 6), stress is "the harmful physical and emotional responses that occur" when the demands of an occupation are much higher than “capabilities, resources, or needs of the worker.” Records show that healthcare occupations are highly stressful and associated with higher psychological distress, depression and anxiety rates than other professions (NIOSH, 2008). Cooper’s excellent study in 2005 on 25,000 individuals identified the nursing occupation as one of the twenty most stressful jobs because of the physical and psychological challenges. The same study found that nursing is one of the ten worst occupations in terms of job satisfaction.

Stress can directly impact quality and safety, which in turn affects financial outcomes. Medical errors, along with physical and psychological symptoms, absenteeism, turnover and low morale, are some responses to occupational stress in healthcare professions (NIOSH, 2008). Stress is a significant contributor to chronic illnesses, which comprise the costliest share of healthcare (Ulrich, personal communications, 2009). Furthermore, the effects of a stressful environment on staff were investigated in Khodadadi’s research (Khodadadi, Pakseresht, Haghighi, Haghdoust & Beshlide, 2008), which found a strong statistical relationship between nurses’ job stress and the occurrence of migraines, chronic fatigue syndrome and anxiety. Jeurissen and Nyklicek’s study in 2001 also discussed the relationships between occupational stress and depression, anxiety, work satisfaction and health related complaints in staff. Stress, along with its costly outcomes, can be affected by environmental and organizational factors (Ulrich, Zimring, Joseph, Quan, & Choudhary, 2004).

Research indicates that stress reduction for both patients and family results in lower pain levels, lower heart rates, reduced medication use (and hence, medication costs) and faster recovery time. For staff, the outcomes have included less annoyance and exhaustion, higher satisfaction and improved health and wellbeing. The design characteristics resulting in these outcomes are explained in the next section.

Efficiency and safety are both affected by the healing environment. The physical environment in health facilities contributes to operational efficiency and safety (Facility Guidelines Institute, 2010). It also plays an important role in escalating or cutting healthcare spending. The Agency of Healthcare Research and Quality [AHRQ] (2007) reported on the growing body of evidence that links quality and safety outcomes to the physical environment. For example, medication errors can be affected by improved lighting, and reduced interruptions and distractions, and by providing private space (Ulrich et al., 2004). Providing supportive work environments is a main objective of Transforming Care at the Bed Side, an initiative created in the last decade by the Robert Wood Johnson Foundation and the Institute for Healthcare Improvement. This initiative addresses the era’s healthcare quality issues as reported by the Institute of Medicine.

Characteristics of a Healing Environment

Research has documented several characteristics of a healing environment. According to Varni et al. (2004), the fundamentals of healing can arise in all aspects of design ranging from interior, exterior and landscape, as well as the use of art. A literature review of 40 articles on adults and children by Sherman, Varni, Ulrich, and Malcarne (2005) found four major components, including the presence of nature, reduced noise and reduced crowding, soft and cyclical lighting and availability of music in improved overall health outcomes. Healing design should support structural safety, healthy exercise and environmental toxin reduction. It may target the reduction of injury, asthma and obesity (Cummins and Jackson, 2001, as cited by Sherman et al., 2005). Based on an extensive literature review, Ulrich et al. (2004) identified noise and spatial disorientation, caused by improper design, as major sources of stress for users. Conversely, nature and positive distractions, use of healing gardens, art work, light exposure and social support reduce stress for patients, their families and staff.

Reduced noise. Noise is a form of interruption that can affect quality and safety. In the healthcare work environment, noise is tied to increased errors, stress, burnout, perceived work demand, loss of control and reduced communication quality (Ulrich et al., 2004). Noise in a clinical workplace may stem from “movement of people and equipment, computer printers, telephones, staff and patient conversations, patient noises, public address system messages and alarms” (Shepley & Davies, 2003, p. 2). Noise resulting in occupational stress has been reported to cause emotional exhaustion and burnout in nurses who work in critical care settings (Topf & Dillon, 1988). Reduced noise levels are associated with perception of “lower work demands and reported less pressure and strain” (Blomkvist, Eriksen, Theorell, Ulrich, & Rasmanis, 2005, p. 1). Research on 112 subjects recruited from 11 acute care hospitals showed increased possibility of errors when work conditions were perceived to be hectic. Subjects also felt more fatigued (Grayson, Boxerman, Potter, Wolf, Dunagan, Sorock, & Evanoff, 2005).

Presence of window views. The restorative impacts of windows have long been investigated. Window views buffered job stress, employment satisfaction and "intention to quit" and enhanced health in 100 non-healthcare workers (Leather, Pyrgas, Beale, & Lawrence, 1998). Vegetation views and window views in the workplace are associated with increased health and wellbeing, as well as reduced stress and increased performance (Leather et al., 1998; Kroelinger, 2005; Heschong Mahone Group, 2003). The impact of window views on patients has also been documented. Surgical patients hospitalized in rooms with nature views have had shorter lengths of stay than patients who were hospitalized in rooms looking at a brick building wall (Ulrich, 1984); they also made fewer negative comments as recorded by nurses, and consumed less pain medications (Ulrich, 1984).

Reduced distractions. Design layouts and features that reduce distraction, interruptions and delays can improve safety and efficiency. "Minor physical changes within a unit (such as distribution points of supplies or medications), can have a major impact on nurse workload" (Hendrich, Chow, Skierczynski, & Lu, 2008, p. 33). Ebright and colleagues found that "disjointed supply sources, missing supplies, repetitive travel and interruptions" caused a series of inconsistencies that distracted the nurses and added complexity to their work (as cited in Potter, Wolf, L., Boxerman, Grayson, Sledge, Dunagan, & Evanoff, 2005, p. 50). Design factors contributing to distractions and interruptions are mainly linked to medical errors (Ulrich et al., 2004).

Medical staff have a high cognitive workload during patient care. For example, nurses may have ten or more tasks waiting to be completed at one time. Based on a report submitted in 2007 to the Agency for Healthcare Research and Quality (AHRQ), “clinician interruptions, duplicate or repeat testing/procedures, delays in care and inefficient use of clinician time” are some of the major causes of waste in healthcare (James & Bayley, 2006, p. 2). Thus, an efficient work environment is one that filters out these elements.

Distractions in the clinical setting can result in missed or incomplete patient care (Potter et al., 2005, p. 46). According to Relihan, O’Brien, O’Hara, & Silke (2010, p. 2), “nursing staff would be likely to benefit from interventions designed to improve concentration” in high pressure acute healthcare environments. By reducing interruptions and distractions, today’s clinical workspace design can be adapted to current medical practice, which is associated with a high cognitive workload.

Presence of daylight or sunlight. Laboratory and field research in non-healthcare settings emphasizes the importance of daylighting indoors. Research on patients in healthcare settings has demonstrated that when patients are exposed to bright sunlight, they experience less stress and less pain, consumed 22% less medication per hour and had 21% lower medication expenses when compared to those who were exposed to lower light levels (Walch et al., 2005). Indirect patterns between sick days and windows in classrooms have been found (Küller & Lindsten, 1992). Windows and views of nature have been shown to buffer job satisfaction and improve health for both white collar and blue collar workers (Leather et al., 1998).

Daylight may also positively affect safety and reduced errors. In an Alaskan study on the relationship between seasonal light availability and medication errors, Booker and Roseman (1995) found the errors to be 1.95 times higher in December than in September. Further studies that link daylight to improved health and performance outcomes are provided in the next section.

Light (general). In healthcare settings, evidence exists that lighting can improve overall healthcare outcomes “by reducing depression among patients, decreasing length of stay in hospitals, improving sleep and circadian rhythm, lessening agitation among dementia patients, easing pain and improving adjustment to night-shift work among staff” (Joseph, 2006).

Light exposure can result in both circadian and acute physiological changes (Cajochen, Zeitzer, Czeisler, & Dijk, 2000). Studies at the Harvard School of Medicine have shown that even small changes in ambient light exposure during the late evening hours can affect cognitive alertness and sleepiness (Zeitzer, Dijk, Kronauer, Brown, & Czeisler 2000). In order to improve circadian efficacy and increase alertness for night workers, bright lighting strategies in the workplace have been suggested by studies done for the National Aeronautics and Space Administration (NASA) (Jha, Duncan, & Bates, 2001). Rivkees, Mayes, Jacobs and Gross (2004) found that circadian light exposure also affects infants; a group of infants became more active during the day and less active at night, compared to the control group who were exposed to continuous dim light. “Manipulation of light and dark is much easier in sleep labs than in the field” (Eastman, Boulos, Terman, Campbell, Dijk, and Lewy, 1995, cited by Jha, Duncan, & Bates, 2001, p. 524). “Field studies are needed to determine how bright artificial light affects objective measures of performance in healthcare workers and medical error." (Jha, Duncan, & Bates, 2001, p. 524)

Gardens. Gardens have been used as places of healing throughout history (Warner, 1995, as cited by Whitehouse et al., 2001). Gardens have been identified as restorative and healing places for patients, their families and staff (Sherman et al., 2005). A series of studies on the effects of gardens concluded that gardens help patients, families and healthcare staff better handle "illness and pain, confusion, depression, the suffering and loss of loved ones and heavy professional demands" (Cooper-Marcus & Barnes, 1999). In addition, studies show that emotional distress and pain are lowered when individuals spend time in gardens rather than indoors (Sherman et al., 2005). Gardens have healing impacts on hospital occupants by improving mood and increasing satisfaction (Whitehouse et al., 2001). Design features can help increase usability of gardens and enhance their healing effects. For example, Sherman et al. (2005) reported that only about one fourth of windows looking at a garden had open blinds ; due to privacy issues the frequency of blocking the window view increased when there was a greater number of visitors in the garden.

Satisfaction as a Measure of Healing Environments

Several means of measuring healing environments exist, the most common of which is user satisfaction. Beginning in October 2012, satisfaction, as an indicator of quality of care, will impact hospital reimbursement by the Centers for Medicare and Medicaid Services (Rau, 2011). A study of 129 patients by Rossberg, Melle, Opjordsmoen and Friis (2008) revealed that the staff working environment is related to both patient satisfaction and patient perceptions of the treatment environment.

The physical environment can affect staff satisfaction, along with patient satisfaction and their perception of care services. Varni and his team (2004) conducted a study and carefully measured patients' satisfaction with the care services and with the built environment. They also measured the satisfaction of medical staff with co-worker relationships and with the built environment. The researchers found that those who were satisfied with the overall care were also satisfied with the building design and vice versa. Medical staff members satisfied with the design were also happy with their relationships with other workers, based on the survey responses (Varni et al., 2004).

Researchers at the National Research Council Canada explored the physical conditions and job satisfaction of 779 nurses in the U.S. and Canada (Farley & Veitch, 2001). The study revealed that three main design categories in the environment directly affected satisfaction, and therefore, those who were happier with their senvironments "were also more satisfied with their jobs, suggesting a role for the physical environment in organizational well-being and effectiveness" (Veitch, Charles, Farley & Newsham, 2007).

Most important environmental factors in workplace design. Research has revealed "privacy/acoustics, lighting, and ventilation/ temperature" were three major areas related to employee satisfaction (Veitch et al., 2007). In addition to their healing effects, many environmental factors relate to work performance and many productivity measures. Environmental variables, such as lighting, ventilation, noise, the degree of privacy, ambient temperature, air quality, furniture, fixtures and equipment, finishing materials, color, artwork, views, auditory visual distractions, appropriately sized work space, windows, sightline to patient rooms and access to the outdoors were identified as stressors (Rashid & Zimring 2008; Gonzalez, Fernandez, & Cameselle, 1997; Veitch & Newsham, 1998; Veitch et al., 2007). Turnover, dissatisfaction and withdrawal from workspace have been linked to privacy, workplace size adjacencies and lighting (Oldham & Fried, 1987).

In terms of alertness, arousal and wakefulness, factors such as lighting, followed by ambient temperature (Mavjee & Horne, 1994), noise (Landstrom & Lofstedt,1987; Landstrom, Lindblom-Häggqvist, & Lofstedt, 1988) and posture (Kräuchi, Cajochen, & Wirz-Justice, 1997) are known as important environmental variables affecting alertness and sleepiness (Kim, Cranor, & Ryu, 2009).

Conclusion

Finally, incorporating the concept of healing environments is a considerable opportunity to create restorative health facilities for caregivers and receivers. The United States is in need of healthcare facility construction and renovation, because the average age of hospitals is about 30 years (Gunther, 2010). In 2009, there was a demand for over 120,000 healthcare building construction and renovation projects, an estimated investment of $300 billion (Enache-Pommer & Horman, 2009). This investment and its implementation will determine the bottom-line for the next 30-40 years of healthcare. These projects give us a chance to rethink healthcare design (Ulrich et al., 2004), specifically by considering how improved design can improve staff conditions, which is the largest of operation expenses.

Documented Impacts of Environmental Lighting

Evidence shows that natural and artificial lighting affect physical and psychological health, social interaction, sleepiness and alertness, productivity, performance, errors, absenteeism and job satisfaction. The following sections summarize the research studies that point at these outcomes.

Physiological and Psychological Changes

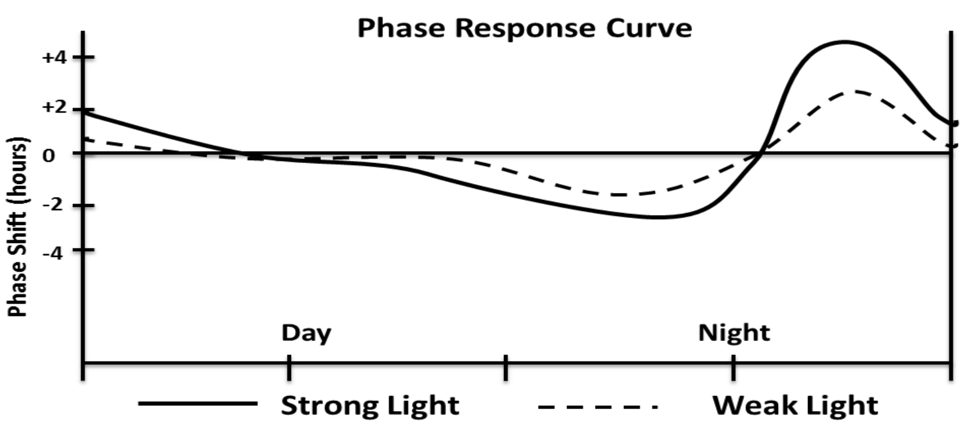
Appropriate lighting is an essential element in the workplace affecting physical health. The following section summarizes research studies that suggest light exposure with a certain intensity and spectrum may affect physiological rhythms, neurohormone production, melatonin suppression, body temperature, heart rate, respiration rate, blood pressure, skin oxygen, brain cognitive function, mood changes and sleepiness.

Lighting and physiological rhythms. Although the full mechanism of the human body and biological systems is not yet fully understood, we know that light is an essential nutrient for the body’s metabolic processes (Edwards et al., 2002). In other words, the main objective of lighting is not only visibility, but also the impact of “photo biological effects (Boyce, 1997). The human body undergoes continuous rhythms affecting physiological and behavioral functions (Halberg, Halberg, Barnum, & Bittner, 1959). These rhythms are called circadian rhythms (Halberg et al., 1959; Crepeau, Bullogh, Figueiro, Porter, & Rea, 2006). Circadian rhythms have become innate over millions of years of exposure to natural light and darkness (Crepeau et al., 2006).

Physiological rhythms may be infradian (longer than 24 hours), ultradian (shorter than 24 hours), or circadian (equal to 24 hours) (Boyce, 1997). Synchronization of circadian rhythms is required for the wellbeing of organisms (Gery & Koeffler, 2007). Lighting manipulates the intensity and duration of such rhythms in humans. Knowing that many people in America and Europe spend about 90% of their lifetime indoors (U.S. Environmental Protection Agency, 1989), indoor lighting plays an important role in adjusting these biological functions.

Circadian rhythms are primarily controlled by the suprachiasmatic nucleus (SCN) in the human brain, which is stimulated by environmental factors (Crepeau et al., 2006). “The mammalian SCN’s most important environmental input appears to be light and darkness transmitted from the eyes’ retinas via the retinohypothalamic tract.” (Crepeau et al., 2006, p. 2) Systems regulated by the SCN include sleep cycles, digestive systems, sleep patterns, blood pressure, immune functions and hormonal systems (Kent, McClare, Crosson, Arnerrm, Wadley, & Sathiakumar, 2009). This explains why light exposure has an impact on the circadian clock, which manipulates mental, behavioral and physiological functions (Czeisler, Allan, Strogatz, Ronda, Sanchez, Rios, Freitag, Richardson, & Kronauer, 1986) as well as affecting sleep dysfunctions (Kent et al., 2009). Lighting impacts body temperature (depending greatly on the intensity and timing of light exposure) and blood pressure (Boyce, 1997; Veitch et al., 2004). Specifically, lower exposure to sunlight has been linked to “cognitive deficits” (Kent et al., 2009). The circadian light dark cycle versus continuous light has been linked to reduced heart rate (Blackburn & Patteson, 1991) and improved growth and development patents in neonates (Miller, White, Whitman, O'Callaghan, & Maxwell, 1995).

Sleep/awake synchronization is highly controlled by lighting in the workplace and home. As shown in laboratory settings, even a small increase in morning light from windows could result in a phase advance in human circadian pacemakers and suppress sleep (Boivin, Duffy, Kronauer, & Czeisler, 1996). A study by Boyce (1997) indicated that long daylight exposure affects body temperature by elevating peaks significantly and advancing the rhythms (see Figure 2.2). Light may have a more significant impact on human circadian rhythms than the sleep/awake cycle (Hätönen, 2000).



Note. Re-created graph, "light phase response curve for core body temperature."(Boyce, 1997)
Figure 2.2. Body temperature and light rate.

Researchers have reported that sleep/awake synchronization may also be associated with obesity (Karlsson, Knutsson, & Lindahl, 2001), the risk of cardiovascular activities (Scott, 2000; Klerman, 2010, cited by National Space Biomedical Research Institute, 2010; Grandner, Patel, Gehrman, Perlis & Pack 2010) and development of depression (Scott, 2000). Reiter, at the University of Texas Health Science Center, states "evolution has dictated biological rhythmicity and physiology influenced by the natural light/dark cycle. Repeated perturbations of this cycle would have biological consequences." (Reiter, 2009, p. 2) Reiter's research also suggests that the regulation of melatonin production in the body reduces the chance of breast cancer, and other research has indicated melatonin production can be predicted by environmental lighting (Vondrasova, Hajek & Illnerova, 1997).

Natural and artificial light are also used for their curative effects. Roberts (2010, P. 7) explains, "…exposure to natural daylight and/or light sources that contain sufficient emission in the circadian blue region to trigger non-visual photoreception and subsequent circadian realignment" is used for curative effects on circadian dysfunction. Roberts also points to several studies that suggest daylight exposure, along with other measures such as melatonin intake and careful timing of meals, are known to effectively resynchronize body rhythms and are used as a remedy for jetlag.

Lighting and psychological changes. Lighting and daylighting have antidepressant effects. In an extensive literature review by Joseph (2006), numerous studies were identified that strongly suggest artificial or natural light is effective in curing depression. Roberts (1995, p. 3) indicates that "visible light exposure ... modulates the pituitary and pineal gland, which leads to neuroendocrine changes. Melatonin, norepinephrine and acetylcholine decrease with light activation, while cortisol, serotonin, gaba and dopamine levels increase." These changes cause mood alterations. Evidence shows that the antidepressant effects of medication are increased by bright light exposure (Loving, Kripke, & Shuchter, 2002) and "morning light treatments." (Benedetti et al., 2003) Therefore, lighting is very effective in improving mood and a successful cure for depression (Hätönen, 2000). Furthermore, the "antidepressant source of visible light is capable of inducing the production of reactive oxygen species in skin." (Oren, Charney, Lavie, Sinyakov, & Lubart, 2001, p. 464)

The term Seasonal Affective Disorder (SAD) originally referred to depression developed annually (Rosenthal, Sack, Gillin, Lewy, Goodwin, Davenport et al., 1984). Partonen and Lönnqvist (1998) describe it as an expression of bipolar disorder or recurrent depression. Bright light has produced successful results in treating SAD patients (Partonen, 1994; Lewy, Bauer, Cutler, Sack, Ahmed, Thomas, Blood, & Jackson, 1998; Hätönen, 2000).

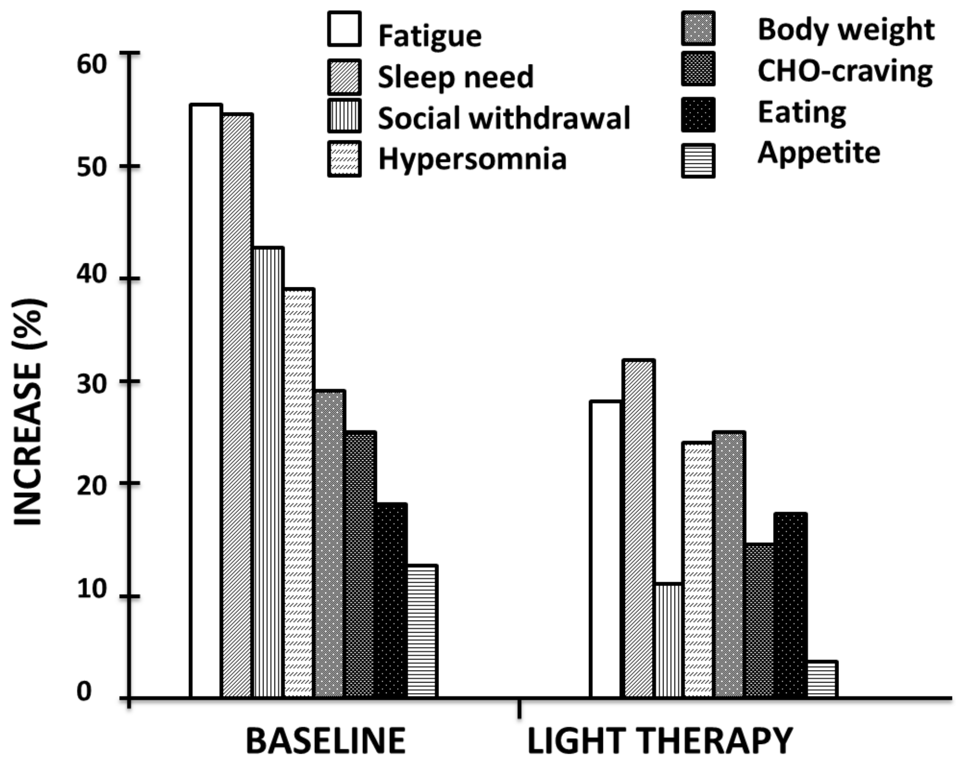
Further studies indicate that sunlight may have the same effect as artificial lighting. Psychiatric patients hospitalized in sunny rooms had significantly shorter stays compared to those staying in darker rooms (16.9 days versus 19.5 days), which means about 2.6 fewer days (Beauchemin & Hays, 1996). The same research team concluded that the healing effect of sunlight for bipolar depression is underestimated. In another study, Benedetti, Columbo, Barbini, Campir and Smeraldi (2001) found that bipolar patients who had access to direct morning sunlight stayed in the hospital an average of 3.67 days less than those who were not. Kent et al. (2009), in a study with 16,800 depressed and non-depressed participants, found that lower levels of sunlight were associated with impaired cognitive status.

A study on an elderly population reported lower saliva cortisol levels (a measure of stress hormone) when participants performed tasks in gardens, compared to working on the same tasks indoors (Rodiek, 2004).

Thus, light and natural light are believed to have therapeutic effects on depression and mental health and can potentially affect the frontline healthcare staff. Environmental lighting can also positively affect the nursing population, whose relationship to their patients is a key to patient satisfaction. Emotionally positive nurses may develop better nurse-patient relationships. Halldorsdottir (2008) found that the nurse-patient relationship is an important component of professional nursing care and is considered life-giving and empowering. The same study also found that the nurse-patient relationship directly affects the patient's sense of health and well-being. Therefore, applying appropriate lighting conditions in nursing work areas, which result in improved mental health in frontline staff, may directly affect patient care. The physiological and psychological effects of light exposure can be tracked to dietary intake, as summarized in the next section.

Light exposure and correlations with dietary intake. Depressed patients typically crave carbohydrates during the winter (Kräuchi, Wirz-Justice, & Graw, 1990). Kräuchi and his research team, from Psychiatric University Clinic, Switzerland, assessed the dietary intake of individuals with SAD in winter and summer, under light therapy and without light therapy. The light therapy was exposure to 2500 lux for one hour. They found that "Carbohydrate intake (both sweet and starch) in the second half of the day was elevated during winter depression," (p. 43) but after light therapy the amounts were lowered to the level of intake in the summer.

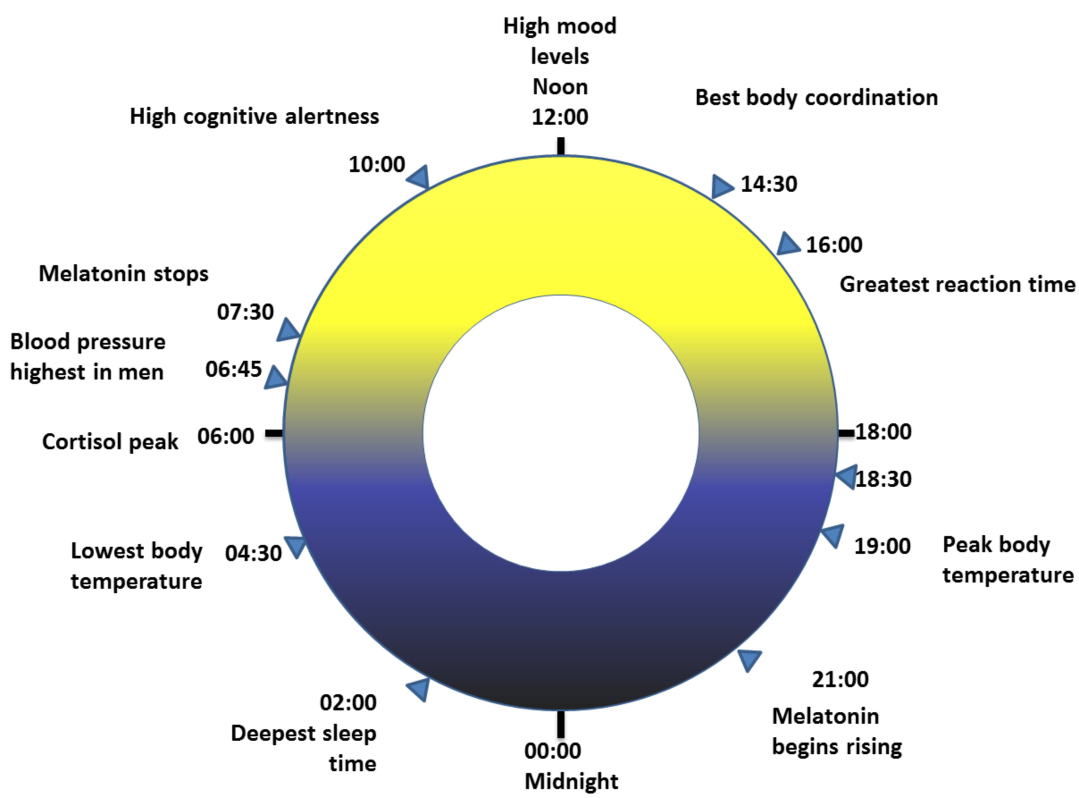
Figure 2.3 shows the results of research about the effect of lighting therapy on caffeine craving, fiber intake, dietary preference, social interaction and sleepiness. Food intake-related items, such as craving and eating, decreased with light (Krauchi et al., 1990). The study also indicated that light therapy for SAD patients reduced consumption of caffeine-containing drinks (tea, coffee and cola), and after the therapy was over, light withdrawal increased craving and consumption of caffeine. Thus, circadian disruption, which is highly connected to environmental lighting, is expressed by sleepiness, and in depressed patients, it is correlated with carbohydrate and caffeine craving.



Note. Re-created graph, Krauchi et al., 1990.
Figure 2.3. Food and caffeine craving predicted by light treatment on SAD patients.

Sleepiness, Safety and Errors. Without appropriate illumination, temperature, or noise levels, the indoor environment can make employees sleepy and tired. Kim et al. (2009) found that during fatigue and sleepiness, individuals are unable to continue functioning at normal performance levels, usually due to lack of vigor or motivation. In addition, fatigue is thought to be a source of accidents in industries such as transit, mining, construction and healthcare and signs and symptoms of sleepiness mimic alcohol intoxication and can impair performance more than alcohol intoxication (Kim et al., 2009; Dawson & Reid, 1997). Fatigue and sleepiness are major contributors to errors and incidents within patient care and occupational safety (Dearmond & Chen, 2009).

Research suggests that increased work sleepiness reduces safety behavior and increases occupational injuries (DeArmond & Chen, 2009). Therefore, environmental lighting can be seen as an opportunity to mediate sleepiness and improve wakefulness and safety in healthcare work environments.



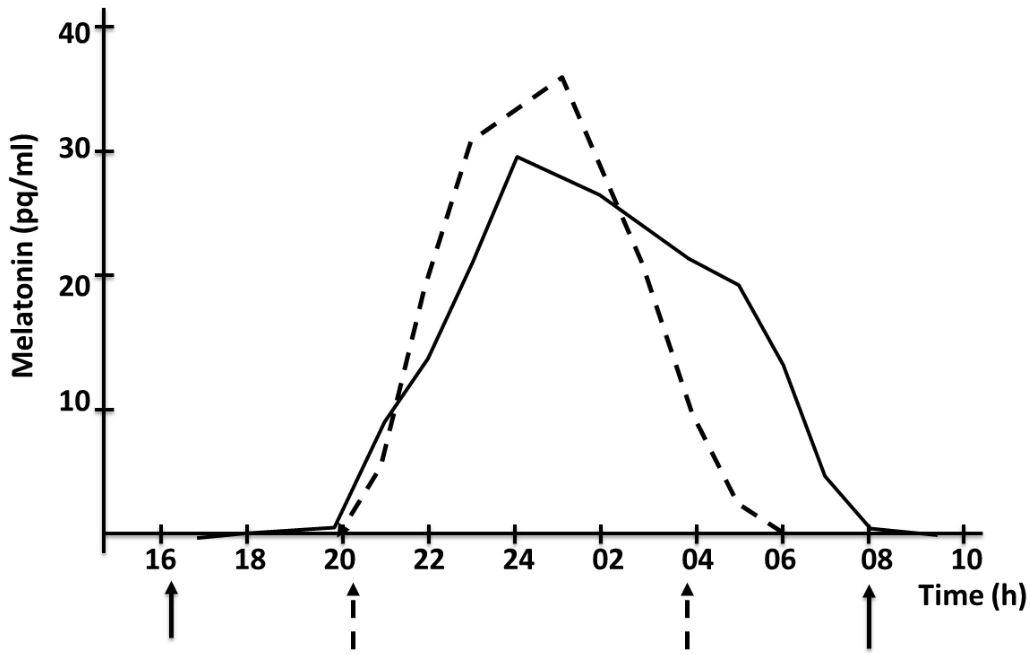
Note. Re-created from the book, *The Body Clock Guide to Better Health* by Smolensky & Lamberg (2000).

Figure 2.4. Hour by hour sleep/awake synchronization of natural light and dark cycle.

Daylighting and artificial lighting affect sleepiness and alertness. Proper lighting is the most important environmental factor (Crepeau et al., 2006) contributing to alertness (Figure 2.4). Nurses work long hours, and their alertness at all times is critical for the wellbeing of patients. Several research studies have linked lighting to sleepiness and alertness. Scheer and Buijs (1999) exposed two groups of human subjects to different light conditions, one to darkness and one to 800 lux light in the morning after waking up. The study showed that being exposed to high intensity light in early morning increased cortisol levels by 35%, and an increase in cortisol is linked to a decrease in melatonin (Vondrasova, Hajek & Illnerova, 1997; Loving, Kripke, & Shuchter, 2002), which creates sleepiness.

A study by Vondrasova et al. (1997) indicated that the seasonal increase of natural light versus electric light reduced sleep signals by two hours. Two different diurnal lighting conditions were introduced to the same population. One condition benefitted from the 16-hour natural bright light cycle of summer, while the second condition was 12 hours of winter light supplemented by four hours of electronic light to achieve the same 16 hour photoperiod. The results confirmed that exposure to a bright natural summer light from sunrise until sunset improves the circadian rhythm, in that morning melatonin declines quickly and cortisol rises. This shortens the duration of the melatonin signal by two hours compared with the winter pattern (see Figure 2.5). This study confirms the important effects of lighting (with the spectrum and intensity of natural light) on physiological sleep signals.

We know that healthcare staffs often spend long shifts (12-16 hours) in windowless work areas usually limited to constant electric lighting. The availability of cycled lighting with the spectrum of daylight is important for health and performance. Healthcare built environments with maximized access to windows and outdoor light may be an opportunity to increase health and efficiency in medical workplaces.



Note. Salivary melatonin rhythms in winter and summer, re-created from Vondrasova et al. (1997).
Figure 2.5. Sleepiness impacted by lighting.

Natural and artificial lighting and medical errors. In a randomized study, Buchanan, Barker, Gibson, Jiang and Pearson (1991) found that prescription-dispensing error rates were predicted by light intensity. The use of high illuminance light levels eliminated 32% of errors. Environmental illumination goes beyond providing clear vision for tasks; it can lead to improved cognition and performance even on nonvisual tasks (Baron, Rea, & Daniels, 1992). Lighting, with the characteristics of daylight, is the most important environmental stressor affecting sleepiness and alertness (Postolache & Oren, 2005; Crepeau et al., 2006). This may explain the findings by Booker and Roseman (1995), who suggested a relationship between dark/night cycle and medication errors.

Environmental and personal factors affecting sleepiness. According to the Commonwealth Fund's 1982 publication, "The Clocks that Time Us," lighting is the number one environmental factor, followed by temperature and noise, that affects alertness and sleepiness circadian rhythmicity (Moore-Ede, Sulzmann and Fuller, 1982). In addition to various environmental factors, the time, duration and quality of sleep, as well as caffeine intake, highly affect sleepiness (Klereman, personal communication, 2010). Van Dongen and Dinges (2005) reported that a variety of factors such as background sound or posture can "mask" the effect of circadian sleepiness. Sleep time, nutrition, physical activity and age also mediate fatigue and sleepiness behavior (Kim et al., 2009).

The impact of environmental lighting is also related to psychological conditions. Research shows that those already affected by depression are more sensitive to environmental factors. According to Lewy, Nurnberger, Wehr, Becker, Powell, & Newsome (1985), depressed participants exposed to lighting at nighttime had twice the melatonin suppression (sleep hormone) as normal subjects. Therefore, depression seems to increase biological sensitivity to environmental factors. It is possible that healthcare staff and patients who experience stress may be even more affected by the environment, as compared to healthy individuals.

Satisfaction, Performance and Productivity

Performance can be improved during the work time using light exposure. Individual performance is regulated by time awake, quality of light, prior sleep and one's personal biological clock (Klerman, 2010, cited by Thomas, 2010). Circadian desynchronization shifts the body's peak performance (by circadian rhythms) from the work schedule (Crepeau et al., 2006). Daylighting has positive effects on worker productivity in factories and schools (Kats, 2006). Baron, Rea and Daniels (1992) found that key characteristics of lighting (e.g., illuminance, spectral distribution) have positive effects on cognition in performing tasks that did not require major visual processing. Based on the available evidence in a non-healthcare setting, it is likely that lighting is associated with performance in healthcare (Rashid & Zimring, 2008).

Because the nursing occupation is among the occupations with the lowest job satisfaction rates and high stress levels (Johnson, Cooper, Cartwright, Donald, Taylor & Millet, 2005), improving the healthcare environment would definitely benefit this occupation. An extensive review of the literature by Farley and Veitch (2001) showed that the presence of window lighting and nature views results in increased job satisfaction and reduced tendency for turnover. Markus (1967), in a study on 400 office workers, found that 95% favored daylight over artificial lighting. Employees sitting by the window had higher satisfaction scores on daylighting. Another study of about 100 employees found that staff tended to "withdraw from offices" and were more dissatisfied if the offices were rated as dark (Oldham & Rotchfor, 1983; Oldham & Fried, 1987). Indirect patterns between sick days and windows in classrooms have also been found (Küller & Lindsten, 1992).

In one study, windows and nature views buffered job satisfaction and improved the health of white collar and blue collar workers (Leather et al.,1998). Alimoglua and Donmez's (2005) study on nurses working at Akdeniz University Hospital in Antalya, Turkey, found daylight exposure indirectly affected burnout via work-related stress and job satisfaction levels.

Communication, Social Interaction and Social Withdrawal

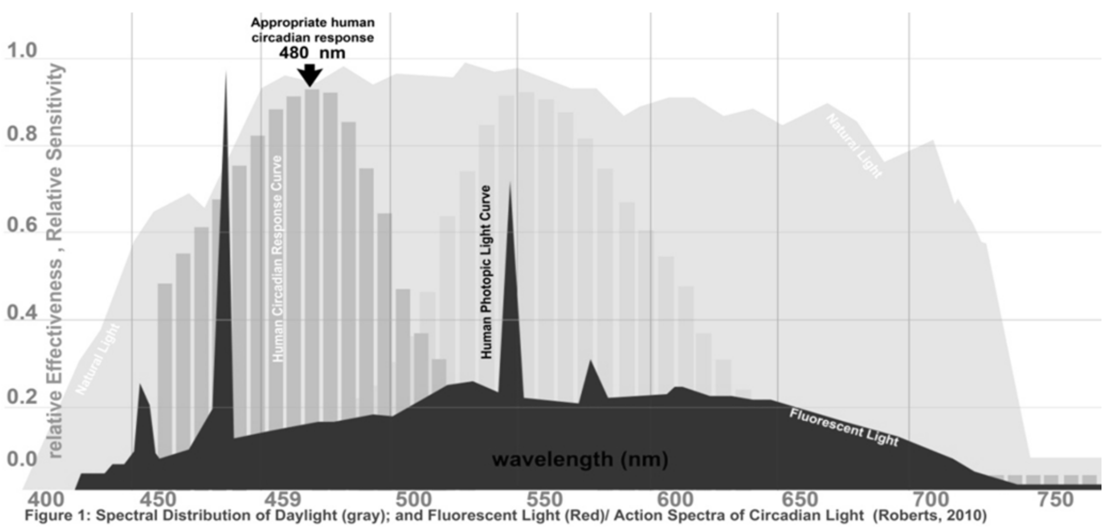
Communication among caregivers represents approximately 20% of a nursing practice (Hendrich et al., 2008). Therefore, this is an inherent component of quality of care (Becker, 2007). Communication has an inverse relationship with sleepiness (Kim et al., 2009), which appears to be altered by light therapy. Exposure to light has been associated with reduced social withdrawal (Kräuchi, Wirz-Justice, & Graw 1990). The effects of lighting on "social relations and/or interpersonal conflicts" in the workplace have been highlighted by Rashid and Zimring (2008). Baron, Rea and Daniels (1992) found that participants exposed to warm white light (as opposed to cool white light) indicated "stronger preferences for resolving conflicts through collaboration" (p. 1) than through avoidance.

A study allocated school children to four classrooms with different light conditions (with and without windows) and seasonal changes were recorded. The study found morning light was associated with collaboration and interaction (Küller & Lindsten, 1992).

Comparing Natural and Artificial Lighting

Individual performance is regulated by time awake, quality of light, prior sleep and one’s biological clock (Klerman, 2010, cited by National Space Biomedical Research Institute, 2010). The light spectrum most closely matching sunlight stimulates the human brain and affects biological rhythms. Kent and his research team (2009) explain that the SCN, which controls circadian rhythms including sleepiness, is modulated by various factors. The primary modulator for SCN is the sunlight’s prevailing wavelength, 477 nanometers, received by retina (Turner & Mainster, 2008). Uncontrolled electric lighting can potentially have a negative effect on health: electrical light sources that do not emulate natural diurnal/seasonal lighting prohibit proper circadian response (Roberts, 2010).

Spectrum and timing. Natural light provides high intensity blue light (400-500 nm) in the morning. The wavelength smoothly transitions to orange-red light (600-700 nm) at sundown with minimal blue light intensity (Roberts, 2010). Human physiology has evolved by responding to this phenomenon. In fact, exposure to blue light in the morning enhances human health (Roberts, 2010), while the absence of blue light at night contributes to human health (see Figure 2.6).



Note. Re-created and combined two graphs from Roberts, 2010.

Figure 2.6. Spectral distribution of daylight (gray) and fluorescent light (red), action spectra of circadian light.

An effective light wavelength for a circadian response is mainly between 460 - 500 nm (Gaddy et al., 1993, as cited by Roberts, 2010). Non-visual photoreceptors of circadian changes are located in the eyes' retinas (Berson, Dunn, & Takao, 2002; Berson, 2003). These signal the SCN, resulting in the suppression of the sleepiness hormone. As shown in Figure 2.6, fluorescent lighting can only meet the needs for (non-visual and visual) circadian response similar to photopic vision to a certain degree. Natural light, on the other hand, has a high potential to entertain both visual and non-visual light sensors.

Energy Use

Healthcare buildings are among the top three most energy intensive types of commercial buildings (Energy Information Administration, 1995). It is assumed that the provision of windows and daylight would be in conflict with energy efficiency due to, for example, diminished insulation (Stegou-Sagia, Antonopoulos, Angelopoulou, & Kotsiovelos, 2007). However, the U.S. Department of Energy, Energy Efficiency and Renewable Energy, (2000) and the Center for Sustainable Building Research [CSBR] at the University of Minnesota (2009) suggest that windows do not necessarily increase energy use if they are used with the right orientation, appropriate shading and appropriate glazing areas. In addition, daylight can offset the use of artificial lighting, which accounts for about half (42%) of the electricity consumption in healthcare facilities (U.S. Energy Information Administration, Released 2008).

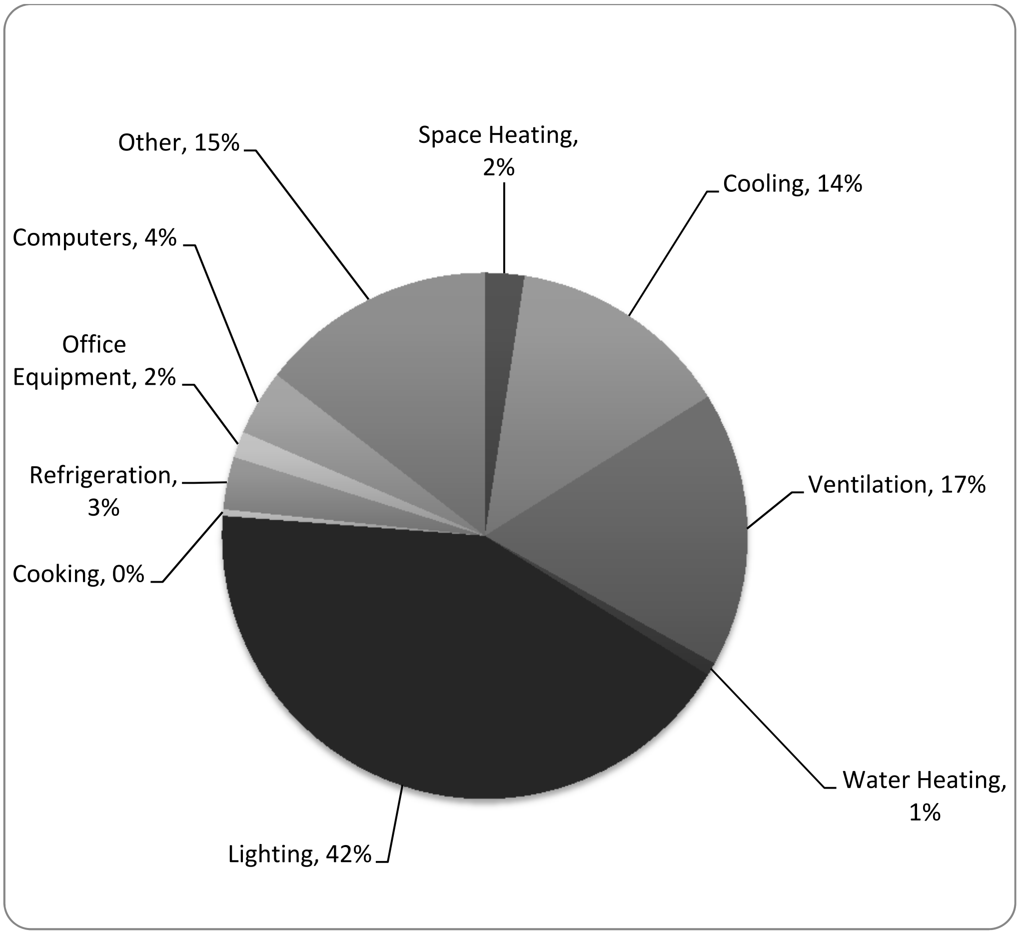
Daylight and sun radiation represent the largest source of available renewable energy. The availability of sunlight provides an enormous opportunity to operate sustainable buildings by capturing this free source. When it comes to lighting, daylight is a more efficient lighting source than fluorescent light in terms of the heat put into a space (Culp, personal communication, 2009). By reducing the electricity needed for lighting in healthcare buildings, the daylighting strategy greatly affects total energy use.

In terms of heating, passive heating by direct sunlight is more efficient than a heat source using photo voltages.

Strategies that save energy in electricity and in lighting could greatly impact the use of healthcare energy nationally (Figure 2.7). Westberg (2005) noted that if we only manage to save 10% of the energy used in healthcare, $600 million would be saved, because hospitals in the U.S. spend more than $6.5 billion a year on energy (CBECS, 1999, cited by Westberg, 2005). Therefore, the opportunity for positive impact is great, because healthcare buildings are one of the top electricity demanding commercial building types.

Conclusion

All the aforementioned evidence about the physiological, psychological and behavioral impacts of lighting indicates that human nature responds and harmonizes itself to the environment, as manifested in health and performance. Current laboratory research on the impact of lighting, with spectrum and intensity similar to natural light, points to improved cognitive function, sleepiness and mood. Field research in non-healthcare settings also link lighting to enhanced mood, satisfaction, conflict resolution and communication. The aforementioned available evidence created the foundation for further studies in support of healthcare staff physical and mental health.



Note. More site electricity is consumed for lighting than any other use according to the U.S. Energy Information Administration (Released 2008).

Figure 2.7. Lighting consumes the largest portion of electricity consumption (Btu) by end use for healthcare buildings in 2003.

CHAPTER III

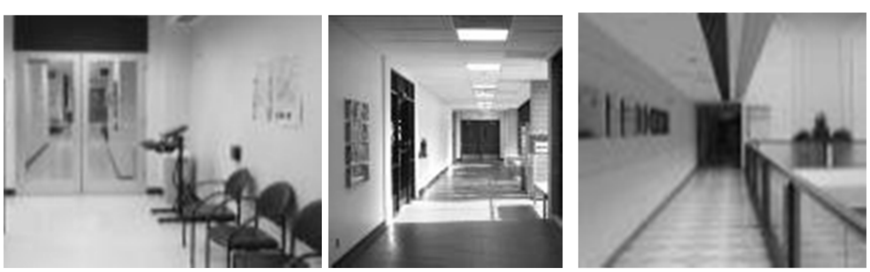
METHODS

Introduction

In this chapter the research sites and the participant's characteristics are introduced. Compliance with human subjects' research requirements as well as ethical considerations are explained. Then, the research hypotheses and the methods used to test these hypotheses are introduced in three studies: an ethnographic study, a quasi-experimental study and a computer simulation study.

Site and Setting

The study was carried out during spring and summer 2011 in three facilities: an outpatient counseling facility, an outpatient health facility and a community teaching hospital (Figure 3.1). To maintain the anonymity of the institutions being studied, the facility names have been removed from the citations.



Note. Facility one, facility two, and facility three.

Figure 3.1. Research sites.

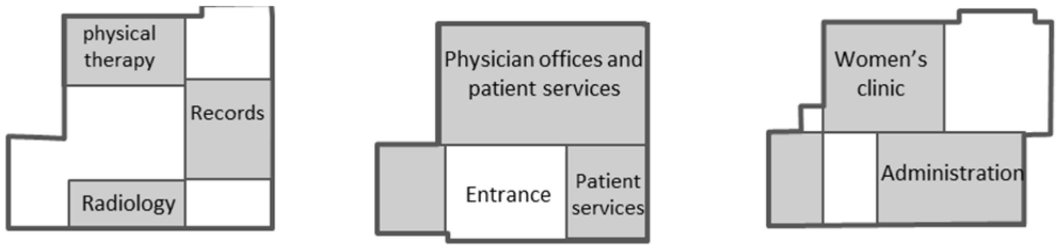
Physical Conditions

Facility one. This site is an outpatient facility. This facility provides preventive, therapeutic and primary care services (retrieved from the facility recourses). Departments include: general clinic, women's clinic, physical therapy, pharmacy, lab, radiology and administration.

The three-story building (including a basement) was built in 1972 and was significantly renovated in 1986 and 1995. Departments such as the lab, radiology, physical therapy and medical records, are located in the basement. The general clinic, pharmacy, physician offices and patient services are on the first floor. The women's clinic, administration and paramedics are on the second floor (Figure 3.2).

According to the health center's managerial staff (personal communications, 2011) the health clinic was built in 1972. In 1986, the facility was expanded for the first time. The health center was not as equipped as a hospital to provide full spectrum care, however, it provided facilities with overnight observation for a patient. In 1986, inpatient care (overnight hospitalization)--which was mainly for observation--was stopped and the building became mainly an outpatient ambulatory clinic. The large rectangular hallways in the facility were originally designed for overnight hospitalization and facilitated wheelchair and bed access to rooms.

To improve client access, "outpatient care usually takes place all in one level," states Scott Draper, M.B.A., Associate Director. The current building poses certain inefficiencies because it does not provide for an efficient fast track clinic, as it was originally designed as an inpatient facility.



Note. Basement, first floor and second floor.
Figure 3.2. Facility one, floor plans.

Lighting. The following sections discuss the availability of natural light and windows, glazing characteristics and electric lighting in this site.

Natural light access. Since the facility is located in the heart of green field with scenic views and tall trees, a great potential exists to capture windows with pleasant views. The building is rotated 45 degrees from true north; hence, the elevations and windows open to the southeast, southwest, northeast and northwest orientations. Some daylight is available in the basement in the physical therapy entrance though windows opening to a courtyard.

Glazing. Staff work in both windowed and windowless spaces. Windows exist on four sides of the building in cubicles, and open bays and offices, but not every office on the perimeter has windows. Although interior windows exist in the office spaces at the core of the building, daylight is not available in most cases. Windows are generally small and narrow and have mixed views of natural and built elements. A typical window in this facility in work areas is 2’ x 6’ 8’’ (Figure 3.3).

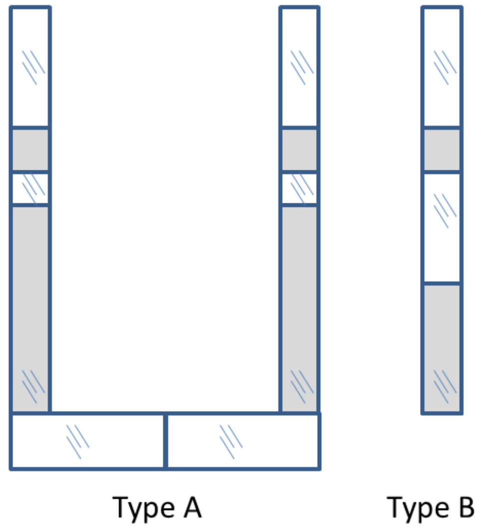


Figure 3.3. Windows at facility one.

Electric lighting. The light fixture system consists of 2' x 4 'recessed fluorescent fixtures with parabolic troffers with T8 fluorescent lamps (Figure 3.4). This is the main source of lighting that enables visual access to tasks for the staff.

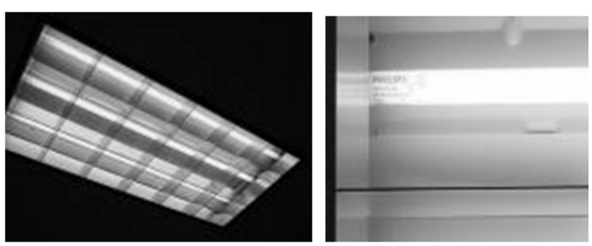


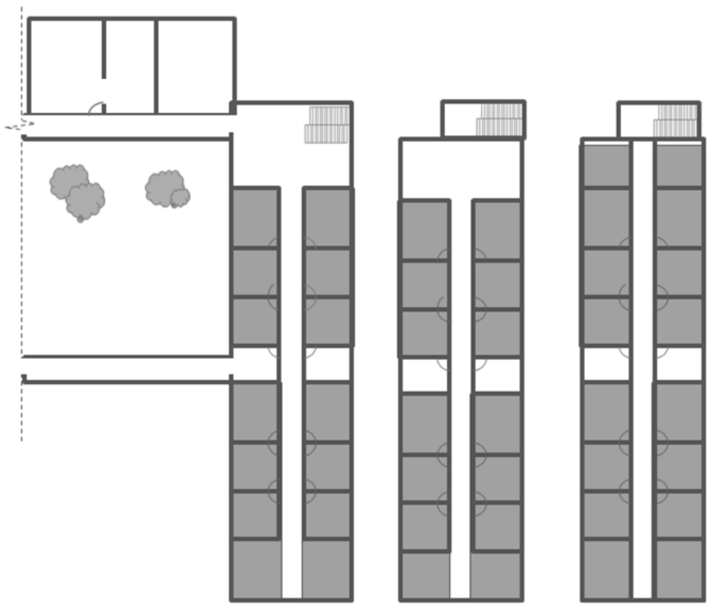
Figure 3.4. Electric lighting in facility one.

Facility two. This site provides psychiatric services, consultation and crisis intervention (retrieved from the facility resources). This facility is located inside a former dorm and athletic training facility built in 1972, located in a green field. The building underwent renovations in 1985 and 2007. The counseling facility is comprised of two areas: a one-story entrance building (shared with other university services) and a three-story counseling building that houses all the counseling staff as well as a portion of the support staff. A testing center, conference room, patient admissions and the remaining administrative offices are located in the one-story-building, which leads visitors to the counseling building.

In this facility, clients can check in with one of two receptionists in the reception area. The entrance door to the reception area is tinted to improve privacy. The waiting area is furnished with comfortable seating, with a corner lounge, hot drinks and computers for registration. Usually, radio or music is played in this area for soothing purposes and also to reduce noise transfer for privacy, explains the Administrative Coordinator at the counseling facility (personal communications, 2010). Two small rooms with tinted glass are available to enable clients experiencing a crisis to check in in privacy and speak with the counseling facility staff in private (Administrative Coordinator, personal communication, 2010).

Access to the counseling tower is limited to the staff and any clients accompanied by the staff. This helps the sessions, to not be interrupted by visitors who may be lost and looking for directions, according to the Administrative Coordinator. The counselors meet their clients in the reception area and accompany them to their office and the counseling spaces (personal communication, 2010).

All counseling spaces are located in the three-story building. Because the tower has a separate entrance to the outside, the restricted access seems essential to keep the counseling areas private (Figure 3.5).



Note. First floor, second floor and third floor schematic plan.
Figure 3.5. Facility two, floor plans**.**

Lighting. The following sections discuss the availability of natural light and windows, glazing characteristics and electric lighting in this site.

Natural light access. The building has a narrow floor plate and is adjacent to a courtyard and a green landscape. These features have the potential to provide scenic views and natural light indoors. The one-story space for admissions and testing has no direct access to daylight and views. However, the client entrance corridor has a pleasant view of a green courtyard. The tinted glass of the client waiting areas provides a limited view of these windows. The three-story rectangular counseling building houses offices on two sides of a long corridor (double loaded corridor). The building elevation opens to the southeast and northwest; one side looks at an open green landscape (with a sculpture and buildings) and the other looks at the green courtyard.

The interior layout consists of dark blue carpet flooring with white walls and white acoustic ceiling tiles. This layout remains unchanged across the facility. Each counseling room consists of a desk for the counselor and a counseling area.

The furniture, wall hangings, decorative objects and lamps have been added to each counseling room by staff. This provides a unique and diverse atmosphere in each counseling room, intended to be soothing and inviting for clients. In addition to the furniture and lighting, certain counseling areas benefit from air fresheners and fragrances, to remove the old building odor.

Glazing. The offices are similar in design and have a narrow (2’ 10’’ x 8’ 8’’) window in one corner of the room, similar to the health clinic. The northwest orientation that opens to a courtyard provides a view of the rooftop of the opposite building on the top floor while the first floor looks directly at the grass (Figure 3.6).

The windows are set back four inches from the exterior wall and eight inches from the interior frame (Figure 3.7). In the majority of the offices, window views are not visible from the occupants’ viewpoint when they sit at the desk. Since the narrow vertical windows are located in a corner of the exterior wall, uniformly distributed daylight is not available in these large counseling rooms.

Note. Southeast view, northwest view, northeast view (the second floor).

Figure 3.6. Views in the counseling and office spaces.

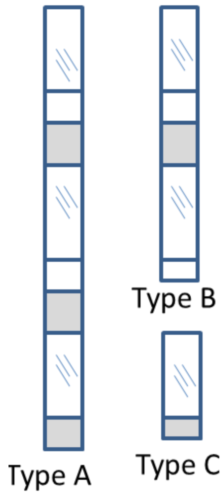


Figure 3.7. Windows at facility two.

Electric lighting. The electric lighting is operable with two switches in most rooms on the first and second floors. The third floor offices have one switch and are supplemented with occupancy sensors. The electric lighting consists of four capacity ballast diffusers, with T8 light bulbs (Figure 3.8). In most of the counseling rooms, additional decorative lighting added by the staff is the main lighting source. Some occupants turn the electric lighting completely off and use decorative and task lighting, some have one switched on, and only a few have both switched on.

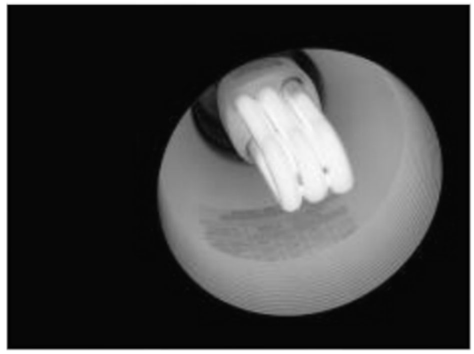
 

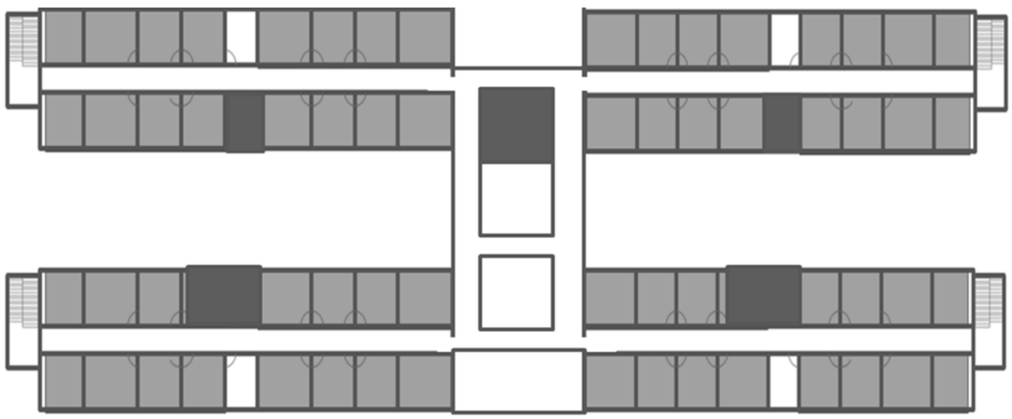
Figure 3.8. Electric lighting at facility two.

Facility three. This facility is a 200-bed hospital that offers comprehensive services to patients (retrieved from the facility three resources). The facility supports a level III Trauma Center, inpatient and outpatient surgery, cardiac, cancer and rehabilitation services (retrieved from the facility resources).

