THE INFLUENCE OF DAYLIGHTING ON THE BEHAVIOR OF NURSES AND FAMILIES IN NEONATAL INTENSIVE CARE UNITS (NICUS)

A Dissertation

by

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ABSTRACT

The neonatal intensive care unit (NICU) is a life-defining place for premature infants and other newborns with serious health conditions. The demand for newborn intensive care has been increasing in the recent years, but there is limited research on NICU room design and lighting environment. This study addresses these knowledge gaps and examines the relationship between daylighting - one of the key factors in the NICU physical environment - and nurse and family behaviors. It also explores trends of NICU design in the United States in terms of room types and daylighting modes in patient rooms.

The project can be divided into two parts, including a nationwide cross sectional survey study of NICU staff, and an in-depth case study of a NICU at one hospital in the southeast United States. The nationwide cross sectional study used two surveys: (1) the online *NICU Room Type & Lighting Condition Questionnaire* distributed to 482 medical directors and with 89 valid responses; and (2) the paper-based *NICU Nurse Satisfaction with Lighting Environment Questionnaire* distributed to 192 nurse attendees at a national professional conference and with 78 completed responses. The in-depth case study used mixed methods, including 50.85 hours of behavioral observation, surveys of 21 nurses working in the NICU, and on-site lighting measurements during observations. The data were analyzed through descriptive and inferential statistics such as two-sample *t*-test, ANOVA, and Tukey's test.

The results from the nationwide surveys suggests that: (1) NICU room types are in transition from multi-beds to single family rooms; (2) NICUs with single family rooms have a higher percentage of rooms with access to daylighting and are perceived to have a more satisfactory lighting environment than those with multi-beds; (3) both medical directors and nurses agree on the impact of daylighting on improving work efficiency and increasing mental alertness. The results from the case study illustrated that: (1) nurses who take care of more rooms with daylighting tend to have more frequent behaviors of direct care and documentation on computer with shorter duration than those who work in rooms without daylighting; and (2) the frequency of family departure from the patient room during a visit is lower in rooms with a window compared to rooms without a window.

The findings support the benefits of using single family rooms in the NICU, provide insights into the behavior of nurses and families in NICUs, and give suggestions on lighting design in NICUs to supplement existing recommendations and guidelines.

DEDICATION

To the days and nights,

Which should be cherished and would be remembered.

ACKNOWLEDGEMENTS

Writing the acknowledgements might be the most joyful moment during the whole process of the dissertation writing. Even before starting a word of the dissertation, I was conceiving the draft of acknowledgements in my mind. Conducting a research study is the same as facing life: respect and trepidation is always helpful.

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The Ph.D may be a different journey for everyone who walked, is walking, and will walk it. For me I always believe in the meaning of effort, no matter how bad or good the times and no matter the challenges or opportunities.

Bless everyone and I hope you will be treated gently and tenderly by the world.

NOMENCLATURE

IRB	Institutional Review Board
MB	Multi-beds
NICU	Neonatal Intensive Care Unit
SFR	Single Family Room

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1. INTRODUCTION

1.1 Background

A neonatal intensive care unit (NICU), also known as a newborn intensive care unit, a neonatal critical care unit, or an intensive care nursery, is defined as "a hospital unit containing a variety of sophisticated mechanical devices and special equipment for the management and care of premature and seriously ill newborns" (Mosby, 2010, p. 899). It is usually directed by the neonatologist(s) and involves a team of specialized nurses and technicians (Santiago, n.d.).

The history of neonatology in the United States can be traced back to the 18th century. The first NICU was established in 1960s (Historical Archives Advisory Committee, 2001). In 2011, the number of NICUs in the United States was more than one thousand (American Academy of Pediatrics (AAP), 2011). Many high-risk babies are saved in NICUs, which would be barely possible before the NICUs appeared. For example, a baby born with a mass tumor on lung was getting ready to leave the NICU after one month stay to live a healthy and normal life when the dissertation was written (Anonymous, 2015).

1.1.1 Neonatal Mortality and Birth Parameters in the United States

The development of neonatal medicine and the advancement of technology may be contributing to a decrease in the mortality rate of newborns. The neonatal mortality rate in the United States has decreased from 18.73 per 1000 live births in 1960 to 5.85 in

1990 and has been below 5 since 1995 (Centers for Disease Control and Prevention (CDC), 2015a) (see Figure 1.1) .

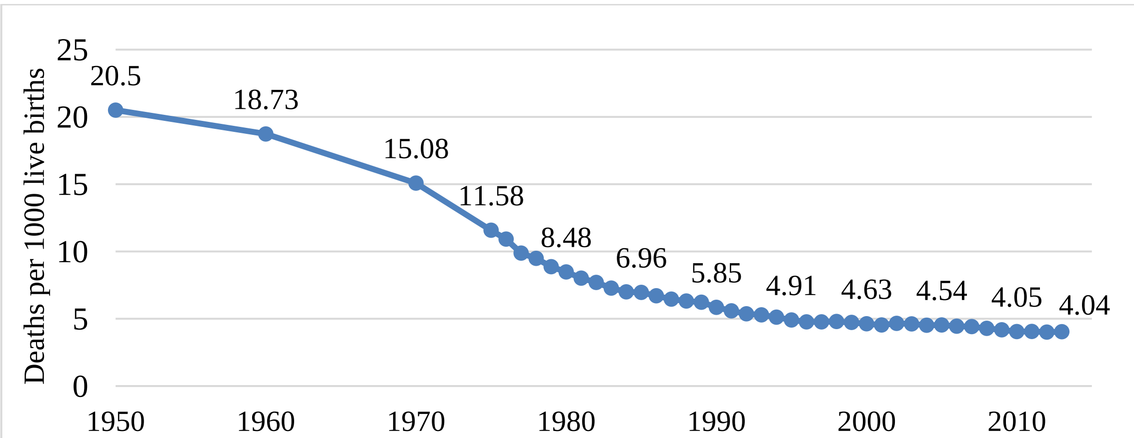

Figure 1.1 Neonatal mortality rates in the United States (data from CDC, 2015a: Table 20)

The percentage of NICU admissions among newborns in the United States has grown more than 6% in the recent decade. In fact, the rate has been on a rise, from 6.08% in 2006 to 7.97% in 2013 (CDC National Center for Health Statistics, 2015b) (see Figure 1.2). This rise may be related to the increase of preterm (less than 37 weeks of gestation), very preterm (less than 34 weeks of gestation), low birthweight (less than 2500grams), and very low birthweight (less than 1500 grams) births in the United States, for which the data have been available since 1981. Figure 1.3 shows the changes of these variables over years. The preterm rates rose slowly in the early years and then have decreased since 2007. They have exceeded ten percent since 1987 with a peak of 12.80% in 2006.

The low birthweight births have a similar trend with the lowest percentage (6.72%) in 1981 and the highest (8.26%) in 2006. The very preterm birth rates ranged from 1.81% to 2.04%, while the very low birthweight birth rates ranged from 1.16% to 1.49% (Martin, Hamilton, Osterman, Curtin, & Mathews, 2015).

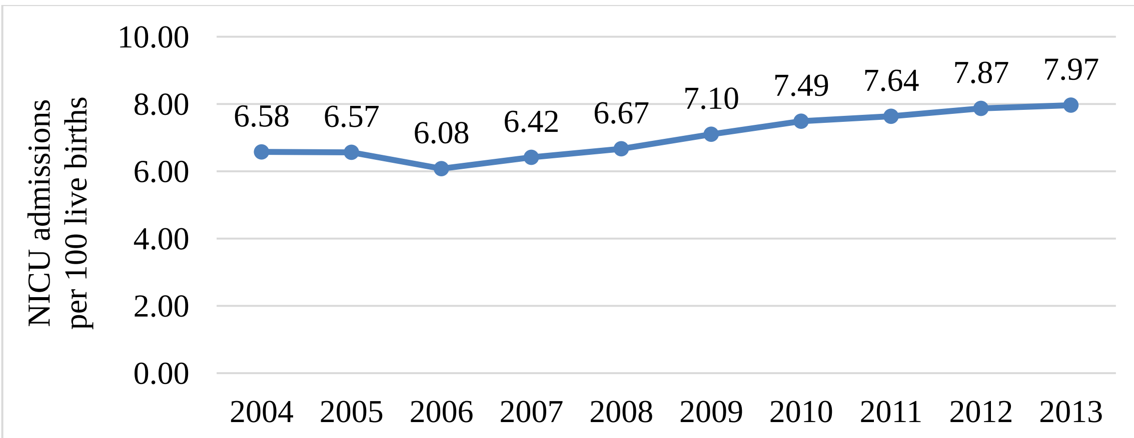

Figure 1.2 Percentages of NICU admissions among new births in the United States, 2004-2013 (data from CDC National Center for Health Statistics, 2015b)

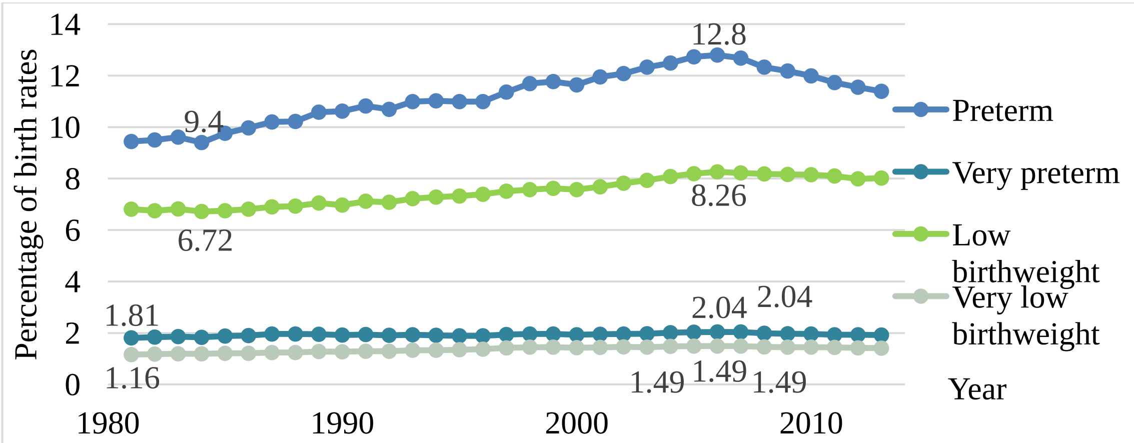

Figure 1.3 Very preterm and preterm birth rates in the United States, 1981-2013 (data from Martin, Hamilton, Osterman, Curtin, & Mathews, 2015: Table 24)

1.1.2 The Physical Environment of the NICU

The NICU is a life-defining place for infants, their families, and caregivers (White, 2011b). The NICU environment serves multiple purposes: it is the caring environment for the patients, the social environment for the families, and the work environment for the nurses. In NICUs, lighting, sound, color, and room layout are important contributors to effective physical environments (Harrell & Moon, 2008). These factors not only impact subjective experiences, but also influence infant patient outcomes, family satisfaction, and caregiver work efficiency.

A review of the literature suggests that the need for daylighting is intuitively and empirically evident for both adults and infants. However, there is little research to clarify the relevant need in NICUs. The existing building codes do not require a window in the NICU room. As to room types, although several projects and studies emphasize the design trend of using private rooms instead of the traditional multi-beds rooms, there has been little documentation regarding such transitions of NICU layouts from either architectural design or healthcare perspectives.

1.1.3 Goals, Theoretical Basis and Research Questions

This study explores the trend of transition in NICU design practice from multi-bed configurations toward private rooms and the impact of daylighting on behaviors of staff and families. The latter is based on a modified social-ecological framework that considers human behavior to be influenced by personal, social, and physical environmental factors (see Figure 1.4). In NICU settings, personal factors may include the infant's gender, gestational age, disease, and severity level. Physical factors may include room layout, sound environment, light, temperature, incubator design, and other amenity spaces. Social factors include family and caregiver influences. All three categories are independent variables; they all affect the patient's behaviors, which include awake/asleep status and health outcomes. In this study, the physical factors are narrowed down to the use of daylight and the NICU layout. Family and nurse presence and the interactions between them and towards the infant are the main social factors.

Research questions include: Is there a trend of NICU room types transitioning from multi-beds rooms to private rooms in the United States? Is this change related to access to daylight? How does daylighting impact staff satisfaction? What are the nurses' and families' behavior patterns in NICUs, and do they relate to the daylighting conditions?

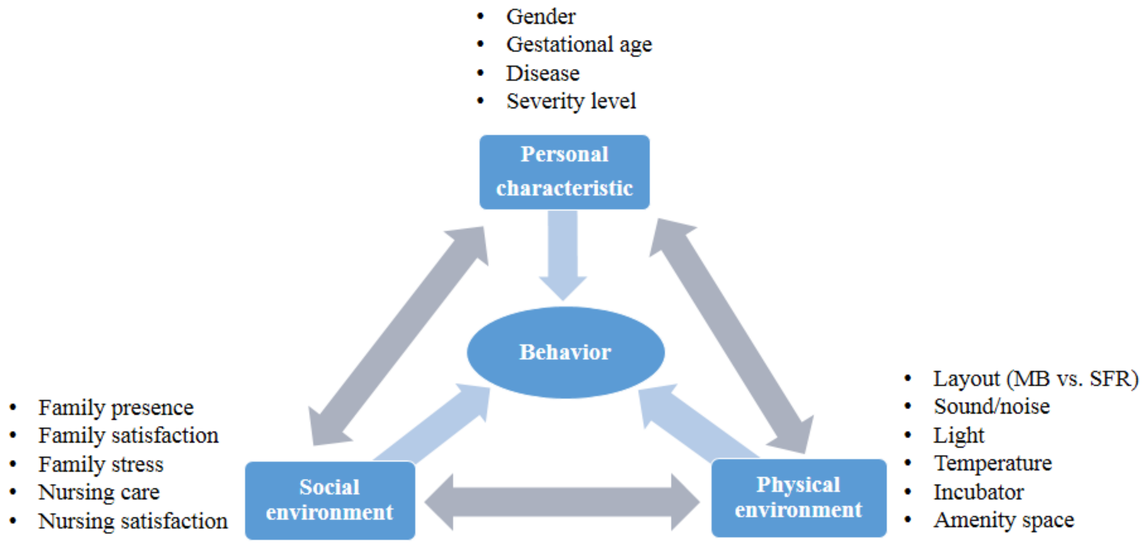

Figure 1.4 Social-ecological framework of the study

1.2 Research Significance

This study examines the trend of the room type transition and the impact of daylight on behavior of staff and families in NICUs. The significance of this study is threefold:

(1) The research provides factual data for the trend of NICU room type transition and lighting conditions in NICUs, which are understudied despite their importance;

(2) The research provides insight into the behavior pattern of nurses and families in NICUs and explores the connections between these behaviors and lighting conditions; and

(3) The research provides design recommendations on NICU interior space arrangement and unit organization to enhance the lighting conditions and better meet the needs of families and nurses.

1.3 Dissertation Structure

This dissertation is comprised of six chapters. The current chapter introduces the study background, goals, theoretical basis, research questions, and research significance. The second chapter presents a literature review on NICU development and design considerations, especially on studies regarding the single family room and lighting in NICUs. The third chapter proposes a conceptual model based on the literature review and describes the research design and methodology, including the hypotheses and data collection procedures. The fourth chapter illustrates the process of data analysis and corresponding results. The limitations and discussion of the study is presented in the fifth chapter, and the sixth chapter describes the implications for practice and suggests the need for future research.

2. LITERATURE REVIEW*

This section traces the history of neonatology and the development of NICU departments. It also reviews different NICU care models, NICU design considerations, and recommendations and standards regarding NICU environment. In addition, this section also discusses previous studies focusing on multi-beds (MB) and single family room (SFR) and lighting in NICUs.

2.1 History of Neonatology

Neonatology is a relatively new discipline in the medical world; the term 'neonatology' was introduced in the 1960s (Philip, 2005). The science of neonatology began with studies on particular infant diseases and feeding issues. In the late 19th century, the infant incubator, a specialized piece of equipment that provides care for infants, appeared. The key events related to the neonatology development were introduced in the report *American Pediatrics: Milestones at the Millennium* and listed in Table 2.1. The primary milestones included: the establishment of the first preterm infant incubator station at the end of 19th century, the publication of the first American textbook on prematurity in 1922, the design of the modern incubator prototype in 1938, the opening of the first American NICU in early 1960s, and the launch of the sub-board

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* Section 2.7 was first published as a guest essay "Lighting in NICU" in Shepley, M. M. (2014). *Design for Pediatric and Neonatal Critical Care*, p.158-159, London & New York: Routledge.

certification in Neonatology in 1975. The exact years of some events are not consistent with those cited in other sources but the time periods are comparable to each other.

Table 2.1 Key events of neonatology's development in the United States (Source: Historical Archives Advisory Committee Report, 2001)

Year	Event	Location	Physical environment related [a]
1788	Dr. Hezekiah Beardsley described hypertrophic pyloric stenosis of infancy	New Haven, CT	
1893	Pasteurization plants and milk stations providing safe milk for poor infants were established by philanthropist Nathan Strauss, in collaboration with Dr. Abraham Jacobi	New York, NY	
1894	Dr. Luther Emmett Holt wrote *The Care and Feeding of Children* and published his classic textbook, *The Diseases of Infancy and Childhood*	New York, NY	
	Dr. Charles Wendell Townsend described the hemorrhagic disease of the newborn	Boston, MA	
1898	Dr. Joseph Bolivar DeLee established the first premature infant incubator station	Chicago, IL	★
1901	"Incubator Infant" show at World Exposition	Buffalo, NY	★
1904	"Incubator Infant" show at World Exposition	St. Louis, MO	★
1919	Dr. John Price Crozier Griffith published *The Disease of Infants and Children*	Philadelphia, PA	
1922	Dr. Julius Hayes Hess published *Premature and Congenitally Disabled Infants*, the first American textbook on prematurity	Chicago, IL	
1938	Dr. Charles Chapple designed a modern infant incubator-prototype of the isolette which permitted high levels of oxygen therapy	Philadelphia, PA	★

Table 2.1 Continued

1941	Drs. William Edwards Ladd and Robert Edwards Gross published *Abdominal Surgery of Infancy and Childhood*, the first American textbooks of pediatric surgery	Philadelphia, PA	
1943	Dr. Ethel Dunham and the Children's Bureau published Standards and Recommendations for the Hospital Care of Newborn Infants, Full Term and Premature	Washington, DC	☆
1946	Dr. Clement Andrew Smith published *The Physiology of the newborn Infant*, the first American textbook on neonatology	Boston, MA	
	Dr. Benjamin Spock published *The Common Sense Book of Infant and Child Care*	New York, NY	
1952	Dr. Virginia Apgar described the 'Apgar Score' for evaluation of the condition of the newborn	New York, NY	☆
1959	Drs. Mary Ellen Avery and Jere Mead described a deficiency of surface-active material in lungs of infants dying of respiratory distress syndrome	Baltimore, MD	
1960	Dr. Carl Henry Smith published *Blood Diseases of Infancy and Childhood*, the first textbook of pediatric hematology/oncology	New York, NY	
1963	Dr. Robert Guthrie described a test for detecting phenylketonuria in the newborn period	Albany, NY	
1960/ 1965[b]	The first American newborn intensive care unit was opened	New Haven, CT	★
1975	The American Board of Pediatrics conducted examinations for sub-board certification in Neonatology		

Note: a ★: Directly relating to NICU physical environment. ☆: Indirectly relating to NICU physical environment.

b: Conflicting dates provided in literature. The Committee Report listed the first American NICU, which was designed by Dr. Gluck, was opened in 1965 (Historical Archives Advisory, 2001). This source has been cited several times. However, Dr. Gluck (1992) mentioned that it was opened on October 15, 1960.

2.2 Establishment and Rise of NICUs

Incubators are medical equipment that maintain babies' thermal and humid micro-environment stability (Antonucci, Porcella, & Fanos, 2009). They first received success and recognition in exhibitions in the late 1800s (Gartner & Gartner, 1992). Later, in 1898, Dr. DeLee established an incubator station in the Lying-in Hospital in Chicago, which was the first incubator station in a hospital setting (Gartner & Gartner, 1992).

The initial NICU concept emerged when Dr. Julius Hess and his nursing director Evelyn Lundeen enlarged the premature unit at the Sarah Morris Hospital in Chicago in 1922 (Gartner & Gartner, 1992). They emphasized minimal intervention, temperature and infection control, and supportive feedings based on the "quiet premature nursery" concept, realizing that preterm and term babies required different care environments (Lee, 1996, p.3-4). The first formal NICU in the world was established at the Yale-New Haven Hospital in New Haven on October 15th, 1960 (Gluck, 1992). Since then, the number of NICUs has grown and the design has evolved. The important events related to the NICU environment are listed in Table 2.1. As shown in Figure 1.2, the percentage of NICU admissions has increased in the recent years. In the meantime the number of NICU facilities in the United States has increased by 20% from 832 in 1996 to 1007 in 2011 (AAP, 1996, 1999, 2002, 2011; Shepley, 2014) (see Figure 2.1).

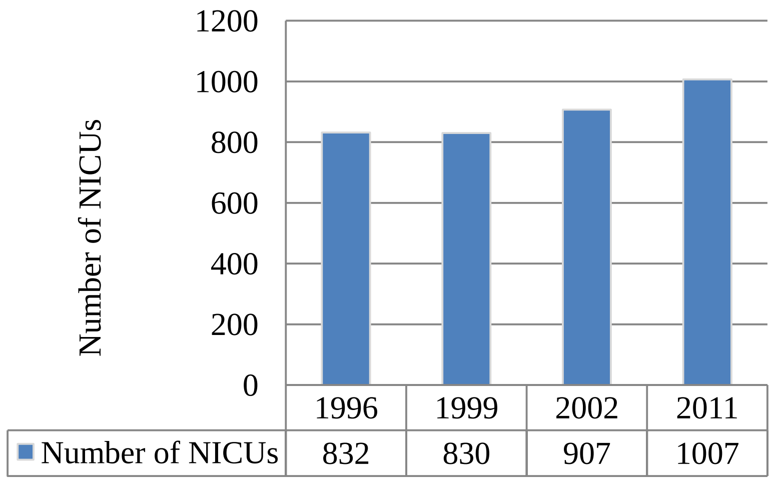

Figure 2.1 Number of NICU facilities in the United States, 1996-2011 (data from Shepley, 2014: Figure 3.6; originally from AAP, 1996, 1999, 2002, 2011)

The intensity of neonatal care was classified into three levels with subdivisions, as stated in the AAP 2004 policy statement: Level I for basic well newborn nursery; Level II A and B for specialty care; and Level III for subspecialty NICU, including three sub-levels of IIIA, IIIB, and IIIC (Committee on Fetus and Newborn, 2004). A higher level indicated the more severe infant condition. In 2012, the updated version consisted of four simplified levels: Level I for well newborn nursery; Level II for special care; Level III for NICU; and Level IV for regional NICU (Committee on Fetus and Newborn, 2012) (see Table 2.2). This new version omitted the previous subdivisions and added the highest level for regional NICU.

Table 2.2 Levels of neonatal care (Committee on Fetus and Newborn, 2012)

Level	Level IV	Level III	Level II	Level I
Description	Regional NICU	NICU	Special care nursery	Well newborn nursery
Gestation age	< 32 weeks		32 - 35 weeks	35 - 37 weeks
Weight	< 1500 g		>1500g	
Status	Critical illness		Physiologic immaturity or moderately ill	Stable
Care	Capable to provide surgical repair of complex congenital or acquired conditions	Sustained life support, comprehensive care, advanced imaging	Convalescing care for infants after intensive care	Provide resuscitation at every delivery, postnatal care
Respiratory support	Full range of respiratory support (include conventional and/or high-frequency ventilation and inhaled nitric oxide)		Mechanical ventilation for < 24 h or continuous positive airway pressure or both	N/A

The level of staffing is based on the patient acuity level. The nurse-patient ratio should be 1:3-4 for continuing care, 1:2-3 for stable care, 1:2-3 for intensive care, and 1:1 or even higher for advanced complex care (Stokowski, 2013).

2.3 Care Models

Historically, NICUs were designed to provide the medical care environment for infants; in some extent, caregivers' and families' needs had to be compromised or overlooked (Griffin, 2006). As the advancements in medicine and technology are increasingly saving infant lives (Legendre, Burtner, Martinez, & Crowe, 2011), nurses and other medical staff are further exploring different care models to better serve both patients and their families, which directly or indirectly involve the NICU physical environment.

2.3.1 Family-Centered Care

Family-centered care is an approach to embrace a partnership between staff and families (Griffin, 2006). The key concepts include: (1) dignity and respect of family perspectives and choices; (2) complete, accurate, and unbiased information sharing with families; (3) encouraging parental involvement in infant caregiving; and (4) families collaboration with healthcare professionals (Ahmann, Abraham, & Johnson, 2003). The environmental design, such as providing a private room and other family spaces, could encourage the family presence.

In the study of a Level III NICU at a Copenhagen University Hospital, the rooms holding one or two infants with a parent bed next to each incubator provided parents a stronger feeling of family unit compared to the rooms with open spaces accommodating more infants and only armchairs for family members (Beck, Weis, Greisen, Anderson, & Zoffmann, 2009). According to a case study at Stockholm, for both mothers and infants, salivary cortisol levels, as an indicator of stress level, showed no significant difference between family care NICUs (private rooms and family staying overnight) and standard care NICUs (two to four beds per room and family staying only during the daytime). However, staying in the same unit with the family care model increased the concordance of the salivary cortisol levels between infants and mothers (Mörelius, Broström, Westrup, Sarman, & Örtenstrand, 2012). Caskey, Stephens, Tucker, and Vohr (2011) have illustrated that parent talk was beneficial to infant vocalization development, which is another reason to encourage parental presence in the NICU.

2.3.2 Developmental Care

Based on Dr. Heidelise Als' Synactive Theory of Development, the infants regulate and control their behaviors through autonomic/physiology, motor, state, attention, and self-regulation subsystems (Als, 1982). However, the preterm birth interrupts infants' normal development progress. They are not prepared for the environment outside the womb, especially if they stay in NICUs with all kinds of stressors such as noise, bright light, and frequent handling. (Legendre, Burtner, Martinez, & Crowe, 2011). The concept of developmental care aims to minimize the stress of the NICU environment; the interventions including the external stimuli control, clustering of nursery care activities, and positioning or swaddling of the infant patient (Symington & Pinelli, 1996). The external stimuli are related to the visual, acoustic, lighting, and thermal environment; controlling them (e.g., decreased the noise level and controlled incubator temperature) help provide the low-stimuli physical environment that is beneficial for the infants. In term of nursery care activities, they can be facilitated by optimizing the functional layouts, therefore decrease inefficient and unnecessary nurse activities. Holding and swaddling infants involve the kangaroo care and skin-to-skin care theories, which accentuate the importance of building physical connections to babies. Studies have supported that the best environment for the stable preterm babies is parents' faces, voices, and bodies (Browne, 2003), which means the developmental care encourages family presence as the family-centered care does.

2.4 Design Considerations for NICUs

Dr. Browne (2003) points to the importance of preventing prematurity and the impact of the physical environment on patient development. The former issue is under the scope of medicine on which architects can hardly make any contribution; the latter does involve the built environment that could be improved through considerate architectural design and planning. In practice, such considerations about NICU physical environment are often built on professional or private experiences rather than empirical studies. Heroux (2011) discusses design objectives for specific spaces in the NICU department that might help provide a supportive environment, which includes the patient rooms, isolation patient rooms, transient care rooms, medication rooms, lactation rooms, parent sleep rooms, staff charting areas, support stations, reception and waiting areas, family lounges, sibling play areas, full bathrooms, and resource centers. Radcliff (2010) proposes suggestions for NICU planning and design based on his personal experience as a member of the patient family, including providing the right space for infant, family, staff, and equipment; enabling observation and communication; reducing the environmental stressors; and protecting the privacy and improving the safety.

Incubators serve as the “microenvironment” for infant patients, which should have the ability to control light, sound, smell, temperature, and infection to accommodate individual care (White, 2005). Marshall-Baker (2011) suggested that the new generation of incubators should encourage parental and nurses’ interactions with infants through better color and pattern design, providing arm rests, and more spaces near the incubator, and should upgrade to human- and environmental friendly materials, such as rubber, formaldehyde-free fiberboard, fiberglass, and soy-based foam.

Several studies focus on the acoustical environment in NICUs. Besides the importance of reducing noise levels (Gilad & Arnon, 2010; Panagiotidis & Lahav, 2010), Stewart and Schneider (2000) point out the effectiveness of music on enhancing communications. For the thermal environment, researchers have noted the impact of thermal differences due to seasonal changes and room design. The lowest humidity in winter makes the largest difference between dry bulb and wet bulb temperatures across all seasons. Interior temperatures also differ by distances between measured points and exterior windows and their relative positions and air flows (Thomas et al., 2010).

Dr. Robert D. White published several papers reviewing the NICU environment over the last several years. He underlines the importance of visual, auditory, and other sensory environment of NICUs to newborns and caregivers (2005, 2011b), recommending paying attention to safety and privacy issues (2004, 2005), and encouraging involving families in the care procedure and decision making process (2004, 2005, 2011a). These issues are linked to the transition of room types from the MB room to SFR (2005, 2011a, 2011b) and development of new care models (2004, 2011a, 2011b).

Architects Harrell and Moon (2008) have demonstrated similar considerations. They emphasize the integration of design and family centered care, compare the SFR and open rooms, and discuss the factors such as light, noise control, air quality and infection control, and interior design.

The care models have been introduced in Section 2.3. More detailed literature reviews on room types and lighting environment are discussed later in Sections 2.6 and 2.7. Other topics such as the acoustic and thermal environment of NICUs are beyond the scope of this dissertation. The author strongly recommend readers to review the book *Design for Pediatric and Neonatal Critical Care* (Shepley, 2014) and other publications for extended and thorough discussions on this topic.

2.5 Recommendations and Standards of Neonatal Intensive Care Unit Facilities

There are two primary sources for recommendations and standards for NICU design. The *Recommended Standards for Newborn ICU Design* (White, Smith, & Shepley, 2013) is the most relevant and systematic guidelines regarding the NICU design. *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* (The Facility Guidelines Institute, 2014) also includes the NICU design as one independent section. Other specialized guidelines on healthcare facilities do not include specialized sections on NICU design.

For lighting requirements, the two aforementioned standards and *LEED Reference Guide for Green Building Design and Construction – Healthcare Supplement* (USGBC, 2009) provide recommendations of the lighting environment in NICUs. Other documents related to lighting environment, such as, the *Lighting for Hospitals and Health Care Facilities* (IESNA, 2006) and *Lighting Guide 2: Hospitals and Health Care Buildings* (The Society of Light and Lighting, 2008), focus on the general healthcare facilities rather than being specialized on NICU departments.

2.5.1 Recommended Standards for Newborn ICU Design

The *Recommended Standards for Newborn ICU Design* was first published in 1992 (White, 1999) and the most up-to-date version is the eighth edition (White, Smith, & Shepley, 2013). The new edition includes *Introduction, Application of these standards, Substantive changes*, *Glossary*, and the *Standards*, which is composed of the *Delivery room standard* and *Newborn ICU standards*.

In this document, there are 27 specific standards for Newborn ICU, with each followed by an interpretation. The outline of the standards is shown in Table 2.3. It covers diverse aspects ranging from the location planning of NICU departments to the patient room interior design elements such as the ceiling finishes, wall surfaces, and furniture selections. The Recommended Standards point out that (1) the NICU should be systematically programmed and designed; (2) be a distinct area and close to obstetric or other birth-related departments; and (3) be part of an overall security program for the sake of infant, family, and staff safety. Other requirements for NICU department areas are summarized in Table 2.4.

Table 2.3 The outline of *Recommended Standards for Newborn ICU Design* (White, Smith, & Shepley, 2013)

Aspect	Number	Standard
Configuration principle	1	Unit configuration
Location	2	NICU location
Entry and reception	3	Family entry and reception area
Safety	4	Safety/infant security
Patient room	5	Infant space
	6	Private room
	7	Airborne infection isolation room
Support areas for NICU	8	Operating room
	9	Electrical, gas supply and mechanical needs
	12	General support space
	14	Support space for ancillary services
	15	Administrative space
Support areas for staff	13	Staff support space
Support areas for visitors	16	Family support space
	17	Family transition room
Handwashing	11	Handwashing
Interior	18	Ceiling finishes
	19	Wall surfaces
	20	Floor surfaces
	21	Furnishings
Thermal environment	10	Ambient temperature and ventilation
Lighting environment	22	Ambient lighting in infant care areas
	23	Procedure lighting in infant care areas
	24	Illumination of support areas
	25	Daylighting
	26	Access to nature and positive distractions
Acoustic environment	27	Acoustic environment

Table 2.4 The requirements for NICU department areas in *Recommended Standards for Newborn ICU Design* (2013) and *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* (2014)

<table>
<tr><th colspan="2" rowspan="2">Aspect</th><th colspan="2">Requirement</th></tr>
<tr><th>Recommended Standards</th><th>Guidelines for Design and Construction</th></tr>
<tr><td colspan="2" rowspan="2">Entry and reception</td><td colspan="2">All entries to the NICU should be controlled</td></tr>
<tr><td colspan="2">The family entrance and reception area should be clearly identified</td></tr>
<tr><td colspan="2">Safety</td><td colspan="2">NICU department should be designed as part of an overall safety program</td></tr>
<tr><td rowspan="7">Patient room</td><td>Area</td><td>• Multiple-bed room: minimum clear floor area of 120 square feet per infant space excluding handwashing stations, columns, and aisles
• Single room: minimum clear floor area of 165 square feet</td><td>• Multiple-bed room: minimum clear floor area of 120 square feet per infant care bed excluding sinks and aisles
• Single room: minimum clear floor area of 150 square feet excluding sinks and aisles</td></tr>
<tr><td>Aisles</td><td colspan="2">• Multiple-bed room: adjacent to each infant care space with a minimum width of 4 feet
• Single room or fixed cubicle partitions: minimum clear width of 8 feet</td></tr>
<tr><td rowspan="2">Clearances</td><td rowspan="2">Multiple-bed room: minimum clearance of 8 feet between beds; 12 feet for the speech privacy</td><td>Multiple-bed room: minimum clearance of 8 feet between beds</td></tr>
<tr><td>Minimum clearance of 4 feet between the sides of infant care beds and any wall or other fixed obstruction in bed areas</td></tr>
<tr><td rowspan="3">Window(s)</td><td colspan="2">At least one source of daylight shall be visible from infant care areas, either from each infant area itself or from an adjacent area</td></tr>
<tr><td colspan="2">Exterior windows in infant care areas shall be sized, glazed, and situated at least 2 feet from any part of an infant's bed to minimize radiant heat loss</td></tr>
<tr><td colspan="2">All daylight sources shall be equipped with shading devices</td></tr>
</table>

Table 2.4 Continued

<table>
<tr><td>Patient room</td><td>Airborne infection isolation room</td><td>Shall be available for NICU infants, minimum clear floor area of 150 square feet; have self-closing devices on all rooms' exit doors</td><td>Required; shall be enclosed with provisions for observation of the infant from adjacent area(s) of the NICU</td></tr>
<tr><td colspan="2" rowspan="12">Support areas for NICU</td><td>Administrative space: for activities directly related to infant care, family support or other activities routinely performed within the NICU</td><td>Administrative center/nurse station: shall have space for counters and storage; hand-washing station(s) shall be located in, next to, or directly accessible to the administrative center or nurse station</td></tr>
<tr><td colspan="2">Documentation/charting area</td></tr>
<tr><td colspan="2">Clean workroom or clean supply</td></tr>
<tr><td colspan="2">Soiled workroom or soiled holding</td></tr>
<tr><td colspan="2">Diagnostic, treatment, and service areas</td></tr>
<tr><td rowspan="3">Ancillary service space: space for preparation and storage of formula and additives to human milk and formula shall be provided within the unit or other location that is away from the bedside; when requiring a separate room, the room shall include ante area, preparation area, storage space, and clean-up area</td><td>Lactation support area: a hand-washing station and counter shall be provided in, next to, or directly accessible; refrigeration and freezing, storage for pump and attachments and educational materials shall be immediately accessible to the NICU</td></tr>
<tr><td>Feeding preparation facilities</td></tr>
<tr><td>Nurse/supervisor office or station</td></tr>
<tr><td rowspan="4">Mechanical needs: at least 20 simultaneously accessible electrical outlets; mechanical requirements at each bed shall be organized to ensure safety, easy access and maintenance</td><td>Multipurpose room(s)</td></tr>
<tr><td>Medication safety zone</td></tr>
<tr><td>Emergency equipment storage</td></tr>
<tr><td>Environmental services room</td></tr>
</table>

Table 2.4 Continued

Support areas for staff	Staff lounge, locker, private toilet facilities, and on-call rooms	Staff lounge, storage facilities, and toilet
Support areas for visitors	Family support space: in or immediately adjacent to the NICU for the functions: lounge, lockable storage, telephone(s) and toilet facilities	Family and visitor waiting room: immediately accessible to the NICU
	Family transition room(s): provide extended private time for parents and infants; in or immediately adjacent to the NICU	Parent/infant room(s): provide extended private time for parents and infants; shall be omitted if all NICU rooms are private
Handwashing	Every bed position shall be within 20 feet of a hands-free handwashing station	Multiple-bed room: every bed position shall be within 20 feet of a hands-free handwashing station
	Handwashing stations shall be no closer than 3 feet from an infant bed, clean supply storage or counter/worksurface unless use of splash guard	Single room: a hands-free handwashing station shall be provided in each infant care room

2.5.2 Guidelines for Design and Construction of Hospitals and Outpatient Facilities

The newest version of *Guidelines for Design and Construction of Hospitals and Outpatient Facilities* was published by the Facility Guidelines Institute (FGI) in 2014. It was developed by the American Institute of Architects and the American Hospital Association to support the design process. Several government standards organizations have adopted these standards.

