# STUDY OF THE RELATIONSHIP BETWEEN INDOOR DAYLIGHT ENVIRONMENTS AND PATIENT AVERAGE LENGTH OF STAY (ALOS) IN HEALTHCARE FACILITIES

A Thesis

by

JOON HO CHOI

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

MASTER OF SCIENCE

December 2005

Major Subject: Architecture

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Approved by :

| | |
|---|---|
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December 2005

Major Subject: Architecture

# ABSTRACT

Study of the Relationship between Indoor Daylight Environments and Patient Average Length of Stay (ALOS) in Healthcare Facilities. (December 2005)

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This study investigates how indoor daylight environments affect patient Average Length of Stay (ALOS), by evaluating and analyzing daylight levels in patient rooms in comparison to their ALOS. The patient ALOS data were taken at one general hospital in Inchon, Korea and the other in Bryan, Texas, U.S.A.; physical, environmental and daylighting conditions were assessed at each building site. The gathered data were analyzed using SPSS statistical package to determine the trends in patients' length of stay in hospital wards with 95% and 90% statistical significances. The data were categorized based on the orientation of a patient room and were compared between different orientations and types of patient rooms in the same ward of each hospital.

Selected hospital wards were classified based on their orientations and types of patient rooms. The other variables considered in the study were: the differences in daylighting environments (illuminance, luminance ration, daylight factor, diversity and uniformity of illuminance), and physical environment properties of the patient rooms of

each hospital, and how these affected patient ALOS in both locations (Inchon and Bryan). To analyze the daylighting environment, on-site measurements, RADIANCE simulations and physical scale model measurements were conducted. This study also investigated patients' feelings and opinions, and their preferences in daylighting environments with the questionnaire survey.

Through this study, three hypotheses were tested and was evidence for the following conclusions.

First, there may be a positive relationship between indoor daylight environments and ALOS. Second, seasonal weather differences cause different indoor daylighting levels and may influence the length of patient hospitalization. Third, overall patient satisfaction and reactions to patient rooms may be related with indoor daylight environments. More controllable shading devices, naturally lighted indoor environments, and glare prevention create positive outcomes for patient ALOS and visual comfort.

To increase the validity and confidence about the positive effects of daylight on human physiological conditions, further studies are necessary which provide more samples, facilities and other variables.

This study was created as a basis for the development of recommendations for designing patient rooms in healthcare facilities and, as a result, should be used to achieve more effective healing environments.

For my father and mother

who have taught the love of learning and education

as the most important thing in life.

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I am deeply grateful to my wife, Sunhee, and her family for their endless love. From the time we met 7 years ago Sunhee has brought so many changes to my life and continues to inspire me.

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# 1. INTRODUCTION

## 1.1. BACKGROUND

Saving energy has been a hot issue in every society. The increasing energy cost in the last decades has made people concentrate on developing energy saving strategies in construction and in the design of buildings. One of the energy saving architecture design strategies is reducing the admitted amount of daylight to indoor areas. This method is cost effective and popularly used for reducing energy consumption. To accomplish energy efficiency, many researchers and engineers have concentrated on intercepting solar rays into indoor environments and using heavily tinted glasses, sun shading devices, and other tools for blocking natural light.[1]

As our societies rapidly have developed and changed rapidly, people have become concerned about indoor environment quality. Human preferences on design buildings are not based on energy savings, but on occupants' satisfaction with their indoor environments. As one of the components, views and daylight through windows in buildings are recognized as an important factor in increasing the Indoor Environment Quality (IEQ).

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This thesis follows the style and format of the *Journal of the Illuminating Engineering Society.*

As a result, recent researches were focused on the beneficial aspects of spaces regarding windows, window views and daylight.

A study by Roger Ulrich shows the importance of window views to nature by suggesting that natural elements make quick and positive psychological status that are very beneficial for occupants reduce physiological stress.[2]

Kuller stated that "the health and behavior of children in classrooms have significant differences in concentration, stress and growth hormones when comparing significant environments with and without windows".[3] Those conclusions are further supported by Heschong Lisa who found that "students in classrooms with the most window area or daylight were found to have 7% to 18% higher scores on standardized tests than those with the least window area or daylight".[1]

However, there are few studies showing the orientation of windows and healthcare facilities that are related with the amount of inside daylight with the thought of architectural components. Indoor environments in healthcare facilities are particularly critical to patients' well-being. The most patient rooms that Roger observed had the same size windows and volume of spaces regardless of orientation and daylighting conditions.

Ulrich states that "the patients with tree views have shorter postoperative hospital stays, fewer negative evaluative comments from nurses, fewer moderate and strong analgesic doses, and slightly lower scores for minor post surgical complications". This research finally shows the natural scene had a positive influence on patients' outcomes. [4]

However, in densely populated urban areas, it is difficult to provide natural forest window scenery and well-decorated gardens.

Thus, this study begins with the hypothesis that as facility orientation determines indoor daylight levels, it will also affect the health outcomes of patients in the area. This study focuses on how indoor daylighting level and patients' hospitalization length of stay are correlated with each other in healthcare facilities.

## 1.2. RESEARCH OBJECTIVES

As discussed earlier, the goal of this study is to provide architects and daylighting researchers with information on the impact of daylight on the length of patient hospitalization in healthcare facilities. The particular emphasis of the study is placed on the correlation between indoor daylight environments and patient average length of stay with recognizing seasonal patterns in healthcare facilities.

To achieve this goal, the specific objectives of this study are defined as follows:

- To understand the environmental variables to impact on patient health outcome.
- To understand positive and negative effects on daylight on human
- To evaluate how the illuminance levels are changed by the solar position and building orientations.
- To estimate the amount of daylight in patient rooms.

- To analyze ALOS (Average Length of Stay) and statistically significant differences in hospitalization length of patients who stay in each different orientation. ALOS is used as an indication of patients' recovery and health improvement in this study.
- To investigate the co-relationship between the daylighting level and ALOS.

## 1.3. RESEARCH HYPOTHESIS

This study is based on the hypotheses that indoor daylighting environment may have effects on patient hospitalization length in healthcare facilities. In order to address the objectives of the study, the following three hypotheses are tested:

1) There is a relationship between indoor daylight environments and ALOS(Average Length of Stay).

2) Seasonal weather differences make different indoor daylighting level and influence the length of patient hospitalization. Differing sun paths in each season make different daylighting level. Those environments provide different daylighting condition with patient rooms.

3) Overall patient satisfaction and feeling about patient rooms are related with indoor daylighting environment. Indoor daylight impacts the atmosphere and mood of patient rooms.

## 1.4. RESEARCH APPROACH

First, literature on impacting patient length of stay and general effects of daylighting on human are reviewed.

Second, in selected healthcare facilities, the illuminance levels are measured. The reflectance properties of indoor facility materials are also investigated. Those data are used for verifying the result of daylighting simulation program (RADIANCE). RADIANCE is used to test the daylighting level in patient rooms. To verify the data from RADIANCE, the data of on-site measurement and simulation calculation are compared in the case of Inha University Hospital, Inchon, Korea, and, the data of on-site measurement, RADIANCE, and scale model are compared with each other in the case of St. Joseph Regional Health center, Texas, U.S.A.

Third, the data of patients' hospitalization times in each orientation of selected wards in the hospitals are collected. The data are categorized based on the orientation of a patient room. The data are analyzed and compared with statistics theory.

Fourth, the significant difference of patient hospitalizations between orientations in a same ward in each hospital is investigated with a statistical method (with 95% significance).

Fifth, the correlation analysis between indoor daylighting environment in patient rooms and ALOS would be analyzed monthly. A few variables related daylighting; average illuminance level, and direct solar radiation time, are used for correlational analysis with ALOS.

Sixth, through the questionnaire survey, patients' feelings and opinions, and their preference in daylighting will be investigated.

Figure 1 shows the general procedure of this study.

To minimize other variances in patient recovery rates, this study is performed with the following assumptions to maintain its objectivity:

- Leaving the hospital is regarded as recovery.
- Patients leaving without staff permission happen with the same frequency in each ward.
- Variables other than indoor daylighting level are not considered in indoor physical environment.
- The qualities of other environmental factors are regarded as equivalent.
- The medical treatment quality of each nurse and doctor has no significant differences in each ward.

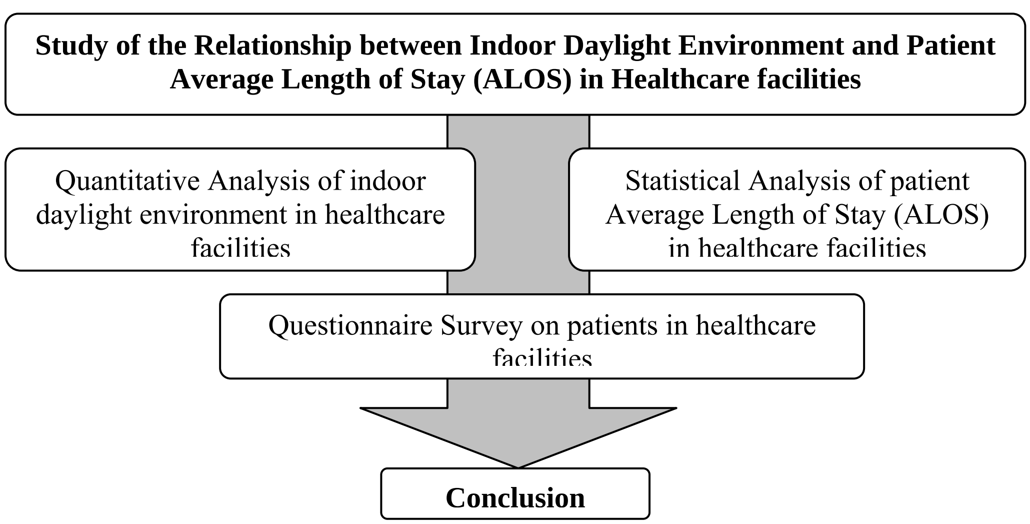



**Figure 1-General procedure of the study.**

## 1.5. SCOPE AND LIMITATIONS

Because the effects of daylight in a patient room are complex, there are many psychological and physiological effects of daylight on occupants in buildings. Moreover, other variables also influence patients' recovery and their psychological condition. This study only focuses on the patients' hospitalization length and indoor daylight environment. It is a correlational research with the two variables: the length of patient hospitalization and indoor daylight environments in patient rooms.

Because of the difficulties accessing patient medical data and their symptoms during the hospitalization, in this study the data of length of patients' hospitalization are used as an indication of patient recovery and health improvement. The length of stay is defined as day of treatment to day of discharge.

For on-site daylighting measurements, one or two sampled patient rooms that can be representative in each ward are investigated. Based on the on-site measurement data, overall daylighting environment of a patient room are simulated via a computer program. Because there are variances in material properties of scale models and computer simulated models, the simulated models may be different from real patient rooms in detail.

Particularly, the results of the study do not consider each patient's physiological condition and potential differences in indoor environments

# 2. LITERATURE REVIEW

## 2.1. VARIABLES AFFECTING PATIENT HEALTH OUTCOMES

### 2.1.1. Psychological variables

Patient physiological processes for recovery are complex and difficult to prove objectively. The most important thing to patient recovery is the quality of care given from medical staffs in hospitals. However, the quality of the physical environment is also important for patient recovery. It is significantly related with specific stressors, which affect the patient. One study shows that "patient stress is centrally important because it is both a significant outcome in itself, and it directly affects many other health outcomes".[5] Those health effects are from the stress whose responses include several kinds of psychological and physiological changes.[6]

Patient health outcomes are significantly related with stress. Ulrich suggests that "green gardens can remove the effects of stressors from patients". He proposes that "sense of control and access to privacy, social support, physical movement and exercise, and access to nature and other positive distractions are important stress mitigating resources for patients".[7] Another study of Ulrich shows the importance of window views to nature by insisting that natural window views are beneficent for patients to reduce physiological stress.[2] Such psychological access to patient health outcomes can help to effectively mitigate patients' stress and their health outcomes. Unfortunately, in the healthcare facilities of urban areas, well-designed gardens are rare for patients. Of particular concern are old hospitals as they rarely have special facilities designed to aid patients' recovery.

### 2.1.2. Environment architectural variables

From the viewpoint of environmental architecture, there are several variables that have impacts on human physiological conditions. Human health and comfort are major concerns in environmental architecture. Moreover, "comfort" is regarded as a basic need for human health. A positive definition of comfort is "a feeling of well-being". This thought is based on environmental variables; "thermal condition, humidity, indoor air quality, visual comfort, and acoustic comfort". Depending on different degrees of the environmental variables, human physical conditions are changed and exhibited differently.[8] As a result, those environmental components are necessary for positive healing outcomes.

Today, mechanical engineers can efficiently control the indoor environment. As a result, the control of conditioned space is usually met with patients' environmental requirements for physical comfort. Therefore, all environmental variables in healthcare facilities may positively affect patients' outcomes if those could be controlled properly.

### 2.1.3. Functions of a window

The major function of a window can be categorized into the following; "Daylight, ventilation, view and privacy, and contribution to general visual character".[9]

Among the functions, Ulrich indicated window views to nature to be significantly helpful to patient outcomes. Moreover, window views can provide a positive distraction to patients and subsequently reduce their stress.[2]

Another major function of windows is to admit daylight to indoor areas. There are psychological and qualitative benefits from the use of daylight in buildings. Because daylight is a full spectrum light, the quality of natural illumination is highly desirable.[10]

The result of Kuller and Lindsten's study indicated that "working in classrooms without daylight may influence the basic hormone pattern in children, and this in turn may influence the children's ability to concentrate or cooperate, and also eventually have an impact on annual body growth and sick leave".[3] The influence of daylight intensity variation (about 3,000 lux to 60,000 lux) on psychological responses is small, but larger windows are typically preferred.[10,11]

## 2.2. DAYLIGHT AND HUMAN HEALTH

### 2.2.1. Seasonal Affective Disorder (SAD)

Seasonal Affective Disorder (SAD) is a mood disorder associated with depression episodes and related to seasonal variations of light.[12] "SAD is a type of winter depression in particular during December, January and February. It is caused by a biochemical imbalance in the hypothalamus due to the shortening of daylight hours and the lack of sunlight in winter".[13] In some cases, because of the orientation of a building, rooms may be so dark that people can suffer from insufficient daylight. Such cases can perpetuate SAD symptoms.

Kripke supports this fact by stating that "spending an extended period of time in a dark room can potentially disrupt the circadian rhythms so much that a person who suffers from SAD may experience severe depressive episodes".[14]

As treatments for SAD, phototherapy or bright light therapy improves and prevents the symptoms of SAD. The National Mental Health Association recommends more daylight can be effective on the symptoms of SAD. "Spending time outdoors during the day or arranging homes and workplaces so that they receive more sunlight may be beneficial".[12] SAD Association shows that light therapy has been proven effective in up to 85 percent of diagnosed cases.[13] Therefore, occupants in dark or dimmed rooms may experience SAD symptoms. More daylight could be effective in preventing or improving the symptoms.

### 2.2.2. Visual comfort and glare

"Light sources of excessive brightness or uneven distribution in the field of view can cause glare of varying degrees from a mild sensation of discomfort to an intolerable feeling of pain".[15] Glare is usually due to an excessive light. Such visual discomfort causes people to experience tension headaches, eyestrain and visual fatigue.[16] As a result, excessive daylight may be a stressor which causes negative effects in people.

According to CIBSE (Chartered Institute of Building Services Engineers), the recommended illuminance level at floor level in patient rooms should be 300 lux (Table 1), and high luminances in the patients' field of view should be prevented. From the psycho-physiological aspects such as visual comfort and well-being, illuminance level in patient rooms is highly emphasized.[17] This is due to the fact that patients in hospitals are more sensitive to their environments and become depressed relatively more easily.

| | **CIBSE (2002)** [17] | **IES (2000)** [18] |
|---|---|---|
| General Lighting | 100 lux | 75-200 lux |
| Reading Lighting | 300 lux | 200-350-500 lux |

**Table 1- Recommendations for a patient room (Illuminance at floor level).**

However, bright light is not necessarily always good for patients. Glare from windows should be covered when direct sunlight falls on a light-colored surface in the immediate field of view in patient rooms. Solar control is essential in most buildings;

this may be in the form of the design of the building's overall shape and orientation, or the use of external screens and louvers, or internal blinds and curtain.[17] But, most healthcare facilities based on pursuing economical profit have uniformed patient rooms and give little consideration for the brightness of the rooms' orientation. Such facilities having various environments can cause stress to patients who stay in relatively bad indoor areas where there exists too little or too much daylight.  Thus, glare should be carefully considered to prevent it from harming the health of individuals.