The setting for this study is an 86-bed acute nursing unit. The nursing unit accounts for one-third of all the inpatient beds, explains the Nursing Unit Director (2011).

In this unit, the patient’s heart is continuously monitored using telemetry technology (retrieved from the facility three resources). Thus, patients who are age 18 or above and require nursing care with technical skills beyond those of a basic medical/surgical nurse, but who do not require critical care nursing are admitted to this unit (retrieved from the nursing unit documents). When the acuity rises and patients need further resources, they are transferred to higher acuity units.

Admitted patients mainly have one of the following diagnoses: "post coronary bypass surgery, post stent placement, post cardiac catheterization, heart attack, congestive heart failure, heart rhythm abnormalities" (retrieved from the facility three resources).



Note. Second Floor.

Figure 3.9: Facility three, floor plan.

The nursing unit has two long wings, north and south, which are connected in the middle and form an H (Figure 3.9). Patient rooms are located on two sides of the corridors all along the North and South wings (double-loaded corridors). The patient population is similar across the unit and categorized as acuity 2, 3 and 4 (see Appendix A) and nurses rotate among the stations. Three large nurse's stations are located at the center of the southwest, southeast and north center wings. Two mini stations, which share the same space with medication and supply rooms, are located in the far back of the northwest and northeast wings.

The entire unit has similar finish materials, white paint on gypsum walls, acoustic ceiling tiles and 12”x12” vinyl composition tiles, satin gloss, waxed finish. The furniture is similar in the work areas: dark green office chairs and white built-in countertops and desks. The nurse’s stations all have a front desk facing the hallway where unit secretaries and technicians (teletechs) work. They also have four to none work stations equipped with computers and sometimes phones for nurses who provide patient care, social workers and charge nurses. In the north wing, adjacent to the nurse’s station, is additional seating for doctors, a 9’x12’ space for charting, accessing patient information, writing orders or conducting dictations and reports. However, in the south wing, physicians share seating with other staff.

Every nurse’s station has convenient access to a nutrition room. A large linen cart containing towels and bed sheets for patient rooms is located in an alcove in the center of each hallway (NW,NE, SW,SE). This facilitates access and reduces walking. Every hallway has medication and supply storage, which are usually located in one room with code access.

Lighting. The following sections discuss the availability of natural light and windows, glazing characteristics and electric lighting in this site.

Natural light access. The building is formed in a fairly narrow floor plate facing north/south, which increases the potential for windows and natural light. The window view is mainly an urban and built space with limited greenery. Staff work in offices or open bay areas. Staff offices, including administrative staff, pharmacy and shared monitor technician rooms, are mainly located in the center with no access to daylight.

The nurse's stations in the north wing have no access to daylight (Figure 3.10). In contrast to the north central station, the southeast and southwest nurse's stations both have windows. These windows face north and their view is mainly of portions of the hospital building. All patient rooms have vertical narrow windows located mainly in the corner of the exterior wall.

The southwest station looks at a courtyard which is a healing garden. From the nurses' seating area, only the brick wall from the other side of the courtyard is visible, however. The southeast station mirrors the southwest, except that it opens to a rooftop, which is where the mechanical systems are currently located. Another distinctive characteristic of these two windowed stations is that both mainly receive north diffused daylight in the summer months for a few hours in early morning and afternoon. Therefore, the southeast station better receives east light and the southwest receives slightly more west light. The diffused daylight received in these two stations is direct (sky) and indirect (reflected by the built space of the brick wall and the rooftop and equipment on the rooftop).

During the pilot study, the window view located in the southwest station was covered by tree foliage; however, a renovation in the healing garden resulted in the removal of the trees. The replacement trees in the healing garden are too short to be visible from the southwest nurse's station. SE, NW and NE medication and storage rooms benefit from windows. However, the windows are fully covered by blinds most of the time.

Note. North, South West and South East Nurse's Stations.
Figure 3.10. Windows and views.

Figure 3.11. Glazing in facility three.

Glazing. Architectural drawings on glazing characteristics were not available. However, the glazing information was found on site from a sticker on the window, which indicated a ¼'' tempered, single-pane glass in these work areas (Figure 3.11).

Electric lighting. The main source of lighting in the entire unit is 2' x 4' recessed, fluorescent fixtures with acrylic lenses with T8 fluorescent light bulbs (Figure 3.12). In the nurse's stations with windows, both windows and electric lighting are used for visual access to tasks.

Figure 3.12. Electric lighting at facility three.

Summary

The site characteristics are summarized in Table 3.1.

Table 3.1: Site characteristics.

Facility	1	2	3
Building type	Outpatient clinic facility	Outpatient counseling facility	Acute inpatient nursing unit, community hospital
Staff Population	85 staff (75 in Summer)	45 staff	140 (100 day staff and 40 night staff)
Floor Area	~58,000 ft^2	~27,000 ft^2	~27,000 ft^2
Building age	39 years (1972)	39 years (1972)	42 Years (1969)
Last major renovation	1995	2007	2009 (small renovation)
Methods used	1-Archival and document evaluation 2-Walk through evaluation 3-Evaluation questionnaires	1-Archival and document evaluation 2-Walk through evaluation 3-Evaluation questionnaires and interviews	1-Archival and document evaluation 2-Walk through evaluation 3-Evaluation questionnaires, observation and biological measurements

Note. The chart format adapted from the book, *Post Occupancy Evaluation* by Preiser, Rabinowitz, & White (1988).

Table 3.1: Continued.

Finish materials			
Wall	Gypsum board, off white paint, vinyl base	Gypsum board, off white paint, vinyl base	Gypsum board, off white paint
Flooring	Sheet vinyl, high gloss,waxed finish. 12 ft rolled, looped commercial and rolling Carpet	12 ft., tight looped, commercial carpet with area rug.	12”x12” vinyl composition tiles, satin gloss, waxed finish.
Ceiling	Suspended acoustic MIN fiber	½’’ Acoustic tile in gypsum board	Acoustic tile
Glazing			
Glass	¼’ Solar Bronze PL Glass, Single	¼’’ Gray Glass, Single	¼’’ Tempered Glass, Single
Frame	Anodized Bronze Aluminum	Aluminum frame	Aluminum frame
Size	2’ X 6’ 8’’	2’ 4’’ x 8’ 6’’	3’ 6”
Floor to Ceiling height	9’	9’ 4’’	9’
Electric lighting related			
Light fixture	2’ x 4‘ recessed fluorescent fixture with parabolic louvered troffer	2’ x 4’ recessed, fluorescent fixture with acrylic lens	2’ x 4’ recessed, fluorescent fixture with acrylic lens
Light bulb	T8	Philips F32T8/TL735, Watt Universal/ Hi-vision, USA	Philips F32 T8/t 735 Universal/ Hi-vision, USA c.4

Participant Information

The size of the total potential subject pool, as well as the occupation categories at each facility, are described below. The actual number of participants is provided in the results sections.

Overview

Facility one. In this facility, 85 employees work fulltime, on a nine hour daily basis, including a one-hour lunch, across multiple departments, including the general clinic, women's clinic, physical therapy, pharmacy, lab, radiology, medical records and administration. Some permanent employees work on a nine-month basis, and 75 employees who worked for 12 months were present in the summer when the study took place.

Since only fulltime employees were eligible, this number does not include the part-time student workers and Emergency Medical Technicians (EMTs), who may work only a few days a week according to the Facility Director (2011). The participants were Registered Nurses (RN), Licensed Vocational Nurses (LVN), case managers, medical assistants (MA), certified nursing assistants (CNA), physicians, nurse practitioners, physical therapists**,** lab technicians, x-ray technicians**,** administrative and business staffs**,** pharmacists, pharmacy technicians and other administrative assistants.

Facility two. A total of 45 employees work fulltime on a 40-hour weekly basis. All employees were eligible to participate. The participants hold the following titles: support staff**,** counselor, psychologist in training, psychologist, psychiatrist**,** and administrator.

Facility three. Overall, 148 employees were employed fulltime at the time of the study. However, the number of employees, present at work on the Unit, changes daily. This number is continuously adjusted based on the average patient census (Unit Director, personal communication, 2011). The average census was 71 in 2011. This number is calculated yearly “based on historical admission and discharge trends.” The staffing grid, based on this data, is used to design monthly staff schedules. House Supervisors (HS), who monitor the daily census, adjust the final schedule and staffing (retrieved from the nursing unit resources). For example, based on the researchers’ observations, if the census is unexpectedly low one day, a number of staff who are scheduled to work may be told not to come to work that day. Also, if the census is high, the HS may call staff that are on call or the PRN(Pro Re Nata) nurses to come to work (retrieved from the nursing unit documents). PRN staff, are those who are “utilized as needed when staffing needs warrant additional staff” (retrieved from the nursing unit documents).

Job titles of the participants are RN, LVN, charge nurse, case manager, team leader, monitor tech, teletech and unit secretary. The staffing job descriptions were provided to the researchers by the health facility.

Anonymity and Confidentiality

The research team completed the required training to conduct human subject research. This research promoted a voluntary participation of human subjects. At the beginning of the experiment, the information sheets and consent documents were distributed to all participants. The collected surveys were all anonymous. Following IRB protocols, drop boxes were provided at every facility.

Additional measurements were taken to maintain the confidentiality of the participants in the observation and physiological measurement section. The hospital keeps a schedule that indicates which staff member is working at which location on which day. Prior to data collection, the principal investigator used these schedules and replaced all the subjects' names with numbers. As the schedule changed, the numbers were updated by the PI. This numbering system enabled us to track each participant on the first and second day of observation without recording their names.

Signed consent and information sheets. Signed consent was waived by the IRB committee at Texas A&M University, as it was a means of identifying the participants. Therefore, an information sheet was distributed in the first and second facilities. In the third facility, hospital policy required that a signed consent be completed prior to the study. To ensure anonymity, the consent forms were collected separately from the surveys. The participants in the inpatient unit signed an informed consent approved by the Institutional Review Board, Office of Research Compliance Staff of the Division of Research at Texas A&M University, as well as Institutional Review Board at the hospital.

Procedure for Study 1: Ethnographic Research

The study began with an ethnographic study to educate the researchers about the site culture and characteristics. Previous researchers have conducted studies to identify the key design elements of a successful office space; however, no study has yet identified the most important environmental characteristics in healthcare and counseling environments. Therefore, ethnographic introductory research was conducted in which the participants responded to structured and unstructured survey questions and identified the most important environmental features applicable to an ideal healthcare or counseling workplace.

Moreover, the overall role of lighting and its impacts on perceived sleepiness and mood was assessed. Participants were asked to look at three images and imagine that they have to do some documentation in a typical day in one of the three environments shown in the images. Then they were asked to report their perceived mood and sleepiness. Finally, follow up interviews were held as needed to explain the responses.

Eligibility and Recruitment

Staff surveys were intended for all fulltime employees on all shifts with any job title. The study was introduced in monthly meetings in all three facilities. A total of 268 healthcare and counseling staff (age 20 to 69), who worked fulltime at one of these three health and counseling facilities, were eligible to enroll in the study for the survey.

In Facility one, usually one or more monthly meetings are scheduled and are required for all staff. The surveys were distributed in June, 2011 in one monthly meeting at this facility. In addition, three drop boxes and additional blank surveys and pens were placed in common areas for the surveys that were not returned in the unit meeting. To increase the response rate, reminder emails were sent to the staff by an Administrative Assistant.

In Facility two, one weekly meeting is required for all staff. The surveys were distributed in June 2011 in one monthly meeting. In addition, two drop boxes were put in common areas and additional blank surveys were provided for the staff who were not present in the meeting and pens were placed in common areas. To increase the response rate, reminder emails were sent to the staff by the administrative coordinator.

In Facility three, three monthly unit meetings are scheduled to accommodate day and night shift staff. Staff are only required to attend 50% of the annual monthly unit meetings. Thus, in order to increase participation, we introduced the study and distributed surveys in two consecutive months, May and June 2011, in six meetings. Furthermore, blank surveys and one drop box were provided in a designated area.

Since staff only work 3 days a week and may not be called to work if the patient census is low, surveys were distributed to the staff in the nurse’s stations during an entire week every day to increase the response rate. For the counseling facility, follow up interviews were held to uncover the detailed design characteristics of counseling environments. This section was limited to staff working fulltime. In total, 45 people at the counseling facility were eligible to participate in the interview phase. Appointments were scheduled during the month of June to meet with staff who chose to participate in the interview.

Hypothesis Statements

The following main hypotheses are addressed in this study:

1) When it comes to employees' health and performance, there is a pattern in the importance of contributing environmental factors addressed in this study.
2) Daylight is among the three most important environmental factors that contribute to wakefulness and reduced sleepiness in healthcare and counseling staff.
3) The availability of windows in the healthcare and counseling workspace will increase perceived wakefulness and improve mood.

Measurements

Assuming that when they are more wakeful and alert, medical and counseling staff provide safer and higher quality care. The study investigated whether or not windows with daylight can improve wakefulness and so benefit quality and safety. Multiple methods were used to test these hypotheses, which are explained in detail below. Prior to the study, a total of 32 hours of pilot unstructured observation were conducted to learn about the setting. The measurement variables were identified based on the observations during the pilot study.

The methodologies used to explore the hypotheses in this study include a) participant surveys in the forms of questionnaires and Likert scales, as well as open ended questions and b) interviews.

Participant survey. Although the main hypothesis in this research was on the topic of lighting, there was a need to understand the natural setting. An interdictory ethnographic section enabled smoothly unraveling the research. According to Joseph and

Hamilton “Ethnographic studies provide in-depth qualitative information about a setting or design issue. These studies are useful in identifying how things actually work within a setting and what corrective measures may be instituted to remedy conflicts. These studies can be conducted before the visioning and concept design phase to identify problem areas and to focus on research questions. Such studies are helpful in developing strategies to improve existing conditions and processes” (Joseph & Hamilton, 2008, p.136).

This section of the study involved qualitative research based on the approach recommended in *Naturalistic Inquiry* (Lincoln and Guba, 1985). Naturalistic inquiry can be applied to research discoveries which are “context-bound” which means the experiment occurs in the field, in real-life situations, as opposed to laboratory setting or simulation. The contribution of each participant is important in this method (Lincoln & Guba, 1985, p.82). Naturalistic inquiry methods usually closely connect the researchers with the participants and enable them to explore practical and real-life questions. Thus the results of this research can be a “workable hypothesis” such that can be applied in future practice (Lincoln & Guba, 1985, p.82).

Overall characteristics of an ideal healthcare environment. The hypothesis was defined to understand the importance of environmental factors of the healthcare and counseling facilities on the staff health and performance. This section had a high response rate from the participants at all three facilities. A large body of data was collected to inform the researchers about the place of lighting among other environmental factors. This introductory information provided a suitable context for the next studies, which were more complex and slightly more intrusive. Since the participants were familiar with the study, they became more likely to participate in the second study.

Two hundred and seven (207) healthcare and counseling staff (with a mean age of 30-39) enrolled in the ethnographic study by filling out a two-page survey. The study was conducted across a total of eight monthly staff meetings. All participants were provided an information sheet about the research and those from the inpatient unit signed an informed consent. The research was approved by the Institutional Review Board, Office of Research Compliance Staff of the Division of Research at Texas A&M University as well as Institutional Review Board at the hospital. The surveys had both structured and unstructured components.

Structured questions. First, the participants were asked to identify the characteristics of their ideal workspace. In this structured question, they simply ranked the various design characters from one to nine (structured) and could add other important characteristics which were not listed. Then they were asked to comment about their ideal workspace (unstructured).

The nine environmental factors were identified by a review of research in workspace design in healthcare and non-healthcare settings. These environmental factors are provided in the literature review section. The pool of environmental factors pointed to by research was further modified by the administration and staff in each facility and finally, only the environmental factors common to all three facilities were included in the survey: 1) temperature, 2) air quality, 3) appropriately sized workplace, 4) noise, 5) privacy, 6) ergonomics, 7) electric lighting, 8) natural light and 9) window views. Additional space was provided for participants to list other factors.

Second, participants were asked to identify the top three most important factors in their workplace design which could help them maintain alertness and wakefulness and minimize sleepiness. The seven environmental factors provided in this question were identified based on the review of literature on sleepiness, alertness and circadian rhythms and environmental stimulants. The seven factors included: 1) temperature, 2) air quality, 3) electric lighting, 4) daylighting, 5) noise levels, 6) comfort and ergonomics and 7) privacy.

Unstructured questions. The participants were asked to further describe the characteristics of their ideal workplace in a paragraph. In addition, they were asked about various daily strategies they use daily to manage with sleepiness and maintaining alertness in the workplace. The responses were studied using the content analysis method to openly investigate all existing coping techniques with sleepiness and maintaining wakefulness in the healthcare workplace. The participants' responses were broken into units of information and were organized into categories, which were internally consistent (Lincoln & Guba, 1985).

In unstructured surveys, participants were asked to explain non-environmental strategies in coping with sleepiness and maintaining alertness in the workplace. The responses were studied using the content analysis method to openly investigate all existing coping techniques with sleepiness and maintaining wakefulness in healthcare workplace.

The role of windows and daylight on sleepiness, alertness and mood. The same participants who enrolled in the ethnographic study were asked to fill out a survey and report their mood and sleepiness using an analog scale by looking at three colored images. The method of showing images to participants was based on a study by Schwindel (2010), who showed images of long-term health facilities in different urban contexts to evaluate participant responses. The images shown in this study were identical except that the first image did not have a window; the second had a window with daylight and no view; and the third one had a window with daylight and a view (Appendix B).

The mood survey was summarized based on the Profile of Mood State which was developed by McNair, Lorr and Droppleman, 1971(cited by McNair, 1984; Multi-Health Systems, 2004-2012). Five different emotions were evaluated in this scale: sleepy, sad, gloomy, irritated and tired. The average rating for these five emotions was used to measure overall mood.

A seven-point Likert scale was used to measure overall mood. To collect participants' responses a two-point, three-point, five-point and ten-point scales were also considered. The small and large ranges were not considered, as participants cannot accurately report their responses when there are a limited number of rating points in a scale, and too many rating points make it difficult for them to differentiate among rating categories (Lehmann & Hulbert, 1972). Too few or too many rating points will result in the escalation of measurement error (Lehmann & Hulbert, 1972). Additionally, a 10-point scale may become lengthy, especially if associated with descriptions (Dawes, 2008). An even number of points in a scale (which results in a mid-point) may help eliminating bias in the responses by giving the participant the flexibility to report a neutral response and do not lean toward one of the two directions the scale offers (Garland, 1991). Hence, five or seven points might be good options. Having narrowed it down to these options, and knowing that a moderately increased number of points in a scale can elevate its sensitivity (Cummins & Gullone, 2000), a seven-point scale was found to be the most appropriate for the overall mood measurement.

Interviews. A total of 32 (median age of 40-49) counseling staff participated in the interview section. An information sheet explaining the study was provided to the participants during the unit meetings. The interviews were typically 15 minutes in duration. The interview was conducted in an unstructured and open discussion including descriptive and structural questions (Spradley, 1979). Three major areas were discussed during the interviews: lighting (both daylighting and electric lighting), windows and other environmental factors. Finally, every participant was asked what they would change in their work environment if they had one wish that would be fulfilled immediately. Participants' discussions were typed and the topics mostly frequently discussed were analyzed by each of the four categories, as described by Lincoln & Guba (1985).

The unstructured interview with the counseling staff was originally suggested by the facility director and was implemented because of a major need for research on counseling facility design. The outcomes of the analysis resulted in a graph and a set of guidelines for this setting.

Procedure of Study 2: Quasi-Experimental Research

Eligibility and Recruitment

A focused quasi-experimental study was conducted to directly measure the physiological, psychological and behavioral impacts of the presence of windows and daylight. For this portion of the study, the selection criteria was limited to RNs who work fulltime on the day shift in the inpatient nursing unit.

For the observation and vital sign measurements, only RN's on the day shift were invited to participate during May, June and July. There are more extraneous variables in a field research compared to a laboratory research. Many of these variables were controlled. Others were measured and incorporated as explanatory variables.

Controlled variables. Field research is always associated with unlimited external variables. Controlling personal and organizational factors provides an opportunity to carefully study the impact of environment on building occupants. The positive impacts of lighting may be traced in improved health and performance, which result in elevating system productivity and return on the investments made on the built environment (Figure 3.13).

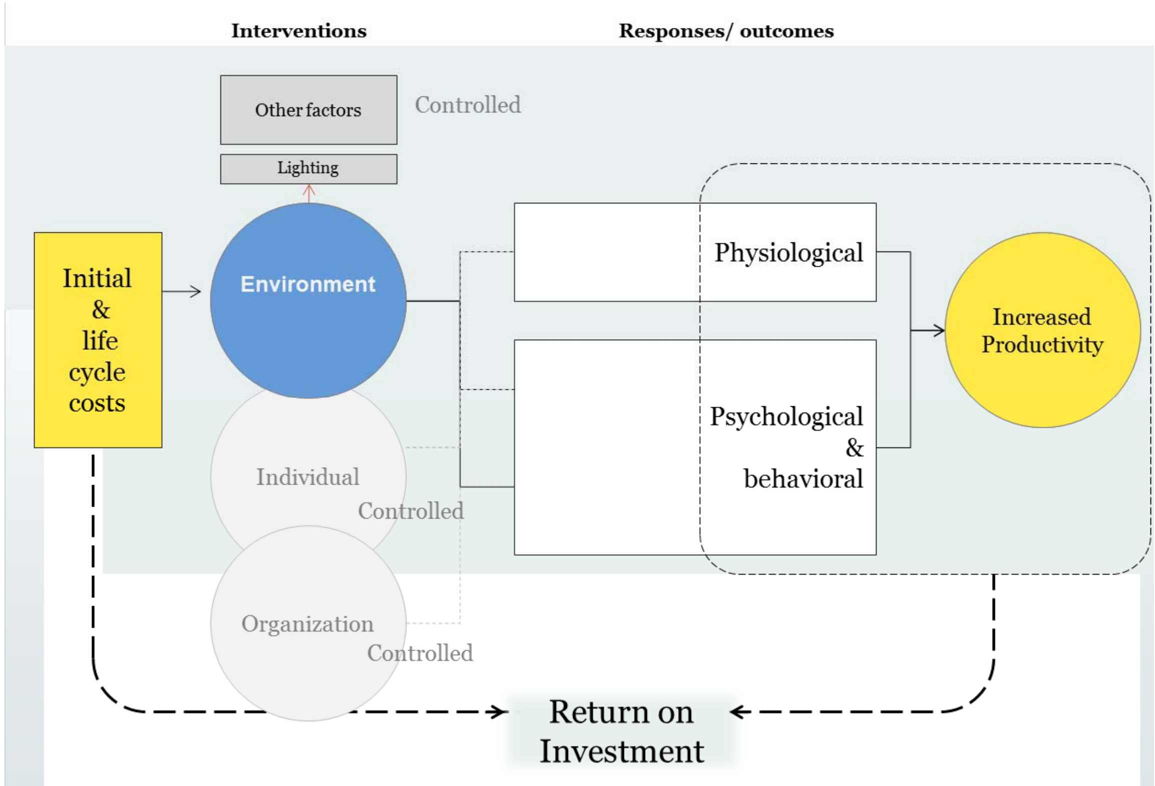


Figure 3.13. Positive impacts of improved environmental factors.

In this study those variables, including several environmental, organizational and social factors, directly affecting the measurement of interest were controlled.

Same participants. The same participants were studied under two conditions. Therefore, only staff who rotate on the north and south wings were included in the study. Therefore, a group of RNs who worked permanently on the southeast wing and specialized in stroke patients were excluded. The main reason for limiting the study to staff in the north and south wing was that rotating between two locations would enable comparing work behavior of each participant under two distinct lighting conditions.

Same research observers. The observer effect was controlled. A total of three researchers conducted the biological measurements and the observations. The same researcher conducted the physical measurements under both conditions for each participant. If one researcher was not able to follow the same participant, the study was repeated.

Similar working patterns. The effect of weekdays was controlled because during the weekends, staffing and procedures are different than on weekdays. The study was conducted only on weekdays.

Similar environmental setting. The study was conducted in areas with similar unit layouts. Nurses rotate among several pods. Therefore, nurses were not studied if they were assigned to work in the overflow areas (circular observation areas attached to the nursing unit), because the setting was quite different from the rest of the unit.

Similar workload. The work fatigue resulting from day of the shift was controlled. Only participants that were scheduled to work two days in a row each week were eligible. We only observed participants on the second day of their shift. Number of the day of nurse's 3-day shift is a random effect, which will account for trends in fatigue across the three consecutive workdays. The variation arising from differences in the amount of sleep or other non-work-related factors could affect the day-to-day energy level of each nurse and impact patient safety (National Association of Neonatal Nurse Practitioners Council [NANNP] and Board of Directors, 2012).

Explanatory variables. Explanatory variables recorded are: 1) daylighting condition in which the nurse is being observed—the variable of interest (fixed effect), 2) number and acuity of patients under nurse's care (covariate), 3) participants' age and gender, 4) duration and sleep quality of participants.

Further considerations. Controlling for external variables can be challenging in field research. Since the census may change rapidly and the staffing is updated every 12 hours, as workdays changed, so did eligibility and therefore, so did the study schedule. Eligible participants were identified in the monthly schedule. Then, the eligibility schedule and the search schedule were updated weekly after the release of weekly work schedules. On the day of the observation prior to the beginning of the study, we verified whether the schedule was unchanged, to ensure the participants scheduled for observation still met eligibility requirements.

If the eligibility status had changed, the observation and biological measurements would be rescheduled. The chance that an observation would be cancelled or rescheduled was highly likely, and occurred if 1) the eligible nurses were assigned to the overflow area, 2) the registered nurse (RN) had been absent from work due to personal leave the same day or the day before, or 3) the work schedule had changed due to census changes or personal leave. These criteria to control for confounding variables extended the data collection period, because it limited the eligible participants per day to only one or two nurses (or even none on some days). From the 62 RNs, about 32 participants met the eligibility criteria during the data collection period in May and June 2011. A total of 22 staff participated in the study at least one day. Since the study continued on two days in two different weeks, only 14 of the 22 RNs continued to be eligible or remained with the study.

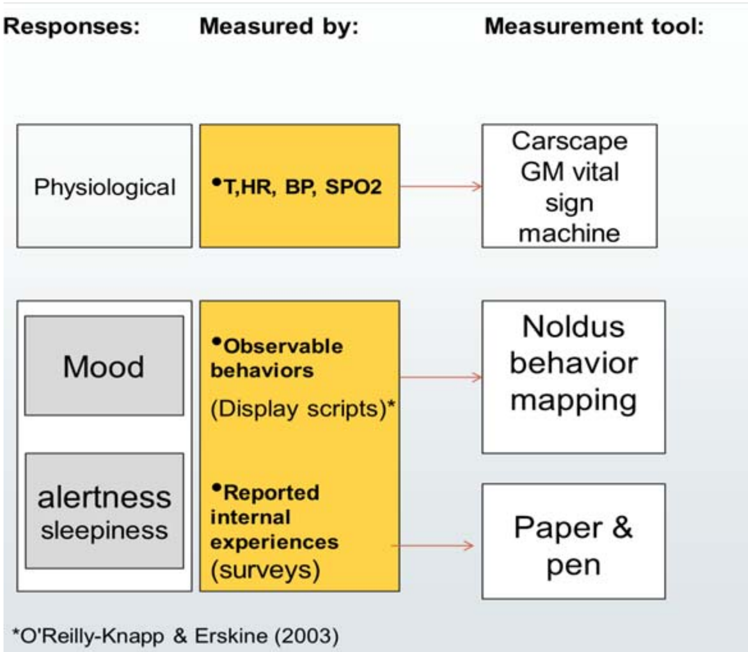
Hypothesis Statements

The following hypotheses were tested in this study phase:

4) The presence of a window in healthcare work areas can result in improved biological responses (decreased blood pressure, heart rate, increased oxygen saturation) by causing phase-advance circadian rhythms manifested by rhythms in body temperature, blood pressure, heart rate and blood oxygen.
5) Availability of windows and daylight will reduce sleepiness and improves mood evidenced by subsidiary behavior representing deteriorated mood and sleepiness.
6) Availability of windows and daylight will increase the frequency of interaction and sociability.
7) Availability of windows and daylight will reduce the frequency of medication errors.

Measurements

The measurement methods used to test the hypotheses in this study included: 1) physiological measurements, 2) behavioral mapping 3) participant surveys and 4) records analysis. Biological measurement (vital signs), and behavioral mapping (work-related and non-work-related behavior) and survey responses (mood and sleepiness) were recorded simultaneously for each participant, once under the control and once under the light –treated condition (Figure 3.14).



Note. The physiological, psychological and behavioral outcomes were measured using a vital sign machine, a behavior mapping PDA, and survey instruments. *Display script according to a figure by O'Reilly-Knapp & Erskine (2003) is a behavior manifestation with three categories of observable behaviors, reported internal behaviors or Fantasies.

Figure 3.14. Measurement methods.

A total of 34 days (272 hours) were spent gathering data in the hospital. Only 28 days (204) of this period were applicable for analysis. The pilot study and reliability test took an additional 87 hours in the field setting. The participants provided direct patient care in the nursing unit for 12 hours per day for three days a week (additional one day if working overtime). For the analysis, the light conditions (the variable of interest) were categorized as ‘daylight and artificial light,’ and ‘only artificial light,’ which reflects the conditions in the south and north nurse’s stations in the nursing unit.

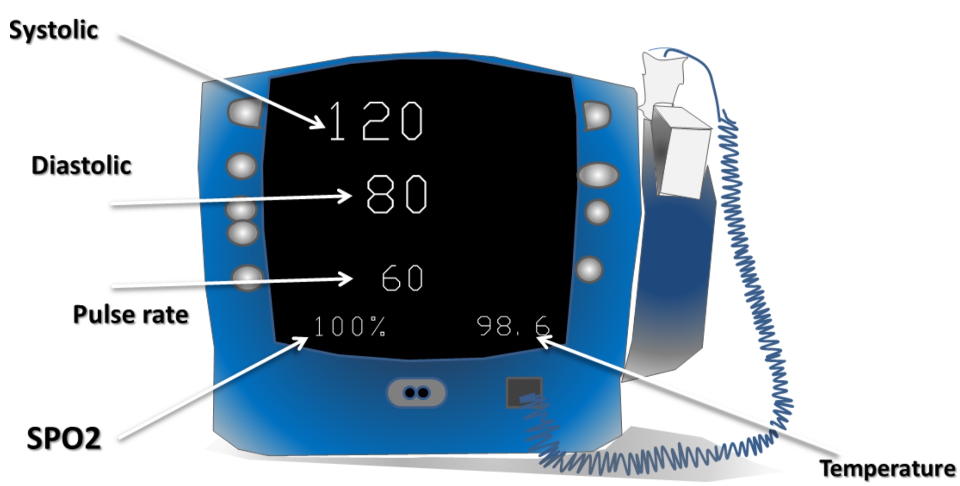
Several extraneous variables were controlled (explained in the previous section) and other explanatory variables were continuously measured. Therefore, every participant was observed under both daylight conditions; the same observer collected data under both conditions foreach participant; the study was only conducted during weekdays; the participants were only shadowed on the second day of their two-day shift if they worked 2 days in a row; and the participants were only observed when they were assigned to stations with similar design layouts.

Physiological measurements. From 20 eligible participants who were approached, twelve volunteer RNs (median age 30-39) maintained eligibility in the study and their physiological conditions (reflected in vital signs). The participants provided direct patient care in the Nursing unit for 12 hours per day for three days a week (additional one day if working overtime).

Nurses' vital signs (body temperature, blood pressure, heart rate and SPO2) were measured bi-hourly 5 times in a day (total 5 minutes). These measurements were taken from each participant, once they were working close to windows and once in windowless workstations. The same survey page used in the bi-hourly sleepiness assessment was used to record the bi-hourly physiological assessments all on one page (Appendix B).

The measurements were taken using a Carescape™ V100 monitor from GE Healthcare. The participants were in a seated position during the measurements and all five measurements during one day were taken at the same location. On a number of occasions when the RN participant was very busy, asking the nurse to return to the nurse's station and be seated would have added additional interruptions to patient care. In those instances, the measurements were taken at a standing position in the hallway. The Carescape was provided by the hospital (3.15). When the Carescape was not available to the researchers, a Welch/allyn, Model#52000 was used as a backup. Both machines were calibrated by the hospital and provided by the nursing unit to the researchers.

The vital sign measurement procedure was noninvasive. It was administered during the time that the bi-hourly survey was being filled out by the participants in order to minimize the impact on staff. A maximum of one minute was spent for each measurement, which was repeated five times a day. The biological rhythms were compared under the two lighting conditions and also under different light intensities.



Note. Re-created from General Electric (2010).

Figure 3.15. Vital Sign machine.

Additional considerations. Before behavior shadowing (and biological measurement) procedures, a set of written guidelines for researchers were provided and reviewed right before the observation began. In addition, the research team was cautious at all times to be observant of the various circumstances to not interrupt the care process by any means. To avoid causing stress for patients, the observers were instructed to exit patient rooms immediately when the patient was going to take a bath or use the bedpan.

Gathering data on the second workday. The study was controlled by shadowing the nurses on their second consecutive workday. This benefitted the study in several ways. Observing nurses on their second workday in a row minimized interruptions during high cognitive load for nurses and became less intrusive for patient care. Observation on the second day in a row held more potential to capture the effects of environmental factors in the workplace. Also, the second workday of three in a row is a better indication of participants' circadian rhythms; and finally, it had greater potential to observe consistent work processes. These reasons are further explained below.

Nurses may have higher cognitive task on the first day of their shift. The average length of stay in this unit is 2.5 days (Unit Director, personal communication, 2011). Nurses begin orienting themselves to their assigned patients, their medical history, conditions and medication types on the first day of their shift. This causes a considerable cognitive load. On the second day of patient care, their work routine is further stabilized. This means nurse cognitive load may be lower on the second day of the shift because they have oriented themselves to most of their patients, except for the new admissions which can occur at any time. This helped the study be less invasive of the care process. Also, it improved consistency in the activities that were recorded.

As noted, observing nurses on their second workday of three in a row is a better indication of their circadian rhythms. RNs work 3 days in a week and are typically off work for the remainder of the week. Therefore, on the first day of their period, they transition from an off day to a 6:30 a.m.-7:30 p.m. day shift. According to our data collection, nurses wake up about 5:23 a.m. (± 26 minutes) and their work begins at 6:30 a.m. by receiving reports from the night shift. Assuming that normally one may not wake up as early as 5:20 am on an off day, the nurses' circadian clocks may not be well adjusted on the first day of their shift. Based on this notion, observing nurses on their second consecutive workday has greater potential to observe consistent work processes and is least intrusive to providing care.

Finally, on the second day, nurses have already been exposed to the environmental lighting in the hospital over the previous 24 hours. If the notion that hospital lighting has any effect on their circadian response is true, this effect has already begun the day before and affected their biological rhythm. As such, observing participants on the third day of work would be even more beneficial. However, only a handful of nurses are scheduled to work 3 days in a row. Most nurses elect not to work three days in a row because they say they feel too tired on the third day to excel in providing care.

Occurrence of repeated shadowing. Three observers conducted the study. The same observers observed the participants in the design case and reference case. A number of occasions occurred during which the observer was not able to be present or continue to shadow their assigned participants for the second day, due to schedule changes or personal circumstances. In such cases, the observation was repeated from day one. If during the observation, a patient had a complication that disrupted a nurse's emotional state, the observation was repeated on another day.

Reducing interruptions. The timing for bi-hourly measurements was estimated by studying the RNs. Studying the daily work routines in this unit enabled maximizing the risk of interruptions by predicting nurses' cognitive workload. It also increased measurement reliability because if nurses were too busy with patient care, conducting measurements with the defined methods would not be possible. We identified five intervals with the lowest cognitive workload for bi-hourly sleepiness and vital sign assessments by assessing the timing of medication pass, meal tray distribution and shift change and reports (Figure 3.16). Estimating the time for certain tasks (such as patient admission and discharge procedures) is unpredictable. Also, patients' conditions may change at any time. So, although the best timing for the measurements was identified, to further minimize distractions to patient care, the research team was asked to delay the measurement times up to a maximum 30 minutes when such events occurred.

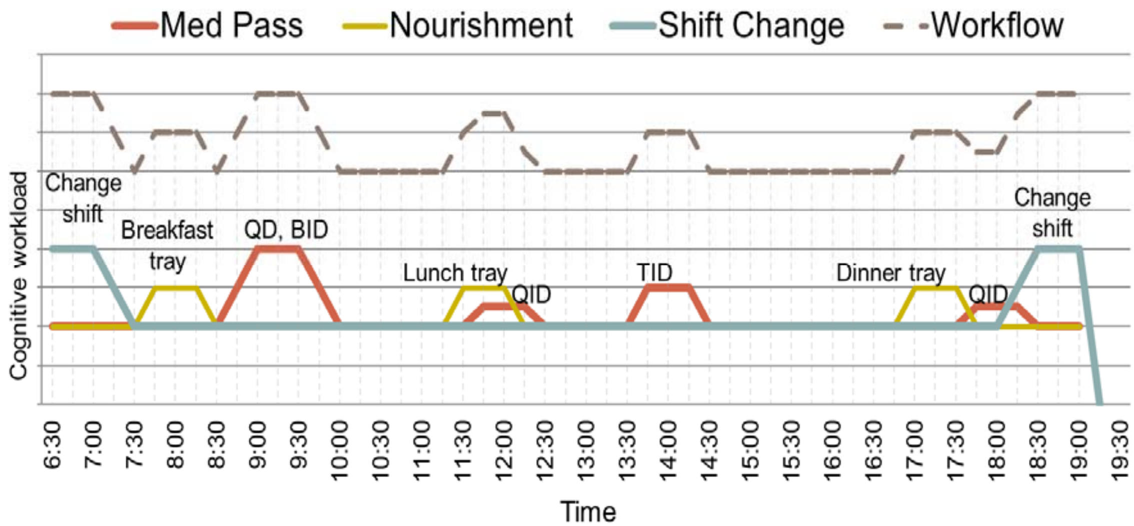


Figure 3.16. RNs' daily cognitive work load.

Behavior observation. In total, 204 hours (28 days) of behavior observation were collected. For the analysis, a total of 120 minutes of data in the beginning and end of data collection were eliminated. Therefore only six hours of data per day was analyzed. The shadowing procedure was introduced to the participants prior to the study in the morning. A set of guidelines was provided for the observers and reviewed before every study to the observers. The participants' work behavior related to alertness/sleepiness and mood, as well as light exposure during the work routine, was recorded using Noldus Behavior Mapping software and equipment--handheld PDAs (Olsen et al., 2000). The behavior mapping consisted of recording work-related and subsidiary behavior (Takanishi, Ebara, Murasaki, Kubo, Tachi, Itani et al., 2010) related to coping with sleepiness, location change, illumination levels, frequency of communication and caffeine intake.

Subsidiary behavior are those “psychological or physiological responses” that are not directly related to the work task, but are behavior manifestations that contribute to tasks (Takanishi et al., 2010). Takanishi and his team identified three functions for these subsidiary behavior responses: habitual (HB), sleepiness related (SRB) or distractive against monotony (DBM) (Takanishi et al., 2010). They found a decrease in autonomic nervous system balance was most likely followed by a sleepiness subsidiary behavior. This response interestingly led into “restriction of the deterioration in performance.” The study indicated subsidiary behaviors are related to errors and changes in “autonomic nervous system balance” (Takanishi et al., 2010).

Several behaviors in Takanishi’s research that correlated in factor analysis with monotony (stretching), sleepiness (yawning, sighing, rubbing eyes) and habitual (touch head) were observed in this study. The variables that were observed were in four categories:

1) Verbal communication (meaningful words), either work-related or non-work-related;
2) Paralinguistic communication (sighing and yawning);
3) Non-verbal communication, meaningful actions with no words, related to monotony, fatigue and sleepiness (leaning against wall, touching head, stretching and rubbing eyes); and
4) Liquid intake and caffeine craving (sweet caffeinated, unsweet caffeinated, sweet non-caffeinated and unsweet non-caffeinated).

The observed non-verbal behavior was captured by “counting the movement of body part” (Takanishi et al., 2010). The verbal and paralinguistic behavior were counted upon hearing noise and recounted again if continued more than 60 seconds.

In addition to the identified variables, observers were asked to comment on events or behavior related to fatigue, sleepiness and mood. Some examples included conducting heavy physical activities due to moving or showering the patient or rearranging beds, rushing to assist co-workers in case of a patient code alarm in the same unit, caring for a patient whose conditions has drastically changed, thus affecting the nurse’s emotional state, having sweet snacks, taking a break, having energy drinks and chewing gum or ice.

Personal digital assistant program. The pre-coded PDAs (Olsen et al., 2000) program was designed to record location on the first screen, the subsidiary behavior on the second screen and sub-categories of behavior and other behaviors on the third screen. Adding comments were possible, which enabled recording light levels and documenting other circumstances. When one entry was completed, the PDA displayed the first screen for a new entry starting from location entry (Table 3.2).

Table 3.2. PDA screens for behavioral mapping.

PDA Screen one													
Location													
Nurse station	Patient room	Supply room	Medication room	Hallway NW	Hallway NE	Hallway SW	Hallway SE	Hallway MID	Hallway FISH	Nutrition room	Soiled room	Break room	Off unit

PDA Screen two: Behavior										
Verbal	Paralinguistic and nonverbal									
Talking	Yawning	Sighing	Having a drink				Additional subsidiary behavior			Other
PDA Screen three										
			Caff.& Sweetened	Caff. & unsweetened	Decaff & Sweetened	Decaff & unsweetened	Body stretch	Lean	Touch head	Whistle or sing
Comments: Insert Illumination levels										

The participants were told to maintain their daily activities. They were given the option to ask the researcher, at any time, not to shadow the participant and to pause or stop the observation for any reason including the benefit of the participants or patients.

The observers were asked to see the participants as informants. As they shadow their informants, they should act as an actual shadow and not interrupt or interfere with the job routines. Thus, they should not create the reality but, rather, observe the reality (Yvonna Lincoln, personal communications, April, 2011). Further guidance to observers to maintain the field culture was provided in writing and was reviewed before every observation.

Survey response. The survey included two sets of structured questions, one to document momentary sleepiness and wakefulness during the workday, and the other to assess overall participants' satisfaction of their assigned work area.

Ecological momentary assessment measuring sleepiness and mood. This section of the study was combined with behavioral mapping and physiological measurements. From 20 eligible nurses, fourteen volunteer RNs (ages ranging from 20 to 69) enrolled in the study for a total of 28 days. All participants provided direct patient care in the Nursing unit for 12 hours per day for three days a week (additional one day if working overtime).

The participants assessed their sleepiness/alertness in the form of an ecological momentary assessment (EMA) data collection method (Stone & Shiffman, 1994). The format of the survey (see Appendix B) was borrowed from PedsQL™ Visual Analogue Scales and enabled participants to input their selection by choosing a number from 0 to 10 a maximum of five times daily. The visual analog EMA enabled participants to quickly measure the at-moment feeling (Sherman, Eisen, Burwinkle & Varni, 2006). The total time spent filling out this form throughout the day was a total of three minutes. Further description of the EMA follows.

Description of ecological momentary assessment. Ecological momentary assessment ---versus "retrospective reconstruction" -- is less likely to be "biased by other events occurring after the event to be recalled" (Smyth & Stone, 2003). When measuring a rapidly changing variable such as mood or blood pressure, the outcome variables may be mediated with various effects in a natural setting. If the research is solely conducted in a laboratory, the "ecological validity" of the findings can be questioned (Smyth & Stone, 2003). A benefit of conducting the study in the natural environment is its generalizability, which may not be as strong in the laboratory setting because the setting may not be complex enough to reveal different aspects of the treatment (Smyth & Stone, 2003).

Likert scale, measuring satisfaction from environmental factors. At the end of the study, the nurses were asked to rate their satisfaction from environmental factors in their workplace using a Likert scale to rate their mood using an ecological momentary analog scale. The participants' responses were compared when they were exposed to the two lighting conditions and also compared based on light intensity.

Light measurement. A digital light meter, model 401025 by EXTECH Instruments, was used to measure illumination levels during the observation. Horizontal illumination levels were measured when participants changed location, or every five minutes if participants were sedentary at one location for longer than five minutes.

Illumination is an indication of light levels on the work surface. Therefore, the illumination measurement plane was set to remain at a consistent distance from the participants' eyes. This means if the participants were sitting, the measurement plane would be 30," which represents the height of their workstation and when standing the measurement plane was set at 40," a typical height for a standing counter (Waggener, personal communications, 2011).

Because taking a tape measure at all times was not possible during shadowing the participants, to keep this measurement plane consistent, the observers created anatomical markers for themselves (using a tape measure) to be able to rapidly measure lighting at the correct height every five minutes as the participant was moving around the unit.

The observers used a unified method to measure lighting. The methods were practiced before the beginning of the study. In these experiments, we ensured that the light measurement would be taken in a way that the reader was not shadowed by an object or by observers' or participants' bodies. Therefore, the observers held the reader away from their bodies. The light meter was held stationary for at least two seconds (counting one, one thousand, two one thousand) in a horizontal position before reading the digits shown on the screen. The observers also practiced working with the light meter under room light or outdoor light to learn the adjustments needed for the light meter (Figure 3.17).

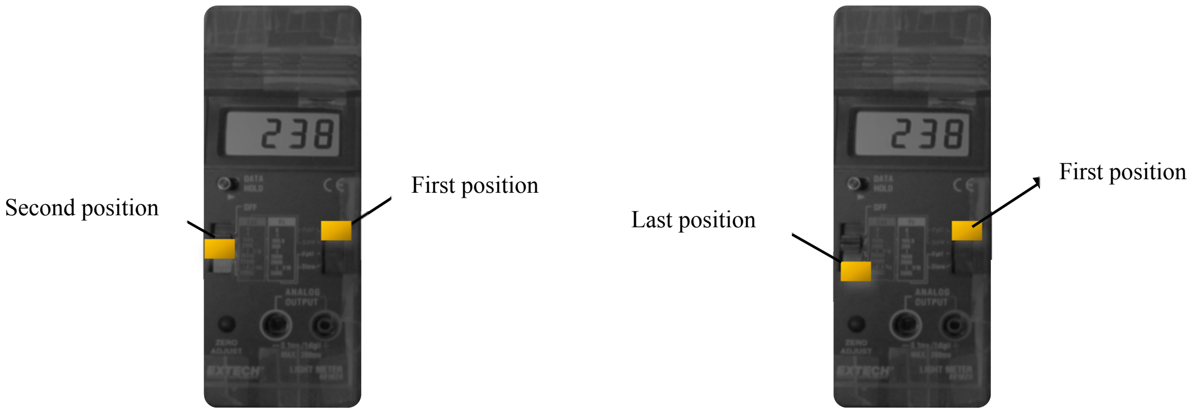


Figure 3.17. Illuminance meter.

Positioning the light meter adjusters for indoor and outdoor reading. During the pilot study, since the light measurement was not accurate when the nurse was in motion in the hallway, average illumination levels assigned to each hallway were used instead of the light measurements.

Medical records. Non- intravenous (IV) and IV medication errors, in all existing categories, were studied for the windowed (design case) and windowless (reference case) wards from January 1, 2009 to December 31, 2011. The medication errors included incidents with harm and incidents without harm, both of which were included in the analysis.

Procedures for Study 3: Energy Modeling Research

Both energy savings and occupants' wellbeing are aspects of high performance buildings. It is believed that daylighting creates a conflict between efficiency and healing design. Having windows and daylight is associated with elevated energy use due to heat transfer through glass. "Glazing… provides views and daylight, but can also increase energy consumption" (Stegou-Sagia et al., 2007).

Alternatively, evidence indicates that adding a window with a careful choice of materials may result in limiting or even eliminating the energy loss, thus creating a synergy between healing and green design strategies. Two computer simulation experiments were conducted using the software, eQuest 3.63 (Hirsch, 1998-2009) to test this notion. The first experiment was conducted in a medical treatment room and the second experiment was done in one of the physician office spaces, both in the outpatient facility. In this facility the patient is usually examined in the treatment room. Then he or she is directed to the physician's office for further consultation or prescription pick up.

Hypothesis Statements

The following hypothesis was tested in Study 3:

8) Comparing work areas with and without windows from an energy efficiency perspective, the presence of windows and natural light in healthcare work environments may not increase total energy consumption if the correct design features and glazing types are used (Method: computer energy simulation).

Measurements

Pilot study. The pilot study enabled investigating the impacts of light on electricity consumption and resulted in the creation of the main study which directly addressed the hypothesis. The energy modeling in the pilot study consisted of a baseline and a design case.

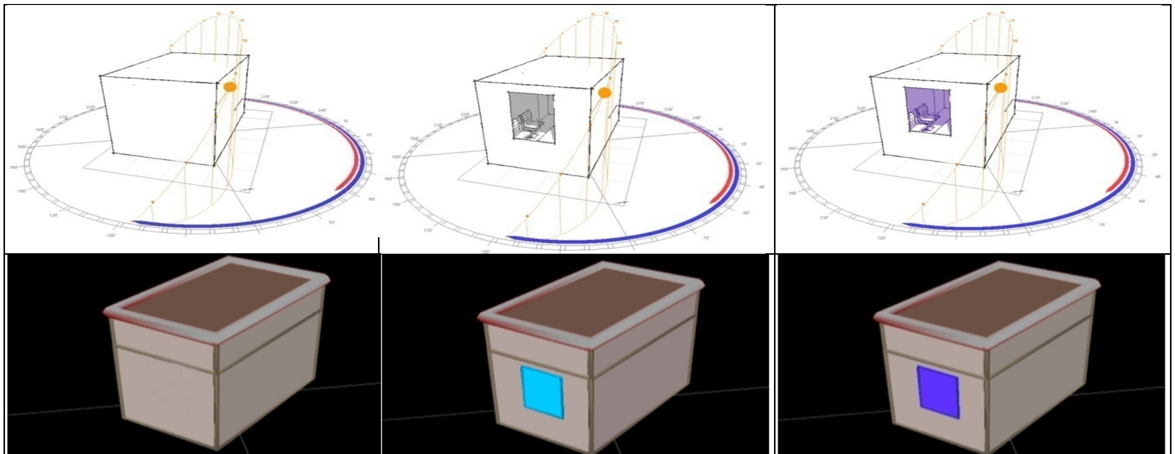
Baseline. The baseline pilot model consisted of a room 20' x 15' with adiabatic interior walls, floor and ceiling, as well as one side exterior wall facing northwest (Figure 3.18). This model represents a computer simulation of the treatment rooms in the outpatient facility. All other characteristics of the building envelope, system and fuel were specified by the software based on typical values for a multistory outpatient building. Computer simulation was done on the model to observe changes in total annual energy use when a window was added to the baseline model (design case).

Design case. The design case was identical to the baseline in every aspect, except that a window was added to the specified room. The window added had a 6' x 8' window frame and was 0.11' wide. Thermal conductance was specified 0.5 Btu/hr-ft^2-F. A double paned glass was added with the shading coefficient of 0.80 and transmittance of 0.7. The total annual energy consumption was measured and compared to the base case.

Parametric runs. After simply adding a window with the glazing characteristics mentioned in the design case, six additional cases using parametric runs were created. The glazing characteristics in a parametric run was modified by changing in each run one value of the glass's shading coefficient, while maintaining the other glass characteristics. The annual energy consumption was measured in these six cases and the trend was compared to the base case and design case.

Note. Reference case (windowless), design case (windowed).
Figure 3.18. pilot study, treatment room.

Main analysis. The main simulation study consisted of three daylight conditions: 1) Reference case, windowless; 2) design case I, with window type one; & 3) design case II, with window type two. Both window type one and two represent actual window products available for commercial buildings (Figure 3.19). Rendering images of case I and II are provided in the results section.

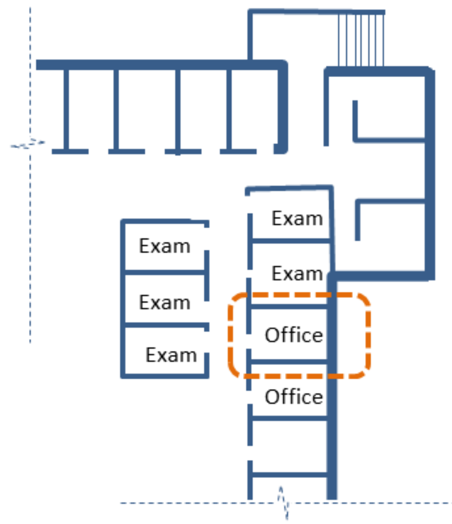


Reference case: Windowless physician's office	**Design case I:** Windowed, Glazing type one	**Design case II:** Windowed, Glazing type two

Note. Three lighting conditions as modeled with Autodesk Ecotect and eQuest.

Figure 3.19. Lighting conditions main study.

The simulation was conducted in the Detailed Mode in eQuest 3.63 (Hirsch, 1998-2009). The baseline main model consisted of one of the physician offices in the outpatient facility. Therefore, only a small section of the building was modeled. The office was 9' wide and 15' long with 9' 4" height (floor to ceiling) with an exterior wall facing southeast (Figure 3.20). To improve increased daylight distribution and uniformity, the window size and location were designed differently (3.5' x 5' at 3.5' seal height) in the computer model compared to the actual windows in the physician offices outpatient facility (2' 4'' x by 8' at 3' seal height). As a result, the window was centered and the window width was increased.



*Note***.** Schematic plan.

Figure 3.20. The physician office space modeled, marked on the floor plan**.**

Construction materials. The room was modeled using adiabatic floor, ceiling and walls (except for one exterior wall). Therefore, the model represented a section of the entire building as described before (Table 3.3). The adiabatic material assigned to the walls and ceiling, and floor had a U-value= 0.0001 Btu/hr-sq ft-°F, which blocked the heat transfer from outside. The exterior wall overall U-value was assigned at 0.046 Btu/hr-sq ft-°F for a metal framed exterior wall based on the Envelope Thermal Performance Factors suggested, by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) for small hospitals and healthcare facilities (2007).

Table 3.3. Resistance values for small hospitals and healthcare facilities.

Roof Assemblies Insulation Entirely Above deck		Walls		Floors	
		Above Grade Mass Walls		**Mass**	
R	**U**	**R**	**C**	**R**	**U**
20	0.048	5.7	0.151	4.2 c.i.	0.137
25	0.039	7.6	0.123	10.4 c.i.	0.074
30	0.032	11.4	0.09	12.5 c.i.	0.064
35	0.028	13.3	0.08	14.6 c.i.	0.056
		15.2	0.063	16.7 c.i.	0.05
		25	0.049	19.5 c.i.	0.044
		Steel-Framed		20.9 c.i.	0.042
		R	**U**	23 c.i.	0.038
		13	0.124	**Steel Joist**	
		13 + 7.5 c.i.	0.064	**R**	**U**
		13 + 15.6 c.i.	0.042	19	0.052
		13 + 18.8 c.i.	0.037	30	0.038
		13 + 21.6 c.i.	0.034	38	0.032
				49	0.027
				60	0.024

Note. Re-created from a chart at The Advanced Energy Design Guise for Small Hospitals and Healthcare facilities by ASHRAE, 2007.

Glazing types. Two glass types were modeled and were used for the design case 1, and design case 2.

Glass type one. The first glazing assigned to the window had a translucent glazing with a 0.53 U-factor of 0.69 SHGC and 0.75, visible transmittance. These characteristics represent an actual window product installed at the Rapson Hall at the University of Minnesota (Carmody, Lee, Selkowitz, Arasteh, and Willmert, 2004).

Glass type two. The second window was selected among the high performance commercial window products available in the market. From the pool of window products available which are listed at *High Performance Windows Volume Purchase Program* (a website hosted and maintained by Pacific Northwest National Laboratory for the DOE EERE Building Technologies Program), one product that could be shipped to Texas was selected for simulation. The selected window was a fiberglass high performance commercial window system with 0.21 U-factor, 0.22 solar heat gain coefficient and 53% visible light transmittance (Serious Energy, retrieved 2011).

Lighting characteristics. According to ANSI/IESNA (2006, p. 44), the horizontal illuminance needed for visual tasks varies from 300 to 500 lx, depending on the sensitivity of the task and contrast levels of the space. The medical office space in this case study was assigned a minimum illuminance level of 500 Lx at the task level defined as 3' above the finished floor. This light level must be sufficient for focus demanding tasks (according to IESNA, Health Care Facilities Committee, 2006).

For the electrical light source, suspended fluorescent lighting (recessed/non-vented) was selected in the model that represents the lighting in this outpatient facility. The overhead lighting would provide 1.240 watt/ square feet power (1.24 x 135 square feet = 170 W in total). Based on the current installed electric lighting (32 Watt Philips F32T8/TL735/ALTO) a minimum of five fluorescent tubes must be installed in the room (170 W/ 23 W = 4.8).

Two light controls where installed in the simulated medical office, the first one at the physician's work area and the second one at the visitor's seating area. The light control was defined so that it would dim the electric light levels when the daylight elevated the total illuminance to a minimum 500 Lx.

Other loads. eQuest recommended loads for medical offices were maintained for the equipment and occupancy. For example, total heat gain, sensible heat gain and latent heat gain were assumed at 450, 250 and 200 Btu/h-person respectively. Equipment input power density was set at 0.750 W/square feet (0.75 x 135 square feet = 102 W in total). Infiltration flow was at 0.1257 cfm/ square feet.

Building loads schedule. The outpatient facility's operation runs from 8:00 to 17:00. The light and occupancy schedules were both set as zero before 7:00 and after 18:00. This means the lights were turned off at night from 18:00 to 7:00 the following morning. Heating, cooling and fan schedule, however, remained active 24 hours. The heating and cooling set points were assigned respectively 70°F to 76°F. For afterhours this range increased to 64°F to 82°F. This means the air-conditioning would continue to function in extreme weather conditions. Standard U.S. holidays were taken into consideration in the schedules.

Weather data. Because the College Station, Texas weather file was not available in eQuest software, the Houston weather data (which was the closest city available) was used in the model.

Building systems. All the characteristics of building systems were set as default for a multistory outpatient medical building, as defined by eQuest software. A computer simulation was conducted to observe changes in total annual energy use, electricity and fuel consumption for the three lighting conditions.

CHAPTER IV

ETHNOGRAPHIC RESEARCH RESULTS AND DISCUSSION

Introduction

The results for each study are provided in three separate chapters. In the beginning of each chapter, the participants' characteristics have been provided. Chapter IV, describes the results of the ethnographic study, which includes both qualitative and quantitative analyses. The following three hypotheses are addressed in this section:

1) When it comes to employees' health and performance, there is a pattern in the importance of contributing environmental factors addressed in this study.
2) Daylight is one of the three most important environmental factors that contributes to wakefulness and reduces sleepiness in healthcare and counseling staff.
3) The availability of windows in the healthcare and counseling workspaces will increase perceived wakefulness and improve mood.

Finally, the healthcare and counseling employees' comments and descriptions of alternative coping mechanisms regarding sleepiness are presented.

Population Characteristics

Total Population

Of the 268 eligible participants, a total of 207 participated. Therefore, most healthcare and counseling employees completed the survey (counseling facility n=41(45), 91%, outpatient clinic, n=52 (76) 68% and inpatient acute nursing unit 110 (148) 74%). In the outpatient clinic four surveys, which were filled out by part-time student workers, were not counted because the participants work on a part-time basis and did not meet the eligibility criteria.

Table 4.1. Population characteristic, age.

		20-29	**30-39**	**40-49**	**50-59**	**60-69**	**Missing**	**Total**
Age	**Frequency**	57	52	45	33	18	2	207
	Percent	27.5%	25.1%	21.7%	15.9%	8.7%	1.0%	100.0%

Table 4.2. Population characteristic, gender.

		F	**M**	**Missing**	**Total**
Gender	**Frequency**	157	49	1	207
	Percent	75.8%	23.7%	0.5%	100.0%

As displayed in Figure 4.1 participants consisted of both female and male employees ranging from ages of 20 to 69 (Tables 4.1 & 4.2). Participants included frontline caregivers as well as support, administrative and business personnel in healthcare and counseling (Figure 4.2). The participant demographics are further explained for each site in the following section.