The FGI Guidelines include the *neonatal intensive care unit* section under the *Nursing Units* of *Specific Requirements for General Hospitals* and *Specific Requirements for Children' Hospitals*. As Recommended Standards, FGI Guidelines accentuate that NICU department should be designed as part of an overall safety program as well. The different requirements for NICU department areas are also summarized in Table 2.4.

2.5.3 Lighting Guidelines

Both Recommended Standards and FGI Guidelines provide the lighting requirements in NICUs. The Recommended Standards set the requirements by function of lights and locations, while FGI Guidelines includes more considerations about the features of lighting fixtures themselves. Comparing the Tables 2.5 and 2.6, the ambient lighting in infant care areas in Recommended Standards covers most NICU lighting requirements in FGI Guidelines. Also, there is a separate standard regarding daylighting in Recommended Standards right after lighting standards; the similar contents are listed under the clause of window(s) in FGI Guidelines (see Table 2.4).

Table 2.5 Lighting requirements for NICU department in Recommended Standards (2013)

Element	Location	Requirement	
Ambient light	Infant care area	No direct view of both natural and electric light sources	
		Both natural and electric light sources shall have controls to allow immediate darkening of any bed position sufficient for transillumination when necessary	
		Adjustable through the range of 10 to 600 lux at the horizontal plane of each bedside	
		Electric light	Color rendering index: ≥ 80
			Gamut area: [80, 100]
			Avoid unnecessary ultraviolet or infrared radiation by the use of appropriate lamps, lens, or filters
Procedure light	Infant care area	Separate and be mounted at each infant bed	
		≥ 2000 lux at the plane of the infant bed	
		Must be framed so that ≤2% of the light output beyond its illumination field	
		Adjustable	
Illumination	Support area	Including the charting areas, medication preparation area, the reception desk and handwashing areas	
		Conform to IESNA specifications	

Table 2.6 Lighting requirements for NICU department in FGI Guidelines (2014)

Element	Requirement
Electric light	Color rendering index: ≥ 80
	Full-spectrum color index: ≥ 55
	Gamut area: [65, 100]
Controls	Enable lighting to be adjusted over individual patient care area
	Shall be darkened sufficient for transillumination when necessary
Ambient light	No direct ambient lighting in the infant care space
	Direct ambient lighting outside the infant care area shall avoid the direct line of sight from any infant to the fixture
Fixtures	Easy to clean

LEED Reference Guide for Green Building Design and Construction – Healthcare Supplement (USGBC, 2009) focuses more on the efficiency and sufficiency of use of daylight. It scores one point for controllability of lighting system for all occupants, staff areas, and patient areas (p.273), two points for daylight (p.283), and one to three points for views (p. 291). The requirements for achieving these points are summarized in Table 2.7.

Table 2.7 Credits and requirements regarding lighting in the LEED Reference Guide (2009)

<table>
<tr><th>Aspect</th><th>Credit</th><th>Point</th><th>Requirement</th></tr>
<tr><td>Controllability</td><td>6.1</td><td>1</td><td>Provide lighting system controls for all shared multi-occupant spaces; individual lighting controls for 90% of the FTE staff and 90% of patients</td></tr>
<tr><td rowspan="3">Daylight</td><td rowspan="3">8.1</td><td rowspan="3">2</td><td>Achieve a minimum of two points under Credit 8.2</td></tr>
<tr><td>Install daylight responsive controls in 100% of the area that meets the daylight quantity thresholds</td></tr>
<tr><td>A minimum of 75% of perimeter area used to qualify under Credit 8.2 achieves daylighting through simulation, prescriptive, measurement, or combination</td></tr>
<tr><td rowspan="2">Views</td><td rowspan="2">8.2</td><td>1</td><td>Inpatient units: a minimum of 90% of the inpatient staff and public areas shall be within 20 feet and twice the window head height of the perimeter; all such perimeter areas must have windows that provide at least an 11 °angle of unobstructed view in the vertical and horizontal direction</td></tr>
<tr><td>1 - 2</td><td>Non-inpatient areas: 90% of the perimeter rooms have windows that provide at least 11 °angle of unobstructed view in the vertical and horizontal direction</td></tr>
</table>

Table 2.7 Continued

			Perimeter area with window access		
			Floor plate area (bgsf)	Threshold A: 1 point	Threshold B: 2 point
Views	8.2	1 - 2	⩽15,000	7348	8248
			20,000	8785	9985
			25,000	10087	11587
			30,000	11292	13092
			35,000	12425	14525
			40,000	13500	15900
			45,000	14528	17228
			⩾ 50,000	15516	18516

There are other specialized healthcare lighting guides that do not focus on NICUs but are relevant. The *Lighting for Hospitals and Health Care Facilities* is published by the Illuminating Engineering Society of North America (IESNA, 2006). It includes sections of critical care areas and nurseries and mentions NICUs under the nurseries briefly. This document accentuates the flexibility of lighting: some infants prefer darkness, while high intensity is needed in emergencies. For families, dimming or individually controlled areas help build the bond, and a space with ample daylighting might reduce depression as well (IESNA, 2006, p. 14). The *Lighting Guide 2: Hospitals and Health Care Buildings* is published by The Society of Light and Lighting (2008) and provides a general lighting schedule for both the internal and external lighting. The intensive care unit is listed and the suggested lighting levels of ICU and nurse station are shown in Table 2.8.

Table 2.8 Suggested lighting levels of ICU and nurse station in the Lighting Guide (2008)

Location	Illuminance (lux)
Bed head observation	10-20
Bed head	30-50
Bed, clinical	400
Bed, examination	1000
Nurse station desk, day and evening	300
Nurse station, night-time	30-200

2.6 Multi-Beds Room versus Single Family Room NICUs

Most NICUs are MB units (see Figure 2.2) or SFR units (see Figure 2.3). Researchers have been concerned about whether there are differences in outcomes of infants, families, and staff between these two NICU room types. Shehheidari and Homer (2012) conducted a systematic literature review on the peer-reviewed articles published from 2001 to January 2011 and found 12 relevant studies. The outcomes examined in these studies include infection control, length of stay, noise, workload and communication, and privacy and comfort (Shehheidari & Homer, 2012). Shepley (2014) summarized the detailed outcome measures and conclusions of SFR studies in her book *Design for Pediatric and Neonatal Critical Care* (p.127-128). Their reviews were combined and reorganized in Table 2.9.

Figure 2.2 Example of a multi-beds room (Photo by the author)

Figure 2.3 Example of a single family room (Photo by the author)

Table 2.9 Empirical studies of NICU MB and/or SFR (based on Shehheidari & Homer, 2012 & Shepley, 2014)

Title (Author, year)	Outcome measures	Conclusions
Alterations in brain structure and neurodevelopmental outcome in preterm infants hospitalized in different neonatal intensive care unit environments (Pineda et al., 2013)	Hemispheric asymmetry, cerebral maturation, language development	Infants in SFRs had a diminution of normal hemispheric asymmetry, lower amplitude electroencephalogram maturation, and lower language scores at 2 years.
Challenges in design and transition to a private room model in the neonatal intensive care unit (Carlson, Walsh, Wergin, Schwarzkopf, & Ecklund, 2006)	Length of stay, family experiences about privacy, noise, light, and confidentiality, nursing staff satisfaction	The private room NICU has decreased the average length of stay; improved parents' perceptions on privacy, noise, and light; and increased nurse job satisfaction.
Documenting the NICU design dilemma: Comparative patient progress in open-ward and single family room units (Domanico, Davis, Coleman, & Davis, 2011)	Physician estimate of mortality risk, mortality and nosocomial events, discharge weight, lengths and head circumferences, respiratory and nutritional parameters, breastfeeding success, noise level, illumination, air quality	Infants in the SFR unit had fewer apneic events and reduced nosocomial infections and mortality. More mothers sustained mature milk lactation, and more infants were discharged breastfeeding.
Effects of NICU design on infection control, patient outcomes and parental satisfaction (DiFiore & Schirripa, 2013)	Infection, parental outcomes, parental satisfaction, patient outcomes	In SFRs, mothers were more likely to breast feed; parents visited longer and were more satisfied. Infection frequency unchanged.
Families' views upon experiencing change in the neonatal intensive care unit environment: From the 'baby barn'to the private room (Carter, Carter, & Bennett, 2008)	Length of stay, environmental stimuli, access to caregivers, access to information, personal privacy	The SFR was perceived by parents to offer an improved spacious environment that was less overstimulating for the infant and themselves. Access to staff, information, and overall support appeared to be improved in spite of a larger overall floor area.

Table 2.9 Continued

From “baby barn” to the “single family room designed NICU”: A report of staff perceptions one year post occupancy (Cone, Short, & Gutcher, 2010)	Staff perceptions of NICU design on patient care delivery, safety, staffing patterns and nursing workload, and education	Staff perceived better patient care, less stress for staff, and improved physical environment for patients, families, and staff in SFRs than in open units.
I want my own room! The journey from open to private NICU rooms (Greer & Black, 2013)	Length of stay, costs, walking behavior, parent satisfaction, family overnight, visitors	Families in SFR NICUs were more satisfied.
Impact of single family NICU rooms on family behavior (Shepley, Harris, White, & Steinberg, 2008)	Behavioral observation of families	More frequent interactions were found in open-bay units, but longer interactions in SFRs. Recommended that open-bay units provide spaces for longer encounters, and that SFRs provide spaces that allow for spontaneous encounters.
Neonatal intensive care nursery staff perceive enhanced workplace quality with the single-family room design (Stevens, Helseth, Khan, Munson, & Smith, 2010)	Quality of employment, quality of work environment, quality of patient care, job quality in NICU, health and safety, safety and security, interaction with NICU team, interaction with technology, off-job quality of life, overall satisfaction	Staff perceptions of workplace quality were significantly higher in the SFR than in the open-bay NICU. Exceptions were some aspects of health and safety, nature of interaction with NICU teams, and off-job quality of life.
NICU redesign from open ward to private room: A longitudinal study of parent and staff perceptions (Swanson, Peters, & Lee, 2013)	Teamwork, communication, development, facility, safety, privacy	Advanced practitioners reported more teamwork, but nurses did not. Nurse satisfaction initially higher in SFR, but declined later on.

Table 2.9 Continued

Open-bay and single-family room neonatal intensive care units: Caregiver satisfaction and stress (Shepley, Harris, & White, 2008)	Job Satisfaction Scale, Nurse Stress Scale, Satisfaction and Perception of Physical Environment	SFR NICU design may increase staff satisfaction and reduce staff stress.
Perceptions of maternal stress and neonatal patient outcomes in a single private room versus open room Neonatal Intensive Care Unit environment (Smithgall, 2010)	Heart rate variability, cardiac interbeat interval, continuous electrocardiogram	The SFRs encouraged parental access to infants but did not impact maternal stress.
Room for family-centered care – a qualitative evaluation of a neonatal intensive care unit remodeling project (Beck, Weis, Greisen, Anderson, & Zoffmann, 2009)	Family and staff perceptions based on interviews	SFRs enhanced family-centered care in a NICU, and the healthcare providers saw the increased workload as challenging.
Room for improvement: Nurses' perceptions of providing care in a single room newborn intensive care setting (Walsh, McCullough, & White, 2006)	Observations of the nurses guided by a questionnaire identifying benefits, risks, and patient safety concerns	SFRs were thought to be more effective for patient care and parent satisfaction compared to open bay units. However, nurses believed that success depended on sufficient staff, due to decreased patient visibility and longer distances. Large units presented quality improvement, unique communication, and staff training challenges.
Single family room care: Before and after data (Rosenblum, 2005)	Weight, days requiring total parental nutrition, infections	The SFR demonstrated higher weight gain among patients, fewer days before parental nutrition, and fewer hospital acquired infections.

Table 2.9 Continued

Single room NICU: Fad or future (Oelrich, 2003)	Patient outcomes, length of stay, communication, staffing, infection	Good communication was found in the SFR. There was an increase in nosocomial infections at one site, which may have been due to carpet use or increased acuity among patients.
Staff perceptions of work quality of a neonatal intensive care unit before and after transition from an open bay to a private room design (Smith, Schoenbeck, & Clayton, 2009)	Staff perceptions and performance	Rankings of overall physical environment, patient care, job, technology, and off-the-job quality significantly improved in the SFR, but evaluations of patient care team interaction significantly declined. No meaningful changes were found up to 22 months afterwards.
The impact of individual room on rehospitalization and health service utilization in preterms after discharge (Erdeve et al., 2008)	Numbers of routine follow-up visits, acute care visits, total applications, and consultation by phone	The individual rooms allowed maternal presence and participation, and was correlated with lower rates of rehospitalization and healthcare applications.
The impact of single family room design on patients and caregivers: Executive summary (Harris, Shepley, White, Kolberg, & Harrell, 2006)	Space allocations, construction costs, staff preferences and perceptions, occupant behaviors	SFR NICU design provided solutions for increasing parent privacy and presence, supporting Health Insurance Portability and Accountability Act compliance, minimizing the number of undesirable beds, increasing staff satisfaction and reducing staff stress
The influence of neonatal intensive care unit design on sound level (Chen et al., 2009)	Sound level	The sound levels in the enclosed room were lower than in the open space. A NICU with enclosed space would be quiet and private for family.

Domanico, Davis, Coleman, and Davis (2011) support the benefit of the SFR units: in their study, the patients had fewer apneic events, reduced incidence of nosocomial sepsis and mortality, and earlier transitions to enteral nutrition. In other research, staff perceptions of workplace quality were significantly higher in the SFR than in the open-bay NICU with regard to quality of employment, quality of work environment, quality of patient care, job quality in NICU, safety and security, and interaction with technology (Stevens, Helseth, Khan, Munson, & Smith, 2010).

Stevens and colleagues (2011) also conducted a "comparison of outcomes of care in an open-bay and single-family room neonatal intensive care facility." They used mortality rate, grade III-IV intraventricular hemorrhage, > 28 days of supplemental oxygen, and the need for retinal laser ablation surgery as indicators to compare the adverse outcomes of patients in the open-bay and SFR NICUs (Stevens et al., 2011). Statistical analysis showed no significant difference between the two situations. However, when they compared parent satisfaction in these units, parents whose infants were in SFR NICUs expressed higher satisfaction with the NICU environment, overall assessment of care, and total survey scores than those in open-bay NICUs (Stevens, Helseth, Khan, Munson, & Reid, 2011). Based on these two studies, it seems possible that the use of an SFR rather than an open-bay unit does not influence incidence of severe adverse outcomes but does improve the overall quality of care and may have a positive influence on infants' general outcomes.

In Smithgall's dissertation, "Perceptions of Maternal Stress and Neonatal Patient Outcomes in a Single Private Room Versus Open Room Neonatal Intensive Care Unit

Environment" (2010), she found that the single private room encouraged parental access to infants but did not affect the level of maternal stress.

Regarding cost effectiveness of the two types of units, based on a medium-sized NICU with 40 beds: the annual operating costs of a unit with SFRs would be 1.1 million dollars lower than a unit with MB, while the one-time construction costs is $1,188,000 higher. If planning to construct and operate a NICU for more than two years, SFR would be a better choice on returns than MB (Shepley, Smith, Sadler, & White, 2014).

2.7 Lighting in Neonatal Intensive Care Units

Lighting is one of the most important environmental factors in NICU design. It could influence the outcomes of infants and the experience of families, as well as the behavior of healthcare professionals. However, understanding the actual effects of lighting, especially those of daylighting, is a complicated topic and needs to be further explored.

Infants and caregivers have different lighting needs, and infants' needs may vary based on gestational ages and health conditions. Before the age of one year, infants sleep through a large proportion of the day (White, 2004). Because of their underdeveloped vision systems, the primary principle of lighting design in the NICU is to keep excessive direct light away from the infants so as to provide an ideal sleeping environment for them (Bowen, 2009; White, 2006). From the perspective of caregivers, they observe patients day and night, detect infants' skin coloration, measure their heart and respiration rates, and write down or input electrical medical records near the bedside. While dim lighting seems appropriate for the infants in the NICU, it creates a difficult work environment for caregivers, as they must maintain alertness and fulfill healthcare responsibilities (White, 2005). Staff members need bright lighting to improve their work efficiency and effectiveness, and thereby, ensure patients' safety.

Both electrical lighting and daylighting have advantages and disadvantages. With good planning and control, electrical lighting can provide numerous required lighting levels for any space at any time. However, people who stay in the electrical lighting environments for an extended period may become disoriented; their circadian rhythms are disrupted, especially for nurses and staff who work night shifts (Stevens & Rea, 2001).

In contrast, daylighting is a more natural and sustainable approach; the lighting levels change according to time, date, and weather. Both patients and caregivers could experience the diurnal cycle, which may positively influence their physical and spiritual conditions. We all know that natural light benefits people's circadian rhythms. Figueiro, Appleman, Bullough, and Rea (2006) note that infants "receive light/dark signal information through maternal time-of-day cues (e.g., hormones and activity)" before birth (p.S24). Mann, Haddow, Stokes, Goodley, & Rutter (1986) compared day-night cycled light with continuous light, while Brandon, Holditch-Davis, D., & Belyea (2002) studied the influence of moving from near darkness to cycled light on preterm infants. Both of these studies found significantly greater weight gain in the group of infants in the day-night cycled light environment (Floyd, 2005). Other related research has illustrated that infant patients with cycled lighting had "earlier initiation of oral feedings, decreased number of days on the ventilator and under phototherapy, and enhanced motor coordination" (Bowen, 2009, p.4). Also, reducing light levels in NICUs increases infants' respiratory stability, decreases their heart and respiratory rates and activity levels, and reduces time on mechanical ventilation and oxygen support (Bowen, 2009). The main challenge of daylighting is the difficulty in constantly maintaining and controlling the required levels of lighting. In the NICU, the issue of the most concern is preventing excess lighting exposure to infants. For example, to avoid infants receiving direct light, the staff could shield the incubator with a cover (see Figure 2.2) and/or lower indirect lighting during the night, keeping the balance of permitting infants to sleep while maintaining optimal lighting for the staff's work.

2.8 Summary

Neonatology is a new discipline in the long history of medicine and has been developing rapidly in recent decades. The survival rate of infant patients has been increased. The NICU is more than a place to solely save infant lives; it is expected to provide better environment, both physically and spiritually, to serve infants, families, and doctors and nurses. Contemporary care models lead to the request of more family involvement, which asks for improvement in patient safety and protection of privacy. The appearance of SFR is one of the promising solutions. Several studies supported the benefits of SFRs over the traditional MB rooms on patient outcomes and satisfactions and perceptions of families and nurses. However, only limited studies focused on lighting in NICUs, and even less investigated the relationships between user behaviors and lighting conditions. From the review of design guidelines, the researcher found that the guidelines: (1) included both room types of MB and SFRs, (2) encouraged, but did not require, direct access to daylight in NICU patient rooms, and (3) divided the rooms into several areas by functions to regulate the lighting environment.

3. RESEARCH DESIGN AND METHODOLOGY

3.1 Conceptual Model

Based on the review, a conceptual model is proposed for factors influence patient outcomes and family perceptions in NICU (see Figure 3.1). NICU physical environment, nurse intervention, and family presence (skin-to-skin contact and sleeping in the room) could directly affect the infant's outcomes, and therefore, have an influence on the family's perceptions about their stress levels and satisfaction. The physical environment directly relates to nurses' satisfaction and the family's perceptions; it also can affect the infant's outcomes through an influence on family visits and interactions among different user groups (infants, families, and nurses).

The NICU physical environment includes factors such as the layout (access to windows/natural light and lack of access), sound or noise, lighting, temperature, air quality, and design and arrangement of incubator and other functional spaces. The infant outcomes can be captured by variables such as weight gain, length of stay, ventilator days, mortality, nosocomial events, and other outcome measures. The infant's age, gender, race, original weight, and reason to be in NICU will moderate the impacts of physical environment on NICU while also influencing infant outcomes directly. The social factors such as nurse behaviors and perceptions and family behaviors, especially the interactions between the family and the infant, between the family and the nurses, and between different families, will mediate the impact of physical environment on infant outcomes.

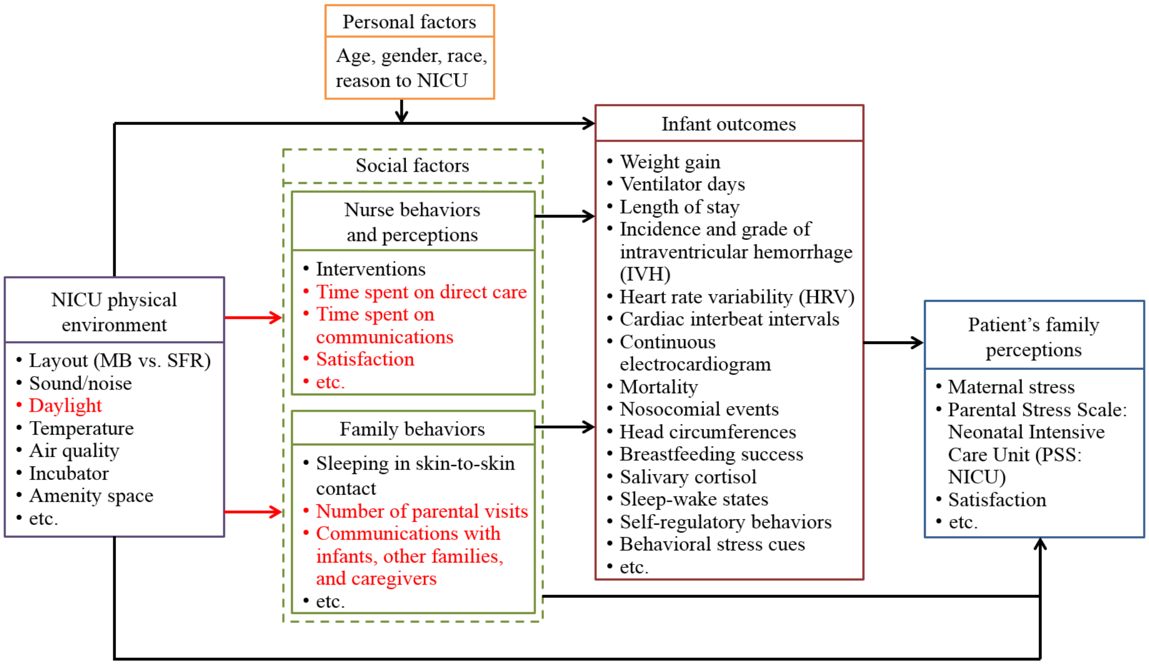

Figure 3.1 Conceptual model of the study

This study only examines a section of this framework, and those considered variables are highlighted in red in Figure 3.1. The independent variables are the daylighting environment. The data regarding family and staff behavior and staff satisfaction are the dependent variables. During data collection, factors such as the incubator location within the room and other functional space arrangements are controlled. Sound/noise levels, temperature, air quality, caregivers' intervention, and infant's age, gender, race, and basic physical conditions may be the confounding variables in this study, and their possible effects are considered when analyzing the results.

3.2 Overview of Qualitative and Quantitative Research Method

One of the main means of distinguishing research types is by categorizing the research as either qualitative or quantitative (Kothari, 2004; Creswell, 2013). Qualitative studies focus on the complexity of phenomena in natural settings (Leedy & Ormrod, 2004, p. 133), while quantitative approaches pay attention to the measurable characteristics of phenomena (Kothari, 2004, p. 3). Both methodologies have their own advantages and disadvantages and are appropriate to use in a variety of study fields.

Qualitative methods are useful when one really needs to listen to the subjects, especially in social studies (Taylor & Bogdan, 1984). For example, when conducting an interview or creating a questionnaire with open-ended questions, the responses may extend beyond what the researcher initially assumes. Different people have unique experiences, and their responses may focus on diverse topics; the same events can be explained in myriad ways. As a result, an individual expression of judgment may not be as important as the reason behind it. Input from subjects is beneficial to the facticity and effectiveness of a study (Al-Busaidi, 2008). However, those analyzing qualitative data run the risk of misinterpretation or missing hidden meanings; it is difficult to eliminate the influence of a researcher's personal perspective or bias.

Quantitative methods tend to be more accurate and reliable. The data they produce are relatively easy to compare with other quantitative data, even if the data come from various studies (so long as certain rules and principles are followed). Unlike qualitative methods, which to some extent rely on manual analyses, quantitative data are isolated from subjective factors whenever possible. The limitation, though, is that such data only unmask the results that can be measured and have already been included in the hypothesis. Whether to utilize a single method or to adopt a mixed approach should be decided based on the specific topic and research questions.

3.3 Research Design

This study focused on the clarification of the transition in NICU room types and the relationship between daylighting (as one of the key factors in the NICU physical environment) and nurse and family behavior. It includes two sections: (1) the nationwide cross sectional study with NICU staff and (2) an in-depth case study of one hospital. The cross sectional study includes two nationwide surveys: one was distributed to NICU medical directors through email with a link to the survey website, and the other to NICU nurses at a national NICU nurse conference. Both of them aimed to collect basic information of the NICU built environment and receive evaluations from broad samples. The case study used multiple methods including behavioral observation, survey, and direct lighting measurements to depict and analyze the scenario of a specific NICU in practice. The behavioral observation was conducted to record the times and locations of nurse and family behaviors, as specifically and accurately as possible. The survey was used to collect nurses' real-time evaluations of lighting environment. Lighting measurements provided the necessary objective metrics to evaluate and compare the lighting environmental factors. Details of the methods and associated subjects in this study are summarized in Table 3.1.

Table 3.1 Components of the study and corresponding data collection methods

Method		Subject	Data
Nationwide cross sectional study	Survey I, distributed online	NICU medical directors	NICU room types and lighting conditions at respondent's facility and respondent's evaluations
	Survey II, distributed at a conference	NICU nurses	Evaluations for lighting environment at respondent's facility and impacts of respondent's perceptions about impacts of daylighting on behavior
Case study of one hospital	Behavioral observation	NICU nurses and families	Social interactions of nurses and families under different lighting conditions
	Survey III	NICU nurses	Evaluations for lighting environment and respondent's perceptions about impacts of daylighting on behavior
	Lighting measurement	N/A	Lighting levels and daylight glare

3.4 Nationwide Cross Sectional Study

As mentioned in Section 3.3, the nationwide cross sectional study utilized two surveys: (1) *NICU Room Type and Lighting Condition Questionnaire (Survey I)*, and (2) *NICU Nurse Satisfaction with Lighting Environment Questionnaire (Survey II)*.

3.4.1 Instrument

3.4.1.1 Survey I: NICU Room Type and Lighting Condition Questionnaire

The Survey I collected information about the NICU physical environment and respondents' subjective evaluations of the lighting environment, of which the latter part was developed based on the study by Shepley, Harris, White, & Steinberg (2008). The specific survey items are shown in Table 3.2.

Table 3.2 Components of *NICU Room Type & Lighting Condition Questionnaire*

Domain	Item	Question type
Physical environment	Hospital location	Fill-in-the-blank
	Year in which the NICU was built or renovated	
	Number of rooms for • Single family rooms • Rooms with 2-3 baby beds • Rooms with more than three baby beds	
	Number of beds for • Single family rooms • Rooms with 2-3 baby beds • Rooms with more than three baby beds	
	Number of rooms with access to daylight • By exterior windows only • By interior windows only • By skylight only • By exterior and interior windows • By exterior windows and skylight • By interior windows and skylight	
Subjective perception of lighting environment and their impacts	Importance of • Electric lighting • Daylighting	Multiple choice of seven-point Likert scale (from *Not important at all* to *Very important*)
	Satisfaction about • Electric lighting • Daylighting	Multiple choice of seven-point Likert scale (from *Very dissatisfied* to *Very satisfied*)
	Influence on behavior • Improving work efficiency • Decreasing medical errors • Increasing mental alertness • Increasing length of family visits • Decreasing times that families leave their baby's room • Increasing interactions between families and infants • Increasing interactions between staff and infants	Multiple choice of seven-point Likert scale (from *Strongly disagree* to *Strongly agree*)

Physical environment were measured using fill-in-the-blank questions; subjective opinions were captured using multiple-choice questions with a seven-point Likert scale, except for one that asked for open-ended comments. There were a total of 25 items examined under nine nested questions (see Appendix A).

3.4.1.2 Survey II: NICU Nurse Satisfaction with Lighting Environment Questionnaire

The Survey II was composed of four parts with a total of 37 multiple-choice questions and one open-ended question (see Appendix B).

The first part asked for background information about the respondent, such as gender, age, job title, and work experience in NICUs. The categories of age, job title, and work experience were extracted from the survey questionnaires used by official healthcare-related organizations (e.g., American Nurses Association) or healthcare systems (e.g., AMN Healthcare) after 2010.

The second part, “current lighting environment evaluation,” was concerned with the lighting quality’s effects on personal visual comfort and the impact of lighting conditions on different work tasks conducted in the patient rooms. The former was based on the *Questionnaire regarding windows and light* developed by Lawrence Berkeley National Laboratory (Clear, Inkarojrit, & Lee, 2006), which was originally used for soliciting opinions about lighting’s effects in office space. In this study, the NICU department was the work space of nurses, and the variables of lighting qualities were kept the same. Westbrook, Duffield, Li, & Creswick (2011) provided the categories and definitions of the nurse work tasks that were used to evaluate the latter aspect.

The third part, "importance of lighting," was also based on the questionnaire developed by the Lawrence Berkeley National Laboratory (Clear, Inkarojrit, & Lee, 2006) and adjusted for use in the NICU setting as in the second part.

The last part dealt with the impact of daylighting on behavior. The hypothesized behavior changes were based on the study by Shepley, Harris, White, & Steinberg (2008).

The composition of survey items and the original sources are shown in Table 3.3.

Table 3.3 Components and sources of *NICU Nurse Satisfaction with Lighting Environment Questionnaire*

Domain	Item	Question type	Source
1. Background information	Age category	Multiple choice (< 25, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, > 65)	Fact sheet: Registered nurses in the U.S. (American Nurses Association, 2011)
	Job category	Multiple choice (Director/CEO, Manager/administrator, RN/staff nurse, Nurse practitioner/physician assistant, Certified nurse anesthetist, Clinical nurse specialist, Educator, Midwife, Other)	The registered nurse population: Findings from the 2008 national sample survey of registered nurses (U.S. Department of Health and Human Services HRSA, 2010)
	Work experience category	Multiple choice (< 2 years, 2-9 years, 10-19 years, 20-29 years, > 30 years)	2012 Survey of registered nurses: Job satisfaction, career patterns and trajectories (AMN Healthcare, 2012)

Table 3.3 Continued

2. Current lighting environment evaluation	Room type	Multiple choice (Single family room, Room with 2-3 baby beds, Room with more than three baby beds)	N/A
	Room access to daylight	Yes-no	N/A
	Lighting quality • Lighting level • Lighting distribution • Glare • Window views of nature • Impact of the view • Overall ambience of room • Overall satisfaction	Multiple choice of seven-point Likert scale (from *Too dark* to *Too bright*) (from *Poorly distributed* to *Well distributed*) (from *Intolerable* to *Not perceptible*) (from *No View* to *Good View*) (from *Negative* to *Positive*) (from *Gloomy* to *Cheerful*) (from *Very dissatisfied* to *Very satisfied*)	Subject responses to electrochromic windows (Clear, Inkarojrit, & Lee, 2006)
	Impact of lighting conditions when fulfilling work tasks • Direct care • Indirect care • Medication task • Documentation • Professional communication • Social • Ward related activities • Supervision • In transit • Other	Multiple choice of seven-point Likert scale (from *Very dissatisfied* to *Very satisfied*)	How much time do nurses have for patients? A longitudinal study quantifying hospital nurses' patterns of task time distribution and interactions with health professionals (Westbrook, Duffield, Li, & Creswick, 2011)

Table 3.3 Continued

3. Importance of lighting	Overall importance • Electric lighting • Daylighting	Multiple choice of seven-point Likert scale (from *Not important at all* to *Very important*)	Subject responses to electrochromic windows (Clear, Inkarojrit, & Lee, 2006)
	Importance of daylighting factor • Lighting level • Lighting distribution • View of nature • Ambience		
4. Impact on behavior	Influence on behavior • Improving work efficiency • Decreasing medical errors • Increasing mental alertness • Increasing length of family visits • Decreasing times that families leave their baby's room • Increasing interactions between families and infants • Increasing interactions between staff and infants	Multiple choice of seven-point Likert scale (from *Strongly disagree* to *Strongly agree*)	Impact of single family NICU rooms on family behavior (Shepley, Harris, White, & Steinberg, 2008)

The first part consisted of multiple choice questions. The responses to most questions in the other parts were recorded on a seven-point Likert-type scale, ranging from Very Dissatisfied (1) to Very Satisfied (7), Not Important at All (1) to Very Important (7), or Strongly Disagree (1) to Strongly Agree (7); other responses depended upon the characteristics of the evaluated items. The only exceptions are the first two questions in the second part, which asked about room types and whether or not the room had a window opening to the outdoors; and the last open-ended question of the questionnaire that asked for comments or suggestions.

3.4.2 Subjects

3.4.2.1 Survey I: NICU Room Type and Lighting Condition Questionnaire

Survey I was distributed nationwide through emails to all NICU medical directors in the United States, according to records provided by the *Newborn Intensive Care Units (NICUs) and Neonatologists of the USA & Canada Directory* (2011). The directory listed a total of 1,007 NICUs in the United States, including seven hospitals in Puerto Rico and one naval hospital in Okinawa, Japan, which were not in the scope of this study. Among the remaining 999 NICUs, 589 NICUs provided medical directors' email contact information. Therefore, the population of the survey consisted of these 589 NICU medical directors.

3.4.2.2 Survey II: NICU Nurse Satisfaction with Lighting Environment Questionnaire

Survey II was distributed to 192 nurse attendees from different hospitals at an annual conference of neonatal nurses in February, 2014.

3.4.3 Research Questions and Hypotheses

3.4.3.1 Survey I: NICU Room Type and Lighting Condition Questionnaire

The following questions will be explored based on the distribution of NICU built years, room types, and lighting conditions: (1) whether NICU room types have changed over time; (2) whether NICU rooms with access to daylighting differ by room type; and (3) whether different types of NICU rooms offer different types of access to dayligthing.

Table 3.4 listed the hypotheses that would be statistically tested based on data from the Survey I.

Table 3.4 *NICU Room Type & Lighting Condition Questionnaire* hypotheses

Hypothesis	Independent variable	Dependent variable
Evaluation of lighting importance and satisfaction		
I1. People perceive the importance of electric lighting and daylighting in a NICU to be the same.	Lighting sources (daylight and electrical light)	Importance
I2. People who work in different room types perceive different levels of importance for electric lighting in the NICU.	NICU room type in which the respondent works (single family room, rooms with 2-3 beds, and rooms with >3 beds)	Importance of electric lighting
I3. People who work in different room types perceive different levels of importance for daylighting in the NICU.	NICU room type in which the respondent works	Importance of daylighting
I4. People experience the same level of satisfaction with the NICU general lighting environment and daylighting.	Lighting sources	Satisfaction
I5. People who work in different room types experience different levels of satisfaction with the NICU lighting environment.	NICU room type in which the respondent works	Satisfaction with lighting environment
I6. People who work in different room types experience different levels of satisfaction with the NICU daylighting environment.	NICU room type in which the respondent works	Satisfaction with daylighting environment
Evaluation of daylighting impact		
I7. People have the same opinions on the impacts of sufficient daylighting on staff and family behavior in NICU.	Behavior impacts	Opinions

3.4.3.2 Survey II: NICU Nurse Satisfaction with Lighting Environment Questionnaire

The hypotheses that would be statistically tested based on the Survey II are listed in Table 3.5.