### 2.2.3. Circadian rhythms

Circadian rhythms mean biological systems that repeat about every 24 hours. These rhythms are controlled by melatonin. "Disruption of the melatonin circadian cycle can result in poor sleep quality, seasonal depression, and immune deficiencies". Depending on the timing of the light exposure, the circadian rhythms can be delayed or advanced. "Because the human circadian clock needs to be phase advanced every day in order to be entrained with the day/ night cycle, the timing of the light exposure is very important".[19] A free running sleep/wake cycle can cause a lot of stress physically and mentally.[20]

In brief, such an unwillingly irregular life pattern causes negative effects on human health, so daylight in indoor areas is important to prevent and to improve the problem of abnormal circadian rhythms.

### 2.2.4. Daylight and human performance

The Heschong Mahone Group (HMG) directed a study about daylight and human performance; to quantify the effect of daylighting on human performance. They found that "students with the most daylighting in their classrooms progressed 20% faster on mathematics test and 26% faster on their reading examinations over those in classrooms with the least amount of daylighting".[21] The results of this study consistently show a very positive and significant correlation between daylighting and improvement in the academic performance and work efficiency.[21,22] Consequently, daylight may be a primary factor in human performance.

## 2.3. DAYLIGHTING IN ARCHITECTURE DESIGN

### 2.3.1. Daylighting in healthcare facilities

As a design feature, admitting daylight in indoor areas makes a more pleasing and productive environment for occupants. Daylighting directly delivers and distributes natural light. It can improve visual performances and enhance visual comfort.[23] Daylight has essential components, which allow occupants a greater satisfaction level when introduced into indoor environments.

Ne'eman stated that patients are eager for natural light in the patient rooms. He interviewed occupants in four types of buildings; houses, schools, offices and hospitals, around London, England. A total of 375 responses have been examined, as shown in Figure 2.[24]

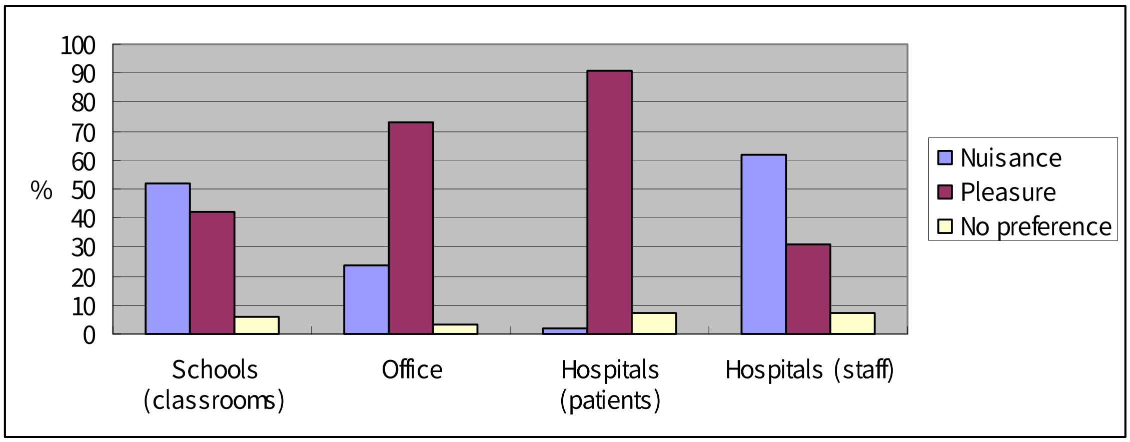



**Figure 2-Preferences of sunhsine inside building as a pleasure or a nuisance.**

According to Figure 2, over 90% of patients in hospitals answered that sunshine was pleasant in the building. However, just about 30 % of the staff considered sunshine to be pleasant in their environment. The author indicates the reason may stem from their mobility. He says "staffs have the option of leaving the premises and experiencing daylight more easily than patients who have low mobility".[24] Like this, the role of daylight through windows of patient rooms in healthcare facilities is very positive especially for patients, and should be examined to a greater extent.

### 2.3.2. Daylight as a traditional architectural design component

The orientation of the building for admitting daylight is one of the major components in the building design. Traditionally, buildings have been designed to be oriented to the south in the northern hemisphere as this optimizes thermal and lighting conditions. Today, in a few Asian countries, people focus their attention on selecting site and orientation before building their houses. The natural light condition is one of the more important components for obtaining an auspicious location and is further analyzed using Feng-Shui theory to create the perfect healthy environment. The theory suggests that each orientation has a seasonal property (east-spring, south-summer, west-fall, and north-winter). These seasons represent the thermal properties of each orientation of individual facilities in a house or a building. It has been a useful design strategy for Korean traditional architecture plans. Rooms arranged with poor orientation could cause occupants to catch seasonal diseases like colds or heatstroke. [25]

As a result, from the view point of Korean traditional architecture, building a house facing the south optimizes lighting and thermal effects on the occupants in such a house. As a result, building orientations are related to daylight conditions and, therefore, to occupants' physiological conditions.

### 2.3.3. Daylight vs. electric light

Even though daylight and electric light may have the same illuminance level, the properties of daylight and electric light are different through the human perspective. The emotional and physiological effects are especially dissimilar.

The Heerwagen couple in 1986 showed their survey results about occupants in whether they preferred daylight or electric light for different psychological physical needs in Table 2. It shows daylight is regarded as a better light source than electric light. It is preferred more for physiological reasons like psychological comfort, general and visual health, and environmental appearance. There are just minor differences in the preference between daylight and electric light in work performance and jobs requiring fine observation.[26, 27] Like this, daylight is clearly preferred over electric lighting as a source of illumination. Even though daylight and electric light have the same lighting level, occupants may prefer daylight for their physiological comfort. For human health reasons, electric light should not be substituted for daylight.

| | **Daylight better** | **Electric better** | **Both equal** | **No opinion** |
|---|---|---|---|---|
| For psychological comfort | 88 % | 3 | 3 | 6 |
| For office appearance and pleasantness | 79 | 0 | 18 | 3 |
| For general health | 73 | 3 | 15 | 8 |
| For visual health | 73 | 9 | 9 | 9 |
| For color appearance of people and furnishing | 70 | 9 | 9 | 12 |
| For work performance | 49 | 21 | 27 | 3 |
| For job requiring fine observation | 46 | 30 | 18 | 6 |

**Table 2-Percent of occupants preferring daylight or electric light for different psychological physical needs.**

# 3. EXPERIMENT DESIGN

In this research, on-site measurement, scale model and computer simulation were used to evaluate indoor daylighting in patient rooms in healthcare facilities. As for the analysis of the Patient Average Length of Stay (ALOS), Analysis of Variance (ANOVA) method was used with a statistics computer program, SPSS.

There are a few variables which are used for analyzing the indoor daylighting environment. Table 3 summarizes the variables for daylight and the programs used. The analysis variables are discussed in the section of 3.2.

| Feature | Variable |
|---|---|
| Interior Lighting Analysis | Daylight Factor |
| | Luminance Ratio |
| | Illuminance |
| | Diversity of Illuminance (Gradient) |
| | Illuminance Uniformity |
| Exterior Lighting Analysis | CIE sky condition |

**Table 3-Variables analyzed in the study.**

## 3.1. METHODOLOGY FOR ANALYSIS TOOLS

### 3.1.1. On-site measurement

In the two hospitals, St. Joseph Regional Health Center, Bryan, Texas and Inha University Hospital, Inchon, Korea, on-site measurements are conducted to verify the output data from the scale model and RADIANCE. In each case, four reference points are selected and measured in specific dates.

**Figure 3-Illuminance meters (Minolta T-10M (left) and T-10).**

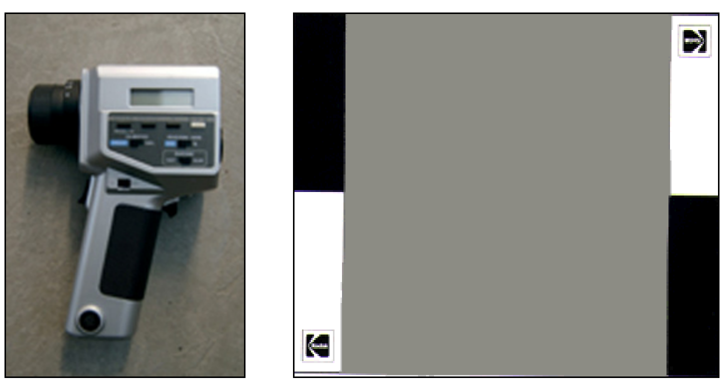


**Figure 4-Luminance meter (left) (Minolta LS-100) and Gray card (Kodak).[28]**

For the measurements, two illuminance meters are used. Minolta T-10 is used for interior measurements, and Minolta T-10M is used for exterior measurements (Figure 3).

The luminance meter is used along with Kodak Gray card to investigate the reflectance values of interior materials in patient rooms of each hospital (Figure 4).

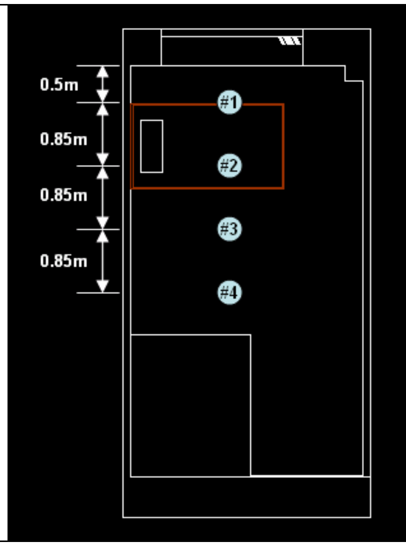
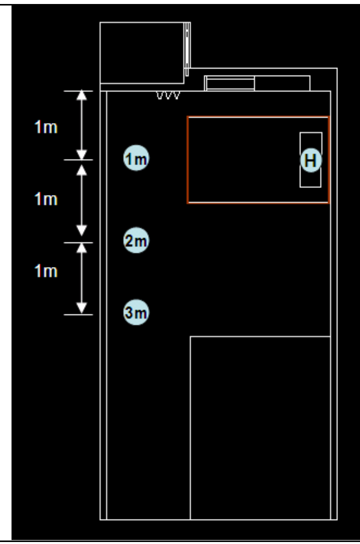
| | **Inha University Hospital** | **St. Joseph Regional Health Center** |
|---|---|---|
| Reference points |  |  |
| Height (from floor) | 0.95 m | 0.95 m |

**Table 4-Reference points.**

As Table 4 shows, the reference points used for on-site measurements. The measured values are compared with the values from the RADIANCE model and the scale model to estimate the discrepancy between the two models.

### 3.1.2. Physical scale model

A physical scale model (Figure 5) is constructed to check the illuminance of St. Joseph Regional Health Center and to verify the output data of RADIANCE with reducing the size to the 1:10 scale. The scale model is made with Crescent boards that are matched with the almost same reflectance values in RADIANCE model and actual site of St. Joseph Regional Health Center. The reference points are used with the same of on-site measurements at St. Joseph Regional Health Center (Table 4).

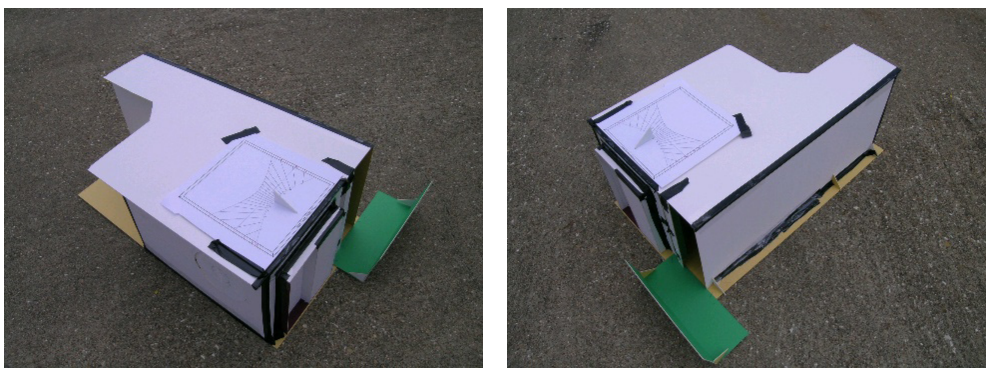


**Figure 5-The scale model of a patient room of Inha University Hospital.**

The scale model is measured with the illuminance meters (Figure 3) with the same process as on-site measurement are conducted. It has to be tilted to make the reference time and dates same with when on-site measurement are performed. The sundial has the same latitude (30.6º N) and longitude (+96.31º) of Bryan, Texas

### 3.1.3. RADIANCE

The Lighting simulation program, RADIANCE, was used to test the illuminance and luminance level in this study. To verify the output data from RADIANCE, the calculated data produced by RADIANCE were compared with the data from the site and scale model measurement. There are two versions of the RADIANCE program; the Desktop RADIANCE (windows base) and the UNIX RADIANCE. RADIANCE was initially developed as a lighting research tool based on the UNIX system, which is complex text-based. Desktop RADIANCE (version 2.0B) uses the same engine as that of UNIX RADIANCE. RADIANCE was developed primarily for the U.S. Department of Energy.[29]

RADIANCE is a suite of programs for the analysis and visualization of lighting in design. The primary advantage of RADIANCE over other lighting calculation and rendering tools is that there are no limitations on the geometry or types of materials that may be simulated. Radiance is used by lighting professionals and engineers to predict illumination, visual quality and appearance of innovative design spaces, and by researchers to evaluate new lighting and daylighting technologies.[29] In this study, the parameters of "Rtrace" calculation are shown in Table 5. The "Rtrace" is the calculation of the trace of rays in the RADIANCE scene.[30]

| Parameter | Description | Value |
|---|---|---|
| -ab | Ambient bounce | 5 |
| -aa | Ambient accuracy | 0.2 |
| -ad | Ambient division | 500 |
| -ar | Ambient resolution | 19 |
| -as | Ambient supers-samples | 64 |

**Table 5-Rtrace parameters in RADIANCE.**

### 3.1.4. SPSS

SPSS is a software package used for conducting statistical analyses, manipulating data, and generating tables and graphs that summarize data. Statistical analyses range from basic descriptive statistics, such as averages and frequencies, to advanced inferential statistics, such as regression models, analysis of variance, and factor analysis. SPSS also contains several tools for manipulating data, including functions for recoding data and computing new variables as well as merging and aggregating datasets.[31] SPSS also has a number of ways to summarize and display data in the form of tables and graphs.[32] In this study, SPSS is used for ANOVA with 95% and 90% significance level.

#### 3.1.4.1. ANOVA

ANOVA stands for Analysis of Variance. It is a basic statistical technique for analyzing experimental data. Analysis of variance (ANOVA) is used to uncover the main and interaction effects of categorical independent variables (called "factors") on an interval dependent variable. [33]

It subdivides the total variation of a data set into meaningful component parts associated with specific sources of variation in order to test a hypothesis on the parameters of the model or to estimate variance components. In this research, one way analysis of variance was used. It compares several groups of observations, all of which are independent but possibly with a different mean for each group. A test of great importance is whether or not all the means are equal. [33]

The formulas for the t-test (a special case of one-way ANOVA), and for the F-test used in ANOVA, thus reflect three things: the difference in means, group sample sizes, and the group variances. That is, the ANOVA F-test is a function of the variance of the set of group means, the overall mean of all observations, and the variances of the observations in each group weighted for group sample size. That is, the larger the difference is means, the larger the sample sizes, and/or the lower the variances, the more likely a finding of significance. One-way ANOVA tests differences in a single interval dependent variable among two, three, or more groups formed by the categories of a single categorical independent variable. This is the method used in the study.[34]

#### 3.1.4.2. Statistical significance level

In statistics, a result is significant if it is unlikely to have occurred by chance, given that a presumed null hypothesis is true. More precisely, in traditional frequent statistical hypothesis testing, the significance level of a test is the maximum probability of accidentally rejecting a true null hypothesis (a decision known as a Type I error). The significance of a result is also called its p-value. [34]

If the significance level is smaller, a value will be less likely to be more extreme than the critical value. So a result which is "significant at the 1% level" is more significant than a result which is "significant at the 5% level".[34] Conventionally, the level of significance of 0.05 (5%) is generally used for ANOVA analysis. But depending on the number of samples in an analysis, other levels may be used. In this study, the level of significance of 0.05 (5%) is mainly used, and 0.10 (10%) is also considered in the case of the insufficient number of samples or the analysis of trends of ALOS (Table 6).[35]

| **Significance level** | **Properties** |
|---|---|
| 0.10 (10%) | Marginally significant |
| 0.05 (5%) | Significant |
| 0.01 (1%) | Highly significant |

**Table 6-Properties of statistical significant level.**

## 3.2. ANALYSIS VARIABLES

### 3.2.1. CIE sky condition

For daylighting purposes, the CIE (International Commission on Illumination) has defined a number of sky descriptions as standard CIE skies. These are defined by functions, depending on the solar altitude, even when the sun is hidden. Sunny sky is any sky condition where the sun happens to shine (through the clouds, if there are any). This can be combined with any of the following three conditions. Clear sky has less than 30% cloud cover, or none. This sky is most likely to be combined with sun. Partly cloudy sky has between 30% and 70% cloud cover. This sky can be combined with sun in some cases. Cloudy sky has more than 70% cloud cover. This sky normally excludes the sun. Overcast sky has a completely closed cloud cover (100 %). Obviously, this sky can't be combined with sun in a meaningful way. This is the sky condition applied in daylight factor calculations. The "cloudy sky" as used in the Radiance software corresponds to the CIE overcast sky definition. Table 7 and Figure 6 show the properties of each CIE sky conditions. [36, 37]

| CIE sky condition | Percentage of cloud cover |
|---|---|
| Clear sky | Less than 30% cloud cover |
| Intermediate sky | Between 30% and 70% cloud cover |
| Overcast sky | More than 70% cloud cover |

**Table 7-CIE sky condition.**

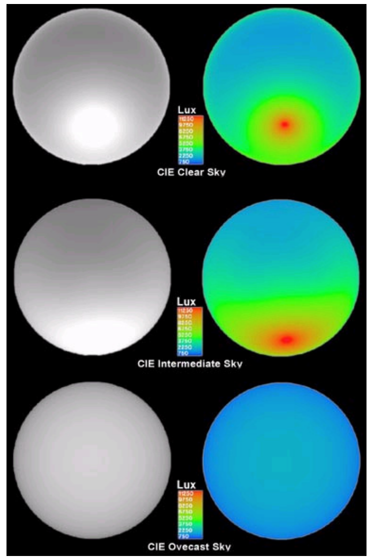



**Figure 6-CIE standard sky types and their distribution.**

### 3.2.2. Turbidity

In this study, the Linke turbidity factor is used for RADIANCE simulation. It describes the optical thickness of the atmosphere due to both the absorption by the water vapor and the absorption and scattering by the aerosol particles relative to a dry and clean atmosphere. It is the turbidity of the atmosphere, and the attenuation of the direct beam solar radiation. The larger turbidity factor, the larger the attenuation of the radiation by the clear sky atmosphere becomes. The turbidity indicates the transparency of the cloudless atmosphere. [38]

### 3.2.3. Daylight Factor (DF)

Daylight factor is expressed as a percentage of the outdoor light under overcast skies that is available indoors.