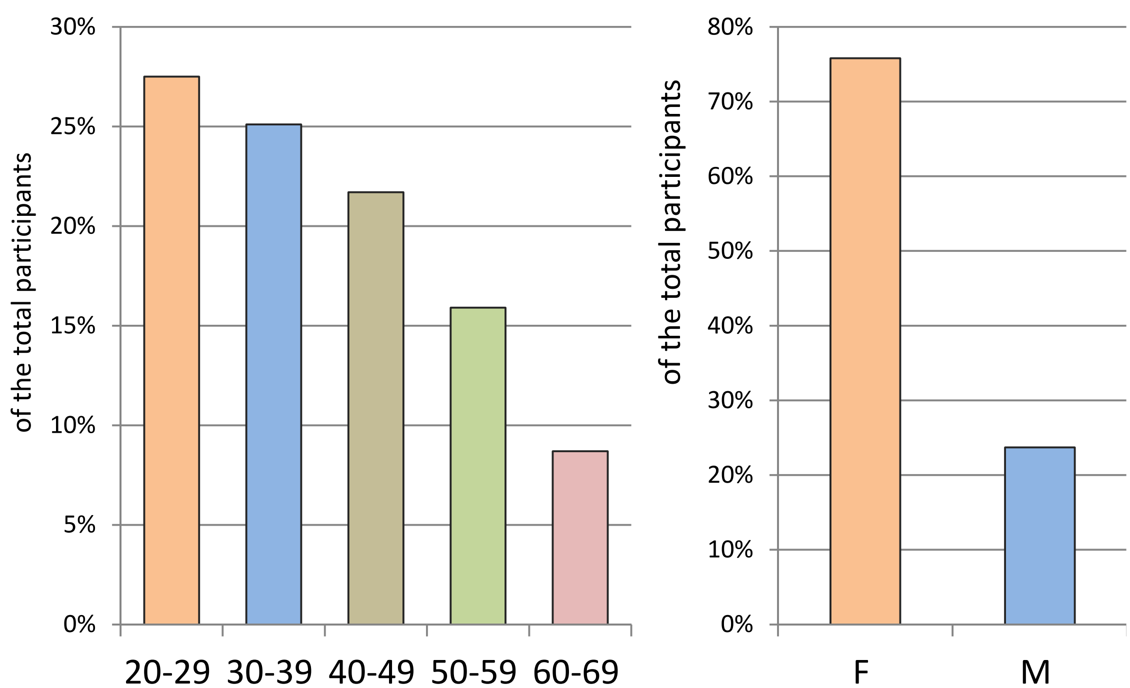


Figure 4.1. Population characteristic, age and gender.

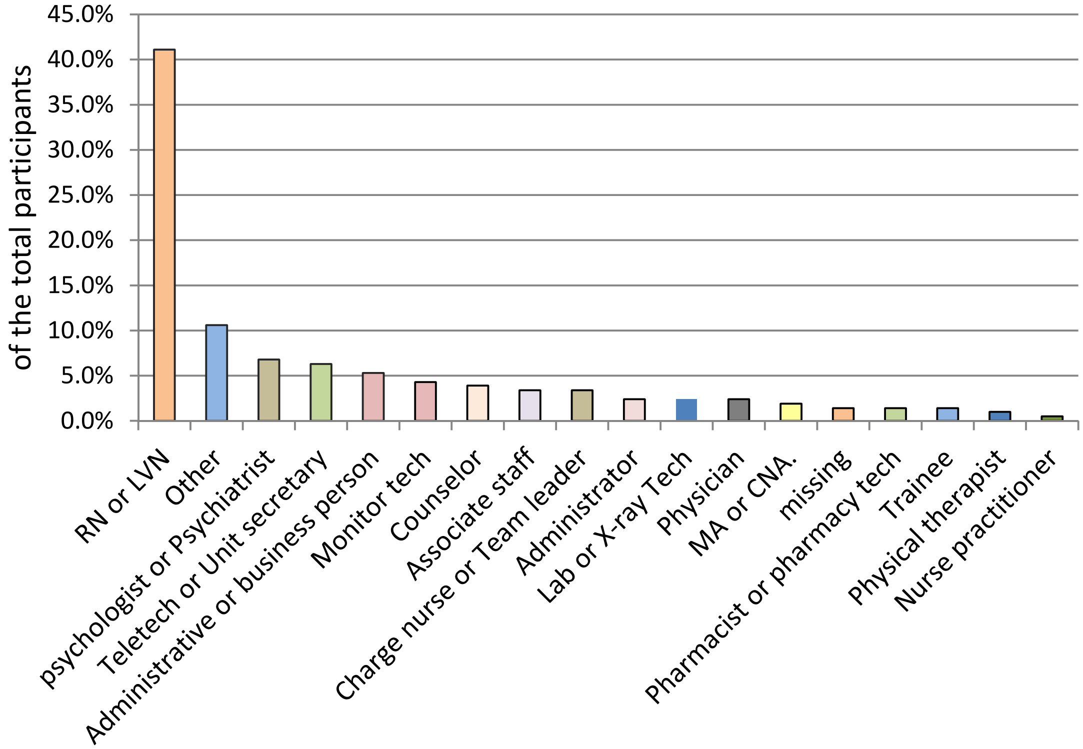


Figure 4.2. Population characteristic, job title.

Population per Research Site

Site 1. The counseling facility sample included psychologists and psychiatrists (14, 32%), counselors (8, 20%), psychologist trainees (3, 7%, administrator (5, 12%) associate staff (7, 17%), other (2, 7%) and two unspecified. Participants were both female (n=24, 59%) and male (n=17, 41%) and their median age group was 40-49 years old.

Site 2. The outpatient facility sample included RN and LVN (7, 13%), MA or CNA (4, 7%), physician (5, 9%), nurse practitioner (1, 2%), physical therapist (2, 4%), lab or X-ray technician (5, 9%), administrative or business person (11, 20%), pharmacist or pharmacy technician (3, 5%) and other (14, 32%). Participants were both female (n=44, 79%) and male (n=12, 21%) and their median age group was 40-49 years old.

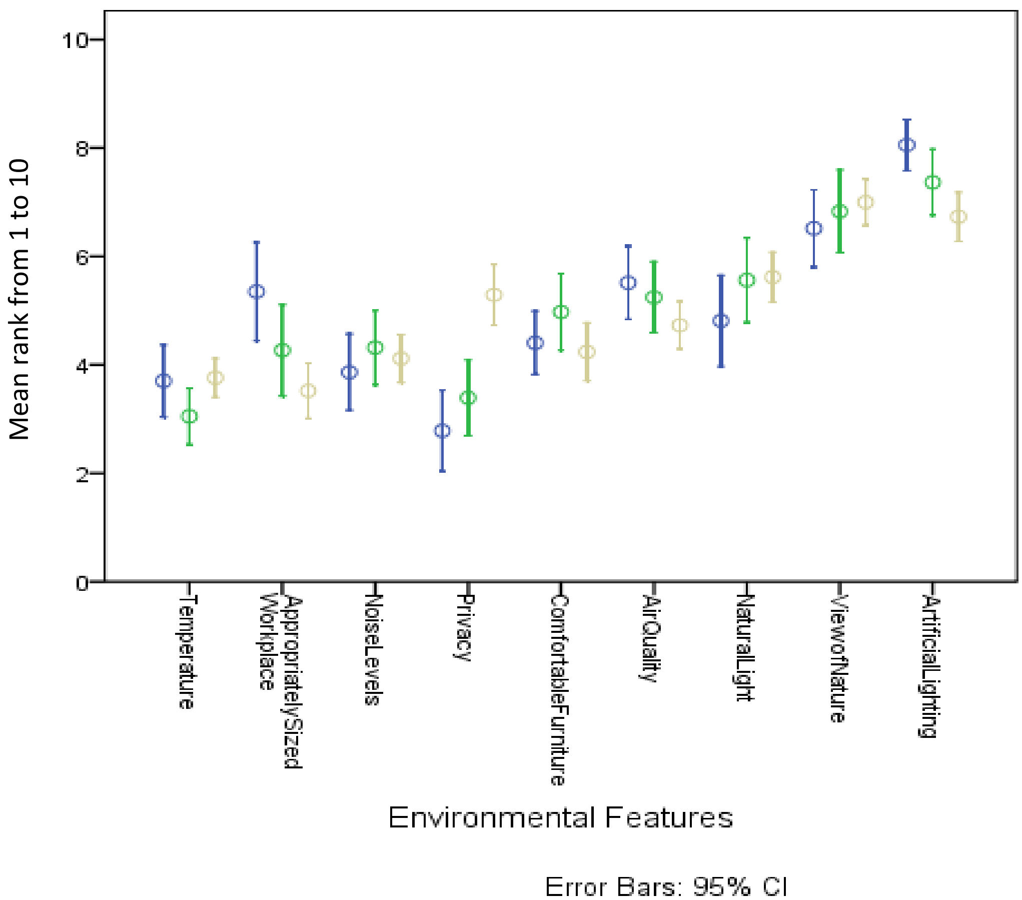
Site 3. The inpatient facility sample included RN and LVN (78, 71%), teletech or unit secretary (13, 12%), monitor tech (9, 8%), charge nurse or team leader (7, 6 %), other (2, 2%) and one missing (n=1, 1%). Participants were both female (n=89, 81%) and male (n=20, 18%) and one unidentified. Their median age group was 30-39 years old. The participants worked both during the day shift (n=65, 59%) and night shift (n=44, 40%) and one unspecified (n=1, 1%).

Hypothesis 1: Overall Environmental Factors

Since no studies have identified the most important environmental factors in the health and counseling settings, an exploratory hypothesis was designed to test whether or not there is a significant pattern in the ranking of environmental factors by staff. The study described in this dissertation helped to identify the most important variables based on staff preferences on their work environment. The findings enable us to make a comparison with similar studies in other settings.

4) It was hypothesized that when it comes to employees' health and performance, there is a pattern in the importance of contributing environmental factors addressed in this study.

Figure 4.3 shows the mean ranking of the nine environmental factors per each facility. The figure depicts that the responses are clustered per variable. We can clearly see a trend in the ranking which is in the three facilities. Therefore we can visually observe that the nine environmental variables are not equally important and have a prioritized ranking.



Note. Counseling facility (blue), health clinic (green) and inpatient unit (beige).

Figure 4.3. Ranking the environmental factors.

Analysis of the Responses

The response variables were studied for normality. The assumption of normality holds for all the nine response variables (Appendix C). Since analysis of variance (ANOVA) is robust to the violation of this assumption in large sample sizes according to SPSS tutorial, it can be used regardless of the results of the normality test. The choice of Post hoc analysis however, relies on the normality of the data.

One-way ANOVA method was used to evaluate whether there is a significant difference in the preferred ranking of environmental variables by staff. A strong significant pattern was found in the ranking of these nine environmental variables, regardless of research site, gender, age group and title of participants (P= 0.0000).

In addition, the same hypothesis was tested per each research site to study the ranking variations among these three types of facilities. The hypothesis that the nine environmental features differ significantly in terms of importance was supported in site one (counseling facility) (P= 0.0000), site two (health clinic) (P= 0.0000) and site three (inpatient nursing unit) (P= 0.0000).

Table 4.3 displays the nine variables (ordered by the mean ranking) from the most to the least important in the entire sample (all sites, site 1, 2 and 3). The variables under consideration were temperature, appropriately sized workplace, low noise levels, privacy, comfortable furniture, air quality, natural light, view of nature and artificial lighting.

Table 4.3. ANOVA comparing the differences among the environmental factor contributing to healthcare and counseling employees' health and performance.

Ranking	Environmental factors	N.	Mean	SD	df	F	P
All three facilities							
					8 1557	52.38853	0.0000
1st	Temperature	174	3.5805	0.1362			
2nd	Appropriately sized workplace	174	4.0862	0.2026			
3rd	Noise levels	174	4.1092	0.1635			
4th	Privacy	174	4.3103	0.2090			
5th	Comfortable furniture	174	4.4483	0.1805			
6th	Air quality	174	5.0172	0.1615			
7th	Natural light	174	5.4310	0.1803			
8th	View of nature	174	6.8563	0.1660			
9th	Artificial lighting	174	7.1609	0.1565			
Facility one (counseling facility)					8 324	20.67451	0.0000
1st	Privacy	37	2.7838	0.3679			
2nd	Temperature	37	3.7027	0.3262			
3rd	Noise levels	37	3.8649	0.3469			
4th	Comfortable furniture	37	4.4054	0.2886			
5th	Natural Light	37	4.8108	0.4134			
6th	Appropriately sized workplace	37	5.3514	0.4472			
7th	Air quality	37	5.5135	0.3325			
8th	View of nature	37	6.5135	0.3501			
9th	Artificial lighting	37	8.0541	0.2323			
Facility two (outpatient health clinic)					8 360	17.38248	0.0000
1st	Temperature	41	3.0488	0.2589			
2nd	Privacy	41	3.3902	0.3455			
3rd	Appropriately sized workplace	41	4.2683	0.4162			
4th	Noise levels	41	4.3171	0.3394			
5th	Comfortable furniture	41	4.9756	0.3483			
6th	Air quality	41	5.2439	0.3234			
7th	Natural light	41	5.5610	0.3858			
8th	View of nature	41	6.8293	0.3776			
9th	Artificial lighting	41	7.3659	0.2999			
Facility three (Inpatient nursing unit)					8 855	28.44649	0.0000
1st	Appropriately sized workplace	96	3.5208	0.2552			
2nd	Temperature	96	3.7604	0.1788			
3rd	Noise levels	96	4.1146	0.2226			
4th	Comfortable furniture	96	4.2396	0.2681			
5th	Air quality	96	4.7292	0.2214			
6th	Privacy	96	5.2917	0.2821			
7th	Natural light	96	5.6146	0.2315			
8th	Artificial lighting	96	6.7292	0.2268			
9th	View of nature	96	7.0000	0.2161			

Site 1 (counseling facility). In Site 1 (counseling facility), the order of the variables from the most important to the least important (based on the mean ranking) was temperature, low noise levels, comfortable furniture, natural light, appropriately sized workplace, air quality, view of nature and artificial lighting. The fact that privacy is placed as the most important factor was to be expected due to the nature of counseling. Also, factors such as natural light and comfort seem to be more important in the counseling facility.

The importance of privacy and stress-reducing environmental qualities was also picked up in the unstructured questionnaires. "Due to the confidential nature of my work, the most important features are privacy and quietness … lighting should be even throughout the workplace, without casting shadows or glare. Several distributed light sources are better. Fluorescent lights create unpleasant glare and harsh environment. At least one significant source of natural light is important," explains a psychiatrist at the counseling facility. According to a trainee psychologist who was explaining the most important features of her workspace, the counseling space, where she meets with clients, "needs to have lower light, natural light, comfortable furniture, high privacy and esthetically calming decorations."

The feedback from the counseling staff explains many of these patterns. Because of their stress-reducing and relaxing effects, environmental features, such as natural light and comfortable furniture are employed by the counseling staff in the treating process of their clients. These features move up in the ranking in the counseling facility compared to the other sites. A psychologist stated that he wishes to have "a large office with extensive natural lighting" and he added "it would be nice to have two complete walls consisting of only glass windows. Of course as a psychologist, privacy and noise control is important. Appropriate temperatures are always essential." Another counselor emphasized that an environment that endorsed nature would be ideal. It will be nice to have a park outside and an indoor garden and water fountain will be very nice to be in a natural setting or to be surrounded by nature will be ideal. "Privacy and quietness are also important" stated a counselor in Site 1.

The environmental variable "workplace size" is less emphasized in the counseling facility. However, because the studied facility benefited from large offices, the size of the work space might have been overlooked because it is not currently an issue for the counseling staff. Had their workplace been different, they may have responded differently.

Site 2 (outpatient health clinic). The participants at the outpatient health clinic identified the environmental factors from the most to the least important, as temperature, privacy, appropriately sized workplace, low noise levels, comfortable furniture, air quality, natural light, view of nature and artificial lighting. This pattern is very similar to the pattern found across all three facilities except that privacy has become slightly more important for participants. The participants in this site have a diverse distribution of job titles, which may contribute to the fact that this site is very similarly ranked to the entire sample size. When the ranking for an environmental factor such as privacy is higher, this may be interpreted as a certain need for this specific facility. For example the selection of privacy as the most important factor may point at needing more quiet or nondistracting work areas due to the nature of their work, or it can be interpreted as more private offices and isolated cubicles are needed in the design of a facility of this nature.

Site 3 (acute inpatient nursing unit). The most prioritized environmental factors provided by staff at the inpatient nursing unit, based on the mean rankings, are appropriately sized workplace, temperature, noise levels, comfortable furniture, privacy, natural light, artificial lighting and view of nature. The pattern of ranking in this facility was different from the ranking presented among all three sites. This might be related to the nature of this type of facility. The fact that the patients are more acute than the other types, and that there are differences in staff title may explain these variations. In the inpatient facility, most of the staff are nurses, who provide direct patient care, whereas in an outpatient facility nurses are only a small portion of the staff. In addition, the inpatient facility also includes night staff whose environmental needs may differ.

A Pot hoc Tukey test was performed to analyze the pair-wise differences in rankings of the nine environmental factors with respect to the main hypothesis. For all three sites, temperature, appropriately sized workplace, noise levels and privacy, were ranked the highest and were significantly different from any other variables. Both privacy and temperature as well as noise levels were ranked significantly higher than any other environmental feature in the counseling facility. Temperature, noise levels, comfortable furniture and natural light were grouped second. In the outpatient clinic, temperature, privacy and appropriately sized workplace were ranked the highest and are significantly different from any other variable.

In the acute care nursing unit, the four categories of appropriately sized workplace, temperature, noise levels and comfortable furniture are the most important environmental factors, which are significantly different from any other variable.

Post Hoc Analysis of the Responses on Overall Environmental Factors

The Post hoc analysis enabled a comparison of the differences in rankings among the three types of facilities and the identification of the most and least important factors across all the populations in addition to each facility. Furthermore, it was evaluated whether respondents with similar age, gender and occupation categories had similar response patterns to the question.

Comparison among facilities. the Test of Homogeneity of Variances indicated that, except for the responses on artificial lighting and comfortable furniture, the remaining response categories held the assumption of equality of variances (Table 4.4). Therefore, the Tamhane T-2 test was performed for those two categories with unequal variances and the Tukey HSD Post hoc test was conducted if the assumption of equal variances was supported.

Table 4.4. Test of homogeneity of variances.

	Levene Statistic	df1	df2	Sig.
Privacy	2.833	2	171	.062
Air quality	.249	2	171	.780
Temperature	1.128	2	171	.326
Noise levels	.030	2	171	.970
View of nature	1.391	2	171	.252
Natural light	1.009	2	171	.367
Artificial lighting	7.853	2	171	.001
Comfortable furniture	8.945	2	171	.000
Appropriately sized workplace	.992	2	171	.373

In fact, post hoc analysis comparing the factors between the three facilities indicated that employee privacy, was ranked remarkably higher in both counseling (0.0000) and health clinic (0.0003) settings, compared to the inpatient nursing clinic. There was no significant difference in the ranking of privacy between the counseling and the outpatient clinic (P=0.5442). Staff in the inpatient nursing units place less emphasis on privacy.

In addition, participants at the acute inpatient nursing ranked artificial light differently from the counseling staff (0.0023) The previous table, which provides the rankings in these three facilities' artificial lighting, indicates that the inpatient nursing unit overall has a higher rank for artificial lighting than other facilities. Comfortable furniture remains as an important factor in this type of health facility.

The factor of workplace size was ranked first in the inpatient acute nursing unit. The difference on the ranking of workplace size between sites 1 and 3 was significant (0.0010). Artificial lighting was ranked higher in the inpatient unit compared to the counseling facility, but not to the outpatient facility. This may be because the inpatient facility also includes night staff for whom artificial lighting is the only source of light for vision.

In summary, factors of privacy, appropriately sized workspace and electric lighting were significantly ranked differently in the counseling facility, outpatient clinic and acute inpatient nursing unit. Therefore they may not be equally important for the health and performance of participants in the three types of facilities. The remaining six variables were not found to be ranked differently in the three sites (based on Tukey-HSD Post Hoc Test). Table 4.5 shows the variation of ranking between the three sites.

The grouping among the ranked variables in each facility and in all three facilities is displayed in Figures 4.4, 4.5, 4.6, and 4.7. As we see, the four environmental factors, temperature, appropriately sized workplace, noise and privacy form one group containing the most important environmental variables for an ideal workplace in terms of healthcare and counseling preferences.

Table 4.5. The impact of environmental factors on health and performance, a comparison between counseling workspace, outpatient workspace and acute inpatient nursing workspace.

	Descriptives				ANOVA		Post hoc (Tukey HSD, or Tamhene T2 P Value)		
	Site	N	Mean	Std. Error	F	P	Site1/Site2	Site1/Site3	Site2/Site3
Privacy					16.5575	0.0000	0.5442	0.0000	0.0003
	1	37	2.7838	0.3679					
	2	41	3.3902	0.3455					
	3	96	5.2917	0.2821					
Air quality					2.1421	0.1205	0.8405	0.1374	0.3950
	1	37	5.5135	0.3325					
	2	41	5.2439	0.3234					
	3	96	4.7292	0.2214					
Temperature					2.4009	0.0937	0.2407	0.9847	0.0848
	1	37	3.7027	0.3262					
	2	41	3.0488	0.2589					
	3	96	3.7604	0.1788					
Noise levels					0.4252	0.6543	0.6275	0.8223	0.8707
	1	37	3.8649	0.3469					
	2	41	4.3171	0.3394					
	3	96	4.1146	0.2226					
View of nature					0.6606	0.5178	0.8012	0.4872	0.9086
	1	37	6.5135	0.3501					
	2	41	6.8293	0.3776					
	3	96	7.0000	0.2161					
Natural light					1.616475	0.2016	0.3453	0.1889	0.9919
	1	37	4.8108	0.4134					
	2	41	5.5610	0.3858					
	3	96	5.6146	0.2315					
Artificial lighting					6.1025	0.0028	0.2054*	0.0003*	0.2712*
	1	37	8.0541	0.2323					
	2	41	7.3659	0.2999					
	3	96	6.7292	0.2268					
Comfortable furniture					1.3860	0.2528	0.5095*	0.9768*	0.2912*
	1	37	4.4054	0.2886					
	2	41	4.9756	0.3483					
	3	96	4.2396	0.2681					
Appropriately sized workplace					6.8184	0.0014	0.1578	0.0010	0.2710
	1	37	5.3514	0.4472					
	2	41	4.2683	0.4162					
	3	96	3.5208	0.2552					

Note. * Tamhane T2 was used because of non-equality of variances.

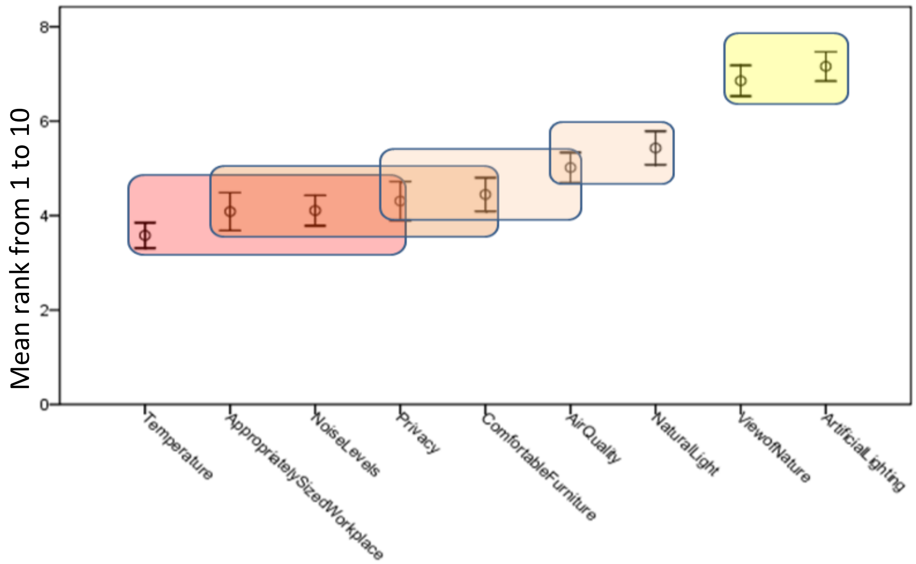


Figure 4.4. The grouping among the ranked variables in all three sites.

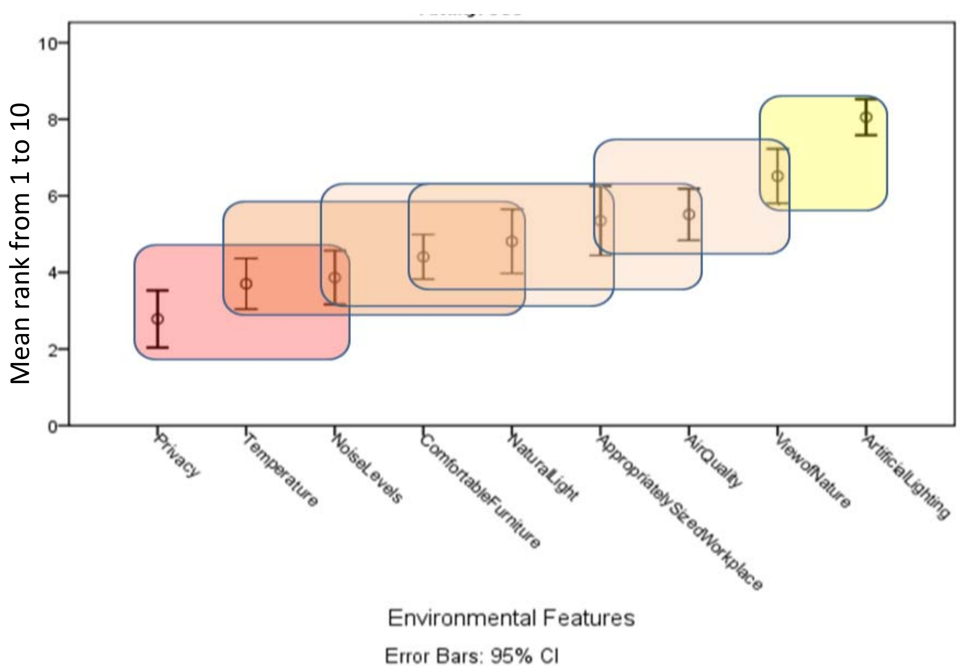


Figure 4.5. The grouping among the ranked variables in the counseling site.

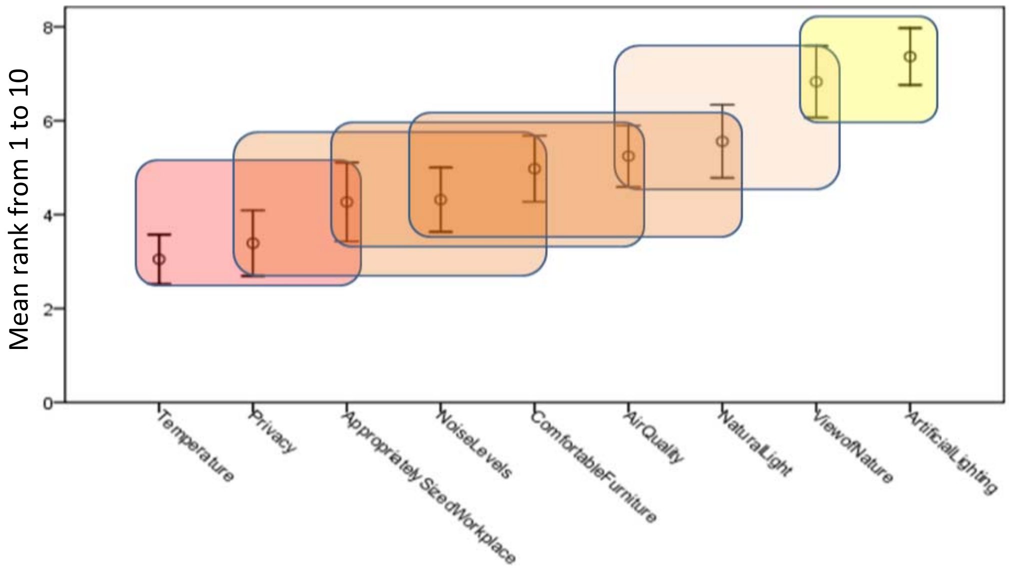


Figure 4.6. The grouping among the ranked variables in the outpatient site.

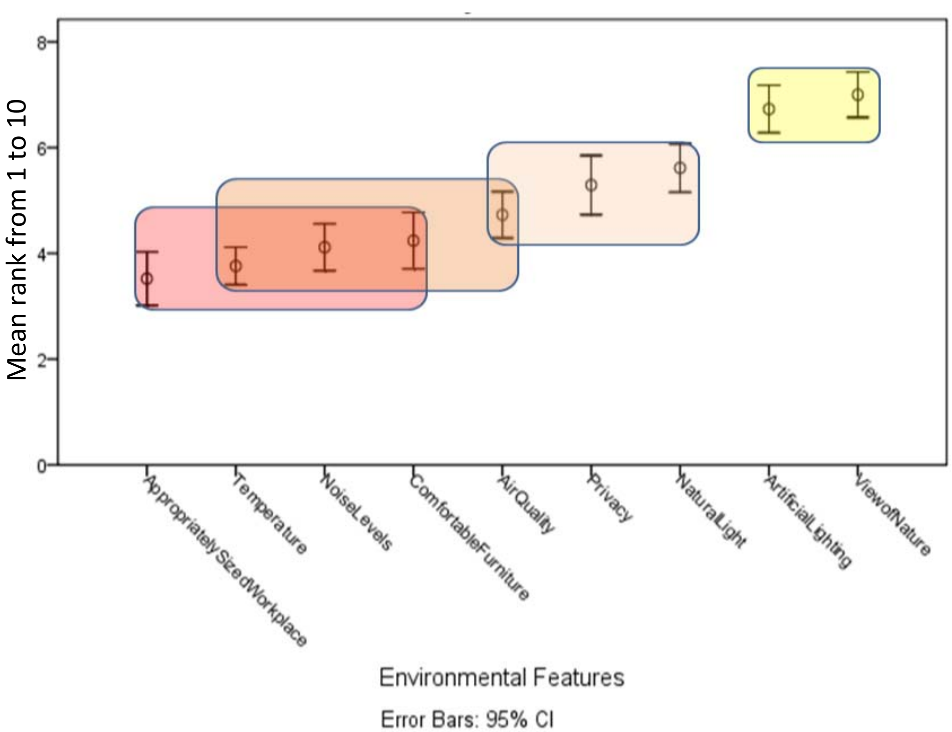


Figure 4.7. The grouping among the ranked variables in the inpatient site.

Comparison between gender. Analysis of variance (ANOVA) showed both female and male respondents closely ranked in all of the 9 variables. The test of equal variance confirmed that all variables had equal variances except for the responses to appropriately sized workspace (Table 4.6).

Table 4.6. Test of homogeneity of variances, responses separated by gender.

	Levene Statistic	df1	df2	Sig.
Privacy	.533	1	172	.466
Air quality	.349	1	172	.555
Temperature	1.050	1	172	.307
Noise levels	1.773	1	172	.185
View of nature	.111	1	172	.739
Natural light	.580	1	172	.447
Artificial lighting	1.637	1	172	.202
Comfortable furniture	.132	1	172	.716
Appropriately sized workplace	4.162	1	172	.043

The mean rank of 8 out of 9 variables was not statistically different for female and male participants. Although the p-value for air quality was significant for the difference in mean for both genders, the mean only changed from 5.2348 for female to 4.3333 for male participants; male participants have shown slightly higher preference to air quality. Overall we did not identify any remarkable differences in the opinion of female and male participants in the importance of environmental variables on their health and performance when looking at the entire sample, across all three sites (Table 4.7).

Table 4.7. Response variations by gender.

	Descriptives				Inferential	
	Gender	N	Mean	Std. Error	F	Sig.
Privacy					0.4949	0.4827
	F	132	4.2273	0.2384		
	M	42	4.5714	0.4366		
Air Quality					5.8678	0.0165
	F		5.2348	0.1859		
	M	42	4.3333	0.3061		
Temperature					0.6815	0.4102
	F	132	3.6439	0.1540		
	M	42	3.3810	0.2911		
Noise levels					0.0449	0.8325
	F	132	4.1288	0.1925		
	M	42	4.0476	0.3085		
View of nature					0.4212	0.5172
	F	132	6.7955	0.1920		
	M	42	7.0476	0.3321		
Natural light					0.7842	0.3771
	F	132	5.3409	0.2088		
	M	42	5.7143	0.3579		
Artificial lighting					1.1998	0.2749
	F	132	7.2576	0.1740		
	M	42	6.8571	0.3485		
Comfortable furniture					0.0076	0.9308
	F	132	4.4394	0.2114		
	M	42	4.4762	0.3479		
					1.8337	0.1775
Appropriately sized workplace	F	132	3.9318	0.2238		
	M	42	4.5714	0.4549		

The effect of gender was also studied separately within each site. The analysis showed that in the counseling and outpatient facility there was no significant difference in the mean ranking of the various environmental factors. Therefore, all the nine environmental variables tested were equally important to both male and female respondents. In the outpatient facility, there was no significant difference between male and female respondents in eight of the nine categories; only air quality showed a significant difference (0.0010). The female respondents in this facility ranked the air quality lower (mean ranking= 5.0506) than the male respondents (mean ranking= 3.2353).

Comparison among job titles. The effect of job title on the ranking of the nine environmental factors was studied using ANOVA. The importance of these environmental factors for different jobs within the healthcare and counseling facilities was explored. A total of 21 job titles were identified and they were binned into 12 job categories to perform the analysis (figure 4.8).

The comparison among various job categories across the three sites using ANOVA, indicates that there was a statically significant difference in the ranking of the factors privacy, air quality and artificial lighting based on job title category (P= 0.0000, P=0.0312 and P=0.0487). In addition, the factor appropriately sized workspace showed nearly significant difference in ranking among job title categories (P= 0.0845). Comfort, natural light, view of nature and temperature were equally important regardless of job title. Therefore, participants with all job categories had similar preferences.

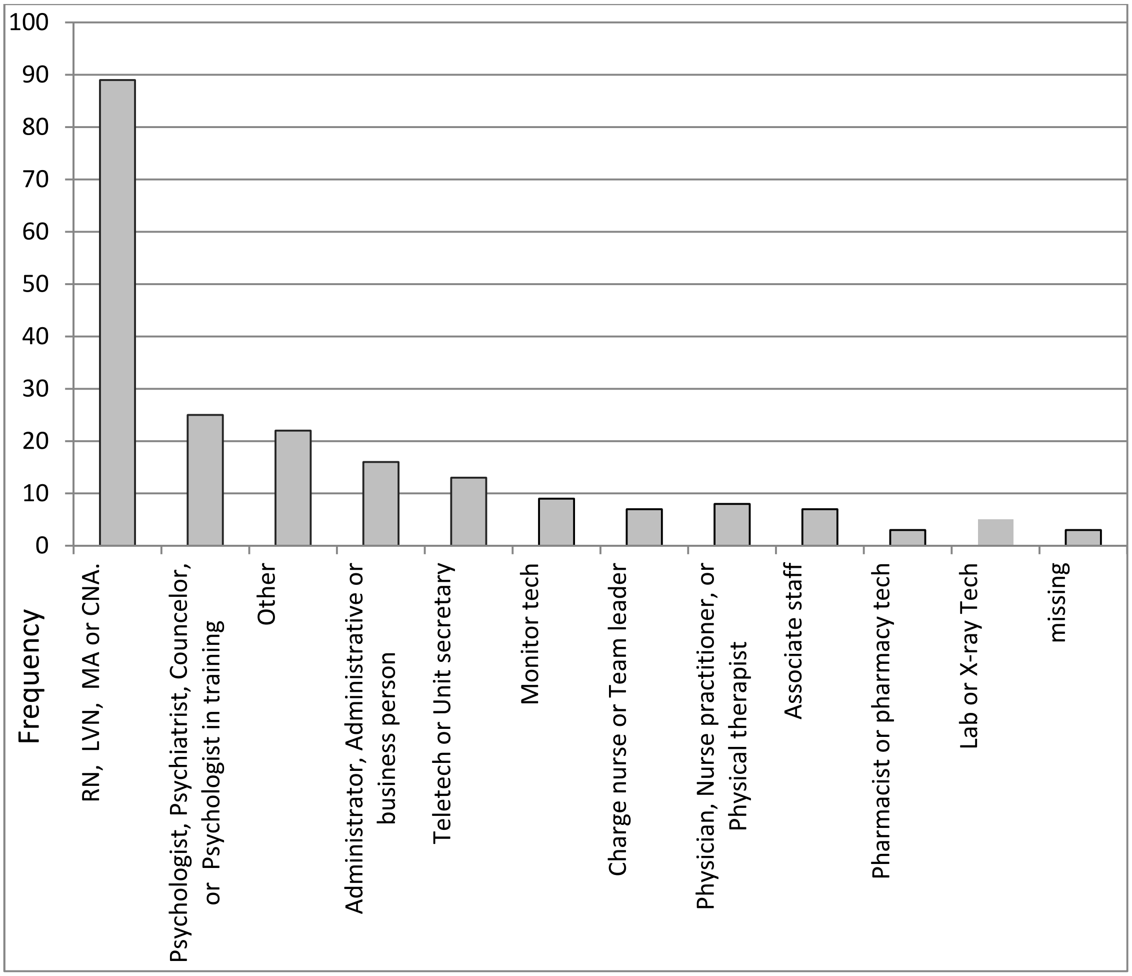


Figure 4.8. Job titles in all three sites collapsed to 12 main categories.

Table 4.8. ANOVA comparisons among various job categories.

		Sum of squares	**df**	**Mean square**	**F**	**Sig.**
Privacy	Between Groups	274.2270	10	27.4227	4.2368	.0000
	Within Groups	1048.5360	162	6.4724		
	Total	1322.7630	172			
Air quality	Between Groups	88.1851	10	8.8185	2.0534	.0312
	Within Groups	695.7224	162	4.2946		
	Total	783.9075	172			
Temperature	Between Groups	29.5582	10	2.9558	.9122	.5235
	Within Groups	524.9274	162	3.2403		
	Total	554.4855	172			
Noise levels	Between Groups	46.8871	10	4.6887	1.0226	.4267
	Within Groups	742.8123	162	4.5853		
	Total	789.6994	172			
View of nature	Between Groups	40.2426	10	4.0243	.8263	.6038
	Within Groups	788.9597	162	4.8701		
	Total	829.2023	172			
Natural light	Between Groups	50.2546	10	5.0255	.8900	.5439
	Within Groups	914.7512	162	5.6466		
	Total	965.0058	172			
Artificial lighting	Between Groups	77.5028	10	7.7503	1.8986	.0487
	Within Groups	661.2834	162	4.0820		
	Total	738.7861	172			
Comfortable furniture	Between Groups	79.0703	10	7.9070	1.4076	.1810
	Within Groups	910.0048	162	5.6173		
	Total	989.0751	172			
Appropriately sized work place	Between Groups	116.9830	10	11.6983	1.7007	.0845
	Within Groups	1114.3465	162	6.8787		
	Total	1231.3295	172			

Table 4.8 describes the differences in ranking of privacy among various job titles. The job categories above the mean ranking indicate less concern for privacy and therefore, may require more socialization. Those below the mean ranking may require more self-concentration and focus. This explanation matches with the job descriptions. For example, psychologists, psychiatrists and counselors may need more privacy due to their job requirements. External stimuli may interrupt their conversation or focus. On the

other hand, charge nurses need immediate and fast access to patients. This explains why they have ranked privacy as less important.

The only exception in this chart for which job requirements for privacy does not match with the ranking is the monitor techs. Their job requires concentration and focus in order to monitor patients' heart rates. However, the participants care little for privacy. Perhaps this can be explained by their need for external stimulation. Evidence indicates that social interaction is an external stimulus which improves arousal and alertness. The current monitor tech room, however, is a very small, windowless space completely isolated from the rest of the unit. Therefore, monitor techs who work in this specific nursing unit, which is neither vibrant nor stimulating, may feel abandoned if they stay in their room for extended periods. Further research is required on balancing external clues in order to provide the required social triggers for arousal which do not disturb concentration.

Privacy, air quality and artificial lighting have been significantly ranked differently by the participants based on Table 4.8. The same effect is visible in figures 4.9 to 4.17 where the variation in ranking is the higher. However, other variables have a more linear trend and less variation in ranking.

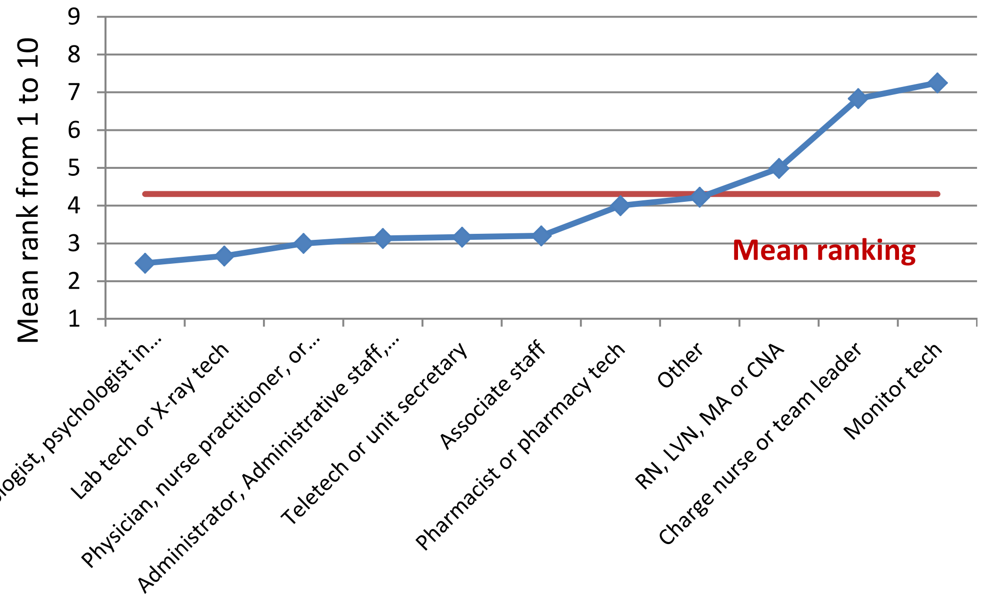


Figure 4.9. Privacy ranking by job title.

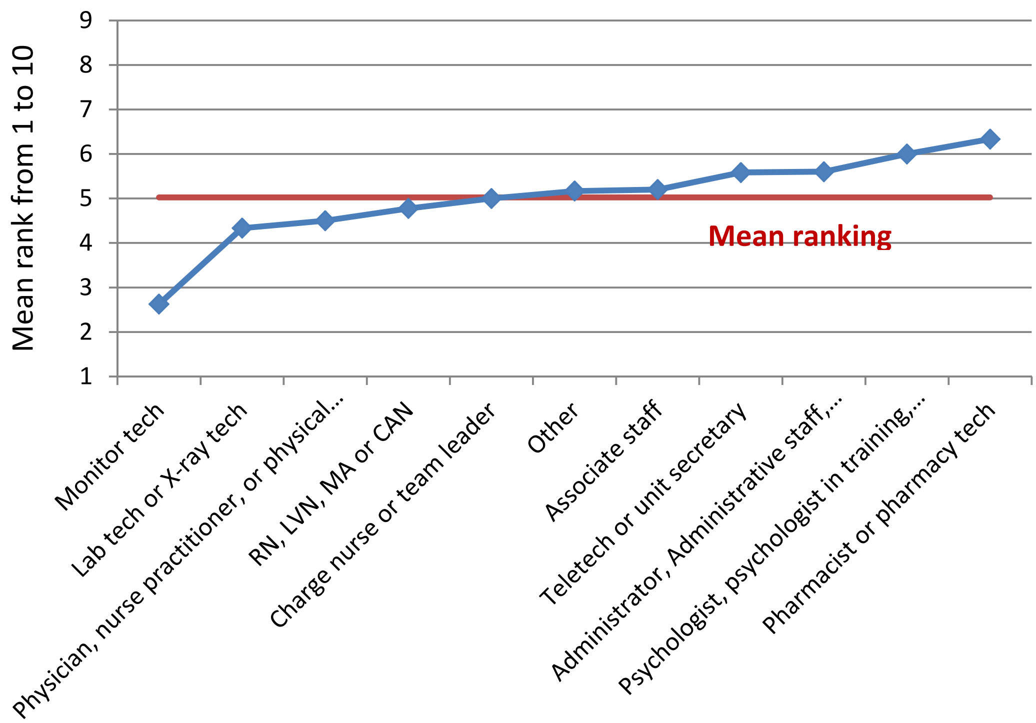


Figure 4.10. Air quality ranking by job title.

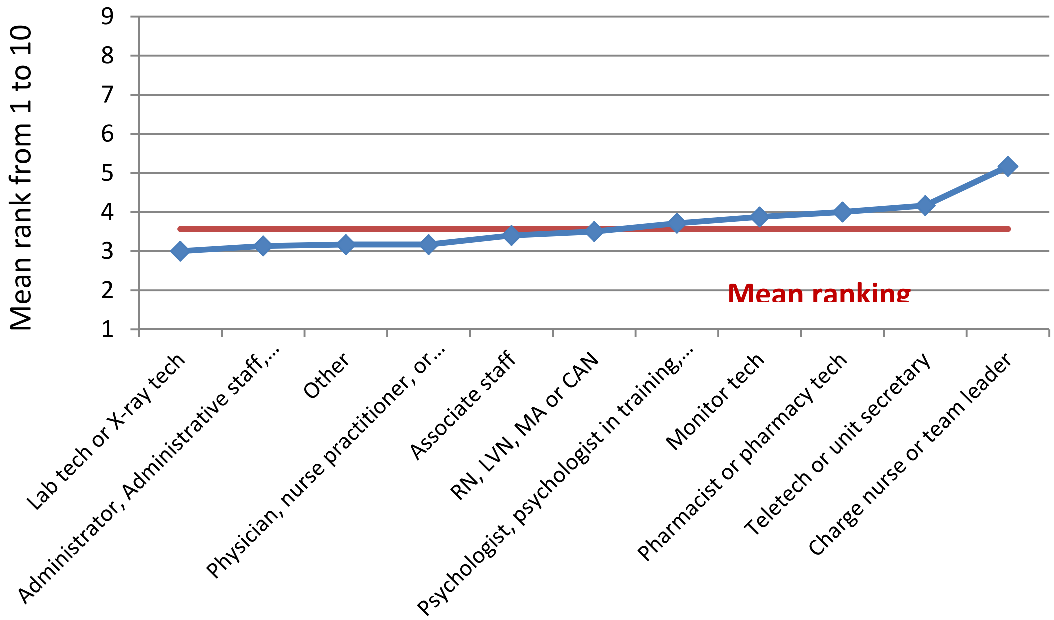


Figure 4.11. Temperature ranking by job title.

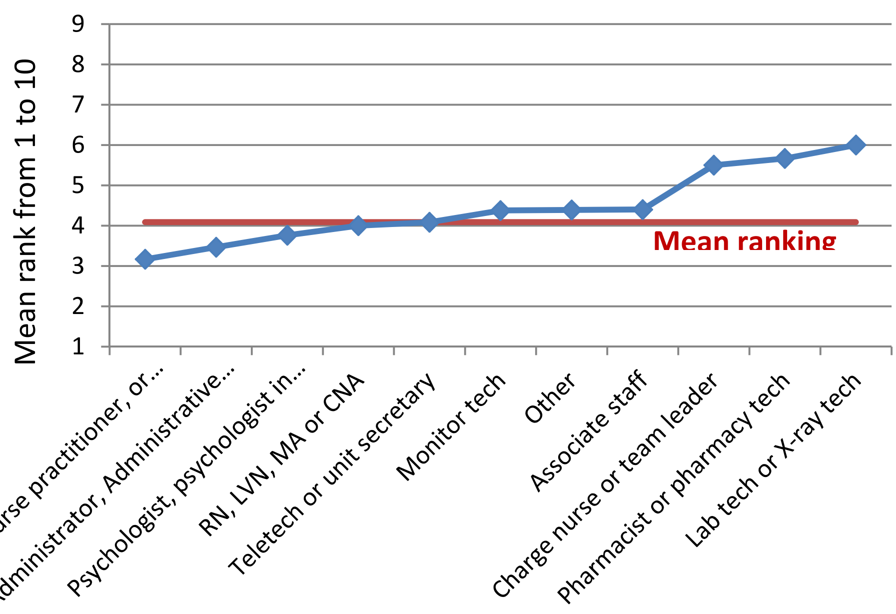


Figure 4.12. Low noise levels ranking by job title.

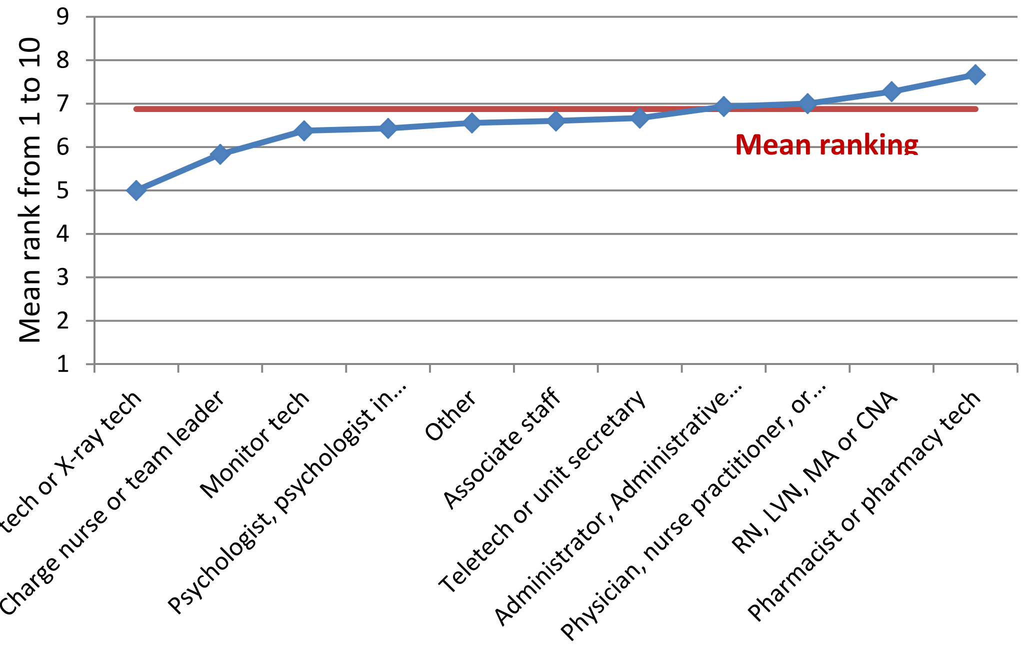


Figure 4.13. View of nature ranking by job title.

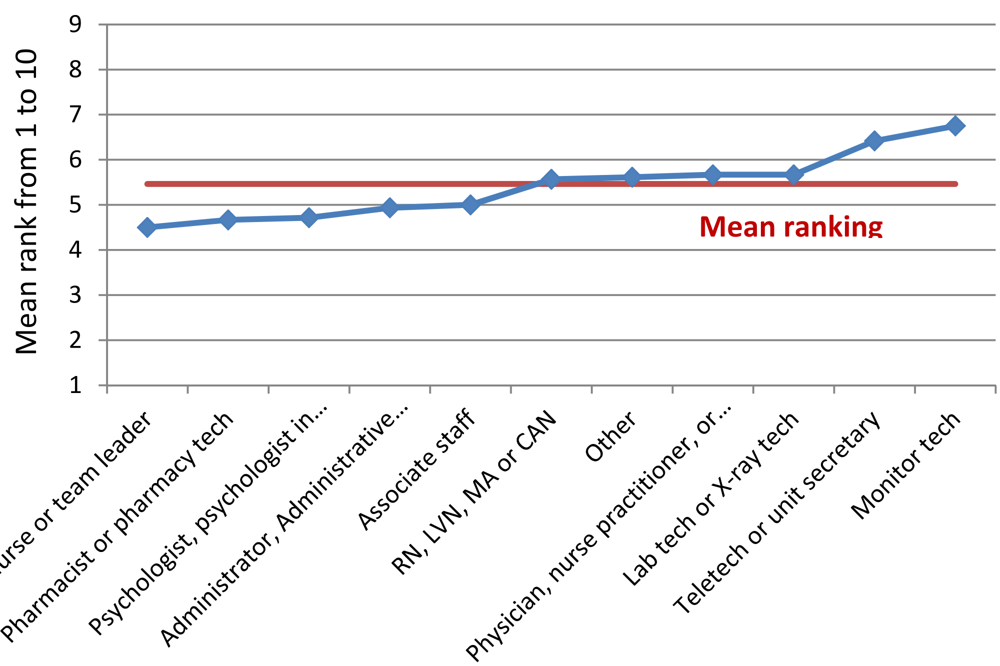


Figure 4.14. Natural light ranking by job title.

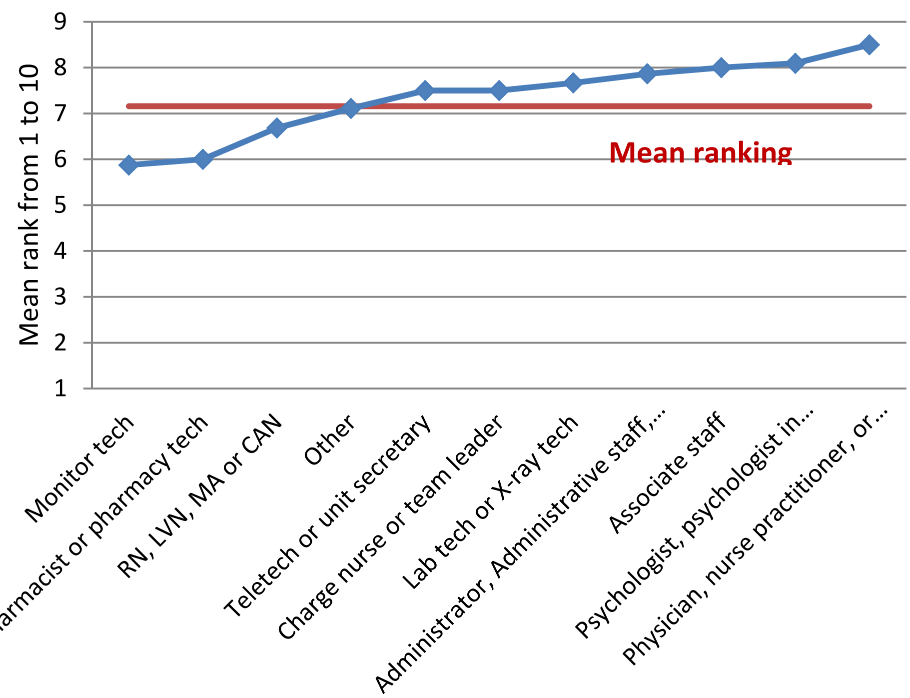


Figure 4.15. Artificial light ranking by job title.

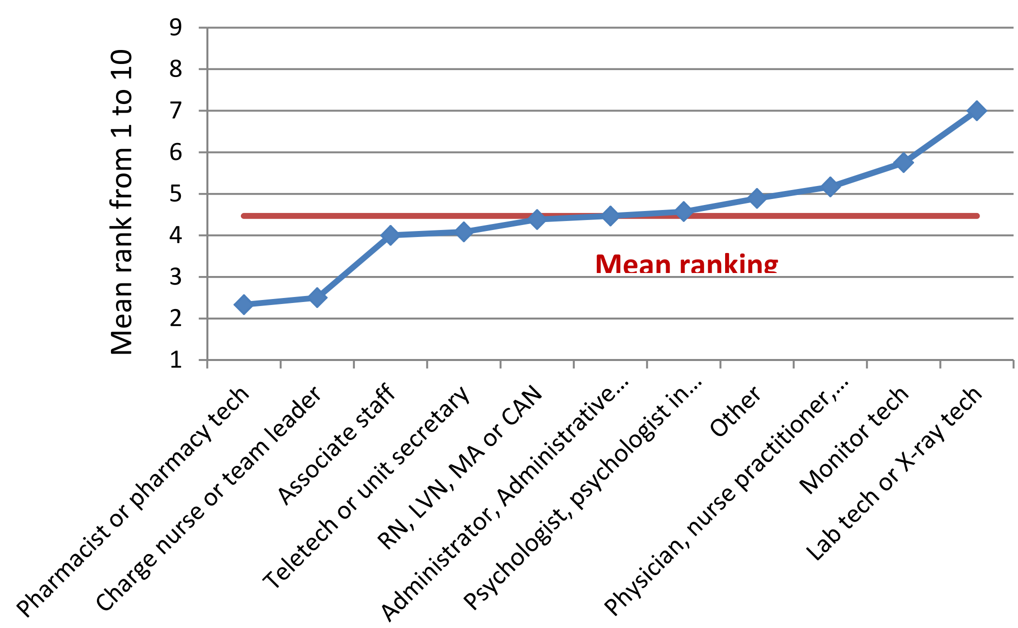


Figure 4.16. Comfortable furniture ranking by job title.

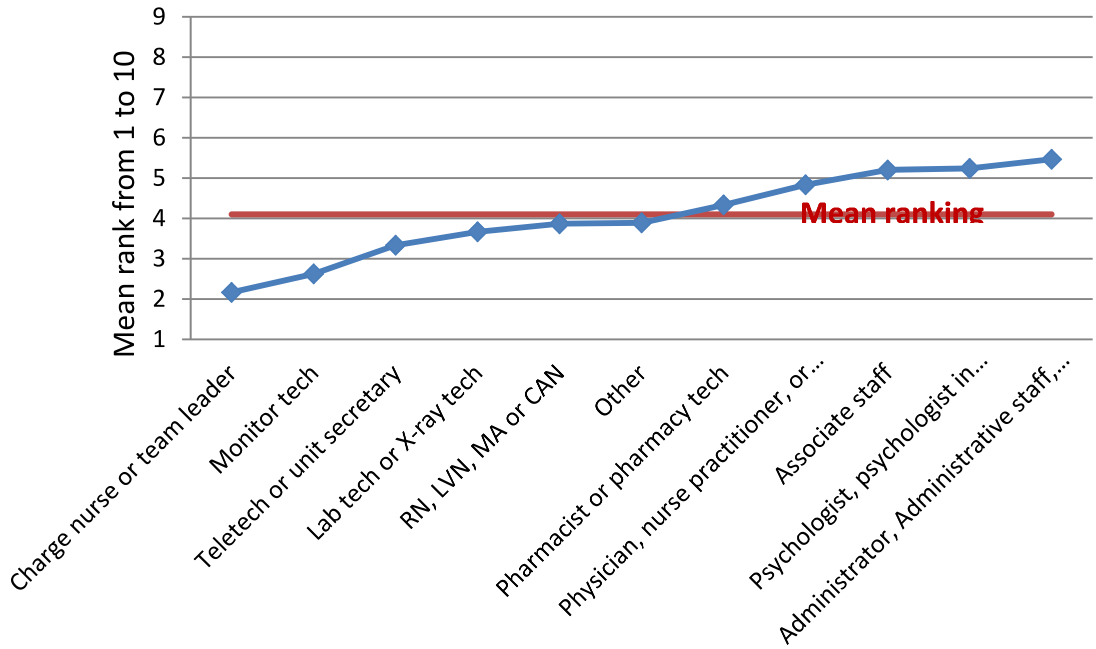


Figure 4.17. Appropriately sized workspace ranking by job title.

Comparison among age groups. ANOVA analysis showed there was no significant difference in the ranking of any of the environmental factors based on age. However, privacy and appropriately sized workplace were almost significant in the difference of ranking among age groups.

We know that job title and age may interact with each other. The Univariate procedure, which provides analysis of variance for a dependent variable with multiple factors according to SPSS 16.0 tutorial, was used to investigate the relationship between these factors. It is possible that the difference observed in privacy can be a result of the job title rather than of age (Table 4.9). However, further analysis is necessary in order to explain which one is the most significant.