Table 3.5 *Nurse Satisfaction with Lighting Environment Questionnaire* hypotheses

Hypothesis	Independent variable	Dependent variable
Evaluation of lighting qualities		
II1. People hold different perceptions of NICU lighting qualities.	Lighting qualities	Evaluation on visual comfort experience
Lighting satisfaction when fulfilling work tasks		
II2. People perceive different levels of satisfaction regarding lighting conditions when fulfilling different work tasks in a NICU.	Work tasks	Satisfaction on lighting condition
Evaluation of lighting importance		
II3. People perceive the importance of electric lighting and daylighting in a NICU to be the same.	Lighting sources	Importance
II4. People who work in different room types perceive different levels of importance for electric lighting in a NICU.	NICU room type in which the respondent works	Importance of electric lighting
II5. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance for electric lighting in a NICU.	NICU room in which the respondent works access to daylighting or not	Importance of electric lighting

Table 3.5 Continued

II6. People who work in different room types perceive different levels of importance for daylighting in a NICU.	NICU room type in which the respondent works	Importance of daylighting
II7. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance for daylighting in a NICU.	NICU room in which the respondent works access to daylighting or not	Importance of daylighting
Evaluation of importance of daylight and window related factors		
II8. People perceive different levels of importance of daylight and window related factors in a NICU.	Daylight and window related factors	Importance
II9. People who work in different room types perceive different levels of importance of appropriate lighting level in a NICU.	NICU room type in which the respondent works	Importance of lighting level
II10. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of appropriate lighting level in a NICU.	NICU room in which the respondent works access to daylighting or not	Importance of lighting level
II11. People who work in different room types perceive different levels of importance of appropriate lighting distribution in a NICU.	NICU room type in which the respondent works	Importance of lighting distribution
II12. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of appropriate lighting distribution in a NICU.	NICU room in which the respondent works access to daylighting or not	Importance of lighting distribution

Table 3.5 Continued

II13. People who work in different room types perceive different levels of importance of providing views of nature in a NICU.	NICU room type in which the respondent works	Importance of nature view
II14. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of providing views of nature in a NICU.	NICU room in which the respondent works access to daylighting or not	Importance of nature view
II15. People who work in different room types perceive different levels of importance for appropriate room ambience in a NICU.	NICU room type in which the respondent works	Importance of room ambience
II16. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of appropriate room ambience in a NICU.	NICU room in which the respondent works access to daylighting or not	Importance of room ambience
Evaluation of daylighting impact		
II17. People have different opinions on the impact of the presence of sufficient daylight on staff and family behavior in the NICU.	Staff and family behavior	Opinions on the impact of the presence of sufficient daylight
II18. People who work in different room types have different opinions on whether sufficient daylight increases work efficiency.	NICU room type in which the respondent works	Opinions on the impact of sufficient daylight on work efficiency
II19. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases work efficiency.	NICU room in which the respondent works access to daylighting or not	Opinions on the impact of sufficient daylight on work efficiency

Table 3.5 Continued

II20. People who work in different room types have different opinions on whether sufficient daylight decreases medical errors.	NICU room type in which the respondent works	Opinions on the impact of sufficient daylight on medical error
II21. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight decreases medical errors.	NICU room in which the respondent works access to daylighting or not	Opinions on the impact of sufficient daylight on medical error
II22. People who work in different room types have different opinions on whether sufficient daylight increases mental alertness.	NICU room type in which the respondent works	Opinions on the impact of sufficient daylight on mental alertness
II23. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on the whether sufficient daylight increases mental alertness.	NICU room in which the respondent works access to daylighting or not	Opinions on the impact of sufficient daylight on mental alertness
II24. People who work in different room types have different opinions on whether sufficient daylight increases length of family visits.	NICU room type in which the respondent works	Opinions on the impact of sufficient daylight on length of family visits
II25. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases length of family visits.	NICU room in which the respondent works access to daylighting or not	Opinions on the impact of sufficient daylight on length of family visits
II26. People who work in different room types have different opinions on whether sufficient daylight decreases the time that families leave their baby's room during their visit.	NICU room type in which the respondent works	Opinions on the impact of sufficient daylight on frequency that family leave patient room during visit

Table 3.5 Continued

II27. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight decreases the time that families leave their baby's room during their visit.	NICU room in which the respondent works access to daylighting or not	Opinions on the impact of sufficient daylight on frequency that family leave patient room during visit
II28. People who work in different room types have different opinions on whether sufficient daylight increases the interactions between families and infants.	NICU room type in which the respondent works	Opinions on the impact of sufficient daylight on interactions between families and infants
II29. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases the interactions between families and infants.	NICU room in which the respondent works access to daylighting or not	Opinions on the impact of sufficient daylight on interactions between families and infants
II30. People who work in different room types have different opinions on whether sufficient daylight increases the interactions between staff and infants.	NICU room type in which the respondent works	Opinions on the impact of sufficient daylight on interactions between staff and infants
II31. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases the interactions between staff and infants.	NICU room in which the respondent works access to daylighting or not	Opinions on the impact of sufficient daylight on interactions between staff and infants

3.4.4 Procedure

3.4.4.1 Survey I: NICU Room Type and Lighting Condition Questionnaire

The Survey I was created using the online survey platform *Qualtrics*. The link was emailed nationwide to the NICU medical directors identified in the directory (AAP, 2011) during March of 2014. Two reminder emails were sent two weeks and then four weeks after the initial distribution to enhance the response rate. The email provided the link to the online survey. The first page of the online survey was the information sheet, and the participant was given the opportunity to choose whether or not to fill out this anonymous survey. The survey takes less than ten minutes to complete. The entire survey process lasted seven weeks to allow the medical directors enough time to respond. The data of completed questionnaires were exported from Qualtrics into Microsoft Excel and analyzed using descriptive statistics, inductive statistics, and content analysis. Section 4.1.1 in “Data Analysis” provided more details.

3.4.4.2 Survey II: NICU Nurse Satisfaction with Lighting Environment Questionnaire

For the Survey II, the researcher first contacted the conference committee to get approval to distribute the questionnaire. The committee agreed to help print the questionnaire with the information sheet and include them in the conference package given to all attendees. At the opening session of the conference, the committee announced certain events that would take place during the conference, which included the distribution and collection of the questionnaire; they also encouraged attendees to participate. It was estimated that the survey takes about 15 minutes to complete. A ballot box was placed next to the registration desk to collect the completed questionnaires. The researcher retrieved the box after the conference was completed (four days later) to allow the attendees enough time to fill out and return their questionnaires. The results were entered in Microsoft Excel and analyzed in Excel and JMP. The details of cleaning and analyzing data were explained in Section 4.1.2.

3.5 Case Study of One Hospital

The in-depth case study was conducted at the NICU in one general hospital in the southeast United States from April 16th to April 25th of 2014. The methods used included behavioral observations of nurses and families, surveys for the nurses, and on-site measurements of the lighting environment.

3.5.1 Site Selection

Since the main concern of this project was the influence of daylighting in NICUs, the researcher contacted more than five hospitals with NICUs throughout the country as long as at least part of their patient rooms had access to daylight. Due to the sensitivity of neonatal patients, only one NICU with SFR in a hospital in the southeast United States agreed to participate as the study site. Figure 3.2 shows the floor plan of the NICU department, which has been simplified in details for confidentiality. It was designed to with two double-loaded corridors: 16 SFRs along the south corridor and 12 SFRs and two double-occupancy rooms along the north corridor. Either eight SFRs or four SFRs with double-occupancy rooms by adjacency composed a pod. The configuration of the study site was such that some rooms faced outward with direct access to daylight, and others faced inward with no access to daylight. Other physical features of all patient rooms were similar, including the shape and area of rooms, materials used, and furniture and equipment arrangements, which ensures that differences in the results attributable to control factors were kept to a minimum.

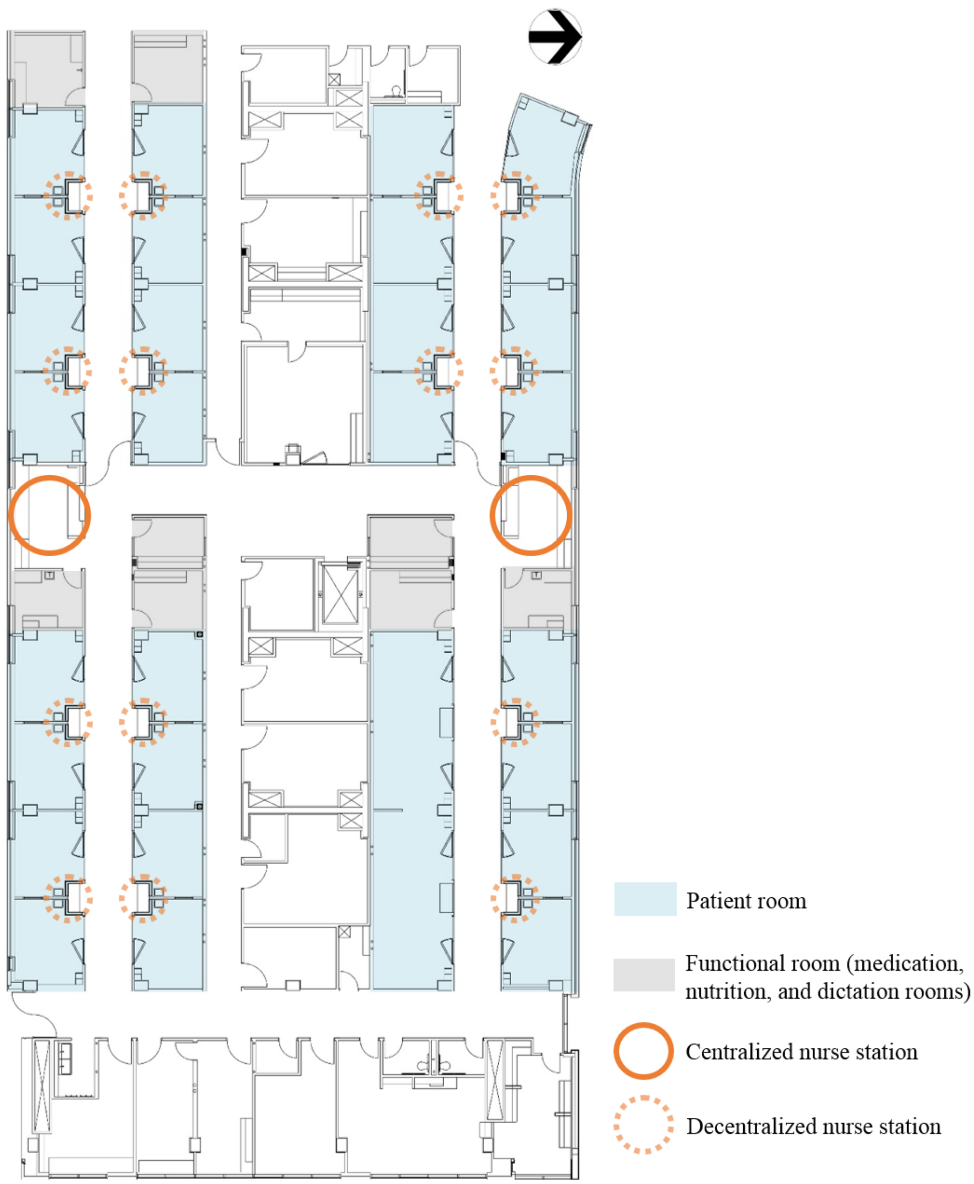

Figure 3.2 NICU department floor plan

3.5.2 Instrument

3.5.2.1 Behavioral Observation

The behavioral observation portion of the study used a method similar to that of the study conducted by Shepley, Harris, White, and Steinberg (2008). Nurse and family behaviors in the NICU department, including corresponding locations and times were recorded. The specific observation schema is illustrated in Table 3.6. The categories of nurse behaviors were defined based on the study conducted by Westbrook, Duffield, Li, and Creswick (2011). Considering the practicality and simplicity of observation, some modifications of the original categories are made: (1) ward related activities was merged into indirect care; (2) professional communication and social were merged as the category of communication; and (3) both paper- and computer- based works were included in the documentation. The modified nurse behavioral categories are listed in Table 3.7.

Table 3.6 Behavioral observation schema

Time	Start time
	End time
Subject	Nurse
	Family
Behavior	Direct care
	Indirect care
	Medication
	Documentation
	Communication
	Supervision

Table 3.6 Continued

Behavior	In transit	
	Other	
Location	Patient room	Patient care zone
		Support zone
		Family zone
	Central nurse station	
	Decentralized nurse station	
	Medical room	
	Nutrition room	
	Corridor	

Table 3.7 Definitions of observed nurse behaviors (modified from Westbrook, Duffield, Li, and Creswick, 2011)

Nurse behavior	Definition
Direct care	Tasks directly involved with patient care in the patient room, e.g., bathing, apply dressings, nursing procedures, etc.
Indirect care	All tasks indirectly related to patient care in the patient room, e.g., reviewing results, planning care, washing hands, reviewing documentation, etc.
Medication	All tasks associated with medication, includes preparation, administration, discussion, and clarification
Documentation	Documentation (paper and electronic)
Communication	All communication
Supervision	Supervising others, including students
In transit	Transit between tasks and between patients
Other	Not included in the list, add explanation in the note

Note: In actual observations, the curtains at entrances of patient rooms were closed most of the time, which made it difficult for the researcher to distinguish nurse behavioral types when the nurse worked inside the room with the curtain closed. In such situations, the researcher would use her best guess and recorded the nurse activity as direct care when no other cues are available.

Data were gathered using a pocket PC (Nexus 7 tablet) preprogrammed with Noldus software *The Observer XT* (see Figures 3.3 and 3.4), which allowed the researcher to record the observed behaviors. The Noldus software has been widely used in psychology studies and research on healthcare facilities, education settings, human factors, and user experiences, etc. Some previous studies on parent-infant interaction (Reissland & Stephenson, 1999) and communication between patients and physicians (Graugaard, Holgersen, & Finsest, 2004) used the same software installed on mobile equipments.

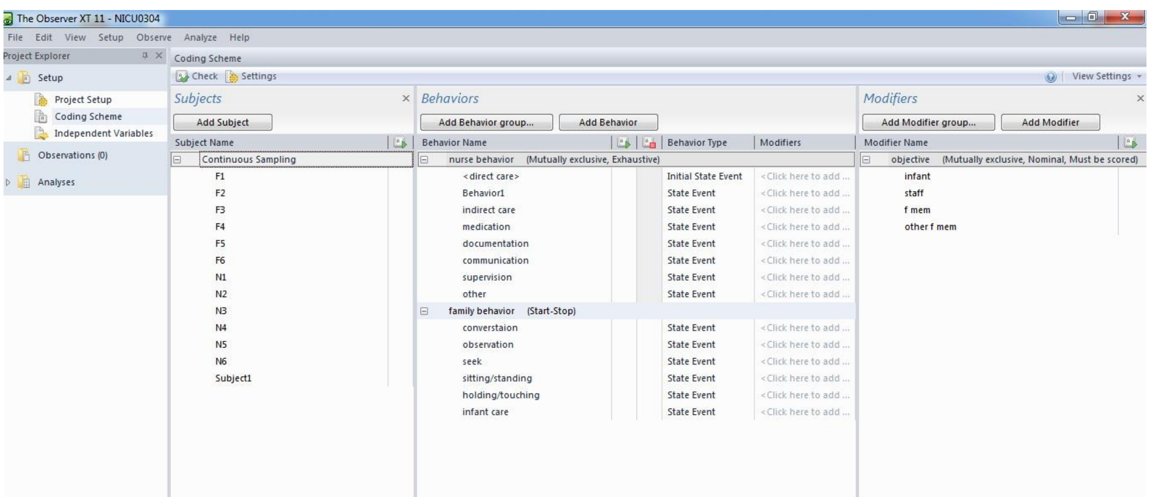

Figure 3.3 The interface of Noldus software for programming at computer

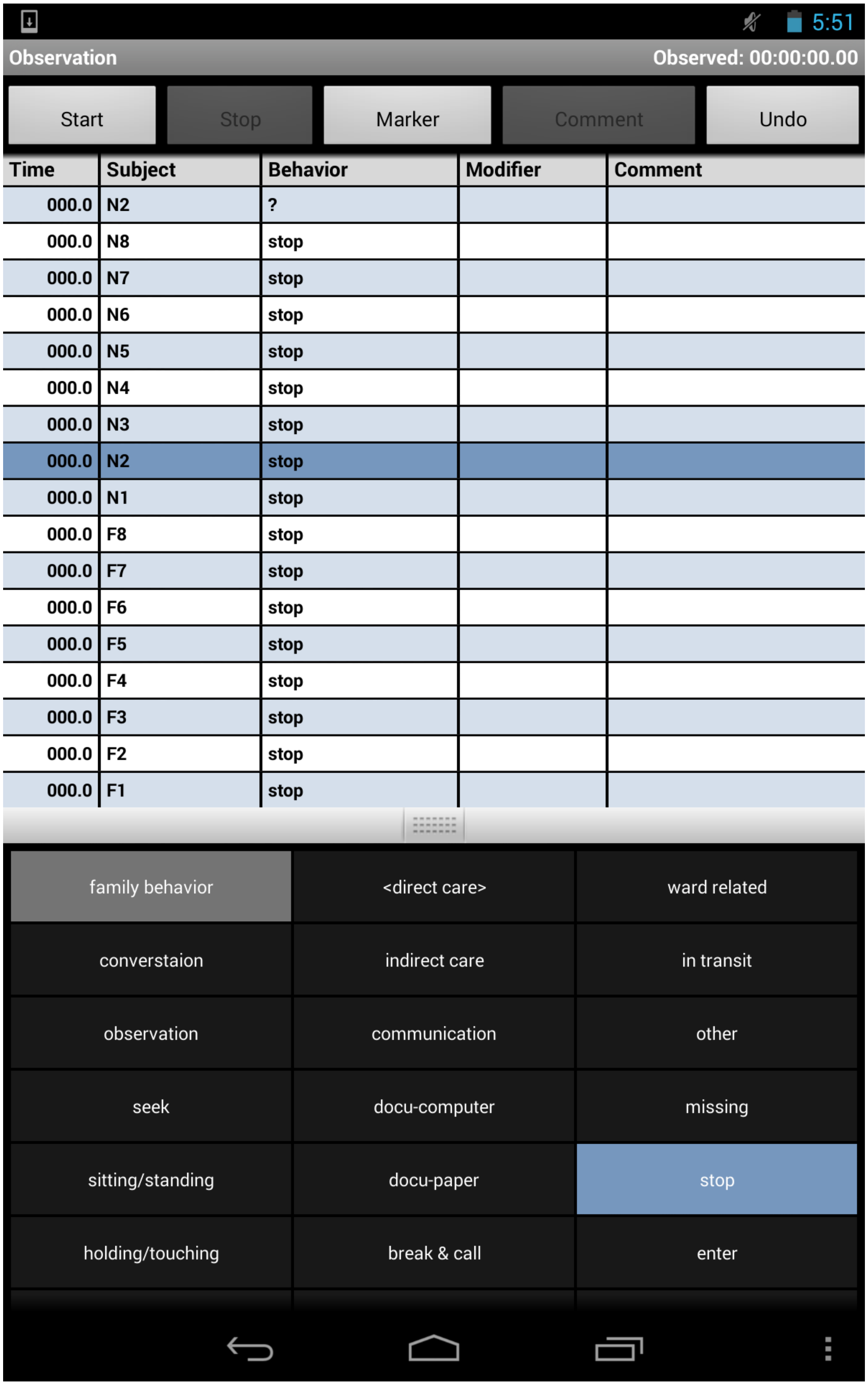

Figure 3.4 The interface of Noldus software for observation at pocket PC

3.5.2.2 Survey III

The nurses at the participating NICU were also asked to answer the nurse satisfaction questionnaire, which was similar to the one distributed at the professional conference (see Section 3.4.1.2). The only difference between the two versions were in the second part. For conference attendees, their evaluations of *current* lighting environments were based on their *impressions* of NICUs where the majority of their work time was spent; here "current" referred to real-time, on site situations. Nurses at the participating hospital were asked about their last hour of experience in the NICU in relation to the lighting environments, which was more precise and time-dependent; they also provided the exact date and time for filling out the questionnaire.

3.5.2.3 On-Site Measurement

The lighting levels were measured by a lighting meter. High-dynamic-range (HDR) photos of the interior environment were taken by a digital camera for glare analysis.

3.5.3 Subjects

3.5.3.1 Behavioral Observation

Twenty-five NICU day shift nurses who cared for patients and the people who visited those patients (mostly families) during the study period (from April 16th to April 25th of 2014) were the target subjects. Only people who agreed to participate in the study and signed the consent forms were included in the observation.

3.5.3.2 Survey III

Same as the nurse subjects of behavioral observation, 25 NICU day shift nurses who cared for patients during the study period (from April 16th to April 25th of 2014) were the target subjects for the survey.

3.5.3.3 On-site Measurement

Not applicable.

3.5.4 Research Hypotheses

3.5.4.1 Behavioral Observation

(1) Nurses who work in NICU patient rooms with more daylight are more satisfied with their lighting environment than those who work in rooms with less daylight.

(2) Nurses who work in NICU patient rooms with more daylight spend a greater percentage of their time on direct care than those who work in rooms with less daylight.

(3) Family members in NICU patient rooms with more daylight spend more time with their infants than those in NICU rooms with less daylight.

(4) Family members in NICU patient rooms with more daylight have longer communication times with nurses and other families than those in NICU rooms with less daylight.

3.5.4.2 Survey III

Same as Section 3.4.3.2. See Table 3.5.

3.5.4.3 On-site Measurement

Not applicable.

3.5.5 Procedure

3.5.5.1 Behavioral Observation

Before the observation began, the researcher participated in the nurses' quarterly meeting, introduced the project, and distributed the consent forms for behavioral observation and survey with the information sheet to nurses. The researcher left a non-transparent folder at the nurse station to collect the signed consent forms and completed questionnaires. The researcher checked the folder every day during the observation period until April 25th - the last day at the hospital, so as to not miss any consent form or questionnaire.

For the consent forms for participating family members, after consulting with the nursing staff as to the appropriateness of contacting particular families, the researcher introduced the project to families who were passing by and asked their permission to be observed during the observation period.

For each observation day, the researcher randomly chose one of the two corridors, then observed those nurses in charge of the rooms along the selected corridor who also had signed the consent form. The researcher stayed in the selected corridor and recorded when and where interactions and other activities (verbal, visual, and body behaviors) took place and how long each behavior lasted using the pocket PC (see Figure 3.5). The time a visitor entered and left each patient room was also recorded. For each day's observation, nurses were coded as n1, n2, n3, etc. and family members were coded as f1, f2, f3, etc. The assignments were based on the order in which the subject presented him or herself, rather than as a link to specific individuals. The subjects, behaviors, and locations were recorded in the Noldus software on the Nexus 7 tablet using pre-coded categories. The researcher only needed to click the corresponding buttons to record specific behaviors; the exact time of clicking the buttons was automatically recorded. There was also a pre-programmed note choice allowing the researcher to add extra information. When needed, the researcher also took notes on paper. This allowed for the recording of any relevant information that might have potential influences or cause bias with regards to the recorded behaviors. To get more accurate observation data, the researcher walked around the corridor but neither entered patient rooms nor talked to other people (except when asking for consent from family members, or when being asked by nurses or families to respect patient and family privacy and minimize the possible impact on nurses' regular work).

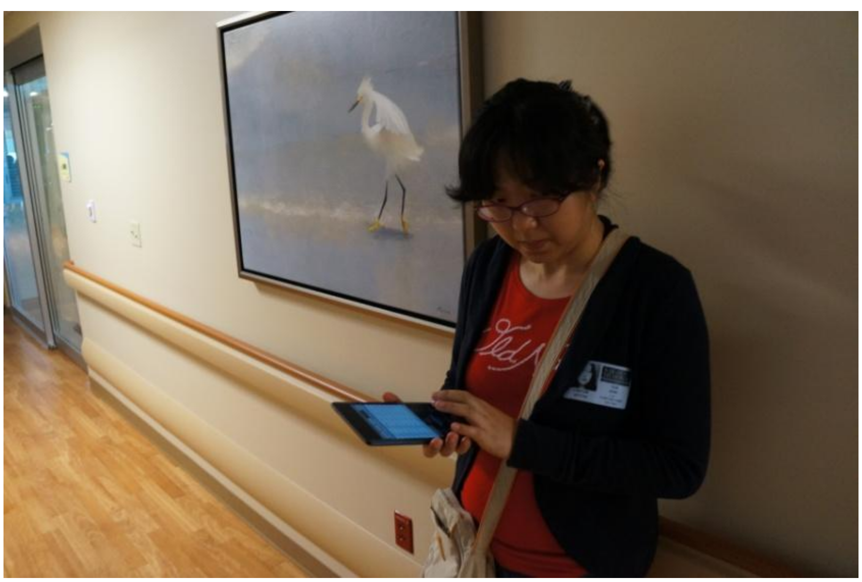

Figure 3.5 Researcher conducted the behavioral observation

The observations lasted about eight hours per day, usually from 8:00am till 6:00pm, and excluding two hour for lunch and break time. When there was an emergency situation (e.g., code blue or fire drill), the researcher immediately paused the observation and resumed data collection when everything was clear.

3.5.5.2 Survey III

The consent process for the survey was conducted together with the consent process for the behavioral observation (see Section 3.5.5.1). Some extra questionnaires were collected after the researcher left the hospital, and were mailed to the researcher by the head nurse. The entire period - from distribution of the questionnaire to receipt of all returned questionnaires - lasted about 20 days in April of 2014.

3.5.5.3 On-site Measurement

Unoccupied NICUs with the same configuration and orientation as those under behavior observation were photographed and measured for lighting levels; photographs were taken in different zones during the observation period in order to record the lighting conditions (see Figure 3.6).

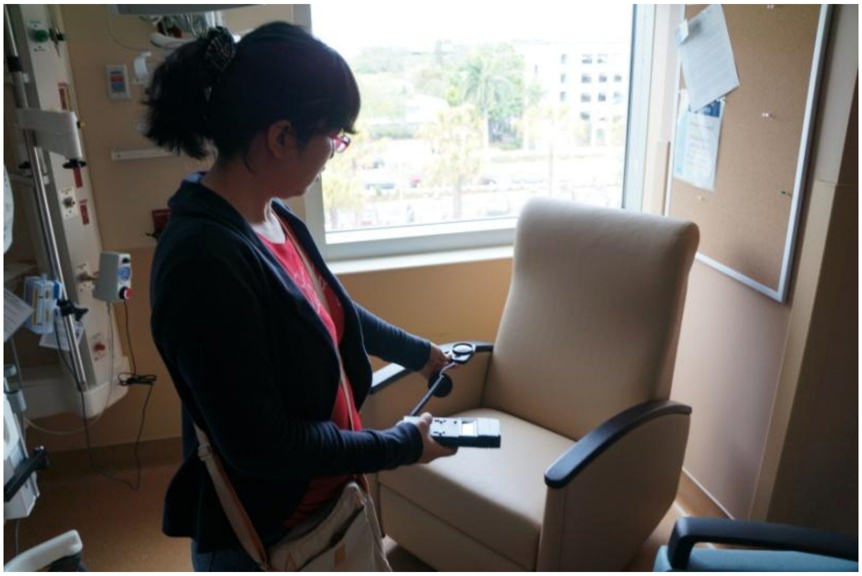

Figure 3.6 Researcher measured the lighting level in an unoccupied NICU

3.6 Research with Human Subjects

The behavioral observation and surveys involved medical staff and family participants. Information sheets were used for surveys, and consent forms were provided to nurses and families for behavioral observations. Three institutional review board (IRB) applications were submitted and approved for this study (see Appendix C), including:

(1) IRB application for conducting the nationwide cross sectional study (*Survey I and Survey II*), submitted to Texas A&M University IRB;

(2) IRB application for behavioral observations and survey at the participating hospital, submitted to Texas A&M University IRB; and

(3) IRB application for behavioral observation and survey at the participating hospital, submitted to the hospital IRB.

All of the participants were recruited after the IRB approvals. To protect the human subjects, participation in all surveys and behavior observations were voluntary. Study subjects had the right to stop participating in the study at any time as they wished; their decision to participate or not had no effect on their employment, work evaluation, or relationship with either the hospital or Texas A&M University. All the data collected were anonymous and coded with no identifiable personal information included. There were no links between the people who signed the consent forms and the data collected. For the behavior observations, the people being observed were randomly selected based on the corridors where they worked, and only consenting subjects were observed.

4. DATA ANALYSIS*

4.1 Nationwide Cross Sectional Study

This section will analyze the results of two surveys: (1) the online *NICU Room Type & Lighting Condition Questionnaire* distributed to a nationwide sample of medical directors and (2) the paper-based *NICU Nurse Satisfaction with Lighting Environment Questionnaire* distributed to nurse attendees at a national professional conference.

4.1.1Survey I: NICU Room Type & Lighting Condition Questionnaire

The following will provide information about the response distribution, relationships between built years/periods and NICU room types, daylighting conditions, importance and satisfactions of lighting conditions, and evaluations on the impacts of daylight on nurse and family behaviors based on the results of collected responses of Survey I.

4.1.1.1 Response Distribution

As mentioned in Section 3.4.2 in "Research Design and Methodology," Survey I was distributed to 589 NICU medical directors whose email addresses were provided on the *Newborn intensive care units (NICUs) and neonatologists of the USA & Canada directory* (AAP, 2011), among which 482 emails were successfully delivered. Ninety-seven medical directors opened the link to the online survey and agreed to participate. A

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* Part of the data reported in Section 4.1 was first published in the *Academy Journal*, the official journal of the AIA Academy of Architecture for Health. Source: Song, Y. & Shepley, M. M. (2015). Neonatal intensive care unit (NICU) room type design trends. *Academy Journal, 17*, 26-32.

submitted questionnaire was considered valid for the analysis if the respondent answered the first question regarding the hospital location as well as at least one more question. Eighty-nine valid questionnaires were retrieved after such a selection. If all the 482 medical directors with effective email address saw the invitation email, then the response rate was 20.1% (97/482), and the valid response rate was 18.5% (89/482). However, in reality, it is likely that some of these email recipients did not really receive and read the invitation email due to changes in their email addresses or other reasons. So these numbers are conservative estimate for response rates.

The 482 medical directors who were contacted for the survey came from 49 states. The only two states without any sample were Wyoming and South Dakota. Wyoming did not have a hospital with an NICU listed in the Directory (AAP, 2011). For South Dakota, three were listed in the Directory but their email addresses turned out to be ineffective. The 89 valid questionnaires covered 29 states and eight out of the nine regions (see Figure 4.1). The response rates by region are shown in Table 4.1.

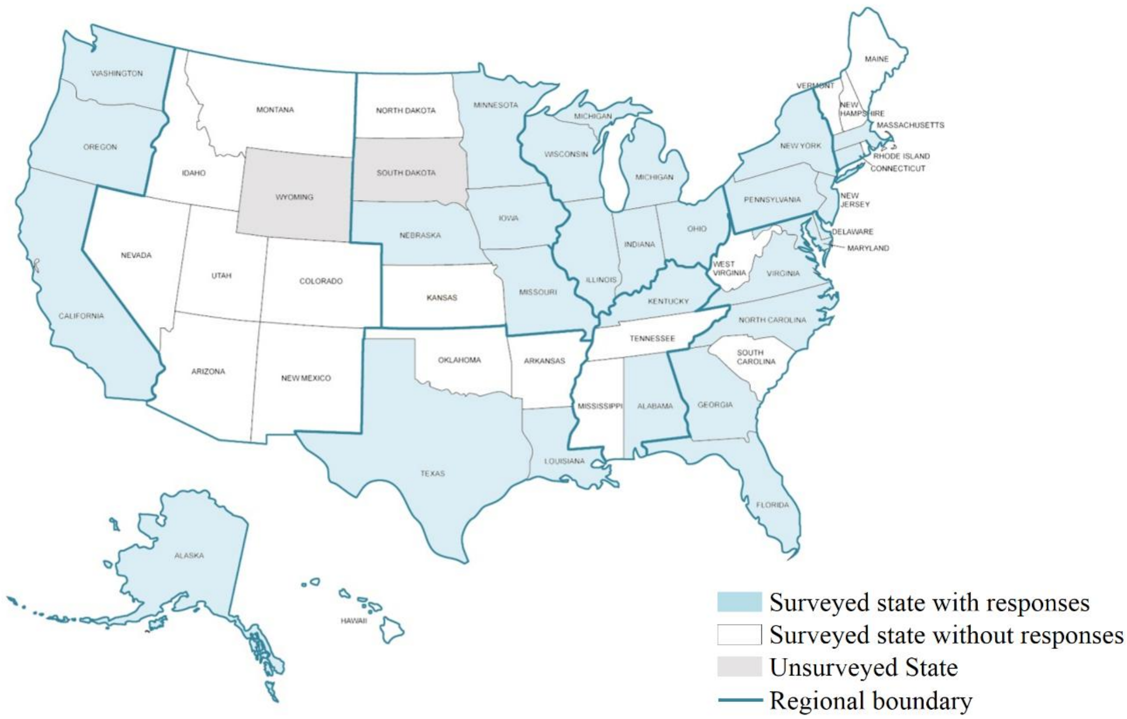


Figure 4.1 Responses by state and by region

Table 4.1 The response rates by regions of *NICU Room Type & Lighting Condition Questionnaire*

Region	Total number of NICUs on the Directory	Valid responses	Valid response rate (%)
New England (CT, MA, ME, NH, RI, VT)	48	7	14.58
West North Central (IA, KS, MN, MO, ND, NE, SD)	63	9	14.29
Pacific (AK, CA, HI, OR, WA)	169	21	12.43
South Atlantic (DC, DE, FL, GA, MD, NC, SC, VA, WV)	181	17	9.39
East North Central (IL, IN, MI, OH, WI)	128	10	7.81

Table 4.1 Continued

West South Central (AR, LA, OK, TX)	145	11	7.59
Middle Atlantic (NJ, NY, PA)	134	10	7.46
East South Central (AL, KY, MS, TN)	68	4	5.88
Mountain (AZ, CO, ID, MT, NM, NV, UT, WY)	63	0	0.00
Total	**999**	**89**	**8.91**

The response time for the online survey ranged from 1.5 minutes (92 seconds) to more than 19 hours (70,571 seconds). There was a noticeable gap between the mean time, which was 24.5 minutes (1470 seconds), and the median value, which was 5.1 minutes (306 seconds). After four outliers were removed, the average response time was 6.4 minutes (384 seconds), and the median time was 5.0 minutes (302 seconds). The specific distributions are shown in Figures 4.2 and 4.3.

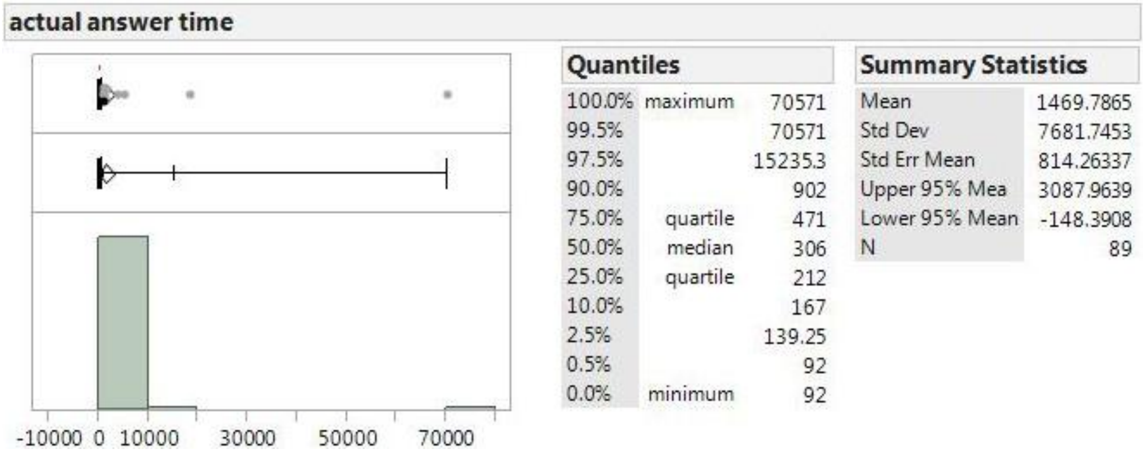


Figure 4.2 Original distribution of response time (seconds)

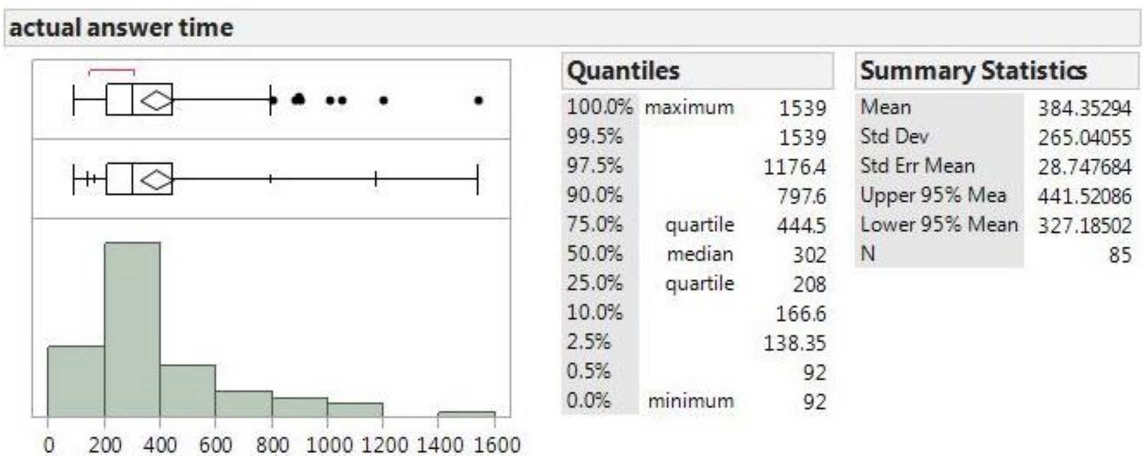


Figure 4.3 Adjusted distribution of response time (seconds) after removing the outliers

4.1.1.2 NICU Built Years and Room Types

Six respondents answered the question about the built year for the NICU she or he works in but chose no room type out of all three available options (single room, room with 2-3 baby beds, and room with more than 3 beds). These responses were excluded for analysis of room types and the relationship between built years and room types, but were still counted for the analysis of built years. Another five responses were excluded due to missing the answer for the built year. For a NICU that had been rebuilt or renovated, the most recent year of construction was used for the analysis.

Based on the responses, the NICUs were built or most-recently-renovated between 1980 and 2014 (see Figure 4.4). Figure 4.5 illustrates the stacked numbers of NICUs by room type and year. There was no 2-3 beds unit until 1990, and SFRs did not appear until 1994. Considering that there may be more than one room type in a given NICU, the proportion of NICU with each room type out of the total number of hospitals with NICUs for each year was calculated (See Figure 4.6). For instance, there were four NICUs built in 2006: two of them only had > 3 beds units, and the other two had both SFRs and 2-3 beds units. So the proportion of the number of each room type out of the total built NICUs in 2006 was 50%; the stacked proportions were 150%. If only one single type was been used, the total would have been 100%; the higher the total, then, the more multiple room types there were.