DF = (indoor illuminance from daylight) / (outdoor illuminance) x 100%

When a building is designed to reply on daylighting, a prime design concern is the daylight factor. Table 8 shows the recommended daylight factors by Stein.[8]

The normal recommended daylight factors are shown in Table 8.[8] In this study, because all patient rooms for this study have side windows, the recommended daylight factors by Thomas are used (Table 9). [39]

| Task | DF |
|---|---|
| Ordinary seeing tasks, such as reading, filling, and easy office work | 1.5 ~ 2.5 % |
| Moderately difficult tasks, such as prolonged reading, stenographic work, normal machine tool work | 2.5 ~ 4.0 % |
| Difficult, prolonged tasks, such as drafting, proofreading poor copy, fine machine works, and fine inspection | 4.0 ~ 8.0 % |

**Table 8-Recommended daylight factor.**

| Space | Minimum (%) | Average (%) |
|---|---|---|
| Lounges in dwellings | 0.5 | 1.5 |
| School classrooms | 2 | 5 |
| Office: general | 2 | 5 |
| Hospital | 1 | 5 |

**Table 9-Recommended DF for rooms with side lighting only.**

### 3.2.4. Luminance ratio

Luminance is the amount of light reflected from a surface in candela/m2 (or Nits). Visual performance increases with contrast with difference in luminance between the object being viewed and its immediate surroundings. Conversely, however, the difference between the average luminance of the visual field (task) and the remainder of the field of vision should be low to avoid the discomfort of large rapid changes in eye adaptation level. Contrast is desirable in the object of view but undesirable in the wider surrounding field of view (Table 10).[8]

| Max. Luminance Ratio | Description |
|---|---|
| 1 to one third | Between task and adjacent surroundings |
| 1 to one tenth | Between task and more remote darker and surfaces |
| 1 to 10 | Between task and more remote lighter surfaces |
| 20 to 1 | Between luminaries (or fenestration) and surfaces adjacent to them |
| 40 to 1 | Anywhere within the normal field of view |

**Table 10-Recommended maximum luminance ratios.**

To achieve a comfort brightness balance, it is desirable to limit luminance ratios between areas of appreciable size as seen from normal viewing position as Table 10 shows. These rations are recommended as maximums; reductions are generally beneficial. Effective visual performance is entirely possible in environments with much higher ratios. It is simply not as visually comfortable and may be fatiguing.[8] Especially in healthcare facilities, according to CIBSE, high luminance ratio should be prevented in the patient's field of view[17]. In this study, luminance ratios are investigated on the TV wall and between human eye and the TV point of the patient rooms where are mainly consisted of patient view. The recommended value 40 to1 is used for the luminance ratio of the first case, and the recommended 1 to 10 is used for that of the second case (Table 10). Those are more discussed in the section of 3.3.

### 3.2.5. Illuminance level (Lux)

The illuminance and its distribution on the task area and its surrounding area have a great impact on how quickly, safely and comfortably a person perceives and carries out a visual task. The proper illuminance values are valid for normal visual conditions and take into account the following reasons:[17]

- Psycho-physiological aspects such as visual comfort and wellbeing.
- Requirements for visual tasks.
- Safety
- Visual ergonomics.

There are some different recommendations for tasks depending on the types of buildings and rooms. Table 11 shows the recommendations for a patient room in healthcare facilities. 300 lux is used for analyzing illuminance variables in this study as the minimum recommended value.

| | **CIBSE (2002)** [17] | **IES (2000)** [18] |
|---|---|---|
| General Lighting | 100 lux | 75-200 lux |
| Reading Lighting | 300 lux | 200-350-500 lux |

**Table 11- Recommended illuminance level for a patient room by CIBSE and IESNA.**

### 3.2.6. Diversity of illuminance

The diversity of illuminance expresses changes in illuminance across a larger space. It is a measure of the range of lighting, in the space. It is meant to limit the peaks and troughs in the levels of lighting seen by the users of that space. The diversity of illuminance is expressed as the ratio of the maximum illuminance to the minimum illuminance at any point in the working plane of the main area of a room or space should not exceed 5:1.[17]

There are no specific guidelines for healthcare facilities. Most guidelines of diversity are focused on working places and museums. In this study, the guide line for a working plane is used to analyze the diversity of illuminance of a patient room.

### 3.2.7. Uniformity of illuminance

The uniformity of illuminance is concerned with illuminance conditions on the task and the immediate surroundings. Usually, it does not apply to the whole working plane, but to a series of defined task areas on the working plane. It is expressed as the ratio of the minimum illuminance to the average illuminance on a surface. A higher value is a better uniformity of illuminace. CIBSE (2002) recommends that working plane illuminance should have a uniformity rate of not less than 0.8. [17] As a result, the higher the uniformity of illuminance is, it is better to occupants' visual comfort.

However, there are no specific guidelines of the uniformity of illuminance for healthcare facilities. Most recommended values are for working spaces like an office. In this study, the guide line for a working plane is used to analyze the uniformity of illuminance of a patient room.

## 3.3. LIGHTING PERFORMANCE METHODOLOGY

### 3.3.1. Lighting variable analysis

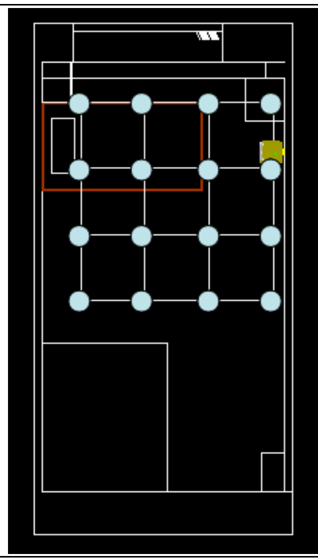
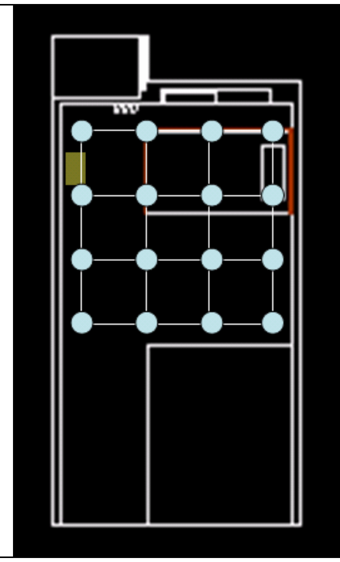
| | **Inha University Hospital** | **St. Joseph Regional Health Center** |
|---|---|---|
| 16-Reference Grid |  |  |
| Size | 0.8m X 0.8 m | 0.85m X 0.85 m |
| Height | 0.95 m from the floor | 0.95 m from the floor |

**Table 12-Reference grids for lighting performance analysis.**

Sixteen reference grids were used to calculate daylight factor (DF), illuminance, and illuminance gradient (diversity of illuminanc). For calculating DF and illuminance, average values from 16 grids are used as Table 12 shows. The sensor height is placed 0.95m from the floor. This is the height of a table for patients and is where visual behaviors most often occur.

### 3.3.2. Luminance ratio (LR)

Depending on the location and orientation of patient rooms, glare effects are happened on the wall of TV set in the two hospitals. While patient stays their rooms with watching TV, patient meet glare from the TV wall by the reflected daylight on the TV wall and the direct daylight disturbing human vision comfort.

In this study, two luminance ratios are investigated. The first one is the ratio between the maximum and minimum luminance on the TV wall.

Human vision angle is horizontal 45-60º, and vertical 100-130º.[40]

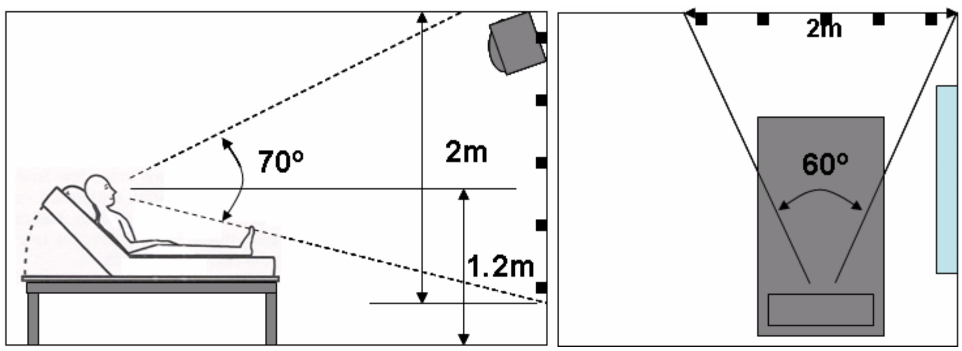



**Figure 7-Location of the reference grids for LR of TV wall and patient angle of vision, (vertical view-left, and horizontal view).**

As Figure 7 shows, 25 reference grids (0.5m x 0.5m) on the 2m x 2m area of TV wall are installed and calculate the Luminance Ratio (LR) between maximum and minimum luminance (cd/$m^2$ or Nits) by RADIANCE. As the maximum recommended LR value, 40 is used for analyzing the luminance ratio on the TV wall (Table 10).

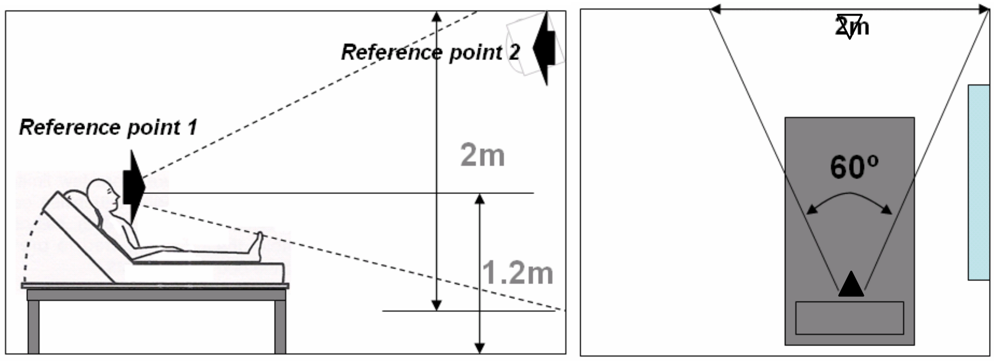



**Figure 8-Location of the reference points for LR between TV point and patient eye (vertical-left, and horizontal).**

The second is the ratio between the TV point and human eye (Figure 8). The window is near from the location of patient bed. It can bring a lot of glare to patient and disturb his visual discomfort. One reference point facing TV wall near patient head and the other reference point on the TV point are placed. It is for analyzing LR when direct sunlight shines near to patient head directly and indirectly. As the maximum recommended LR value, 10 is used for the second (Table 10).

# 4. RESEARCH DESCRIPTION OF INHA UNIVERSITY HOSPITAL

## 4.1. INHA UNIVERSITY HOSPITAL

Inha University Hospital was opened in May, 1996. This is one of major health facilities in Inchon, Korea. This hospital comprises just one building that is “T” shaped in plan and uniformed in each floor (Figure 9). As Figure 10 shows, it is a eighteen story building. Patient rooms occupy from seventh to sixteenth floor of this building.

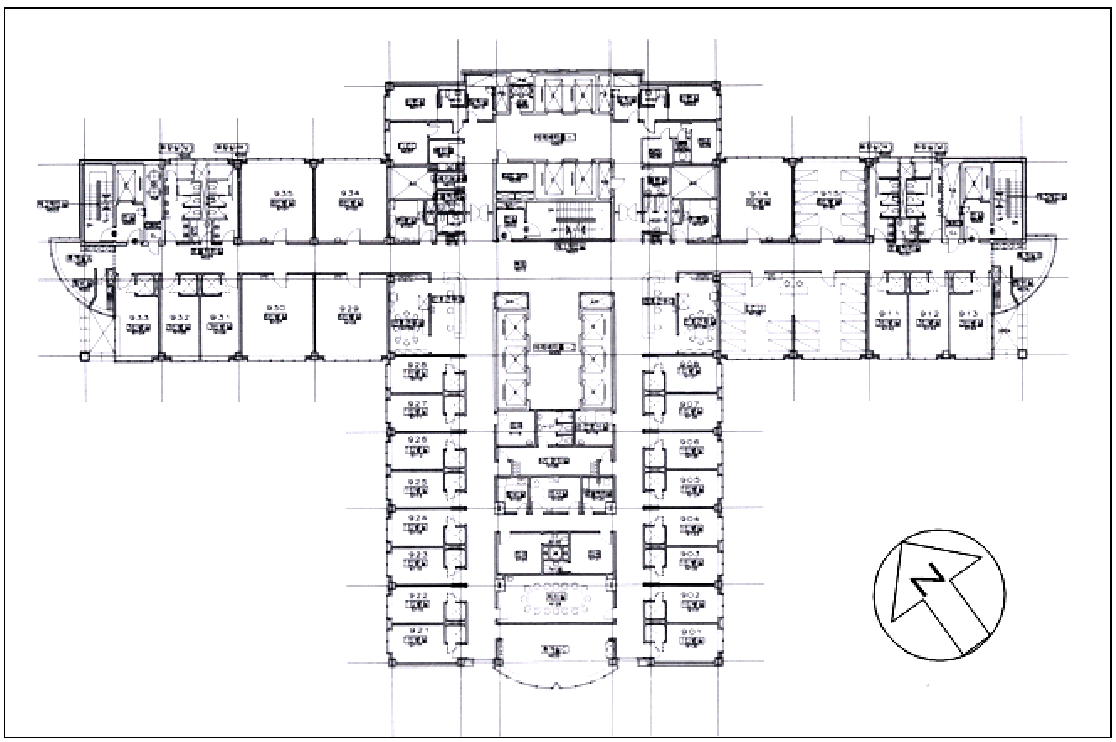


**Figure 9-Floor plan of Inha University Hospital.**

There are three kinds of units in patient rooms; single room, triple room, and room for six. The total number of patient beds is 794. This research focuses on the environment of single rooms and its patient data. The single rooms are placed in the bottom block of the hospital.

**Figure 10-Exterior view of Inha University Hospital.**

| Floor | Ward |
|---|---|
| 17, 18th floor | Special facilities for VIP. |
| 16th floor | Internal |
| 15th ,14th ,13th floor | N/A |
| 12th floor | Otorhinolaryngology (Medical) |
| 11th floor | Surgery |
| 10, 9th floor | N/A |
| 8th floor | Gynecology |

**Table 13-Patient wards in each floor of Inha University Hospital.**

| Ward | Definition |
|---|---|
| Internal | The diagnosis and treatment of any ailment in adults that does not require surgery. |
| Otorhinolaryngology | The branch of medicine that specializes in the diagnosis and treatment of ear, nose, throat, and head & neck disorders. |
| Surgery | The branch of medicine concerned with the treatment of disease, injury, and deformity by operation or manipulation. |
| Gynecology | The branch of medicine particularly concerned with the health of the female organs of reproduction and diseases thereof. |

**Table 14-Definitions of wards.[41]**

In this study, the 8th, 11th, 12th and 16th floors are chosen. Tables 13 and 14 summarize the wards of this facility and those descriptions.