Table 4.9. ANOVA comparison among age group.

		Sum of Squares	df	Mean Square	F	Sig.
Privacy	Between Groups	61.6680	4	15.4170	2.0614	.0881
	Within Groups	1263.9469	169	7.4790		
	Total	1325.6149	173			
Air quality	Between Groups	8.2280	4	2.0570	.4476	.7741
	Within Groups	776.7203	169	4.5960		
	Total	784.9483	173			
Temperature	Between Groups	2.1610	4	.5402	.1619	.9573
	Within Groups	564.0459	169	3.3375		
	Total	566.2069	173			
Noise levels	Between Groups	26.5714	4	6.6428	1.4423	.2222
	Within Groups	778.3539	169	4.6056		
	Total	804.9253	173			
View of nature	Between Groups	20.4952	4	5.1238	1.0662	.3749
	Within Groups	812.1944	169	4.8059		
	Total	832.6897	173			
Natural light	Between Groups	22.1886	4	5.5471	.9739	.4233
	Within Groups	962.6160	169	5.6960		
	Total	984.8046	173			
Artificial lighting	Between Groups	13.8661	4	3.4665	.8044	.5239
	Within Groups	728.3006	169	4.3095		
	Total	742.1667	173			
Comfortable furniture	Between Groups	23.9775	4	5.9944	1.0474	.3844
	Within Groups	967.2409	169	5.7233		
	Total	991.2184	173			
Appropriately sized workplace	Between Groups	66.4190	4	16.6048	2.3999	.0520
	Within Groups	1169.2879	169	6.9189		
	Total	1235.7069	173			

Hypothesis 2: Environmental Factors Impacting Alertness

Participants were asked to select three of the seven given environmental factors, (temperature, air quality, low noise levels, daylight, electric lighting, privacy and comfort), which they believed would most help them improve their wakefulness and reduce their sleepiness during work hours. The most important was to be ranked 1 and the least important of the three was to be ranked 3.

It was hypothesized that daylight would be identified in the top three environmental factors contributing to wakefulness. Figure 4.18 graphically displays the distribution of ranking among the seven environmental factors. Daylight, temperature and comfort were closely ranked in the top tree important factors. Temperature and daylight seem to have similar frequencies; however, participants were most likely to select daylight as a more important factor than temperature. Therefore, the weighted average ranking better describes the participants' preferences (Figure 4.19). Table 4.10 displays the frequency of ranking for each environmental factor. As displayed in the table, daylight, temperature and comfort were ranked as the top three most important environmental factors contributing to alertness and reducing sleepiness.

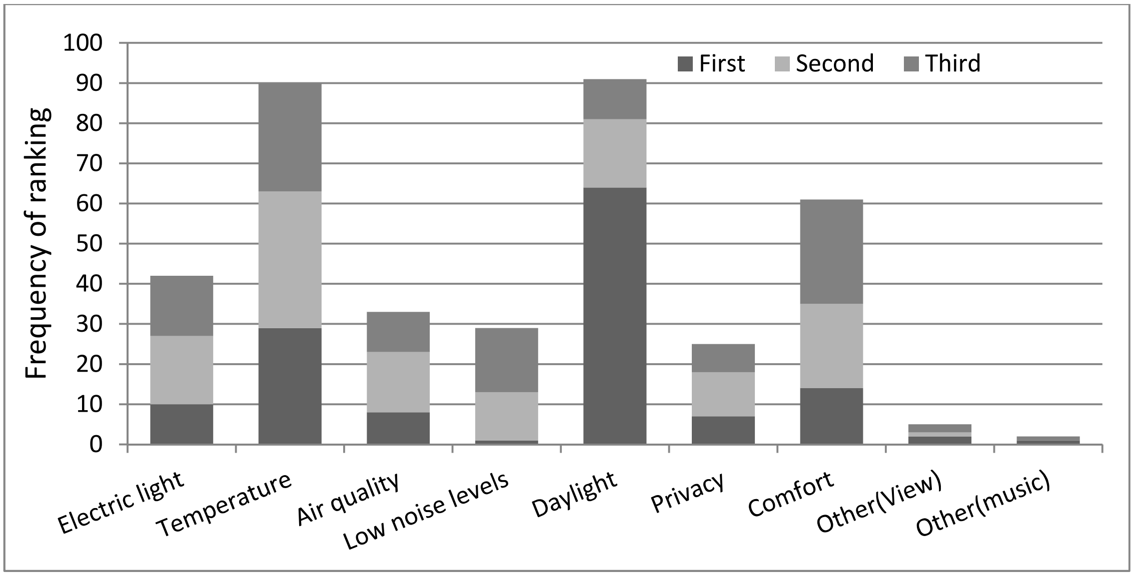


Figure 4.18. Frequency of ranking of environmental factors in terms of improving alertness and reducing sleepiness.

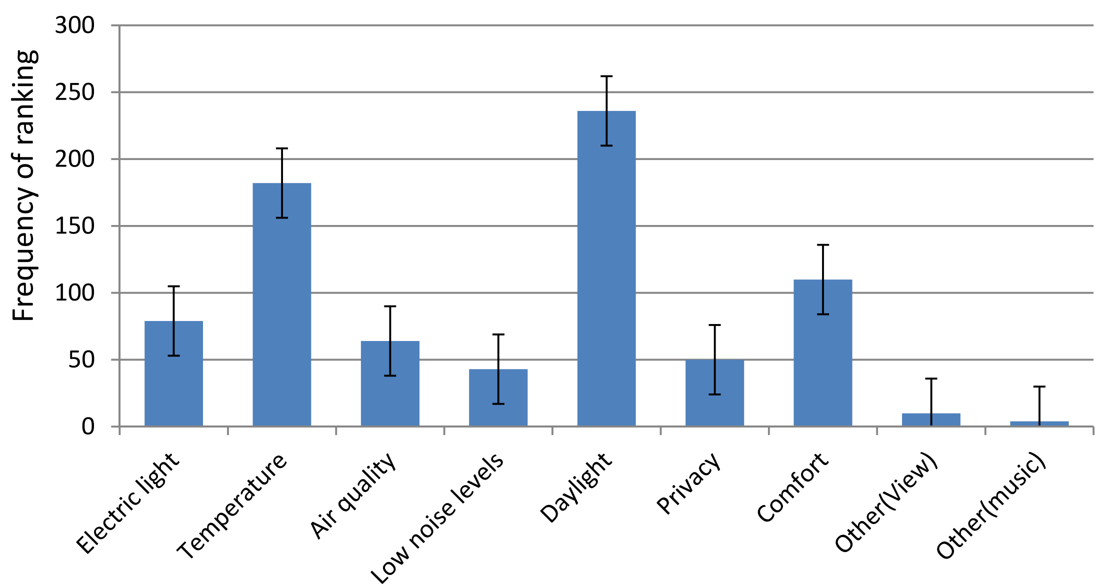


Figure 4.19. Weighted rank of environmental factors in terms of improving alertness and reducing sleepiness**.**

Table 4.10. The most important environmental factors stimulating wakefulness and alertness in the workplace in all three facilities.

		First	Second	Third	Total rank	Weighted rank
1st	**Daylight**	64	17	10	91	236
2nd	**Temperature**	29	34	27	90	182
3rd	**Comfort**	14	21	26	61	110
	Electric light	10	17	15	42	79
	Air quality	8	15	10	33	64
	Privacy	7	11	7	25	50
	Low noise levels	1	12	16	29	43
	Other (View)	2	1	2	5	10
	Other (Music)	1	0	1	2	4
	Total	136	128	114		

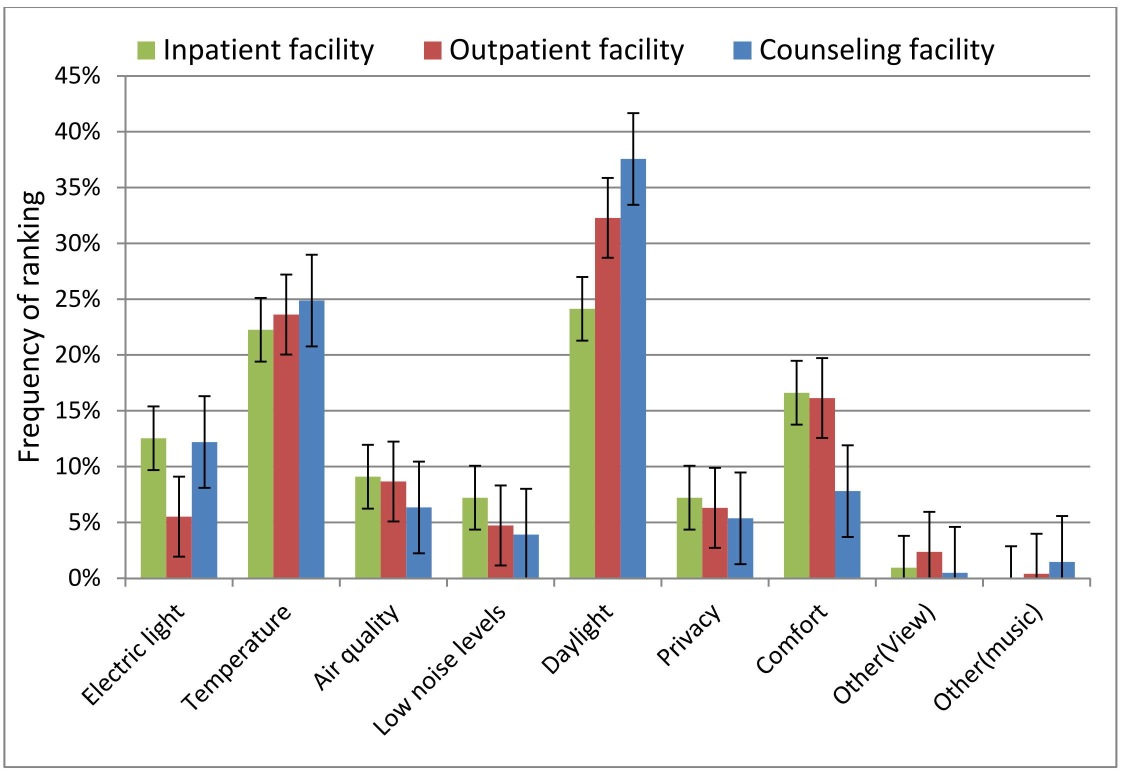


Figure 4.20. Weighted rank of environmental factors in terms of improving alertness and reducing sleepiness for all three facilities.

The respondents had occasionally added the variables “view to outside” or “music” to their list although these variables were not in the original categories. These variables were added to the analysis and are included in the findings because they were mentioned by more than one participant.

Research sites. The same analysis was made to study the rankings per facility. The weighted ranking of the factors are displayed in table 4.11 and Figure 4.20. The inpatient and outpatient facility ranking was similar to the overall response in which daylight, temperature and comfort were selected as the most important components contributing to wakefulness and alertness in the workplace. In the counseling facility however, daylight, temperature and electric light were selected as the most important environmental factors contributing to alertness. Comfort was ranked lower in terms of providing wakefulness in the counseling facility.

Table 4.11. Weighted average, the most important environmental factors stimulating wakefulness and alertness in the workplace.

*Ranking	Environmental Factors	First	Second	Third	Total rank	Weighted rank
Counseling facility						
1st	**Daylight**	21	5	4	30	77
2nd	**Temperature**	6	12	9	27	51
3rd	**Electric light**	4	5	3	12	25
	Comfort	2	3	4	9	16
	Air quality	1	3	4	8	13
	Privacy	0	5	1	6	11
	Low noise levels	0	1	6	7	8
	Other (music)	1	0	0	1	3
	Other (view)	0	0	1	1	1
	Total	35	34	32	101	205
Outpatient facility						
		First	**Second**	**Third**	**Total rank**	**Weighted rank**
1st	**Daylight**	21	7	5	33	82
2nd	**Temperature**	11	10	7	28	60
3rd	**Comfort**	5	9	8	22	41
	Air quality	4	3	4	11	22
	Privacy	1	4	5	10	16
	Electric light	0	3	8	11	14
	Low noise levels	1	4	1	6	12
	Other (view)	1	1	1	3	6
	Other (music)	0	0	1	1	1
	Total	44	41	40	125	254
Inpatient facility						
		First	**Second**	**Third**	**Total rank**	**Weighted rank**
1st	**Daylight**	22	5	1	28	77
2nd	**Temperature**	12	12	11	35	71
3rd	**Comfort**	7	9	14	30	53
	Electric light	6	9	4	19	40
	Air quality	3	9	2	14	29
	Low noise levels	0	7	9	16	23
	Privacy	6	2	1	9	23
	Other (view)	1	0	0	1	3
	Other (music)	0	0	0	0	0
	Total	57	53	42	152	319

Note. *Ranking based on Weighted Average

In conclusion, the descriptive analysis indicated that the hypothesis that daylight is among the top three most important environmental factors contributing to reduced sleepiness. Therefore, the hypothesis was supported.

Analysis of the Ranking of Environmental Factors

The Pearson Chi-Square test was used to find out if there was significant difference in the ranking of environmental factors in terms of their ability to stimulate wakefulness and alertness. When the data was analyzed across all three sites, there was a statistically significant relationship between the frequencies of ranking of environmental variables (P=0.0000). The analysis was conducted per each facility. The findings confirmed there was a significant difference in the ranking of the environmental variables in terms of stimulating wakefulness and reducing sleepiness in the both the counseling (0.0003) and outpatient facility (P=0.0097) as well as the inpatient nursing unit (P=0.0000). In all facilities daylight was consistently ranked among the top three most important features; therefore, the hypothesis was supported (Table 4.12).

Table 4.12. Cross-tabulation table of ranking in all three facilities.

Site	*Ranking	Environmental factors	first	Second	Third	Total	DF	Pearson Chi-Square	P
All three facilities							16	76.9717	.0000
	1st	Daylight	17%	4%	3%	24%			
	2nd	Temperature	8%	9%	7%	24%			
	3rd	Comfort	4%	6%	7%	16%			
	4th	Electric light	3%	4%	4%	11%			
	5th	Air quality	2%	4%	3%	9%			
	6th	Low noise levels	0%	3%	4%	8%			
	7th	Privacy	2%	3%	2%	7%			
	8th	Music	0%	0%	0%	1%			
		Total	36%	34%	30%	100%			
Facility one (Counseling facility)							16	42.6232	.0003
	1st	Daylight	21%	5%	4%	30%			
	2nd	Temperature	6%	12%	9%	27%			
	3rd	Electric light	4%	5%	3%	12%			
	4th	Comfort	2%	3%	4%	9%			
	5th	Air quality	1%	3%	4%	8%			
	6th	Low noise levels	0%	1%	6%	7%			
	7th	Privacy	0%	5%	1%	6%			
	8th	View	0%	0%	1%	1%			
	9th	Music	1%	0%	0%	1%			
		Total	35%	34%	32%	100%			
Facility two (Outpatient health clinic)							16	32.1149	.0097
	1st	Daylight	17%	6%	4%	26%			
	2nd	Temperature	9%	8%	6%	22%			
	3rd	Comfort	4%	7%	6%	18%			
	4th	Electric light	0%	2%	6%	9%			
	5th	Air quality	3%	2%	3%	9%			
	6th	Privacy	1%	3%	4%	8%			
	7th	Low noise levels	1%	3%	1%	5%			
	8th	View	1%	1%	1%	2%			
	9th	Music	0%	0%	1%	1%			
		Total	35%	33%	32%	100%			

Note. *The rankings are based on non-weighted average and therefore they may differ from the descriptive study's ranking. The weighted average better reflects the importance of the environmental factors.

Table 4.12. Continued.

Facility three (Inpatient nursing unit)						14	49.5935	.0000
1st	Temperature	8%	8%	7%	23%			
2nd	Comfort	5%	6%	9%	20%			
3rd	Daylight	14%	3%	1%	18%			
4th	Electric light	4%	6%	3%	13%			
5th	Low noise levels	0%	5%	6%	11%			
6th	Air quality	2%	6%	1%	9%			
7th	Privacy	4%	1%	1%	6%			
8th	View	1%	0%	0%	1%			
	Total	38%	35%	28%	100%			

Post Hoc Analysis of the Responses

Figures 4.21, 4.22, 4.23 and 4.24 display the frequency of ranking in all three sites. The vertical access in these graphs shows the frequency of the selection of each environmental factor, regardless of which ranking they were selected (non-weighted). In the inpatient facility, the night shift nurses tended not to select daylight since it is not applicable to their setting. This is why the ranking of daylight has dropped to third in the non-weighted average displayed in the Table 4.12. If the day shift population were studied, the ranking of daylight increases to the first in this facility as well.

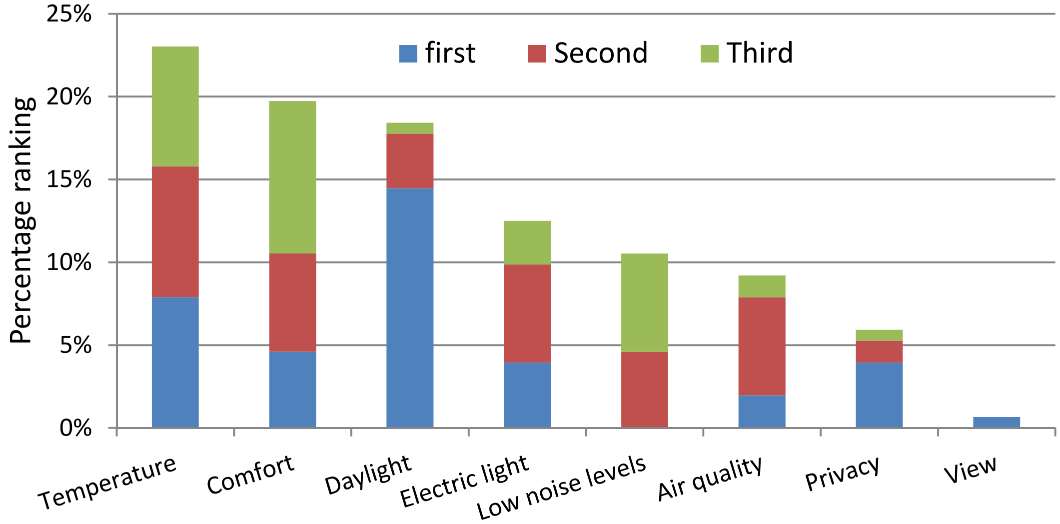


Figure 4.21. Frequency of ranking, facility three (inpatient nursing unit).

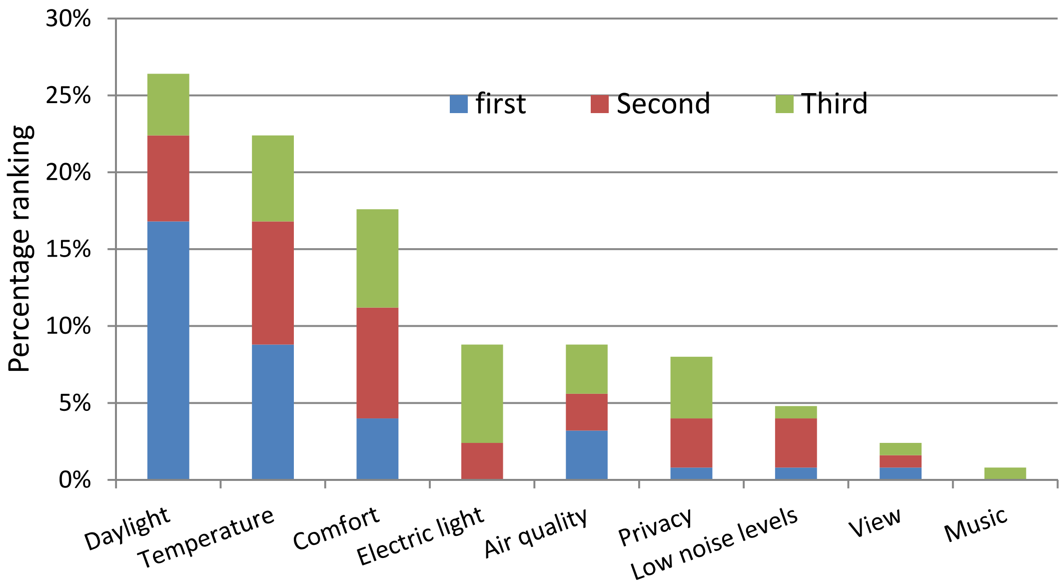


Figure 4.22. Frequency of ranking, facility two (health clinic).

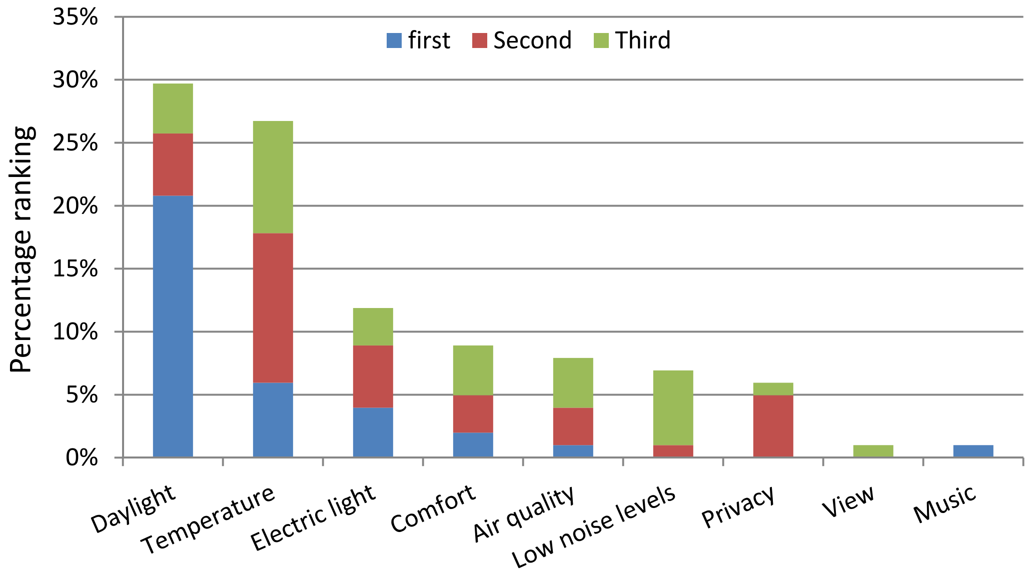


Figure 4.23. Frequency of ranking, facility one (counseling facility).

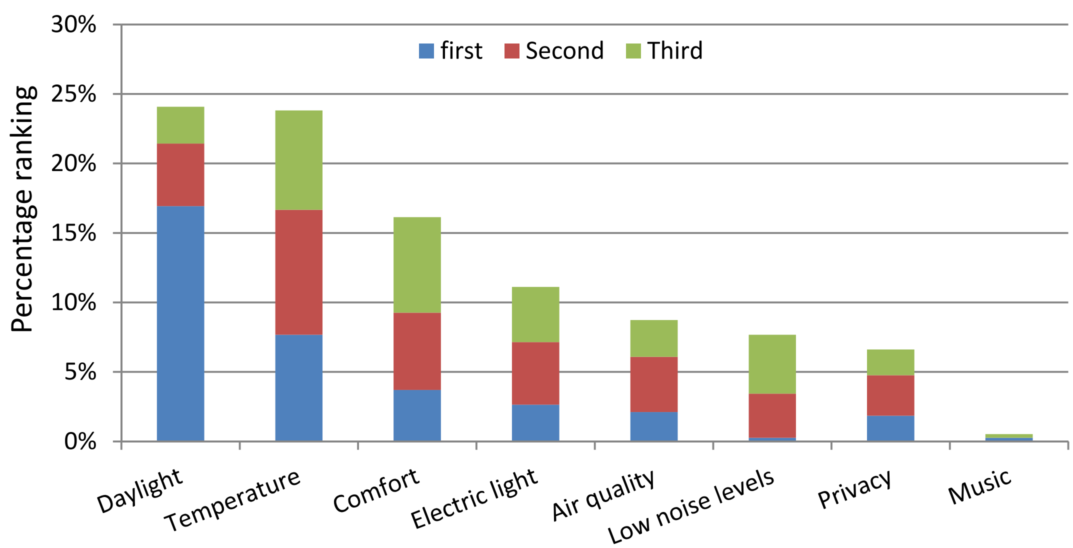


Figure 4.24. Frequency of ranking, all three facilities.

Hypothesis 3: Perceived Mood and Sleepiness

Figure 4.25 below displays the mean responses in the five mood categories for all three lighting conditions. The error bars display the 95% confidence interval, which means 5% extreme cases in each data are not included in the error bars according to SPSS 19.0.0.

As shown, the respondents reported a highly distinct difference in all categories under the three lighting conditions. The Figure depicts that the results of the categories of gloomy, sleepy and tired are even more considerable than the categories of irritable and tense. This may be because tense and irritable components of mood are more likely to be related to organizational and personal factors than the built environment.

Figure 4.26 6displays the mean responses in the category of sleepiness in three facilities for all three lighting conditions. The graph shows a reduction in sleepiness if daylight is available and, when both daylight and view are available.

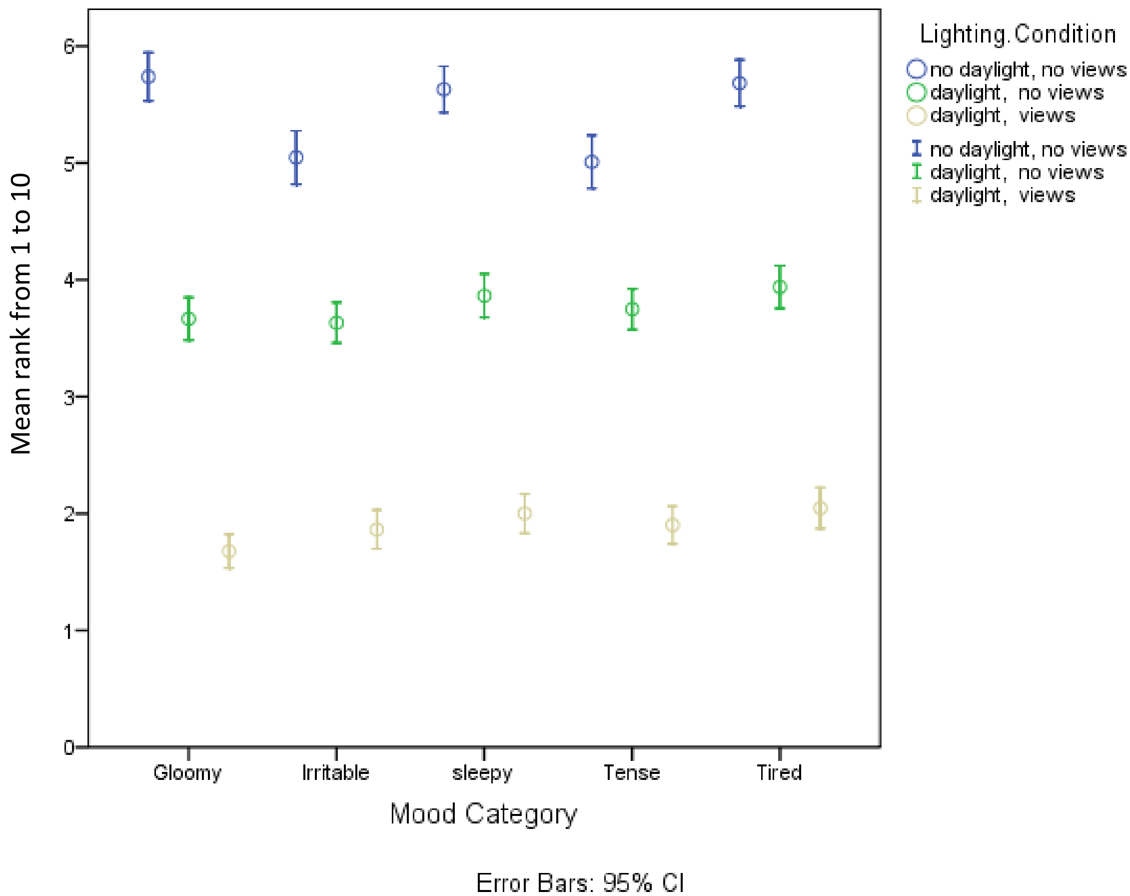


Figure 4.25. Average perceived mood.

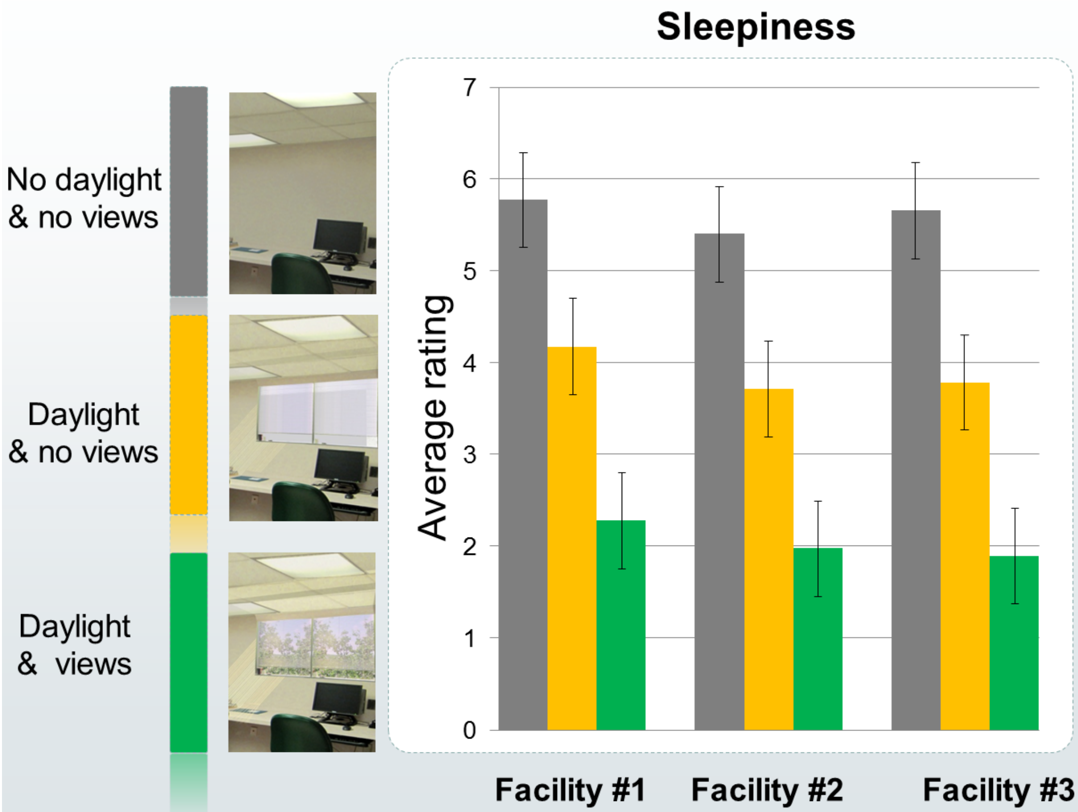


Figure 4.26. Average perceived sleepiness.

Figure 4.27 displays the mean responses by participants to five mood categories. If we consider the average responses to the categories indicate the overall mood state, it is visible that the mood state is improved in the presence of daylight and, daylight and view.

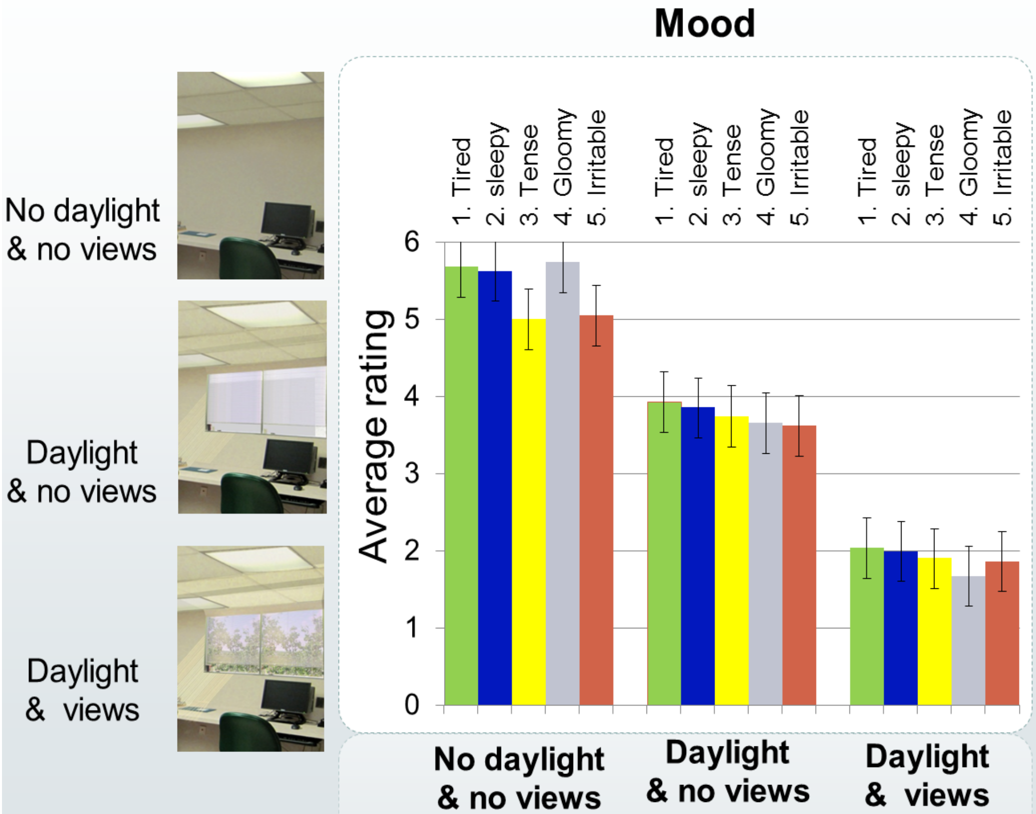


Figure 4.27. Average perceived mood per category.

Figure 4.28 demonstrate a consistent pattern in the responses of sleepiness and mood across all three sites. Therefore, the same descriptive finding on the reduction of sleepiness and improvement of mood is correct within every facility as well.

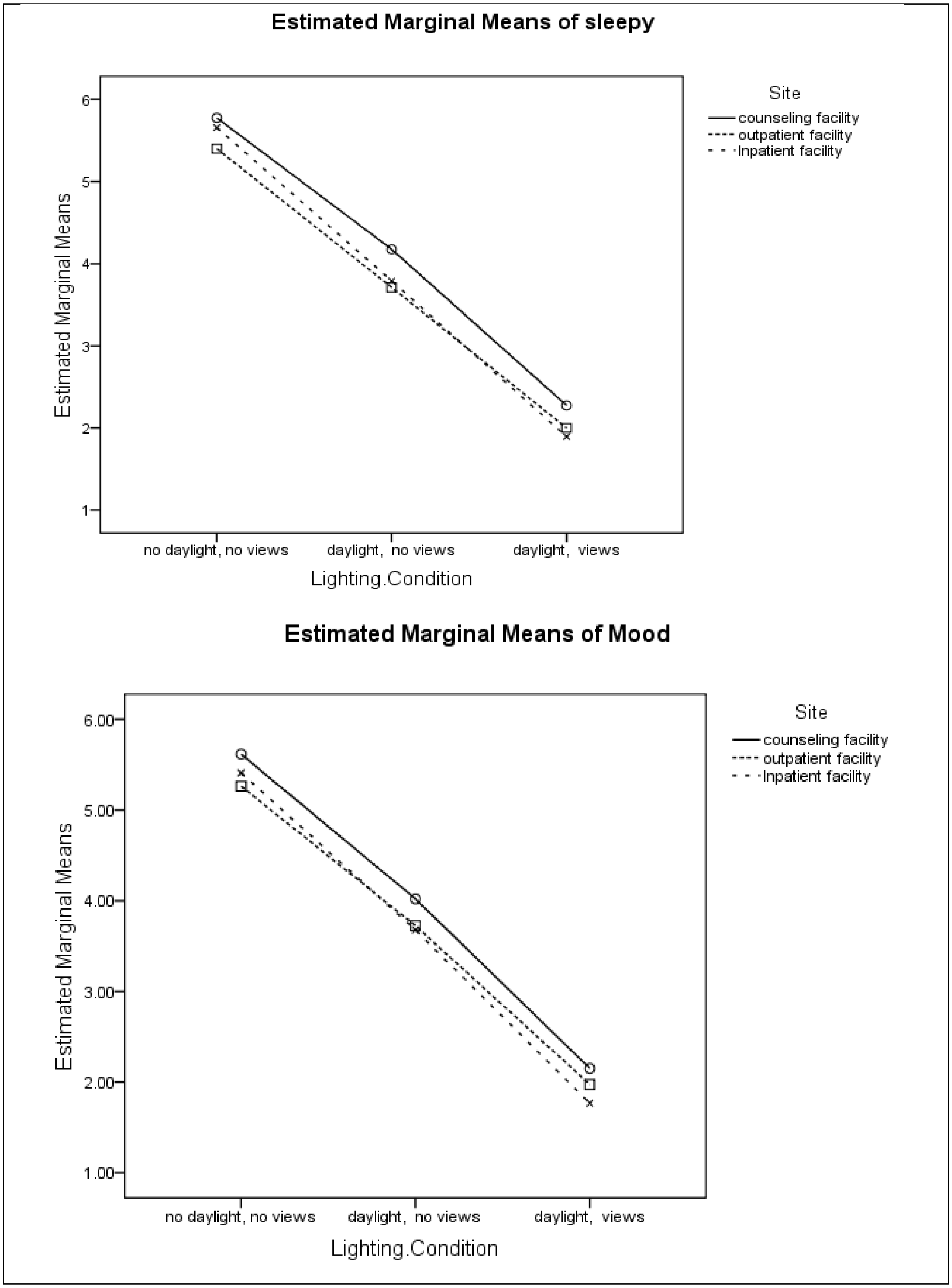


Figure 4.28. Estimated marginal means of sleepiness.

Analysis of the Perceived Mood and Sleepiness

It was hypothesized that participants report improved sleepiness and overall mood (sleepy, tired, gloomy, irritable, sad) if they work close to windows with daylight compared to windowless work spaces. Table 4.13 displays the five components of mood used throughout the entire sample and all sites (1,2 and 3). The participants were asked to imagine that they had some documentation to complete in a typical day when working in one of the three conditions shown in the images. Then they reported their mood (sleepy, tired, gloomy, irritable, sad) in a Likert scale (1 to 5).

One-way analysis of variance (ANOVA) method was used to first evaluate if there were a difference in the responses in the five categories under the three light conditions. Then, the conditions of equal variance and normality were investigated as follows.

Levene's test for homogeneity of variance was used to evaluate the equality of variances. ANOVA itself is robust to the violation of this assumption, according to the SPSS16 Tutorial, if the sample sizes are almost equal. However, this data will be useful to select the appropriate post-hoc ANOVA test to identify which lighting condition varied from the other two to test the main hypothesis. The Levene statistic rejected the hypothesis of equality of variances among three groups for the mood categories. In conclusion, a Post-hoc ANOVA for non-equal variances is appropriate.

The response variables were studied for normality using Histograms and Q-Q plots. The assumption of normality holds for all the nine response variables for the second lighting condition (daylight and no view), confirmed by the bell-shaped histograms and linear Q-Q plots. However, the data distribution for the first (no daylight, no view) and third (daylight and view) lighting condition are skewed (Appendix C) and are not normal. ANOVA is robust to the violation of this assumption in large sample sizes.

Table 4.13. Test of homogeneity of variances for mood components.

	Levene Statistic	df1	df2	Sig.
Tired	4.23	2	573	0.02
Sleepy	5.18	2	570	0.01
Tense	11.65	2	570	0.00
Gloomy	11.98	2	570	0.00
Irritable	10.60	2	567	0.00
Mood	4.00	2	573	0.02

As displayed in Table 4.14, a strong significant pattern was found similar to the responses of the five mood categories when the data was analyzed regardless of research site, gender, age group and title of participants (p_1= 0.0000, p_2= 0.0000, p_3= 0.0000, p_4= 0.0000, p_5= 0.0000). In addition, the same hypothesis was tested per each research site to study the variation of responses among these three types of facilities. Based on the table, the perceived sleepiness under the second lighting condition (daylight and no view) was reduced by 31% and under the third lighting condition (daylight and view) by 65%. Based on the responses to five mood categories, mood was improved by 31% under daylight and no view and by 65% under daylight and view. Therefore, the hypothesis was supported.

Table 4.14. ANOVA study comparing the differences among the environmental factor contributing to healthcare and counseling employees' health and performance.

Ranking	Environmental Factors	N. of subjects	Mean	SD	Reduced by	df	F	P
Tired								
						2 573	371.5211	0.0000
1st	no daylight, no views	203	5.6800	0.1020				
2nd	daylight, no views	203	3.9300	0.0930	31%			
3rd	daylight, views	203	2.0400	0.0890	64%			
Sleepy						2 570	375.7518	0.0000
1st	no daylight, no views	203	5.6200					
2nd	daylight, no views	203	3.8500	0.0940	31%			
3rd	daylight, views	203	1.9900	0.0850	65%			
Tense						2 570	263.4218	0.0000
1st	no daylight, no views	203	5.0000	0.1150				
2nd	daylight, no views	203	3.7400	0.0880	25%			
3rd	daylight, views	203	1.9000	0.0820	62%			
Gloomy						2 570	492.2766	0.0000
1st	no daylight, no views	203	5.7300	0.1060				
2nd	daylight, no views	203	3.6500	0.0930	36%			
3rd	daylight, views	203	1.6700	0.0730	71%			
Irritable						2 567	269.2861	0.0000
1st	no daylight, no views	203	5.0500	0.1170				
2nd	daylight, no views	203	3.6200	0.0870	28%			
3rd	daylight, views	203	1.8600	0.0840	63%			
Overall Mood						2 573	460.4923	0.0000
1st	no daylight, no views	203	5.4109	0.0900				
2nd	daylight, no views	203	3.7599	0.0805	31%			
3rd	daylight, views	203	1.8969	0.0745	65%			

Table 4.15. Perceived mood and sleepiness per research site.

Ranking	Environmental Factors	N.	Mean	SD	df	F	P
Counseling facility							
1st	Tired	40	5.8800	0.2510	2	52.7208	0.0000
		40	4.3500	0.2280	117		
		40	2.4800	0.2240			
2nd	Sleepy	40	5.7800	0.2570	2	57.7650	0.0000
		40	4.1800	0.2370			
		40	2.2800	0.1930	117		
3rd	Tense	40	5.4800	0.2370	2	55.2960	0.0000
		40	3.9800	0.2160			
		40	2.0800	0.2330	117		
4th	Gloomy	40	5.5800	0.2840	2	66.7758	0.0000
		40	3.7800	0.2190			
		40	1.8200	0.1710	117		
5th	Irritable	40	5.3800	0.2520	2	49.6970	0.0000
		40	3.8200	0.2200			
		40	2.1000	0.2230	117		
	Mood	40	5.6150	0.2311	2	70.2171	0.0000
		40	4.0200	0.1962			
		40	2.1500	0.1913	117		
Outpatient facility							
1st	Tired	46	5.5200	0.1910	2	78.4077	0.0000
		46	3.7400	0.2050			
		46	2.1100	0.1820	135		
2nd	Sleepy	46	5.4100	0.2030	2	73.4275	0.0000
		46	3.7200	0.2150			
		46	1.9800	0.1830	135		
3rd	Tense	46	4.8000	0.2560	2	49.1927	0.0000
		46	3.7000	0.1840			
		46	1.9800	0.1570	135		
4th	Gloomy	46	5.7200	0.2100	2	105.9022	0.0000
		46	3.7800	0.2060			
		46	1.7600	0.1560	135		
5th	Irritable	45	4.8700	0.2450	2	54.0767	0.0000
		45	3.6700	0.1740			
		45	1.9600	0.1680	132		
	Mood	46	5.2674	0.1759	2	97.3294	0.0000
		46	3.7196	0.1771			
		46	1.9522	0.1500	135		

Table 4.15. Continued.

Inpatient facility							
1st	Tired	106	5.6700	0.1350	2	261.1534	0.0000
		106	3.8500	0.1110			
		106	1.8400	0.1080	315		
2nd	sleepy	105	5.6600	0.1280	2	261.7019	0.0000
		105	3.7900	0.1090			
		105	1.9000	0.1110	312		
3rd	Tense	105	4.9000	0.1490	2	164.9416	0.0000
		105	3.6700	0.1120			
		105	1.8000	0.0980	312		
4th	Gloomy	105	5.8000	0.1310	2	340.6414	0.0000
		105	3.5500	0.1160			
		105	1.5700	0.0940	312		
5th	Irritable	105	5.0000	0.1550	2	169.6575	0.0000
		105	3.5200	0.1120			
		105	1.7300	0.1030	312		
	Mood	106	5.3962	0.1149	2	97.3294	0.0000
		106	3.6792	0.0992			
		106	1.7774	0.0927			

Research sites. ANOVA test was also performed separately for each research site (Table 4.15). The result for all three sites (the counseling facility, the outpatient facility and the inpatient facility) were similar. Strong significant difference was consistently found among the reported responses under the three lighting conditions in all three sites for the five mood categories (p_{sleepy}= 0.0000, p_{tired}= 0.0000, p_{gloomy}= 0.0000, $p_{irritable}$= 0.0000, p_{tense}= 0.0000) as well as overall mood (p_{mood}= 0.0000).

Tamhane's T2 Post hoc test, appropriate for data with non-equal variances, was employed to test the hypothesis of whether or not the lighting categories, which provide daylight, resulted in better overall mood and reduced sleepiness compared to the windowless category (Table 4.16). The results consistently showed the remarkable difference among the three lighting categories. In all cases, the lighting condition with daylight and nature view would improve mood and reduce sleepiness more than the lighting category with daylight and no view. Both categories with daylight showed improved mood and reduced sleepiness compared to the category without window (no daylight, no view). Therefore, the null hypothesis was rejected and the *a priori* hypothesis was supported (P=0.0000).

Table 4.16. Post hoc Tamhane multiple comparison test.

Dependent Variable	(I) Lighting Condition	(J) Lighting Condition	Mean Difference (I-J)	Std. Error	Sig.
Tired	no daylight, no views	daylight, no views	1.7500	0.1375	0.0000
	no daylight, no views	daylight, views	3.6406	0.1348	0.0000
	daylight, no views	daylight, views	1.8906	0.1283	0.0000
Sleepy	no daylight, no views	daylight, no views	1.7696	0.1378	0.0000
	no daylight, no views	daylight, views	3.6283	0.1324	0.0000
	daylight, no views	daylight, views	1.8586	0.1267	0.0000
Tense	no daylight, no views	daylight, no views	1.2618	0.1448	0.0000
	no daylight, no views	daylight, views	3.0995	0.1410	0.0000
	daylight, no views	daylight, views	1.8377	0.1204	0.0000
Gloomy	no daylight, no views	daylight, no views	2.0785	0.1407	0.0000
	no daylight, no views	daylight, views	4.0628	0.1285	0.0000
	daylight, no views	daylight, views	1.9843	0.1182	0.0000
Irritable	no daylight, no views	daylight, no views	1.4263	0.1458	0.0000
	no daylight, no views	daylight, views	3.1842	0.1438	0.0000
	daylight, no views	daylight, views	1.7579	0.1214	0.0000
Overall mood	no daylight, no views	daylight, no views	1.6510	0.1208	0.0000
	no daylight, no views	daylight, views	3.5141	0.1168	0.0000
	daylight, no views	daylight, views	1.8630	0.1097	0.0000

Post Hoc Analysis of the Perceived Mood and Sleepiness

Comparison between gender. The analysis of variance (ANOVA) showed both female and male respondents reported mood and sleepiness under three light levels similarly. The mean rank of 8 out of 9 variables was not statistically different for female and male participants. The mean rating of sleepiness and mood in female respondents was slightly but consistently more sensitive to the lighting conditions as the following Figure indicate (Figure 4.29).

Consistently, in all categories the windowless condition (reference case) was much more effective in inducing sleepiness and deteriorated mood.

Multivariate test was used to identify the effects of gender on the participants' responses under the three lighting condition (Table 4.17). The analysis indicates gender had no significant effect on responses (P= 0.83).

Comparison among age groups. The effect of age on mean responses of mood and sleepiness was studied to explore its importance in healthcare and counseling facilities.

Table 4.17. Gender variations, Multivariate tests (Pillai's Trace).

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept		.890	8.973E2	5.000	557.000	.0000
Lighting.condition	Pillai's Trace	.601	47.888	10.000	1116.000	.0000
Gender	Pillai's Trace	.004	.451[a]	5.000	557.000	.8130

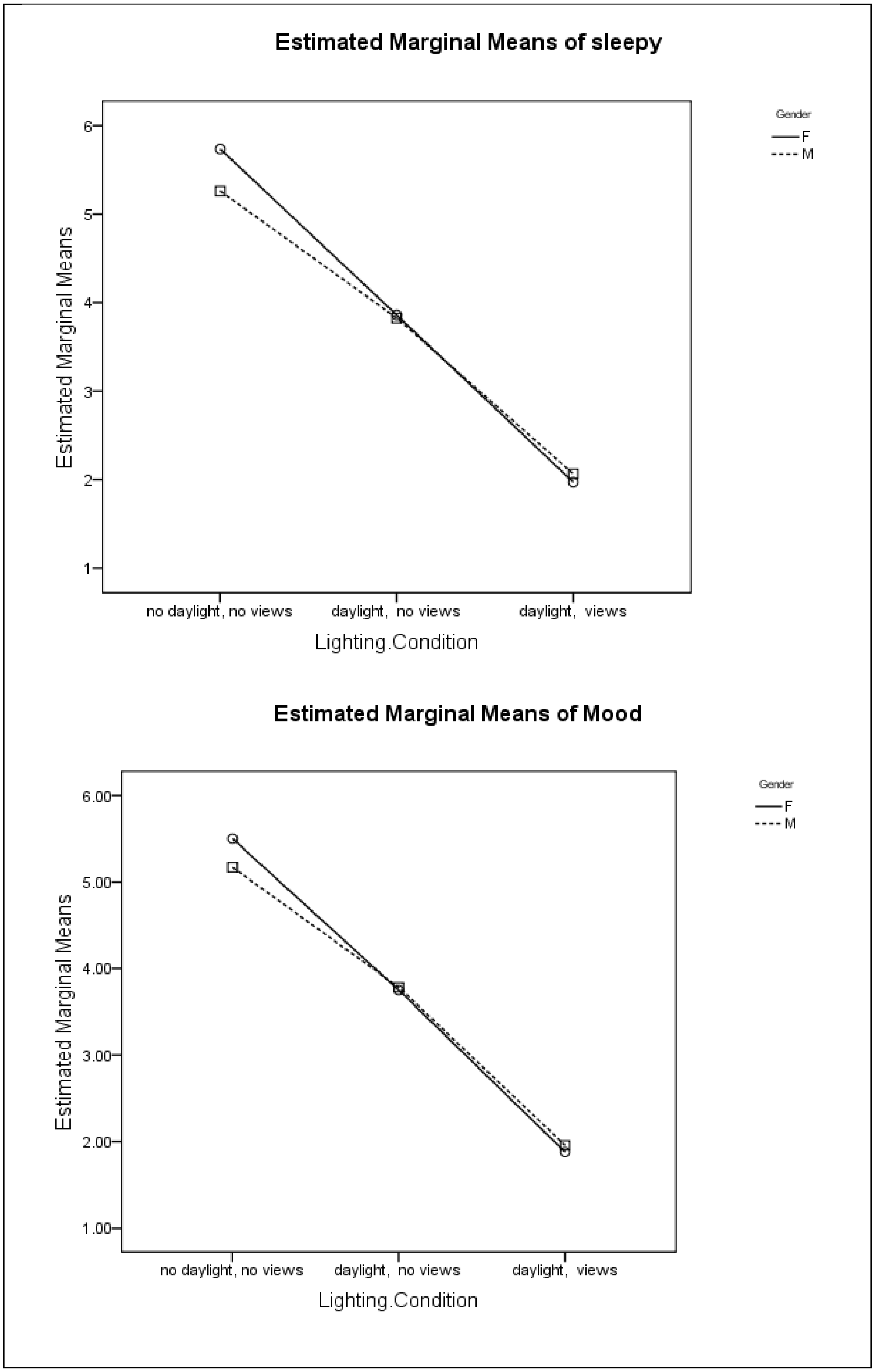


Figure 4.29. Gender variations of perceived mood and sleepiness.

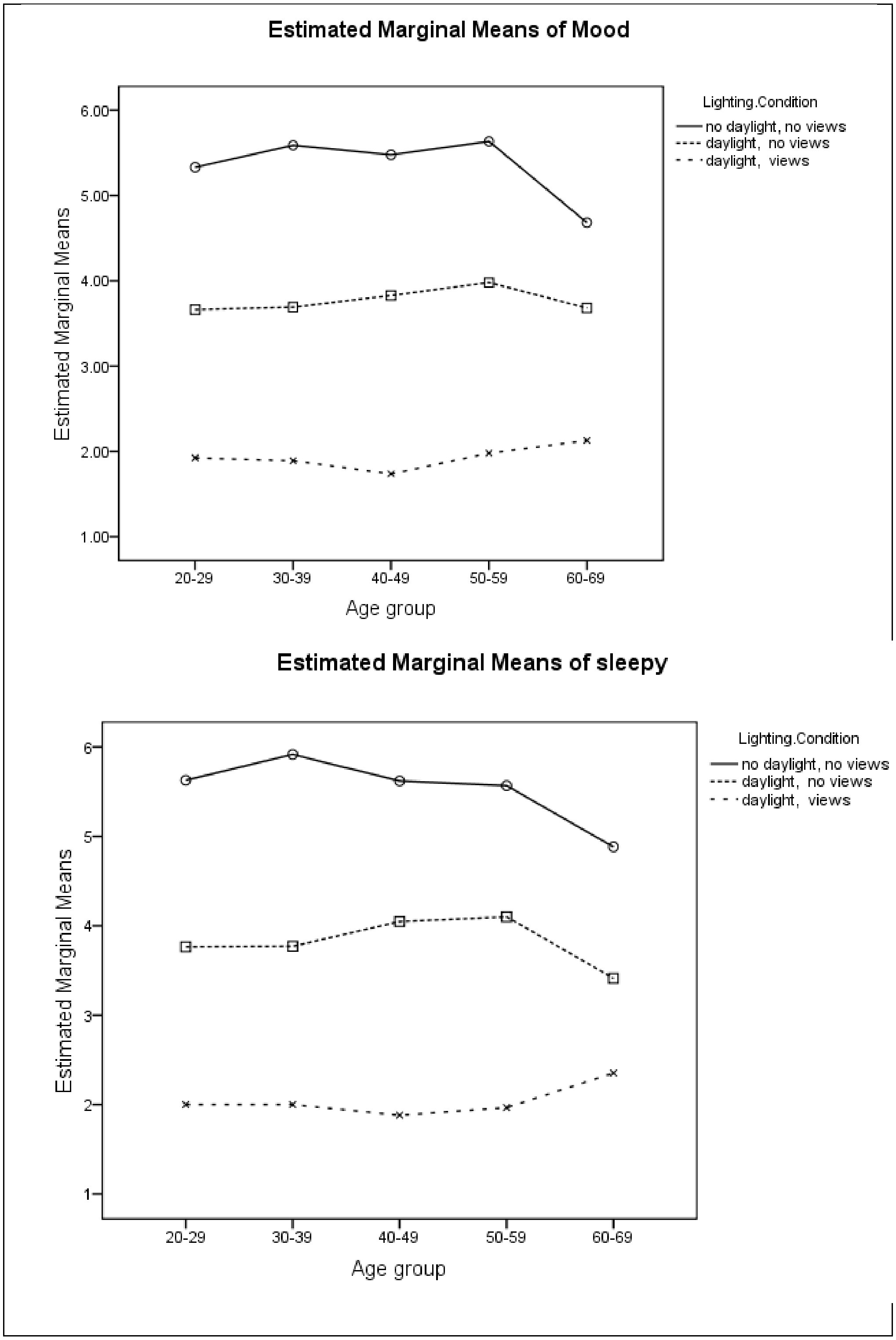


Figure 4.30. Mood and sleepiness by age group.

Figure 4.30 demonstrates no distinct pattern between the responses of mood level and sleepiness among different age categories. Multivariate analysis showed there was no significant difference in the responses under the three lighting conditions based on age (Table 4.18).

Table 4.18. Age variations, Multivariate tests (Pillai's Trace).

Effect	Value	F	Hypothesis df	Error df	Sig.
Intercept	.9050	0.001034	5.000	545.000	.000
Lighting condition	.6390	51.2410	10.000	1092.000	.000
Age	.0310	.8490	20.000	2192.000	.653

Qualitative Results: Overview of Wakefulness Strategies

Providing a comprehensive image of both environmental and non-environmental strategies to maintain vigilance, alertness and wakefulness helps designers and administrators improve these measures. Design professionals, specifically, can explore the role of built environment to support all these strategies. Facilities so designed can play an important role in supporting both environmental and organizational solutions because people’s activities in buildings are usually enabled or disabled by the built environment around them.

Analysis of the Descriptive Responses

Survey responses from three facilities revealed coping with sleepiness to be a common behavior response among healthcare/counseling employees. They work long hours mainly in windowless spaces under constant environmental conditions such as light, temperature and air flow which can create monotonous surroundings. “I yawn throughout the day, constantly excusing myself, usually relying on caffeine but it is not always effective.” “Oh yes. Sleepiness is a big deal! I could drop down on the floor!” explained two RNs who provide direct patient care in two different facilities. Although in this survey question only non-environmental strategies were addressed, many of the responses directly had to do with creating an environmental change or leaving the workplace for an environmental change. Other strategies such as walking or interpersonal interaction are also indirectly affected by the built environment.

To maintain wakefulness and limit sleepiness, strategies listed include taking short breaks, self-medicating with caffeinated drinks, having cold soft drinks, changing position, stretching, walking, leaving the work area to walk around, talking with co-workers, listening to specific music, going outside, looking outside, changing light, temperature or airflow, changing tasks, washing one’s face, using tobacco, adjusting sleep, exercising, or dieting outside work time, or even taking a power-nap at work. Table 4.19 summarizes the category of responses and their frequencies.

Table 4.19. Wakefulness coping strategies.

Response category	Frequency	Percentage
Caffeinated drinks (coffee, tea,& energy drinks), soda (Coke & Pepsi)	105	61%
Leave work area to walk around, visit a coworker or other certain areas	81	47%
Stay active, stay busy or increase activity	25	15%
Cold liquids, water, fruit juice, punch, or Gatorade	23	13%
Go outside (to get fresh air, see sun or get daylight), look at outside	21	12%
Exercise, stretch, or change positions	19	11%
Have food, snacks (sweet snacks, chocolate candy, fruits), vitamin pills or chew gum	15	9%
Switch tasks or help others	12	7%
Talk to colleagues/co-workers	11	6%
Listen to specific music	7	4%
Environmental changes (such as increasing light, changing temperature or airflow)	7	4%
Get proper rest at night	6	3%
Just a short break	5	3%
Other (Wash face, use tobacco, eat right, game on computer, work out after work)	5	3%
Do not drink coffee or eat to stay wakeful	4	2%
Take a mini nap at work	3	2%
Push through	2	1%

Caffeine intake. More than 60% of the respondents directly pointed to caffeine intake as a coping mechanism for maintaining wakefulness in the workplace. A technician, in response to the question of how sleepiness can be reduced using non-environmental mechanisms, responds "Coffee, coffee, coffee, a walk to see daylight."

Walking around. About 47% of participants believed walking around and briefly leaving the main work area, visiting a coworker, or a location (for example water fountain) would be the second most used strategy to reduce sleepiness.