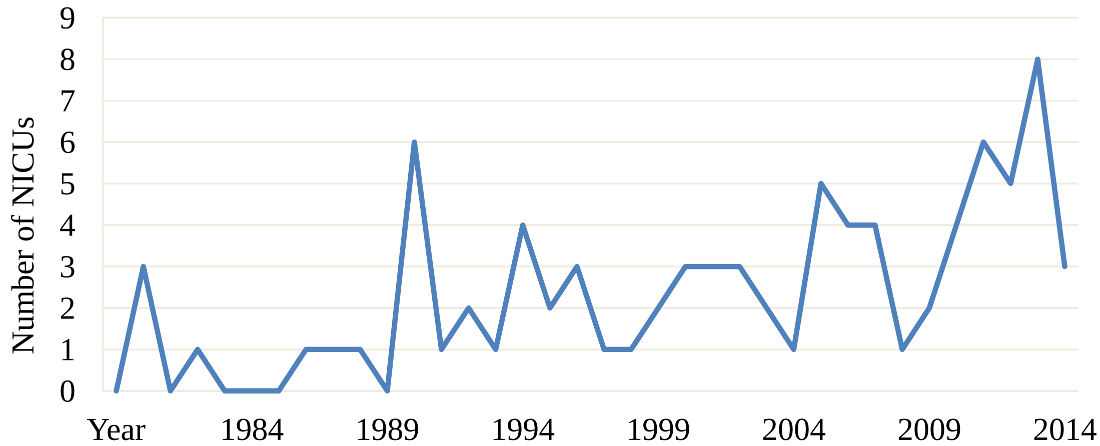


Figure 4.4 Number of NICU constructions and renovations by year

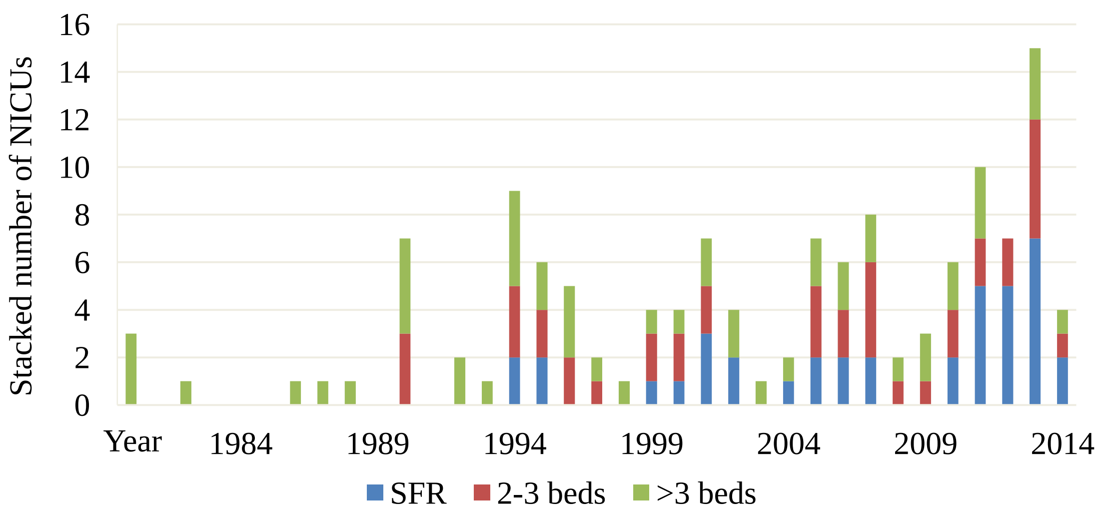


Figure 4.5 Stacked number of NICU facilities by room type and most recent year built or renovated

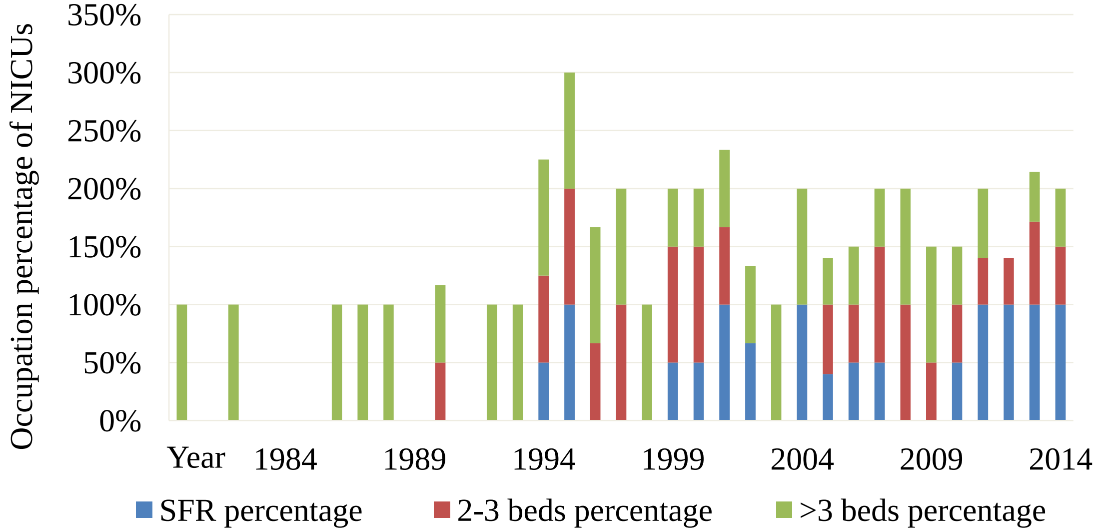


Figure 4.6 Occupation percentages of different NICU room types in hospitals by most recent year built or renovated

Figure 4.7 shows the distribution of different room types: the inner circle represents the proportions of mixed and non-mixed NICU room types in hospitals, while the outer circle illustrates the specific distribution of each type. The number of NICUs with mixed room types was slightly higher than those with single types. The most popular type was > 3 beds unit (28%), followed by a mix of SFR and 2-3 beds unit (18%) and a combination of all three types (16%). On average, there were 2.71 beds per room for units with 2-3 beds and 6.89 beds per room for > 3 beds units. Due to the large number of SFRs, the overall average number of beds per room was 2.01 (See Table 4.2).

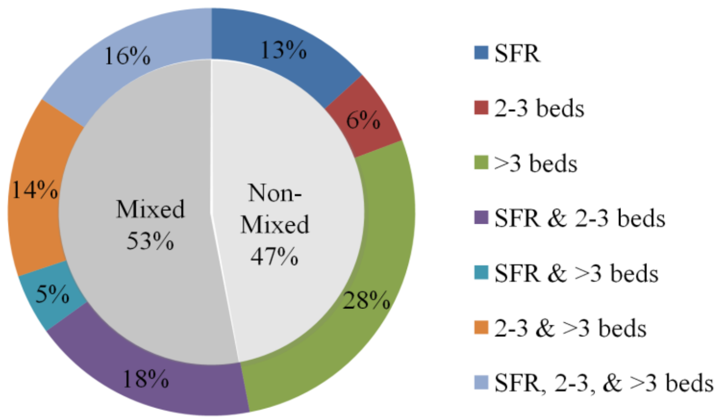


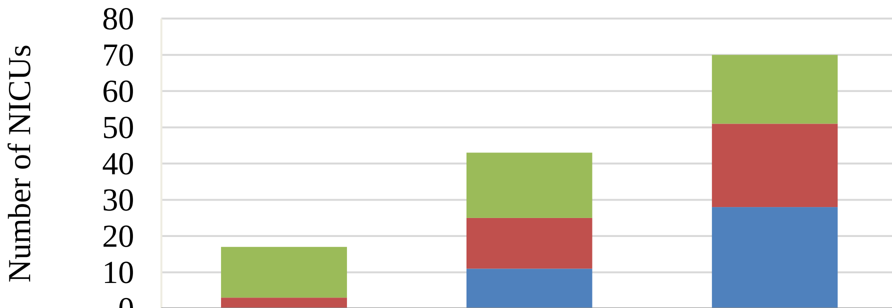
Figure 4.7 Distribution of hospitals with mixed and non-mixed NICU room types

Table 4.2 Average numbers of beds per NICU and beds per room by room type

Room type	Number of NICUs	Number of rooms	Number of beds	Average number of beds/NICU	Average number of beds/room
SFR	41	1060	1060	25.85	1
2-3 beds	41	265	718	17.51	2.71
> 3 beds	52	183	1260	24.23	6.89
Total	**134**	**1508**	**3038**	**22.67**	**2.01**

4.1.1.3 NICU Built Time Periods and Room Types

To simplify the analysis and better illustrate temporal trends of NICU room types, built years were divided into three periods: pre-1994 (before the appearance of SFR NICUs), 1994-2003 (the following decade), and post-2003. As shown in Figure 4.8, the number of newly built or renovated NICUs with > 3 beds units was relatively stable throughout the three periods; however, NICUs with both SFRs and 2-3 beds units increased dramatically.

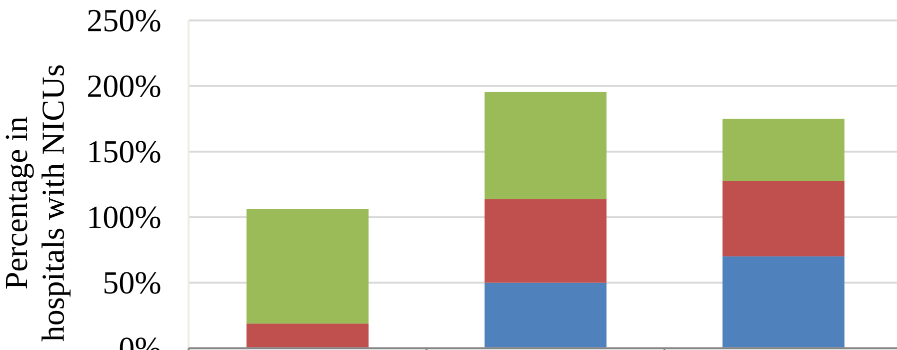


	pre-1994	1994-2003	post-2003
>3 beds	14	18	19
2-3 beds	3	14	23
SFR	0	11	28

Figure 4.8 Number of hospitals by NICU room type and most recently built or renovated time period

Taking into account the co-existence of different room types in the same NICU, the proportion of NICUs with each room type relative to the number of hospitals with NICUs was calculated for each period. The results are shown in Figure 4.9. As in Figure

4.6, the totals exceeded 100% due to the facts that some units had multiple types of rooms. The total percentages almost doubled, from 106.3% in the pre-1993 period to 195.4% in the 1994-2003 period, and then slightly decreased to 175% for the post-2003 period. This decrease reflects a drop in the percentage of > 3 beds units, but the percentage of SFR was still increasing.



	pre-1994	1994-2003	post-2003
>3 beds	87.5%	81.8%	47.5%
2-3 beds	18.8%	63.6%	57.5%
SFR	0.0%	50.0%	70.0%

Figure 4.9 Percentages of different NICU room types in hospitals by most recently built or renovated time period

Before 1994, NICU room types were either 2-3 beds unit or > 3 beds units with the exception of one hospital that had both room types. Since SFRs appeared, there are more NICUs with mixed room types. Comparing the latter two periods, SFR only

NICUs and NICUs with a mix of SFRs and 2-3 beds increased quickly, while other types were relatively stable (see Figure 4.10).

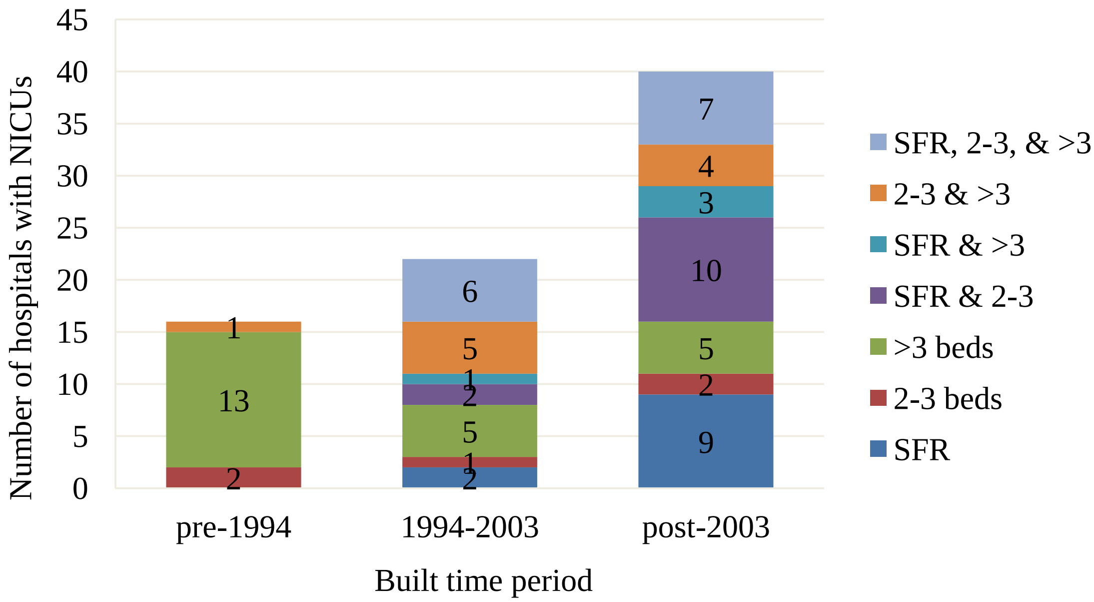
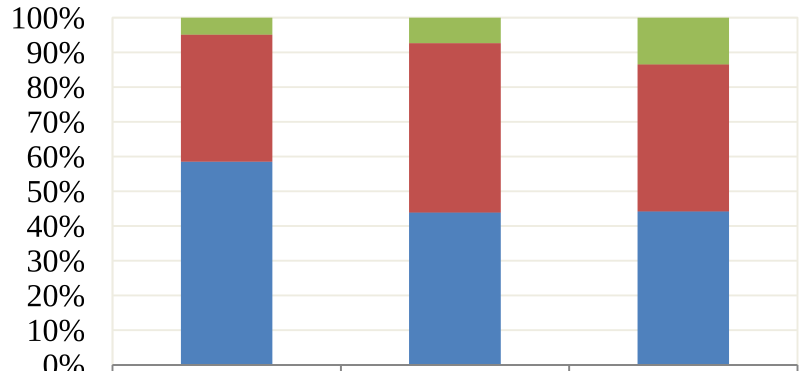


Figure 4.10 Number of hospitals with mixed and non-mixed NICU room types by most recently built or renovated time period

4.1.1.4 NICU Daylighting Conditions

Daylighting conditions of NICUs were categorized into six types: (1) exterior windows only (EO), (2) interior windows with daylighting from exterior windows only (IO), (3) skylight only (SO), (4) exterior and interior windows (EI), (5) exterior windows and skylight (ES), and (6) interior windows and skylight (IS). Even in the same room type of a given NICU department, not all the rooms have the same lighting conditions. The numbers of NICUs with access to daylighting by room type are shown in Figure 4.11. The NICUs of each room type were divided into one of the three groups: all rooms with access to daylighting, some rooms with access to daylighting, and no rooms with access to daylighting. SFRs had the highest percentage of all rooms with access to daylighting (58.5%) and the lowest percentage of no room with access to daylighting (4.9%). The other two types, 2-3 beds unit and > 3 beds unit, had similar percentages of all rooms with access to daylighting (43.9% and 44.2% respectively), whereas the percentages of no room with access to daylighting were 7.3% and 13.5% respectively, which were 1.5 and 2.8 times of the value of SFR type.



	SFR	2-3 beds	>3 beds
No room	2	3	7
Some rooms	15	20	22
All rooms	24	18	23

Figure 4.11 Number of hospitals with NICUs access to daylighting by room type

The utilization of different daylighting types in NICUs is shown in Table 4.3. Receiving daylight directly through the exterior wall (the “EO”) was the most frequently used model among all three room types. For SFRs, daylighting through interior windows (the “IO”) was the second most commonly used model with strong advantage than other models. For 2-3 beds units, the model of using both exterior and interior windows (“EI”) was the second most common, and the IO was the third most common. These two types, EI and IO, were the second most frequent among > 3 beds units. The three lighting models (“SO,” “ES,” and “IS”), which all involved the utilization of skylight, were less frequently used in all room types.

Table 4.3 Frequency and percentage of daylighting types in NICUs by room type

Room type	EO	IO	SO	EI	ES	IS	Total
SFR	31 (55.4%)	17 (30.4%)	0 (0.0%)	6 (10.7%)	2 (3.6%)	0 (0.0%)	**56** (100%)
2-3 beds	31 (62.0%)	7 (14.0%)	1 (2.0%)	9 (18.0%)	1 (2.0%)	1 (2.0%)	**50** (100%)
> 3 beds	37 (60.7%)	9 (14.8%)	2 (3.3%)	9 (14.8%)	3 (4.9%)	1 (1.6%)	**61** (100%)

Note: EO stands for exterior windows only, IO interior windows only, SO skylight only, EI exterior and interior windows, ES exterior windows and skylight, and IS interior windows and skylight.

Focusing on the commonly used lighting models EO, IO, and EI, as shown in Figure 4.12, more than half of NICUs with 2-3 beds and > 3 beds used the EO model (59.6% and 56.4% respectively), which was higher than in SFRs (44.4%). SFRs had a higher percentage of having some rooms with the EO model while some with IO than the other two room types.

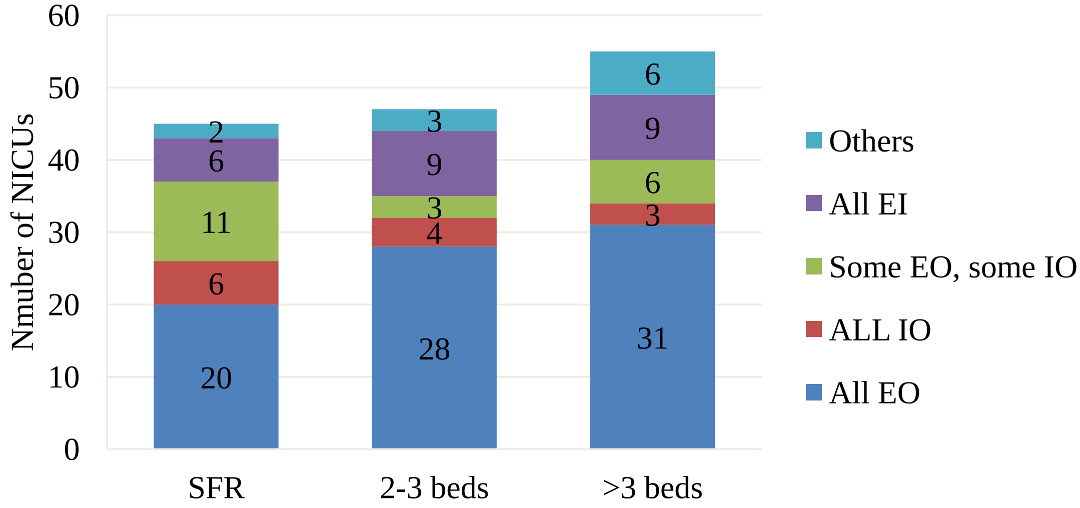
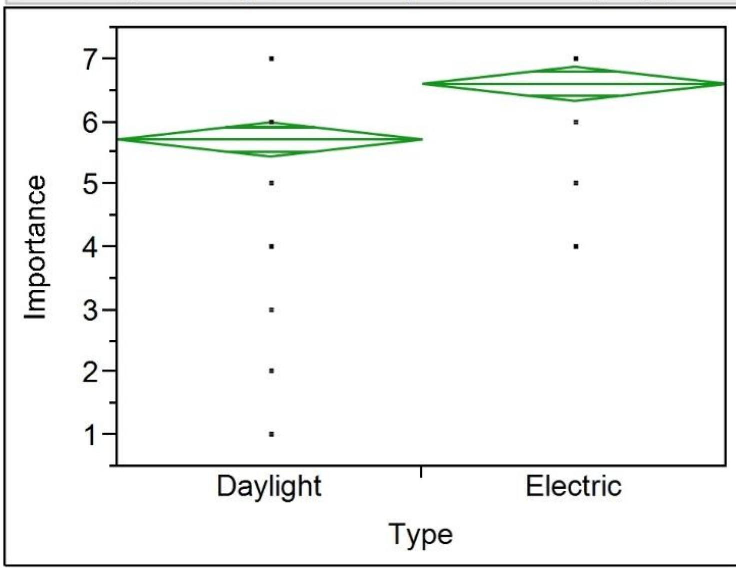


Figure 4.12 Number of NICUs access to daylighting through exterior and/or interior windows by room type

4.1.1.5 Importance of and Satisfactions with NICU Lighting Conditions

The respondents rated the importance of electric lighting and daylighting in NICUs with the mean values of 6.61 and 5.73 respectively on a seven-point scale (1 = not important at all; 7 = very important). As shown in Figure 4.13, the mean difference ($M_{diff.}$) between electric lighting and daylighting was 0.888. According to the two-sample *t*-test, there was a significant difference between these ratings ($p < 0.0001$): the respondents perceived more importance of electric lighting than daylighting in NICUs though both ratings were high.

Oneway Analysis of Importance By Type



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Daylight	80	5.72500	1.59885	0.17876	5.3692	6.0808
Electric	80	6.61250	0.70250	0.07854	6.4562	6.7688

t Test

Electric-Daylight

Assuming unequal variances

Difference	0.88750	t Ratio	4.545427
Std Err Dif	0.19525	DF	108.4067
Upper CL Dif	1.27451	Prob > |t|	<.0001*
Lower CL Dif	0.50049	Prob > t	<.0001*
Confidence	0.95	Prob < t	1.0000

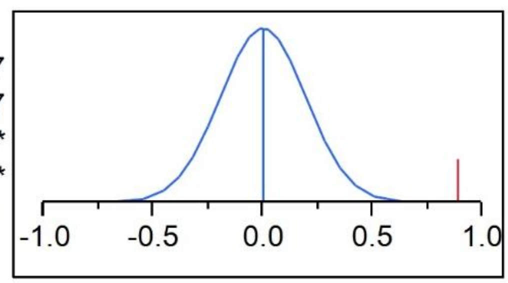


Figure 4.13 Comparison of importance between electric lighting and daylighting in NICUs

The researcher was interested in importance ratings relative to room types where respondents worked. Figures 4.14 and 4.15 show the distributions of ratings for importance of electric lighting and daylighting by the room type in which respondents worked. Tables 4.4 and 4.6 list the means and standard deviations (SD) of these data. The mean ratings for importance of electric lighting were from 6.167 to 6.857 across all room types, while the mean ratings for importance of daylighting by room type ranged from 4.400 to 6.667. The standard deviations of importance of daylighting were larger than those of electric lighting. Among the seven room types (see Tables 4.4 and 4.6), four of which had more than ten responses: (1) “> 3 beds,” (2) “SFR and 2-3 beds,” (3) “2-3 and > 3 beds," and (4) “SFR, 2-3, and > 3 beds,” and student’s *t*-tests were conducted for them to test whether there were significant differences between different rom types. For the importance of electric lighting, two out of six groups showed significant differences: (1) “SFR and 2-3 beds unit” and “SFR, 2-3 beds unit, and > 3 beds unit” ($M_{diff.} = 0.690$, $p = 0.0157$); (2) “2-3 beds unit and > 3 beds unit” and “SFR, 2-3 beds unit, and > 3 beds unit” ($M_{diff.} = 0.583$, $p = 0.0477$) (see Table 4.5). Only the group of “> 3 beds unit” and “SFR, 2-3 beds unit, and > 3 beds unit” showed significantly different regarding the ratings for importance of daylighting in NICUs by room type ($M_{diff.} = -1.220$, $p = 0.0312$) (see Table 4.7).

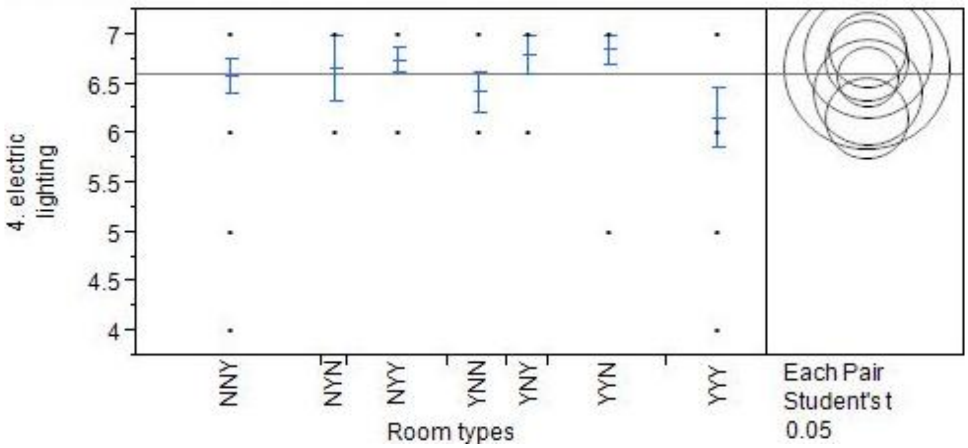


Figure 4.14 Distributions and pair comparisons of importance of electric lighting in NICUs by room type

Table 4.4 Means and standard deviations of electric lighting importance in NICUs by room type

Room type abbreviation	Room type	N	Mean of electric lighting importance	SD
YYN	SFR and 2-3 beds	14	6.857	0.535
YNY	SFR and > 3 beds	5	6.800	0.447
NYY	2-3 and > 3 beds	12	6.750	0.452
NYN	2-3 beds	3	6.667	0.577
NNY	> 3 beds	22	6.591	0.796
YNN	SFR	7	6.429	0.535
YYY	SFR, 2-3, and > 3 beds	12	6.167	1.030

Table 4.5 Comparisons of importance of electric lighting in NICUs among selected room types

Room type 1 (N)	Room type 2 (N)	Importance of electric lighting		
		Mean difference	SD	*p* value
> 3 beds (22)	SFR and 2-3 beds (14)	-0.266	0.242	0.2756
> 3 beds (22)	2-3 and > 3 beds (12)	-0.159	0.254	0.5336
> 3 beds (22)	SFR, 2-3, and > 3 beds (12)	0.424	0.254	0.0998
SFR and 2-3 beds (14)	2-3 and > 3 beds (12)	0.107	0.279	0.7019
SFR and 2-3 beds (14)	SFR, 2-3, and > 3 beds (12)	0.690	0.279	0.0157*
2-3 and > 3 beds (12)	SFR, 2-3, and > 3 beds (12)	0.583	0.289	0.0477*

Note: *$p < 0.05$.

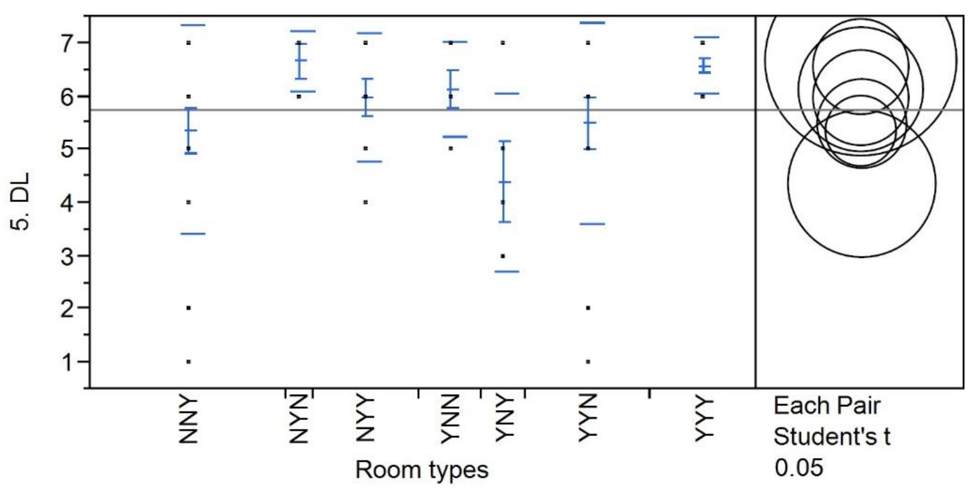


Figure 4.15 Distributions and pair comparisons of importance of daylighting in NICUs by room type

Table 4.6 Means and standard deviations of daylighting importance in NICUs by room type

Room type abbreviation	Room type	N	Mean of daylighting importance	SD
NYN	2-3 beds	3	6.667	0.577
YYY	SFR, 2-3, and > 3 beds	12	6.583	0.515
YNN	SFR	7	6.143	0.900
NYY	2-3 and > 3 beds	12	6.000	1.206
YYN	SFR and 2-3 beds	14	5.500	1.871
NNY	> 3 beds	22	5.364	1.965
YNY	SFR and > 3 beds	5	4.400	1.673

Table 4.7 Comparisons of importance of daylighting in NICUs among selected room types

Room type 1 (N)	Room type 2 (N)	Importance of daylighting		
		Mean difference	SD	*p* value
> 3 beds (22)	SFR and 2-3 beds (14)	-0.136	0.528	0.7970
> 3 beds (22)	2-3 and > 3 beds (12)	-0.636	0.554	0.2550
> 3 beds (22)	SFR, 2-3, and > 3 beds (12)	-1.220	0.554	0.0312*
SFR and 2-3 beds (14)	2-3 and > 3 beds (12)	-0.500	0.608	0.4135
SFR and 2-3 beds (14)	SFR, 2-3, and > 3 beds (12)	-1.083	0.608	0.0791
2-3 and > 3 beds (12)	SFR, 2-3, and > 3 beds (12)	-0.583	0.631	0.3582

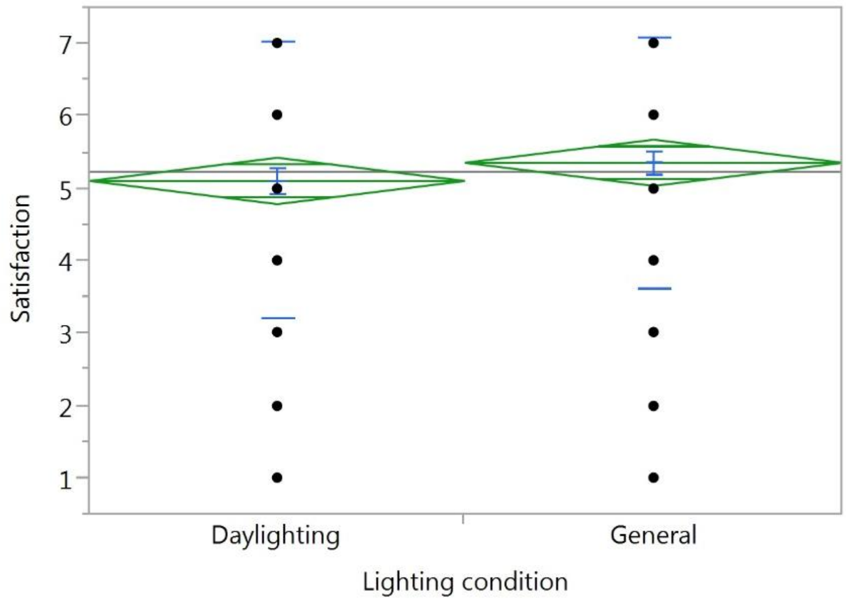
Note: *$p < 0.05$.

Regarding lighting satisfaction in NICUs, there was no significant difference between the general lighting environment and daylighting ($M_{diff.} = 0.251$, $p = 0.2756$). The mean rating of satisfaction with the general lighting environment was 5.362 out of 7, which was slightly higher than the mean of satisfaction with daylighting (5.111). Both of them were close to the category of 5 (somewhat satisfied) out of a seven-point scale (see Figure 4.16). When comparing satisfaction about the general lighting environment with satisfaction about daylighting within each room type, no significantly differences were found; though the satisfaction with general lighting environment remained higher than satisfaction with daylighting in all three room types (see Table 4.8).

Table 4.8 Means, standard deviations, and comparisons of satisfactions with the general lighting and daylighting environment in NICUs

Room type	Satisfaction with the general lighting			Satisfaction with the daylighting			Mean difference	*p* value
	N	Mean	SD	N	Mean	SD		
SFR	38	6.132	0.264	38	5.895	0.294	0.237	0.4121
2-3 beds	39	5.590	0.260	39	5.282	0.291	0.308	0.4519
> 3 beds	50	4.600	0.230	49	4.367	0.259	0.233	0.5562

Oneway Analysis of Satisfaction By Lighting condition



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Daylighting	126	5.11111	1.91090	0.17024	4.7742	5.4480
General	127	5.36220	1.73968	0.15437	5.0567	5.6677

t Test

General-Daylighting

Assuming unequal variances

Difference	0.25109	t Ratio	1.092628
Std Err Dif	0.22981	DF	248.4405
Upper CL Dif	0.70371	Prob > |t|	0.2756
Lower CL Dif	-0.20152	Prob > t	0.1378
Confidence	0.95	Prob < t	0.8622

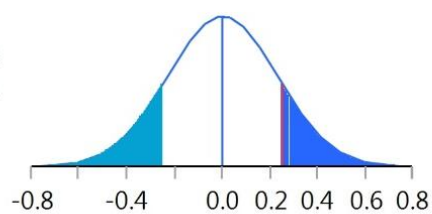


Figure 4.16 Comparison of satisfaction with the general lighting and daylighting environment in NICUs

Figures 4.17 and 4.18 illustrate the distributions of satisfactions with the general lighting environment and the daylighting in NICUs by room type. In both circumstances, satisfactions were increased while the numbers of beds per room decreased: SFRs received the highest satisfaction, followed by the 2-3 beds units and the > 3 beds units. There were significant differences in satisfaction with the general lighting environment among room types ($p < 0.0001$), as well as in the satisfaction with daylighting among room types ($p = 0.0006$). Specifically, for the general lighting, the satisfaction in the > 3 beds units were significantly different compared to the other two room types; regarding the daylighting, the satisfaction in the SFRs and > 3 beds units was significantly different (see Table 4.9).

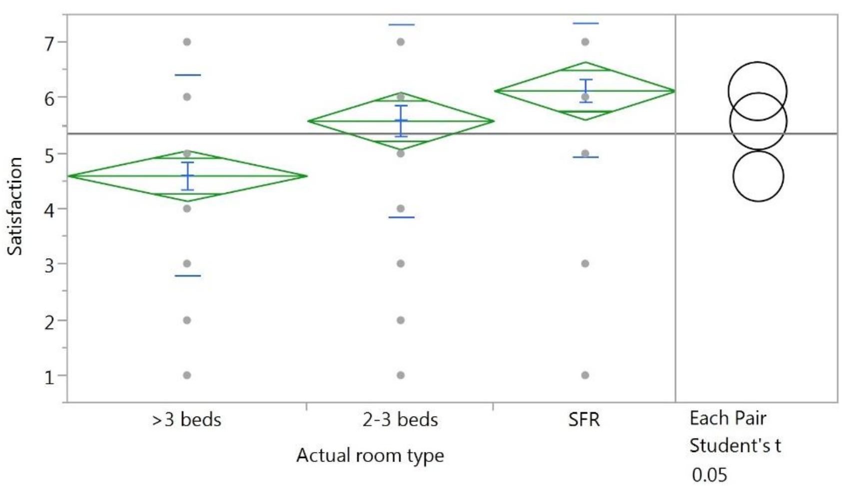


Figure 4.17 Distributions and pair comparisons of satisfactions with the general lighting in NICUs by room type

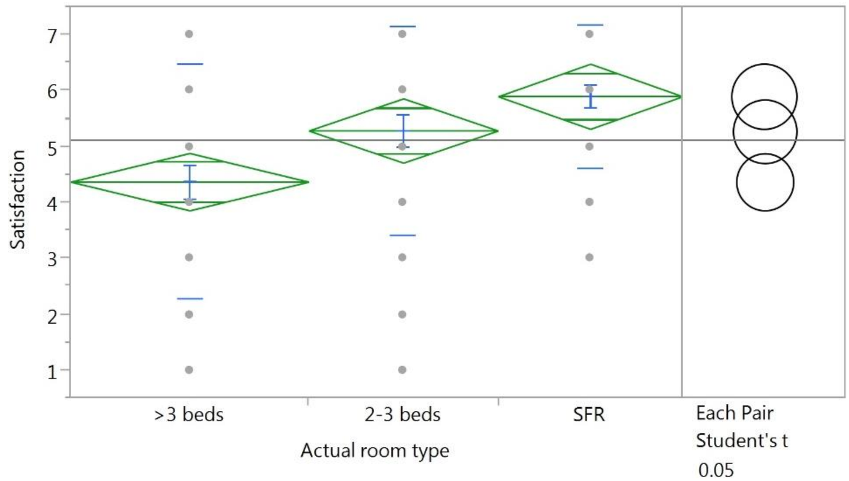


Figure 4.18 Distributions and pair comparisons of satisfactions with the daylighting in NICUs by room type

Table 4.9 Comparisons of satisfaction with the general lighting and daylighting in NICUs among different room types

Room type 1 (N)	Room type 2 (N)	Satisfaction with the general lighting			Satisfaction with the daylighting		
		Mean difference	SD	*p* value	Mean difference	SD	*p* value
SFR (38)	2-3 beds (39)	0.542	0.371	0.1463	0.613	0.414	0.1410
SFR (38)	> 3 beds (50)	1.532	0.350	< 0.0001 ***	1.527	0.392	0.0002 ***
2-3 beds (39)	> 3 beds (50)	0.990	0.347	0.0051 **	0.613	0.414	0.0204

Note: *p < 0.05; **p < 0.01; ***p < 0.001.