### 4.1.1. Location and climatic conditions in Inchon, Korea

Inha University Hospital is located in Inchon (Latitude : 37.30 ºN, Longitude : 126.38 ºE). Inchon is 30 km away to west from Seoul, the capital of South Korea. Korea uses Greenwich Mean Time (GMT) +9. Korea's climate is regarded as a continental climate from a temperature standpoint and a monsoonal climate from a precipitation standpoint. The climate of Korea is characterized by four distinct seasons: spring, summer, fall, and winter.

Table 15 and Figure 11 summarize the climatic properties. During summer season, it is hot and humid with monthly average highs ranging from 77°F to 67.7°F (25°C-19.8°C). The highest temperature in summer is 94°F (34.4°C). The summers are lasting from June to August. July is the hottest months. The relative humidity is from 78.8% to 82.4% during summer.

Energy-10 Weather File Summary
Inchon,

File Name: C:₩Weather Data₩korea weather data₩KR-INCHON-471120.ET1
Comment:
Latitude: 37.483
Longitude: 126.633
Elevation: 230 ft
Design Day Dry Bulb (Winter 99.0%): 6.0 °F
Design Day Dry Bulb (Winter 97.5%): 6.0 °F
Design Day Dry Bulb (Summer 2.5%): 90.0 °F
Design Day Wet Bulb (Summer 2.5%): 76.0 °F

| Month | TAA | TMXA | TMNA | TMX | TMN | TWBA | RH | WSA | HS | HDD | CDD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 26.7 | 34.0 | 19.3 | 48.0 | 6.0 | 23.2 | 62.5 | 9.4 | 637 | 1190 | 0 |
| February | 29.7 | 37.2 | 21.6 | 51.0 | 12.0 | 26.1 | 65.2 | 9.6 | 922 | 997 | 0 |
| March | 39.1 | 46.7 | 31.2 | 59.0 | 21.0 | 34.8 | 66.8 | 9.8 | 1176 | 807 | 0 |
| April | 50.8 | 58.6 | 42.2 | 74.0 | 32.0 | 45.8 | 70.0 | 9.4 | 1456 | 439 | 1 |
| May | 60.7 | 68.4 | 52.1 | 79.0 | 44.0 | 55.1 | 71.6 | 8.3 | 1467 | 161 | 13 |
| June | 67.7 | 74.5 | 60.1 | 83.0 | 53.0 | 63.0 | 78.8 | 6.7 | 1459 | 15 | 84 |
| July | 74.7 | 80.4 | 68.2 | 94.0 | 61.0 | 70.4 | 82.4 | 7.4 | 1149 | 0 | 288 |
| August | 77.0 | 82.7 | 70.5 | 91.0 | 63.0 | 72.2 | 80.8 | 6.9 | 1134 | 0 | 360 |
| September | 68.5 | 76.4 | 60.0 | 87.0 | 50.0 | 63.2 | 76.4 | 6.3 | 1139 | 19 | 115 |
| October | 58.1 | 66.5 | 49.2 | 78.0 | 35.0 | 52.3 | 70.6 | 6.7 | 956 | 226 | 3 |
| November | 44.4 | 52.4 | 36.1 | 64.0 | 22.0 | 39.7 | 67.8 | 9.0 | 673 | 622 | 0 |
| December | 32.2 | 39.4 | 24.4 | 52.0 | 11.0 | 28.3 | 64.4 | 9.2 | 537 | 1027 | 0 |
| Year | 52.5 | 59.8 | 44.6 | 94.0 | 6.0 | 47.8 | 71.4 | 8.2 | 1059 | 5501 | 863 |

TAA Average Dry Bulb Temperature, °F
TMXA Average Daily Maximum Dry Bulb Temperature, °F
TMNA Average Daily Minimum Dry Bulb Temperature, °F
TMX Maximum Dry Bulb Temperature, °F
TMN Minimum Dry Bulb Temperature, °F
TWBA Average Wet Bulb Temperature, °F
WSA Average Wind Speed, MPH
HS Average Daily Horizontal Solar Radiation, Btu/ft? RH Relative Humidity, %
HDD Heating Degree Days, Base 65.0 °F
CDD Cooling Degree Days, Base 65.0 °F

**Table 15-Summary of weather data for Inchon, Korea (Weather Maker v.1.01).**

Winters in Korea, which generally last from December to February, are cold and dried. In January, the coldest month, daily average temperatures range from 32.2°F to 26.7°F (0.11°C- -2.9°C). The lowest temperature is 6°F (-14.4°C). The relative humanity is from 62.5% to 65.2% during winter. During spring and fall in Inchon, the climate is mild and comfort. In spring, the average monthly temperature is from 39.1°F to 60.7°F (3.94°C to 15.9°C). The highest temperature is 79°F (26°C). The relative humidity is from 65.2% to 70 %. In fall, the average monthly temperature is from 44.4°F to 68.5°F (6.89°C to 20.2°C). The highest temperature is 78°F (25.6°C). The relative humidity is from 67.8% to 76.4 %. Table 16 shows the values of the turbidity of Korea in each month.

| Month | Inchon, Korea |
|---|---|
| January | 2 |
| February | 2.5 |
| March | 3 |
| April | 3.5 |
| May | 4 |
| June | 4 |
| July | 4 |
| August | 4.5 |
| September | 4.5 |
| October | 3.5 |
| November | 2.5 |
| December | 2.5 |

**Table 16-Turbidity of Inchon, Korea.** [37]

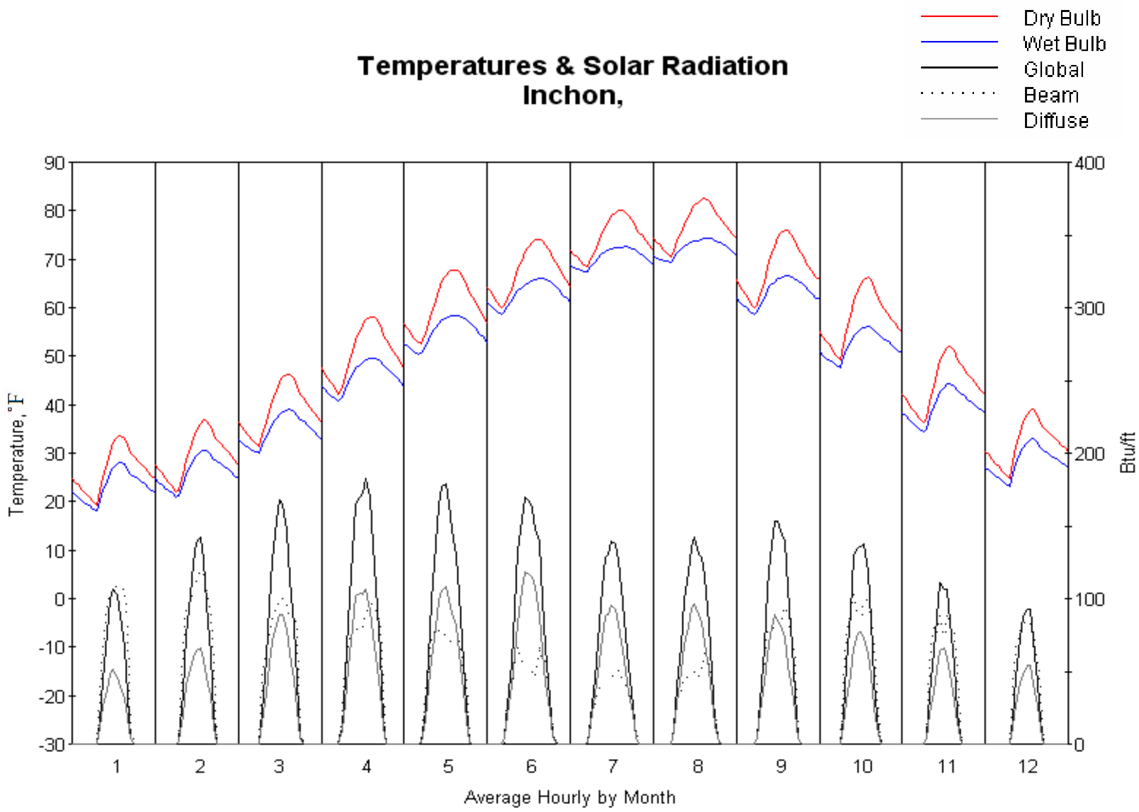



**Figure 11-Hourly temperature and solar radiation in Inchon, Korea (Weather Maker v.1.01).**

| Month | Percentage of cloud | CIE sky condition |
|---|---|---|
| Jan | 37.0% | Intermediate |
| Feb | 39.0% | Intermediate |
| Mar | 44.0% | Intermediate |
| Apr | 46.0% | Intermediate |
| May | 50.0% | Intermediate |
| Jun | 60.0% | Intermediate |
| Jul | 71.0% | Overcast |
| Aug | 61.0% | Intermediate |
| Sep | 49.0% | Intermediate |
| Oct | 38.0% | Intermediate |
| Nov | 41.0% | Intermediate |
| Dec | 38.0% | Intermediate |

**Table 17-Annual average percentage of cloud in sky condition, Inchon, Korea, 2004.**

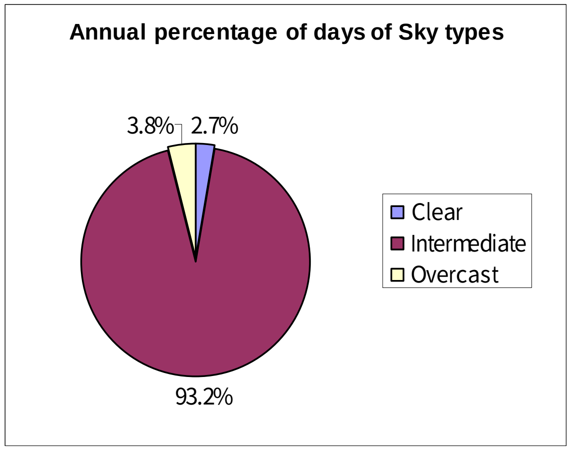



**Figure 12-Percentage of types of sky condition, Inchon, Korea, 2004.**

As Table 17 and Figure 12 shows, the sky condition of Inchon, Korea is usually partly cloudy (intermediate).[42] Over 93% of days are intermediate and only about 2.7% of days are considered to have a clear sky condition. Overcast days take up 3.8% and are concentrated in July, the rainy season.

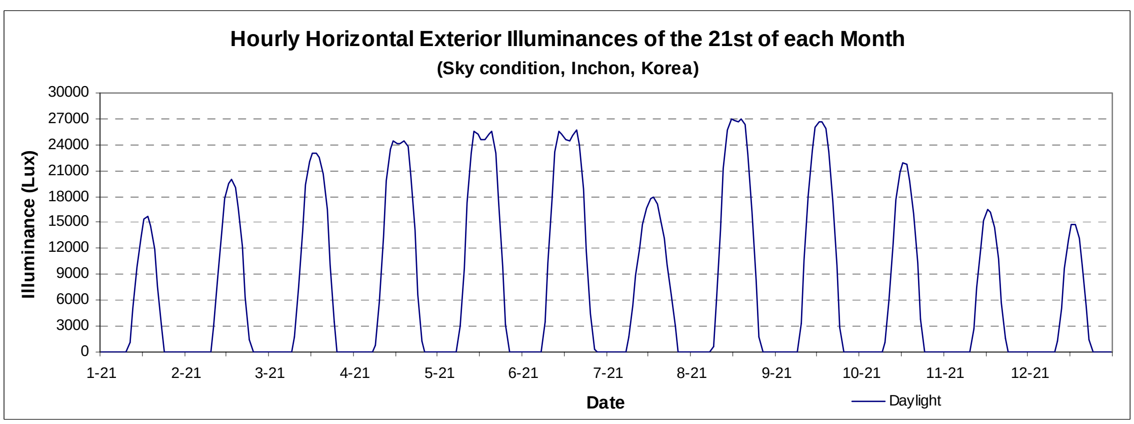



**Figure 13-Calculated hourly horizontal exterior illuminances of the 21st of each month, Inchon, Korea based on the climate data and CIE sky condition (RADIANCE).**

As Table 17 shows, average amount of cloud in sky of Inchon is from 37% to 71%. As CIE sky condition shows, this average amount of cloud data are categorized into two types; intermediate and overcast sky conditions. In July, it is typically an overcast sky, and other months exhibit intermediate sky conditions. Depending on the Hourly Horizontal Exterior Illuminance data (Figure 13) of the CIE sky conditions, four seasons are categorized : Spring (March, April, May, & June) and Fall (August, September, & October) are between 20000 and 30000 lux, Summer (July) is overcast, and Winter (January, February, November, & December) is below 20000 lux.

## 4.2. ANALYSIS OF INDOOR DAYLIGHT ENVIRONMENT IN INHA UNIVERSITY HOSPITAL

### 4.2.1. Reflectance

The reflectance of material surfaces in patient rooms at Inha University Hospital was investigated. The reflectance of wall, floor, and bed are higher than the recommended surface reflectance by IESNA. Table 18 compares the reflectance of materials in the actual site, RADIANCE model and the recommended by IESNA.

| | Site | RADIANCE | Recommended surface reflectance (IESNA, 1995) [43] |
|---|---|---|---|
| Wall1 | 0.66 | 0.66 | 0.4-0.6 |
| Wall2 | 0.55 | 0.55 | 0.4-0.6 |
| Floor | 0.46 | 0.46 | 0.2-0.4 |
| Ceiling | 0.64 | 0.64 | 0.7-0.8 |
| Bed | 0.67 | 0.67 | 0.25-0.45 |
| Curtain | 0.35 | 0.35 | 0.25-0.45 |
| Furniture | 0.39 | 0.39 | 0.25-0.45 |
| Refrigerator | 0.49 | 0.49 | 0.25-0.45 |
| Transmittance of Vertical blind | 30 % | 30 % | n/a |
| Transmittance of glazing (window) | 50.2 % | 50.2% | n/a |

**Table 18-Reflectance values of material in site, and RADIANCE in Inha University Hospital.**

### 4.2.2. Properties of a patient room

Properties of patient rooms are shown in the table below. It has a large window, but only 25% of the window area is operable. All walls and ceiling are concrete, and the window is an insulated glass. Table 19 shows the properties of windows in patient rooms.

| | Property |
|---|---|
| Window area | 2.76 m2 |
| Glass type | Double |
| UV coating | N/A |
| Window/wall ratio | 0.20 |
| Window/floor ratio | 0.355 |
| Vertical Blind | 30% (transmittance) |

**Table 19-Properties of windows in Inha University Hospital.**

**Figure 14-Interior view of a patient room in Inha University Hospital at 12:50 PM, June 7, 2004.**

Patient rooms at Inha University Hospital are designed symmetrically with 2 types. Patient beds are located head to head and foot to foot with a wall between two rooms. Each type has differences in a window view and facing direction to daylight. In this study, the patient rooms are separated into type A and type B depending on patient head location. (Figures 14, 15 and 16)

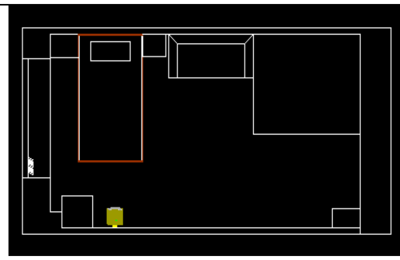
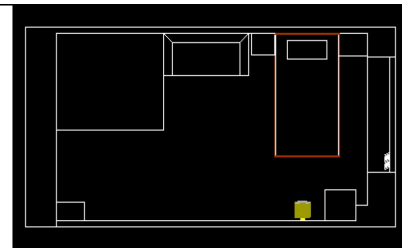
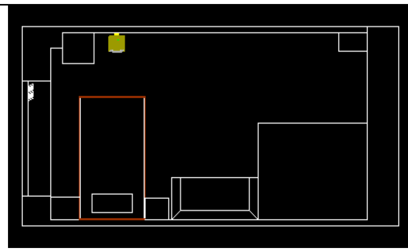
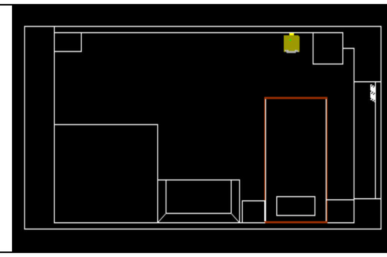
| | NW | SE |
|---|---|---|
| Type A |  |  |
| Type B |  |  |