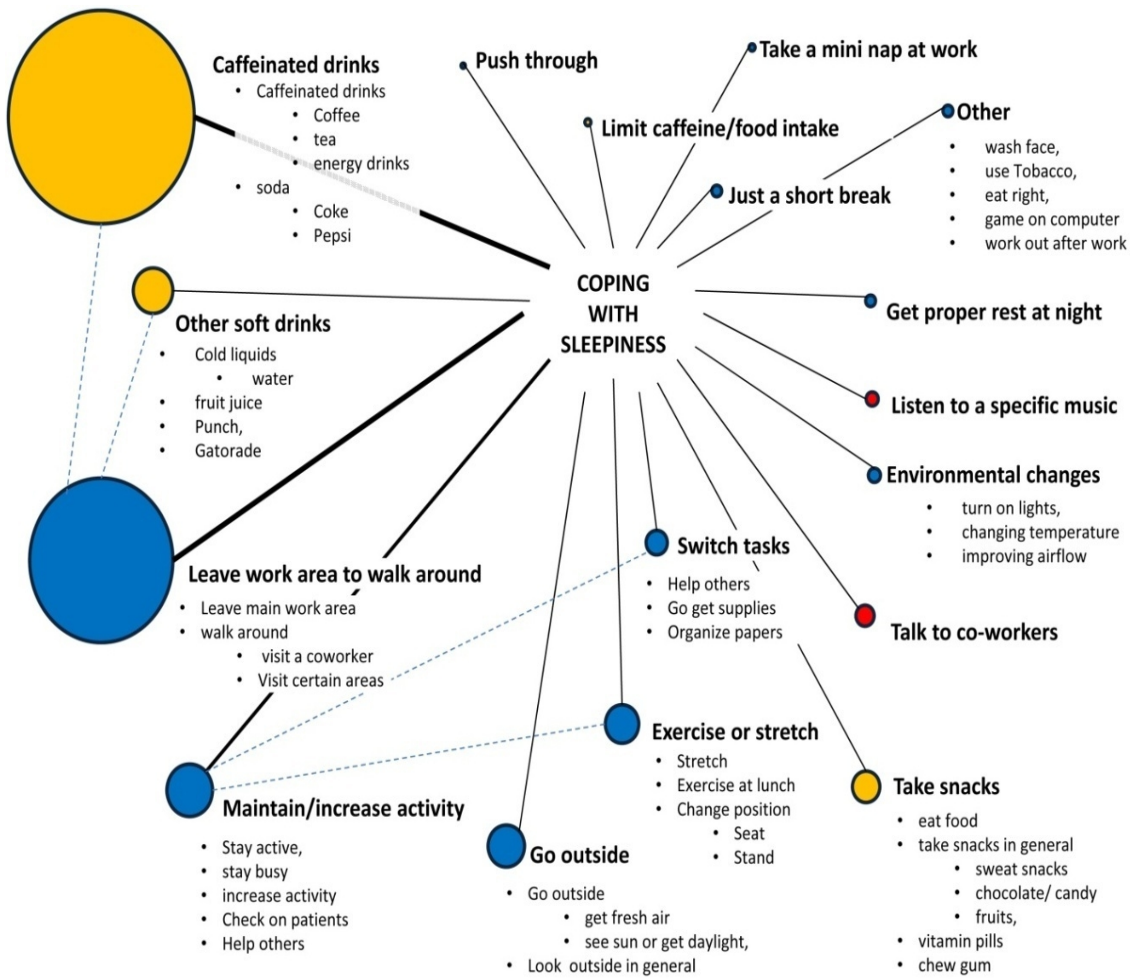
The responses like “walk around to get a drink” or “walk to water fountain” which indicate leaving the workplace to get coffee or water, may not only refer the importance of caffeine or water in helping with sleepiness but also emphasize the action of ‘going to purchase or make coffee’. This will help break monotony and stimulate energy. Therefore, a link exists between the categories of getting caffeinated drinks and getting up to walk around or go to a destination. The linkages among categories are displayed in Figure 4.31.

Stay busy /increase activity or switch tasks. Participants also consistently highlighted the importance of maintaining activity during the slow time, or increasing activity by “helping other co-workers,” “walking to patient rooms,” “getting up and checking on patients,” “walking to another unit to get supplies,” “finding some kind of project to keep busy on down time" and “walking to stations to put up papers.” These activities can also be categorized as ‘a shift in tasks’. For example, unit monitor technicians need to occasionally leave the monitor room to nurse stations to place printed documents in the patient-charts. One monitor tech mentioned “walking to stations to put up papers,” uses this activity, as a waking mechanism and performs it when he needs a stimulating change. Figure 4.31 displays the linkage between ‘increasing activity’ and ‘changing tasks’.

Change in environmental factors. Many responses involved an intervention in the surrounding environment, for example, "turning on the light," or "standing in front of the fan," "regulating office temperature," "listening to music." It is notable that only a few work environments provided control over light, temperature, air quality, or playing music. Some others pointed at leaving their designated workplace for an environmental change such as "a walk to see daylight," "go outsides to see the sun," "brief walk outside on the breezeway for fresh air," "breaks of fresh air," "go far at lunch" or "walk to other areas."

Social interaction. Interaction and talking with co-workers was mentioned in 6% of the responses. Based on participants' observations during the data collection, engaging in a positive social interaction such as telling a joke to a coworker and laughter, seemed to be a common and effective behavior to maintain energy, vigilance and alertness. However, no participant directly identified positive interaction or laughter as their coping technique.

Other coping techniques. Only one participant referred to using tobacco a solution for sleepiness (less than 1%). However, during the time spent with the participants, the researchers' understanding was that this behavior response would be used by more than one participant.



Note. the size of the circles for each category explains the frequency responses in that category.

Figure 4.31. Coping mechanisms for maintaining wakefulness and limiting sleepiness in healthcare and counseling workplace based on content analysis.

Other responses. Only 4% of the respondents stated that sleepiness was not a common problem to cope with in their work condition. From this 4%, two participants said their job requires them to move around and not stay at one place, which may be why they do not have much trouble with sleepiness. One participant said "I don't have a sedentary job so I rarely have that kind of problem. ” Other added “My job tasks allow me to move around. Since I am out of my office, I do not get sleepy.” Two individuals stated that they were too busy or did not have time to be sleepy. One individual stated that sleepiness would not be an issue in the busy winter season. “I don’t get sleepy in the winter time which is busy.” A night shift registered nurse also pointed to down times at night and her coping mechanisms to maintain wakefulness. “I keep myself awake on slower nights by getting up and moving around."

One participant stated that sleepiness was not an issue but tiredness was. Then he/she informed the researchers about the need for an additional work area to reduce frustration and tiredness. "I feel having more room for privacy and a designated admission/interview area for each doctor or set of doctors would help frustration immensely because the admission wait time would be dramatically reduced and there would be a room for each patient needing care (obviously directed for our busiest seasons).”

As mentioned in the methods section, the study was only open to fulltime employees working at the three facilities. A number of part time student employees filled out the surveys in each of the three facilities, but their responses were not included in the analysis and were studied separately. To cope will sleepiness and maintaining wakefulness, one of the part-time student employees suggested playing “games like Sudoku, or crosswords to get one to concentrate or to read" when not busy. This is an interesting statement because the suggested coping mechanism still aimed to maintain energy and wakefulness using a subsidiary activity.

Discussion of the Findings

Summary of the Findings

Environmental factors for an ideal workplace. This study identifies the most important environmental factors that impact healthcare and counseling employees. The findings point to a strong, coherent, significant pattern of ranking among the participants from all three sites in all age groups and occupations.

The results indicate the employees' ideal work spaces respect personal privacy, provide adequate work areas, control unwanted noise and assure thermal comfort. In addition, the study demonstrates the employees' need for comfortable and ergonomic furniture.

The post hoc analysis shows that certain of these design factors were valued differently among the three facilities. Providing workspaces with private areas was most highlighted in the counseling facilities, followed by outpatient facilities. Other factors over rode the importance of privacy in inpatient acute care work areas. This may be explained by the necessity that the staff be visible and have easy access to their acute patients in order to best perform their jobs. This requirement does not undermine the fact that privacy allows staff to focus on demanding tasks, such as medication dispensing or charting, thus reducing medical errors.

Second, the role of electric lighting was determined to be more important in the impatient acute care unit as compared to outpatient and counseling spaces. This may be explained by the need for night shift work which is not utilized at the other sites. Also, the fact that there were more windowless spaces in the inpatient facility as compared to the other two facilities, contributed to making electric lighting a more common source of vision to task.

Third, the workplace size was more emphasized by inpatient facility staff than by the staff of either of the other facilities. Some of this emphasis may be based on the fact that in this particular acute inpatient unit the charting surfaces and work areas were very limited, which further emphasized the need for more space. The director of the outpatient facility suggested that adequate workspace is more important in clinical areas than in counseling areas because separate spaces for exams areas are required in clinical areas and there must be enough room for the caregiver to move around the patient's bed.

In summary, privacy, appropriately sized workspace and electric lighting have different weights in inpatient, outpatient and counseling work environments. As one size does not fit all, this points to the important role of designers in providing the right design response for each setting,

The remaining six variables, air quality, noise, view of nature, daylight, comfort and temperature, were equally important in all three sites.

Environmental Factors Impacting Alertness. As hypothesized, daylighting was identified among the top three environmental factors which support wakefulness and alertness. Environmental temperature, comfort and ergonomics were the next design factors limiting sleepiness and improving wakefulness. View of the outside and access to music were two factors not provided to the participants for ranking. However, these factors were continously mentioned by the participants as providing wakeful qualities.

The impact of windows on wakefulness and mood. The findings support the hypothesis that the presence of daylight can improve wakefulness and reduce sleepiness. The evaluation of five mood categories showed that mood could be elevated 31% with daylight and no view and by 65%r with daylight and view. From the five mood categories it was found that the categories of gloomy, sleepy and tired were much more highly affected by windows than were the categories of tense and irritated.

We found that a window with a nature view had twice as many positive impacts as a window with no view (looking at a white wall). The benefits of nature view on improved mood and wakefulness may be described by Kaplan's "micro-restorative experience" (Kaplan, 1993, p. 196). The natural view provides restoration and therefore improved performance (Kaplan, 2001) for the healthcare staff.

The above mentioned sections describe the environmental factors contributing to wakefullness and sleepiness. The following section expands this topic to non-environmental factors. All other coping techniques concerning sleepiness and wakefulness have been described by directly quoting the particpants.

Wakefulness strategies. Almost all employees in healthcare and counseling environments use coping techniques to minimize sleepiness and increase alertness. Many of the coping responses had to do with creating change or reducing monotony. Some involved a change in the surrounding environmental conditions or leaving the designated workspace to experience a change in the environmental conditions. Strategies such as walking around or interaction also were motivated indirectly by needing a change in the built environment: for example, “leave office to go walk to someone else’s for a change of scenery.”

The remaining coping techniques were sometimes accompanied with leaving the work environment: for example, “go get coffee or sweet snacks,” “go lay down on a couch for a brief moment.” In such cases these actions of getting coffee or stretching resulted in an environmental change.

The underlying response to maintaining wakefulness and vigilance may therefore be creating some external stimulation and change which can emerge in different forms, “like look outside” or “have candy/chocolate.” All these forms of behavior can be categorized as subsidiary activities which benefit work quality without being directly related to work activities (Takanishi, et al., 2010).

Literature explains that alertness, wakefulness and cognitive performance during the day and night are predicted by circadian biological rhythms via neuro-hormonal pathways. These rhythms are adjusted by time and duration of night sleep (Horowitz, Cade, Wolfe, & Czeisler, 2001), physical activity (Redlin & Mrosovsky, 1997), social clues (Aschoff, Fatranska, Giedke, Doerr, Stamm, & Wisser, 1971), social interaction and food intake (Duffy, Kronauer & Czeisler, 1996), although lighting is the principal and most important circadian synchronizer (Duffy, Kronauer & Czeisler, 1996; Youngstedt, Kripke, Elliott, Rex, 2005). Further explanation may be found in neuroscience and psychology as to how such behaviors found in the current study increase vigilance and wakefulness. Table 4.20 displays those coping strategies which directly create a change in environment and escape from monotony.

Table 4.20. Wakefulness coping strategies related to environment.

Response category	Resulted in direct change in the surrounding environment	Occasionally accompanied by a change in the surrounding environment
Caffeinated drinks (coffee, tea,& energy drinks), soda (Coke & Pepsi)		x
Leave work area to walk around, visit a coworker or other certain areas	X	
Stay active, stay busy or increase activity		x
Cold liquids, water, fruit juice, Punch, or Gatorade		x
Go outside (to get fresh air, see sun or get daylight), look at outside	X	
Exercise, stretch, or change positions	X	
Have food, snacks (sweet snacks, chocolate/ candy, fruits)vitamin pills or chew gum		x
Switch tasks or help others		x
Talk to colleagues/co-workers		x
Listen to a specific music	X	
Environmental changes (such as increasing light, changing temperature or airflow)	X	
Get proper rest at night		
Just a short break		
Other (Wash face, use tobacco, eat right, game on computer, work out after work)		x
Do not drink coffee or eat to stay wakeful		
Take a mini nap at work		
Push through		

Below further discussion is provided some of which result in hypotheses generation for future studies.

Built environment possibly correlated with caffeine craving. The results of this study show that caffeine intake and mainly, having coffee, is a coping mechanism to maintain wakefulness in healthcare and counseling environments (Figure 4.32). If the built environment supports wakefulness, the need for caffeine self-medication may be reduced, and this way the occupants' health can be positively impacted. Based on available evidence we know that the feeling of sleepiness and reduced alertness can be predicted by physical environment, namely by lighting (Moore-Ede, Sulzmann & Fuller, 1982; Vondrasova et al. 1997; Hätönen, 2000 ; Kent et al., 2009), temperature (Mavjee & Horne, 1994) noise levels, or posture (Van Dongen and Dinges 2005). Therefore, we conclude there may be a link between the wakeful qualities of workspace design and the frequency of caffeine intake among healthcare and counseling employees.

Previous research which directly links frequent light exposure to caffeine and carbohydrate craving (Krauchi et al., 1990) is another confirmation for this notion. Creating an "alert" space will not only help the participants stay alert but also may potentially improve dietary intake by reducing caffeine consumption. Further research to confirm this conclusion is required.

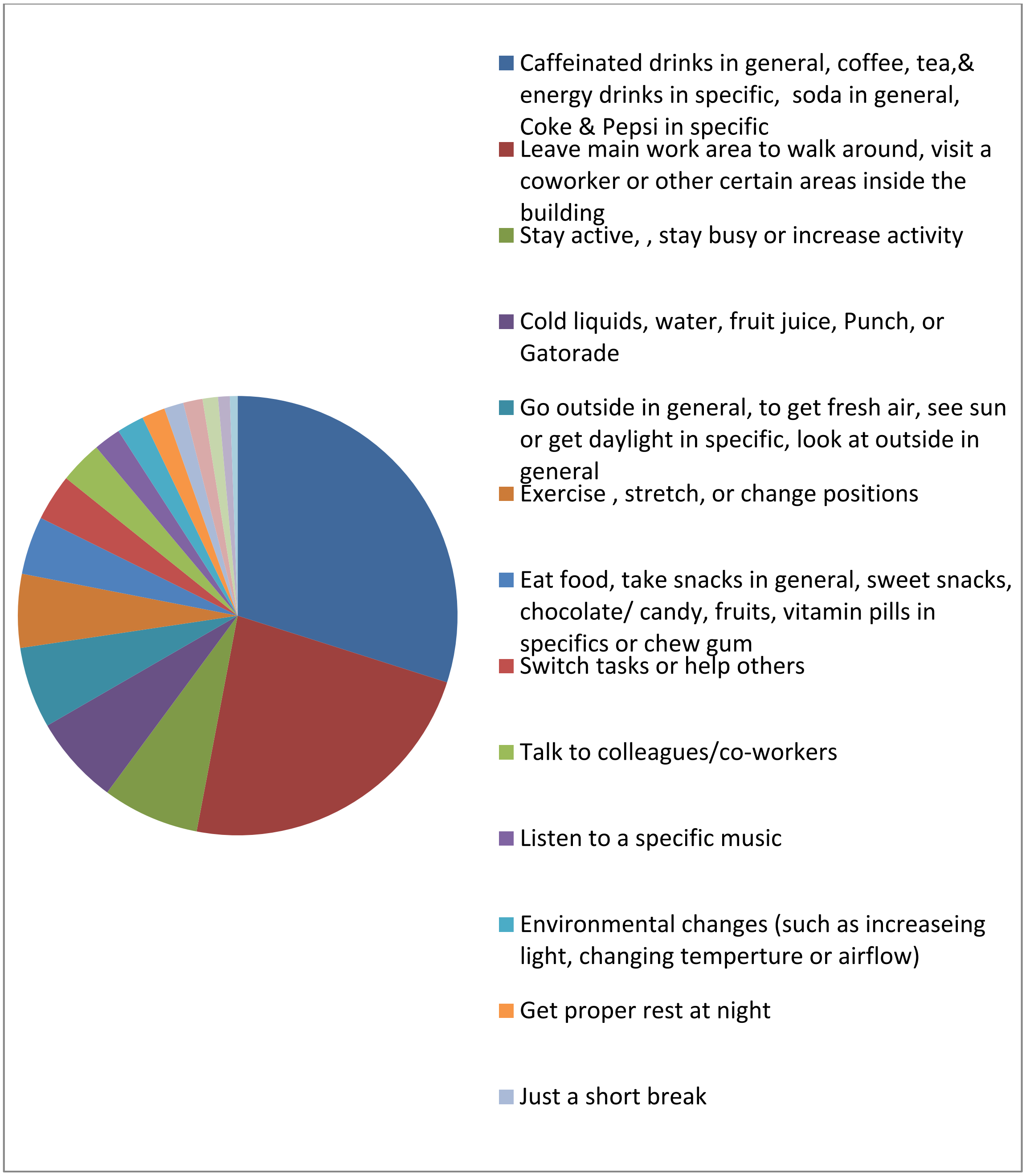


Figure 4.32. Percentage of coping responses to sleepiness, in healthcare and counseling workplaces.

Employees' need for a meditation area. A young employee explained that he/she manages sleepiness mainly by increasing caffeine intake and walking around. He/she added "I have a new baby at home which makes me sleepy, so getting more sleep at night is a good strategy. I wish I had time/space for a nap." A "nap space" or "nap time" was mentioned by a number of participants. A bad night's sleep happens to everyone! Such an occurrence could be addressed by a work environment designed to enhance vigilance and alertness. A meditation room would enable employees to obtain their maximum potential performance, and would provide a cushion for workplace safety in healthcare.

Some respondents explained that if their work condition does not allow coping strategies due to time or space limitations, they "just push through." A nurse described that he/she goes "outside for a brief time if time allows." Another respondent stated that she takes a short break on a couch, otherwise, "I just push through since I don't drink coffee."

By supporting awakening and energizing strategies, built environments can create the safety cushion to prevent sleepiness from reaching the point that could create a safety menace to caregivers and receivers.

Employees' need for outdoor areas for lunch and walking. Lunch time was highlighted by a number of participants as the time when sleepiness/wakefulness coping strategies can occur. A healthcare/counseling administrator emphasized that walking around and listening to music helps with wakefulness during work hours. This administrator added, "I exercise at lunch and that really helps!" Another administrative staff, in addition to eating sweet snacks and changing position at the workstation, suggested it is good to “go far by walking outside at lunch” to limit sleepiness. Therefore, healthcare and counseling facilities that provide easy access to appropriately designed outdoor areas for eating lunch or having a brief walk can considerably help with wakefulness and freshness of their employees.

Ultimately, the occurrence of sleepiness, which can be related to human biological rhythms adjusted by environmental stimuli, should not be ignored. Facilitating coping strategies at personal, organizational and environmental levels can be an effective approach to reduce sleepiness, improve alertness and elevate vigilance. The built environment plays a key role in supporting these coping strategies to maintain wakefulness and vigilance and, therefore, improving safety and quality.

Strengths and Limitations of the Study

The study was conducted at three facilities. The consistency of the responses among the three sites confirms the external validity of the results.

The current design conditions of each site could be a limiting factor for the findings and conclusions. For example, the participants in the inpatient facility highlighted the importance of workplace size. Repeating this research in other inpatient and outpatient facilities could determine if the size of workplace is a unique nature of inpatient work spaces, or was specific to the participating facility. In addition, the ratio of job titles in the third facility was such that most participants were registered nurses providing direct care. Therefore, the overall conclusion may be weighted toward the nurses' needs rather than the mix of all other occupations such as unit director or pharmacist.

The measurements of perceived sleepiness and wakefulness might have improved if more than three images were shown to the participants. Ideally, at least six images with several variations would be shown so that the variable of interest (windows) would not be easily identified (Stephanie Schwindel, personal communications, November 2010; Roger Ulrich, personal communications, 2010).

Finally, the exploratory research on relating coping techniques to sleepiness was limited to each participant's current resources to cope with these factors. The participants in the inpatient facility did not commonly mention walking outside or getting fresh air as their selected wakefulness technique. This may be due to the size and design of this particular facility; employees' access to the gardens might be so far away, that it would take too long for them to utilize them without missing work. However, some staff mentioned walking to the hospital atrium or looking outside through the windows.

Implications of the Findings

Facility design can play an important role in both environmental and non-environmental strategies to maintain alertness, vigilance and wakefulness in medical and counseling environments.

In the first section of the study the medical and counseling employees' message to the designers (of their future workplaces) was to provide special attention to personal privacy, adequate work space, low noise levels and pleasant temperature (flexible). In addition, they highlighted the importance for comfortable and ergonomic furniture.

It was found that design factors such as, privacy, appropriately sized workspace and electric lighting must be adapted differently for inpatient, outpatient and counseling work settings. Informed decision-making on design helps provide an appropriate response for each type of setting.

The second and third sections of the study showed almost all employees in healthcare and counseling environments use coping techniques to minimize sleepiness and increase alertness. Their coping strategies have to do with both environmental and non-environmental elements. It was found that daylight, appropriate and adjustable temperature and comfort and ergonomics were the most important factors for creating an alert space. Interestingly, the opccupants' feedback matches results from laboratory research, as research shows lighting, followed by ambient temperature (Mavjee & Horne, 1994), noise (Landstrom, Lindblom-Häggqvist, & Lofstedt, 1988) and posture (Kräuchi, Cajochen, & Wirz-Justice, 1997) to be the most important environmental variables affecting alertness (Kim, Cranor, & Ryu, 2009). Daylighting is the best form of lighting for circadian realignment (Rea, Figueiro & Bullough, 2002). It is ironic that although alertness is vital for healthcare staff, most healthcare staff work in windowless environments.

From a non-environmental perspective, participants' responses to reduce sleepiness mainly addressed about creating a change or reducing monotony. These measures included having caffeinated or cold liquids, increasing activity, switching tasks, changing the surrounding conditions (such as going outside for fresh air or sun, or changing the light levels or temperature and listening to music), interacting with peers, exercising or stretching or taking sweet snacks. The presence, or absence, of convenient access to outdoor green areas seemed to relate to the occurrence of responses about getting fresh air or sunlight.

Due to common design strategies to improve adjacencies and reduce energy use, healthcare buildings are designed with deep floor plates and, therefore, they provide little immediate view or access to the outside for their employees. Typical healthcare workspaces are windowless with constant light, airflow and temperature which create a monotonous environment. The primary design response to maintaining vigilance, and avoiding sleepiness at medical and counseling workplace may therefore to create forms of external stimulation which can be environmental or non-environmental, "like look outside" or "have candy/chocolate." Facility design can play a vital role in supporting wakefulness strategies and creating an energizing work space.

CHAPTER V

QUASI-EXPERIMENTAL RESEARCH RESULTS AND DISCUSSION

Introduction

An overview of the participant's characteristics is provided in the first section. The results of the physiological measurements along with momentary psychological evaluations are reported in the second section. Sections three and four present the results of behavior mapping on subsidiary behavior and social interaction.

Population Characteristics

This section reports on participants' characteristics, documented, controlled and explanatory variables and the evaluation of the variable of interest. The focus of this study was only front line caregivers. From 20 RNs that were found potentially eligible, 14 completed the study. However, the data for two individuals was eliminated because they relocated to a daylit location during the control trial (reference case). One of the remaining participants refused the self-report subjective sleepiness measure on day one. Therefore, the sleepiness data is only available for 11 of the 12 subjects.

Because the study was conducted in similar fashion under the controlled and treated condition and participants did not know the variable of interest, in this study design we avoided measuring the placebo effect "when the experimental participants generate a favorable response whenever any reasonable treatment is applied" (Ott & Longnecker, 2008, p. 474)

The Variable of Interest

The presence of daylight is the variable of interest in this study. The amount of daylight varies during the day. Therefore, time interaction with the variable of interest cannot be ignored. Figure 5.1 displays a computer model by Radiance confirming the daylight variation in morning and afternoon in the nurse station.

Actual Photo | Daylight model in the morning (08:00) | Daylight model in the afternoon (04:00)

Note. Light model with Autodesk Ecotect and Radiance.

Figure 5.1. Variable of interest varies during the time.

Controlled and Exploratory Variables

Controlled variables. The study setting was such that the variable's personal, organizational and environmental factors were controlled. The effects of work fatigue, due to day of shift, were controlled as well.

Personal factors. Subjects served as their own control because the same participants were studied under treated and control condition.

Organizational factors. The unit was split into two different wards with similar settings which enabled control of organizational factors. Therefore, the unit, the management, the charting system, and the patient type was similar.

Environmental factors. Same colors, finish materials, furniture, air quality, etc. were present in both settings because the study was conducted in similar nursing wards mirrored on the same level.

Work fatigue. Only nurses who worked 2 days in a row were observed. The observation was on the second day of the workday in the week.

Since subjects served as their own control, factors of age and gender were equal for the design case and reference case. Tables 5.1 and 5.2 explain the population characteristics with respect to age and gender. As displayed in Figure 5.2 and Tables 5.1 and 5.22, there were more female participants than male participants. Participants were mainly between the ages of 20 to 59.

Table 5.1. Gender frequency.

		Female	Male	Total
Gender	Frequency	10	2	12
	Percent	83%	17%	100%

Table 5.2. Age frequency.

		20-29	30-39	40-49	50-59	Total
Age	Frequency	4	1	4	3	12
	Percent	33%	8%	33%	25%	100%

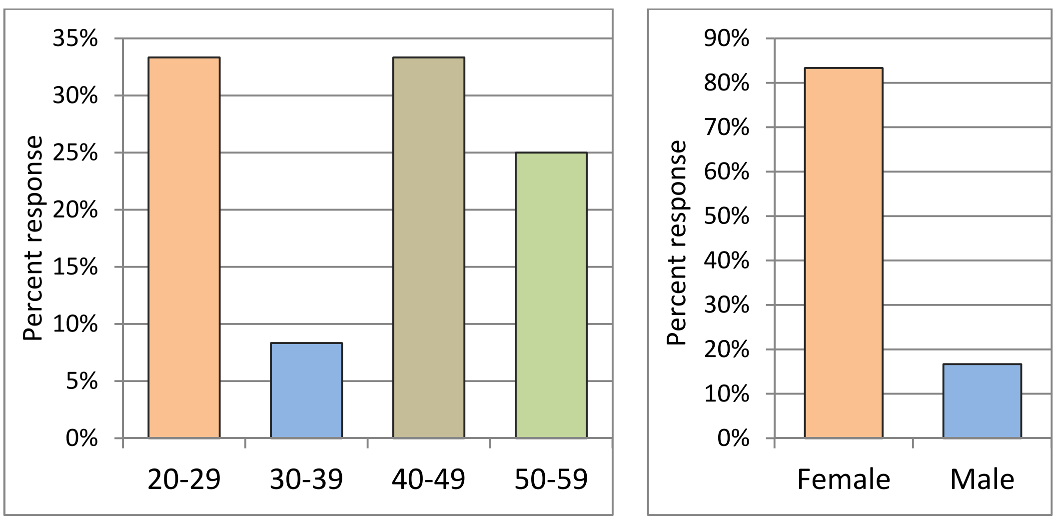


Figure 5.2. Frequency of responses based on age and gender.

Explanatory variables. The explanatory variables which were not controlled but were continuously monitored during the study were Number and acuity of patients under nurse's care and duration and sleep quality of subjects and wake up time. Researchers recorded the number and acuity of patients under nurse participant's care every day. In the beginning of the study, the participants reported what time they went to bed and what time they woke up and how refreshing their sleep was.

The study of explanatory variables showed that the design case and reference case were compatible with respect to subjects' sleep quality, sleep duration, Patients' acuity and the number of patients that the subjects cared for (Table 5.3). Notably, the sleep duration and quality were slightly lower in the design case. Although this value does not have statistical significance, considering that night's sleep is an important predictor for circadian indicators and sleepiness, it would be important to include the effect of this variable and its interaction with the environment.

Hypothesis 4: Physiological and Psychological Measurements

Subjective sleepiness was measured bi-hourly along with vital signs for each participant under both light conditions.

Figure 5.3 visually shows that the greater the sleep duration the lower the mean of reported sleepiness during the day in both design case and reference case. This Figure illustrates that participants' sleep duration was shorter when they were studied under the treated condition. This may bias the findings and mask the effect of the variable of interest. Therefore we studied the entire sample only once and only those who slept a minimum of six hours under both design case and reference case.

Table 5.3. Population characteristics, explanatory variables.

	Reference case (mean ± s.e.)	Design case	P Value	
Patient acuity	3.1639±.05983	.3.3368±.06735	.133	NS
Number of Patients	4.3333±.14213	4.1667±.20719	.438	NS
Subjects' sleep duration	6.7783± .27453	6.7400± .26667	.831	NS
Subjects' sleep quality	4.0000± .17408	3.5000 ±.26112	.139	NS

Note. NS= not significant.

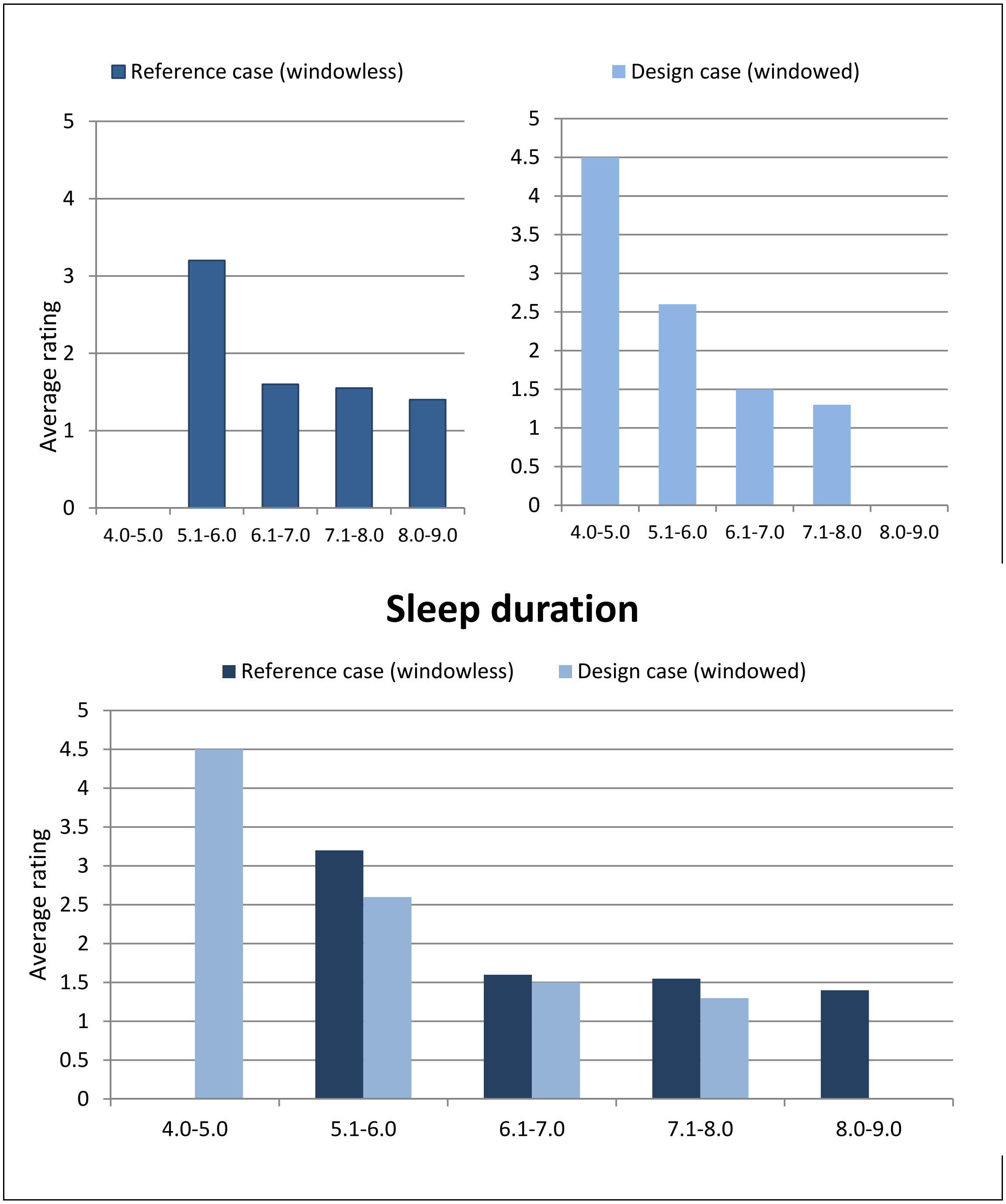


Figure 5.3. Sleepiness during the shift and its relationship with night's sleep prior to the shift.

Workload (as measured by daily number of patients or level of patients' acuity) may predict sleepiness (which may be interpreted as tiredness). Figure 5.4 show that as patient acuity increased, average sleepiness also increased. The windowed condition (design case) may limit the increase in sleepiness with similar acuity levels.

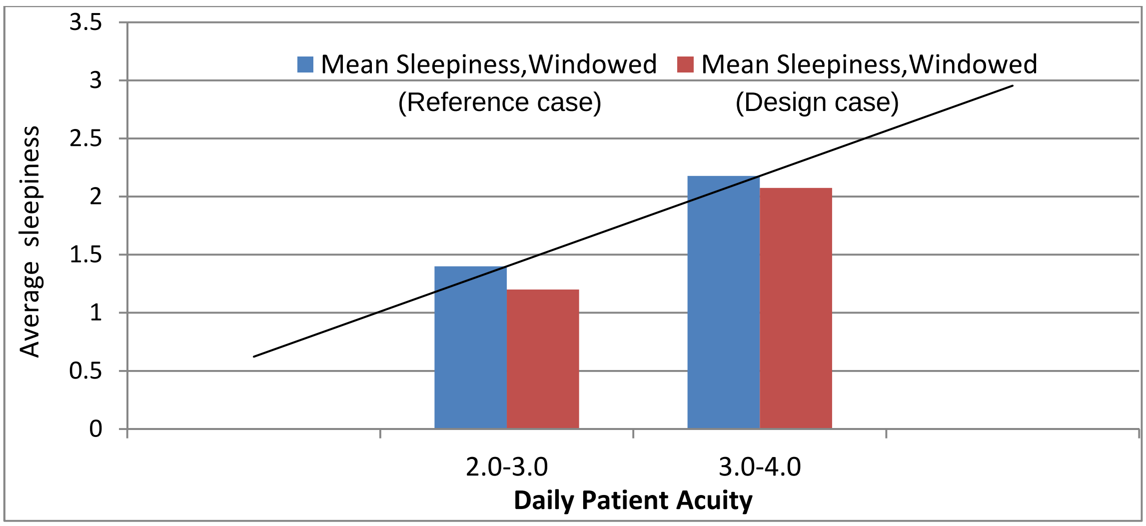


Figure 5.4. Sleepiness and workload (measured by daily patient acuity).

Measurement Repeatability and Reproducibility

By comparing the two trials, we first measured the reproducibility (Leproult, Colecchia, Berardi, Stickgold, Kosslyn, & Van Cauter, 2003) for objective measurements of T,HR,BPdia, PBsys, SPO2 and mood (sleepy, tired, tense, gloomy, irritable) subjective sleepiness/alertness, and second, we studied the interrelationships between the measurements following the method used by Leproult et al. (2003). First, the paired correlation of the measurements showed that the bihourly measurements of T, HR, BPdia, BPsys, SPO2 and sleepiness/alertness as well as the subjective reported overall mood, mood(tired) and mood (sleepy) are highly reproducible per individual (Tp=0.0104, HRp= 0.0007, BPdiap=0.0050, BPsysp=0.0019, SPO2p=0.0010, sleepiness/alertnessp=0.0059, average overall mood p= 0.0168, Mood (Tired) p= 0.0034 and Mood(sleepy)= 0.0058). However, Figure5.5 shows the mean profiles of T, HR, BPdia, BPsys, Sleepiness,SPO2 on the left. The scatter plot on the right demonstrates Reproducibility across the two trials per each subject (method used previously by Leproult et al., 2003). On the left, the mean profile of the measurements are plotted for the design case and reference case during the repeated bihourly measurements.

In contrast with the above mentioned variables, among the five mood indicators, the repeatability of the measurements of tense, gloomy and irritable were not supported in these two trial runs per given individual. This suggests that these measures' effects may be masked by other factors in the two settings. This indicates that in a paired T-test, the equality of means may not be helpful as this comparison of means would not unmask the effect of covariates. Interestingly, there was a strong relationship between bihourly momentary measured sleepiness, and the sleepiness factor measured in the mood survey that was found per each trial for every individual (reference case P= 0.004 and design case P= 0.001).

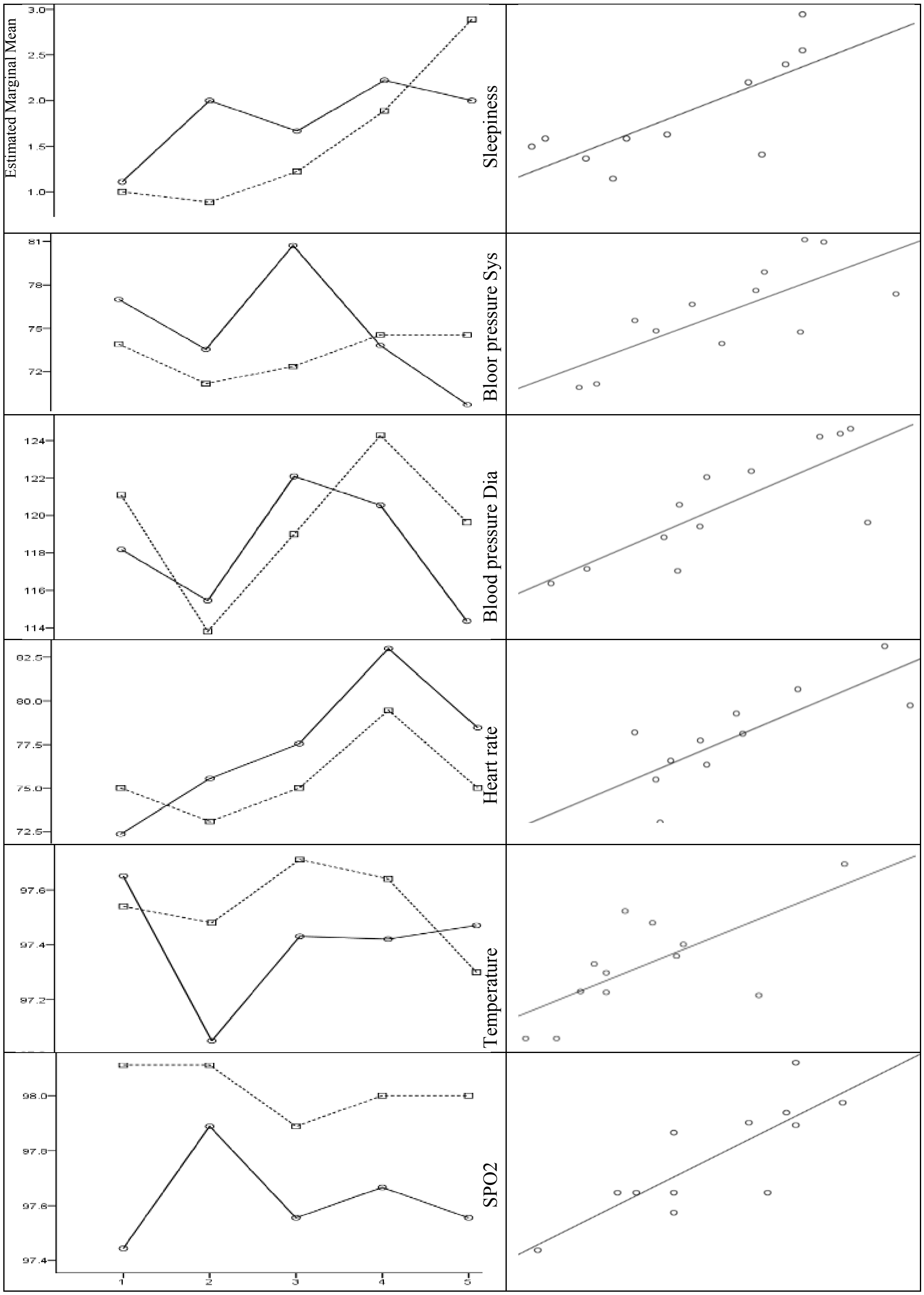


Figure 5.5. Repeatability graphs design case versus the reference case.

Second, the interrelationships between these objective and subjective measurements were studied using the bivariate method of Pearson Correlation (2-tailed) on the magnitude of variations per each measurement, which are visually described in Figure 5.5 and Table 5.4. The Pearson Correlation (instead of Spearman Correlation) was used to study these relationships because the data was mainly normal (see the section, Analysis of the Physiological Responses**)**. The magnitude of variation calculated for each measurement is simply the change between the reference case and the design condition, ex. $T_{control} - T_{windowed} = \Delta T$. The cross correlations between the changes of both diastolic and systolic blood pressure were high (P= 0.0150). Systolic and diastolic blood pressure variations were both related to body temperature across the trials in each individual (ΔBPdia & ΔT P= 0.0478, ΔBPsys & ΔT P= 0.0044).

The variations in heart rate for each individual and body temperature were interdependent as well (ΔHR & ΔT P= 0.0381). Changes in the objective measurement of mean heart rate for each subject, which was measured bihourly 8 to 16, was positively related to the reported subjective levels of *Tense* and *Irritable* in the mood survey (ΔHR & ΔTense= 0.0396, ΔHR & ΔIrritable P= 0.0335) while the reported levels of *Tense* and *Irritable* were highly dependent on each other (ΔTense & ΔIrritable P= 0.006), suggesting that both measurements can be grouped as one subjective measurement. Both measures of subjectively reported *Tense* and *Irritable* also had significant relationship with body temperature ΔT & ΔTense= 0.019,7 ΔT & ΔIttitable P= 0.0234).

Table 5.4. Correlation among subjective and objective measurements.

Pearson Correlation		Shift in the # of Pts	Shift in Pt acuity	Shift in Daylight Factor	Difference in Sleep Duration (Binned)	Shift in Avg. Blood pressure dia 8:00 to 16:00	Shift in Avg. Blood pressure sys 8:00 to 16:00	Shift in Avg. oxygen saturation 8:00 to 16:00	Shift in Avg. Heart rate 8:00 to 16:00	Shift in Avg. Sleepiness 8:00 to 16:00	Shift in Avg. Body Temp.8:00 to 16:00	Mood survey--Shift in the rating of Tired	Mood survey--Shift in the rating of Sleepy	Mood survey--Shift in the rating of Tense	Mood survey--Shift in the rating of Gloomy	Mood survey--Shift in the rating of Irritable	Mood survey--Shift in the av[g] mood indicators
Shift in the # of Pts	Correlation		-.40	.17	.07	-.53	-.23	.23	.08	-.33	-.13	-.48	-.18	-.03	-.23	-.07	-.37
	Sig. (2-tailed)		.19	.61	.82	.07	.47	.46	.79	.32	.69	.11	.57	.93	.47	.82	.24
Shift in Pt acuity	Correlation			-.12	.03	.44	-.07	.12	.49	.13	.31	.24	-.31	.16	.09	.57	.38
	Sig. (2-tailed)			.72	.92	.15	.83	.70	.11	.71	.32	.46	.32	.62	.78	.05	.22
shift in Daylight Factor	Correlation				-.02	-.48	-.16	-.34	-.23	.05	.09	.23	.62*	-.27	-.12	-.40	-.07
	Sig. (2-tailed)				.95	.12	.61	.28	.46	.88	.78	.47	.03	.40	.70	.20	.83
Difference in Sleep Duration (Binned)	Correlation				1	-.06	-.30	.04	.00	-.15	-.01	-.30	-.32	.18	-.58*	.00	-.31
	Sig. (2-tailed)					.85	.35	.91	.99	.66	.98	.35	.31	.57	.05	1	.32
Shift in Avg. Blood pressure dia 8:00 to 16:00	Correlation						.68*	-.03	.45	.59	.58*	.29	-.15	.37	.02	.51	.51
	Sig. (2-tailed)						.01	.92	.14	.05	.05	.36	.63	.23	.95	.09	.09
Shift in Avg. Blood pressure sys 8:00 to 16:00	Correlation							-.48	.37	.31	.76**	.18	.22	.48	-.04	.34	.54
	Sig. (2-tailed)							.11	.24	.36	.00	.58	.50	.11	.91	.29	.07
Shift in Avg. oxygen saturation 8:00 to 16:00	Correlation								-.22	.22	-.41	-.12	-.27	-.28	-.07	.13	-.23
	Sig. (2-tailed)								.49	.51	.18	.71	.39	.38	.83	.69	.47
Shift in Avg. Heart rate 8:00 to 16:00	Correlation									-.29	.60*	-.19	-.40	.60*	.25	.61*	.47
	Sig. (2-tailed)									.39	.04	.56	.20	.04	.44	.03	.12
Shift in Avg. Sleepiness 8:00 to 16:00	Correlation										.10	.67*	.39	-.35	-.09	-.21	.16
	Sig. (2-tailed)										.78	.02	.24	.29	.80	.54	.64
Shift in Avg. Body Temp.8:00 to 16:00	Correlation											-.07	.00	.66*	-.24	.65*	.55
	Sig. (2-tailed)											.82	.99	.02	.44	.02	.06
Mood survey--Shift in the rating of Tired	Correlation												.61*	-.26	.32	-.22	.45
	Sig. (2-tailed)												.03	.41	.31	.50	.14
Mood survey--Shift in the rating of Sleepy	Correlation													-.38	.11	-.51	.17
	Sig. (2-tailed)													.22	.74	.09	.60
Mood survey--Shift in the rating of Tense	Correlation														.01	.74**	.64*
	Sig. (2-tailed)														.98	.01	.03
Mood survey--Shift in the rating of Gloomy	Correlation															.00	.47
	Sig. (2-tailed)															1	.13
Mood survey--Shift in the rating of Irritable	Correlation																.62*
	Sig. (2-tailed)																.03
Mood survey--Shift in the avg mood indicators	Correlation																
	Sig. (2-tailed)																

Thus, from the previous statement, we conclude that interrelationships existed among all the variations of HR and T (objective measure) and Tense and Irritable (subjective report). Finally, not only did a relationship exist between tense and irritable within the mood survey, the variation of reported measurement of Tired was dependent on both the measurement of Sleepy in this survey (ΔTired & ΔSleepy P= 0.0321) and the momentary bihourly sleepiness assessment (ΔTired & ΔSleepiness P= 0.0244).

Last but not least, daylight exposure (daylight factor) was significantly related to the sleepiness component of mood measurement (ΔDaylight Factor & ΔSleepiness P= 0.0316). This finding directly addresses the research hypothesis. All above are explained in Table 5.4.

Figure 5.6 summarizes the correlations and interrelationships between the shifts in biological and psychological measurements. The width of the line represents the significance of the correlation. As displayed, the variations in both biological and psychological responses relate to each other indicating how these indicators are interconnected.

Figure 5.7 specifically display the shifts of Temperature and mood (Tense) between the design case and reference case. The graph shows how the magnitude of variations matches for different participants. Figure 5.8 displays a comparison between the changes in systolic blood pressure and body temperature.

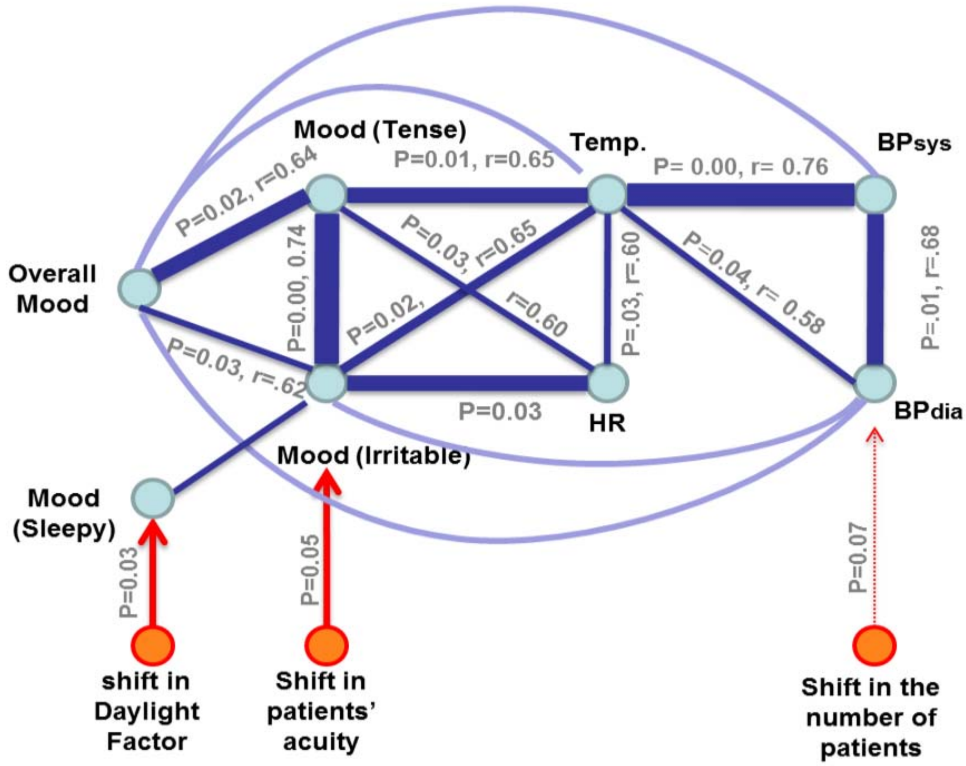


Figure 5.6. Relationships among physiological and psychological measurements.

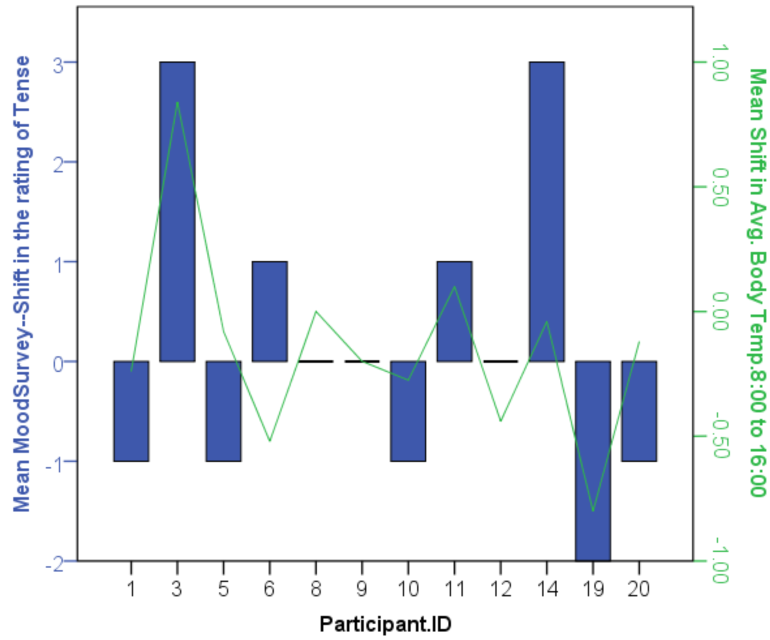


Figure 5.7. Variation of body temperature and mood (tense).

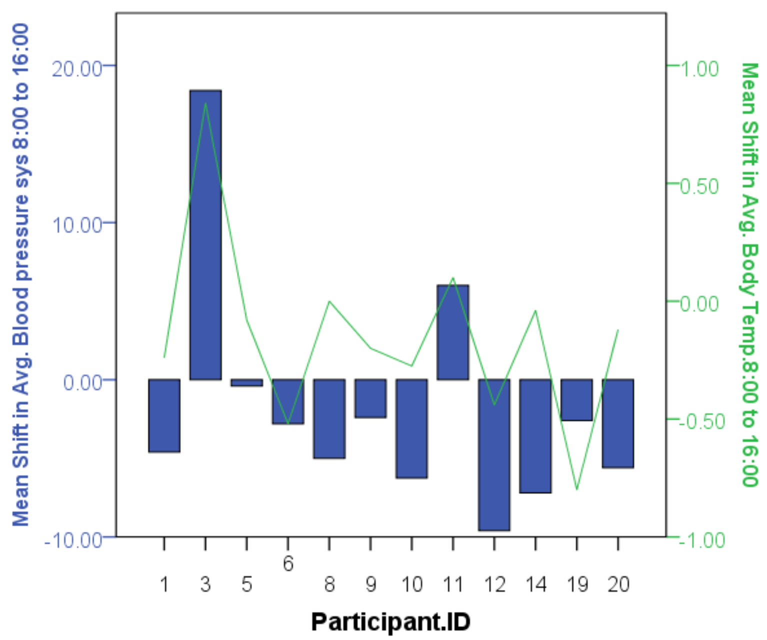


Figure 5.8. Variations of BP sys and temperature.

Analysis of the Physiological Responses

It was hypothesized that the windowed nurse station improved biological responses (decreased blood pressure and heart rate, increased oxygen saturation and body temperature) and resulted in phase-advance circadian rhythms manifested in vital sign measurements.

The measurements for all of the response variables was paired for each individual and was first compared per hour under the reference case and the design case. We then averaged the repeated measurements into two segments, morning and afternoon. The hypothesis was tested for the measurements for the entire day, morning and afternoon. Whether or not a shift had occurred in the circadian biological responses was studied descriptively by analyzing the curves in the comparison graphs. Comparing hourly responses in the design case and reference case, via T-test, clarified if the suggested circadian variations were significant.

Due to subject assignment difficulties, or the research introduction procedure, sometimes the first morning measurement was not achieved until 9:00, or in once incident, until 9:30. This increased the 8:00 am measurement errors. The variation in the measurement from the target time during the day was less than 15 minutes. Therefore, when segmenting the data to morning and afternoon, the 8:30 measurements were not included. Only data beginning at 10:00am was included. Thus, the morning measurements consisted of the mean measurement taken at 10:00 and 12:00, and the afternoon measurements consisted of the mean measurement taken at14:00 and 16:00.

The required criteria to use the T–test to make inference about the population mean are as follows: 1) The distribution of pair differences must be normal, and 2) the pairs of observations are independent from each other (Ott & Longnecker, 2008, p. 317). Both conditions are correct for the subjective sleepiness data. Therefore, the pairs of repeated measures at 8:00, 10:00, 12:00, 14:00 and 16:00 were studied using paired T-tests.

Normality was tested for the distribution of differences of body temperature, heart rate, blood pressure, and oxygen saturation using histograms and Q-Q plots (Appendix C). The data was mainly found to be normally distributed and was analyzed using paired T-test (Table 5.5). In the instances where the data was not normal, the Wilcoxon signed-rank test as an alternative for the paired T-test was used (Ott & Longnecker, 2008, p. 319).

Table 5.5. One-tailed T-test between design case and reference case.

T-test	**SLP**	**T**	**HR**	**BP Dia**	**BP Sys**	**MAP**	**SPO2**
8:00	0.442	0.421	0.2905	0.1435	0.1825	0.35240	0.0835
10:00	0.0225	0.1665	0.0535	0.1795	0.3995	0.20472	0.0875
12:00	0.207	0.0775	0.1995	0.013	0.2625	0.04012	0.0875
14:00	0.4375	0.135	0.2275	0.4545	0.168	0.31241	0.1705
16:00	0.1305	0.2765	0.164	0.073	0.051	0.05422	0.041
Morning mean	0.0525	0.036	0.073	0.0255	0.3005	0.06623	0.0535
Afternoon mean	0.1825	0.384	0.384	0.2035	0.021	0.09636	0.025
Daily mean	0.2385	0.113	0.1	0.2005	0.2065	0.40420	0.011

The following sections describe the findings per each biological response.

Subjective sleepiness/wakefulness. Duration of sleep (the night before) was negatively correlated with average sleepiness at work. Also, the higher the patient acuity level that day, the higher the nurses' perceived sleepiness. The bi-hourly ecological momentary assessment of sleepiness (Figure 5.9) showed morning sleepiness was reduced by 34% (P= 0.052). However, the total daily sleepiness was only reduced by 10%, which was not statistically significant (P=0.238). The participants consistently reported less sleepiness in the morning in the windowed condition (design case) until hour 16:00, when the average sleepiness in the windowed condition raised above the control condition (reference case).

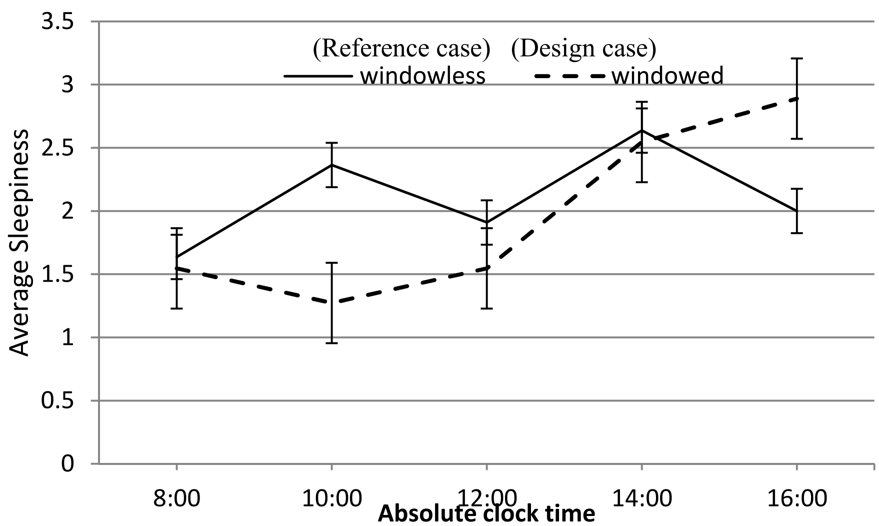
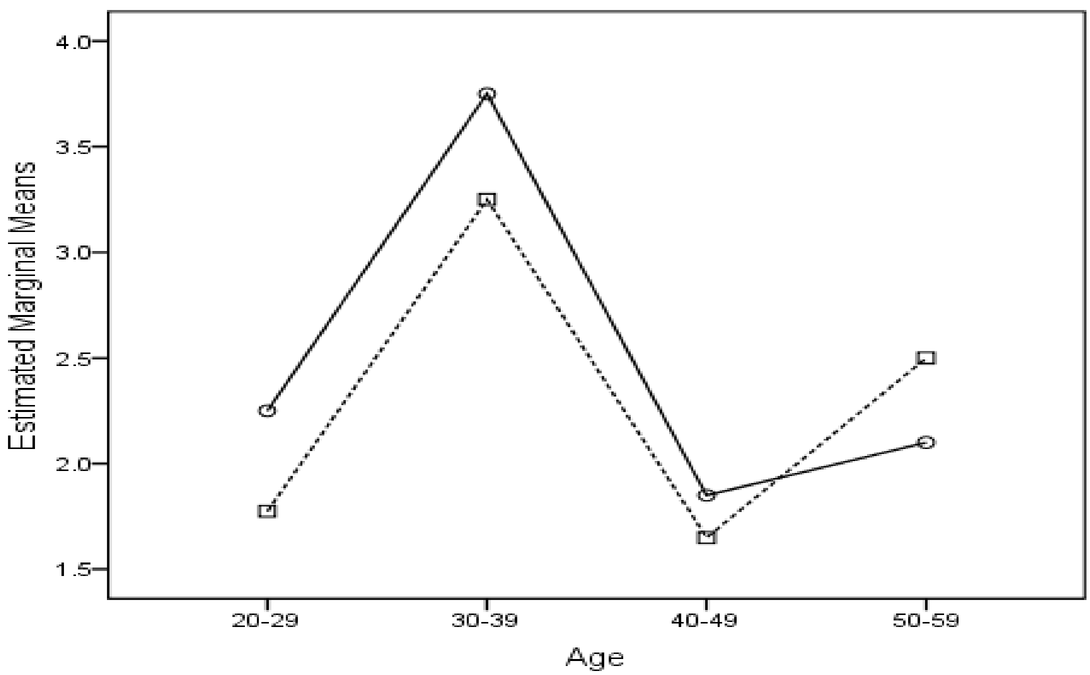


Figure 5.9. Bihourly momentary subjective sleepiness.