4.1.1.6 Impacts of daylight on staff and family behaviors in NICUs

To further study the influence of daylighting in NICUs, respondents were also asked to indicate how much they agree or disagree with seven statements regarding the impact of the presence of sufficient daylight on staff and family behaviors on a seven-point scale (1 = strongly disagree and 7 = strongly agree). Figure 4.19 and Table 4.10 included the specific statements, means, standard deviations, mean and distributions of the ratings. The ratings of these seven statements were significantly different ($p < 0.0001$) based on the one-way ANOVA model. The two statements, “3. Increasing mental alertness” and “1. Improving work efficiency,” received the highest ratings with means being 5.231 and 5.203 respectively (5 = Somewhat agree). The other five statements including “2. Decreasing medical errors,” “4. Increasing lengths of family visits,” “5. Decreasing times that families leave their baby's room,” “6. Increasing interactions between families and infants,” and “7. Increasing interactions between staff and infants” were perceived similar between each other, with the ratings ranging from 4.273 to 4.551 (4 = Neutral). The Tukey’s honest significance test (Tukey-Kramer method) was used to compare the ratings of any two out of the seven statements. Among the 21 pairs, the two statements with highest ratings were significantly different from the other five statements (see Table 4.11).

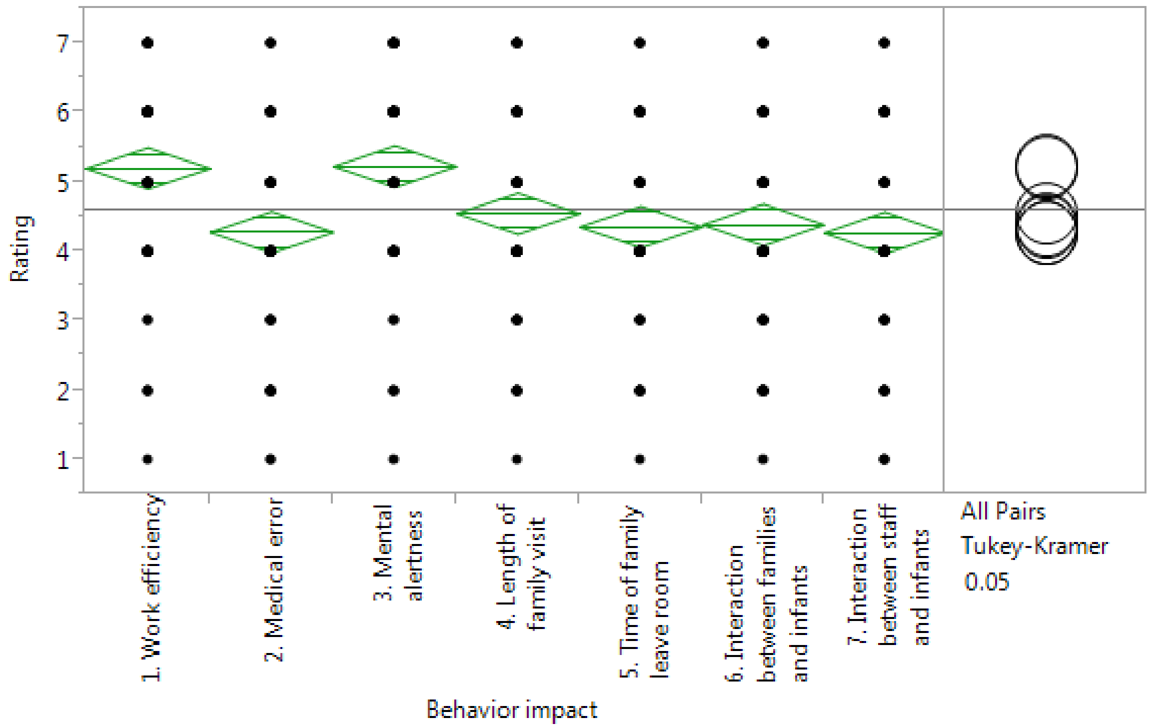


Figure 4.19 Distributions and pair comparisons of the impact of daylighting on staff and family behaviors in NICUs

Table 4.10 Means and standard deviations of the impacts of daylighting on staff and family behaviors in NICUs

Statement of behavior impact	N	Mean	SD
1. Improving work efficiency	79	5.203	0.151
2. Decreasing medical errors	78	4.282	0.152
3. Increasing mental alertness	78	5.231	0.152
4. Increasing length of family visits	78	4.551	0.152
5. Decreasing times that families leave their baby's room	78	4.359	0.152
6. Increasing interactions between families and infants	77	4.390	0.153
7. Increasing interactions between staff and infants	77	4.273	0.153

Table 4.11 Specific comparisons of the impacts of daylighting on staff and family behaviors in NICUs (N = 79[a])

Statement 1	Statement 2	Mean difference	SD	*p* value
1	2	0.920	0.214	0.0004***
1	3	-0.028	0.214	1.000
1	4	0.651	0.214	0.0389*
1	5	0.844	0.214	0.0017**
1	6	0.813	0.215	0.0032**
1	7	0.930	0.215	0.0003***
2	3	-0.949	0.214	0.0002***
2	4	-0.269	0.214	0.872
2	5	-0.077	0.214	1.000
2	6	-0.108	0.215	0.999
2	7	0.009	0.215	1.000
3	4	0.679	0.214	0.0269*
3	5	0.872	0.214	0.0011**
3	6	0.841	0.215	0.0020**
3	7	0.958	0.215	0.0002***
4	5	0.192	0.214	0.973
4	6	0.162	0.215	0.989
4	7	0.279	0.215	0.854
5	6	-0.031	0.215	1.000
5	7	0.086	0.215	1.000
6	7	0.117	0.216	0.998

Note: a: Check Table 4.10 for specific N of each statement.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

4.1.1.7 Summary

Based on different types and sample sizes of variables, either descriptive or inferential statistical methods were used. Observation and descriptive analysis suggested that: (1) NICU room types are in the transition from MB rooms to SFRs; (2) more SFRs have access to daylighting than 2-3 beds units and > 3 beds units; and (3) exterior windows are the most commonly used daylighting type in all three room types.

Table 4.12 summarizes the inferential statistical methods and results for the Survey I hypotheses. Out of seven hypotheses, three were supported, two were partly supported, and two were not supported. The key findings included: (1) medical directors perceive higher importance of electric lighting than daylighting no matter which room type they work in; (2) their satisfaction levels of both general lighting environment and daylighting increase as the numbers of beds per room decrease; (3) they perceive different levels of impact of sufficient daylighting on staff and family behaviors in NICUs, they more agree that daylighting can improve work efficiency and increase mental alertness.

Table 4.12 Statistical methods and results for *NICU Room Type & Lighting Condition Questionnaire* hypotheses

Hypothesis	Statistical method	Result
Evaluation of lighting importance and satisfaction		
I1. People perceive the importance of electric lighting and daylighting in a NICU to be the same.	Two-sample *t*-test	Not supported. People perceived higher importance of electric lighting than daylighting ($p < 0.001$).

Table 4.12 Continued

I2. People who work in different room types perceive different levels of importance for electric lighting in the NICU.	Two-sample t-test (selected data)	Partly supported. Two out of six groups were significantly different (SFR and 2-3 beds and SFR, 2-3, and > 3 beds: p = 0.0157; 2-3 and > 3 beds and SFR, 2-3, > 3 beds: p = 0.0477).
I3. People who work in different room types perceive different levels of importance for daylighting in the NICU.	Two-sample *t*-test (selected data)	Partly supported. One of six groups was significantly different (> 3 beds and SFR, 2-3, > 3 beds: $p = 0.0312$).
I4. People experience the same level of satisfaction with the NICU general lighting environment and daylighting.	Two-sample *t*-test	Supported. No significant difference ($p = 0.2756$).
I5. People who work in different room types experience different levels of satisfaction with the NICU lighting environment.	ANOVA and two-sample *t*-test	Supported. Satisfaction levels increased as the numbers of beds per room decreased (ANOVA: $p < 0.0001$; $M_{SFR} = 6.132$, $M_{2\text{-}3\ beds} = 5.590$, $M_{>3\ beds} = 4.600$).
I6. People who work in different room types experience different levels of satisfaction with the NICU daylighting environment.	ANOVA and two-sample *t*-test	Supported. Satisfaction levels increased as the numbers of beds per room decreased (ANOVA: $p = 0.0006$; $M_{SFR} = 5.895$, $M_{2\text{-}3\ beds} = 5.282$, $M_{>3\ beds} = 4.367$).
Evaluation of daylighting impact		
I7. People have the same opinions on the impacts of sufficient daylighting on staff and family behavior in NICU.	ANOVA and Tukey's test	Not supported. People perceived different on the impacts of sufficient daylighting on staff and family behavior (ANOVA: $p < 0.0001$). They more strongly agreed on the impacts of daylighting on improving work efficiency (M = 5.203) and increasing mental alertness (M = 5.231) than the other impacts.

4.1.2 Survey II: NICU Nurse Satisfaction with Lighting Environment Questionnaire

The Survey II was distributed to 192 nurse attendees from different hospitals who attended an annual national conference of neonatal nurses. Seventy-eight out of 192 questionnaires were collected with a response rate of 40.6%. The following sections depict the demographic information of the respondents first, and then provide an overview of the current lighting environments in NICUs. In the subsequent sections I analyze respondent perceptions of the importance of the lighting environment and the impact on behaviors, and focus on comparisons of evaluations between SFRs and MB rooms and between rooms with or without a window access to the outdoors. The statistical software used was JMP 10.0.0 developed by SAS Institute (Cary, NC) and the significant level used in the analysis was 0.05.

4.1.2.1 Demographic Profile

Among the 78 respondents, one did not answer the question about gender. Among those with responses to this question, only two of them were male. Regarding the age group, the most frequent one was 55-59 years followed by 30-34 and 45-49, and the median age group was 45-49 (see Figure 4.20). Twenty-four respondents (31.2%) worked in NICUs for 20-29 years, followed by 17 (22.1%) who worked in NICUs for 2-9 years (see Figure 4.21). The respondents were asked to choose all the job titles that apply to them. Forty-seven (61.8%) were registered nurses or staff nurses; 14 (18.4%) chose other types, which included 5 family support specialists; 9 (11.8%) educators, 5 (6.6%) managers or administrators, 5 (6.6%) nurse practitioners or physician assistants, and 3 (3.9%) clinical nurse specialists (see Figure 4.22).

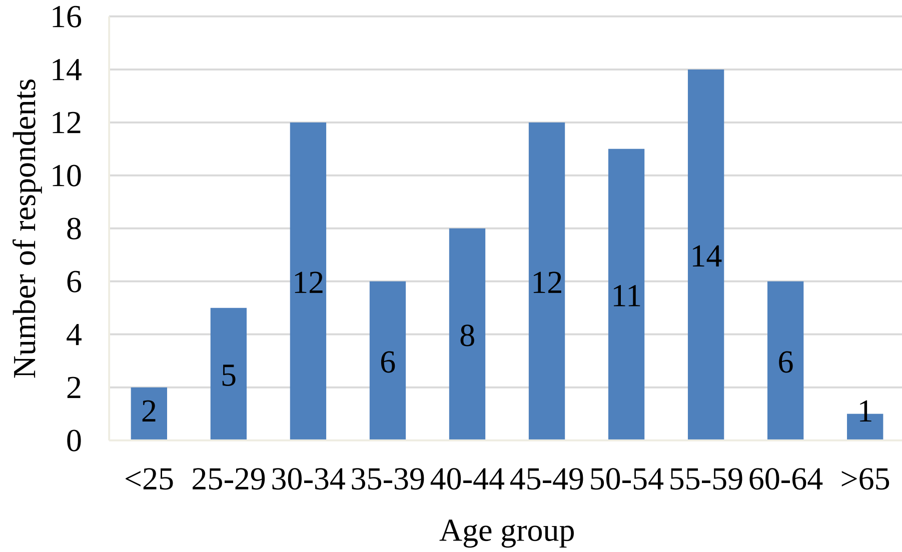


Figure 4.20 Age group distribution of respondents

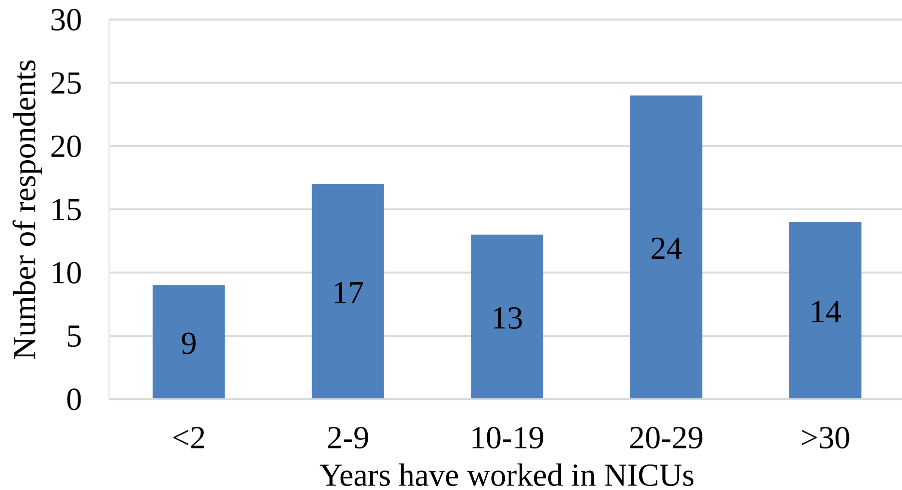


Figure 4.21 Work experience distribution of respondents

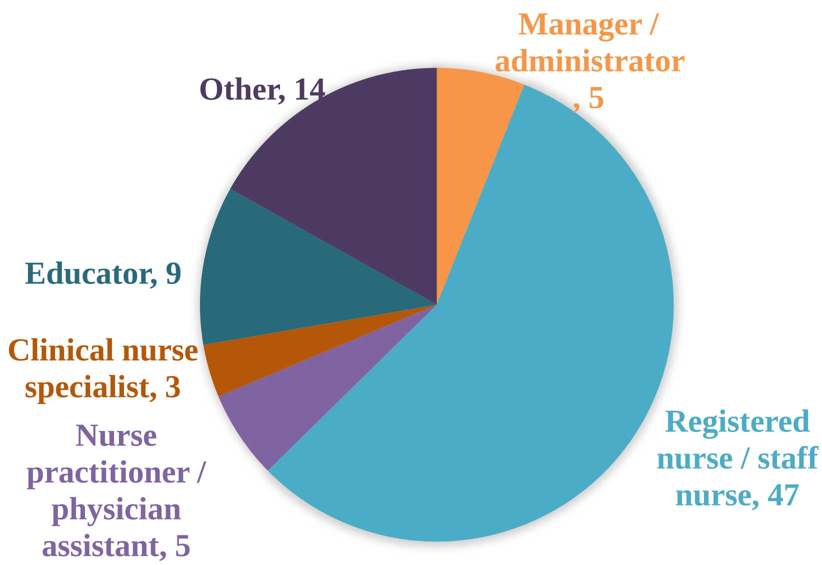
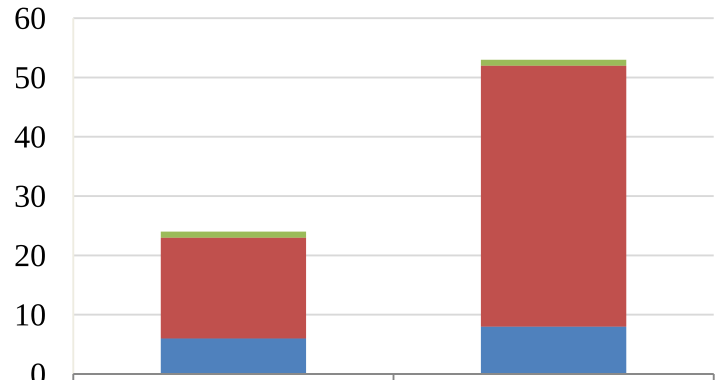


Figure 4.22 Job distribution of respondents

4.1.2.2 Overview of Current Lighting Environment in NICUs

Among the responses, 24 caregivers (30.8%) were working in SFRs; four (5.1%) were working in 2-3 beds units; 48 (61.5%) were working in NICUs with > 3 beds per room; and two reported they were working in two types of patient rooms (one was working in SFR and 2-3 beds, and the other in 2-3 and > 3 beds units). Due to the limited number of NICUs with 2-3 beds units, the type of 2-3 beds was combined with > 3 beds units into the category of MB room for further analyses regarding room types. The response from the person who worked at both 2-3 beds and > 3 beds was calculated in the new category; and the response from the person who worked at both SFR and 2-3 beds was excluded from the data set.

73.9% of the SFR nurses worked in rooms with at least one window that had access to outdoors. 84.6% of the nurses who worked in MB rooms reported that the room they worked in had at least one window providing visual access to the outdoors (See Figure 4.23).



	SFR	MB
No answer	1	1
With window	17	44
Without window	6	8

Figure 4.23 Distribution of NICUs by room type and with or without a window to the outdoor

The distributions, means, and standard deviations of evaluations of five lighting quality factors and the overall visual environment satisfaction are listed in Figure 4.24 and Table 4.13. All the average values of evaluations were between 4.1 and 4.7 except that window views of nature was rated as 3.729 on average. There were significant differences among these factors based on ANOVA (p = 0.0142). When comparing any two out of the five lighting quality factors, two out of the ten pairs were significantly different: (1) “view of nature” and “impact of view on work” ($M_{diff.}$ = 0.919, p = 0.0093), and (2) “view of nature” and “ambience of room” ($M_{diff.}$ = 0.765, p = 0.0462) (see Table 4.14). According to the correlation test, overall satisfaction of lighting environment was highly correlated with four out of five factors (lighting distribution, window view of nature, impact of the view outside on work, and the overall ambience). The exception was the lighting level (see Table 4.15). This is an expected outcome as lighting level has two extremes, too dark or too bright, which means the middle value would be the best situation for the respondents. The other factors are monotonic in that the higher value represents the better light quality. The overall ambience was highly correlated with lighting distribution, window view of nature, and impact of the view outside. The lighting distribution was also highly correlated with the impact of the view outside. The window view of nature and impact of the view outside were correlated with each other as well.

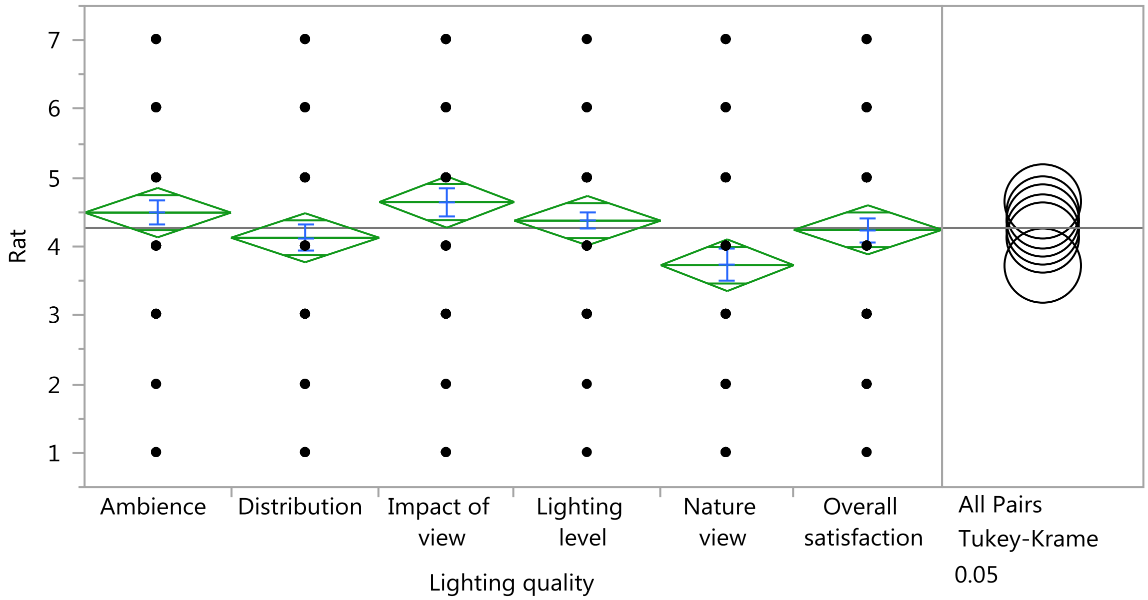


Figure 4.24 Distributions and pair comparisons of lighting quality evaluations

Table 4.13 Means and standard deviations of lighting quality evaluations

Lighting quality	Seven-point scale	N	Mean	SD
Ambience of room	1 = gloomy, 7 = cheerful	77	4.494	0.183
Lighting distribution	1 = poorly distributed, 7 = well distributed	78	4.128	0.181
Impact of view on work	1= negative, 7 = positive	71	4.648	0.190
Lighting level	1 = too dark, 7 = too bright	77	4.377	0.183
View of nature	1 = no view, 7 = good view	70	3.729	0.192
Overall satisfaction	1 = very dissatisfied, 7 = very satisfied	78	4.244	0.181

Table 4.14 Specific comparisons of lighting quality factor evaluations (N = 78[a])

Quality factor 1	Quality factor 2	Mean difference	SD	*p* value
Ambience of room	Lighting distribution	0.365	0.257	0.7154
Ambience of room	Impact of view	-0.154	0.264	0.9920
Ambience of room	Lighting level	0.117	0.258	0.9976
Ambience of room	View of nature	0.765	0.265	0.0462*
Lighting distribution	Impact of view	-0.520	0.263	0.3570
Lighting distribution	Lighting level	-0.248	0.257	0.9287
Lighting distribution	View of nature	0.400	0.264	0.6548
Impact of view on work	Lighting level	0.271	0.264	0.9081
Impact of view on work	View of nature	0.919	0.270	0.0093**
Lighting level	View of nature	0.648	0.265	0.1419

Note: a: Check Table 4.13 for specific N of quality factor.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 4.15 Correlation analysis of lighting quality factors

	Lighting distribution	Impact of view on work	Lighting level	View of nature	Overall satisfaction
Ambience of room	0.4791***	0.5182***	0.0692	0.4595***	0.8214***
Lighting distribution		0.2725*	0.1488	0.1972	0.5436***
Impact of view on work			0.0891	0.6901***	0.5276***
Lighting level				0.0345	-0.0352
View of nature					0.5976***

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Regarding the presence of glare, 42 (53.8%) of the respondents perceived glare in the patient rooms with the mean value of 4.6 on a seven-point scale (1 = intolerable; 7

= not perceptible). The most frequently mentioned sources were the ceiling light (23.1%), reflection on the computer screen (19.2%), and window (17.9%).

When evaluating the impact of the existing lighting conditions on fulfilling work tasks in NICUs, the average ratings of satisfaction under all conditions were between 5.0 and 5.4 on a seven-point scale (1 = very dissatisfied; 7 = very satisfied). The lighting conditions during professional communication and medication were the first and second most satisfactory (Means = 5.385 and 5.381 respectively), while the direct care and indirect care were rated as the least satisfactory (Means = 5.047 and 5.103 respectively) (see Figure 4.25 and Table 4.16). There were no significant differences among the ratings based on ANOVA ($p = 0.7755$).

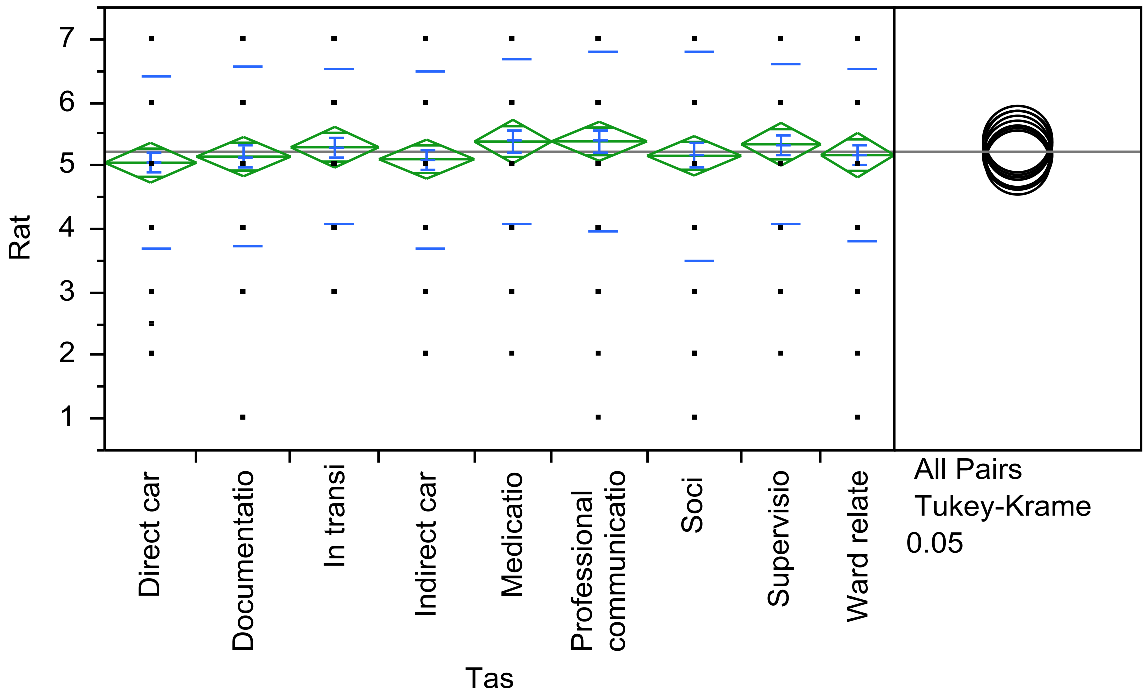


Figure 4.25 Distributions and pair comparisons of satisfaction of lighting condition when conducting different work tasks in NICUs

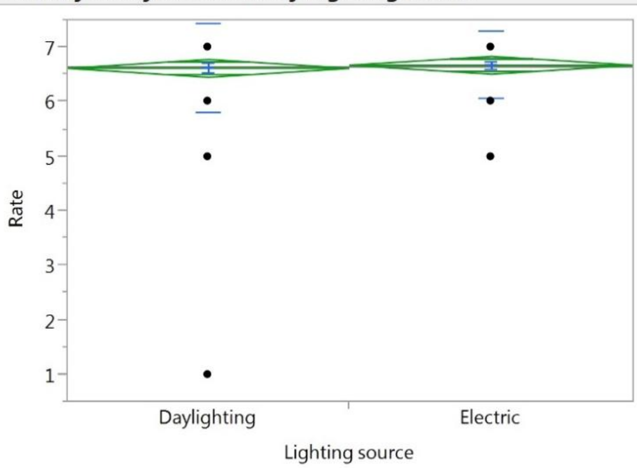
Table 4.16 Means and standard deviations of satisfaction of lighting condition when conducting different work tasks in NICUs

Work task	N	Mean	SD
Direct care	75	5.047	0.160
Indirect care	78	5.103	0.157
Medication task	63	5.381	0.175
Documentation	77	5.143	0.158
Professional communication	78	5.385	0.157
Social	77	5.156	0.158
Ward related activities	60	5.167	0.179
Supervision	65	5.338	0.172
In transit	72	5.292	0.164

4.1.2.3 Importance of NICU Lighting Conditions

Respondents gave high ratings for the importance of both good electric lighting and daylighting in NICUs. Although the importance of electric lighting was slightly higher than that of daylighting (Means = 6.675 and 6.618 out of 7 respectively), there was no significant difference in preference for the electric lighting versus daylighting ($M_{diff.}$ = 0.0569, p = 0.6276) (see Figure 4.26).

Oneway Analysis of Rate By Lighting source



Missing Rows 3

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Daylighting	76	6.61842	0.815959	0.09360	6.4320	6.8049
Electric	77	6.67532	0.616475	0.07025	6.5354	6.8152

t Test

Electric-Daylighting

Assuming unequal variances

Difference	0.05690	t Ratio	0.486232
Std Err Dif	0.11703	DF	139.5906
Upper CL Dif	0.28828	Prob > |t|	0.6276
Lower CL Dif	-0.17448	Prob > t	0.3138
Confidence	0.95	Prob < t	0.6862

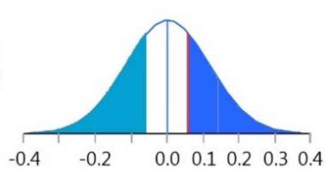


Figure 4.26 Comparison of importance between electric lighting and daylighting in NICUs

Regarding the importance of lighting factors related to daylight and window, respondents expressed less interest in having a nature view in comparison to other factors (appropriate ambience, appropriate lighting distribution, and appropriate lighting level) (see Figure 4.27 and Table 4.17). There was a significant difference among the four factors based on ANOVA ($p < 0.0001$). According to Tukey's test, the pairs of view of nature and each of the other three factors all demonstrated significant differences (see Table 4.18).

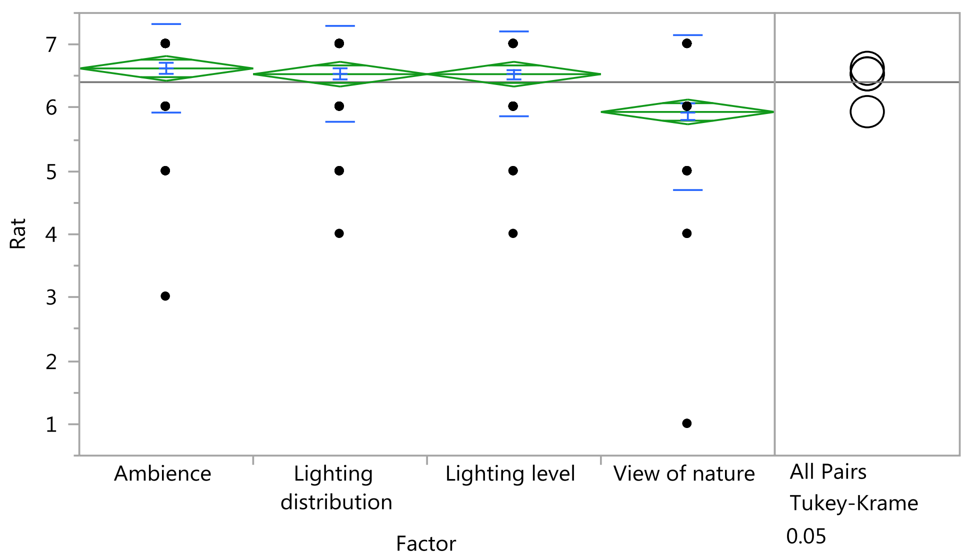


Figure 4.27 Distributions and pair comparisons of importance of daylight and window related factors in NICUs

Table 4.17 Means and standard deviations of importance of daylight and window related factors in NICUs

Daylight and window related factor	N	Mean	SD
Appropriate ambience of room	77	6.623	0.099
Appropriate lighting distribution	77	6.532	0.099
Appropriate lighting level	77	6.532	0.099
Providing view of nature	77	5.935	0.099

Table 4.18 Specific comparisons of importance of daylight and window related factors in NICUs (N=77)

Factor 1	Factor 2	Mean difference	SD	*p* value
Appropriate ambience of room	Lighting distribution	0.091	0.141	0.9166
Appropriate ambience of room	Lighting level	0.091	0.141	0.9166
Appropriate ambience of room	View of nature	0.688	0.141	< .0001***
Appropriate lighting distribution	Lighting level	0.000	0.141	1
Appropriate lighting distribution	View of nature	0.597	0.141	0.0002***
Appropriate lighting level	View of nature	0.597	0.141	0.0002***

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

4.1.2.4 Impacts of daylight on staff and family behaviors in NICUs

Similar to the Survey I, seven statements regarding the impact of the presence of sufficient daylighting on staff and family behaviors were provided. All of them were on a seven-point scale (1 = strongly disagree and 7 = strongly agree). Figure 4.28 and Table 4.19 included the specific statements, means, standard deviations, and distributions of the ratings. The statement “3. Increasing mental alertness” was rated as the highest among the seven statements, with the mean of 6.286, followed by the statement “1. Improving work efficiency” with the average value being close to 6. The statement “5. Decreasing times families leave their baby's room” was the only one with the mean lower than 5. These ratings of statements were significantly different based on ANOVA ($p < 0.0001$). For further Tukey’s test, ten (statements 1 and 3 with other five statements) out of 21 groups comparing the ratings for any two statements were significantly different (see Table 4.20).

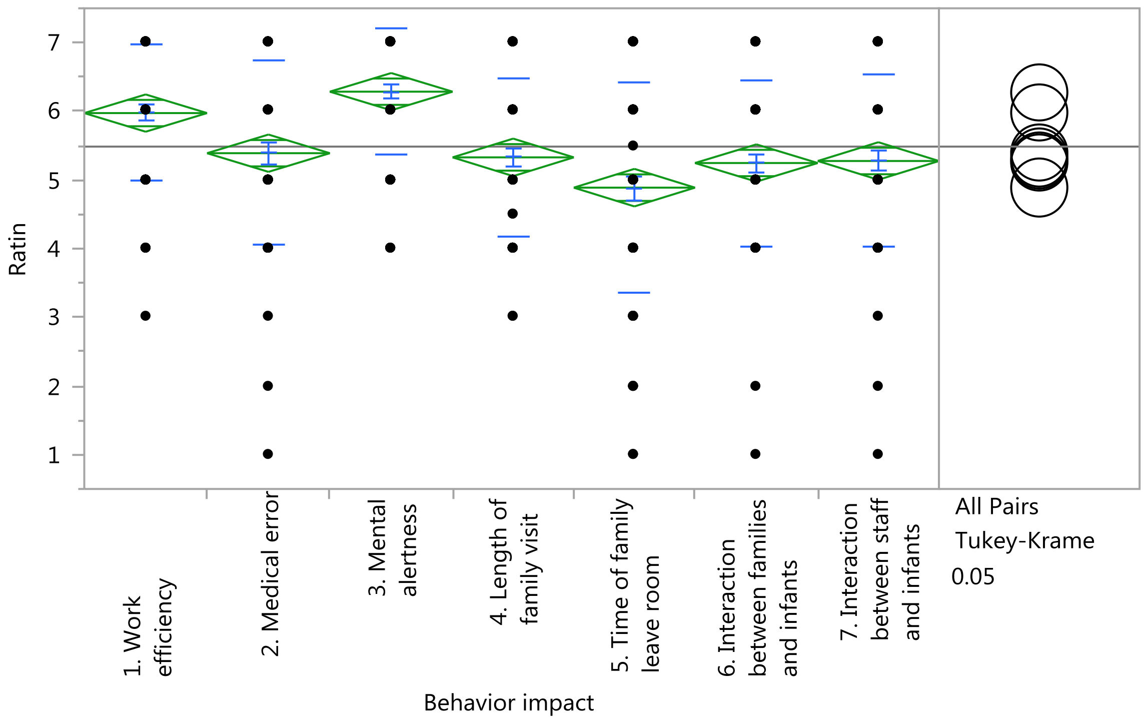


Figure 4.28 Distributions and pair comparisons of the impact of daylighting on staff and family behaviors in NICUs

Table 4.19 Means and standard deviations of the impacts of daylighting on staff and family behaviors in NICUs

Statement of behavior impact	N	Mean	SD
1. Improving work efficiency	77	5.974	0.138
2. Decreasing medical errors	77	5.390	0.138
3. Increasing mental alertness	77	6.286	0.138
4. Increasing length of family visits	76	5.329	0.139
5. Decreasing times families leave their baby's room	76	4.888	0.139
6. Increasing interactions between families and infants	77	5.247	0.138
7. Increasing interactions between staff and infants	76	5.276	0.139

Table 4.20 Specific comparisons of the impacts of daylighting on staff and family behaviors in NICU (N = 77[a])

Statement 1	Statement 2	Mean difference	SD	*p* value
1	2	0.584	0.195	0.0459*
1	3	-0.312	0.195	0.686
1	4	0.645	0.196	0.0184*
1	5	1.086	0.196	< .0001***
1	6	0.727	0.195	0.0041**
1	7	0.698	0.196	0.0074**
2	3	-0.896	0.195	0.0001***
2	4	0.061	0.196	1.000
2	5	0.501	0.196	0.142
2	6	0.143	0.195	0.991
2	7	0.113	0.196	0.997
3	4	0.957	0.196	< .0001***
3	5	1.398	0.196	< .0001***
3	6	1.039	0.195	< .0001***
3	7	1.009	0.196	< .0001***
4	5	0.441	0.197	0.276
4	6	0.082	0.196	1.000
4	7	0.053	0.197	1.000
5	6	-0.359	0.196	0.529
5	7	-0.388	0.197	0.433
6	7	-0.030	0.196	1.000

Note: a: Check Table 4.19 for specific N of each statement.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

4.1.2.5 Comparisons of Lighting Conditions between SFR and MB room

This section focuses on comparing whether or not there is any difference in the lighting environment between SFRs and MB rooms. The Student *t*-test was used for each comparison. For the lighting quality factors, all the evaluations for SFRs were higher than the corresponding measurements for MB rooms except the item regarding lighting levels. Since the lighting level had two extremes, the ratings for lighting levels in SFRs were slightly lower than those in MB rooms (Means = 4.292 and 4.404 respectively), but were closer to the scale of 4, which represent a balanced visual comfortable situation. The ambience of room, overall satisfaction, and lighting distribution were significantly different when comparing SFRs and MB rooms (see Table 4.21).

Table 4.21 Comparison of lighting quality factors by NICU room type

Lighting quality	SFR			MB			Mean differ-ence	SD	*p* value
	N	Mean	SD	N	Mean	SD			
Ambience of room	24	5.333	1.240	52	4.096	1.550	1.237	0.332	0.0005 ***
Lighting distribution	24	4.792	1.414	53	3.811	1.710	0.980	0.372	0.0110 *
Impact of view on work	22	4.910	2.045	48	4.542	1.650	0.367	0.497	0.4646
Lighting level	24	4.292	0.859	52	4.404	1.159	-0.112	0.238	0.6389
View of nature	22	4.136	1.910	47	3.553	1.954	0.583	0.497	0.2473
Overall satisfaction	24	5.042	1.488	53	3.868	1.442	1.174	0.363	0.0023 **

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Except when working on documentation, the satisfaction levels of SFR nurses were significantly higher than those who worked in MB rooms when fulfilling different work tasks. Table 4.22 lists the specific comparisons of lighting satisfactions by work type.