**Figure 15-Type A and B in patient rooms.**

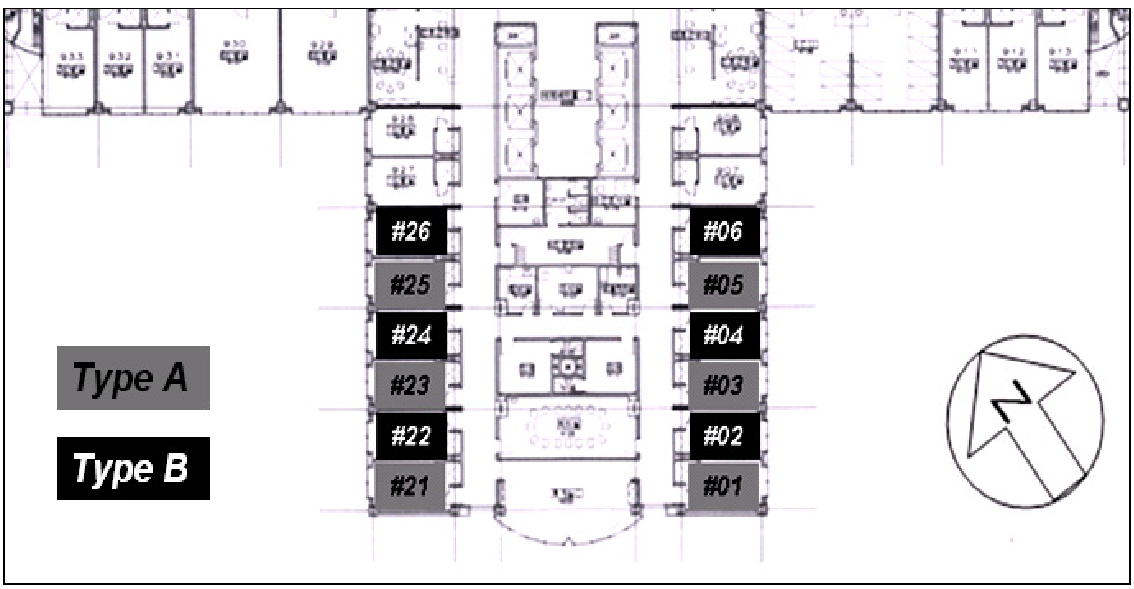



**Figure 16-Types of single patient rooms and the room numbers in a ward (* #26 means the room number 26 on each floor).**

**Figure 17-Window view from a patient bed (left -type A, right-type B).**

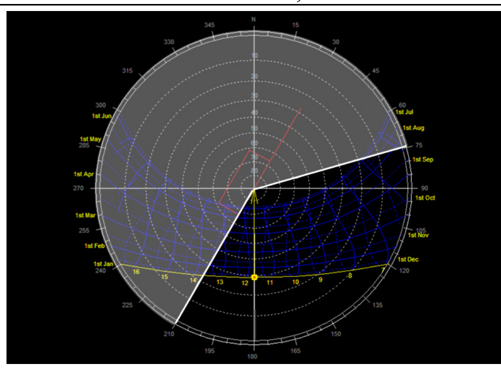
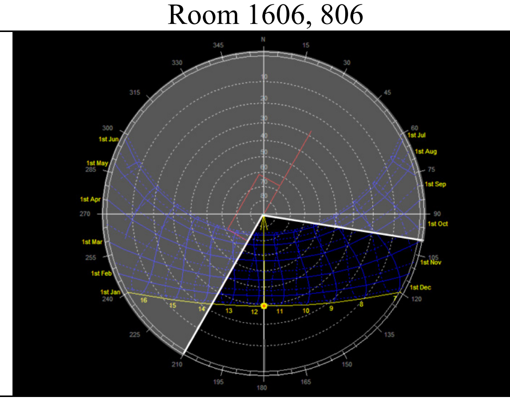
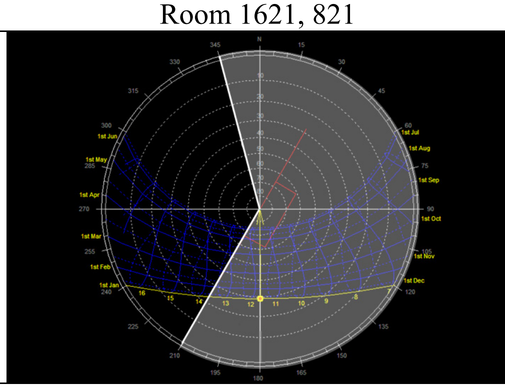
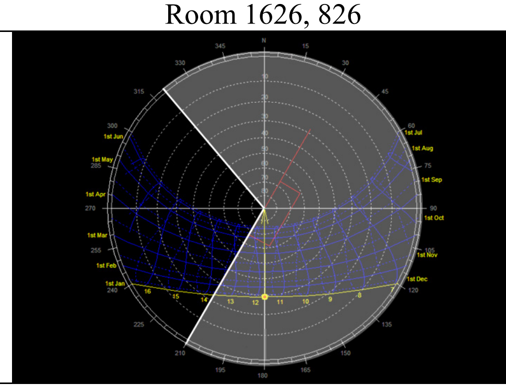
| | Room 1601, 801 | Room 1606, 806 |
|---|---|---|
| SE |  |  |
| | Room 1621, 821 | Room 1626, 826 |
| NW |  |  |

**Figure 18-Shading mask in patient rooms (Ecotect v.5.20).**

Due to the different placement of patient beds in each type, window views are different from patient beds in each type (Figure 17). As Figure 18 shows, the SE facing patient rooms have direct daylight in the morning till about 1:00 PM. In 1606, it can receive daylight over 8:30AM. In NW facing rooms, all rooms can have direct daylight after about 13:30 to dusk. Thus, SE facing rooms are brighter than NW facing rooms in the morning and around noon, and vise versa in the afternoon.

#### 4.2.3. Discrepancy between RADIANCE and on-site measurement

To verify the measured value in the site with calculated values by RADIANCE, four reference points (Figure 19) are investigated in two patient rooms.

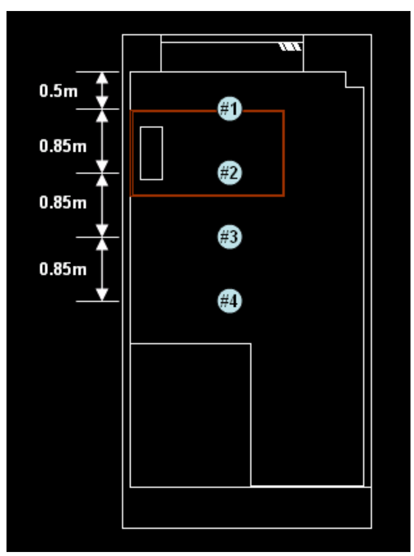
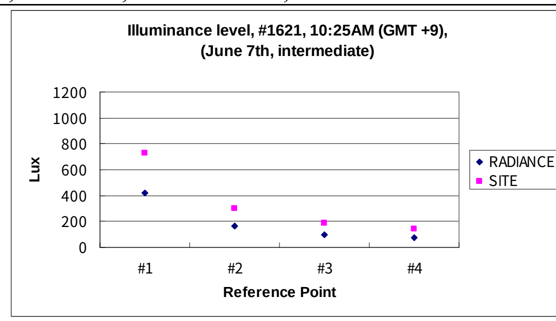



**Figure 19-Placements of reference point in room #1621 and #822.**


**Figure 20- Partly cloudy sky condition (Intermediate sky), the south sky (left) and the north sky in Inchon, Korea, 10:50 AM, June 7, 2004.**

#1621, 10:25AM, June 7th, intermediate,

| R.P. | RAD. (lux) | Site (lux) | Discrep. |
|---|---|---|---|
| #1 | 419 | 729 | 42.5% |
| #2 | 164 | 303 | 45.9% |
| #3 | 99 | 187 | 47.1% |
| #4 | 76 | 140 | 45.7% |
| HEI* | 25643 | 41000 | 37.5% |




#822, 11:10AM, June 7th, intermediate,

| R.P. | RAD. (lux) | Site (lux) | Discrep. |
|---|---|---|---|
| #1 | 769 | 1120 | 31.3 % |
| #2 | 315 | 467 | 32.5 % |
| #3 | 133 | 205 | 35.1 % |
| #4 | 99 | 159 | 37.7 % |
| HEI | 25643 | 43000 | 40.4 % |

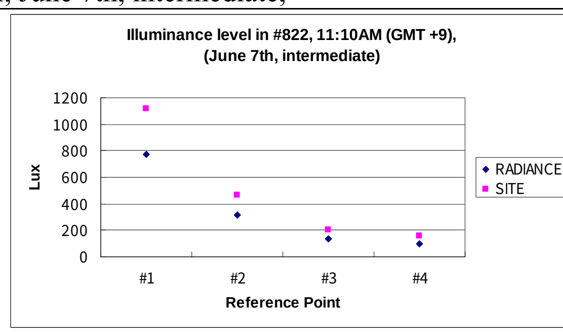



**Table 20-Comparison of Illuminance between RADIANCE and on-site measurement (*HEI : Horizontal Exterior Illuminance).**

The sensor height is 95cm from the floor. It is the height of patient visual behavior. On-site measurements are conducted at the same spots to compare with the calculated data of RADIANCE under the intermediate sky (Figure 20).

As Table 20 shows, the horizontal exterior illuminance levels are different from each other. As a result, the illuminance levels on the reference points are different between RADIANCE and site measurement. But, the trends of the interior illuminance levels are same on the reference points.

The sky condition of the date when site measurements were conducted was partly cloudy. It can be compared with the CIE intermediate sky condition. But, the definition of the CIE intermediate sky condition is from 30% to 70% of cloud on sky. This sky condition does not cover the various amount of cloud on sky. It is not same with the actual sky condition.

## 4.3. COMPARISON AMONG PATIENT ROOMS IN DAYLIGHTING ENVIRONMENTS

“T” shaped Inha University Hospital has 6 single patient rooms in each northwest and southeast orientation. The polygon style building makes daylight environment of each patient room different with other adjacent facilities that partially block daylighting and make shadings to some patient rooms.

With 16-reference grids on the height of 95 cm from floor where patients performs their works (Figure 21), the analyses of comparison in daylight environment are conducted. Each month when Horizontal Exterior Illuminance (HEI) is lowest in each season is selected; March in spring, July in summer, October in fall, and December in winter.

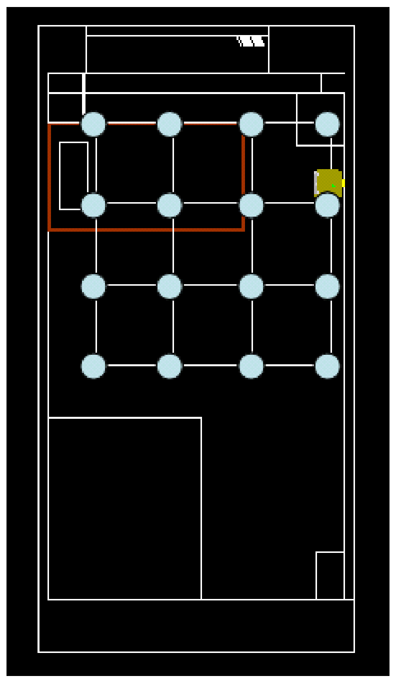


**Figure 21-16 Reference grids for comparison analysis (0.95m height).**

### 4.3.1. Comparison between 8th and 16th floors

8th and 16th floors should be compared to check the difference in illuminance and daylight factor because the research targeted wards are located on 8th, 11th, 12th, and 16th floors. The rooms that are located in the end of each orientation on 8th and 16th floors are selected to analyze the difference (Figure 22). The HEI of the selected times are calculated by RADIANCE (Table 21).


**Figure 22-Analysis targetted patient rooms in 8th and 16th floors.**

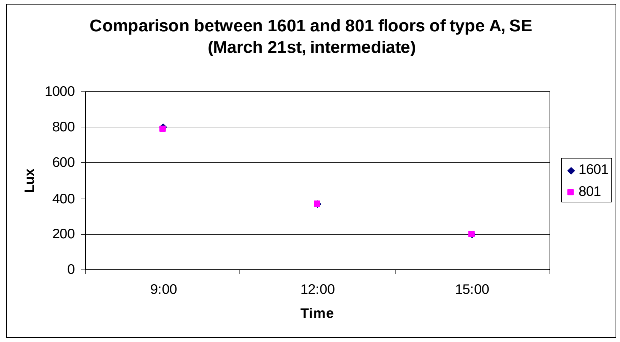
| RADIANCE (HEI) | Sky conditon | 9:00 | 12:00 | 15:00 |
|---|---|---|---|---|
| March | Intermediate | 14196 lux | 22966 | 20686 |
| July | Overcast | 12105 | 17787 | 15514 |
| October | Intermediate | 12524 | 21920 | 15992 |
| December | Intermediate | 5016 | 14769 | 9935 |

**Table 21-Horizontal Exterior Illuminance (HEI) by RADIANCE.**

According to Tables 22,23,24, and 25, there are no significant differences between 16th and 8th floors in Illuminance and daylight factor. It means each room in a same location on the each floor from 8th and 16th floors has almost same indoor daylight environments.

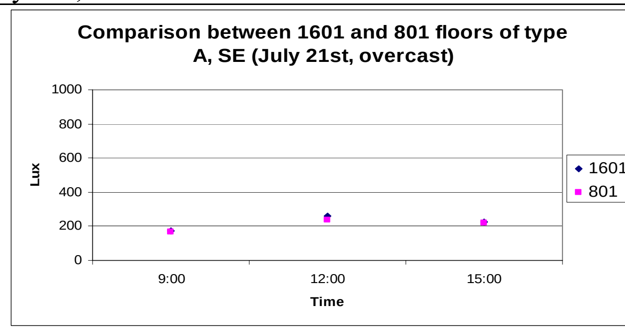
March 21st, intermediate

| Time | Patient room | | Differ.* |
|---|---|---|---|
| | 1601 | 801 | (lux) |
| 9:00 | 803 | 792 | 12 |
| 12:00 | 368 | 367 | 1 |
| 15:00 | 197 | 197 | 0 |
| | | Ave. ** | 4 |



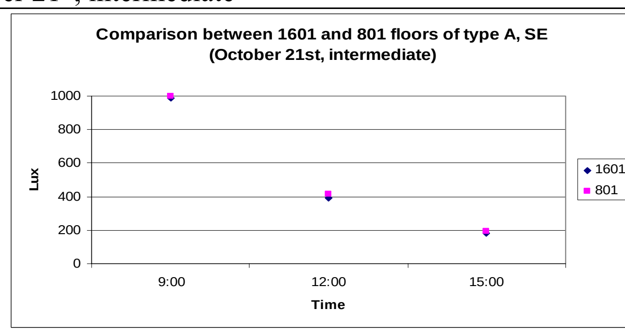

July 21st, overcast

| Time | 1601 | 801 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 174 | 168 | 5 |
| 12:00 | 258 | 240 | 18 |
| 15:00 | 224 | 218 | 6 |
| | | Ave. | 10 |




October 21st, intermediate

| Time | 1601 | 801 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 989 | 1002 | -13 |
| 12:00 | 389 | 415 | -12 |
| 15:00 | 179 | 190 | -11 |
| | | Ave. | -13 |




December 21st, intermediate

| Time | 1601 | 801 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 356 | 355 | 1 |
| 12:00 | 429 | 434 | -5 |
| 15:00 | 129 | 130 | 0 |
| | | Ave. | -1 |

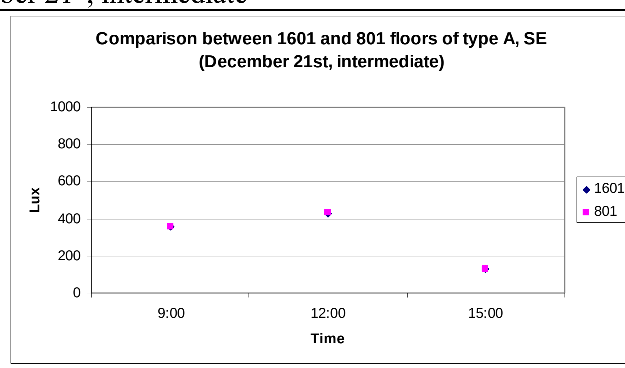
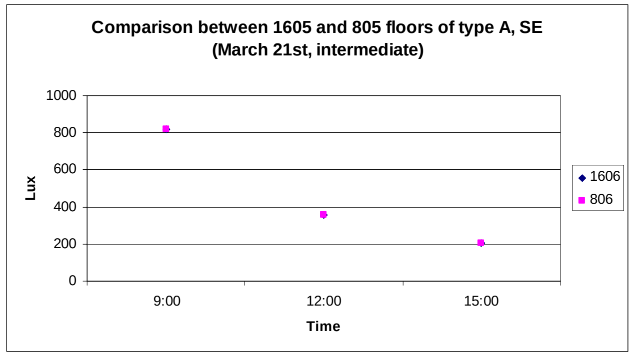