The profile of sleepiness had similar patterns across different age categories under the design case and reference case (Figure 5.10). The design condition commonly had lower sleepiness levels for all age categories except one.



Note. Design case (dotted line), reference case (uninterrupted line).
Figure 5.10. Estimated marginal means of sleepiness for age categories.

Body temperature. In the morning, the participants' average body temperature was significantly higher under the design condition compared to the reference case (97.26±0.18, 97.6±0.18, P= 0.0360). There was an increase of 0.28 F in the average nadir body temperature at 10:00 am, but the shift was not significant (97.16±0.20, 97.44±0.24, P= 0.1665). There was no significant increase in the afternoon body temperature (P= 0.3840). The measurements suggest a possible phase advance shift in the temperature variation in the windowed condition (design case) because the maximum daily body temperature was advanced in hour 16:00 from hour 12:00 in the design case (figure 5.11).

Circadian research studies, such as Bolivin and Czeisler, (1998) and Bolivin, Duffy, Kronaur and Czeisler, (1996) describe this phenomenon usually as a shift in the "upward mean crossing" of the temperature profile and verify that the phase advance or delay is addressed through statistical analysis. However, the current study, having only five daily measurement points, did not provide adequate data points to statistically verify that such a shift occurred.

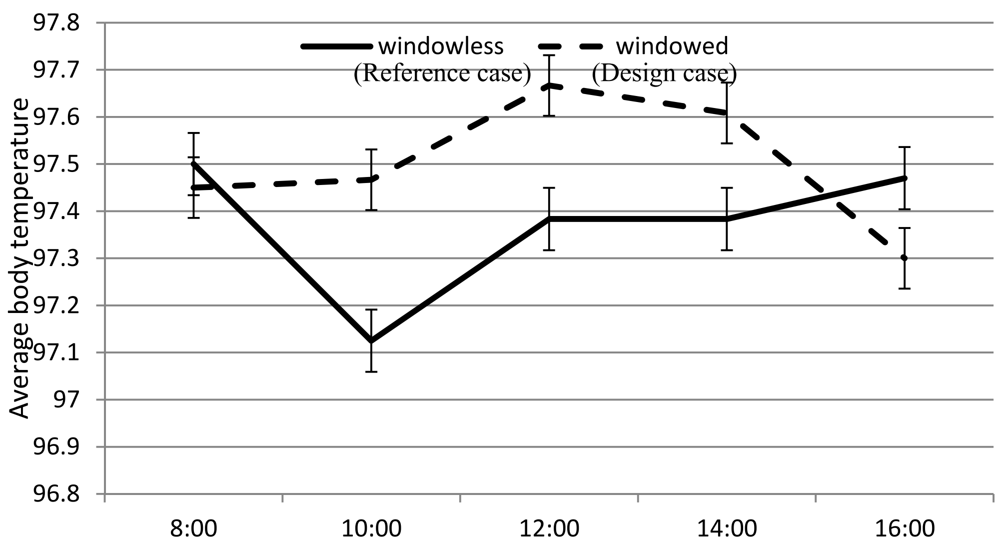


Figure 5.11. Bihourly temperature measurements.

Heart rate. The mean heart rate generally had an upward trend during the day (Figure 5.12). The subjects' heart rate dropped at 16:00 in both reference case and design case. The morning and daily average heart rate was slightly lower in the morning but insignificantly so (P=0.0730, P=0.1000).

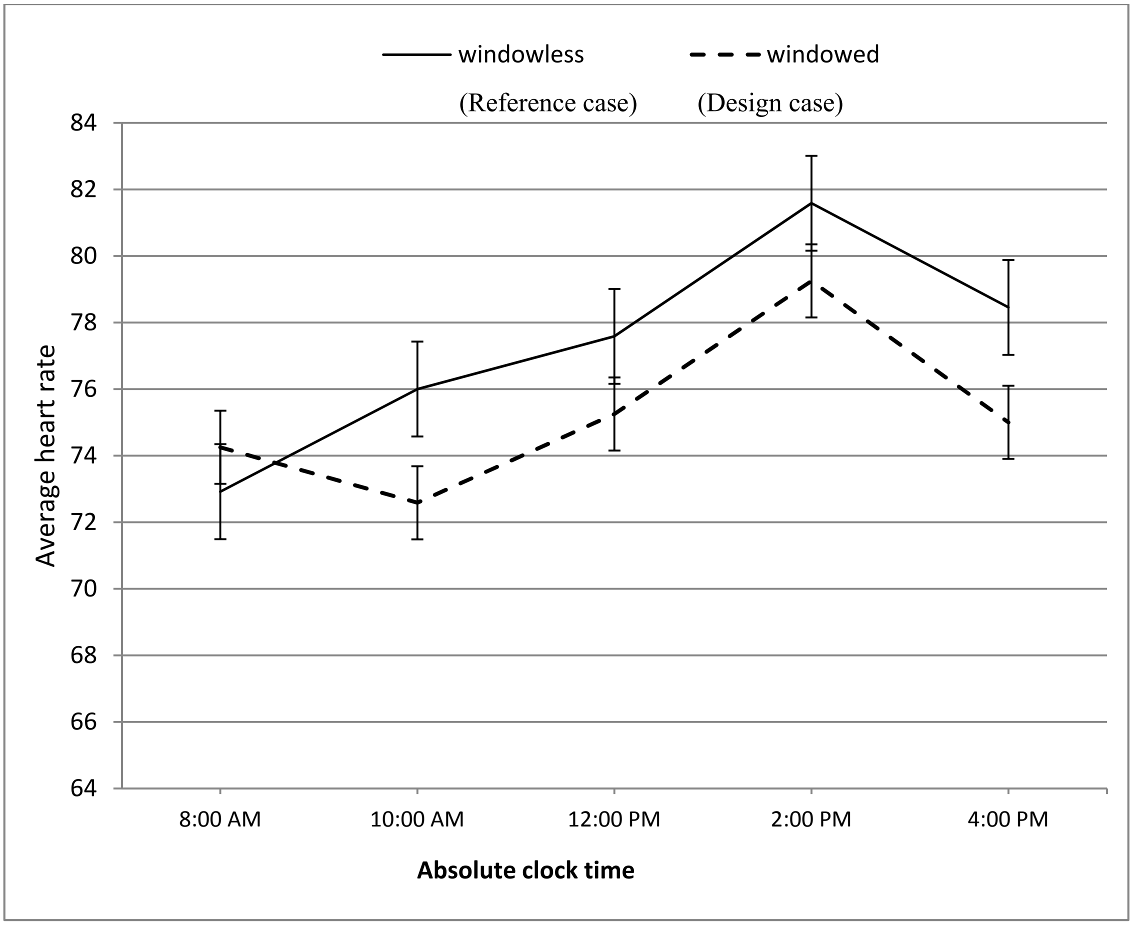
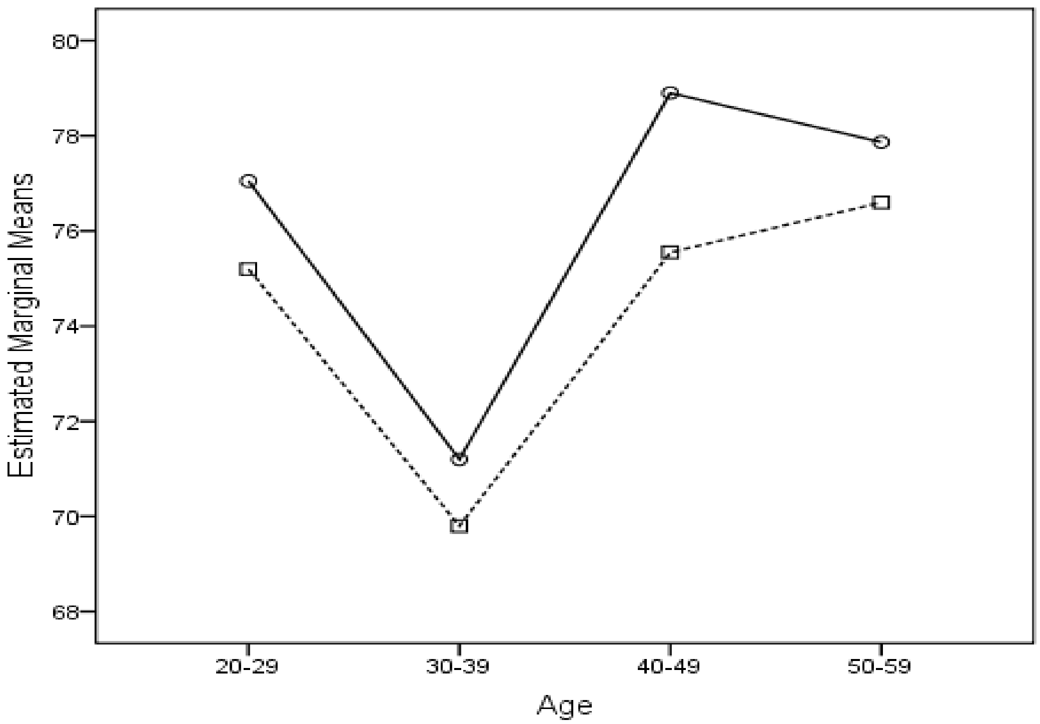


Figure 5.12. Bihourly heart rate measurements.



Note. Design case (dotted line), reference case (uninterrupted line).

Figure 5.13. Estimated marginal means of heart rate per age categories.

Mean daily heart rate per individual was compared in the design case and reference case based on age group. The profile of heart rate showed similar patterns across the four age categories and the design case had consistently lower heart rates compared to the reference case (Figure 5.13).

Diastolic blood pressure. There was a significant reduction in diastolic blood pressure in the morning measures (P=0.0255), but not in the afternoon (P= 0.2035). Consistent with the findings on sleepiness, blood pressure was lower in the windowed condition (design case) until hour 16:00 when it increased beyond that for the reference case (Figure 5.14).

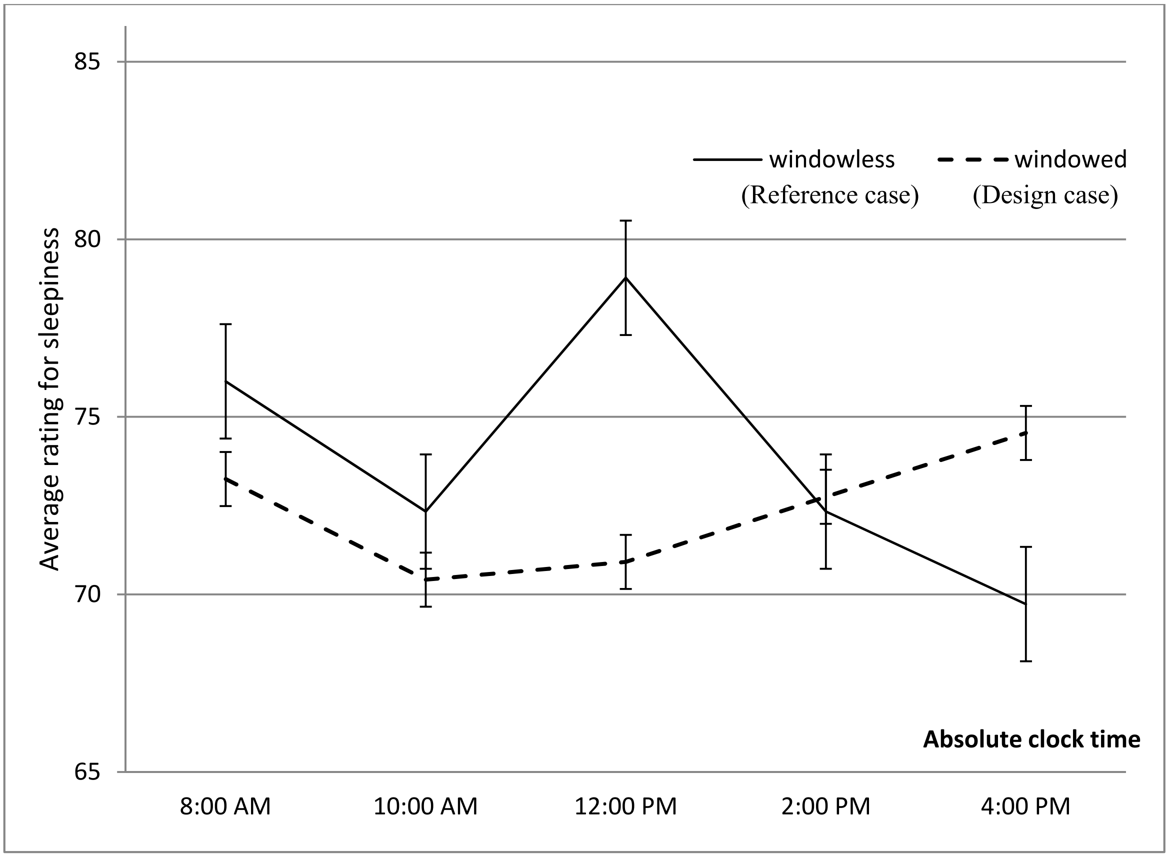
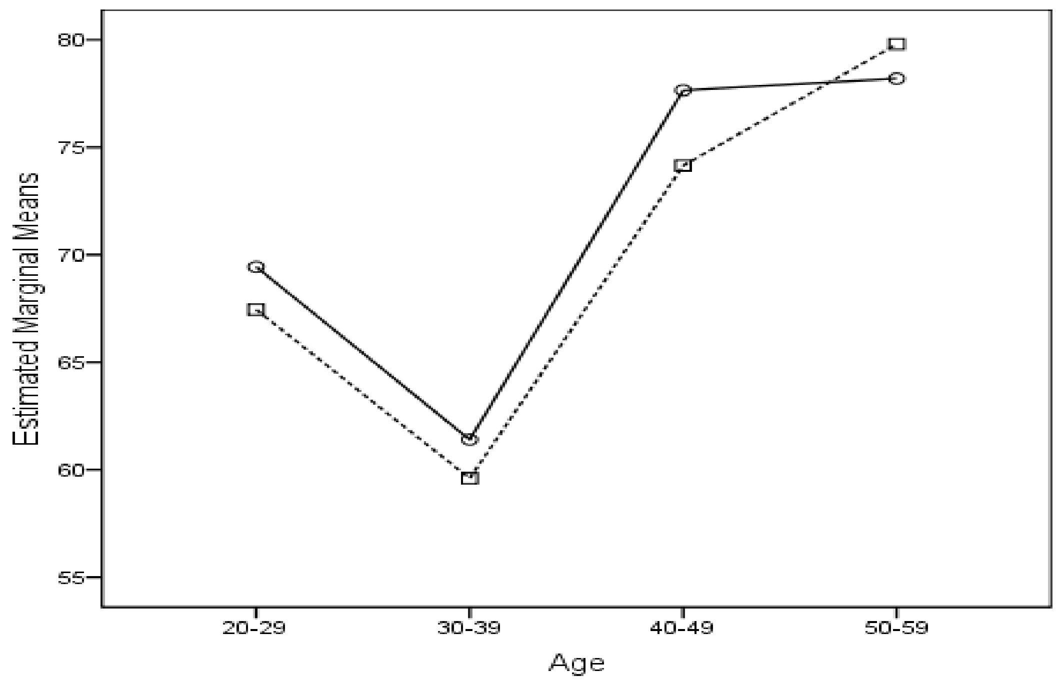


Figure 5.14. Bihourly measurements of diastolic blood pressure.

Looking at the profile of mean daily diastolic blood pressure per individual across different age categories, similar patterns are found in the design case and reference case. Figure 5.15 shows that the diastolic blood pressure was slightly lower under the windowed condition (design case) for all age categories, except 50-59, which had a slight increase in diastolic blood pressure.



Note. Design case (dotted line), reference case (uninterrupted line).

Figure 5.15. Estimated marginal means of diastolic blood pressure per age category.

Systolic blood pressure. An average morning, afternoon and daily systolic blood pressure remained unchanged in the design case compared to the reference case. The systolic blood pressure increase in the windowed condition (design case) at hour 16:00 was almost significant (P=0.0510). This is also consistent with the erratic change in the direction of sleepiness at hour 16:00.

The profile of average systolic blood pressure also indicates there may be a delay in the occurrence of daily maximum blood pressure under the design case because the timing of maximum blood pressure seems to have moved to hour 14:00 from hour 12:00, suggesting a possible phase delay (Figure 5.16). Or we can say a shift in the "midpoint of downward mean crossing" (Bolivin & Czeisler, 1998) to the right occurred as an indication of a possible phase delay. The statistical analysis of such phase delay similar to studies by Bolivin and Czeisler, (1998), was not possible in the current study because five measurement points are not enough to visualize the complete circadian profile to capture the delay by identifying an accurate phase marker.

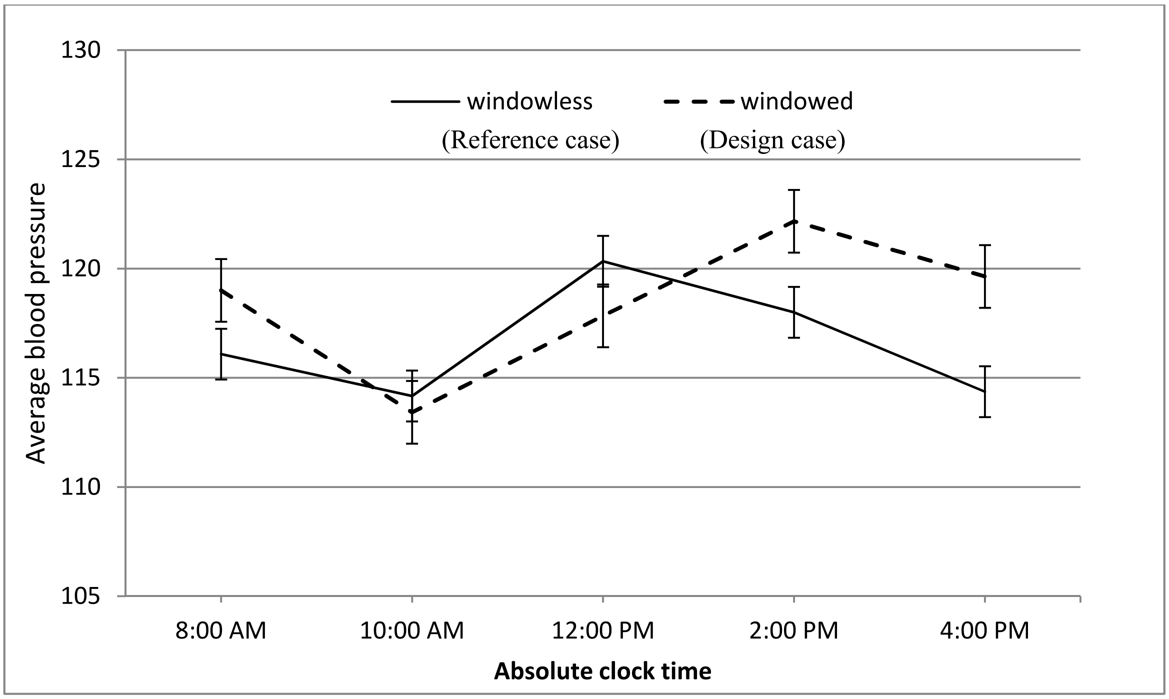


Figure 5.16. Bihourly measurements of systolic blood pressure.

Hypertension. Each individual's systolic and diastolic blood pressure were measured every two hours in both reference case and design case. These values were studied for high blood pressure. According to the *Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure* (Chobanian, Bakris, Black, Cushman, Green, Izzo, . . . and the National High Blood Pressure Education Program Coordinating Committee, 2003), high blood pressure occurs when at least one of the systolic and diastolic measures are higher than normal limits, respectively 120 mmHg and 80 mmHg. Table 5.6 depicts the categories of high blood pressure used in this analysis.

The occurrence of hypertension decreased by 14% during the entire day if windows were available (12% to 10%). Over the entire set of measurements, five measurements daily for 24 days, seven incidents of morning hypertension were recorded, five of which occurred in the windowless station (reference case) and two in the windowed station (design case). The morning occurrence of hypertension in the windowed location was reduced by 54% compared to the windowed location (Figure 5.17). However, the afternoon frequency of occurrence of hypertension increased in the windowed location above the baseline (windowless condition).

Table 5.6. Blood pressure categories.

Category	Systolic		Diastolic	Response
Normal	<120	and	and <80	NA
Prehypertension	120-139	or	80-89	NA
Stage 1 hypertension	140-159	or	90-99	Medication recommended
Stage 2 hypertension	≥160	or	≥100	Medications needed

Note. Source, *Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure*, (Chobanian, Bakris, Black, Cushman, Green, Izzo, . . . and the National High Blood Pressure Education Program Coordinating Committee, 2003).

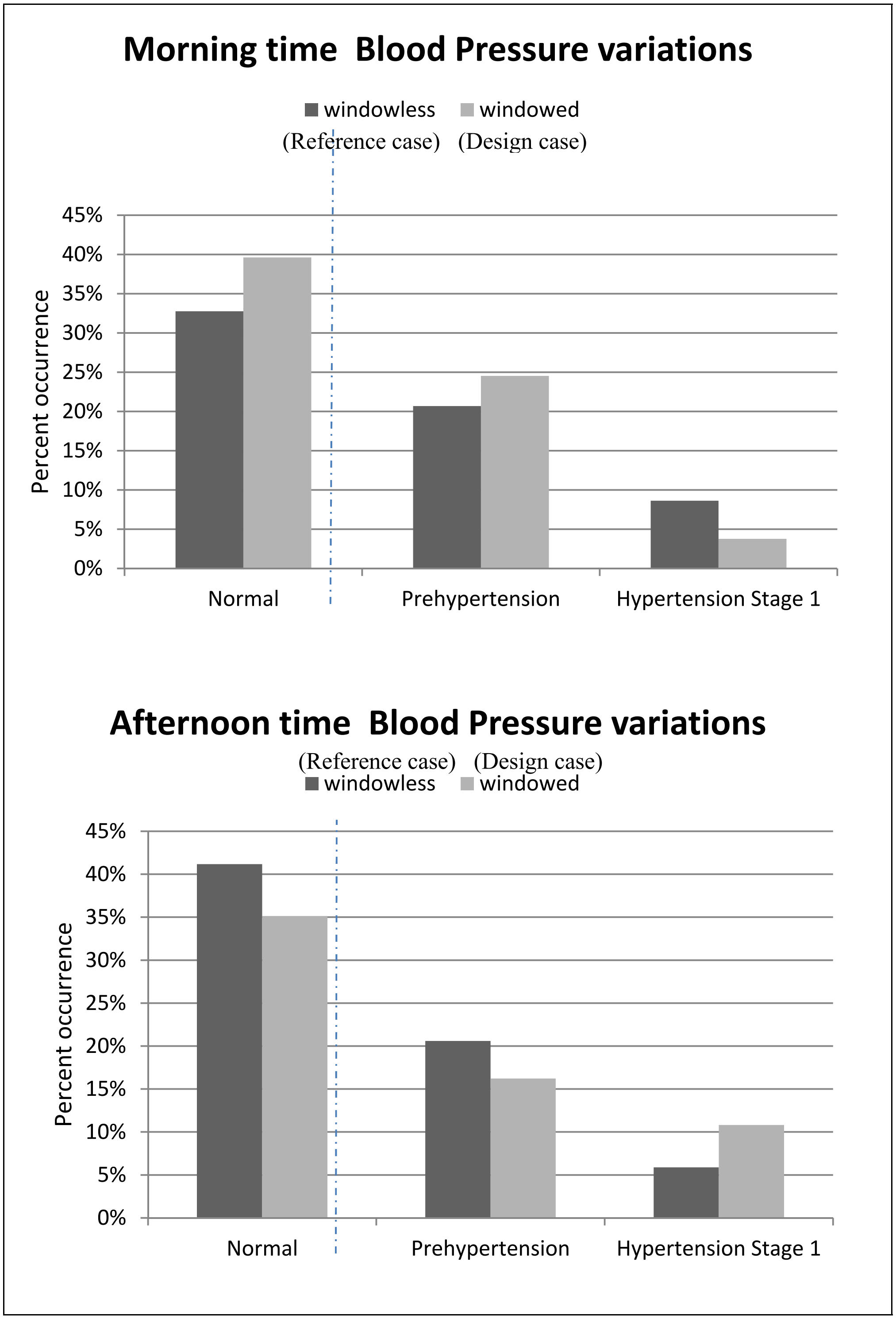


Figure 5.17. Occurrence of normal blood pressure, prehypertension and hypertension.

Normal blood pressure was observed in younger subjects more frequently. Nurses aged 40 or over showed higher rates of hypertension and prehypertension; therefore, they had higher overall blood pressure (Figure 5.18).

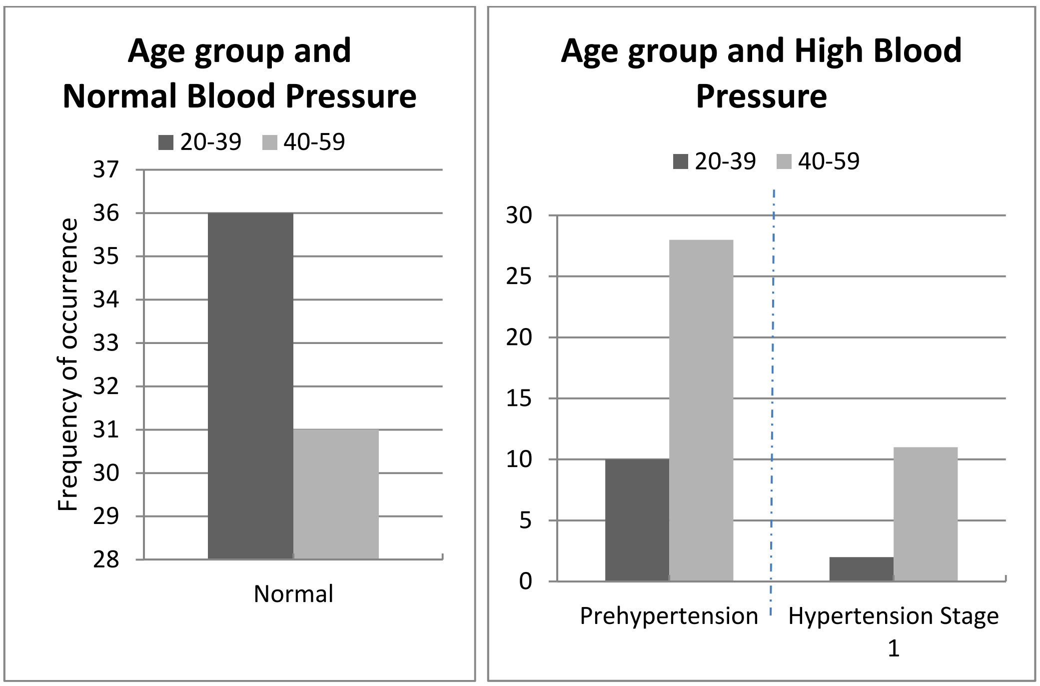


Figure 5.18. Occurrence of normal blood pressure, prehypertension and hypertension per age group.

Mean arterial pressure. Arterial pressure differs from both systolic and diastolic blood pressure (Jan, n.d.). Mean arterial pressure is a combination of the two values. Mean arterial pressure, represented by the formula <u>1/3(SBP-DBP)+DBP</u>, (Rogers, Small, Buchan, Butch, Stewart, Krenzer, & Husovsky, 2001), was calculated using the bihourly systolic and diastolic blood pressure values. Similar to sleepiness, and diastolic blood pressure measures, the participants consistently had lower mean arterial pressure in the windowed condition (design case) before 14:00. This reduction was significant at noon (92.7217 mmHg ±3.2270, 86.5550 mmHg ±2.7443 P= 0. 0401). At hour 14:00, the mean arterial pressure increased in the windowed condition (design case) and the trend was reversed.

Overall, the variation of average mean arterial pressure decreased in the windowed condition (design case) and is closer to a straight line when compared to the windowless location (reference case). The peak mean arterial pressure was lower in the design case (89.2225 mmHg ± 3.9002), compared to the reference case (92.7217 mmHg ± 3.9002).

Figure 5.19 suggests the timing of maximum mean arterial pressure may have been delayed from 12:00 to 16:00. In other words, the “midpoint of the downward mean crossing” (Bolivin & Czeisler, 1998) in the windowed condition may have shifted to the right, compared to the reference case, suggesting a delay in peak mean arterial pressure. Statistical investigation of this notion is beyond this research because five daily measurement points is not sufficient to assess the shift.

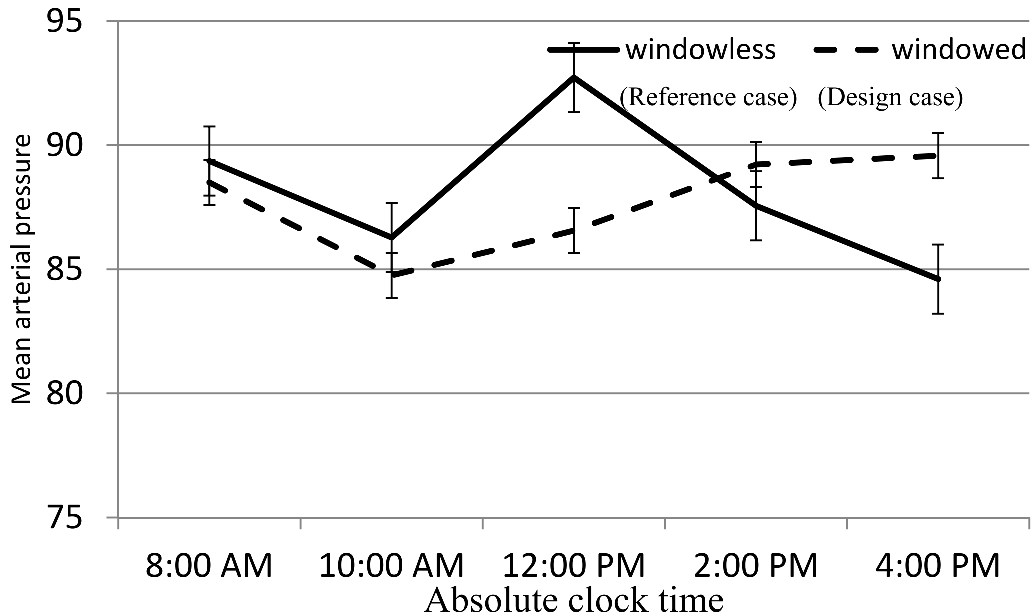


Figure 5.19. Bihourly measurements of mean arterial pressure.

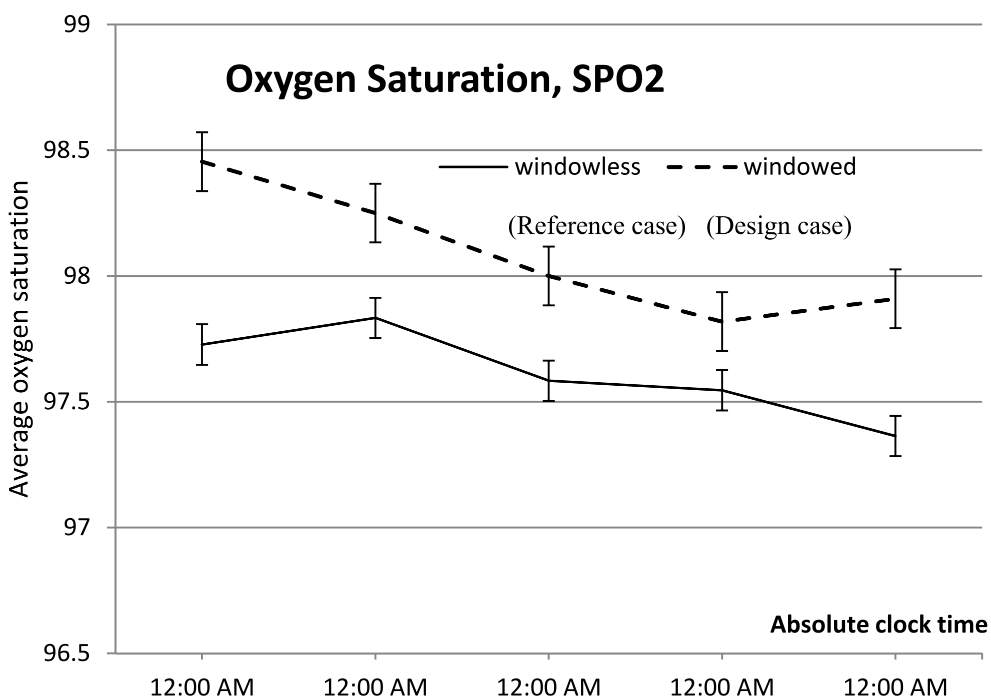


Figure 5.20. Bihourly measurements of oxygen saturation**.**

Oxygen saturation. Oxygen saturation (SPO2) seemed to have a mild downward trend during the day (Figure 5.20). There was a consistent increase in SPO2 in the design case compared to the reference case in all five daily measurements. The average daily SPO2 decreased significantly (0.011)

In the afternoon, SPO2 increased with statistical power (0.025) and the morning increase was close to significant (P=0.0535).

Hypothesis 5: Behaviors Related to Sleepiness and Mood

Table 5.7 displays the mean values of each subsidiary behavior for the reference case and design case. Notably, subsidiary behaviors related to overall sleepiness and deteriorated mood decreased in amount under the treated condition, as opposed to the hypothesized frequency of yawning which did not vary under the reference case and design case (Figure 5.21). However, all other subsidiary behaviors occurred less frequently in the design case.

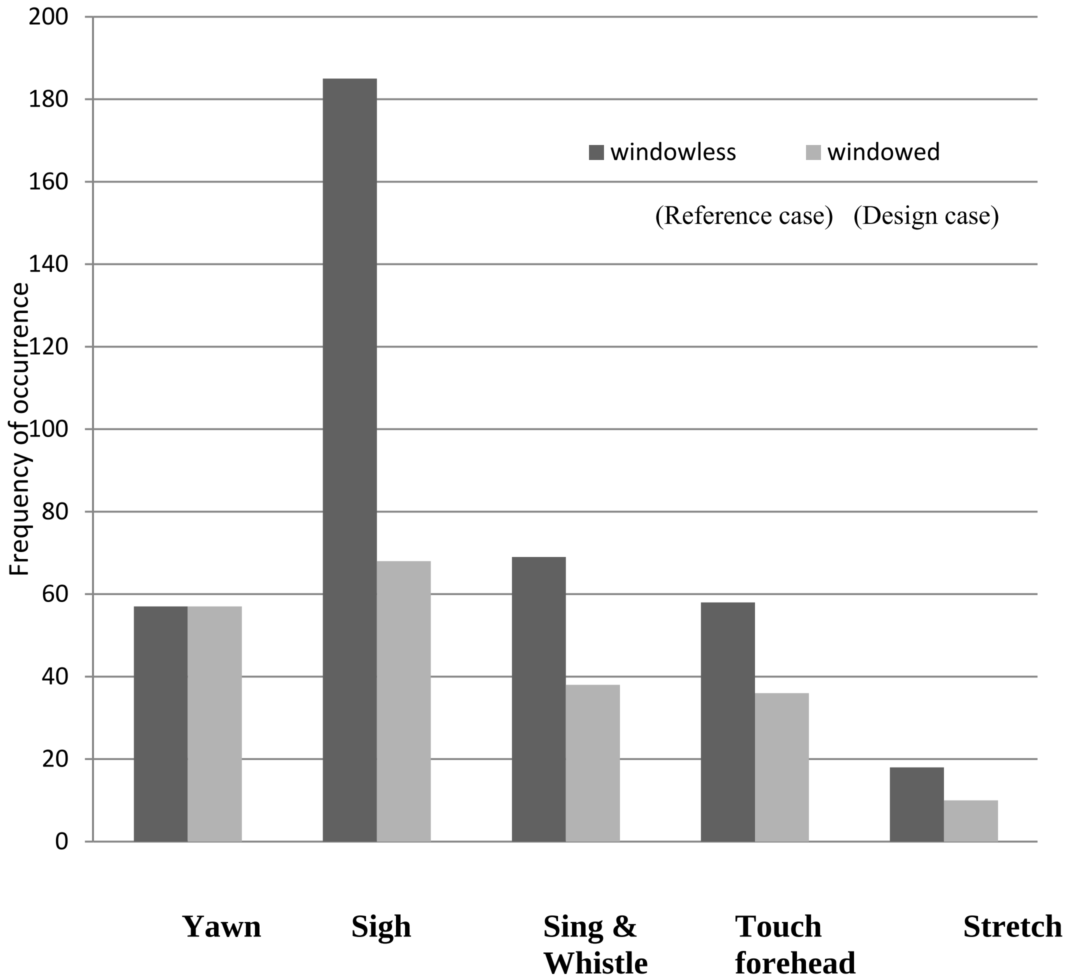


Figure 5.21. Subsidiary behavior related to sleepiness and mood.

Table 5.7. Exploratory analysis of subsidiary variables.

	Reference case	Design case	P=value
Yawn	4.7500±.1.1686	4.7500±.0.7398	0.6646
Sigh	15.4166±.7.4371	5.6667±.1.4890	0.0607
Sing or whistle	5.7500 ± .27453	3.1667 ± .2667	0.2002
Touch forehead or eyes	4.8333 ± .17408	3.0000 ±.26112	0.1016
Stretch trunk	1.5000±0.45227	0.8333±0.3218	0.3213
All subsidiary behavior	32.2500±8.3694	17.4167±2.6125	0.0277
All paralinguistic communication	**25.9167±8.0889**	**13.5833±2.3978**	**0.0325**
All non-verbal communication	**6.3333±1.9707**	**3.83333±0.9911**	**0.0897**
Caffeine Intake	**5.9167±2.0355**	**5.3333±1.6667**	**0.8884**
Total Subsidiary Behaviors	**38.1667± 8.4098**	**22.7500±2.5617**	**0.0167**

Measurement Repeatability and Reproducibility

By comparing the two trials, we first measured the reproducibility (Leproult et al., 2003) of objective measurements of subsidiary behavior (yawn, sign, sing and whistle, stretch trunk, touch forehead or rub eyes), as well as caffeine intake. Second, the interrelationships between the measurements were studied following the method used by Leproult et al. (2003).

The subsidiary behaviors were categorized to paralinguistic (yawn, sigh, sing and whistle) and nonverbal (stretch trunk, touch forehead/rub eyes) for further analysis. The paired correlation of the measurements of the paralinguistic (yawn, sigh, sing and whistle) and nonverbal (stretch trunk, touch forehead/rob eyes) communication was highly reproducible per individual p values respectively are r= 0.710, P= 0.0100, and r=0.7790, P=002 (Table 5.8). The measurement for caffeine intake was almost reproducible (r= 5390 P= 0.0710).

Analysis of the Behavior Responses

Normality of subsidiary data distribution was tested using Q-Q plots (Appendix C) and running Shapiro-Wilk normality test appropriate for sample sizes less than 50, according to the SPSS tutorial. Although the plots showed almost linear form, due to the presence of outliers, the normality assumption was not supported. T –test statistical analysis requires that the normality of the data and paired measurements be independent from each other (Ott & Longnecker, 2008, p. 317). Since the first conditions were not met, Wilcoxon signed-rank test was used to make inferences about the data distribution as an alternative for the paired T-test.

Table 5.8. Paired samples correlations, behavior data.

	N	Correlation	Sig. one-tailed
Yawn	12	-.085	.792
Sigh	12	.525	.080
Sing or whistle	12	.305	.334
Touch forehead or eyes	12	.882	.000
Stretch trunk	12	-.052	.872
All subsidiary behavior	12	.668	.018
All paralinguistic communication	12	.710	**.010**
All non-verbal communication	12	.790	**.002**
Caffeine Intake	12	.539	**.071**

Table 5.9. Tests of normality (Shapiro-Wilk) on behavior data.

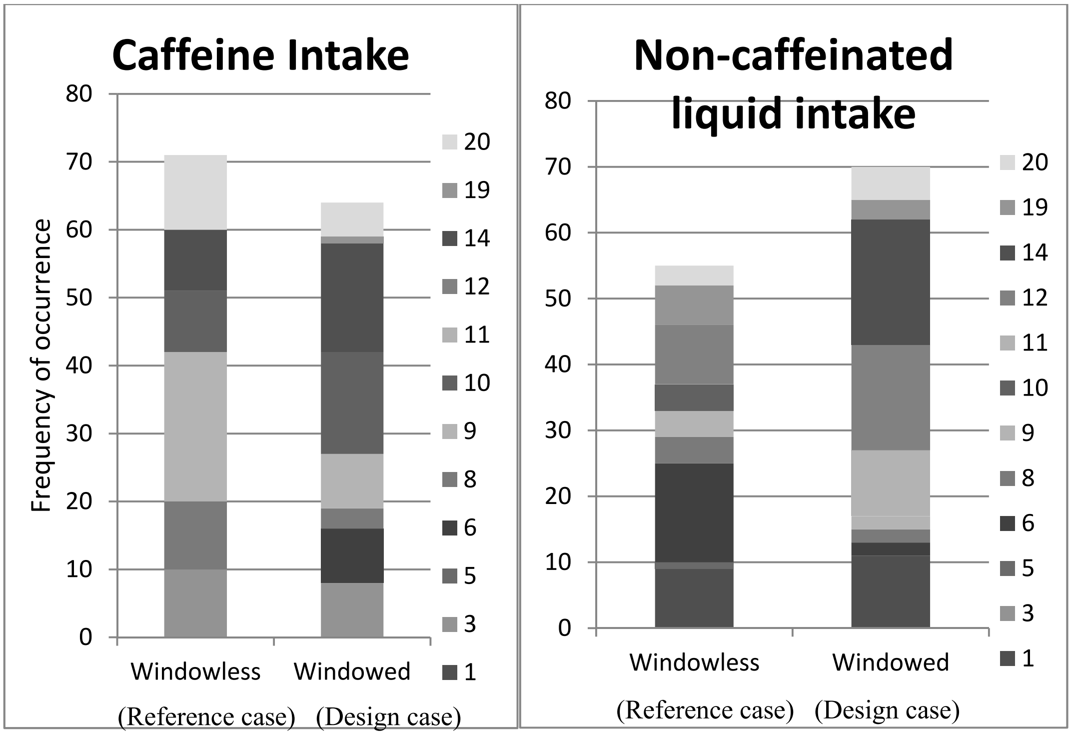
Subsidiary behavior	Lighting Condition	Statistic	df	Sig.
Yawn	Reference case	.911	12	.222
	Design case	.961	12	.794
Sigh	Reference case	.577	12	.000
	Design case	.818	12	.015
Sing or whistle	Reference case	.784	12	.006
	Design case	.804	12	.010
Touch forehead or eyes	Reference case	.800	12	.009
	Design case	.784	12	.006
Stretch trunk	Reference case	.871	12	.067
	Design case	.729	12	.002
All subsidiary behavior	Reference case	.734	12	.002
	Design case	.959	12	.766
All paralinguistic communication	Reference case	.670	12	.000
	Design case	.948	12	.613
All non-verbal communication	Reference case	.813	12	.013
	Design case	.787	12	.007

Based on the non-parametric test, the three subsidiary behavior categories decreased under the treatment conditions. Overall caffeine consumption reduced in the design case by 10%, however, the reduction was not statistically significant (Table 5.10). Behavior mapping revealed that the frequency of non-verbal and paralinguistic subsidiary behavior reduced overall in the design case by 46%, to a statistically significant level (P= 0.0167). The paralinguistic communication was reduced significantly by 41% (0.0139). The average occurrence of subsidiary behavior was reduced by 23 occurrences per day in the windowed condition (design case). The decreases of non-verbal communication of 39% and paralinguistic communication of 48% were significant (P=0.0449).

Table 5.10. Non-parametric paired T-test comparing subsidiary behavior.

Ranking	Environmental Factors	N.	Mean	SUM	SD	%	Z	P
Paralinguistic communication								
						(-48%)	**-2.138**	**0.0163**
1st	Reference case	12	25.9167	311	8.0889	100%		
2nd	Design case	12	13.5833	163	2.3978	52%		
Non-verbal communication								
						(-39%)	**-1.6968**	**0.0449**
1st	Reference case	12	6.3333	76	0.9911	100%		
2nd	Design case	12	3.8333	46	1.9707	61%		
Total Subsidiary behavior (Both Paralinguistic & Non-verbal) communication								
						(-46%)	**-2.2007**	**0.0139**
1st	Reference case	12	32.25	387	8.3694	100%		
2nd	Design case	12	17.4167	209	2.6125	54%		
Caffeine intake								
						(-10%)	**-0.1404**	**0.4442**
1st	Reference case	12	5.9166	71	2.0355	100%		
2nd	Design case	12	5.3333	64	1.6667	90%		

Further investigation of the data indicated that the overall amount of liquid intake did not seem to have decreased in the windowed condition (design case) since, as caffeine intake decreased, decaffeinated unsweetened drinks (water, ice, or fruit juice) increased (Figure 5.22). Therefore, while the overall liquid intake did not decrease (for thirst), there was a greater likelihood that nurses opted for a caffeinated liquid when they were stationed in the windowless setting. It is notable that the change in caffeine consumption was not significant.



Note. The label presents the participant's ID.

Figure 5.22. Comparison of caffeinated and non-caffeinated liquid intake.

Hypothesis 6.1: Social Interaction

Based on available evidence, it was hypothesized that communication would increase in the design case. Therefore, the frequency of communication was compared between the design case and reference case per individual when,1) they were directly in the nurse station, 2) when they were in the nursing care areas and, 3) in all areas.

Figure 5.23 illustrates the distribution of communication in various locations. The graph clearly depicts that the frequency of communication was lower in the reference case (windowless) in the nurse station as compared to the design case with the windowed nurse station. There was no difference in the frequency of communication in all other areas. The location of increased communication in the nursing unit exactly matches the location of the window. The communication frequency slightly increased off unit and in break areas. The break room did not provide windows but provided recreation and a location for relaxation for the nurses. The off-unit category includes locations visited outside the nursing unit consisting of the laboratory where blood packages were picked up, the hospital entrance door, where discharged patients were dropped off and the intensive care unit where patients' belongings were dropped off as the patient was transferred.

According to Figure 5.23, the location of increased communication in the nursing unit exactly matches the location of the window (independent variable).

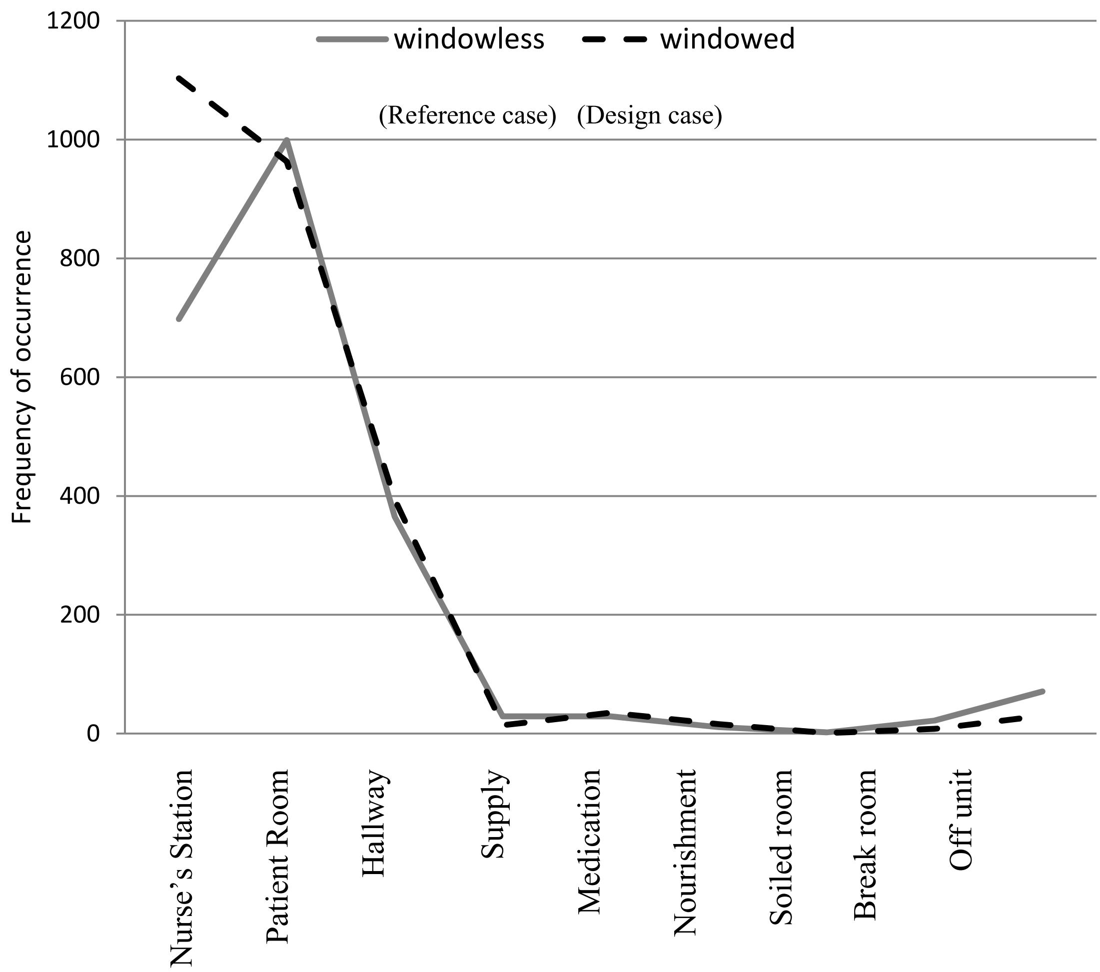


Figure 5.23. Nurses' communication**.**

Measurement Repeatability and Reproducibility

The extraneous variables were controlled in both the design case and the reference case. Therefore, the data collected on frequency of communication must be similar with minor differences resulting from the independent and explanatory variables. The Pearson correlation test assesses whether or not the measured communication data was reproducible and the methods are repeatable.

We first measured the reproducibility (Leproult et al., 2003) of the objective measurement of communication.

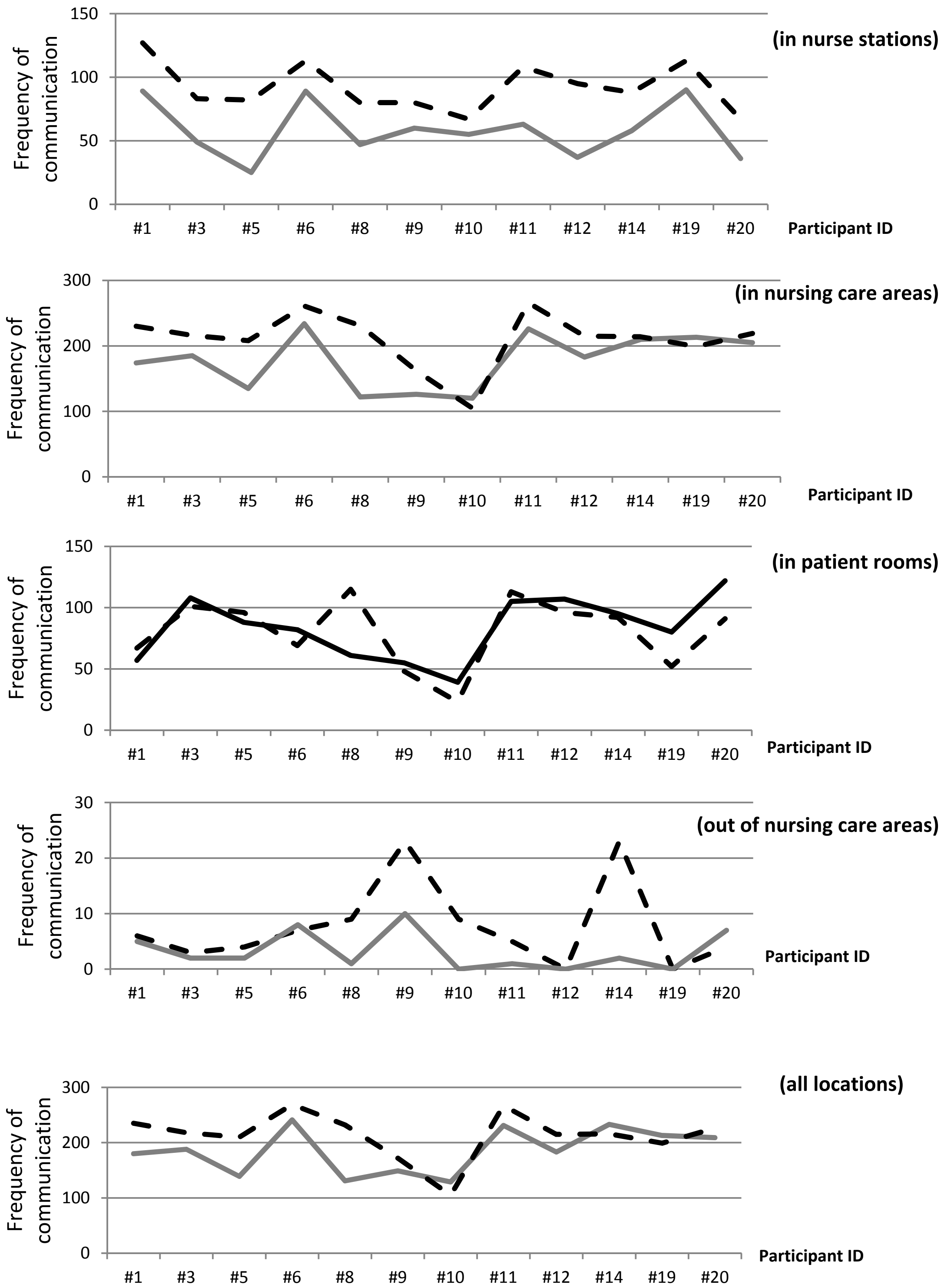
First, the paired correlation of the measurements showed that the frequency of communication measurements in the 1) nurse stations, 2) in all nursing care areas, 3)out of nursing care areas and 4) overall in all locations are highly reproducible per individual ($Com_{nstation}$ r= 0.7724, P= 0.0032, $Com_{–in-care-areas}$ r= 0.6549, P= 0.0208, $Com_{all\ locations}$ r= 0.6265, P= 0.0293). However, the communication measured from the care areas (Table 5.11) was not a reproductive measure ($Com_{out-of-care-areas}$ r= 0.4221, P= 0.1717). This can be explained by the fact that the observer was not allowed to follow the participants off unit at all times, and whether or not the data collection could be continued off the unit depended on the RN participants' choice. This allowed the participants' privacy and rest time to be respected.

Table 5.11. Paired samples correlations between windowless (reference case) and windowed condition (design case).

	N	Correlation	Sig.
Inside Nurse station	12	0.7724	0.0032
Inside nursing care areas	12	0.6549	0.0208
Outside nursing care areas	12	0.4221	0.1717
Total daily communication	12	0.6265	0.0293

Figure 5.24 shows the profiles of frequency of communication plotted once in the windowless (reference case) and once in the windowed condition (design case) per participant (method used previously by LEPROULT et al., 2003). Figure 5.24 shows that the three above mentioned categories closely follow the same pattern in the two measurements. This confirms the repeatability and reproducibility of the measurements.

In addition, the figure shows that the frequency of communication was higher in the windowed nurse station (design case) as compared to the windowless one (reference case) consistently for all participants. The pattern displayed in this graph illustrates the individual differences confirmed by the daily observation notes by the research team. For example, the Participant 11 was noted to be very sociable and Participant 10 was found to be quiet. The same pattern was confirmed by the graphs illustrating frequency of communication.



Note. Design case (dotted line), reference case (uninterrupted line).

Figure 5.24. Frequency of communication by individual participant.

Analysis of the Behavior Responses

Normality of the data distribution for all four categories of 1) nurse stations, 2) inside nursing care areas, 3) outside nursing care areas and, 4) the total communication was evaluated using Q-Q plots. Then the conclusions from Q-Q plots (Appendix C) were compared and confirmed with the results of the Shapiro-Wilk statistic test of normality, which is a test appropriate for sample sizes of 3-50 according to the SPSS 17 tutorials. The results indicated that all data collected in the 4 categories, except for the category "outside nursing care areas" was found to be normal (table 5.12). This is predictable because there was an inconsistency in data collection outside care areas as the data collection was paused most of the time.

Table 5.12. Shapiro-Wilk tests of normality on communication data.

	Statistic	**df**	**Sig.**
Inside Nurse station (Reference case)	.917	12	.263
Inside Nurse station(Design case)	.927	12	.345
Inside nursing care areas(Reference case)	.894	12	.133
Inside nursing care areas (Design case)	.870	12	.066
Outside nursing care areas (Reference case)	.796	12	.008
Outside nursing care areas (Design case)	.838	12	.026
Total daily communication(Reference case)	.915	12	.248
Total daily communication(Design case)	.875	12	.075

Paired T-test was used for analyzing the data with normal distribution and non-parametric paired sample test for non-normal data. The findings show that the hypothesis of increased communication at the nurse station is supported ($p= 0.0000$). The rate of communication at the nurse stations when windows and natural light were present increased by 58%. The increase in communication at the nursing care areas increased by 18% (P=0.0041) and by 15% in all locations.

Interestingly, the communication occurrence off-unit and in break areas decreased by 59% ($P_{2\text{-tailed}}$=0.0362) for the nursing ward with the windowed nurse station. The increase in communication off unit and in break areas in the windowless case may be an indication that the participants spent more time in these areas (table 5.13).

Table 5.13. Comparison of subsidiary behavior under the two trials.

Trial	N.	Mean	SD	%	T	P (2-tailed)	P (1-tailed)
Communication in the Nurse Station				+58%	-8.3273	0.0000	0.0000
1. Reference case	12	58.1667	6.2763				
2. Design case	12	91.9167	5.5779				
Communication in Nursing Care Areas				18%	-3.2125	0.0083	0.0041
1. Reference case	12	177.7500	12.1731				
2. Design case	12	210.5000	12.3665				
Communication out of Nursing Care Areas				-59%	Z*=-2.095	0.0362	0.0181
1. Reference case	12	7.7500	2.2195				
2. Design case	12	3.1667	0.9987				
Total Communication				15%	-2.6755	0.0216	0.0108
1. Reference case	12	185.5000	11.8113				
2. Design case	12	213.6667	12.5072				

Note. *Non-parametric paired- test.

Hypothesis 6.2: Positive Sociability and Approachability

Evidence points to the positive impacts of lighting on sociability (Kräuchi, Wirz-Justice & Graw 1990) and reduced social conflicts (Rashid & Zimring, 2008). Positive sociable behavior was documented to test the notion of whether or not the presence of windows in the nurse stations improved positive sociability for RNs. Determining if communication is positive is a very subjective matter which makes it challenging to obtain an acceptable reliability measurement among researchers, and thus it would increase measurement error. To avoid this measurement error, the best behavior we found which was identifiable and definable was laughter. Laughter is considered as a manifestation of sociability, warmth and approachability behavior (Feagai, 2011; Palmer, 2005). Therefore, we documented any time a positive conversation was held that resulted in a nurse laughing. Laughing was defined as: a) audible b) chest moving and c) out of joy, by the research team.

The laugh data box plots interestingly reveal that the patterns in the patient rooms and hallways (Figure 5.25) were equal both in terms of mean values and distribution form. This is an indication of the repeatability of the measurement.