Table 4.22 Comparison of satisfaction of lighting condition when conducting different work tasks by NICU room type

Work task	SFR			MB			Mean difference	SD	*p* value
	N	Mean	SD	N	Mean	SD			
Direct care	23	5.652	1.335	51	4.775	1.286	0.878	0.332	0.0115 *
Indirect care	24	5.792	1.382	53	4.774	1.310	1.018	0.335	0.0040 **
Medication task	17	6.235	0.970	45	5.067	1.286	1.169	0.304	0.0004 ***
Documentation	24	5.583	1.586	52	4.923	1.311	0.660	0.371	0.0833
Professional communication	24	6.167	1.007	53	5.019	1.448	1.478	0.286	0.0002 ***
Social	24	5.917	1.283	52	4.789	1.719	1.128	0.354	0.0023 **
Ward related activities	17	5.824	1.334	42	4.881	1.292	0.943	0.380	0.0192 *
Supervision	21	5.810	1.250	43	5.093	1.231	0.717	0.331	0.0366 *
In transit	24	5.917	1.060	47	4.957	1.197	0.959	0.278	0.0011 **

Note: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

Both electric lighting and daylighting were perceived as important with average values of more than 6.5 out 7 for nurses no matter which room type they worked in. No significant difference was found on either electric lighting or daylighting by NICU room type. The nurses that worked in the SFRs perceived higher importance for all the lighting factors, including the appropriate lighting level, appropriate lighting distribution, providing view of nature, and appropriate ambience, than those who worked in MB rooms. Only the perceived importance of ambience was significantly different ($M_{diff.}$ = 0.314, p = 0.0236) (see Table 4.23).

Table 4.23 Comparison of importance of lighting by NICU room type

Importance	SFR			MB			Mean differ-ence	SD	*p* value
	N	Mean	SD	N	Mean	SD			
Lighting source									
Electric lighting	24	6.625	0.711	52	6.692	0.579	-0.067	0.166	0.6871
Daylighting	24	6.542	1.285	52	6.667	0.476	-0.125	0.271	0.6479
Daylight and window related factor									
Appropriate ambience of room	24	6.833	0.381	52	6.519	0.804	0.314	0.136	0.0236 *
Appropriate lighting distribution	24	6.625	0.647	52	6.519	0.779	0.106	0.171	0.5380
Appropriate lighting level	24	6.625	0.576	52	6.520	0.700	0.106	0.152	0.4907
Providing view of nature	24	5.958	1.367	52	5.942	1.178	0.016	0.323	0.9607

Note: *p < 0.05; **p < 0.01; ***p < 0.001.

The respondents in SFRs expressed stronger agreement on positive behavior changes of staff and families with sufficient daylight than those who worked in MB rooms, especially on decreasing the frequency of family members leaving patient rooms during their visits ($M_{diff.}$ = 0.853, p = 0.0342) (see Table 4.24).

Table 4.24 Comparison of the impacts of daylighting on staff and family behaviors by NICU room type

Impact of behavior	SFR			MB			Mean differ -ence	SD	*p* value
	N	Mean	SD	N	Mean	SD			
1. Improving work efficiency	24	6.125	1.076	52	5.923	0.947	0.202	0.256	0.4346
2. Decreasing medical errors	24	5.750	1.775	52	5.250	1.064	0.500	0.391	0.2108
3. Increasing mental alertness	24	6.417	0.929	52	6.250	0.905	0.167	0.227	0.4673
4. Increasing length of family visits	23	5.696	1.222	52	5.173	1.093	0.523	0.297	0.0860
5. Decreasing times families leave their baby's room	23	5.478	1.592	52	4.625	1.462	0.853	0.389	0.0342 *
6. Increasing interactions between families and infants	24	5.375	1.527	52	5.212	1.035	0.163	0.343	0.6370
7. Increasing interactions between staff and infants	24	5.333	1.523	51	5.255	1.146	0.078	0.350	0.8239

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

4.1.2.6 Comparisons of Lighting Conditions between Rooms with and without a Window Open to the Outdoors

This section discusses whether or not there is any difference regarding the lighting environment in NICU rooms with or without a window that is open to the outdoors. Student *t*-tests were used for each comparison. For the lighting quality factors, all the evaluations of rooms with a window to the outdoors were higher than those without such windows. Although there were no significant differences between the two groups on the factors of ambience of room, lighting distribution, and lighting levels, they were significantly different regarding overall satisfaction ($M_{diff.} = 1.302$, $p = 0.0149$) (see Table 4.25).

Table 4.25 Comparison of lighting quality factors by NICU room with or without a window to the outdoors

Lighting quality	With window			Without window			Mean difference	SD	*p* value
	N	Mean	SD	N	Mean	SD			
Ambience of room	61	4.656	1.436	14	3.857	1.995	0.799	0.564	0.1756
Lighting distribution	62	4.194	1.648	14	4.071	1.817	0.122	0.529	0.8200
Lighting level	61	4.410	0.990	14	4.286	1.437	0.124	0.405	0.7629
Overall satisfaction	62	4.516	1.423	14	3.214	1.672	1.302	0.482	0.0149 *

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Except the social interaction, the satisfaction levels of nurses who worked in rooms with a window were higher than those who worked in rooms without a window when fulfilling different work tasks. No significant differences were found between the two groups among all the work tasks (see Table 4.26).

Table 4.26 Comparison of satisfaction of lighting condition when conducting different work tasks by NICU room with or without a window to the outdoors

Work task	With window			Without window			Mean difference	SD	*p* value
	N	Mean	SD	N	Mean	SD			
Direct care	59	5.254	1.168	14	4.464	1.692	0.790	0.477	0.1172
Indirect care	62	5.145	1.401	14	5.000	1.519	0.145	0.443	0.7470
Medication task	50	5.580	1.126	11	4.818	1.722	0.762	0.543	0.1860
Documentation	61	5.262	1.315	14	4.643	1.823	0.619	0.516	0.2468
Professional communication	62	5.468	1.340	14	5.143	1.791	0.325	0.508	0.5313
Social	61	5.180	1.727	14	5.286	1.383	-0.105	0.431	0.8088
Ward related activities	50	5.220	1.234	9	5.000	2.000	0.220	0.689	0.7567
Supervision	52	5.481	1.196	11	4.909	1.514	0.572	0.486	0.2605
In transit	56	5.429	1.204	14	4.857	1.292	0.571	0.381	0.1501

Note: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

The nurses who worked in rooms without a window perceived both the electric lighting and daylighting to be of slightly higher importance than those who worked in rooms with a window, though all the mean ratings for importance were high (> 6.6).

Except the factor of appropriate ambience of room, nurses who worked in rooms with a window perceived higher importance of appropriate lighting level, appropriate lighting distribution, and providing view of nature, than those who worked in rooms without a window. No significant difference regarding importance was found in any comparison between the respondents who worked in rooms with a window and without a window (see Table 4.27).

Table 4.27 Comparison of importance of lighting by NICU room with or without a window to the outdoors

Importance	With window			Without window			Mean differ-ence	SD	*p* value
	N	Mean	SD	N	Mean	SD			
Lighting source									
Electric lighting	61	6.672	0.625	14	6.714	0.611	-0.042	0.182	0.8191
Daylighting	60	6.617	0.865	14	6.643	0.633	-0.026	0.203	0.8983
Daylight and window related factor									
Appropriate ambience of room	61	6.623	0.734	14	6.643	0.633	-0.020	0.194	0.9190
Appropriate lighting distribution	61	6.557	0.764	14	6.429	0.756	0.129	0.224	0.5726
Appropriate lighting level	61	6.574	0.670	14	6.429	0.756	0.145	0.219	0.5166
Providing view of nature	61	5.951	1.175	14	5.929	1.542	0.022	0.439	0.9602

Note: $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Among the seven statements regarding the positive impact of sufficient daylighting on behaviors, three received stronger agreement among the nurses who worked in rooms with a window, while the remaining four received greater agreement among the nurses who worked in rooms without a window. None of the seven statements showed significant differences between nurses who work in rooms with a window and without a window (see Table 4.28).

Table 4.28 Comparison of the impacts of daylighting on staff and family behaviors by NICU room with or without a window to the outdoors

Impact of behavior	With window			Without window			Mean difference	SD	*p* value
	N	Mean	SD	N	Mean	SD			
1. Improving work efficiency	61	6.000	1.017	14	5.857	0.949	0.143	0.285	0.6217
2. Decreasing medical errors	61	5.344	1.353	14	5.571	1.399	-0.227	0.412	0.5878
3. Increasing mental alertness	61	6.246	0.960	14	6.429	0.756	-0.183	0.236	0.4475
4. Increasing length of family visits	60	5.333	1.170	14	5.286	1.139	0.048	0.340	0.8900
5. Decreasing times families leave their baby's room	60	4.875	1.548	14	4.929	1.592	-0.054	0.470	0.9104
6. Increasing interactions between families and infants	61	5.295	1.230	14	5.071	1.141	0.224	0.343	0.5219

Table 4.28 Continued

7. Increasing interactions between staff and infants	60	5.217	1.277	14	5.571	1.223	-0.355	0.367	0.3438

Note: *p < 0.05; **p < 0.01; ***p < 0.001.

4.1.2.7 Summary

Table 4.29 summarizes the statistical methods and results for the Survey II hypotheses. ANOVA, two-sample t-test, and Tukey's test were used to analyze the data. Out of the 31 hypotheses, six were supported, and 25 were not supported.

Table 4.29 Statistical methods and results for *NICU Nurse Satisfaction with Lighting Environment Questionnaire* hypotheses

Hypothesis	Statistical method	Result
Evaluation of lighting qualities		
II1. People hold different perceptions of NICU lighting qualities.	ANOVA and Tukey's test	Supported. People held different perceptions of lighting qualities (ANOVA: p = 0.0142). Two out of ten groups were significantly different (View of nature and ambience of room: p = 0.0462; view of nature and impact of view on work: p = 0.0093).
Lighting satisfaction when fulfilling work tasks		
II2. People perceive different levels of satisfaction regarding lighting condition when fulfilling different work tasks in a NICU.	ANOVA	Not supported. People perceived similar levels of satisfaction on lighting condition when fulfilled different work tasks (p = 0.7755).

Table 4.29 Continued

Evaluation of lighting importance		
II3. People perceive the importance of electric lighting and daylighting in a NICU to be the same.	Two-sample *t*-test	Supported. People perceived similar importance of electric lighting and daylighting (p = 0.6276).
II4. People who work in different room types perceive different levels of importance for electric lighting in a NICU.	Two-sample *t*-test	Not supported. People who worked in different room types perceived similar levels of importance for electric lighting (p = 0.6871).
II5. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance for electric lighting in a NICU.	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting perceived similar levels of importance for electric lighting (p = 0.8191).
II6. People who work in different room types perceive different levels of importance for daylighting in a NICU.	Two-sample *t*-test	Not supported. People who worked in different room types perceived similar levels of importance for daylighting (p = 0.6479).
II7. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance for daylighting in a NICU.	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting perceived similar levels of importance for daylighting (p = 0.8973).
Evaluation of importance of daylight and window related factors		
II8. People perceive different levels of importance of daylight and window related factors in a NICU.	ANOVA and Tukey's test	Supported. People perceived different levels of importance of daylight and window related factors (ANOVA: p < 0.0001). View of nature were less importance than the room ambience, lighting distribution, and lighting levels (View of nature and ambience of room: p < 0.0001; view of nature and lighting distribution: p < 0.0002; view of nature and lighting level: p < 0.0002).

Table 4.29 Continued

II9. People who work in different room types perceive different levels of importance of appropriate lighting level in a NICU.	Two-sample t-test	Not supported. People who worked in different room types perceived similar levels of importance of appropriate lighting level ($p = 0.4907$).
II10. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of appropriate lighting level in a NICU.	Two-sample t-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting perceived similar levels of importance of appropriate lighting level ($p = 0.5166$).
II11. People who work in different room types perceive different levels of importance of appropriate lighting distribution in a NICU.	Two-sample *t*-test	Not supported, people who work in different room types perceive similar levels of importance of appropriate lighting distribution ($p = 0.5380$).
II12. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of appropriate lighting distribution in a NICU.	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting perceived similar levels of importance of appropriate lighting distribution ($p = 0.5726$).
II13. People who work in different room types perceive different levels of importance of providing views of nature in a NICU.	Two-sample *t*-test	Not supported. People who worked in different room types perceived similar levels of importance of providing views of nature ($p = 0.9607$).
II14. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of providing views of nature in a NICU.	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting perceived similar levels of importance of providing views of nature ($p = 0.9602$).
II15. People who work in different room types perceive different levels of importance for appropriate room ambience in a NICU.	Two-sample *t*-test	Supported, people who work in SFRs perceive higher levels of importance of appropriate ambience of room than MB rooms ($p = 0.0236$).

Table 4.29 Continued

II16. People who work in rooms with access to daylighting and those without access to daylighting perceive different levels of importance of appropriate room ambience in a NICU.	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting perceived similar levels of importance of appropriate room ambience (p = 0.9190).
Evaluation of daylighting impact		
II17. People have different opinions on the impact of the presence of sufficient daylight on staff and family behavior in the NICU.	ANOVA and Tukey's test	Supported. People had different opinions, and ten out of 21 group comparisons were significantly different (ANOVA: $p < 0.0001$).
II18. People who work in different room types have different opinions on whether sufficient daylight increases work efficiency.	Two-sample *t*-test	Not supported. People who worked in different room types had similar opinions on whether sufficient daylight increases work efficiency (p = 0.4346).
II19. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases work efficiency.	Two-sample *t*-test	Not supported, people who worked in the rooms access to daylighting and not access to daylighting had similar opinions on whether sufficient daylight increases work efficiency (p = 0.6217).
II20. People who work in different room types have different opinions on whether sufficient daylight decreases medical errors.	Two-sample *t*-test	Not supported. People who worked in different room types had similar opinions on whether sufficient daylight decreases medical errors (p = 0.2108).
II21. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight decreases medical errors	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting had similar opinions on whether sufficient daylight decreases medical errors (p = 0.5878).

Table 4.29 Continued

II22. People who work in different room types have different opinions on whether sufficient daylight increases mental alertness	Two-sample *t*-test	Not supported. People who worked in different room types had similar opinions on whether sufficient daylight increases mental alertness (p = 0.4673).
II23. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases mental alertness	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting had similar opinions on whether sufficient daylight increases mental alertness (p = 0.4475).
II24. People who work in different room types have different opinions on whether sufficient daylight increases length of family visits	Two-sample *t*-test	Not supported. People who worked in different room types had similar opinions on whether sufficient daylight increases length of family visits (p = 0.0860).
II25. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases length of family visits	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting had similar opinions on whether sufficient daylight increases length of family visits (p = 0.8900).
II26. People who work in different room types have different opinions on whether sufficient daylight decreases the time that families leave their baby's room during their visit	Two-sample *t*-test	Supported, people who work in SFRs more agree with the opinion that sufficient daylight decrease the time that families leave their baby's room during their visit than those work in MB rooms (p = 0.0342).
II27. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight decreases the time that families leave their baby's room during their visit	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting had similar opinions on whether sufficient daylight decrease the time that families leave their baby's room during their visit (p = 0.9104).

Table 4.29 Continued

II28. People who work in different room types have different opinions on whether sufficient daylight increases the interactions between families and infants	Two-sample *t*-test	Not supported. People who worked in different room types had similar opinions on whether sufficient daylight increases the interactions between families and infants (p = 0.6370).
II29. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases the interactions between families and infants	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting had similar opinions on whether sufficient daylight increases the interactions between families and infants (p = 0.5219).
II30. People who work in different room types have different opinions on whether sufficient daylight increases the interactions between staff and infants	Two-sample *t*-test	Not supported. People who worked in different room types had similar opinions on whether sufficient daylight increases the interactions between staff and infants (p = 0.8239).
II31. People who work in rooms with access to daylighting and those without access to daylighting have different opinions on whether sufficient daylight increases the interactions between staff and infants	Two-sample *t*-test	Not supported. People who worked in rooms with access to daylighting and those without access to daylighting had similar opinions on whether sufficient daylight increases the interactions between staff and infants (p = 0.3438).

Based on all the responses, the results suggest that: (1) nurses hold different evaluations on some of the lighting qualities (view of nature and impact of view on work, and view of nature and ambience of room); (2) nurses perceive similar levels of satisfaction regarding lighting conditions when fulfilling different work tasks; (3) nurses perceive electric lighting and daylighting to be of similar importance; (4) regarding daylight and window related factors, nurses prefer the appropriate ambience, appropriate lighting distribution, and appropriate lighting level than view of nature; (5) nurses express different levels of agreement on the impact of daylight on staff and family behaviors, especially agree with improving work efficiency and increasing mental alertness.

Regarding the comparisons between nurses who work in SFRs and MB rooms, there are significant differences regarding lighting quality evaluations (three out of six factors) and lighting satisfaction when fulfilling different work tasks (eight out of nine tasks). Nurses who work in SFRs perceive appropriate ambience of room to be more important and more strongly agree on the statement that sufficient daylight decreases the frequency of families leaving their baby's room during their visit than those working in MB rooms. Comparing those respondents who work in rooms with access to daylight to those without such access, only the perceptions of the overall satisfaction of lighting environment are different.

4.2 Case Study of One Hospital

As mentioned in Section 3.4, the case study was conducted at a hospital in the southeast United States. The author collected data from more than 50 hours of behavioral observations of nurses and families, 21 questionnaires from nurses, and on-site measurements of lighting levels and glare in the NICU department during the 12-day research period.

4.2.1 Behavioral Observation

4.2.1.1 Overview of Observational Data

The behavioral observations were conducted between 8:00 am and 6:00 pm over nine days, which included eight weekdays and one weekend day. For each day, the researcher randomly selected one of the two corridors in which to stay and observed at most four nurses at the same time. The selection of nurses was based on two criteria: (1) the nurse signed the consent form to participate; and (2) the nurse took charge of patient(s) directly and individually; the managing nurse who did not take care of any infant directly and the in-training nurse who was always accompanied by another nurse was excluded from observation. Additionally an effort was made to observe as many different nurses as possible to minimize the influence of personal habits and preferences. The researcher observed three instead of four nurses in two of the nine days, when there were not enough nurses available. In total, 15 out of 25 nurses who signed the consent forms were observed.

The researcher collected 50.85 hours of observational data and exported the data into an excel file. The data cleaning process included: (1) modifying the typos based on recorded comments and the notes; (2) removing all duplicated records which were generated because the Noldus Observer created a record of the end of last behavior when a new behavior of the same subject was recorded; (3) adding missing behaviors manually, since the software cannot record reciprocal behaviors for both or all subjects automatically (Grieco, Loijens, Krips, Zimmerman, & Spink, 2013, p.159). For example, observed nurses, N1 and N2, communicated with each other. The system cannot automatically create the record of N2 communicating with N1 while simultaneously recording that N1 was communicating with N2. After this cleaning process, 7,555 lines of records were decreased to 4,248 lines. Excluding the time when subjects were out of the observation area and unobservable by the researcher, the total observed hours of all subjects were 156.09 hours (156:05:06).

Regarding the room assignment, patients were randomly assigned to a room with or without a window based on room availability. In practice, patients were assigned to the rooms along the south corridor first, and then assigned to the north corridor when the rooms along the south corridor were full. This promised to accommodate staffing efficiency, since it would be difficult for a nurse to travel back and forth between two corridors to fulfill caring tasks. A nurse took charge of two to four patient rooms, and the typical number of patients cared by each nurse was three. Additionally, the patient rooms for which a nurse was responsible were assigned by the principles of adjacency and providing continuous care of the same patients. If a nurse took care of three rooms, it was common that two of the three rooms were next to each other on the same side of the hallway and the third on the opposite side. In the analysis, the nurses were categorized by the number of rooms with a window (Y) and without a window (N) for which he or she was responsible. For example, a nurse who took charge of one room with a window and two without a window were categorized into the group of 1Y2N. Y meant all rooms were with a window, and N meant all were without a window.

4.2.1.2 Work Time Distribution among Nurses Working in Rooms with and without A Window

To explore the relationship between the behaviors and the lighting conditions, average time spent on each behavior per day among nurses in rooms with different lighting conditions was calculated (see Figure 4.29). The behaviors of direct care, documentation on computer, communication with staff, in transit, and communication with families were the most common. The nurse who worked in rooms all of which had windows (Y nurses) spent less time on direct care and more time on transition than the other three nurse groups. The time spent on documentation on computer was from 57 to 79 minutes in all the groups. The communication with staff took nurses from 34 to 49 minutes, while the communication with families took from nine to 23 minutes on average in all groups.

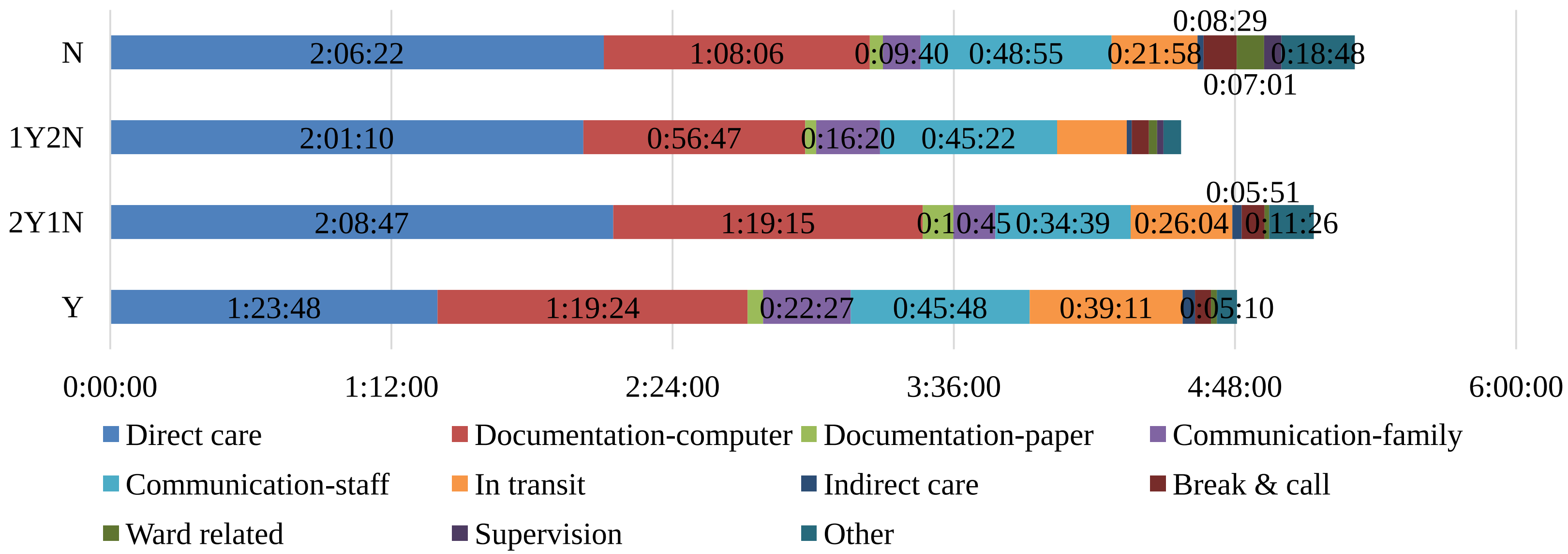


Figure 4.29 Comparison of average task time per observation day among nurses assigned to rooms with different lighting conditions (hh:mm:ss)
Note: A behavior without a number label is less than 5 minutes.

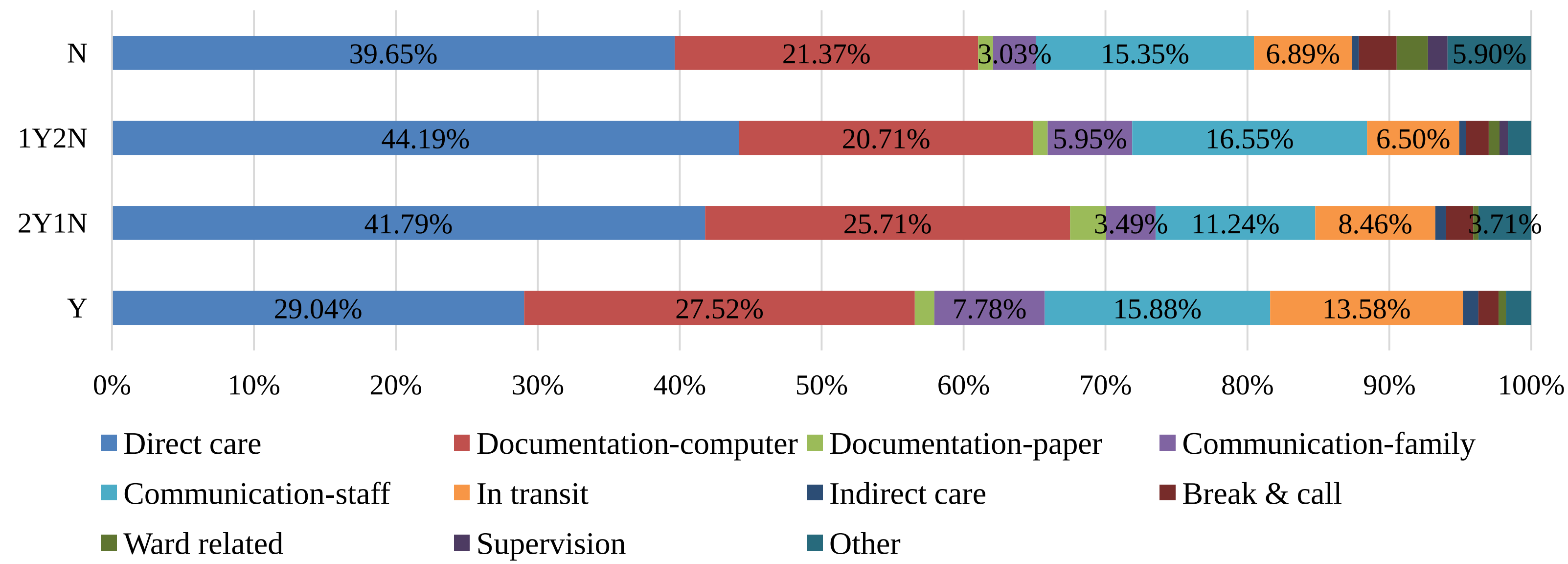


Figure 4.30 Comparison of average task time per observation day among nurses assigned to rooms with different lighting conditions (percent of total time)
Note: A behavior without a number label is less than 3% on distribution.

Table 4.30 Comparison of average task time per observation day among nurses assigned to rooms with different lighting conditions (percent of total time)

Behavior	Number and lighting condition of rooms being took charge of			
	Y	2Y1N	1Y2N	N
Direct care	29.04%	41.79%	44.19%	39.65%
Documentation-computer	27.52%	25.71%	20.71%	21.37%
Documentation-paper	1.38%	2.54%	1.03%	1.06%
Documentation sub-total	28.90%	28.26%	21.74%	22.43%
Communication with family	7.78%	3.49%	5.95%	3.03%
Communication with staff	15.88%	11.24%	16.55%	15.35%
Communication sub-total	23.66%	14.73%	22.50%	18.38%
In transit	13.58%	8.46%	6.50%	6.89%
Indirect care	1.10%	0.77%	0.46%	0.49%
Break & call	1.42%	1.90%	1.61%	2.66%
Ward related	0.51%	0.38%	0.77%	2.20%
Supervision	0.00%	0.00%	0.59%	1.38%
Other	1.79%	3.71%	1.64%	5.90%
Total	**100%**	**100%**	**100%**	**100%**

As the total observation time for each group of nurses was different, the next step in the analysis was to translate the spent time into percentages (see Figure 4.30 and Table 4.30). The nurses who worked in all rooms with windows (Y nurses) spent at least 10% less on direct care than the other three groups. They had the highest percentages of time spent on documentation on computer, communication with families, and in transit among all the groups; they also spent a relatively high percentage of time on communication with staff.

4.2.1.3 Behavioral Duration and Frequency among Nurses working in Rooms with and without A Window

To better understand the nurse behaviors under different lighting conditions, four core behaviors: direct care, documentation on computer, communication with family, and communication with staff, were selected to be analyzed for their durations and frequencies. Since the total time a nurse could work was fixed, the number of infants she cared for would be an confounding factor for the average duration and frequency of a single behavior. Therefore, only nurses taking care of three patients were selected for this analysis, including four 3Y nurses, seven 2Y1N nurses, 13 1Y2N nurses, and four 3N nurses.

The average duration of selected behaviors by nurse group is shown in Figure 4.31. The duration of direct care increased with the nurses working at more rooms without a window (from 3Y to 3N). The duration of documentation on computer showed a similar trend except the 1Y2N group, which spent slightly less time than the 2Y1N group. The 1Y2N group spent the longest time on communication with families among the four groups. The duration of communication with families per time in the other three groups were close to each other. All nurse groups had a similar duration of communication with staff. Table 4.31 lists the specific values of duration and results about whether there is a group difference in each behavior based on the ANOVA test. The duration of direct care by nurse group was significantly different by ANOVA test (p = 0.0345), and the Tukey's test showed that the values of group 3Y and 3N were significantly different ($M_{diff.}$ = -0:02:20, p = 0.0431).

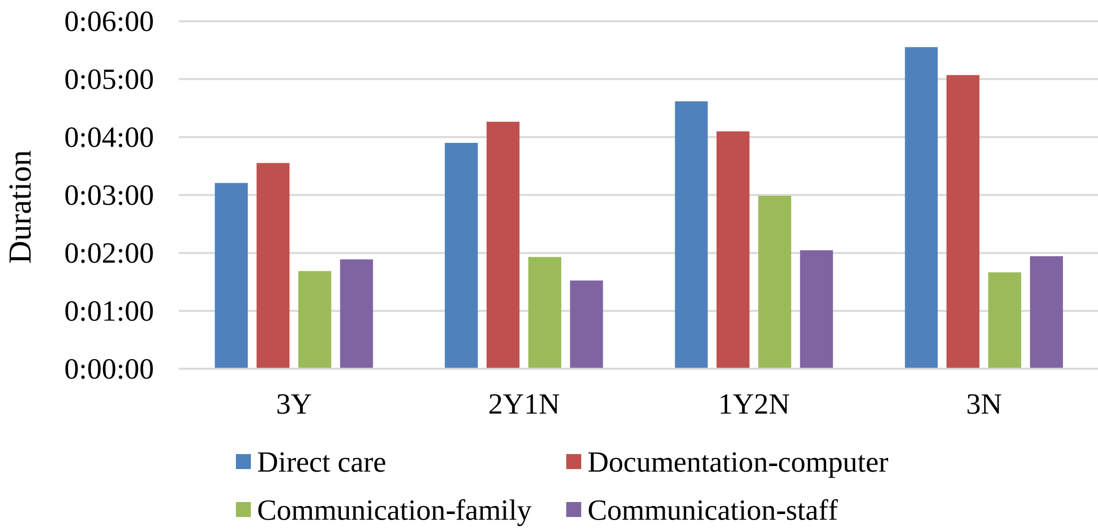


Figure 4.31 Average duration of selected behaviors by nurse group

Table 4.31 Comparison of average duration of selected behaviors by nurse group (N = 28)

Behavior	3Y		2Y1N		1Y2N		3N		*p* value
	N	Duration	N	Duration	N	Duration	N	Duration	
Direct care	109	0:03:13	231	0:03:54	341	0:04:37	94	0:05:33	0.0345 *
Documentation - computer	70	0:03:33	130	0:04:16	180	0:04:06	57	0:05:04	0.3459
Communication – family	34	0:01:41	39	0:01:56	71	0:02:59	15	0:01:40	0.1912
Communication - staff	92	0:01:53	159	0:01:32	288	0:02:03	97	0:01:57	0.1917

Note: *$p < 0.05$.

Besides the duration of a single behavior, how many times the behavior repeats during a certain time period – the frequency- is another important consideration. Figure 4.32 shows the average frequency of selected behaviors by nurse group. The direct care and communication with staff were two most frequent behaviors among all the four groups; except the group 3N with a minor difference of 0.14 times per hour, the other three groups conducted the direct care most frequently. The documentation on computer was the third most frequent behavior, and communication with families was the least. The nurses who worked in all rooms with a window (3Y) had the most frequent behaviors of documentation on computer, communication with families, and communication with staff among the four groups; the only exception was the direct care, of which 2Y1N was the most frequent while 3Y was the second. It was also noticed that the frequencies of documentation on computer increased when the nurses worked at more rooms without a window (from 3N to 3Y).

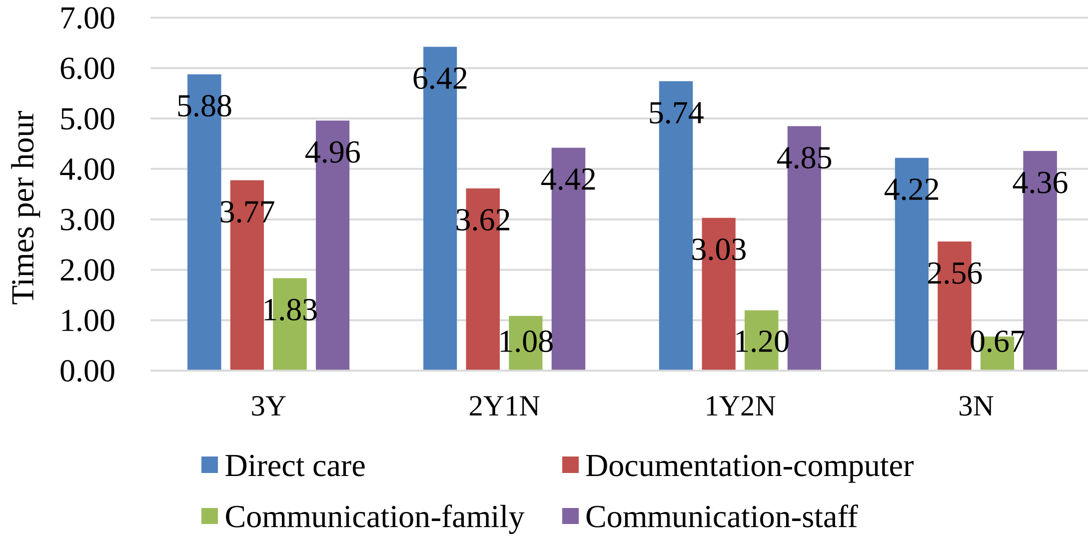


Figure 4.32 Average frequency of selected behaviors by nurse group

The real time behavioral patterns of individuals and overlapped by group are shown in Appendix D, which also supports the observation findings that: (1) direct care and documentation on computer were relatively continuous behaviors with long durations and frequent incidences compared to other transient behaviors such as documentation on paper, communication with staff and family, and transition; (2) nurses who work with more rooms with a window tended to have more frequent, but with shorter duration of, behaviors of direct care and documentation on computer; (3) the transient behaviors happened more frequently among the nurses who worked with more rooms with a window.

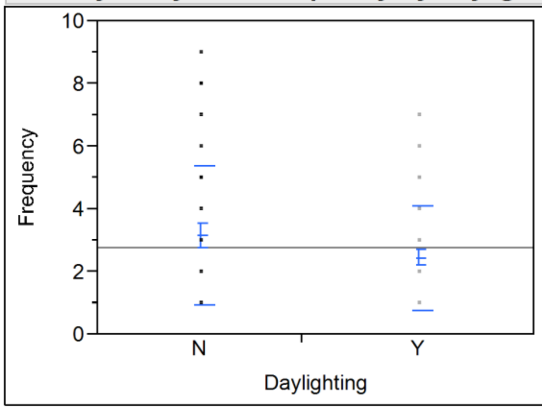
4.2.1.4 Comparison of Family Visit

During the observation period, the researcher collected the time data for when family members entered and left the patient room as well as the patient room numbers of their visits. Ideally, the family is expected to stay with the patient all the time and leave the room as little as possible during a visit. In practice, some families stayed overnight, came earlier than or left after the daily observation period started or ended, and the researcher likely missed either the arrival or departure time of such family visits. Therefore, it was difficult to collect accurate information of how long a family stayed in the patient room. Instead, the researcher counted the frequency of family leaving the patient room during one-day visit. Visits that happened on different days were perceived as independent. There were a total of 232 departures involving 80 rooms during the observation days (see Table 4.32). The data on frequency of family leaves per room per day by room type (with a window or without a window) were tested for the Poisson distribution. The data regarding rooms without a window were good fit the Poisson distribution ($p = 0.1838$). After removing an outlier, the data regarding rooms with a window were also tested ($p = 0.1423$). After the adjustment, the average frequency of family departures was 2.45 per day visit among the rooms with a window and 3.16 for those without a window. T-tests were used to examine whether there was a significant difference regarding the frequency of departures during one-day visit between rooms with a window and those without a window (see Figure 4.33). Though no significant difference was found, the small *p*-value (0.0592) suggested a trend that family members with patients in rooms without a window left more frequent during one-day visit than those whose patients in rooms with a window.