**Table 22-Comparison between #1601 and #801 (type A, SE)**

**(*Differ. : Difference, ** Ave. : Average).**

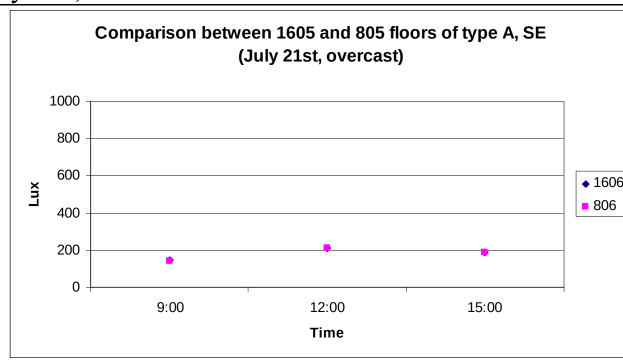
March 21st, intermediate

| Time | Patient room | | Differ. (lux) |
|---|---|---|---|
| | 1606 | 806 | |
| 9:00 | 821 | 820 | 1 |
| 12:00 | 355 | 355 | 0 |
| 15:00 | 204 | 203 | 1 |
| | | Ave. | 1 |



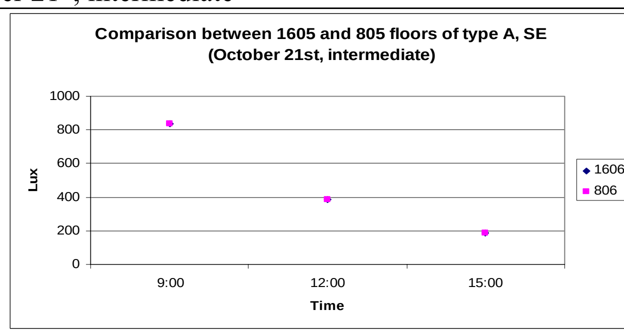

July 21st, overcast

| Time | 1606 | 806 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 143 | 143 | 1 |
| 12:00 | 210 | 210 | 0 |
| 15:00 | 185 | 184 | 1 |
| | | Ave. | 1 |




October 21st, intermediate

| Time | 1606 | 806 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 838 | 837 | 1 |
| 12:00 | 385 | 387 | -2 |
| 15:00 | 187 | 189 | -2 |
| | | Ave. | -1 |




December 21st, intermediate

| Time | 1606 | 806 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 337 | 336 | 0 |
| 12:00 | 427 | 431 | -4 |
| 15:00 | 141 | 142 | -2 |
| | | Ave. | -2 |

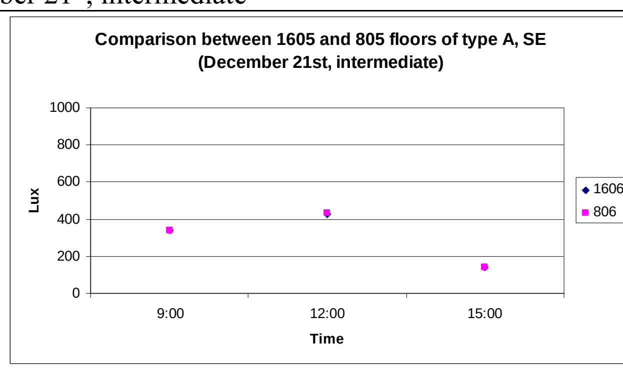
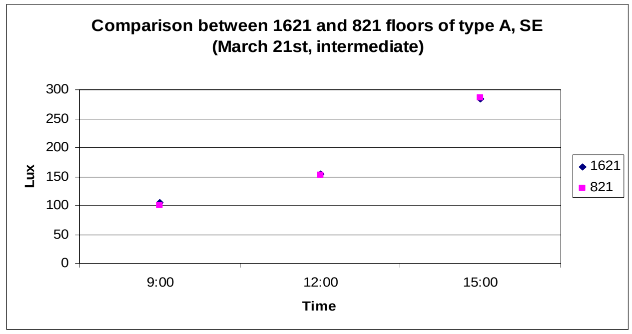



**Table 23-Comparison between #1606 and #806 (type B, NW).**

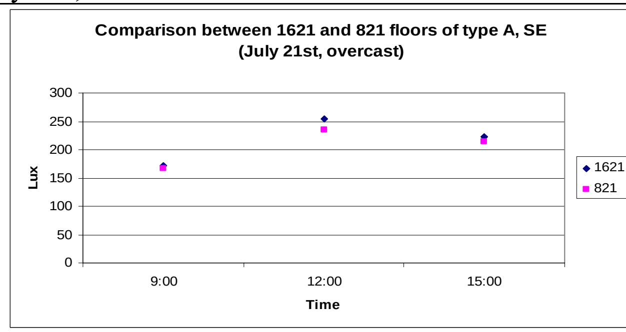
March 21st, intermediate

| Time | Patient room | | Differ. (lux) |
|---|---|---|---|
| | 1621 | 821 | |
| 9:00 | 105 | 100 | 5 |
| 12:00 | 154 | 153 | 1 |
| 15:00 | 284 | 287 | -3 |
| | | Ave. | 1 |



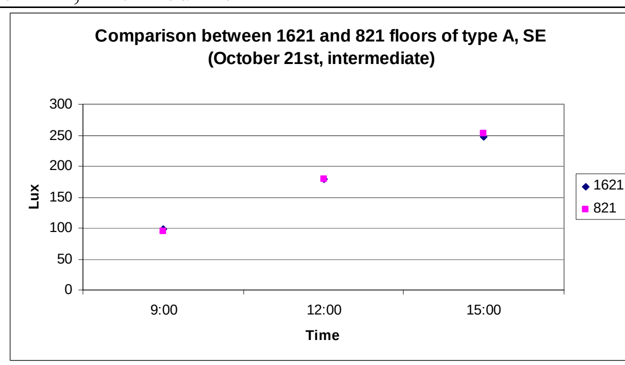

July 21st, overcast

| Time | 1621 | 821 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 171 | 167 | 4 |
| 12:00 | 254 | 235 | 19 |
| 15:00 | 222 | 213 | 9 |
| | | Ave. | 11 |




October 21st, intermediate

| Time | 1621 | 821 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 98 | 95 | 3 |
| 12:00 | 180 | 179 | 1 |
| 15:00 | 248 | 253 | -5 |
| | | Ave. | -1 |




December 21st, intermediate

| Time | 1621 | 821 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 48 | 46 | 2 |
| 12:00 | 130 | 129 | 1 |
| 15:00 | 143 | 146 | -3 |
| | | Ave. | 0 |

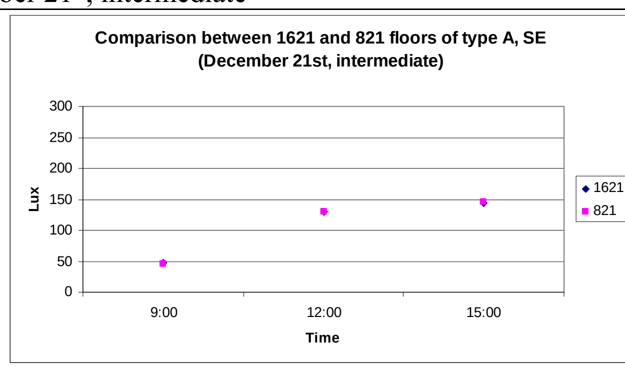
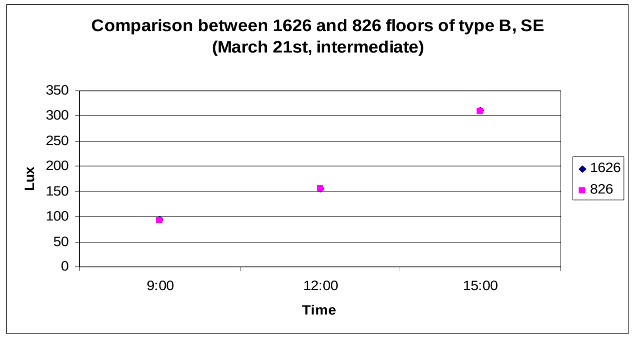



**Table 24-Comparison between #1621 and #821 (type A, SE).**

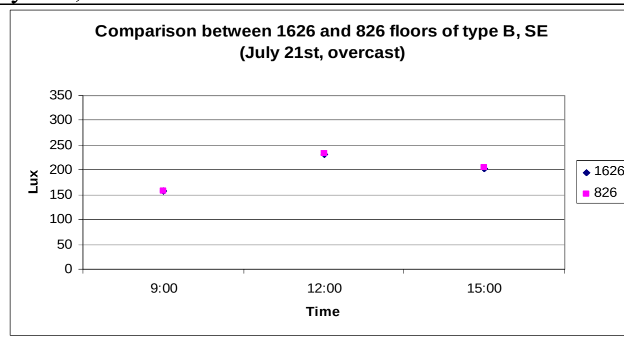
March 21st, intermediate

| Time | Patient room | | Differ. (lux) |
|---|---|---|---|
| | 1626 | 826 | |
| 9:00 | 93 | 92 | 1 |
| 12:00 | 156 | 256 | 0 |
| 15:00 | 311 | 310 | 1 |
| | | Ave. | 2 |



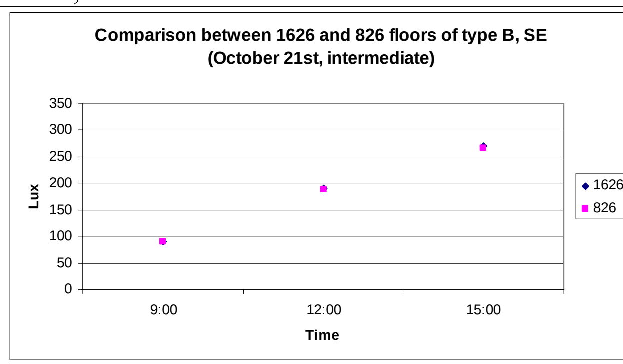

July 21st, overcast

| Time | 1626 | 826 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 158 | 157 | 1 |
| 12:00 | 232 | 233 | -1 |
| 15:00 | 203 | 205 | -2 |
| | | Ave. | -1 |




October 21st, intermediate

| Time | 1626 | 826 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 89 | 91 | -2 |
| 12:00 | 190 | 188 | 2 |
| 15:00 | 270 | 267 | 3 |
| | | Ave. | 1 |




December 21st, intermediate

| Time | 1626 | 826 | Differ. (lux) |
|---|---|---|---|
| 9:00 | 44 | 45 | -1 |
| 12:00 | 136 | 139 | -3 |
| 15:00 | 161 | 163 | -2 |
| | | Ave. | -2 |

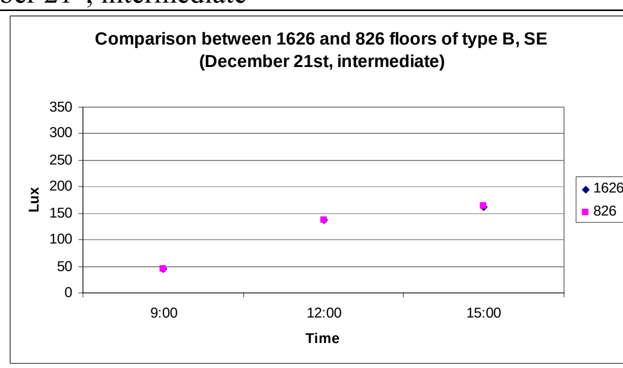
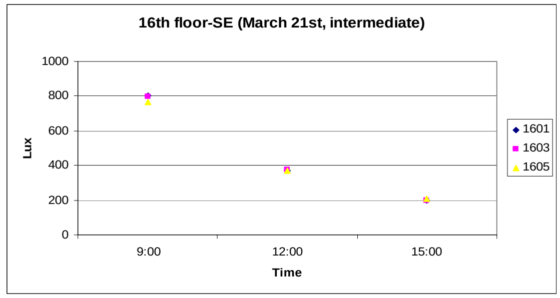



**Table 25-Comparison between #1626 and #826 (type B, NW).**

### 4.3.2. Comparison among a same floor (16th floor)

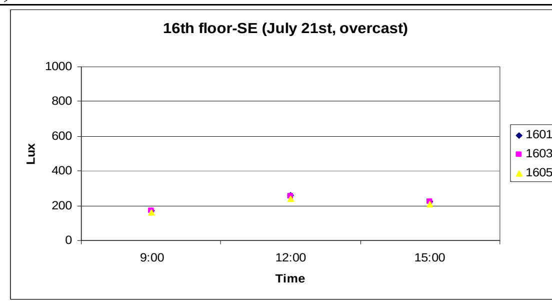
March 21st, intermediate

| Time | Patient room | | | Differ.* |
|---|---|---|---|---|
| | 1601 | 1603 | 1605 | (lux) |
| 9:00 | 803 | 797 | 763 | 40 |
| 12:00 | 368 | 376 | 368 | 0 |
| 15:00 | 197 | 201 | 208 | -11 |
| | | | Ave. | 10 |



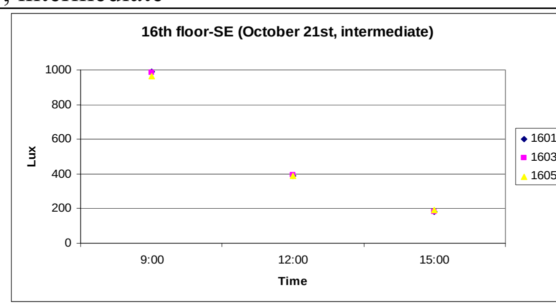

July 21st, overcast

| Time | 1601 | 1603 | 1605 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 174 | 172 | 161 | 13 |
| 12:00 | 258 | 253 | 240 | 18 |
| 15:00 | 224 | 221 | 210 | 14 |
| | | | Ave. | 15 |




October 21st, intermediate

| Time | 1601 | 1603 | 1605 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 989 | 985 | 968 | 24 |
| 12:00 | 389 | 393 | 388 | 2 |
| 15:00 | 179 | 184 | 191 | -12 |
| | | | Ave. | 4 |




December 21st, intermediate

| Time | 1601 | 1603 | 1605 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 356 | 354 | 347 | 10 |
| 12:00 | 429 | 425 | 428 | 1 |
| 15:00 | 129 | 133 | 140 | -10 |
| | | | Ave. | 0 |

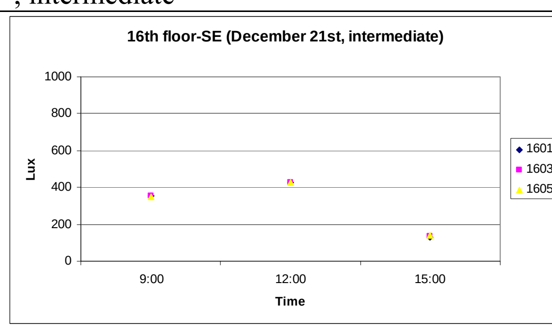
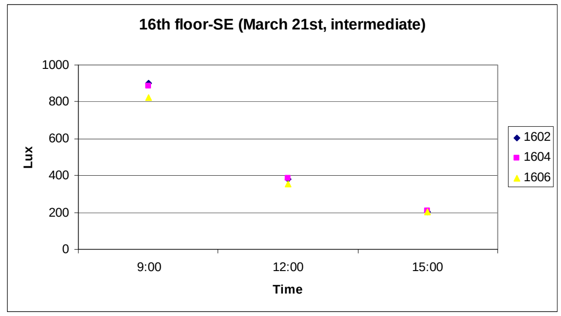



**Table 26-Comparison among #1601, #1603, and #1605 (type A, SE)**

**(*Differ.: Difference=(#1or#2) – (#5or#6)).**

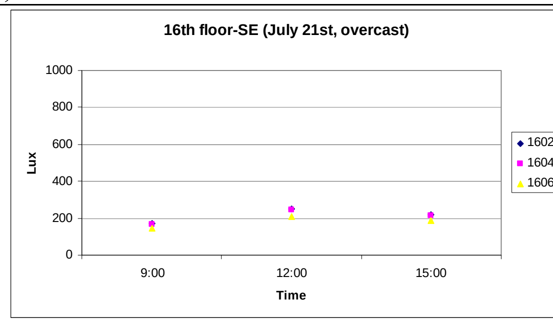
March 21st, intermediate

| Time | 1602 | 1604 | 1606 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 902 | 886 | 821 | 81 |
| 12:00 | 378 | 385 | 355 | 23 |
| 15:00 | 205 | 208 | 204 | 1 |
| | | | Ave. | 35 |



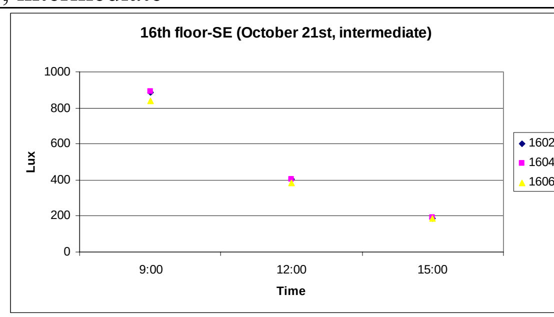

July 21st, overcast

| Time | 1602 | 1604 | 1606 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 170 | 165 | 143 | 27 |
| 12:00 | 249 | 245 | 230 | 19 |
| 15:00 | 220 | 213 | 185 | 35 |
| | | | Ave. | 27 |