There were no differences in terms of the occurrence of conversations with positive content that resulted in laughter in hallways in the north (reference case) and south wards (design case). The patient rooms are equally distributed on both sides of the hallways and are similar in terms of exposure to windows and views. The box plot shows that the occurrence of positive conversation in patient rooms, which was followed by laughter, was quite similar in both wings (design case and reference case).

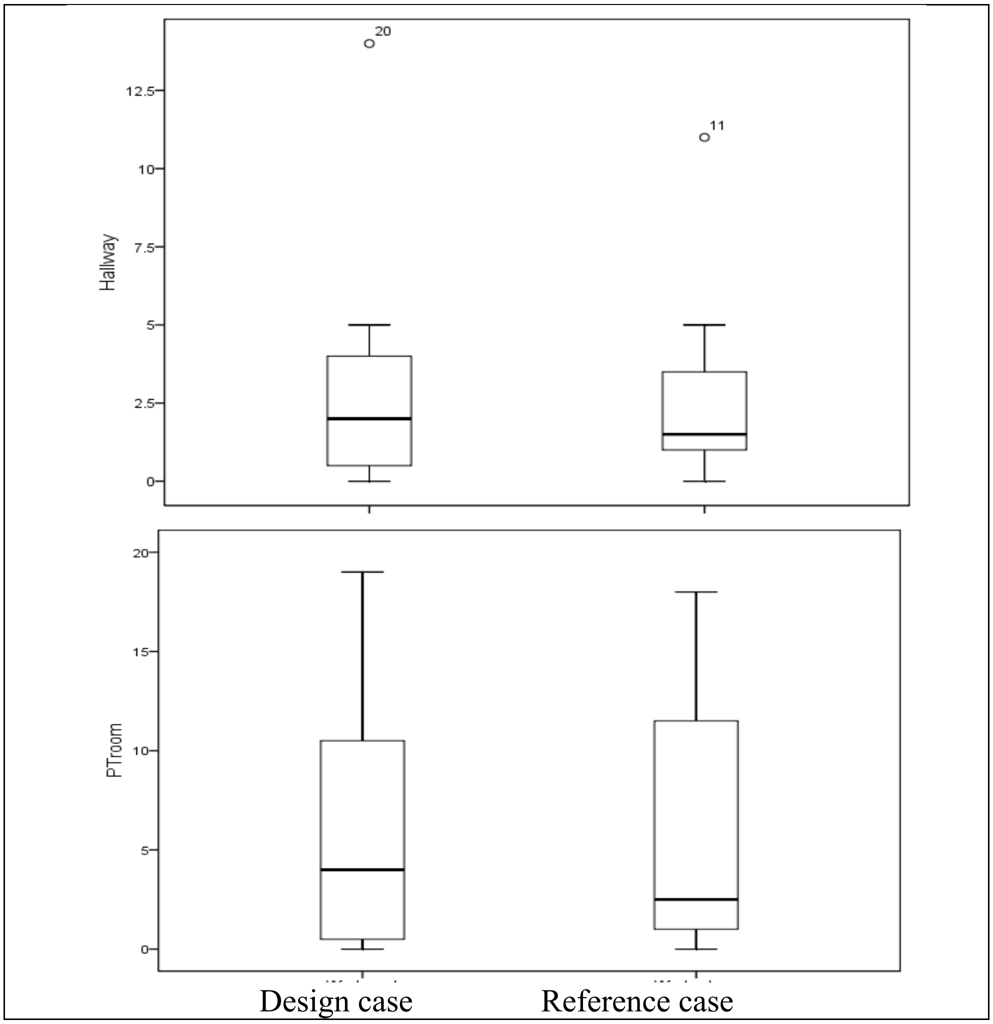


Figure 5.25. Distribution of occurrence of positive sociability in hallways and patient rooms.

The following box plots (Figure 5.26) present the distribution of laugh occurrence in both nurse stations (design case and reference case). These illustrations indicate that there was a considerable reduction in the frequency and variation of laughter in the windowless wing (reference case). In conclusion, there was a noticeable reduction of positive sociability as evidenced by laughter in the windowless wing.

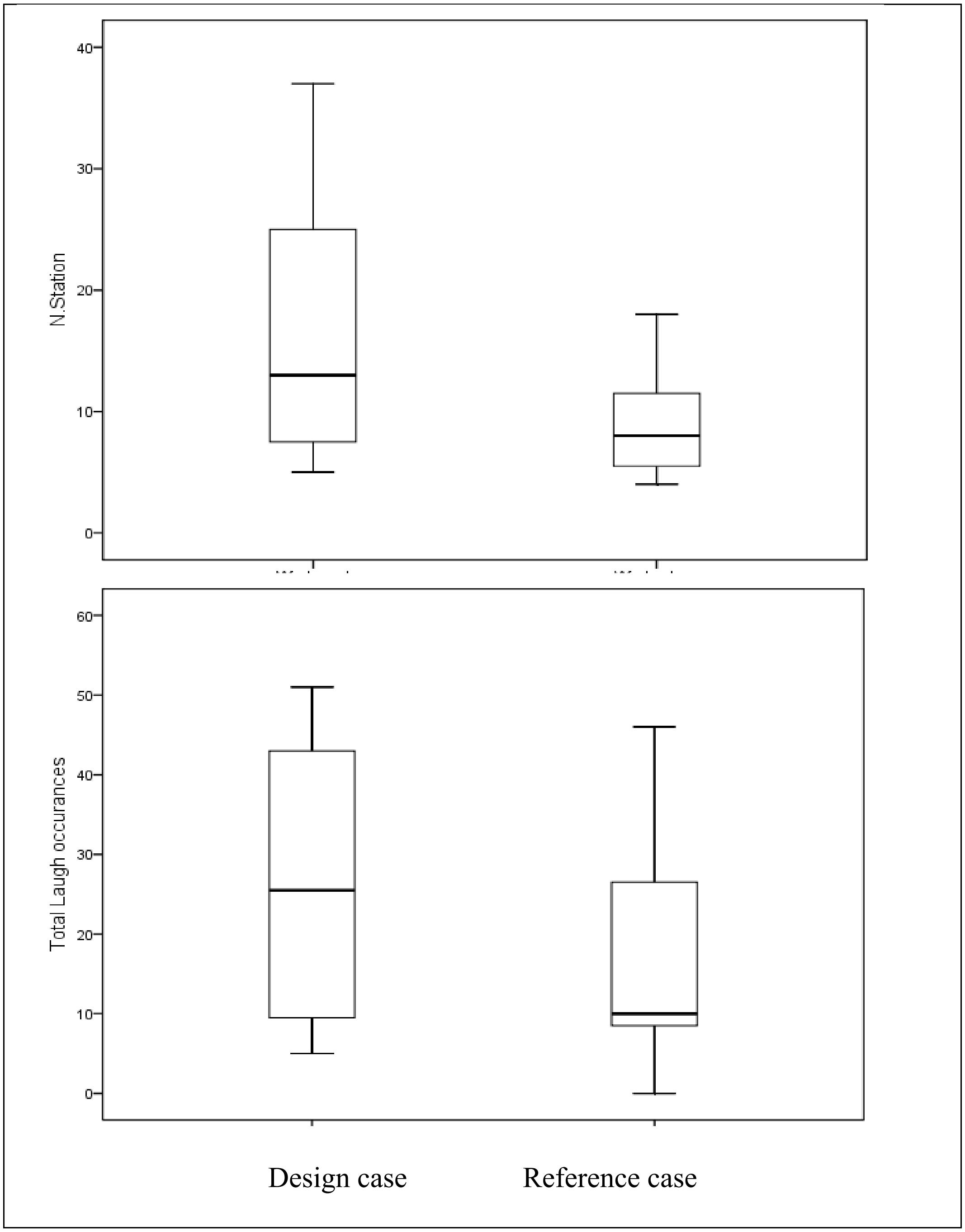


Figure 5.26. Distribution of occurrence of positive sociability in nurse station and all locations.

Figure 5.27 displays the spatial distribution of the occurrence of laughter as an indication of positive sociability. As shown, the distribution is consistent in both the design case and reference case except for the nurse station; this is where the independent variable is located. This finding is consistent with the findings in the previous section about communication.

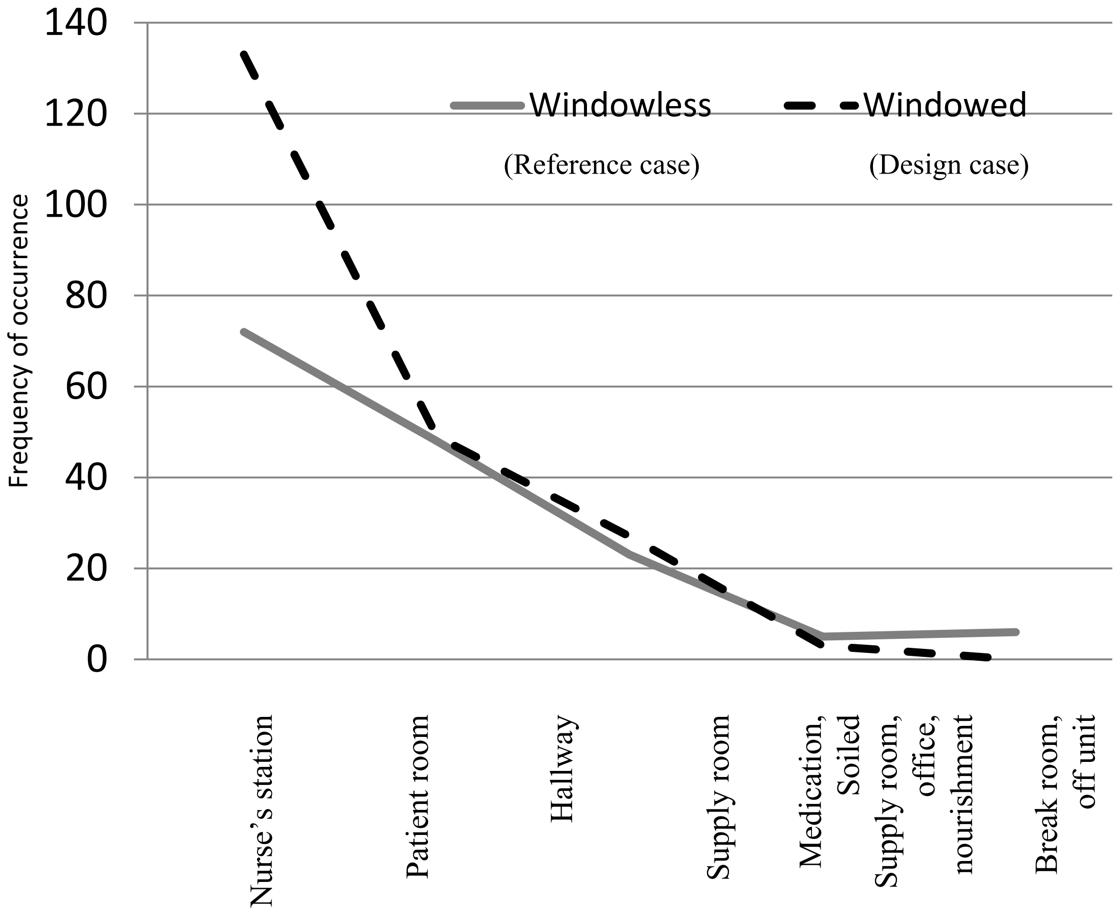


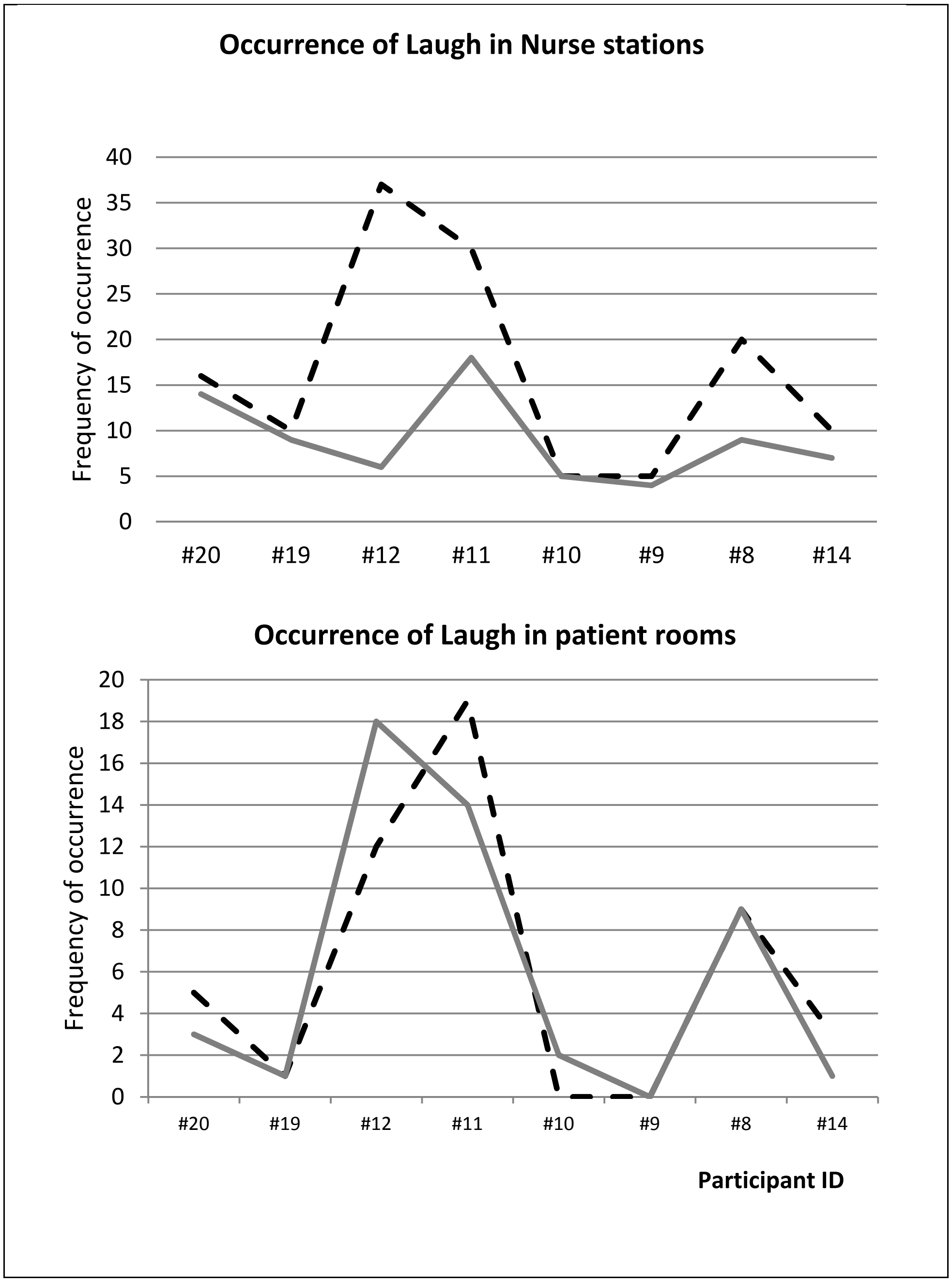
Figure 5.27. Positive sociability and approachability.

Measurement Repeatability and Reproducibility

The reproducibility and repeatability of data measurement was supported both by correlation test and by evaluating the graphs when comparing the wards and when comparing the patient rooms (Figure 5.28). Although the correlation values for the nurse stations are not significant (Table 5.14), the graphs depict a similar pattern between the reference case and design case measurements in the nurse stations. The increase in positive sociability (conversations resulting in laughter) is more significant for participants with a high baseline of positive sociability. Those participants with low frequency of positive sociability tend not to be affected much by windows.

Table 5.14. Paired samples correlations between the design case and reference case.

	N	**Correlation**	**Sig.**
Patient room	8	.888	.003
Nurse station	8	.443	.272
Hallways	8	-.204	.628
Total	8	.719	.044



Note. Design case (dotted line), reference case (uninterrupted line).

Figure 5.28. Spatial occurrence of laugh in the nursing ward per participant.

Analysis of the Behavior Responses

The evaluation of Q-Q plots (Appendix C) and Shapiro-Wilk normality tests confirmed the normality of the laugh data collected in nurse stations and in the entire unit (Table 5.15). Since the sample size is small, and parametric test is not robust for small sample sizes (Motulskey, 1995), non- parametric paired test was used to analyze the data.

Table 5.15. Tests of normality (Shapiro-Wilk) on laugh data.

	Lighting	Statistic	df	Sig.
Patent room	Design case	.880	8	.189
	Reference case	.826	8	.054
Nurse Station	Design case	.894	8	.256
	Reference case	.893	8	.252
Hallway	Design case	.732	8	.005
	Reference case	.731	8	.005
Total Laugh occurrences	Design case	.878	8	.180
	Reference case	.881	8	.192

Based on the non-parametric statistical test, the possibility of laughter increased by 45% when individuals were at the windowed nurse station (design case) compared to the windowless one (P=0.008). Overall, the laugh occurrence also increased by 36% in the ward where windows were available in the nurse station (0.0315). The hypothesis was rejected for the hallway areas and patient rooms (Table 5.16).

Table 5.16. Paired test comparing the frequency of nurses' communication in the design case and reference case.

Trial	N	Mean	SD	SUM	% Increase	Z	P (2-tailed)	P (1-tailed)
Occurrence of Laugh in Nurse stations					46 %	-2.3707	0.0178	0.008
1. Reference case	8	9.0000	1.6903	18				
2. Design case	8	16.6250	4.1487	37				
Occurrence of Laugh in Patient rooms					2 %	-0.1374	0.8907	0.4456
1. Reference case	8	6.0000	2.4202	48				
2. Design case	8	6.1250	2.3937	49				
Occurrence of Laugh in Hallways					15%	-0.1407	0.8881	00.4440
1. Reference case	8	2.8750	1.2739	23				
2. Design case	8	3.3750	1.6250	27				
Occurrence of Laugh in the entire unit					36%	-1.8593	0.0630	0.0315
1. Reference case	8	17.0000	5.3385	46				
2. Design case	8	26.5000	6.6413	51				

Note. *Non-parametric paired- test.

Hypothesis 7: Medical Records

Table 5.17 shows all categories of medication errors collected by the hospital during 2009 to 20011. A total of 14 medication/IV errors occurred in the windowless ward and 9 occurred in the windowed ward (design case). The report shows that 61% of errors occurred in the windowless (reference case) ward and 39% in the windowed ward (Figure 5.29). Therefore, the probability of error in the windowed ward was reduced by 36%.

Table 5.17. Frequency of non-IV and IV medication errors.

Non-IV and IV medication errors	Windowless	Windowed
Extra Dose	2	1
Other (ME)	3	1
Wrong administration Technique	0	0
Wrong dose: Form	0	0
Wrong dose: Quantity	2	0
Wrong additive/Solution (ME)	1	0
Wrong dose: formulation/Strength/ Amount(ME)	1	1
Wrong frequency(ME)	0	1
Wrong medication/unauthorized (ME)	3	1
Wrong patient/Chart(ME)	1	0
Wrong rate (equipment)(ME)	0	1
Wrong route(ME)	1	0
Wrong time(ME)	0	3

Note. All categories of medication errors.

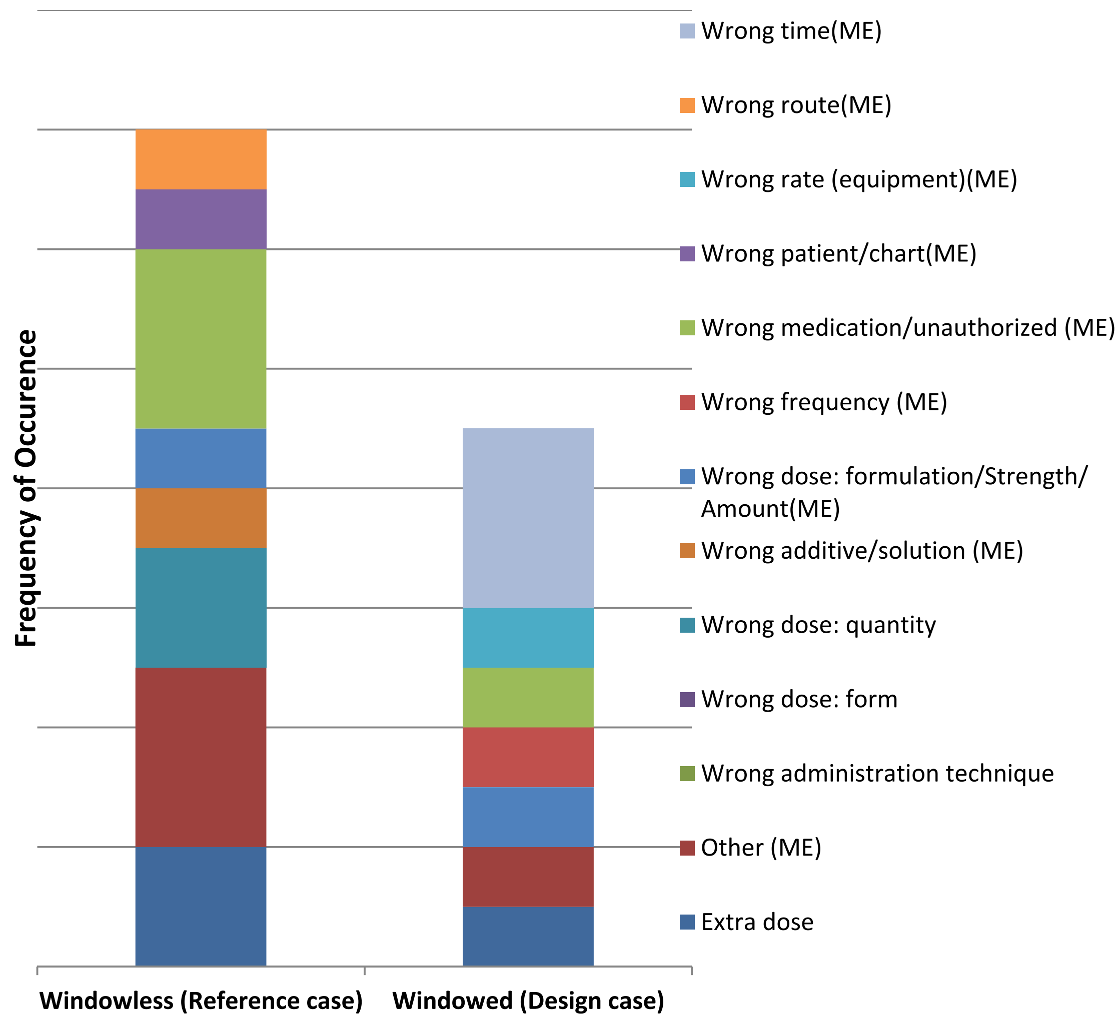


Figure 5.29. Non-IV and IV medication error rates between 2009-2011.

Adjusted for the number of patient rooms. The windowed ward (design case) has 33 patient rooms, whereas the windowless ward (reference case) has 36 patient rooms. Although the patient nurse ratio and patient acuity is similar, the greater number of rooms in the north ward may increase the probability of errors. Therefore, the errors were adjusted per patient room in each ward and compared (Figure 5.30).

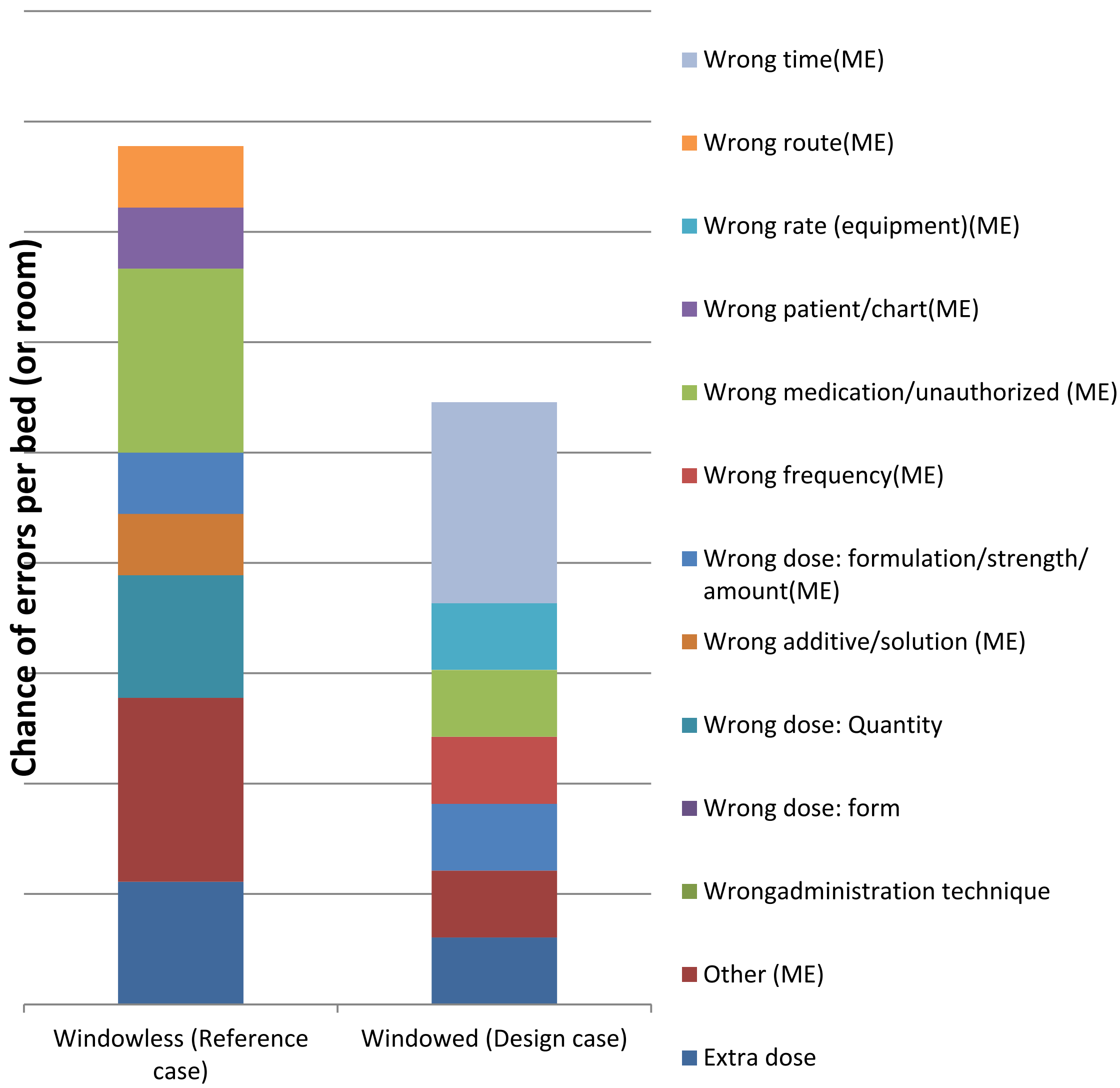


Figure 5.30. Non-IV and IV medication error rates between 2009-2011 per patient room.

The report shows that 0.6 medication/IV errors occurred per room in the windowless ward (North) during 2009-2011. This value was diminished to 0.4 medication/IV errors per room in the windowed ward (design case). Therefore, the probability of error in the windowed ward decreased by 29.9%

Analysis of the Medical Records

The test of normality was conducted on the 13 error categories (Tables 5.18 & 5.19). The analysis indicates that the normality of the data cannot be assumed (Figure 5.31). Therefore, a Non-parametric paired test was used to analyze the data. The box plot confirms that the data distribution is non-normal.

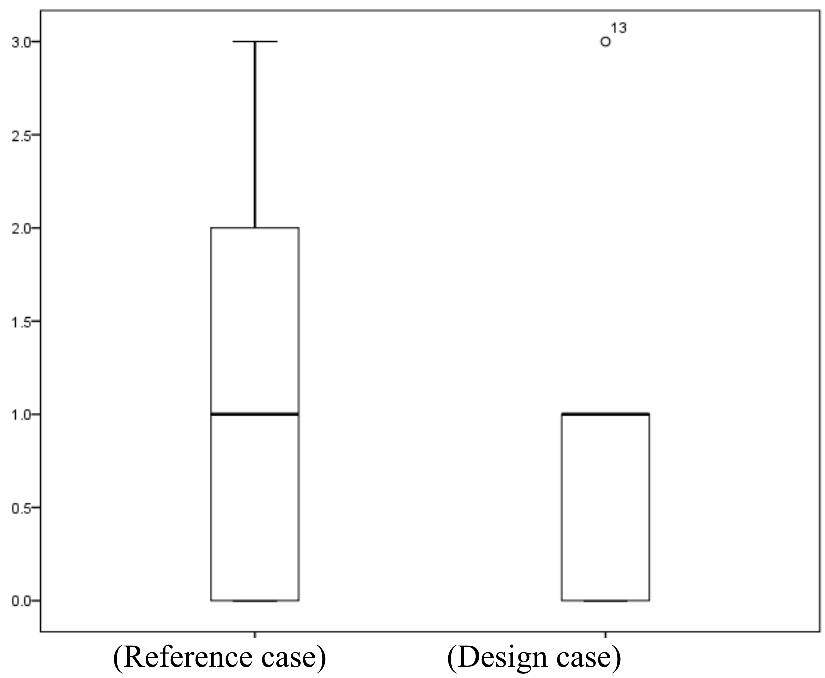


Figure 5.31. Non-IV and IV medication error rates box plot.

The statistical analysis reveals a 30% less chance of occurrence of IV and Non-IV medication errors in the windowed ward (design case) versus the windowless ward (reference case) from 2009 to 2011. However, the reduction is not significant (P= 0.2720).

Table 5.18. Tests of normality (Shapiro-Wilk) on medication errors data.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Reference case	.220	13	.086	.839	13	.021
Design case	.283	13	.006	.722	13	.001

Table 5.19. Wilcoxon Signed Ranks test (based on positive ranks) on medication errors data.

	N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
Negative Ranks	7[a]	5.43	38.00	-1.098[a]	0.2720
Positive Ranks	3[b]	5.67	17.00		
Ties	3[c]				
Total	13				

Note. a. Design case < Reference case, b. Design case > Reference case, c. Design case = Reference case.

Discussion of the Findings

Summary of the Findings

The study compared biological and psychological responses of 12 day shift female and male registered nurses (RNs) providing direct patient care, measured once in windowed (design case) and once in windowless nurse's stations (reference case) in an acute care unit. The nurses rotate weekly among the nurse's stations with similar furniture, interior finishes and equipment in the north and south wings of a double-loaded H-shaped unit configuration of about 20,000 square feet. Therefore, the same RNs in the same organizational and managerial settings, provide care for the same type of patients with similar acuity, in different weeks. In Study 2, the impact of the presence of windows in the nurse's station on the RNs' biological responses and circadian rhythms, as well as sleepiness, mood and sociability, were measured during the shift.

To test the hypothesis, RN vital signs (body temperature, heart rate, oxygen saturation, blood pressure) and subjective sleepiness were measured bihourly from 8:00 to 16:00, during a workday in the windowed (design case) and in another workday in the windowless nurse stations (reference case). In addition, the participants' behavior (related to sleepiness and deteriorated mood) as well as frequency of communication and sociability, was recorded via continuous behavior mapping in one-minute time bins. The RNs also reported their sleep duration and quality the night before at the beginning of the data collection.

Results showed that morning diastolic blood pressure (P=0.025), mean arterial pressure (P=0.0662) and sleepiness (P= 0.052) were reduced, and oxygen saturation

[SPO2] (P=0.0535) and body temperature (P=0.0360) increased in the windowed environment (design case) compared to the control environment (reference case). Also, the chance of morning hypertension was reduced by 54%. Morning average systolic blood pressure remained unchanged.

Daily occurrence of hypertension was reduced by 14% during the entire day if windows were available. The average daily SPO2 increased in the windowed location (P=0.011). The decrease of morning subjective sleepiness was 34% (P= 0.052). The total daily sleepiness reduction was 10%, but insignificant (P=0.238).

The behavior mapping indicated that the frequency of subsidiary behaviors, those related to sleepiness and deteriorated mood, dropped by 40% in the windowed nurse's station compared to the windowless station (P=0.001). Caffeine intake reduced 10%, but insignificantly.

The rate of communication under the windowed (design case) condition increased by 58% (P=0.000). Positive sociability, as measured by the occurrence of frequent laughter, increased by 46%.

The findings based on the analysis of medical records suggest close to 30% of medication errors were avoided in the windowed ward (design case). This trend matched the behavioral and psychological impacts found in this study. This data lends support to the hypothesis that providing natural light may significantly improve front-line care giver's work performance.

Research suggests that not all medication errors are reported. Mayo and Duncan (2004) found that nurses believe that only 25% of errors are reported and nurses in a study by Blegen, Vaughn, Pepper, Vojir, Stratton, Boyd, et al. (2004) indicated that only 47% of medication errors are reported. The common underlying reasons for missed reports are fear of supervisor or coworker pressure, or believing that the incident was not important enough (Mayo & Duncan, 2004). Based on the fact that errors are underreported, we estimate the actual number of errors that occur may be more than twice the numbers reported. In conclusion, it is highly important to minimize errors through design.

Finally, putting biological, behavioral and operational outcomes into perspective, the availability of daylight may positively affect all three measures in the RNs that provide care to acute patients.

Previous evidence has shown that bright sunlight may affect the rate of serotonin production in the brain and result in mood alterations (Lambert, Reid, Kaye, Jennings & Esler, 2002).

Strengths and Limitations of the Study

This research study was conducted in a control setting. However, similar to any other field research, it was not possible to control for all existing variables. Although the furniture, interior finishes, information technology and equipment were similar in the two nurse's stations (design case and reference case), the seating arrangements differed. Seating arrangement may affect the frequency of communication, thereby mediating the research outcomes.

Both nurse's stations (design case and reference case) were in double-loaded corridors with similar patient room form and arrangement. However, one was located in the center of the corridor and the other was centered in the left side of the corridor. This arrangement could impact the walking distance and affect nurse fatigue. However, this factor was controlled, to an acceptable degree in the study, by the charge nurse assignment process; patient rooms in close proximity were assigned to an RN at the closest nurse's station. If the study had also been conducted during the night shift, it could have been confirmed that, in the absence of the independent variable (daylight), the two corridors offer similar work conditions and work output. Figure 5.32 displays the locations of the main nurse's stations included in the study.

The equipment used for biological vital sign measurements may have posed a limitation for the outcomes. A Carscape vital sign machine, as described in the methods section, was typically used. However, another vital sign machine, Welch/Allyn, model#52000, was used as a backup when the Carscape was not available. The alternative machine was used for about one-third of the measurements. Both pieces of equipment were calibrated to hospital standards.

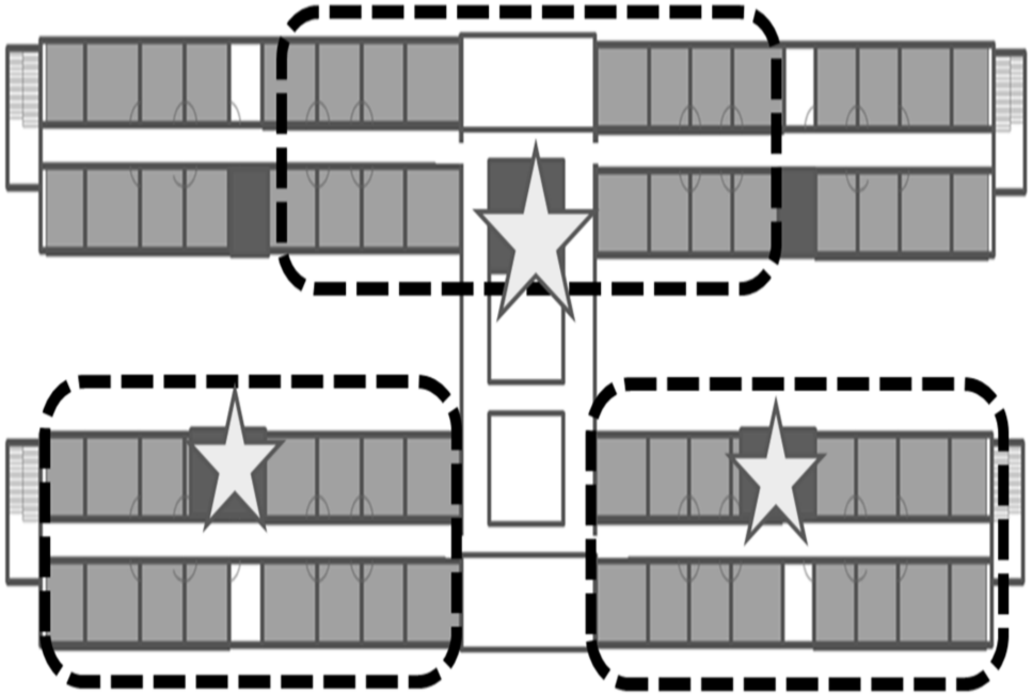


Figure 5.32. Approximate room assignment zones for each nurse's station.

Implications of the Findings

Biological measures. The findings on reduced sleepiness and increased morning body temperature are consistent with Turner et al. (2010) who note that morning sunlight increases vigilance and core body temperature. Also, Wright, Hull & Czeisler, 2002) report that increased body temperature may relate to increased performance and Cajochen, Zeitzer, Czeisler, and Dijk, (2000) report that light exposure may lead to an increase in core body temperature and melatonin suppression. Wright et al. (2002) explain that even an increase of about 0.17 C in body temperature may be associated with enhanced memory and cognitive performance. Therefore, this study suggests that the presence of window and daylight may be associated with increased morning wakefulness and performance.

The presence of windows providing a view of outside has healing effects (Ulrich, 1984). It also provides daylight which is known to reduce perceived stress (Walch et al., 2005). Kaplan describes a window view as a "micro-restorative experience, one that provides a brief respite to one's directed attention" (Kaplan, 1993, p. 196). Such restorative experiences may be associated with a lowered heart rate. Research by Canin (1991) has found that the presence of nature improves functioning and reduces burn-out among AIDS caregivers. Micro-restorative experiences are brief moments with considerable benefits of restoration of performance (Kaplan, 2001). Such events can improve staff health and job satisfaction (Sherman et al., 2005).

In this study, sleepiness, body temperature and systolic BP, MAP and overall blood pressure (measured by hypertension) appear to improve in the morning. However, all deteriorate (increased sleepiness and diastolic BP, decrease of temperature, increased chance of hypertension) in the afternoon -- at hour 16:00 for all, except MAP, which is lower at hour 14:00. While further research is required to understand the origins of these changes, we suggest this may be a result of the dim electric light back up in the windowed condition (design case) which is twice as bright as the electric light in the windowless condition (reference case). The section “variable of interest” in Chapter VI provides further information about this change. Although the total of penetrated daylight and available electric light in the windowed condition is quite similar to the total electric light in the reference case in the morning, as the sun moves behind the building in the afternoon, the total illumination levels in the windowed condition drop below the control condition (reference case).

The SPO2 increase, between the reference case and design case, seems to be fairly consistent. We know that deep and slow breathing can result in increased oxygen saturation (Bernardi, Spadacini, Bellwon, Hajric, Roskamm, & Frey 1998). Possibly, the windowed environment (design case) with natural light, by providing a sense of happiness and freshness to the environment, stimulates more deep breathing compared to the windowless location (reference case), which could possibly impose a feeling of confinement and gloom. More research is needed to verify whether or not daylight increases blood oxygen saturation.

Other experiments with oxygen saturation have been found to be relevant to a stress reducing environment. For example, the psychoneuronal effects of music on reducing anxiety have been discussed. Significantly fewer oximeter alarm occurrences were reported for infants who heard music, and a significant reduction of oxygen saturation occurred after the termination of music, according to Standley and Moore (1995, cited by Shepley, 2006).

In the present study, a decrease in MAP and an increase in SPO2 were observed in the morning. While we might assume that a decrease in blood pressure and MAP would decrease SPO2 and oxygen content in the blood due to increased cardiac activity, research shows that variation in mean arterial pressure does not change oxygen variables (Bourgoin, Leone, Delmas, Garnier, Albanèse, & Martin, 2005).

Behavioral measures. The behavior observations show that the rate of communications by RNs increased at the location where the independent variable (window) was located. The same pattern was demonstrated regarding positive sociability. Behavioral clues about mood and sleepiness also improved at the windowed location (design case), and caffeine consumption decreased. These findings may be linked to the findings of a study by Kräuchi et al. (1990), which showed that lighting therapy reduced caffeine use, increased social interaction and reduced sleepiness for seasonal affective disorder patients. The present study suggests Kräuchi's findings may also apply to non-depressed individuals.

Medical records. "Nurses are the front line of defense to intercept and report medication errors" (Chiang & Pepper, 2006), but medication errors are commonly underreported (Koohestani & Baghcheghi, 2009). The findings indicate that there was 30% less chance of occurrence of medication errors in the windowed ward (design case). The statistical power of this finding was not significant. Perhaps this is because the medication errors data was not separated for day and night shifts; we need further research to confirm the linkage among the presence of daylight, wakeful behavior among care givers, and medication errors.

Findings from the momentary subjective sleepiness in the first section and observed sleepiness in the second section match with some variations that may be related to the measurement method. Sleepiness was reduced by 40%, as evidenced by behavioral clues. However, the same measure reduced only by 10%, when measured by subjective self-reports. The reduced sleepiness measured by observed behavior was three times greater than the observed sleepiness. This may be because the participant caregivers under-reported their perceptions.

CHAPTER VI

ENERGY MODELING RESEARCH RESULTS AND DISCUSSION

Introduction

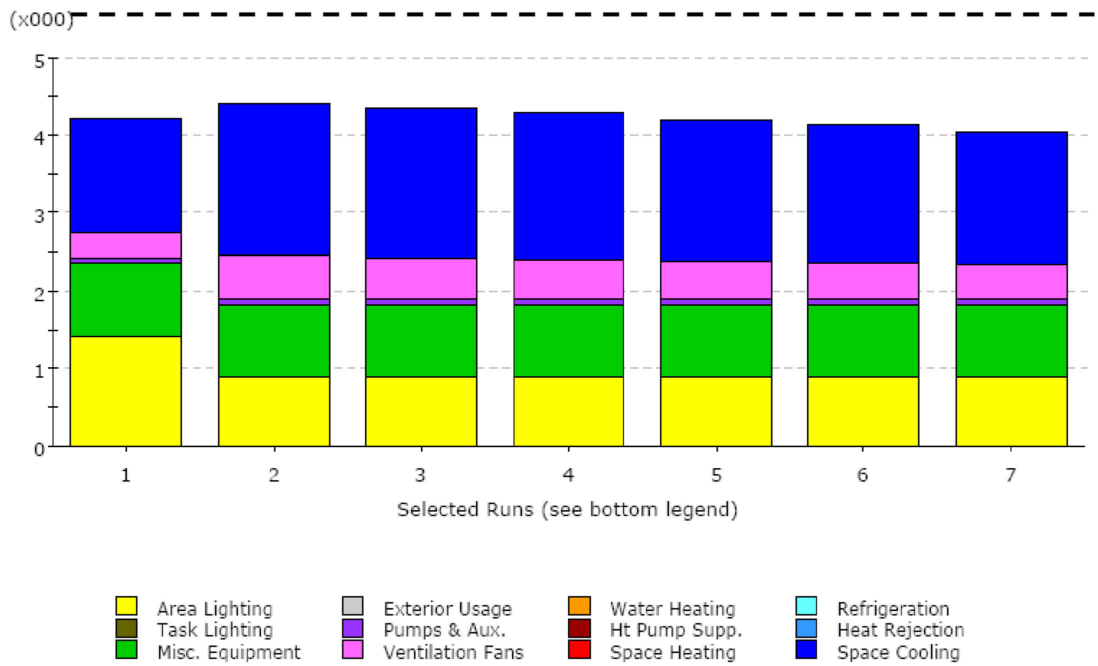
The first two sections of this chapter provide the results of both the pilot study and the main study. The second section provides the findings only of the main study. The implementations of the findings, limitations and design applications are discussed in the last section of this chapter.

Hypothesis 8: Energy Impacts of a Window

The first computer modeling of an outpatient treatment room modeled by eQuest was an exploratory approach. The results set the foundation for the main study which involved *a priori* hypothesis testing.

Pilot Study: An Exploratory Approach

The notion of whether or not changing glazing characteristics in a window influences electricity consumption was explored. As displayed in Figure 6.1, the analysis showed that modifying the Shading Coefficient value for glazing, while maintaining all the other window characteristics, reduced total annual electric consumption below the baseline (room with no window). Therefore, a window with a careful choice of materials may reverse the energy loss trend, and turn the window into an energy conservation strategy. The appropriate glazing characteristic seems to be a primary key to facilitate this positive trend (Figure 6.1). The findings from the pilot study contend that daylight may not necessarily pose a conflict between heating and energy efficient design strategies.



Note. 1. Design case (window less room), 2. SC=0.80, 3. SC=0.75, 4. SC=0.70, 5. SC=0.65, and 6. SC=0.60. 7. SC=0.55.

Figure 6.1. Changing glazing characteristics (Shading Coefficient in this case), has decreased the energy consumption lower than baseline (no windows).

Main Study: Energy Impacts of a Window

It was hypothesized that adding a window with appropriate glazing characteristics would not increase total energy consumption. Three case studies with various lighting conditions were compared to test this hypothesis. The three lighting conditions are displayed in Figure 6.2.

Base case: Windowless Design case I: Glazing type 1 Design case II: Glazing type 2

Note. Images generated using Autodesk Ecotect and Radiance software.

Figure 6.2. Three lighting conditions.

First, the annual total lighting energy use was calculated in the three lighting conditions to estimate the impact of windows upon lighting energy use reduction. Second, total building electricity and fuel consumption end use were compared in the three cases to understand the overall impact of windows on all heating, cooling and lighting loads.

Lighting energy use. The simulation analysis showed that given the available window, the lighting energy use was reduced by 44% and 43%, respectively, in design cases I and II during operating hours. Table 6.1 displays the percent of lighting reduction for design cases I and II each month.

Table 6.1. Monthly lighting energy reduction by daylighting.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Base case	**Total zone**	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Design Case I	**Total zone**	41	43	44	45	45	45	45	45	44	43	42	41	**44**
	Reference point 1	63	66	67	68	69	69	69	69	68	66	64	62	**67**
Design Case II	**Total zone**	40	42	43	44	45	45	45	45	44	42	41	39	**43**
	Reference point 1	61	64	65	67	68	69	69	68	67	65	62	60	**66**

Note. The values are in percentage and are based on LS-G report data tables generated by eQuest.

Table 6.2 shows the hourly percent of lighting energy reduction for design case II. The values indicate that an average of 46% of electricity consumed for lighting could be avoided between the hours10:00 to 15:00, and at least 15%, and 35% of electricity consumption, respectively, could be eliminated in early morning and late afternoon.

Table 6.2. Hourly lighting energy reduction by daylighting.

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Hours**
Jan	0	0	0	0	0	0	0	15	44	46	46	46	46	46	46	45	35	8	0	0	0	0	0	0	**40**
Feb	0	0	0	0	0	0	0	21	45	46	46	46	46	46	46	45	42	23	0	0	0	0	0	0	**42**
Mar	0	0	0	0	0	0	6	37	46	46	46	46	46	46	46	45	43	27	4	0	0	0	0	0	**43**
Apr	0	0	0	0	0	0	27	45	46	46	46	46	46	46	46	46	46	45	11	0	0	0	0	0	**44**
May	0	0	0	0	0	4	38	46	46	46	46	46	46	46	46	46	45	41	19	0	0	0	0	0	**45**
Jun	0	0	0	0	0	8	44	46	46	46	46	46	46	46	46	46	46	44	29	1	0	0	0	0	**45**
Jul	0	0	0	0	0	3	43	46	46	46	46	46	46	46	46	46	46	44	27	1	0	0	0	0	**45**
Aug	0	0	0	0	0	0	37	45	46	46	46	46	46	46	46	46	46	44	18	0	0	0	0	0	**45**
Sep	0	0	0	0	0	0	24	46	46	46	46	46	46	46	46	46	45	35	4	0	0	0	0	0	**44**
Oct	0	0	0	0	0	0	14	43	46	46	46	46	46	46	46	45	38	13	0	0	0	0	0	0	**42**
Nov	0	0	0	0	0	0	3	36	46	46	46	46	46	46	46	44	31	3	0	0	0	0	0	0	**41**
Dec	0	0	0	0	0	0	0	19	43	46	46	46	46	46	46	45	30	2	0	0	0	0	0	0	**39**
Annual	**0**	**0**	**0**	**0**	**0**	**1**	**29**	**40**	**45**	**46**	**46**	**46**	**46**	**46**	**46**	**45**	**40**	**13**	**9**	**0**	**0**	**0**	**0**	**0**	**43**

Note. the values are in percentage and are based on LS-H Report data tables generated by eQuest. The operation hours are highlighted in the table.

The hourly average illumination levels per month for the hours of operation are displayed in Table 6.3. The blue, yellow and orange cells highlight the illumination achieved above 50, 100 and 150 foot candles. Based on the light illumination levels achieved, the use of shading may be necessary, especially to control daylight between 10:00 to 13:00 for the months of February to November. Designing advanced shading devices allows selective control of daylight monthly and hourly.

Table 6.3. Hourly daylighting illumination.

Month	7	8	9	10	11	12	13	14	15	16	17	18	Hours
Jan	0	18	63	111	134	133	131	114	95	61	32	10	82
Feb	3	20	71	123	140	151	143	134	101	67	47	18	86
Mar	8	40	103	139	168	160	145	124	98	80	51	25	88
Apr	20	65	112	162	185	174	164	139	115	95	72	40	100
May	33	76	113	148	163	163	148	127	112	90	64	40	88
Jun	38	90	125	160	172	165	154	145	123	99	71	46	95
Jul	33	85	134	171	184	181	159	139	126	96	76	49	97
Aug	26	87	132	169	191	179	168	147	123	94	68	44	101
Sep	19	77	136	180	193	174	175	143	104	81	57	26	105
Oct	15	68	135	182	179	172	159	127	93	57	33	12	102
Nov	4	34	112	144	164	164	147	118	84	51	25	6	89
Dec	0	19	64	102	126	137	126	111	83	51	24	5	77
ANNUAL	**22**	**57**	**108**	**149**	**167**	**163**	**152**	**131**	**105**	**77**	**52**	**27**	**93**

Note. The values are in percentage and are based on LS-M Report data tables generated by eQuest.

Total energy use. The annual energy consumption (both electric and natural gas) was studied in all three lighting conditions. The analysis showed that total electricity and fuel consumption were both increased in design case I. The total electricity in design case II, with the high performance glazing, dropped below the reference case (windowless condition). Fuel consumption also decreased considerably but did not surpass the base case.

The cost of electricity and natural gas demand was calculated by using current electricity and natural gas rates. Electric rates for commercial use were estimated at 13 cents per kWh based on the average flat rate provided by a popular electricity provider in Texas. The natural gas rate was assumed at $4.53 per million Btu based on a report dated July 2011, by the Federal Reserve Bank of Dallas which regularly provides information on “Texas economic indicators” (Federal Reserve Bank of Dallas, 2011, P. 1).

Finally, the hypothesis that adding a window would not increase energy use is partially rejected for the glazing type used in case I because the energy costs for design case I were 30% higher than the baseline. The second glazing type, however, was assigned to design case II, resulting in balancing the heating and cooling energy loss and lighting energy gains. The final cost of energy ($194.27) did not exceed the baseline ($ 194.77) in design case II (Table 6.4). Therefore, the hypothesis is supported.

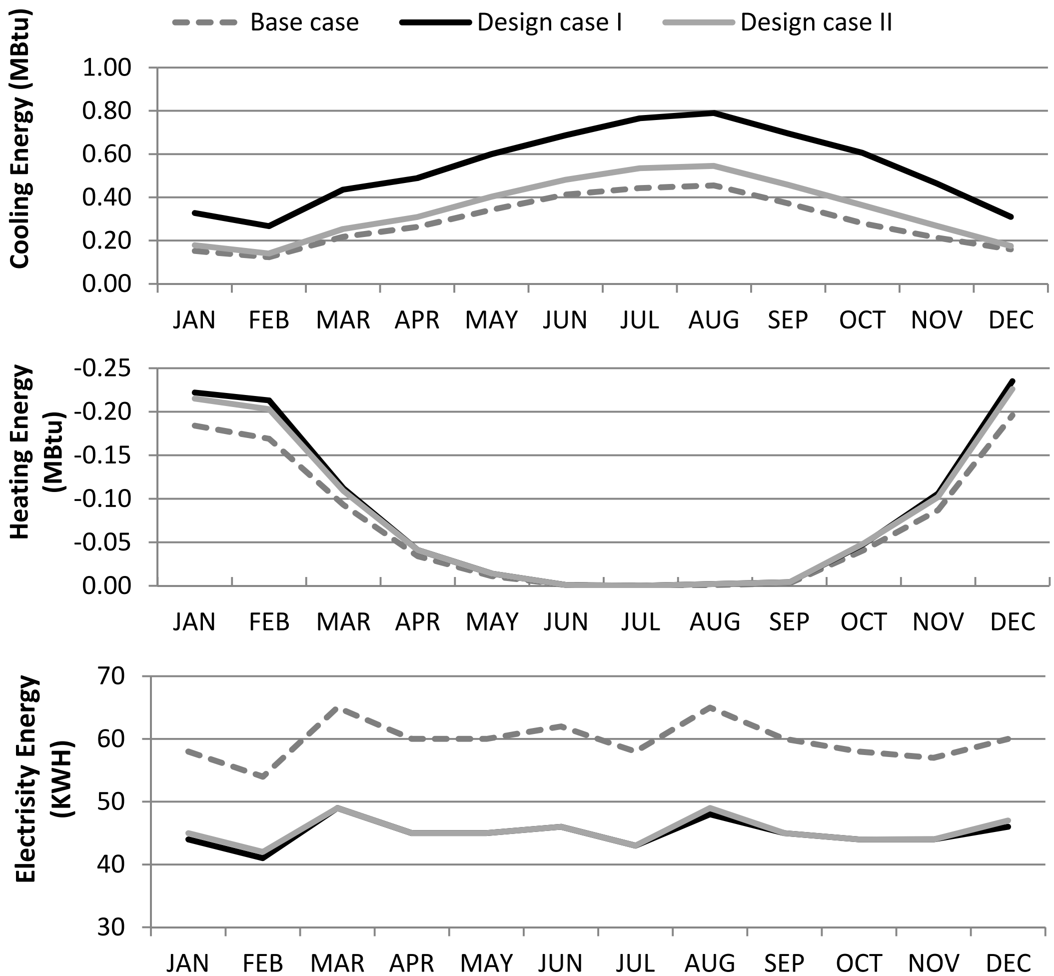
Table 6.4. The cost of electricity and natural gas for each lighting condition.

	Reference case		**Design case 1**		**Design case 2**	
	Electricity	**Natural Gas**	**Electricity**	**Natural Gas**	**Electricity**	**Natural Gas**
	kWh	**Btu (x000)**	**kWh**	**Btu (x000)**	**kWh**	**Btu (x000)**
Space Cool	485.4	0	814.5	0	580.4	0
Heat Reject.	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0
Space Heat	0	2,802.00	0	6,429.80	0	3,912.00
HP Supp.	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0
Vent. Fans	132.9	0	294.1	0	169.4	0
Pumps & Aux.	64.8	0	64.8	0	64.8	0
Ext. Usage	0	0	0	0	0	0
Misc. Equip.	312	0	312	0	312	0
Task Lights	0	0	0	0	0	0
Area Lights	405.5	0	228.7	0	231.5	0
Total	1,400.6	2,802.0	1,714.1	6,429.8	1,358.1	3,912.0
Rate per unit	$0.13000	$ 0.00453	$0.13000	$ 0.00453	$0.13000	$ 0.00453
Total Cost	$ 182.08	$ 12.69	$ 222.83	$ 29.13	$ 176.55	$ 17.72
Total Cost	**$ 194.77**		**$ 251.96**		**$ 194.27**	

Figure 6.3 displays the monthly variation in heating, cooling and lighting for the base case as well as the two design cases. As displayed, the presence of a window considerably increased cooling loads year round. The high thermal resistance of glazing type 2 (design case II) reduced cooling energy demand close to base line in the summer months and almost equal to baseline in the winter months. The presence of a window in both design case I and II resulted in considerable electricity consumption year round. The detailed heating, cooling and electricity loads are provided in table 6.5.

Table 6.5. Monthly cooling, heating and electricity energy demand.

	Reference case			**Design case I**			**Design case II**		
	Cooling Energy (Mbtu)	**Heating Energy (Mbtu)**	**Electricity Energy (Kwh)**	**Cooling Energy (Mbtu)**	**Heating Energy (Mbtu)**	**Electricity Energy (Kwh)**	**Cooling Energy (Mbtu)**	**Heating Energy (Mbtu)**	**Electricity Energy (Kwh)**
JAN	0.153	-0.184	58	0.327	-0.222	44	0.179	-0.215	45
FEB	0.123	-0.169	54	0.267	-0.213	41	0.141	-0.203	42
MAR	0.217	-0.093	65	0.435	-0.112	49	0.253	-0.109	49
APR	0.263	-0.034	60	0.489	-0.041	45	0.309	-0.041	45
MAY	0.343	-0.011	60	0.600	-0.014	45	0.403	-0.014	45
JUN	0.412	-0.001	62	0.687	-0.001	46	0.481	-0.001	46
JUL	0.443	0.000	58	0.765	0.000	43	0.535	0.000	43
AUG	0.455	-0.001	65	0.790	-0.002	48	0.545	-0.002	49
SEP	0.372	-0.003	60	0.695	-0.004	45	0.458	-0.004	45
OCT	0.280	-0.041	58	0.606	-0.048	44	0.364	-0.049	44
NOV	0.214	-0.087	57	0.465	-0.106	44	0.269	-0.102	44
DEC	0.160	-0.196	60	0.310	-0.235	46	0.175	-0.226	47
TOTAL	**3.435**	**-0.821**	**718**	**6.436**	**-0.998**	**541**	**4.111**	**-0.966**	**544**



Note. The graphs were created based on LS-D detailed report data tables generated by eQuest.

Figure 6.3. Plotted monthly cooling, heating and electricity energy demand.

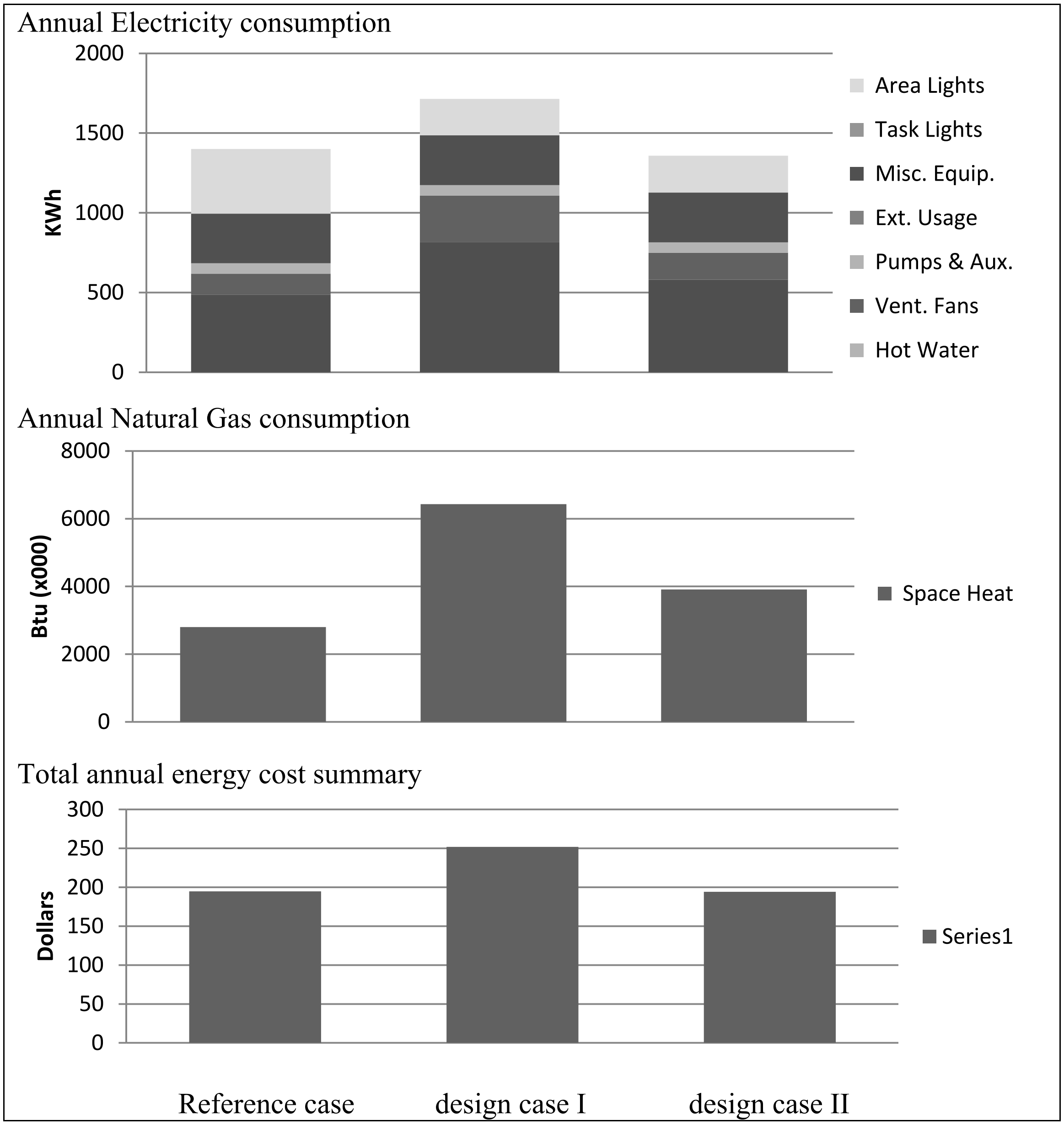
Discussion of the Findings

In this section a summary of the findings from study 3 is provided. Second, the strengths and limitations of study 3 are discussed. Finally, the implications and possible applications of the findings are presented.