Table 4.32 Total family departure times and frequency during one-day visit by room with or without a window

Item	Room with a window		Room without a window
	Original	Adjusted	
Total family leave times	115	103	117
Number of rooms involved	43	42	37
Leave times per room per day	2.67	2.45	3.16

Oneway Analysis of Frequency By Daylighting



Missing Rows	101
Excluded Rows	1

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
N	37	3.16216	2.24244	0.36865	2.4145	3.9098
Y	42	2.45238	1.65577	0.25549	1.9364	2.9684

t Test

Y-N

Assuming unequal variances

Difference	-0.7098	t Ratio	-1.58245
Std Err Dif	0.4485	DF	65.59894
Upper CL Dif	0.1858	Prob > |t|	0.1184
Lower CL Dif	-1.6054	Prob > t	0.9408
Confidence	0.95	Prob < t	0.0592

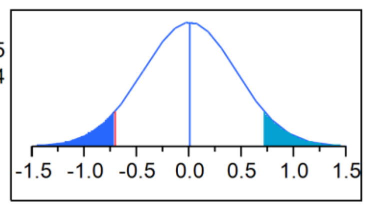


Figure 4.33 Distribution and comparison of frequency of family departures during one-day visit by room with or without a window

4.2.2 Survey III

Among the 21 respondents, only one of them was male, and one did not answer the question of years working in NICUs. Regarding the age group, the most frequent one was 50-54 years followed by 40-44, and the median age group was 45-49 (see Figure 4.34). Eight respondents worked in NICUs for 10-19 years, followed by six worked for 20-29 years and four worked for 2-9 years (see Figure 4.35).

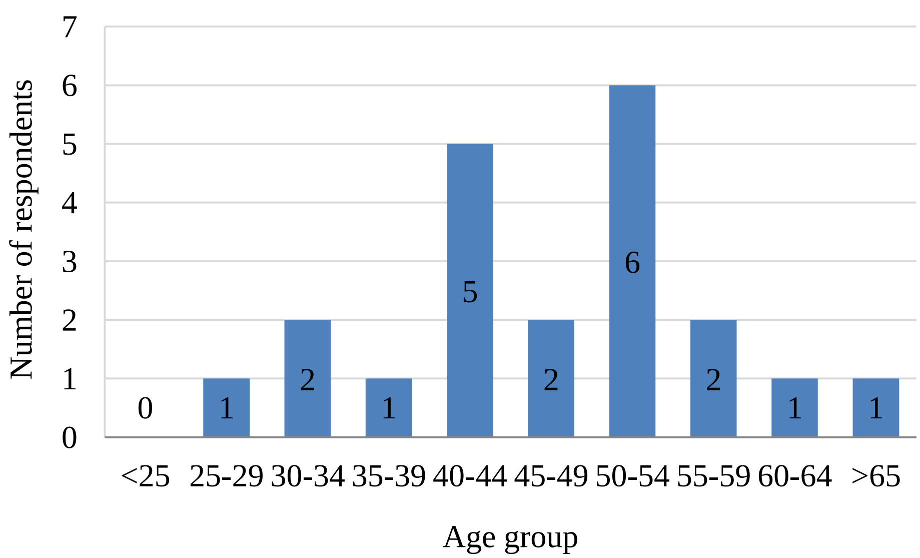


Figure 4.34 Age group distribution of respondents

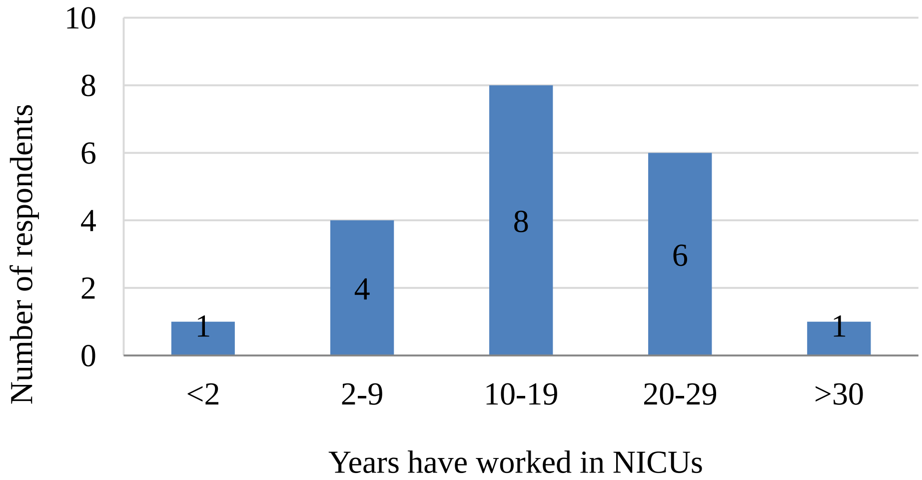


Figure 4.35 Work experience distribution of respondents

Ten respondents were working in a room with a window, and eleven were working in a room without a window when they filled out the survey. Due to the small sample size, the researcher only calculated the means, standard deviations, and mean differences of surveyed items by rooms with or without a window (see Table 4.33).

For the lighting qualities, the respondents who worked in rooms without a window reported better lighting level and less intolerable glare than those who worked in rooms with a window, although seven (63.6%) respondents who worked in rooms without a window reported the existence of glare compared to four (40.0%) of the respondents whom worked in rooms with a window. The latter gave higher ratings for the overall ambience of room and overall satisfaction of the visual environment than the former.

Regarding the satisfactions with existing lighting conditions when fulfilling different work tasks, the two groups rated satisfaction the same for professional communication; except when fulfilling documentation and social interaction tasks, respondents who worked in rooms with a window were more satisfied than those who worked in rooms without a window.

Both nurse groups perceived the electric lighting and daylighting to be important. Respondents who worked in rooms with a window perceived the lighting level and room ambience as the two most important factors, while those working in rooms without a window favored the lighting level and lighting distribution as the top two important lighting factors.

For the impact of daylighting on behavior, both groups agreed that daylighting could increase mental alertness. Generally, the respondents who worked in rooms with a window perceived more positive impacts of daylighting than those who worked in rooms without a window, except with regard to the impact on improving work efficiency.

Table 4.33 Results of Survey III

Item	With a window			Without a window			Mean dif-ference
	N	Mean	SD	N	Mean	SD	
Evaluation of lighting qualities							
• Lighting level	10	4.400	0.699	11	4.000	0.775	0.400
• Lighting distribution	10	5.900	1.101	11	4.818	1.328	1.082
• Glare	4	4.750	0.957	7	4.857	1.574	-0.107
• Window views of nature	10	4.000	1.944	NA	NA	NA	
• Impact of the view	9	5.556	1.509	NA	NA	NA	

Table 4.33 Continued

• Overall ambience of room	10	5.600	0.843	11	4.636	1.502	0.964
• Overall satisfaction	10	5.800	0.919	11	5.182	1.401	0.618
Satisfaction of lighting conditions when fulfilling work tasks							
• Direct care	9	6.111	0.782	10	5.600	1.265	0.511
• Indirect care	10	5.900	0.994	11	5.273	1.555	0.627
• Medication task	8	6.250	0.707	10	5.700	1.494	0.550
• Documentation	10	5.700	1.059	11	5.727	1.348	-0.027
• Professional communication	10	6.200	1.033	10	6.200	1.135	0.000
• Social	8	5.750	0.886	9	6.056	1.130	-0.306
• Ward related activities	6	6.167	0.753	9	5.611	1.054	0.556
• Supervision	5	6.200	0.837	8	5.625	1.302	0.575
• In transit	8	5.750	1.035	11	5.091	1.136	0.659
Importance of lighting conditions							
• Electric lighting	8	6.750	0.707	11	7.000	0.000	-0.250
• Daylighting	8	6.375	1.408	11	6.091	1.300	0.284
Importance of daylighting factor							
• Lighting level	8	6.500	0.535	11	6.273	1.104	0.227
• Lighting distribution	8	5.875	1.356	11	6.273	1.104	-0.398
• View of nature	8	5.500	1.773	11	5.364	1.963	0.136
• Ambience	8	6.500	0.535	11	6.091	1.300	0.409
Influence on behavior							
• Improving work efficiency	10	4.900	1.853	11	5.727	1.104	-0.827
• Decreasing medical errors	10	5.000	1.764	11	4.728	1.618	0.272
• Increasing mental alertness	10	6.100	0.738	11	6.091	1.136	0.009
• Increasing length of family visits	10	4.600	1.506	11	4.364	2.063	0.236
• Decreasing times that families leave their baby's room	10	4.700	1.767	11	4.364	1.912	0.336
• Increasing interactions between families and infants	10	4.900	1.853	11	4.636	1.629	0.264
• Increasing interactions between staff and infants	10	4.600	1.713	11	4.273	1.489	0.327

4.2.3 On-site Measurement

4.2.3.1 Measurement of Lighting Levels

Due to the limited room availability, the researcher only had the chance to measure one south-facing room on a sunny day. Six points/locations in the room were measured at different time: points A and B were next to the incubator and belong to the care zone where nurses delivered direct care most frequently; point C was the nurse working station in the patient room; points D and E belonged to family care zone; and point F was the middle point of the window on the horizon, providing the baseline of outside lighting levels. Figure 4.36 shows the measured points in the patient room and the means of lighting levels except point F due to the excessive value. The specific lighting levels were listed in the Table 4.34.

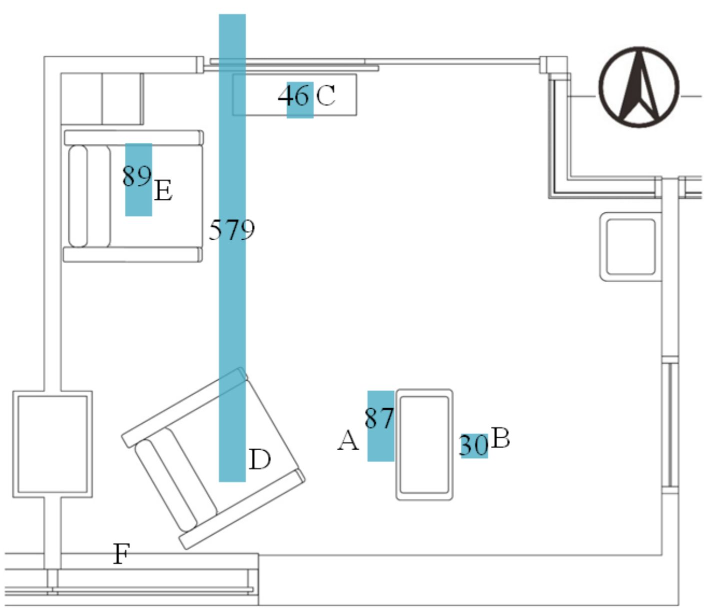


Figure 4.36 Measured points and means of lighting levels (lx) in the patient room

Table 4.34 Measured lighting levels (lx) in the patient room

Time	A	B	C	D	E	F
2:25pm	49	19	33	626	83	4300
3:25pm	40	17	25	78	40	2750
3:30pm	228	75	95	1625	170	6520
4:30pm	82	24	58	487	130	2800
5:50pm	38	13	17	78	24	1020
Average	**87**	**30**	**46**	**579**	**89**	**3478**

4.2.3.2 Glare Analysis

Since the glare might come from the window, incubator, and computer screen, two working scenes were photographed on sunny afternoons (see Figures 4.37 and 4.38). The researcher did not change any arrangement of furniture or adjust any lighting settings. Each scene was photographed seven times with same parameters (aperture size at f/3.5, film speed at ISO 100, and daylight as the white balance mode) with the exception of varied shutter speeds (1/8, 1/15, 1/30, 1/60, 1/125, 1/250, and 1/500 seconds). The seven photos were combined as an HDR photo and then analyzed in the software of Hdrscope (developed by Viswanathan Kumaragurubaran from University of Washington). There was no glare found in the two scenes (see Figures 4.39 and 4.40).

Figure 4.37 HDR photo of scene 1

Figure 4.38 HDR photo of scene 2

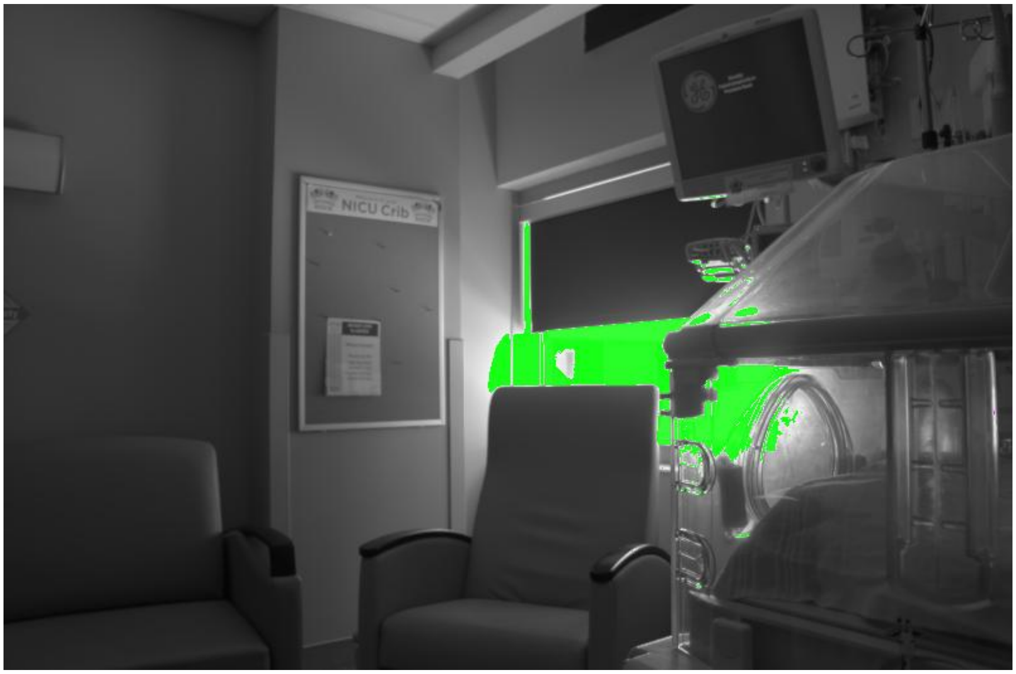


Figure 4.39 Glare analysis of scene 1

Figure 4.40 Glare analysis of scene 2

5. DISCUSSION

This section includes two parts: a discussion of the survey results and a discussion of the results from behavior mapping.

5.1 Survey Results

5.1.1 Trends in SFRs

A summary of all hypotheses can be found in Tables 4.12 and 4.29.

One of the most important questions addressed in the Survey I was whether the type of NICU room (SFRs versus MB rooms) has changed over time. Through the literature review and online search, the researcher found that prior to this dissertation study there has been no empirical data on the number of NICUs with SFRs or other room types even without consideration of NICU built years. The most relevant information was the number of beds per unit in the United States. However, the nationwide average number of beds, according to the Directory (AAP, 2011), was 28.4, as opposed to 22.67 from the returned Survey I, which suggests a possible decrease on the number of beds per NICU. We can infer from this study that there is a trend from MB rooms to SFRs in the last twenty years, while assuming that mixed room configurations will be a common option for the future (see Figures 4.6 and 4.9). This transition is significant to neonate critical care for multiple reasons, including the impact on construction costs, nursing station location (as units get larger the need for decentralized nursing is greater), an increased presence of families, and the impact on floor configuration and overall hospital design. Similar changes in other units, such as single room maternity care, had a significant impact on overall facility design.

Additionally, regarding NICU size, the results reveal that the average number of beds in NICUs with SFRs was higher than the average numbers of beds in NICUs with 2-3 beds and > 3 beds (see Table 4.2). The *Recommended Standards for Newborn ICU Design* (White, Smith, & Shepley, 2013) and the *FGI Guidelines* (FGI, 2014) both mandate the larger required area per bed of a single room as compared the area per bed of a MB room. When taking it into consideration, we can assume that a reduction in the number of NICU beds per room does not mean a reduction in the total area of a NICU; to the contrary, the total area of an NICU may increase.

5.1.2 NICU Lighting Conditions

The other two research questions mentioned in Section *3.4.3.1* addressed lighting sources. SFRs had higher percentages of access to daylighting than the other room types, though access by exterior window was the most commonly used daylighting model in all the room types. The utilization of interior windows with daylighting from exterior windows could be a supplement to, but rarely was, the main daylighting model. The use of skylights is limited to NICUs on the top floor of a building. So if the NICU department is not on the top level, it will be hardly possible to get access to daylight through sky light except through the installation of light tubes. Light tubes, also known as tubular daylighting devices, which are tunnel-like devices that use reflective systems to reflect light over distance, are a relatively recent intervention in offices and dwellings

(Mardaljevic, 2013). However, the high expense on installation and only allowing light to transverse a limited distance hinder the uses of lighting tubes.

This portion of the survey reminds us that researchers need to acknowledge the likelihood that not all rooms in a NICU have the same lighting conditions (see Figures 4.11 and 4.12). For the MB NICUs with the large open space, the lighting conditions may vary at different locations in one room. Even for SFR NICUs, in double-loaded corridors, which are a popular layout, half of the rooms will have direct access to windows while the other half will not. The impact of this difference in amenities has implications regarding room assignment and family perceptions of treatment.

5.1.3 Importance of Electric Lighting and Daylighting in NICUs

Hypotheses I1 and II3 addressed the importance of electric lighting and daylighting. Regarding the importance of different lighting sources, the medical directors perceived electric lighting to be of significantly higher importance than daylighting, while the nurses perceived the importance of electric lighting to be higher, but not significantly. The result that electric light was thought to be more important than daylight make sense as the unit is dependent upon electric lighting throughout the 24-hour day. As the persons who work in the patient rooms every day, nurses may have more personal experience on the importance of daylight.

Hypotheses I2 and I3 and hypotheses II4 through II7 addressed the relationship between setting and lighting importance. Perceptions of importance was not associated with different physical environments, no matter which room type or whether the room had access to daylight or not. This outcome suggests that perceptions of daylight importance are independent of room type, which is an interesting outcome. One might expect that individuals deprived of daylight would be more acutely aware of its absence. However, accustomization might be a stronger reaction (Jackson, 1932).

5.1.4 Satisfaction with NICU Lighting Conditions

Hypotheses I4 through I6 explored the topic of satisfaction with lighting conditions. Unlike importance, satisfaction with lighting conditions was highly related to the actual physical environment. Satisfaction levels of both general lighting environment and daylighting conditions increased as the numbers of beds per room decreased, which means that the SFR provided more satisfactory lighting conditions in comparison to the other room types (see Figures 4.17 and 4.18). We can conclude from this that SFR NICUs have design features that are supporting appropriate lighting conditions.

We also noticed that the satisfaction levels were lower for daylighting than for general lighting environment in all room types (see Table 4.8). Considering that satisfaction was low relative to perceived importance, improving the daylighting in the NICU environment is essential. Other studies in healthcare settings have indicated that lighting is important to staff (Joseph, 2006).

Regarding Hypothesis II1, the evaluations of specific lighting qualities, with the exception of the fact that lighting levels were perceived to be moderately satisfactory, all the other factors including overall satisfaction were relatively low, especially the factor of view of nature (see Tables 4.13 and 4.14). Even in this situation, SFRs received higher evaluations on all the factors compared to MB rooms; as did the rooms with a window compared to those without a window. A satisfactory lighting environment is more than just providing the appropriate lighting levels; ambience of room, lighting distribution, outside view, and view of nature are all important factors (Clear, Inkarojrit, & Lee, 2006).

Though no significant differences were found regarding nurse satisfaction with lighting condition when fulfilling different work tasks (Hypothesis II2), the satisfaction levels when conducting the tasks of direct care, indirect care, and documentation were the three lowest (see Table 4.16). Considering that direct care and indirect care mainly occur in the patient room, the results suggest the need to improve lighting conditions in the area adjacent to the infant. SFRs were perceived as more satisfactory than MB rooms on all the work tasks except documentation. All the evaluations between SFR and MB were significantly different, which seems logical since many documentation tasks take place at computers located at centralized or decentralized nurse stations independent from room types. Satisfaction with lighting condition when fulfilling all work tasks in the room with a window was higher than in the room without a window though no significant difference was found. The results of this response were likely influenced by the use of electric light to compensate for lack of daylight or the orientation of the window relative to the sun.

5.1.5 Impacts of Daylighting on Behaviors in NICUs

Regarding Hypothesis I7 and Hypothesis II17, which addressed the impact of daylighting on staff and family behaviors, medical directors and nurses agreed that appropriate daylighting improved work efficiency and increased mental alertness. The effects on efficiency and alertness are consistent with the results from the Sagha Zadeh, Shepley, Williams, and Chung study (2014).

Concerning Hypotheses II18 to II29, nurses who work in SFRs or in the rooms with a window had more positive perceptions on all the statements about the impact of daylighting on behavior than those working in MB rooms or in the rooms without a window. There was a significant difference on the proposition that frequency of family leaving baby's room would be decreased between nurses who work in SFRs and MB rooms. The difference is based on the nurses' personal working experiences, which might be related to the different visiting policies and furniture arrangements between SFRs and MB rooms (Beck, Weis, Greisen, Anderson, & Zoffmann, 2009; Greisen et al., 2009). SFRs provide dedicated spaces for each family, which allows the family member to leave and re-enter the patient room several times and maintain their "territory." Respectively, MB NICUs usually provide a devoted independent place for all the family visits. After being admitted with their child, the family is placed with their baby in an isolated space. If the family leaves for a while, the baby would be alone, which rarely happens. Such different policies are not related to NICU rooms whether with or without a window.

5.2 Behavioral Observation Results

5.2.1 Work Time Distribution

As demonstrated by behavioral observation, direct care, documentation on computer, communication with staff, and in transit were the four most common behaviors during the nurse work routine. A study by Hendrickson, Doddato, and Kovner (1990) found that the pediatric nurses spent 36% of their time with the patient, 15% on charting including both on computer and on paper, and 8% on professional interaction. When comparing those results with findings from this study, the NICU nurses in this study spent similar percentages on direct care but much higher percentages on charting and communication. One of the differences might be due to the fact that the previous data is 25 years old, and the charting method was changed from paperwork to computerized documentation around the Millennium (Smith, Smith, Krugman, & Oman, 2005). In another study, nurses who worked in a surgical intensive care unit spent 24.2% of their time on documentation on computer (Wong et al., 2003), which is close to the result of this study.

Other differences might originate from two facts associated with the difference between caring pediatric patients and caring NICU infants: (1) the use of decentralized nurse stations in NICUs and centralized nurse station in Pediatrics, and (2) more care procedures taking place while caring NICU patients. The location of decentralized nurse stations allows nurses to readily observe the patient room from outside; nurses can observe patient conditions while working on charting or conducting professional communications. The time spent with patients seems to decrease, but can be more effective and efficient. As a place to provide critical care, NICUs require more team work and collaboration (Copnell et al., 2004). The model of family-centered care encourages family to be more involved into the care process (Harrell & Moon, 2008;

Gooding et al., 2011). As a result, there are more family visits and communications among nurses and between family members and nurses in NICUs.

5.2.2 Individual Behavioral Pattern

The results showed the individuality and complexity of behavioral patterns of subjects (see Appendix D). However we can still identify some behavioral patterns. Direct care and documentation on computer are continuous behaviors, which could be seen as several segments on the diagrams (see Appendices D.1.2 and D.2.2), while the other behaviors are so transient that they are more looked like sets of points.

Short durations and high frequencies for most behaviors suggest a scenario of active behavior transitions. In this case, since these transient behaviors appear at different locations, the active behavior transitions lead to longer time and more distance spent on transition. For visual comfort, the frequent transitions at different locations require an adequate and stable lighting environment in different areas to accommodate nursing tasks.

6. CONCLUSION

6.1 Research Summary

This research included a nationwide cross sectional study and an in-depth case study. The cross sectional study aimed at determining whether there was a design transition in NICU room type from MB to SFR and evaluating the importance of, satisfaction with, and the impact of lighting environment in NICUs from the perspective of medical directors and nurses. The case study focused on one NICU with all SFRs and combined the behavioral observation of nurses and families, survey of nurses regarding the lighting environment, and on-site lighting measurement. The primary conclusions included: (1) NICU room types are in transition from MB to SFR; (2) NICUs with SFRs have higher percentage of rooms with access to daylighting and are perceived to have a more satisfactory lighting environment than NICUs compared to those with MB rooms; (3) both NICU medical directors and nurses are more likely to agree on the impact of daylighting on improving work efficiency and increasing mental alertness over decreasing medical errors, increasing length of family visits, decreasing the time that families leave their baby's room during their visit, and increasing interactions between families and infants and between staff and infants; (4) nurses who take care of more rooms with daylighting tend to have more frequent behaviors of direct care and documentation on computer with shorter duration than those do not work in rooms with daylighting; (5) the frequency of family departure during a visit is decreased when the rooms have a window compared to rooms with a window.

6.2 Limitations of Study

6.2.1 Research Design

This research focuses on the relationship between the physical environment and human behavior. In the setting of NICUs, comparison of outcomes of infant patients with and without daylighting would have been the most direct data regarding the impact of daylighting on patients. This was not gathered due to logistical and protocol limitations. When focusing on the behaviors of families and nurses, video recording would have been a more accurate and reliable method to record all the behaviors. The official records of family visits and the records of nurse medical errors would been a useful supplement as well. However, due to the high sensitivity and privacy, I could not get permission to access these data, although I approached multiple facilities over a 10 month period. As a result, I modified the initial research plan to accommodate the available setting and accessible data.

6.2.2 Nationwide Cross Sectional Study

The nationwide cross sectional study included two surveys, which involved the limitations on sample representativeness and sample size. For example, the Survey I was distributed to the medical directors whose email addresses were listed in the *Directory* 2011 version, which may not include all the current NICUs, especially as it did not include newly built facilities. In some cases the medical directors might have left their positions or changed email addresses over time, thus limiting the response rate and the representativeness of the data. Also, the response rate was disparate by region, because some areas were not represented. All these factors undermined the accuracy and representativeness of the results. With a larger sample size, more hypotheses could be tested using inferential statistical methods, such as whether or not there are more NICU rooms with access to daylighting over the years and whether people perceive daylighting impacts to be different by room type in which they work.

6.2.3 Case Study of One Hospital

Due to the time limitation, only one NICU with limited numbers of nurses and patient rooms participated in the study and only one person, myself, conducted the behavioral observation in a short period of nine days. As a qualitative study involving human beings, especially in the healthcare settings, the study cannot be totally randomized or experimental. There were many cofounding factors, such as the patient physical conditions, nurse personal working habits, my bias and errors during the observation.

6.3 Recommendations for Future Research

Future research is needed to overcome the limitations of this study and expand its scope. More behavioral mappings at different sites with longer observation durations would strengthen the effectiveness of results. More systematic measurement of lighting environment would be a useful supplement for the evaluation and comparison of lighting environments. With the approval from the hospital, the medical records of infants, records of family visits, and records of nurse retention and medical errors would provide direct evidence for studying the impact of daylighting on both nurse and family behaviors and patient outcomes.

From the perspective of architectural design, daylighting is only one of the factors of the physical environment that has impact on people. The study of daylighting should be combined with other relevant aspects, such as the thermal environment, choices of color and material, and room layout. It could be expanded to involve other disciplines such as psychology and physiology to explore the underlying mechanisms for the impact of the environment.

6.4 Applications to Practice

The results indicate the transition of NICUs from SFR to MB with the empirical data and illustrate the advantages of SFR regarding lighting environment over other room types. Based on these results, this research provides a practical example of an NICU with SFRs with the insight into the behavior of nurses and families who stay in rooms with and without access to a window. The study makes suggestions regarding the lighting environment design in NICUs, which supplement existing recommendations and guidelines:

(1) Both electric lighting and daylighting are necessary for the lighting environment of a NICU patient room, which should be considered integrally during the design process.

(2) The NICU patient room shall include three function areas: the infant care area for nurses taking care of the patient, the family area for family members' stay, and the support area for nurses charting, preparation, and other care assistant activities. In practice, the three areas tend to mingle together: a family member

may participate in the caring procedure; and charting on a wheeler next to the incubator, where is the core area of infant care, is quite normal. Figure 6.1 illustrates the optimized arrangement of the NICU patient room in the case study. Family area shall be next to the exterior window to get access to the daylight. The infant care area shall be in the middle of the room to get rid of excessive direct daylight for the infant; the side of the incubator is facing the window, therefore nurses would not perceive strong contrast of lighting levels when working around the incubator. The equipment and furniture of the support area shall be easy to move, therefore this area can be merged into other areas when needed.

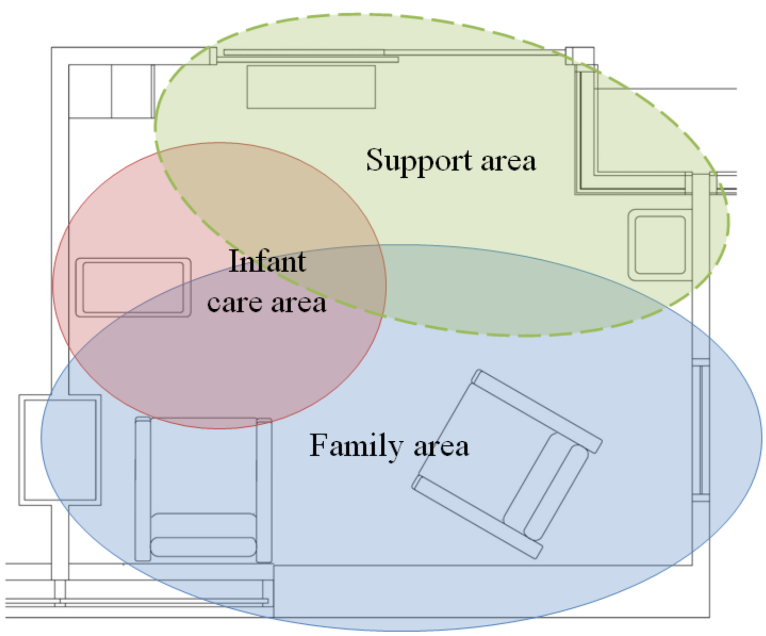


Figure 6.1 Example of an optimized NICU patient room arrangement

(3) For the NICU department design, provide rooms with access to daylighting as many as possible. The functional rooms shall be placed between or among the patient rooms rather than at the end of a corridor (see Figure 6.2) to shorten nurses' travel distances. And the lighting environment should be consistent and stable in the whole department, which includes patient rooms, functional rooms, and corridors, to decrease unnecessary visual adjustments when nurses fulfilling tasks at different locations.

6.5 Closing Statement

This project provided the opportunity to study a specialized topic in depth with the devotion of my time, spirit, and skills. I appreciate having the chance to emerge myself into the NICU environment to really study and understand nurses' daily work and experiences. Even in the limited time frame, I changed my perspective and came to realize the importance of conducting research rooted in practice and people's needs.

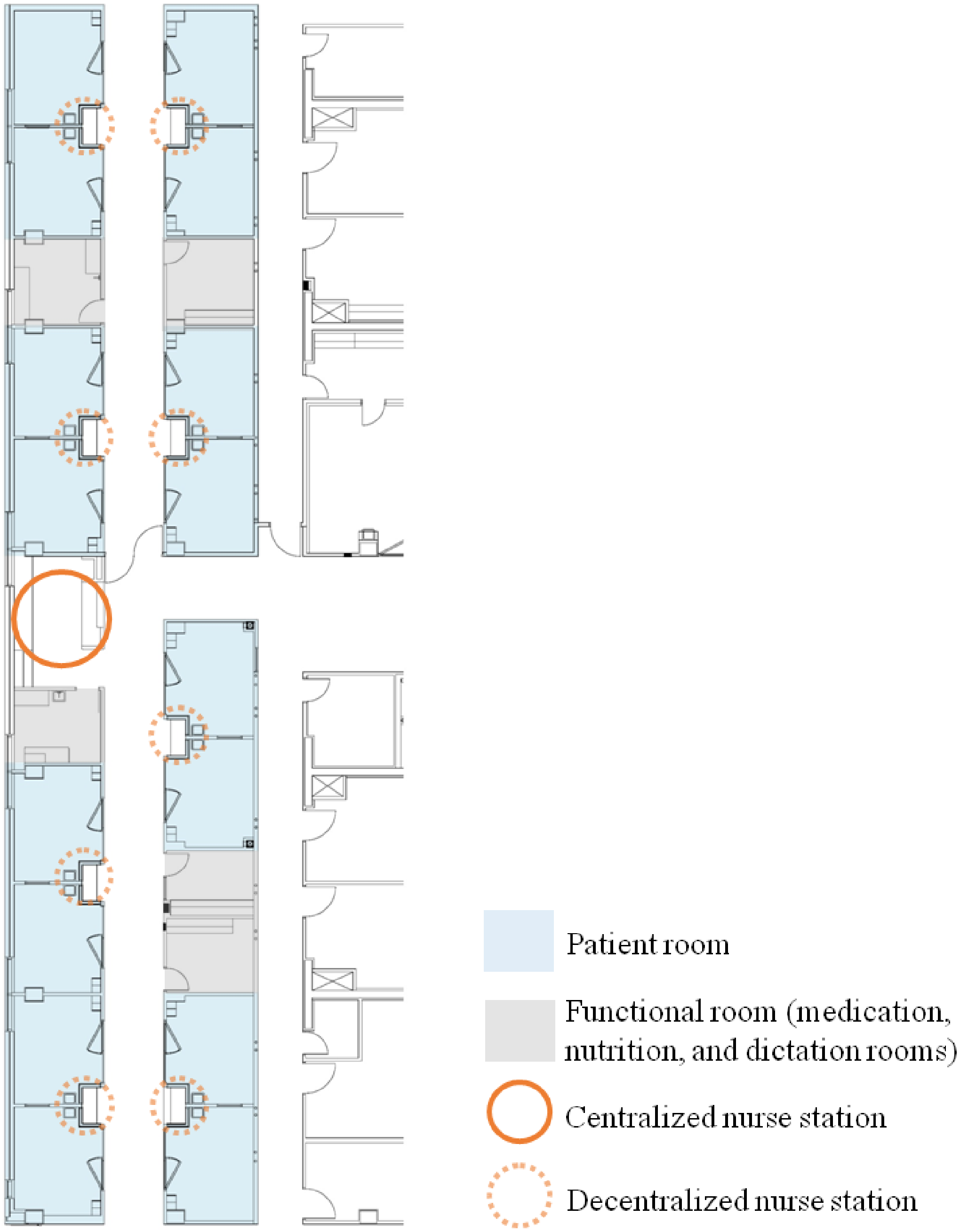


Figure 6.2 Example of an optimized NICU department floor plan

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APPENDIX A

NICU ROOM TYPE & LIGHTING CONDITION QUESTIONNAIRE

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INFORMATION SHEET

You are invited to take part in a research study being conducted by Mardelle Shepley and Yilin Song, researchers from Texas A&M University and funded by the American Institute of Architects' Academy of Architecture for Health and STERIS Corporation (A hospital equipment vender at Mentor, OH, website: http://www.steris.com). The information in this form is provided to help you decide whether or not to take part. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.

Why Is This Study Being Done?
The purpose of this study is to explore how daylighting influences the activities of nurses and families in NICUs.

Why Am I Being Asked To Be In This Study?
You are being asked to be in this study because you are a NICU medical director.

How Many People Will Be Asked To Be In This Study?
Approximately 1000 people will be invited to participate in this study.

What Are the Alternatives to being in this study?
The alternative to being in the study is not to participate.

What Will I Be Asked To Do In This Study?
You will be asked to fill out a questionnaire. Your participation in this study will take about 10 minutes.

Are There Any Risks To Me?
The things that you will be doing are no greater risks than you would come across in everyday life.

Will There Be Any Costs To Me?
Aside from your time, there are no costs for taking part in the study.

Will I Be Paid To Be In This Study?
You will not be paid for being in this study.

Will Information From This Study Be Kept Private?
The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only Mardelle Shepley and Yilin Song will have access to the records.

Information about you will be stored in a locked file cabinet; computer files protected with a password. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

Information about you and related to this study will be kept confidential to the extent permitted or required by law.

Who May I Contact for More Information?
You may contact the Principal Investigator, Dr. Mardelle Shepley, to tell her about a concern or complaint about this research at 979-845-7009 or mshepley@arch.tamu.edu. You may also contact the Protocol Director, Yilin Song at 979-229-3462 or yilin.song@gmail.com.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at (979) 458-4067 or irb@tamu.edu.

What if I Change My Mind About Participating?
This research is voluntary and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, there will be no effect on your medical care, or employment, evaluation, relationship with Texas A&M University, etc.

By participating in the observation, you are giving permission for the investigator to use your information for research purposes.

Thank you.

Dr. Mardelle Shepley
Professor, Director of Center for Health Systems & Design
Texas A&M University

Yilin Song
Doctoral student in Architecture
Texas A&M University

Q1. 1. Hospital Location

This question was not displayed to the respondent.

Q2. 2. Year NICU built or renovated

This question was not displayed to the respondent.

Q3. 3. NICU room type:
3.1. Are there any single family rooms in the NICU?

This question was not displayed to the respondent.

If yes,

	Total number of rooms	Total number of beds
Single family room		

Number of rooms with access to daylight

	by exterior windows only	by interior windows only	by skylight only	by exterior & interior windows	by exterior windows & skylight	by interior windows & skylight
Single family room	0	0	0	0	0	0

Q19. 3. NICU room types:
3.2. Are there any rooms with 2-3 baby beds each?

This question was not displayed to the respondent.

If yes,

	Total number of rooms	Total number of beds
2-3 baby beds per room		

Number of rooms with access to daylight

	by exterior windows	by interior windows with daylight from exterior windows	by skylight	by exterior & interior windows	by exterior windows & skylight	by interior windows & skylight
2-3 baby beds per room	0	0	0	0	0	0

Q21. 3. NICU room type:
3.3. Are there any room with >3 baby beds each?

This question was not displayed to the respondent.