October 21st, intermediate

| Time | 1602 | 1604 | 1606 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 885 | 890 | 838 | 47 |
| 12:00 | 405 | 405 | 385 | 20 |
| 15:00 | 184 | 190 | 187 | -2 |
| | | | Ave. | 22 |




December 21st, intermediate

| Time | 1602 | 1604 | 1606 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 350 | 349 | 337 | 14 |
| 12:00 | 438 | 434 | 427 | 11 |
| 15:00 | 132 | 138 | 141 | -8 |
| | | | Ave. | 5 |

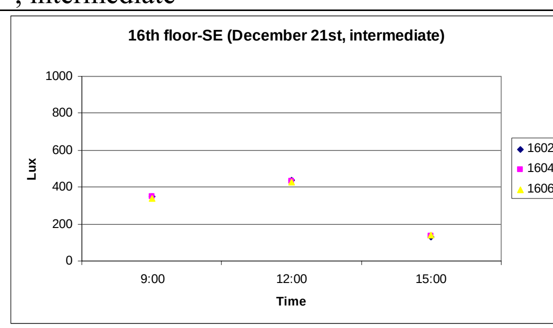
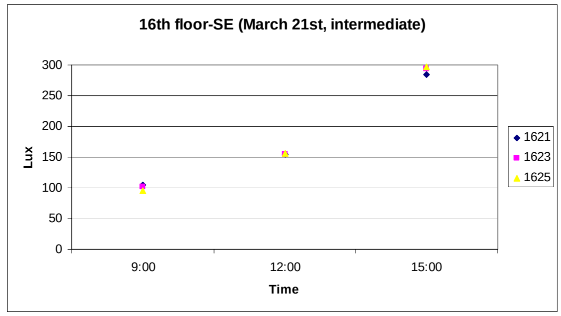



**Table 27-Comparison among #1602, #1604, and #1606 (type B, SE).**

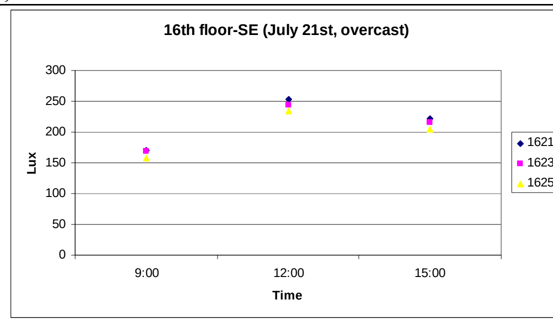
March 21st, intermediate

| Time | 1621 | 1623 | 1625 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 105 | 101 | 95 | 10 |
| 12:00 | 154 | 155 | 156 | -1 |
| 15:00 | 284 | 293 | 297 | -10 |
| | | | Ave. | -2 |



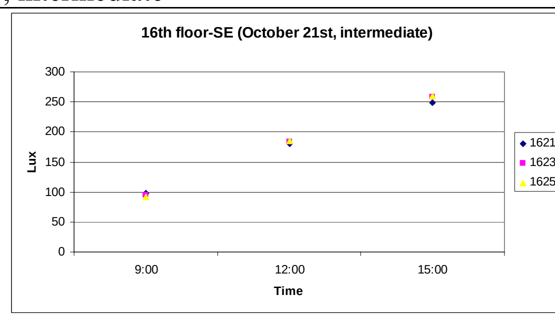

July 21st, overcast

| Time | 1621 | 1623 | 1625 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 171 | 169 | 158 | 13 |
| 12:00 | 254 | 243 | 235 | 19 |
| 15:00 | 222 | 216 | 205 | 17 |
| | | | Ave. | 16 |




October 21st, intermediate

| Time | 1621 | 1623 | 1625 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 98 | 95 | 92 | 6 |
| 12:00 | 180 | 183 | 184 | -5 |
| 15:00 | 248 | 257 | 260 | -12 |
| | | | Ave. | -4 |




December 21st, intermediate

| Time | 1621 | 1623 | 1625 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 48 | 47 | 45 | 3 |
| 12:00 | 130 | 133 | 133 | -4 |
| 15:00 | 143 | 148 | 154 | -11 |
| | | | Ave. | -4 |

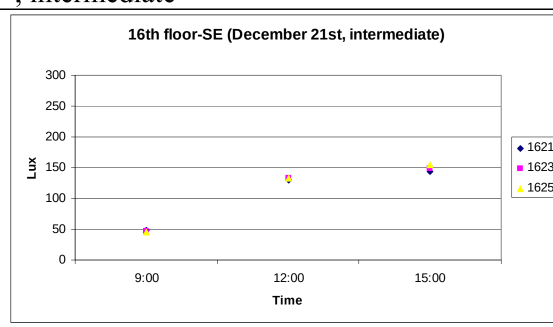
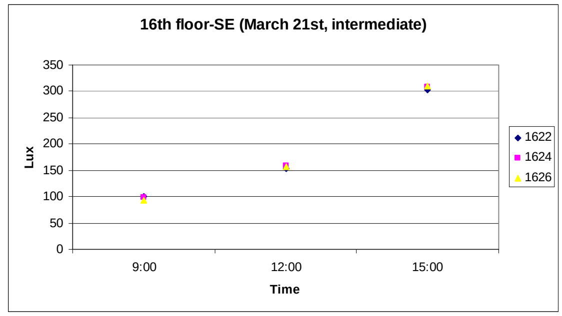



**Table 28-Comparison among #1621, #1623, and #1625 (type A, NW).**

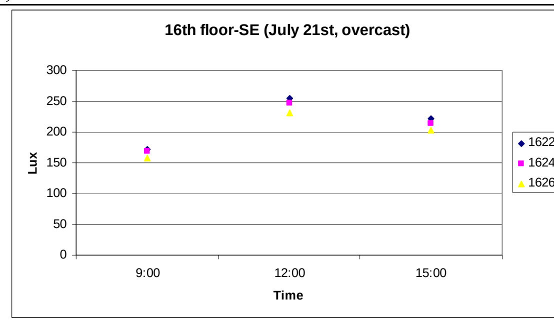
March 21st, intermediate

| Time | 1622 | 1624 | 1626 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 100 | 99 | 93 | 7 |
| 12:00 | 154 | 158 | 156 | -2 |
| 15:00 | 303 | 307 | 311 | -7 |
| | | | Ave. | -1 |



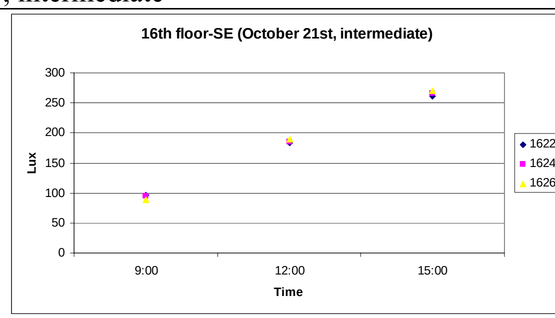

July 21st, overcast

| Time | 1622 | 1624 | 1626 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 172 | 169 | 158 | 14 |
| 12:00 | 255 | 246 | 232 | 23 |
| 15:00 | 222 | 215 | 203 | 19 |
| | | | Ave. | 18 |




October 21st, intermediate

| Time | 1622 | 1624 | 1626 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 96 | 95 | 89 | 7 |
| 12:00 | 184 | 184 | 190 | -6 |
| 15:00 | 261 | 265 | 270 | -8 |
| | | | Ave. | -3 |




December 21st, intermediate

| Time | 1622 | 1624 | 1626 | Differ. (lux) |
|---|---|---|---|---|
| 9:00 | 47 | 47 | 44 | 2 |
| 12:00 | 133 | 136 | 136 | -3 |
| 15:00 | 150 | 155 | 161 | -11 |
| | | | Ave. | -4 |

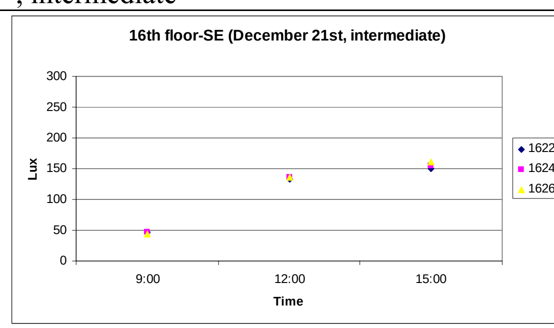



**Table 29-Comparison among #1622, #1624, and #1626 (type B, NW).**

As Tables 26, 27, 28, and 29 show, the overall average illuminance differences among patient rooms of each type and orientation, are from -11 to 47 under intermediate and overcast conditions. As a room in located near the inside corner of the building, the illuminance value is slightly diminished from the influences of other portions of the building. As a result, a middle patient room in each type of each orientation is appropriate to use as a representative sample to demonstrate the properties of indoor daylight environments for Inha University Hospital ; #1603 (Type A, SE), #1604 (Type B, NW), #1623 (Type A, SE), and #1624 (Type B, NW)..

## 4.4. ANALYSIS OF DAYLIGHT VARIABLES

### 4.4.1. Daylight Factor (DF)

| | **Type** | **Patient room** | **DF** | **Type** | **Patient room** | **DF** |
|---|---|---|---|---|---|---|
| Blinds opened | A | 1601 / 1621 | 1.41 % | B | 1602 / 1622 | 1.34 % |
| | | 1603 / 1623 | 1.39 % | | 1604 / 1624 | 1.25 % |
| | | 1605 / 1625 | 1.32 % | | 1606 / 1626 | 1.13 % |
| Blinds closed | **Type** | **Patient room** | **DF** | **Type** | **Patient room** | **DF** |
| | A | 1601 / 1621 | 0.45 % | B | 1602 / 1622 | 0.43 % |
| | | 1603 / 1623 | 0.44 % | | 1604 / 1624 | 0.40 % |
| | | 1605 / 1625 | 0.42 % | | 1606 / 1626 | 0.36 % |

**Table 30-DF values of patient rooms of type A and B on 16th floor.**

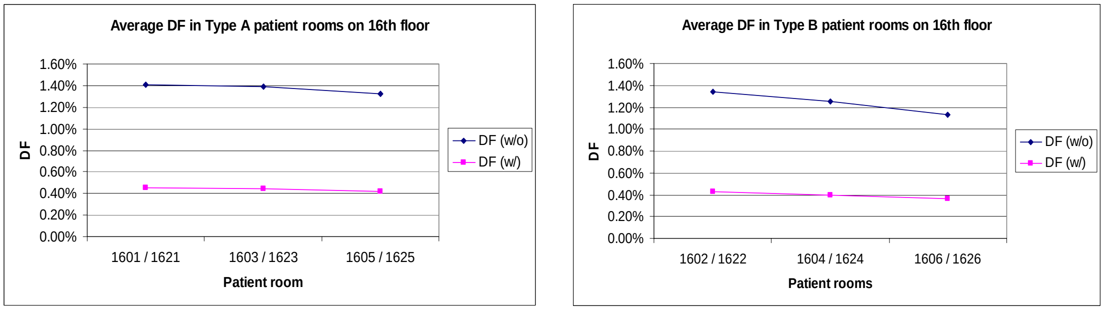



**Figure 23-DF of patient rooms of type A (left) and B on the 16th floor.**

Daylight factors (DF) of type A and B patient rooms show in Table 30 and Figure 23. Daylight Factors of both types have the same numerical pattern reducing DF as the rooms are near to the inside building corner. DF of this facility barely meets the recommended minimum DF in hospitals, 1%, by Thomas.[39]

| | Type A | Type B | Difference (DF) |
|---|---|---|---|
| #1 #2 | 1.41% | 1.34% | 0.07% |
| #3 #4 | 1.39% | 1.25% | 0.14% |
| #5 #6 | 1.32% | 1.13% | 0.19% |
| Ave. | 1.37% | 1.24% | 0.13% |

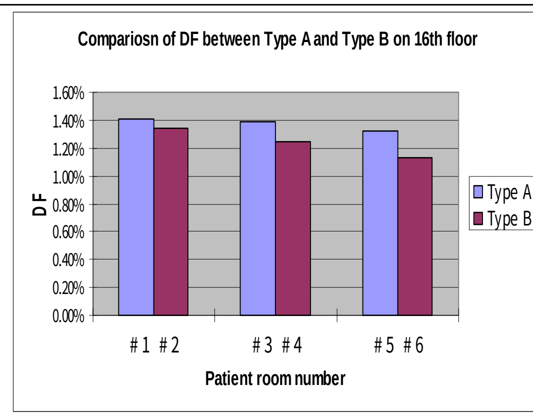



**Table 31-Comparison of DF between type A and B.**

As Table 31 shows, the average difference of daylight factor between type A and B is 0.13%. It is because each type of rooms faces different view and is influenced by a neighbor building.