Summary of the Findings

The results showed that two different choices of glazing (cases I & II) resulted in two opposite outcomes in energy consumption; the first one (case I) increased total energy use by 30 percent, and the second one (case II) maintained similar costs and even slightly decreased total energy use (Figure 6.4).

The findings on electric lighting energy use indicated that glazing type 1 selected in design case I performed slightly better in reducing electric lighting demand. This phenomenon can be explained by the glazing characteristics. Although the thermal performance in glazing type 1 was lower (u-value=0.53) compared to glazing type 2 (u-value=0.21), the visible light transmittance was higher (75%) than glazing type 2 (53%). We conclude that the method used in the pilot study (modifying shading coefficient values without changing other glazing qualities) is not a practical approach. Although theoretically correct, in reality it is not possible to fix all the glazing characteristics and only modify the shading coefficient. As the shading coefficient and U-factor values decrease to obtain higher thermal performance, there may be a decrease in the visible transmittance which will reduce visible daylight penetration into the room. This is why, in the main study, actual window products were applied to the simulation model.



Note. The costs displayed in this graph are under estimated because they do not take fixed fees or taxes for electricity or fuel into consideration.

Figure 6.4. Electricity use, natural gas use and total energy use.

Strengths and Limitations of the Study

It is notable that the glazing type selected in case II was not the most energy efficient glazing option available on the market for the Texas region. Indeed, a number of window products with better thermal performance (lower u-factor and Solar Heat Gain Coefficient) were available from the same window manufacturer that produced glazing type 2. Applying a more thermally resistant glazing product would reduce the energy use below the baseline, and completely reverse energy loss trend.

Only a section of the entire building was evaluated and the glazing faced southeast. The computer model was studied for the weather conditions in College Station, Texas. These factors created limitations for the findings. Further research can be conducted to study the impact of windows in the entire building. More research is needed to test the hypothesis for various climate conditions and in several orientations.

If the energy modeling output were not calibrated with actual lighting and energy performance, modeling the entire building would enable calibrating the computer model with the total energy used in the building.

The interior layout of medical workspaces, and the location of occupants' work station with respect to the window, plays an important role in reducing lighting energy use by natural light. In this experiment we adjusted the interior layout, the location, size and height of the window for optimum conditions.

Implications of the Findings

As a result of these findings, the presence of natural light in medical spaces may not necessarily pose a conflict between energy efficiency and the healing impacts of windows. Indeed, a window with careful choice of materials may result in limiting or even eliminating the energy loss and create synergy between healing and green design strategies. The modification on the shading coefficient value of the glass during the parametric runs showed that glass characteristics may play a primary role in the energy impact of windows.

This study did not take into consideration the effects of implementing shading devices or optimum orientation. These strategies provide more opportunities for energy saving.

We conclude that a medical office space with a window may have similar or less total energy costs than a comparable windowless space. However, this phenomenon is highly dependent on the design of a window with appropriate characteristics and features. The findings emphasized the role of building designers in improving efficiency.

Finally, the use of high performance glazing that maximizes light transmission but blocks solar heat into space, minimized increased energy consumption due to windows (CSBR, 2009). In addition to glazing characteristics, further energy efficiency measures, such as the orientation of glazing, external shading, glazing area and location, improve efficiency in windowed medical office spaces. According to NAHB Research Center at US Department of Energy (DOE), sustainability components such as "additional glazing, added thermal mass, larger roof overhangs, or other shading features" will pay back by reducing future costs. Efficient design strategies will considerably reduce costs through minimizing mechanical heating and cooling needs, HVAC unit size and their maintenance (DOE, 2000).

CHAPTER VII

CONCLUSIONS

Evidence confirms that environmental improvements can result in improved staff productivity if they benefit the staff's physical, mental and behavioral health. The benefits emerge in both financial returns and quality improvements including improved safety satisfaction and retention.

Summary

The present study investigated the impact of windows and daylighting in healthcare and counseling environments based on previous research in field and laboratory settings. Evidence repeatedly points to lighting as one of the most critical environmental elements contributing to safety (Joseph, 2006, Joseph & Rashid, 2007, Rashid & Zimring, 2008). Advances in science describe the biological and psychological impacts of lighting designed with the similar characteristics of sunlight, on circadian realignment and neuro-hormonal effects, as expressed in elevated mood, alertness, vigilance and cognitive function (Czeisler et al., 1986, Postolache & Oren, 2005; Kent et al., 2010).

The first study in this research project explored the overall characteristics of design in order to provide a broad understanding of the environmental requirements in healthcare and counseling facilities. The goal was to educate the researchers about the site culture and create alliances with research participants. Study participants indicated that careful attention must be paid to environmental factors, temperature, workplace size, noise levels and privacy in their workplaces. Furthermore, the importance of environmental factors in reducing sleepiness and maintaining wakefulness was studied. The findings identified daylight, temperature and comfort as the top three important alerting characteristics of the workspace. Alternative behavior responses to maintain alertness and wakefulness were drinking caffeinated or cold liquids, leaving the workplace to walk or visit someone, increasing activity, switching tasks, going outside for fresh air or sunlight, and engaging in social interaction.

Further exploration focused on the impact of daylight upon alertness, sleepiness and mood. Study 2 investigated outcomes by studying the employees' perceptions and feedback on these topics and study 3 directly measured the physiological, psychological and behavioral impacts of daylight in a controlled setting. Measurements included vital signs, subsidiary behaviors of mood and sleepiness and momentary assessments of internal feelings.

The findings point to a minimum of 31% reduction in perceived sleepiness and a 30% improvement in overall mood if daylight is available in the workplace. The presence of natural views doubled the benefits. The participants reported the presence of windows and daylight, along with temperature and comfort as among the most important environmental factors stimulating wakefulness and reducing sleepiness. These findings are consistent with the literature in laboratory settings.

The physiological, psychological and behavioral responses in the second study were significantly affected by the presence of daylight. The frequency of subsidiary behavior (related to sleepiness and deteriorated mood) was reduced by 40% in the nurse station with a window and daylight as compared to a similar windowless nurse station for the same individuals (p-value=0.001). This reduction is similar to the reported perceived reduction of sleepiness by 30% in the previous study.

The rate of communication in the nurse stations, when windows and natural light were present, increased by 58% (p-value=0.000). Positive sociability, as measured by the occurrence of laughing, increased by 46% in the windowed nurse station as compared to the windowless one for the same individuals.

The bi-hourly ecological momentary assessment of sleepiness showed morning sleepiness was reduced by 34% (P= 0.052). However, the total daily sleepiness was only reduced by 10%, which was not statistically significant (P=0.238). The total daily average body temperature increased (97.36± 0.15to 97.50± 0.15), but not significantly. There was a significant increase in body temperature during the morning by 0.3125 (P=0.0360). An increase of about 0.17 C in body temperature can be associated with enhanced memory and cognitive performance (Wright, Hull & Czeisler, 2002).

The average daily heart rate was only lower by 3% in the windowed condition (design case), which was not significant (P=0.1000). The morning decrease in mean heart rate per each individual was also not significant (0.0730). The occurrence of hypertension in blood pressure measurements in the windowed location reflected a reduction of about 54% in the windowed location in the morning (from 9% to 4%). The occurrence of hypertension was reduced by 14% during the entire day if windows were available (12% to 10%). The blood oxygen saturation increased significantly (97.6 to 98.1) in the windowed location (p-value= 0.0110). The morning increase in oxygen saturation was close to significant (0.0535). Evidence shows deep and slow breathing can result in a rise in oxygen saturation (Bernardi, Spadacini, Bellwon, Hajric, Roskamm, & Frey, 1998).

Oren et al. (2001) found that the same components in lighting which alters mood and reduce depression are able to produce “reactive oxygen species in skin.” Therefore, the presence of lighting and the stress-relieving aspects of the presence of windows may have affected the oxygen saturation in the participants.

Additionally, there was a 30% less chance of occurrence of IV and non-IV medication errors in the windowed ward (design case) versus the windowless ward from 2009 to 2011(non-significant, P= 0.2720).

In summary, studies one and two both indicate that the presence of daylight may enhance alertness and mood in frontline caregivers up to 30%, as measured by sleepiness and 40%, as measured by behavioral clues. However, if measured by self-reports during the patient care, reported sleepiness was reduced by 10%. Future studies are required to confirm the findings and elaborate on the profound effects of lighting. Knowing that alertness is connected to both employee and patient safety, maximizing access to daylight in nursing areas may be an opportunity to significantly improve safety and quality by enabling staff to manage sleepiness and stay alert. Such interventions are dependent on healthcare designers and planners’ creative approaches to bringing daylighting into care areas. Their efforts affect staff physical and mental health, alertness and mood.

The findings on the positive impacts of daylight on biological rhythms confirm previous laboratory research. Under similar conditions daylight may have 2.2 times greater effects on circadian adjustments compared to incandescent light, and close to a three times larger effect than fluorescent light (Rea, Figueiro & Bullough, 2002). When it comes to "relative spectral power distribution," both fluorescent and incandescent lights are comparable; whereas daylight provides about three times higher irradiance (Stevens & Rea, 2001; p. 283). Laboratory research has showen that the three light sources (daylight, incandescent and fluorescent), under similar duration and intensity, resulted in significantly different effects on the circadian pacemaker in a laboratory setting in mice (Sharma, Chandrashekaran, & Nongkynrih, 1997). Therefore, maximizing the availability of daylight should be one of the main goals of built environments. In addition, lighting experts and manufacturers can contribute to occupants' health if they "...reoptimize the use of electric lighting in buildings to support both human vision and circadian functions" (Rea, Figueiro & Bullough, 2002, p. 177).

The assumption that windows and daylight are contributing factors to increased cost due to energy loss has created a major roadblock in designing healthcare buildings that provide an abundance of natural light. This notion was evaluated in study 3. Analysis showed that total energy consumption and costs could increase by 30%, however, the assignment of a high performance glazing eliminated this loss. The final cost of energy for the windowed medical space ($194.27) did not exceed the baseline ($ 194.77). In conclusion if designed with optimized characteristics, adding a window does not necessarily increase energy demand.

Finally, designing medical workspaces with an abundance of daylighting provides a synergy between energy efficiency and health, safety and productivity outcomes. The present study investigated this paradigm from multiple dimensions and concluded daylit healthcare environments may be linked to increased health, improved performance and reduced total energy consumption.

Design Recommendations

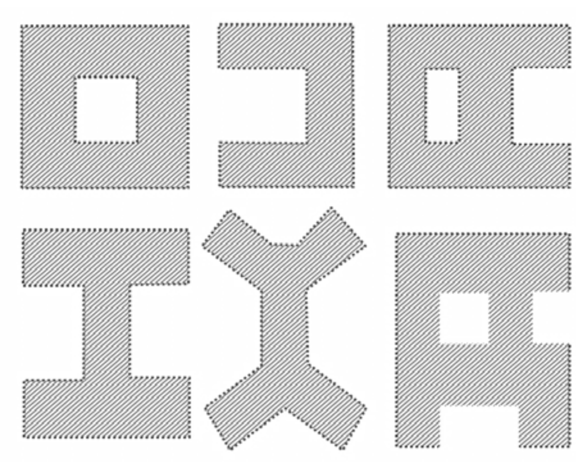
Two main conclusions can be derived from this research for the building industry. The first conclusion involves recommendations about the built environment itself, and the second addresses the challenges in the lighting technology. Daylight in conventional workspaces is often too limited to support circadian rhythms (Pauley, 2004) and when environmental lighting is not adequate to adjust to circadian rhythms, occupants will be trapped in 'biological darkness' (Stevens & Rea 2001). Such occurances may have serious consequences in health and productivity.

The best source of lighting for human health is daylight (Rea, Figueiro & Bullough, 2002, Noell-Waggoner, 2006, Pauley, 2004). Therefore, the design community can significantly contribute to healthcare employees' physical and psychological health as well as work productivity by maximizing access to daylight in their workspace. A few design strategies that can be used to increase access to daylight are explained below.

Site and surrounding. Effective natural light is highly dependent on the open space around the building. Neighboring structures, reflective surfaces, nature bodies and trees not only impact the amount of daylight (O'Connor, Lee, Rubinstein, and Selkowitz, 1997), but encourage or discourage the use of daylight by the building occupants.

Therefore, taking daylighting strategies into consideration from the pre-design and programming stage will ensure successful natural light (O'Connor et al., 1997). Every window "must see the light of day" (O'Connor et al., 1997). Moreover, to ensure that daylighting is going to be practically used, windows must provide good views.

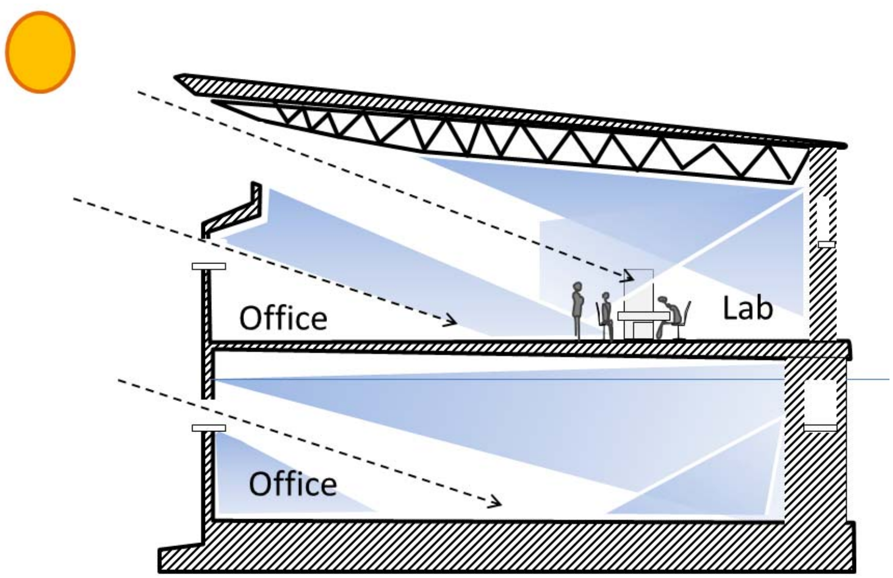
Building envelope. The building form can be shaped to increase opportunities for daylight. Deep floor plates eliminate access to daylight in the core of the space. According to a publication by *Ernest Orlando Lawrence Berkeley National Laboratory,* narrow floor plans are preferred to squared plans, but not too narrow to void energy loss (O'Connor et al., 1997). Some examples of floor plans with maximized daylighting are provided in Figure 6.5. The use of courtyards, light tubes, or toplighting can help deliver natural light deep into space.



Note. The figure was created by combining visual information from DeKay (2010), Ministry for the Environment (2008), and O'Connor et al. (1997).

Figure 6.5. Examples of narrow floor plans maximizing daylighting.

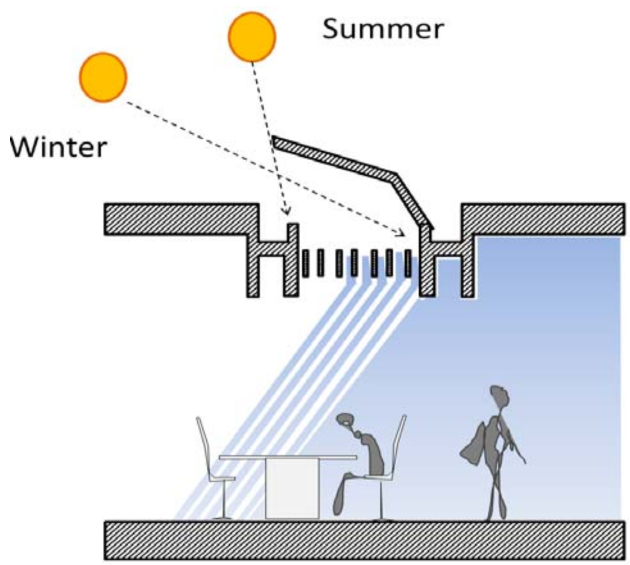
Side lighting. Side lighting is a common daylighting strategy and is defined as the conditions in which an aperture is placed below ceiling height to capture daylight (Wirdzek, Lintner & Carlisle, 2003). In side lighting, traditional windows, can be complemented with overhangs, fins, interior and exterior light shelves and light pipes (Wirdzek, Lintner & Carlisle, 2003) to improve uniformity in daylighting (Figure 6.6). The shape and the position of the window can also improve uniformity (O'Connor et al., 1997). The higher the window is placed in the wall, the deeper the light rays penetrate into the space (O'Connor et al., 1997).



Note. Re-created from *Daylighting in Laboratories, Laboratories For The 21st Century: Best Practices* (Wirdzek, Lintner & Carlisle, 2003).

Figure 6.6. Side lighting strategies used in Georgia Public Health Laboratory. (The windows are located high in the wall to maximize light penetration.)

Toplighting. Toplighting is a great supplement to side lighting, and is defined as the condition when light enters the space beyond the ceiling line (Wirdzek, Lintner & Carlisle, 2003). Skylights, sawtooth ceilings, roof monitors and clerestories are different forms of toplighting (Kwok & Grondzik, 2011). Toplighting can diffuse daylight evenly on the horizontal plane (Kwok & Grondzik, 2011). The design of the aperture is critical in successful toplighting. In the design of toplighting it is important to pay attention to the orientation (Figure 6.7) and the form of the aperture, the use of shading devices, and ceiling height (Kwok & Grondzik, 2011).



Note. Re-created from Daylighting Guide for Canadian Commercial Buildings, Public Works and Government Services (2002).

Figure 6.7. Toplighting, shading devices used to minimize glare in a clerestory.

Alternative lighting. After daylight, good quality electric lighting is an opportunity to enhance the health and productivity of occupants. Based on the findings of the study, the uses of the following strategies are emphasized about electric lighting:

1) Select light fixtures that support appropriate light intensity and spectral sensitivity,

3) Incorporate lighting technologies that support circadian rhythms (Rea, Figueiro & Bullough, 2002) and reduce energy costs (Stallworth & Kleiner, 1996)

4) Provide flexibility and occupancy control of lighting systems (Ander, 2011; Stallworth & Kleiner, 1996)

Research emphasizes the importance of decreasing of circadian light pollution (Pauley, 2004), as well as glare and contrast reduction. Electric lighting must be "designed to minimize interference with normal circadian rhythms in plants and animals" (Pauley, 2004, p. 588). Standards and technology in electric lighting today revolve around the "visual performance" rather than "circadian function" and many of the currently installed light sources result in 'circadian disruption' (Stevens & Rea 2001). The advancement of research on circadian rhythms encourages lighting technologists to opt for innovative solutions (Rea, Figueiro & Bullough, 2002).

Installing advanced lighting both improves occupant health and performance, and reduces energy consumption. For example, lighting energy costs can be reduced by systems that enable diming or turning off the lights based on environmental changes or occupancy (Ander, 2011; Stallworth & Kleiner, 1996). “

Finally, it is important to consider flexibility for successful lighting design. The ability to adjust environmental lighting to the employees’ individual needs has a considerable benefit on increased satisfaction and reduced turnover (Silvester & Konstantinou, 2010). Therefore, lighting systems that provide such flexibility are highly recommended. For example, operable task lighting can add to this flexibility.

In summary, the recent findings on the impact of lighting on occupants’ productivity call for both architectural and engineering solutions to improve indoor environmental quality in the area of lighting. The study concludes that it is critical to maximize natural light and also apply appropriate electric lighting. Hopefully, in the near future, healthcare building codes and standards will adapt these findings and contribute to the quality of healthcare work environments.

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APPENDIX A

Location and tasks		Daylight integration and control (Ranging from very important to not important)
Examination and treatment room		
	General	Important
	Local	Not important or not applicable
Nursing stations		
	General	Important
	Desk	Important
	Medication station	Not important or not applicable
	Work areas, general	Important
	Work tables or benches	Somewhat important
Pharmacy		
	General	Somewhat important

Note. Table re-created from *Lighting for hospitals and health care facilities* by Illuminating Engineering Society of North America, Health Care Facilities Committee (2006).

Appendix A-1. Lighting Design for Health Care Facilities.

Acuity level	
2	
2+	"Minimal amount of time spent in the room Bo drips or ABX Ambulates to BR unassisted"
3	"Monitored drip with frequent signs Assistance needed to ambulate/ transfer Increased frequency of visits to room Respiratory isolation"
3+	"Multiple monitor drips f request ABX 1 person assist to bathroom or ambulate Increased frequency of visits to room d/t Procedure (ex. Post Cath, CABG POD 1&2), PEG tube or tube feeding)"
4+	"Q/h checks (D/t suicide precautions or restraints) 3 person assist with care Feeder"

Note. Re-created from Telemetry Services (2011).

Appendix A-2. Acuity level chart**.**

APPENDIX B

Date__ _/_ _/_ _

An Ideal Workspace

1. **Please circle:**

    your age group:……………….. 20-29 / 30-39 / 40-49 / 50-59 / 60-69

    your current shift: …………… Day shift / night shift

    your gender: ………………… Male / Female

2. **What is your Job title? ……………..** RN / LVN / Charge nurse / Team Leader / Monitor Tech / TeleTech or Unit Secretary

3. **What are the most important design features of a nurse station that enhance your <u>health and performance</u>?**

Please rank, the most important (1) to least important (9). There is no right and wrong answer and the aim is obtain your own preference.

Some examples of features are shown below; however, you can also provide your own suggestions:

- ___ Privacy
- ___ Air quality
- ___ Temperature
- ___ Noise levels
- ___ View of nature
- ___ Natural light
- ___ Artificial lighting
- ___ Comfortable furniture
- ___ Appropriately sized workplace
- ___ Other:______________
- ___ Other:______________

4. What is your ideal nurse station like and what should it have.

……

……

……

……

Appendix B-1. Environmental factors survey Study one.

Date_ _/_ _/_ _

An Ideal Workspace

5. Imagine that it is an ordinary day and you have documentation to do. Please circle how you would feel working all day in each work station in the pictures: There is no right or wrong answer and the aim is obtain your opinion.

Not Tired	1----2----3----4----5----6---7	Tired	Not Tired	1----2----3----4----5----6---7	Tired	Not Tired	1----2----3----4----5----6---7	Tired
Not sleepy	1----2----3----4----5----6---7	Sleepy	Not sleepy	1----2----3----4----5----6---7	Sleepy	Not sleepy	1----2----3----4----5----6---7	Sleepy
Not Tense	1----2----3----4----5----6---7	Tense	Not Tense	1----2----3----4----5----6---7	Tense	Not Tense	1----2----3----4----5----6---7	Tense
Not Gloomy	1----2----3----4----5----6---7	Gloomy	Not Gloomy	1----2----3----4----5----6---7	Gloomy	Not Gloomy	1----2----3----4----5----6---7	Gloomy
Not Irritable	1----2----3----4----5----6---7	Irritable	Not Irritable	1----2----3----4----5----6---7	Irritable	Not Irritable	1----2----3----4----5----6---7	Irritable

Appendix B-2. Perceived sleepiness and mood survey Study one.

Date_ _/_ _/_ _ **Workspace Quality Survey** **Observer _**

Please circle your age group**:** 20-29 / 30-39 / 40-49 / 50-59 / 60-69 Please circle**:** Male/Female Job title (optional): __________

(Please circle the best answer that refers to the work station you most frequently occupied today)

1. The **electric lighting** in my work station was appropriate...	disagree	Somewhat disagree	neither agree nor disagree	Somewhat agree	agree
2. The **temperature** in my work station was pleasant..........	disagree	Somewhat disagree	neither agree nor disagree	Somewhat agree	agree
3. The **air quality** in my work station was pleasant............	disagree	Somewhat disagree	neither agree nor disagree	Somewhat agree	agree
4. My work station had **low noise levels**.........................	disagree	Somewhat disagree	neither agree nor disagree	Somewhat agree	agree
5. My work station provided me with **daylight**.	disagree	Somewhat disagree	neither agree nor disagree	Somewhat agree	agree
6. My work station provided me with **privacy**..................	disagree	Somewhat disagree	neither agree nor disagree	Somewhat agree	agree
7. My workstation was **comfortable** (ergonomically correct).	disagree	Somewhat disagree	neither agree nor disagree	Somewhat agree	agree

8. How many times today did you leave your work area (Including lunch and break intervals) to get fresh air, sunlight, or to smoke? _ _ times.

9. Please pick three of the above that would most help you improve your wakefulness and reduce your sleepiness during the dayshift. Please rank them for importance from the most important (1) to least important (3). There is no right or wrong answer.

Appendix B-3. Environmental factors and sleepiness, Study one.

Station: N/SW/SE/NE/NW/__ Observer _ **Self Report Survey, Sleepiness** **Date__/__/__ Pt. acuity _ _ _ _ _**

1. What time did you fall asleep last night? _ _:_ _
2. What time did you wake up this morning? _ _:_ _

3. How refreshing was your sleep last night? ....

Not at all	A little	Some what	Quite a bit	Very much

4. (Please Circle a number) 0= Not at all sleepy, 10=Very sleepy

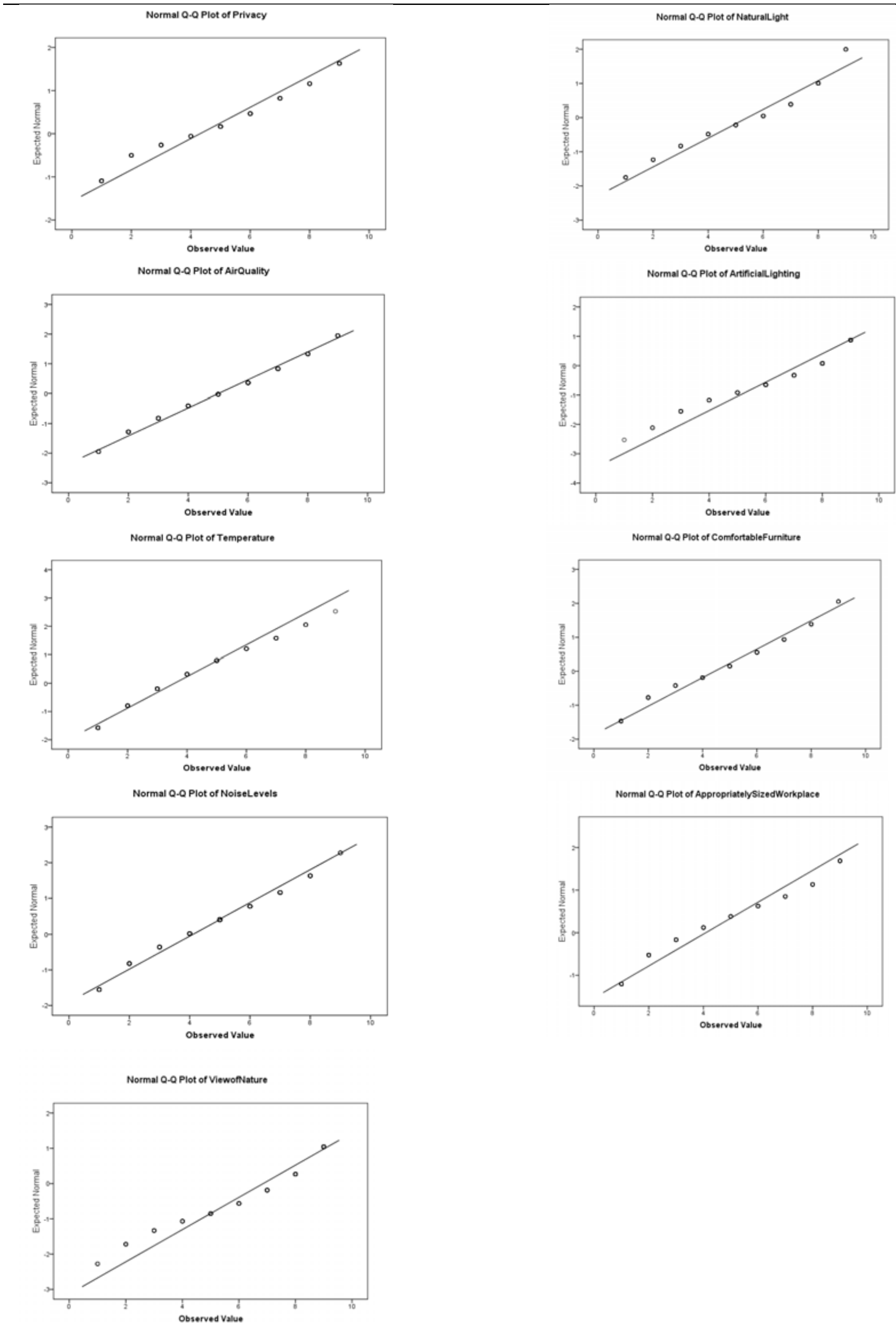
To be filled by researcher

Station	Time		T	BP	HR	Rr	SPO2
__	8:00 _ _:_ _	Not at all sleepy 0 1 2 3 4 5 6 7 8 9 10 Very sleepy	_ _	_ _	_ _	_ _	_ _%
__	10:15 _ _:_ _	Not at all sleepy 0 1 2 3 4 5 6 7 8 9 10 Very sleepy	_ _	_ _	_ _	_ _	_ _%
__	12:30 _ _:_ _	Not at all sleepy 0 1 2 3 4 5 6 7 8 9 10 Very sleepy	_ _	_ _	_ _	_ _	_ _%
__	14:30 _ _:_ _	Not at all sleepy 0 1 2 3 4 5 6 7 8 9 10 Very sleepy	_ _	_ _	_ _	_ _	_ _%
__	16:15 _ _:_ _	Not at all sleepy 0 1 2 3 4 5 6 7 8 9 10 Very sleepy	_ _	_ _	_ _	_ _	_ _%

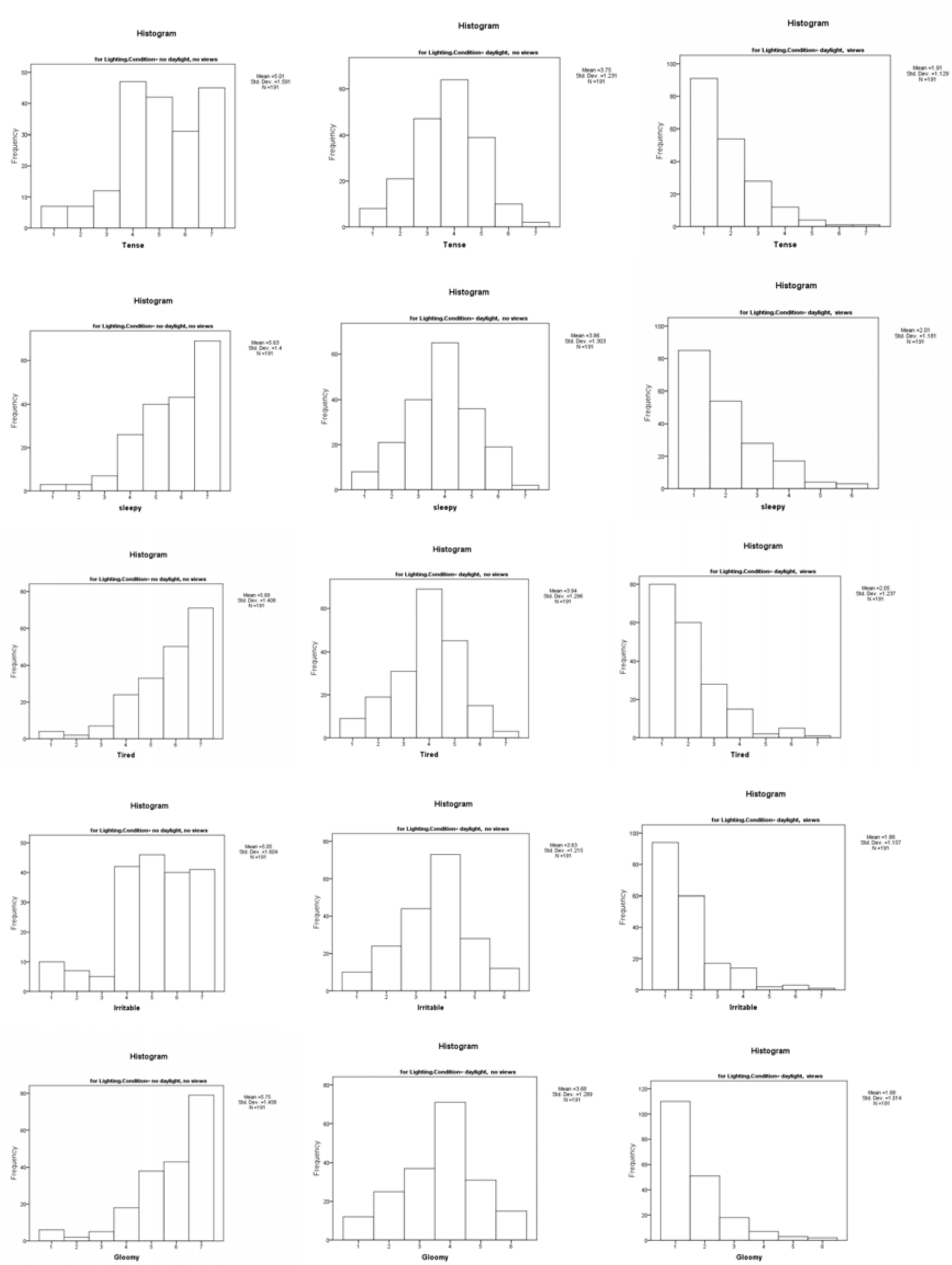
5. Including today, How many days in a row have you worked?	1	2	3	4	5
6. How many patients have you cared for today?	1	2	3	4	5

Appendix B-4. Biological measurements and momentary sleepiness, Study two.

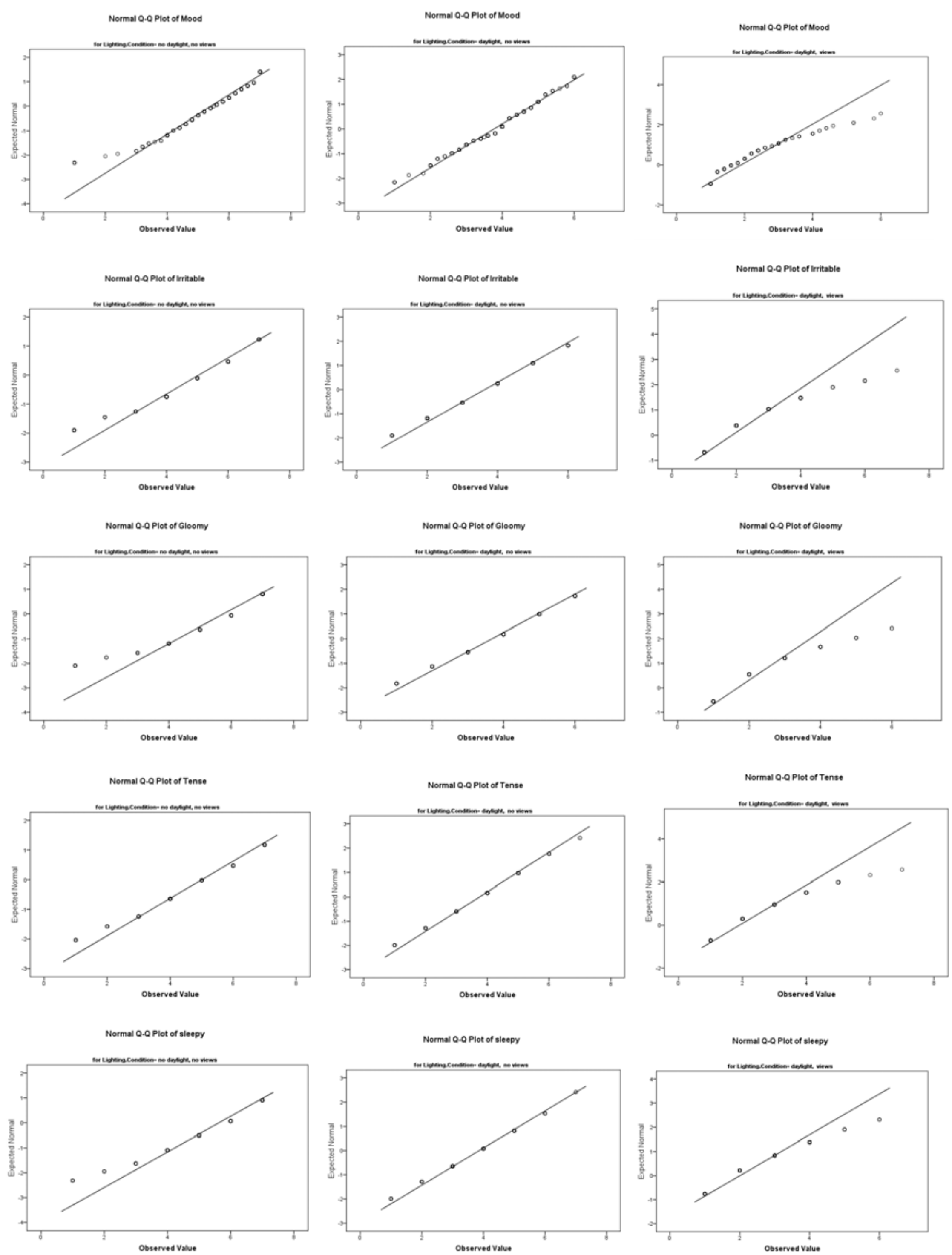
APPENDIX C



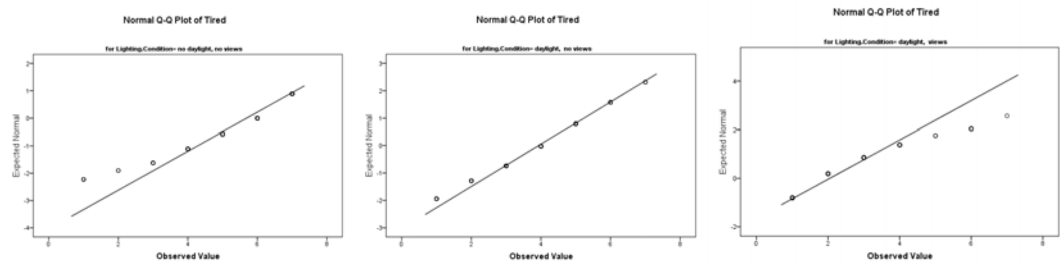
Appendix C-1. Q-Q plot normality test for the nine environmental factors.



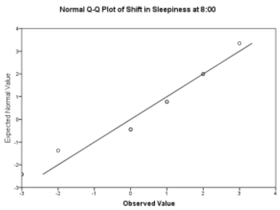
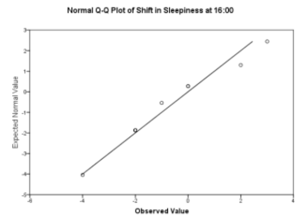
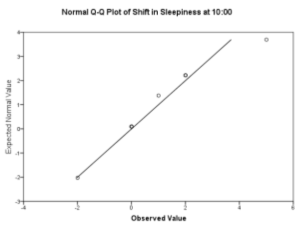
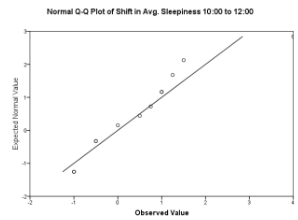
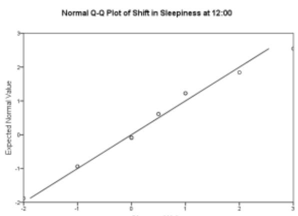
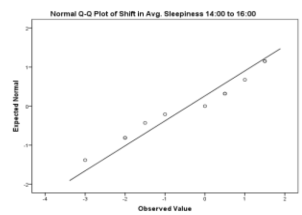
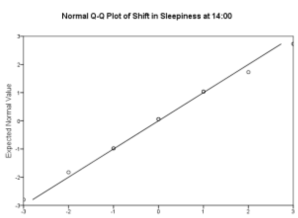
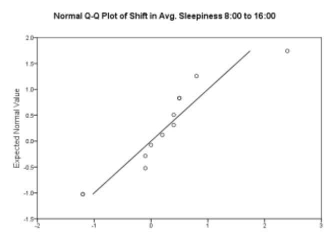
Appendix C-2. Histogram normality test for the five mood categories.



Appendix C-3. Q-Q plot normality test for the five mood categories.



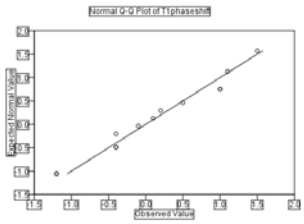
Appendix C-3. Continued.

Distribution of differences			
8:00		16:00	
10:00		Morning	
12:00		Afternoon	
14:00		8:00 to 16:00	

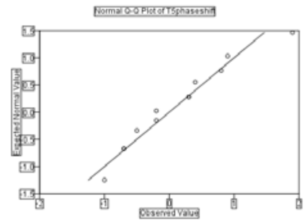
Appendix C-4. Q-Q plot normality test for momentary sleepiness.

Distribution of differences

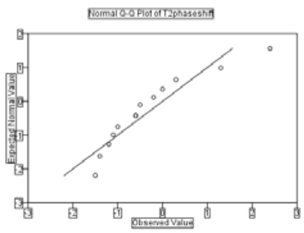
8:00



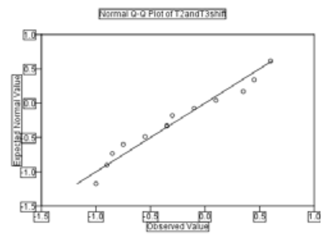
16:00



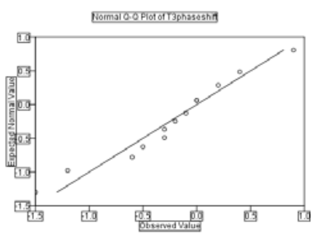
10:00



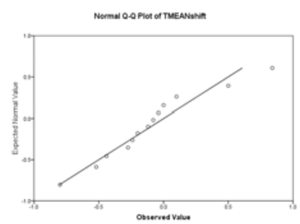
Morning



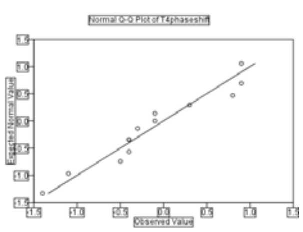
12:00



8:00 to 16:00

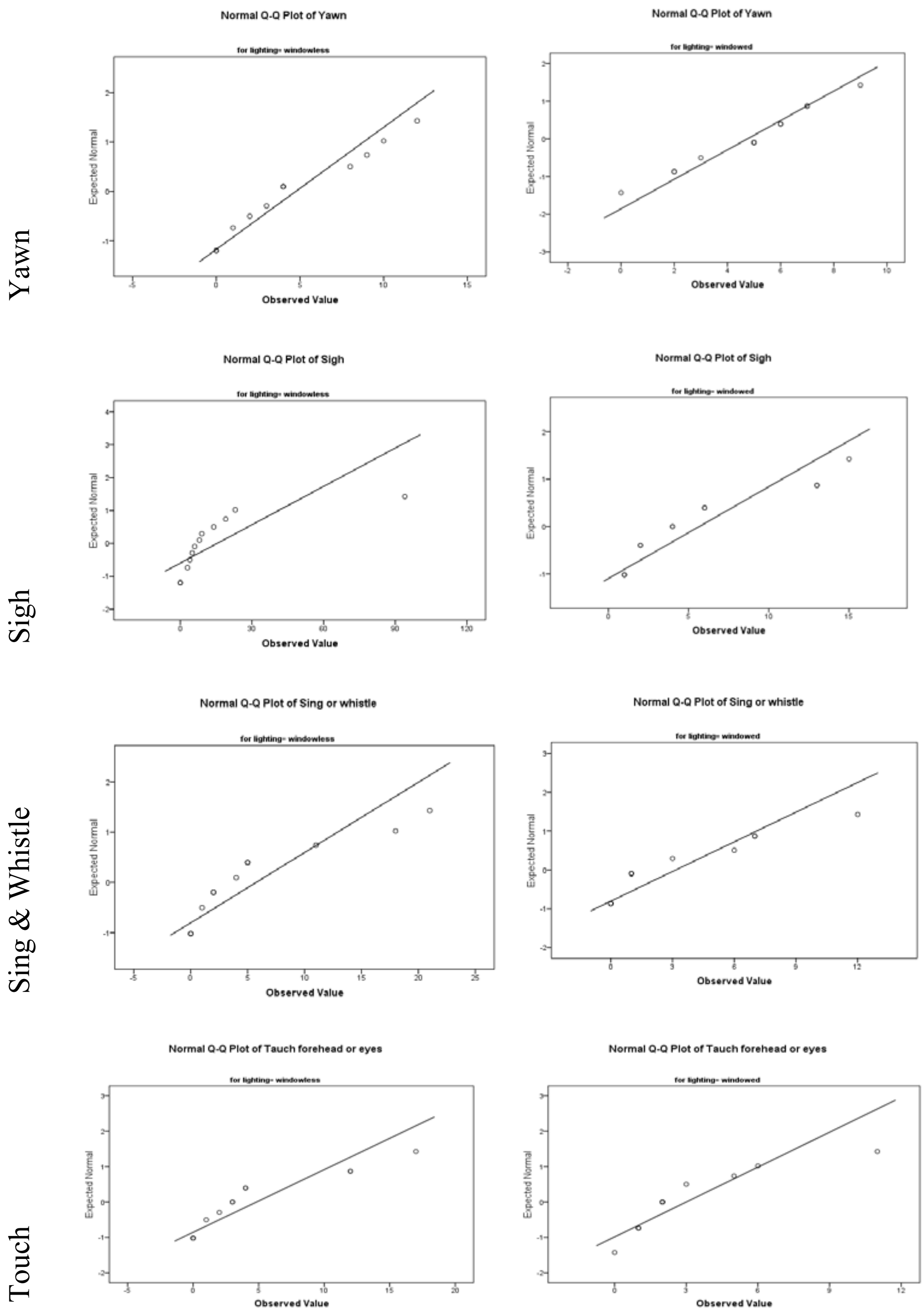


14:00

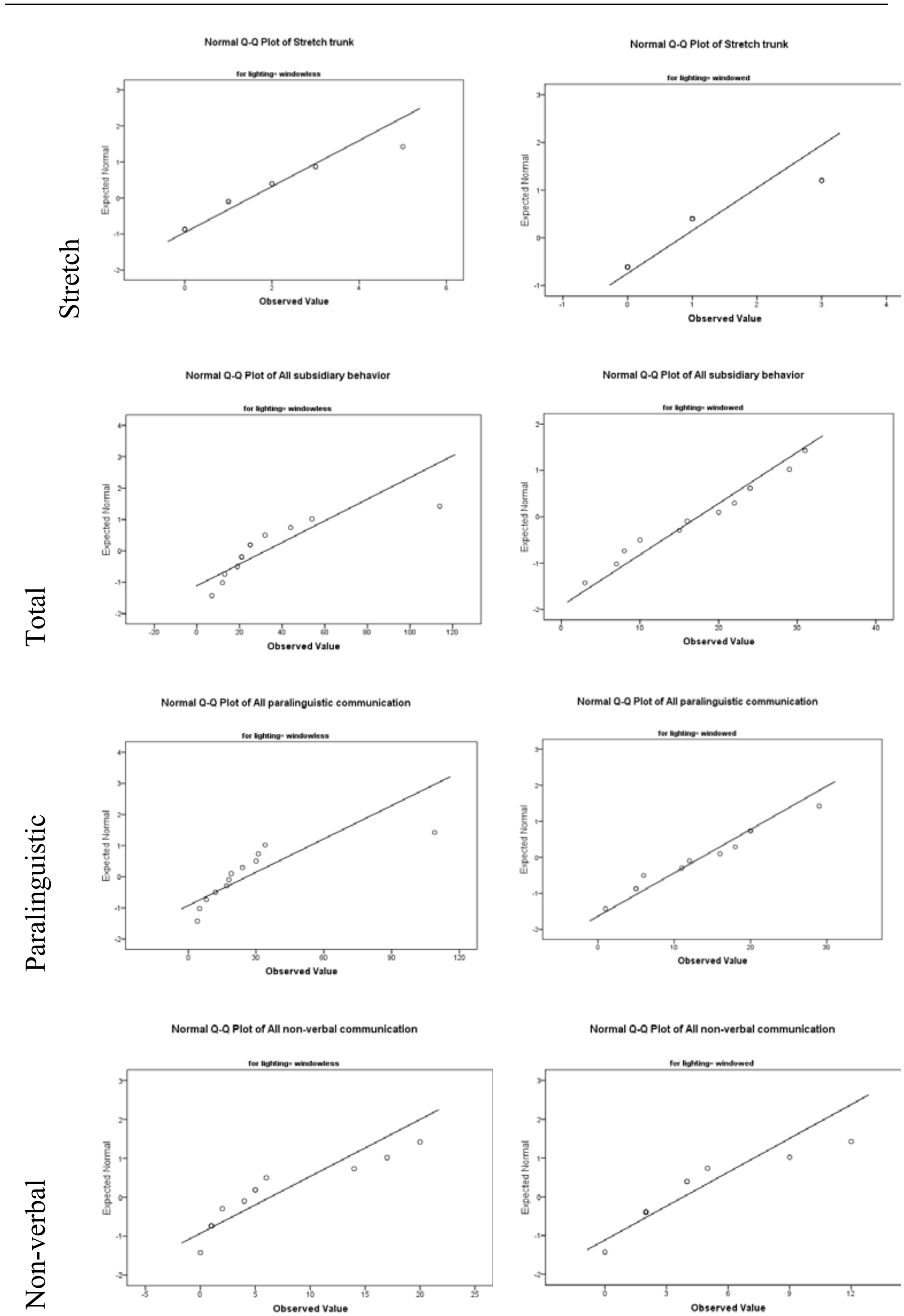


Appendix C-5. Q-Q plot normality test for body temperature.

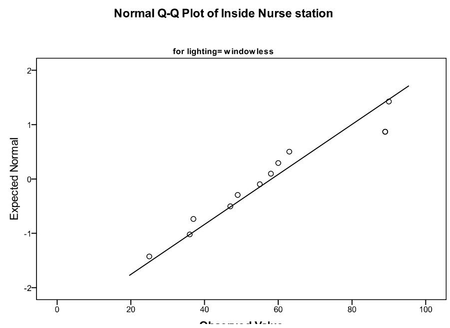
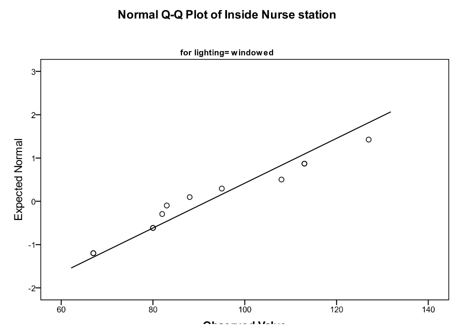
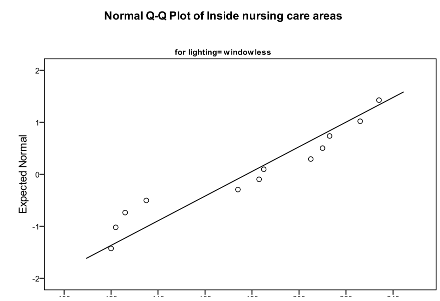
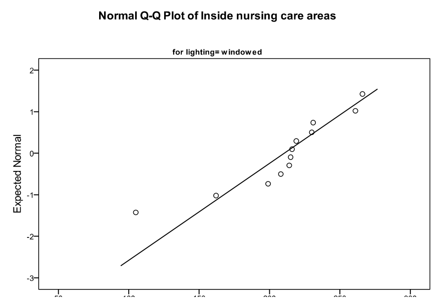
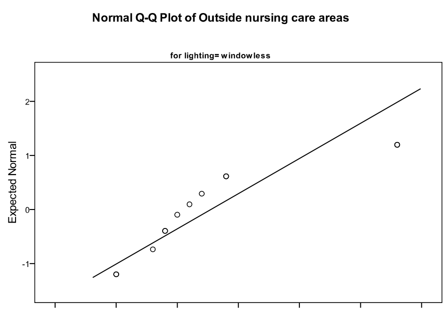
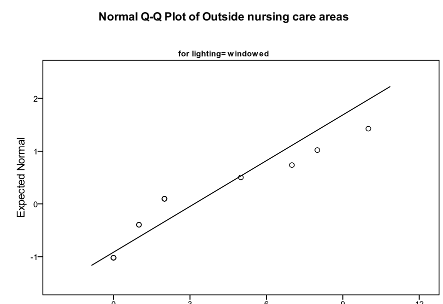
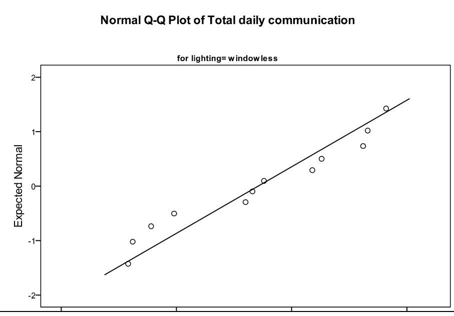
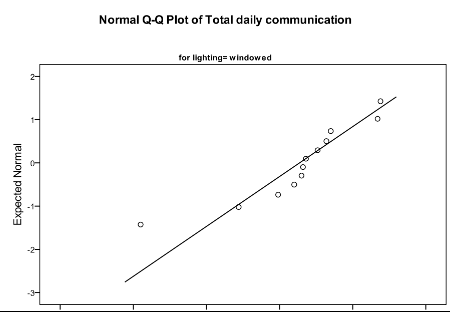
Reference case	Design case



Appendix C-6. Q-Q plot normality test for subsidiary behavior.



Appendix C-6. Continued.

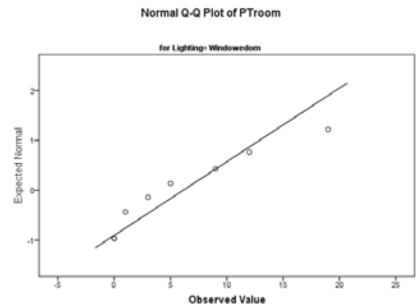
	Reference case	Design case
Inside nurse station		
Inside nursing care areas		
Outside nursing care areas		
Total daily communication		

Appendix C-7. Q-Q plot normality test for communication.

	Reference case	Design case

Inside patient room

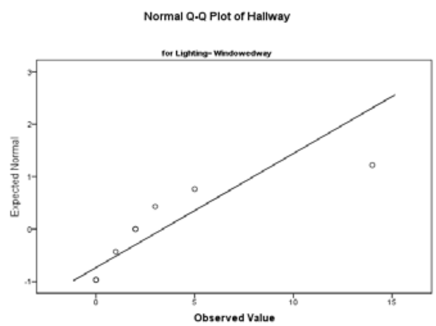
Reference case:



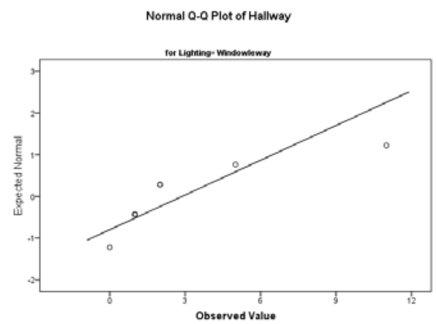
Design case:

Inside nurse station

Reference case:

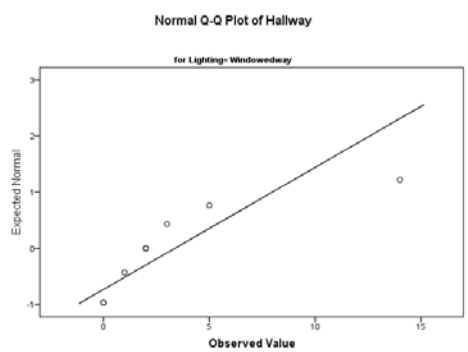


Design case:

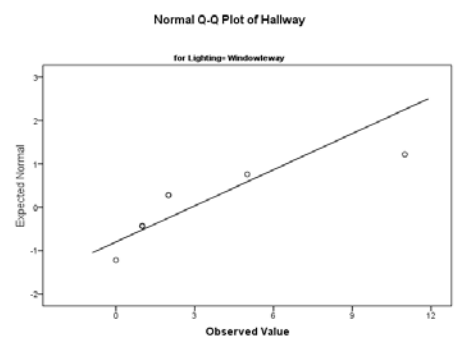


In hallways

Reference case:

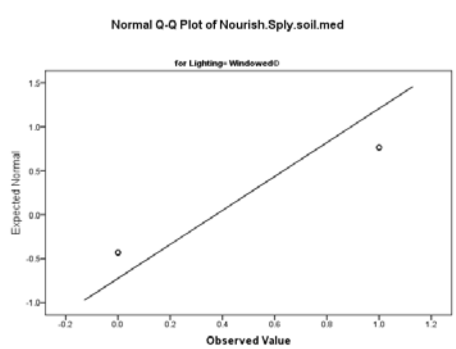


Design case:

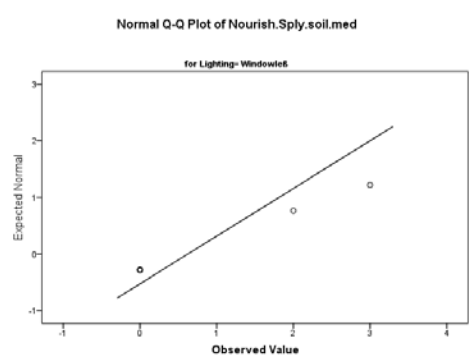


In support areas

Reference case:



Design case:



Appendix C-8. Q-Q plot normality test for sociability.

VITA

Rana Sagha Zadeh, received her Master of Architecture in 2005, and her PhD in Architecture from the College of Architecture at Texas A&M University in 2012. Her areas of interest are evidence-based design, high performance buildings, and the linkage between improved environmental quality and life-cycle cost analysis. She has practiced as a designer at S.G.T Company, and interned at WHR Architects of Houston and RTKL Associates of Dallas. Sagha Zadeh has co-authored articles in peer-reviewed publications: the HERD journal and the Journal of Psychiatric and Mental Health Nursing. She is the recipient of The Center for Health Design Research Coalition's New Investigator Award in 2011.

Ms. Sagha Zadeh may be reached at Mail Stop 3137, College Station, TX 77841-3137. Her email is rana_zadeh@tamu.edu.