If yes,

	Total number of rooms	Total number of beds
> 3 baby beds per room		

Number of rooms with access to daylight

	by exterior windows	by interior windows with daylight from exterior windows	by skylight	by exterior & interior windows	by exterior windows & skylight	by interior windows & skylight
> 3 baby beds per room	0	0	0	0	0	0

4. Importance of electric lighting in the NICU

Not important at all ○ ○ ○ ○ ○ ○ ○ Very important

5. Importance of daylighting in the NICU

Not important at all ○ ○ ○ ○ ○ ○ ○ Very important

6. Satisfaction with the lighting environment in the NICU

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very satisfied
Single family room	○	○	○	○	○	○	○
2-3 baby room	○	○	○	○	○	○	○
> 3 baby bed room	○	○	○	○	○	○	○

7. Satisfaction with the daylighting in the NICU

	Very Dissatisfied	Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Satisfied	Very satisfied
Single family room	○	○	○	○	○	○	○
2-3 baby room	○	○	○	○	○	○	○
> 3 baby bed room	○	○	○	○	○	○	○

8. Impact of the presence of sufficient daylight on staff and family behavior in the NICU

	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Work efficiency will improve	○	○	○	○	○	○	○
Medical errors will decrease	○	○	○	○	○	○	○
Mental alertness will increase	○	○	○	○	○	○	○
Length of family visits will increase	○	○	○	○	○	○	○
The time that family members leave their baby's room during their visit will decrease	○	○	○	○	○	○	○
Interactions between families and infants will increase	○	○	○	○	○	○	○
Interactions between staff and infants will increase	○	○	○	○	○	○	○

Q8. 9. Additional comments

This question was not displayed to the respondent.

. Please click the ">>" button to finish the questionnaire. Thank you for your time!

This question was not displayed to the respondent.

APPENDIX B

NICU NURSE SATISFACTION WITH LIGHTING ENVIRONMENT QUESTIONNAIRE

NICU Nurse Satisfaction
with Lighting Environment Questionnaire

Please take a few minutes to fill out this questionnaire regarding your satisfaction towards the lighting conditions of the neonatal intensive care unit (NICU) in your hospital and return it to the box on the registration desk. Your feedback will be kept confidential and secure. Thank you very much for your participation.

Part I: Background information

1. What is your gender?
   ☐ Female ☐ Male

2. What is your age?
   ☐ <25 ☐ 25-29 ☐ 30-34 ☐ 35-39 ☐ 40-44 ☐ 45-49 ☐ 50-54 ☐ 55-59 ☐ 60-64 ☐ >65

3. What is your job title? (Please choose all the options that apply to you)
   ☐ Director / CEO ☐ Manager / Administrator ☐ RN / Staff nurse
   ☐ Nurse practitioner / Physician assistant ☐ Certified nurse anesthetist ☐ Clinical nurse specialist
   ☐ Educator ☐ Midwife ☐ Other: ____________

4. How long have you worked in NICUs?
   ☐ Less than 2 years ☐ 2-9 years ☐ 10-19 years ☐ 20-29 years ☐ More than 30 years

Part II: Current lighting environment evaluation

If you work on more than one neonatal unit, please answer the following questions based on the unit where you spend the majority of your time.

5. In what type of patient room do you typically work?
   ☐ Single family room ☐ 2 - 3 baby room ☐ Room with more than 3 baby beds

6. Does the room in which you work have at least one window to the outdoors?
   ☐ Yes ☐ No

Please circle a rating from 1 to 7 regarding the impact of the following lighting qualities on your general visual comfort experience in the NICU patient room in which you typically work.

7. Lighting level	Too dark	1	2	3	4	5	6	7	Too bright
8. Lighting distribution	Poorly distributed	1	2	3	4	5	6	7	Well distributed

9. Glare (If there is no glare, go to question 11) Intolerable 1 2 3 4 5 6 7 Not perceptible

10. Please indicate the glare source (Check all that apply)
☐ Window ☐ Ceiling light ☐ Wall surfaces ☐ Desk surfaces
☐ Reflection on the computer screen ☐ Other: _______________

11. Window views of nature (e.g., trees, plants)
☐ N/A No view 1 2 3 4 5 6 7 Good view

12. Impact of the view outside on your work in the NICU
☐ N/A Negative 1 2 3 4 5 6 7 Positive

13. Overall ambience of room Gloomy 1 2 3 4 5 6 7 Cheerful

14. Based on your answers to the question 7 to 13, please rate your overall satisfaction of the visual environment
Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

When conducting the following work tasks in neonatal units, how would you evaluate the impact of the existing lighting conditions generally? If you don't do the type of work mentioned, please choose N/A.

15. Direct care (e.g., direct communication with patient &/or family, bathing, applying dressings, nursing procedures)
☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

16. Indirect care (e.g., reviewing results, planning care, washing hands, reviewing documentation, returning equipment)
☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

17. Medication task (all tasks associated with medication)
☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

18. Documentation (paper & electronic, excludes medication documentation)
☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

19. Professional communication (non-medication related communication with another health professional)
☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

20. Social (non work communication, e.g., breaks & personal calls)
☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

21. Ward related activities (e.g., coordinating beds & staffing)

☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

22. Supervision (supervising others, including students)

☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

23. In transit (time between tasks and between patients, excludes movement between patients in a shared room and movement within a single room)

☐ N/A Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

24. Other: ____________________ Very dissatisfied 1 2 3 4 5 6 7 Very satisfied

Part III: Importance of lighting

25. How important is good electric lighting in the NICU?

Not important at all 1 2 3 4 5 6 7 Very important

26. How important is good daylighting in the NICU?

Not important at all 1 2 3 4 5 6 7 Very important

---

*Please circle a rating from 1 to 7 regarding the importance of the following **daylight and window related** factors on your work in the NICU.*

27. Appropriate lighting level Not important at all 1 2 3 4 5 6 7 Very important

28. Appropriate lighting distribution Not important at all 1 2 3 4 5 6 7 Very important

29. Providing views of nature Not important at all 1 2 3 4 5 6 7 Very important

30. Appropriate ambience (e.g., gloomy or cheerful) of the room

Not important at all 1 2 3 4 5 6 7 Very important

Part IV: Impact of daylighting on behavior

*Please evaluate the following statements regarding the impact of the presence of sufficient **daylight** on staff and family behavior in the NICU.*

31. Work efficiency will improve	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
32. Medical errors will decrease	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
33. Mental alertness will increase	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
34. Length of family visits will increase	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
35. The amount of time that family members leave their baby's room will decrease during their visit	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
36. Interactions between families and infants will increase	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
37. Interactions between staff and infants will increase	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

38. Please feel free to provide comments or suggestions about the lighting environment (e.g. window operation, lighting, visibility, comfort, etc.) in the NICUs in the space provided below.

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Thank you so much for your participation. Please return the questionnaire to the box on the registration desk.

Photo credit: http://www.carefusion.com/Images/Respiratory/Ventilation/sipap/Infant_Flow_SiPAP_System_002.jpg

APPENDIX C

INSTITUTIONAL REVIEW BOARD APPROVAL LETTERS

C.1 Approval Letter for Cross Sectional Study by TAMU IRB

DIVISION OF RESEARCH

Office of Research Compliance

TEXAS A&M UNIVERSITY

APPROVAL DATE: January 07, 2014

MEMORANDUM

TO:	Mardelle Shepley TAMU - College Of Architecture - Architecture
FROM:	Human Subjects Protection Program Institutional Review Board
SUBJECT:	Initial Review Approval

Study Number:	IRB2013-0832
Title:	The Influence of Daylighting on the Behavior of Nurses and Families in Neonatal Intensive Care Units (NICUs) - Questionnaire
Review Type:	Expedite
Approval Date:	01/07/2014
Continuing Review Due:	12/01/2014
Expiration Date:	01/01/2015

Documents Reviewed and Approved:

Title	Version Number	Version Date	Outcome
updated CITI	Version 1.0	null	Approved
Cover letter-quetionnaire II	Version 1.0	12/16/2013	Approved
Cover letter-quetionnaire I	Version 1.0	12/16/2013	Approved
Authorization letter	Version 1.0	11/20/2013	Approved
Proposal	Version 1.0	11/20/2013	Approved
Grant acceptance letter	Version 1.0	11/20/2013	Approved
Grant application	Version 1.0	11/20/2013	Approved
Questionnaire II-Nurse Satisfaction	Version 1.0	11/20/2013	Approved
Questionnaire I-Room Type	Version 1.0	11/20/2013	Approved
Information Sheet-questionnaire II	Version 1.0	11/20/2013	Approved
Information Sheet-questionnaire I	Version 1.0	11/20/2013	Approved

Provisions:

Comments:

This research project has been approved. As principal investigator, you assume the following responsibilities:

1. **Continuing Review:** The protocol must be renewed by the expiration date in order to continue with the research project. A Continuing Review application along with required documents must be submitted by the continuing review deadline. Failure to do so may result in processing delays, study termination, and/or loss of funding.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written

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papers), a Completion Report must be submitted to the IRB.

3. **Unanticipated Problems and Adverse Events:** Unanticipated problems and adverse events must be reported to the IRB immediately.
4. **Reports of Potential Non-compliance:** Potential non-compliance, including deviations from protocol and violations, must be reported to the IRB office immediately.
5. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB for review. The Amendment must be approved by the IRB before being implemented.
6. **Consent Forms:** When using a consent form or information sheet, you must use the IRB stamped approved version. Please log into iRIS to download your stamped approved version of the consenting instruments. If you are unable to locate the stamped version in iRIS, please contact the office.
7. **Audit:** Your protocol may be subject to audit by the Human Subjects Post Approval Monitor. During the life of the study please review and document study progress using the PI self-assessment found on the RCB website as a method of preparation for the potential audit. Investigators are responsible for maintaining complete and accurate study records and making them available for inspection. Investigators are encouraged to request a pre-initiation site visit with the Post Approval Monitor. These visits are designed to help ensure that all necessary documents are approved and in order prior to initiating the study and to help investigators maintain compliance.
8. **Recruitment**: All approved recruitment materials will be stamped electronically by the HSPP staff and available for download from iRIS. These IRB-stamped approved documents from iRIS must be used for recruitment. For materials that are distributed to potential participants electronically and for which you can only feasibly use the approved text rather than the stamped document, the study's IRB Protocol number, approval date, and expiration dates must be included in the following format: TAMU IRB#20XX-XXXX Approved: XX/XX/XXXX Expiration Date: XX/XX/XXXX.
9. **FERPA and PPRA:** Investigators conducting research with students must have appropriate approvals from the FERPA administrator at the institution where the research will be conducted in accordance with the Family Education Rights and Privacy Act (FERPA). The Protection of Pupil Rights Amendment (PPRA) protects the rights of parents in students ensuring that written parental consent is required for participation in surveys, analysis, or evaluation that ask questions falling into categories of protected information.
10. **Food:** Any use of food in the conduct of human subjects research must follow Texas A&M University Standard Administrative Procedure 24.01.01.M4.02.
11. **Payments:** Any use of payments to human subjects must follow Texas A&M University Standard Administrative Procedure 21.01.99.M0.03.

This electronic document provides notification of the review results by the Institutional Review Board.

DIVISION OF RESEARCH

Research Compliance and Biosafety

DATE: February 11, 2014

MEMORANDUM

TO: Mardelle Shepley
TAMU - College Of Architecture - Architecture

FROM: Human Subjects Protection Program
Institutional Review Board

SUBJECT: Expedited Approval

Study Number: IRB2013-0832

Title: The Influence of Daylighting on the Behavior of Nurses and Families in Neonatal Intensive Care Units (NICUs) - Questionnaire

Approval Date: 01/07/2014

Continuing Review Due: 12/01/2014

Expiration Date: 01/01/2015

Documents Reviewed and Approved:

Title	Version Number	Version Date	Outcome
Email	Version 1.0	01/28/2014	Approved
Questionnaire I-online print version	Version 1.0	01/28/2014	Approved
Study Application	Version 1.2	1/28/2014	Approved

Document of Consent: Waiver approved under 45 CFR 46.117 (c) 1 or 2/ 21 CFR 56.109 (c)1

Comments: Change from paper to online survey.

This research project has been approved. As principal investigator, you assume the following responsibilities:

1. **Continuing Review:** The protocol must be renewed by the expiration date in order to continue with the research project. A Continuing Review application along with required documents must be submitted by the continuing review deadline. Failure to do so may result in processing delays, study termination, and/or loss of funding.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB.
3. **Unanticipated Problems and Adverse Events:** Unanticipated problems and adverse events must be reported to the IRB immediately.
4. **Reports of Potential Non-compliance:** Potential non-compliance, including deviations from protocol and violations, must be reported to the IRB office immediately.
5. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB for review. The Amendment must be approved by the IRB before being implemented.
6. **Consent Forms:** When using a consent form or information sheet, you must use the IRB stamped

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approved version. Please log into iRIS to download your stamped approved version of the consenting instruments. If you are unable to locate the stamped version in iRIS, please contact the office.

7. **Audit:** Your protocol may be subject to audit by the Human Subjects Post Approval Monitor. During the life of the study please review and document study progress using the PI self-assessment found on the RCB website as a method of preparation for the potential audit. Investigators are responsible for maintaining complete and accurate study records and making them available for inspection. Investigators are encouraged to request a pre-initiation site visit with the Post Approval Monitor. These visits are designed to help ensure that all necessary documents are approved and in order prior to initiating the study and to help investigators maintain compliance.
8. **Recruitment**: All approved recruitment materials will be stamped electronically by the HSPP staff and available for download from iRIS. These IRB-stamped approved documents from iRIS must be used for recruitment. For materials that are distributed to potential participants electronically and for which you can only feasibly use the approved text rather than the stamped document, the study's IRB Protocol number, approval date, and expiration dates must be included in the following format: TAMU IRB#20XX-XXXX Approved: XX/XX/XXXX Expiration Date: XX/XX/XXXX.

1. **FERPA and PPRA:** Investigators conducting research with students must have appropriate approvals from the FERPA administrator at the institution where the research will be conducted in accordance with the Family Education Rights and Privacy Act (FERPA). The Protection of Pupil Rights Amendment (PPRA) protects the rights of parents in students ensuring that written parental consent is required for participation in surveys, analysis, or evaluation that ask questions falling into categories of protected information.
2. **Food:** Any use of food in the conduct of human subjects research must follow Texas A&M University Standard Administrative Procedure 24.01.01.M4.02.
3. **Payments:** Any use of payments to human subjects must follow Texas A&M University Standard Administrative Procedure 21.01.99.M0.03.

This electronic document provides notification of the review results by the Institutional Review Board.

C.2 Approval Letter for Case Study by TAMU IRB

DIVISION OF RESEARCH

Research Compliance and Biosafety

TEXAS A&M UNIVERSITY

DATE: March 11, 2014

MEMORANDUM

TO: Mardelle Shepley
TAMU - College Of Architecture - Architecture

FROM: Human Subjects Protection Program
Institutional Review Board

SUBJECT: Expedited Approval – Initial Submission

Study Number:	IRB2014-0043
Title:	The Influence of Daylighting on the Behavior of Nurses and Families in Neonatal Intensive Care Units (NICUs) - Observation
Approval Date:	03/11/2014
Continuing Review Due:	02/01/2015
Expiration Date:	03/01/2015

Documents Reviewed and Approved:

Title	Version Number	Version Date	Outcome
Site Authorization Agreement-RI	Version 1.1	01/21/2014	Approved
RI NICU floor plan	Version 1.0	02/27/2014	Approved
Sarasota NICU floorplan	Version 1.0	02/27/2014	Approved
Approval Letter-Sarasota	Version 1.0	02/20/2014	Approved
Sarasota IRB in processing	Version 1.0	01/21/2014	Approved
Questionnaire	Version 1.0	01/21/2014	Approved
Proposal	Version 1.0	01/21/2014	Approved
Grant application	Version 1.0	01/21/2014	Approved
Grant acceptance letter	Version 1.0	01/21/2014	Approved
Consent Form-observation	Version 1.0	01/21/2014	Approved
Information Sheet-questionnaire	Version 2.0	02/17/2014	Approved
Consent Form-Sarasota	Version 2.0	02/20/2014	Approved
Consent Form-RI	Version 2.0	02/17/2014	Approved

Document of Consent: Written consent in accordance with 45 CF 46.116/ 21 CFR 50.27 for observations
Waiver approved under 45 CFR 46.117 (c) 1 or 2/ 21 CFR 56.109 (c)1 for interviews

Comments: Approval for Sarasota only, Research may not begin at Rhode Island Hospital until IRB approval has been granted. An Amendment should be filed when that approval is granted.

This research project has been approved. As principal investigator, you assume the following responsibilities:

1. **Continuing Review:** The protocol must be renewed by the expiration date in order to continue with the

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research project. A Continuing Review application along with required documents must be submitted by the continuing review deadline. Failure to do so may result in processing delays, study termination, and/or loss of funding.

2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB.
3. **Unanticipated Problems and Adverse Events:** Unanticipated problems and adverse events must be reported to the IRB immediately.
4. **Reports of Potential Non-compliance:** Potential non-compliance, including deviations from protocol and violations, must be reported to the IRB office immediately.
5. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB for review. The Amendment must be approved by the IRB before being implemented.
6. **Consent Forms:** When using a consent form or information sheet, you must use the IRB stamped approved version. Please log into iRIS to download your stamped approved version of the consenting instruments. If you are unable to locate the stamped version in iRIS, please contact the office.
7. **Audit:** Your protocol may be subject to audit by the Human Subjects Post Approval Monitor. During the life of the study please review and document study progress using the PI self-assessment found on the RCB website as a method of preparation for the potential audit. Investigators are responsible for maintaining complete and accurate study records and making them available for inspection. Investigators are encouraged to request a pre-initiation site visit with the Post Approval Monitor. These visits are designed to help ensure that all necessary documents are approved and in order prior to initiating the study and to help investigators maintain compliance.
8. **Recruitment**: All approved recruitment materials will be stamped electronically by the HSPP staff and available for download from iRIS. These IRB-stamped approved documents from iRIS must be used for recruitment. For materials that are distributed to potential participants electronically and for which you can only feasibly use the approved text rather than the stamped document, the study's IRB Protocol number, approval date, and expiration dates must be included in the following format: TAMU IRB#20XX-XXXX Approved: XX/XX/XXXX Expiration Date: XX/XX/XXXX.

1. **FERPA and PPRA:** Investigators conducting research with students must have appropriate approvals from the FERPA administrator at the institution where the research will be conducted in accordance with the Family Education Rights and Privacy Act (FERPA). The Protection of Pupil Rights Amendment (PPRA) protects the rights of parents in students ensuring that written parental consent is required for participation in surveys, analysis, or evaluation that ask questions falling into categories of protected information.
2. **Food:** Any use of food in the conduct of human subjects research must follow Texas A&M University Standard Administrative Procedure 24.01.01.M4.02.
3. **Payments:** Any use of payments to human subjects must follow Texas A&M University Standard Administrative Procedure 21.01.99.M0.03.

This electronic document provides notification of the review results by the Institutional Review Board.

C.3 Approval Letter for Case Study by Hospital IRB

SARASOTA MEMORIAL HOSPITAL
INSTITUTIONAL REVIEW BOARD
1700 South Tamiami Trail
Sarasota, FL 34239

TO:	Mardelle Shepley
FROM:	Mark J. Magenheim, MD MPH, Medical Director IRB Ashley Butler, CIP, Coordinator of the Institutional Review Board
DATE:	January 31, 2014
SUBJECT:	Amendment/Modification; New Study Approval
IRB FILE #:	13-NURS-42
TITLE:	The Influence of Daylighting on the Behavior of Nurses and Families in Neonatal Intensive Care Units (NICUs)
EXPIRATION DATE:	December 16, 2014

Thank you for your submission of Amendment/Modification materials for this research study. The informed consent document was revised in accordance with previous requests for revisions made by the Sarasota Memorial Hospital Institutional Review Board. This research study was previously approved, pending modifications to the informed consent document.

Sarasota Memorial Hospital Institutional Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation. This research study involves no greater than minimal risk to subjects, and involves research on individual or group characteristics or behavior and the use of surveys/questionnaires. The revised informed consent document is APPROVED. This research study is now APPROVED, and you may begin subject enrollment.

Only the Informed Consent document with the SMH IRB Approval Stamp dated January 31, 2014 may be copied and used. This original stamped document will be mailed to you. An electronic copy of this original stamped document is also available on IRBNet.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure. Please note that IRB Approval of this research study will expire on December 16, 2014.

If you have any questions, please contact Ashley Butler, CIP, at (941) 917-6268 or ashley-butler@smh.com. Please include your study title and reference number in all correspondence with this office.

cc: Jennifer Rheingans, PhD, RN

APPENDIX D

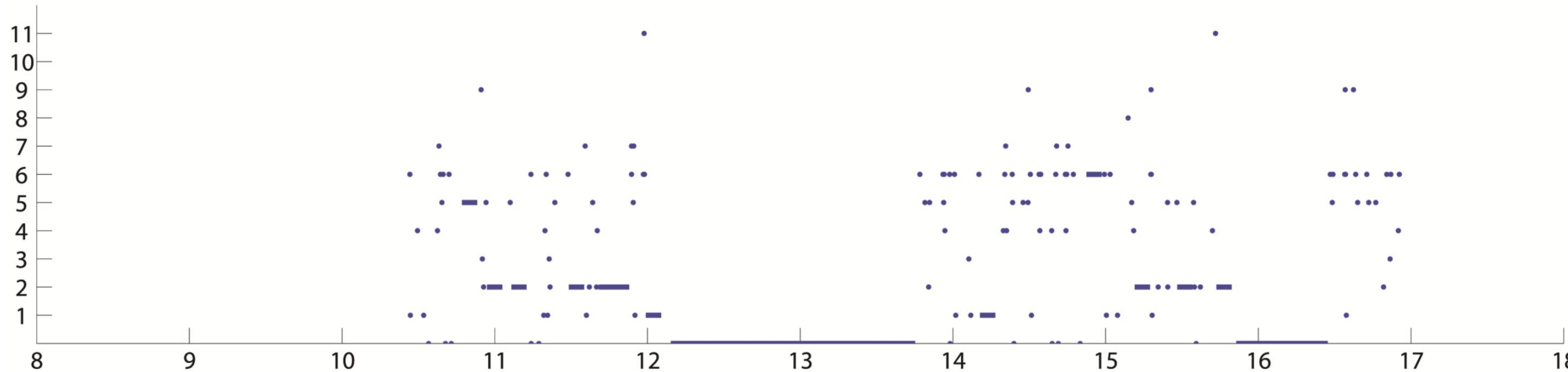
NICU NURSE REAL TIME BEHAVIOR PATTERN

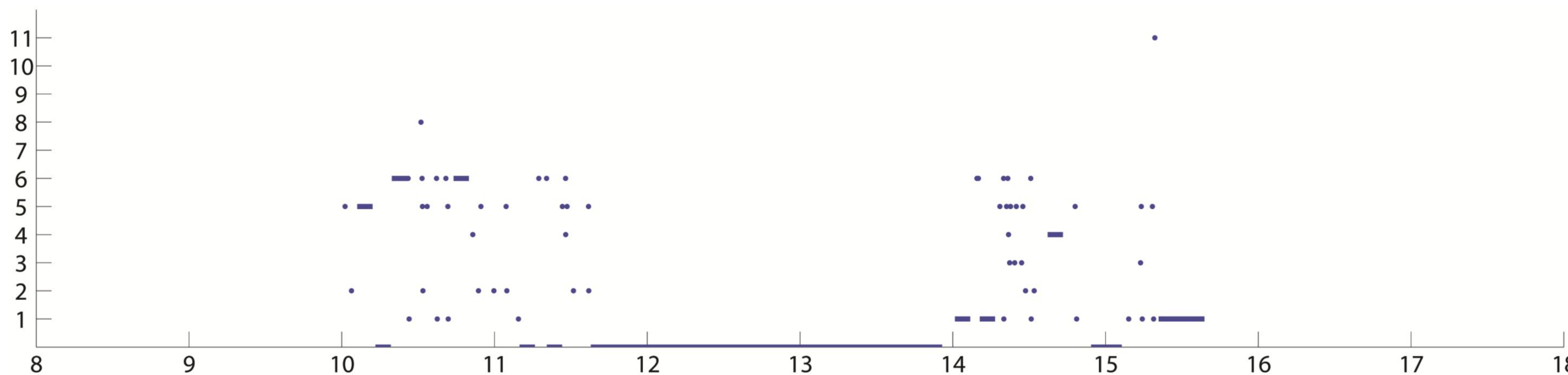
Behavioral code:

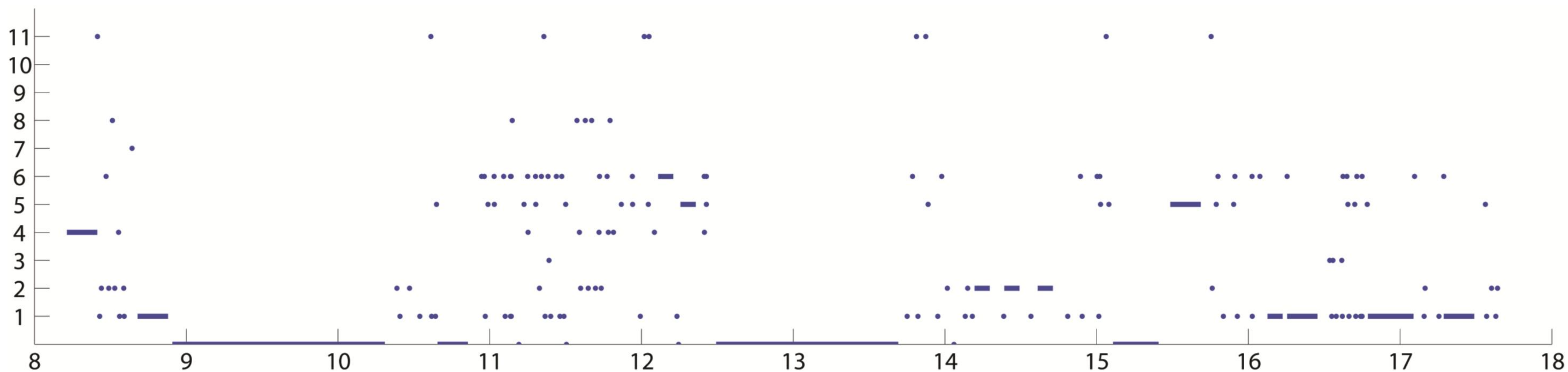
1	Direct care
2	Documentation-computer
3	Documentation-paper
4	Communication-family
5	Communication-staff
6	In transit
7	Indirect care
8	Break & call
9	Ward related
10	Supervision
11	Other

D.1 Nurses taking charge of three rooms all with a window (3Y)

D.1.1 Individual behavior pattern



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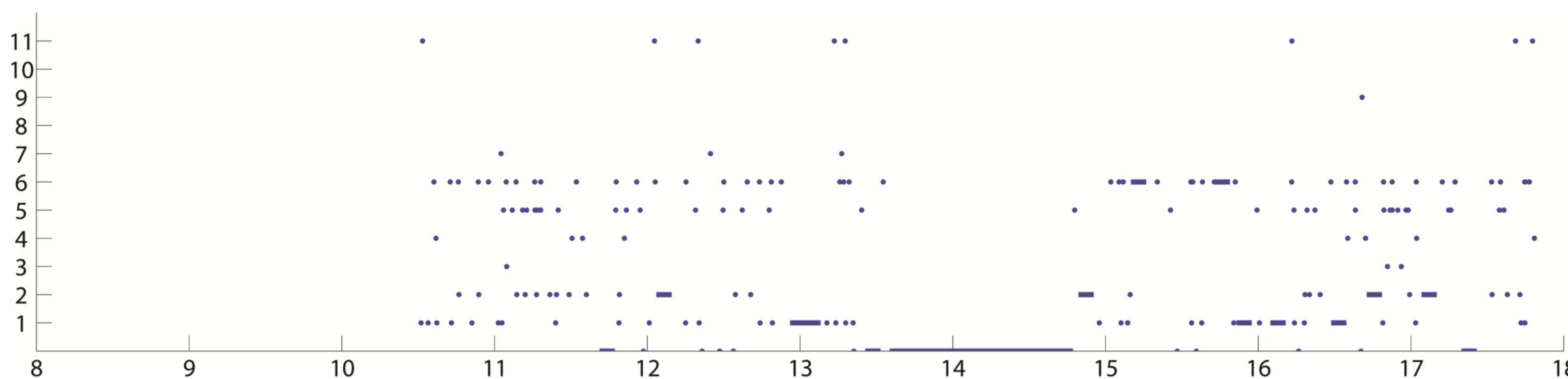
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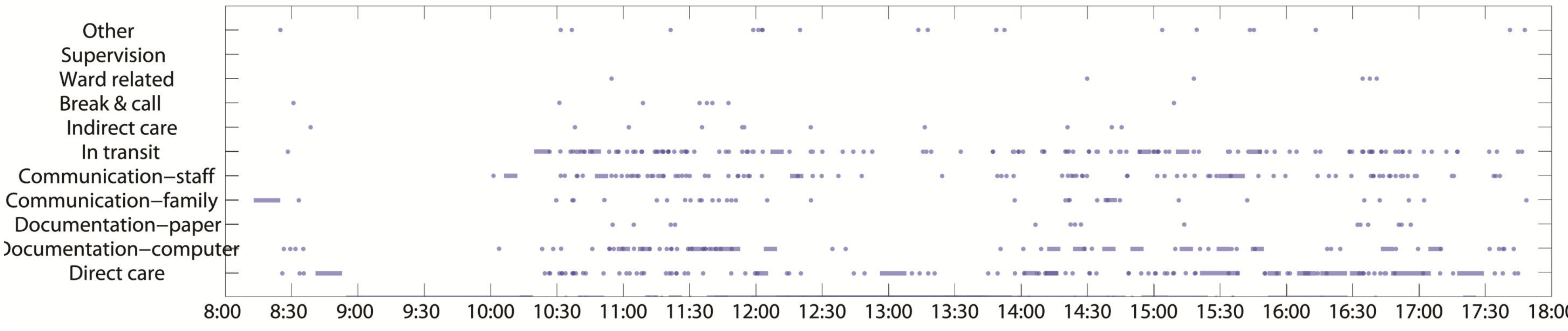
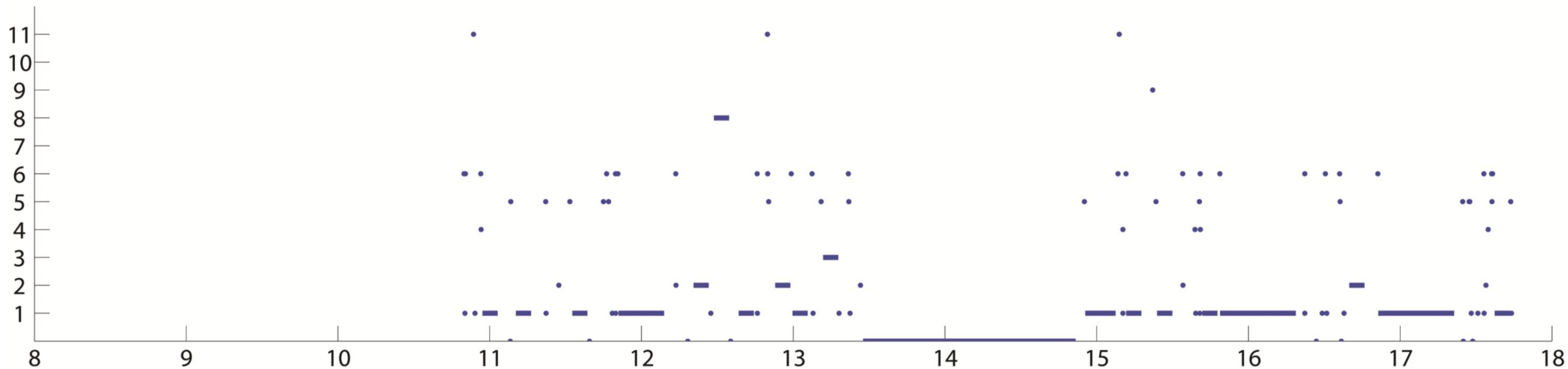
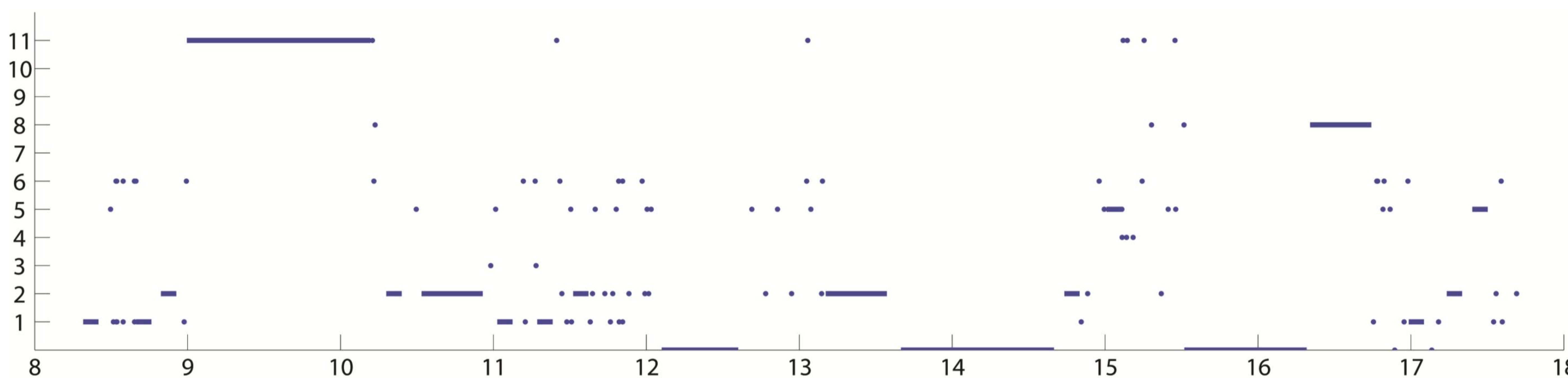
D.1.2 Overlapped behavior pattern of 3Y with 50% transparency of each individual pattern

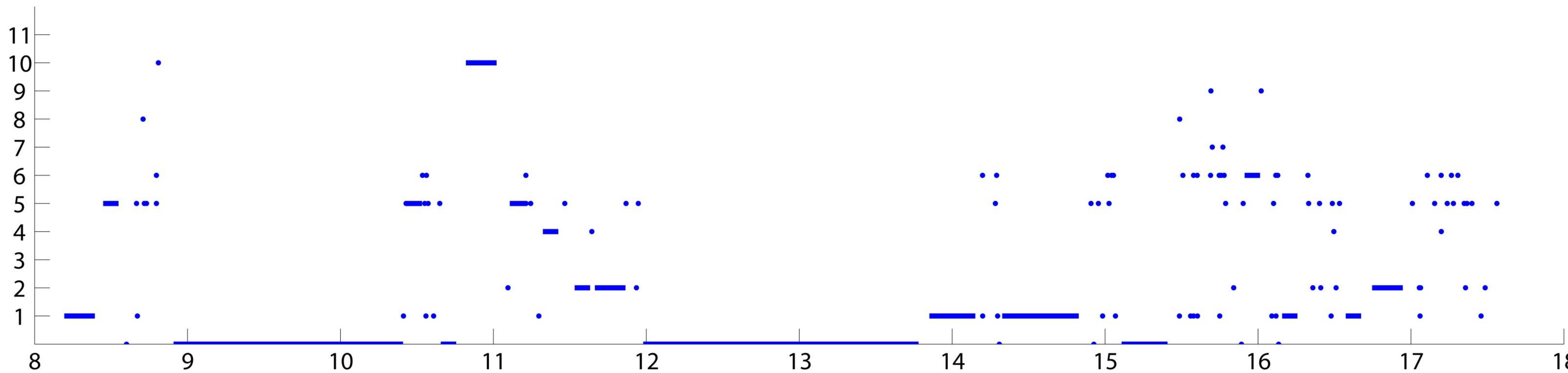


D.2 Nurses taking charge of three rooms all without a window (3N)

D.2.1 Individual behavior pattern







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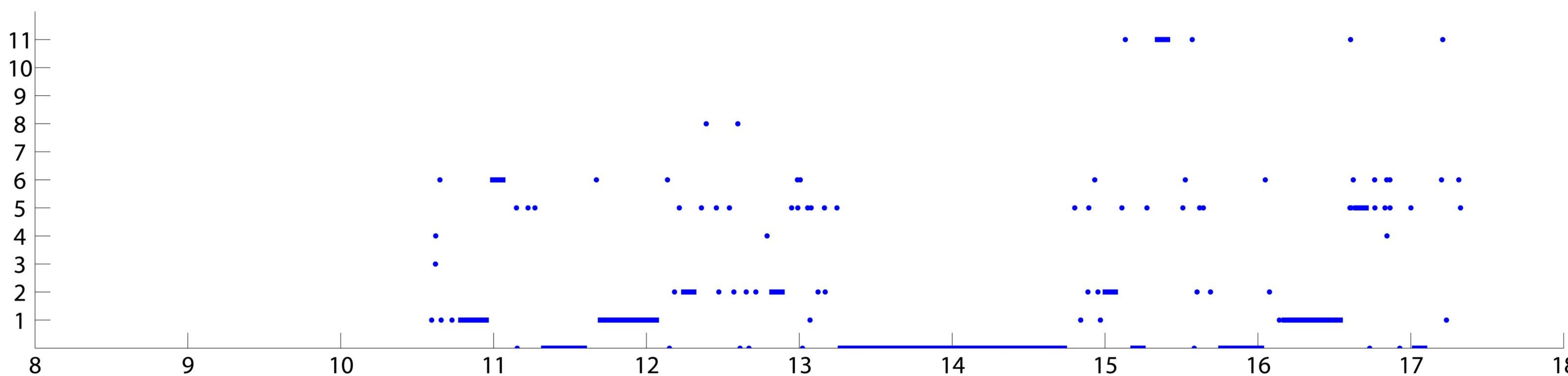

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D.2.2 Overlapped behavior pattern of 3N with 50% transparency of each individual pattern