### 4.4.2. Luminance ratio on TV wall

#### 4.4.2.1. Comparison between type A and B in SE and NW

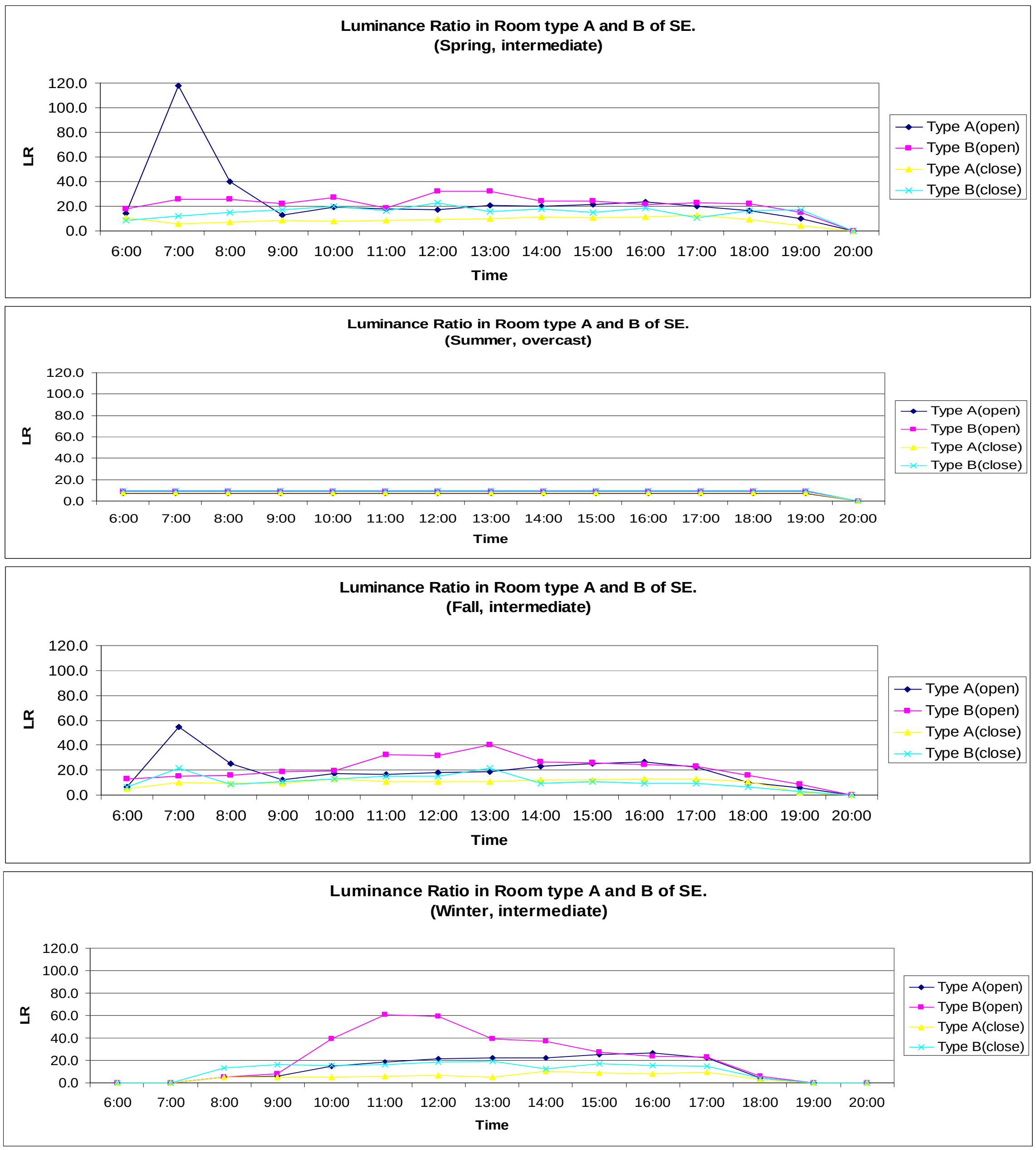



**Figure 24-Comparison between type A and B in SE.**

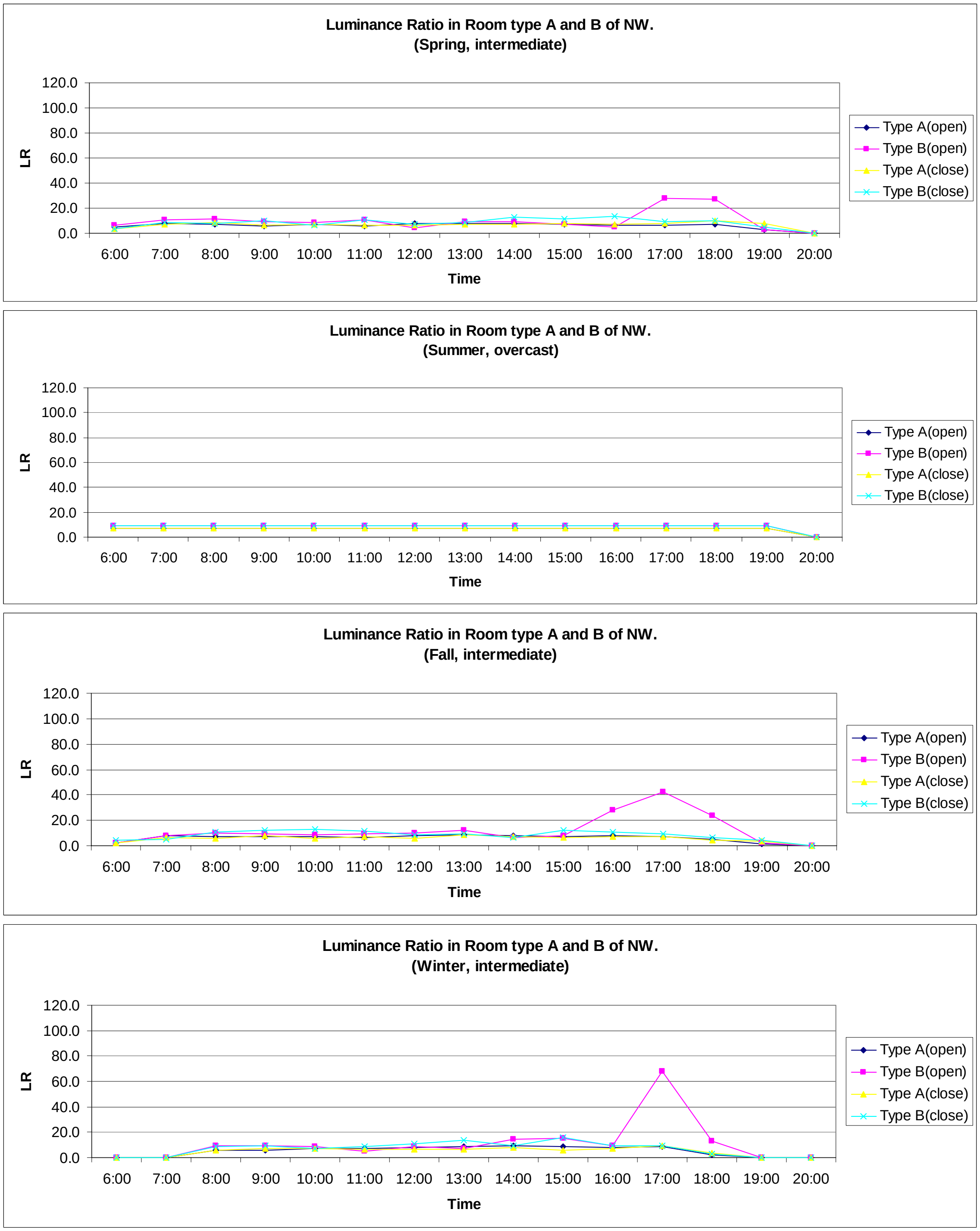



**Figure 25-Comparison between type A and B in NW.**

Because of different types in patient rooms, TV walls face different orientations. It makes different Luminance Ratio (LR) between type A and B. In Figures 24 and 25, SE facing type A room has much direct daylight entered in the morning time so that the excessive LRs are happened in the morning. On the other hand, the type B, NW, has high LR at the afternoon in all season except July. In summer, the overcast season, the LR in both types is moderate and uniformed. The length of time when LR is higher than the maximum recommended value (40:1).[8] It is about 1 or 3 hours in each case. With the blinds closed, all LRs are moderate around 15, and lower than the recommended.

#### 4.4.2.2. Comparison between SE and NW of type A and type B

According to Figures 26 and 27, in the whole year, SE facing rooms have higher LR than NW facing room. But, the excessive LRs are seen in spring and fall for 1 or two hour in the morning. There is higher LR in the evening in the all season except summer in type B, NW, than the recommended values (40:1).[8] It is happened just for 1or 2 hour.

The LRs over the maximum recommended value, max 40:1, can disturb patient visual comfort in their rooms. Those would be a stressor to patients. But, those happen for 1 or 3 hours in the morning and in the evening in turn depending on types, orientation, and seasons. It can be no significant difference between the types and the orientation each.

Further more, if the vertical blinds installed in a patient room is closed on the window, the LR is reduced to 20 below. As a result, the vertical blinds make it possible for a patient to prevent visual discomfort by controlling the daylight level. With the blinds, LR of all patient rooms during all seasons can be lower than over the maximum recommended value, max 40:1,

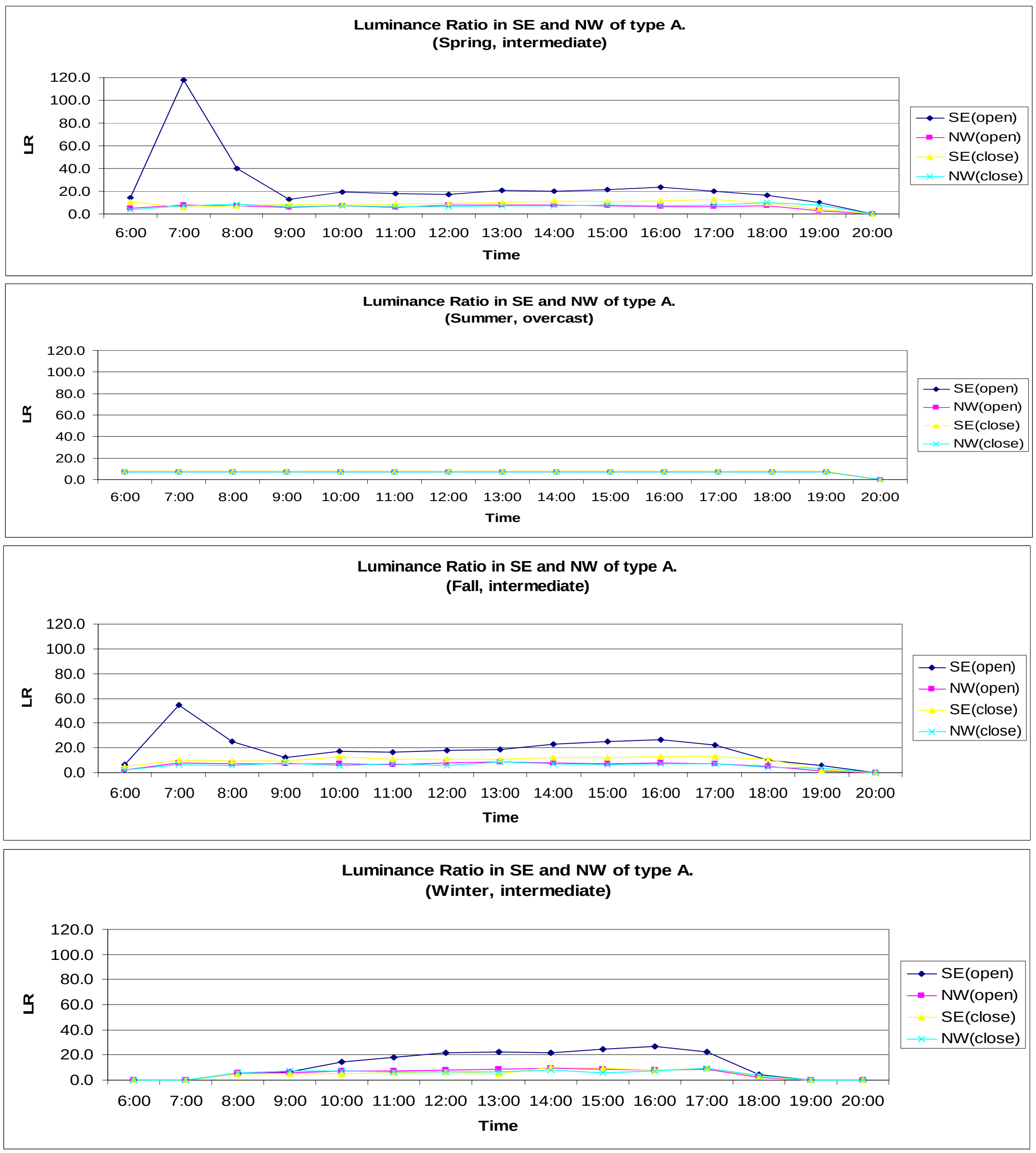



**Figure 26-Comparison between SE and NW of type A.**

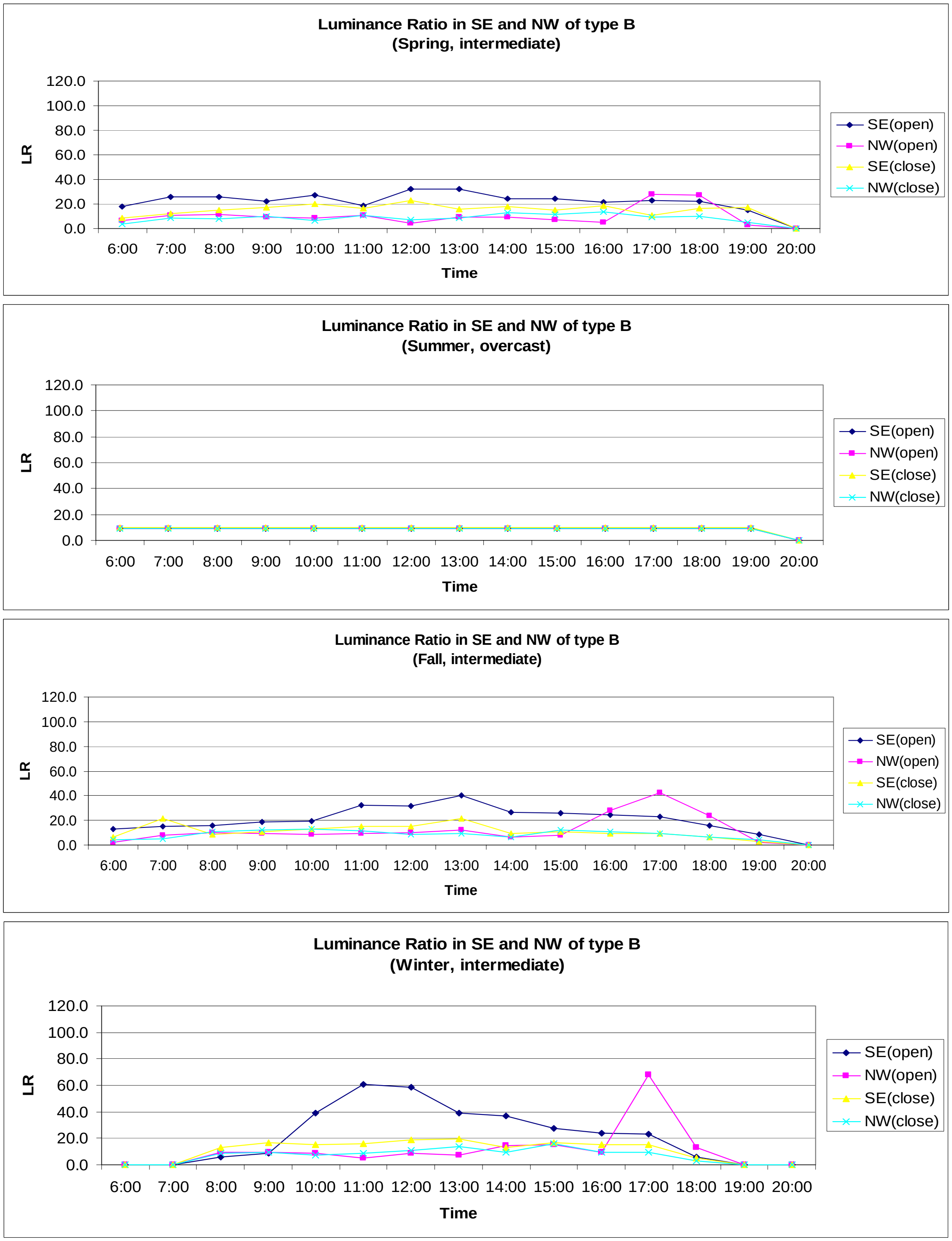



**Figure 27-Comparison between SE and NW of type B.**

Figures 28 and 29 show the critical values of luminance ratio in March and December. The figures show the ranges are much reduced with the blinds closed.

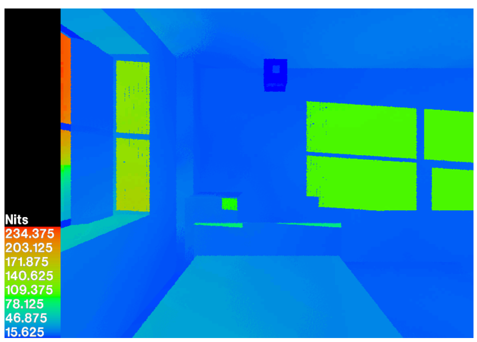
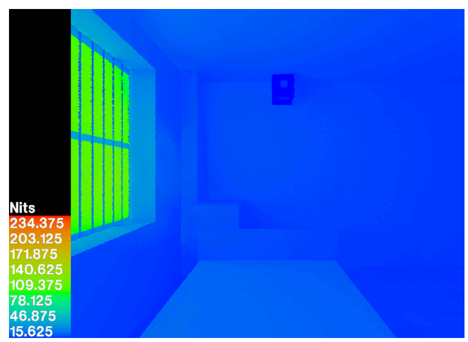
| | Type A(#1603), 10:00 AM, March 21st. Intermediate | |
|---|---|---|
| | Blinds opened | Blinds closed |
| LR |   |   |
| False color |   |   |
| Human sensi-tivity |  |  |

**Figure 28-RADIANCE images of luminance ratio, type A (#1603), 10:00 AM, March 21st, intermediate.**

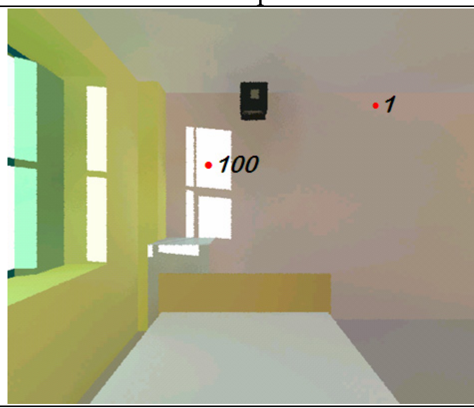
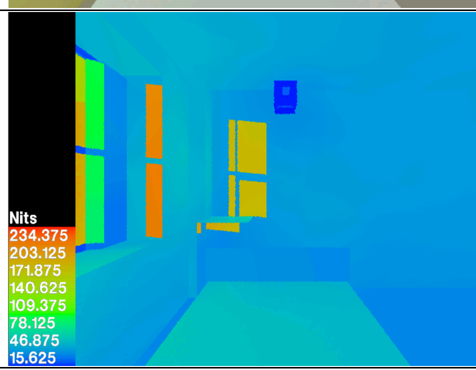
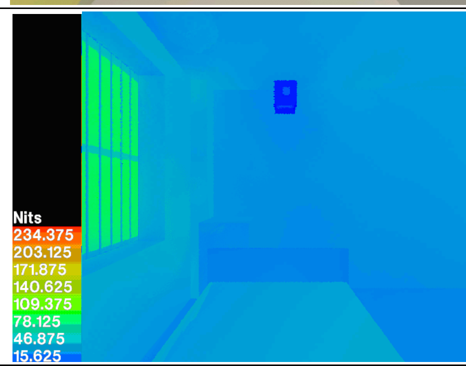
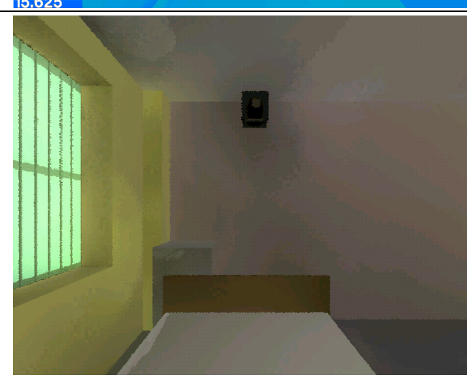
| | Type B(#1624), 5:00 PM , December 21st. Intermediate | |
|---|---|---|
| | Blinds opened | Blinds closed |
| LR |   |   |
| False color |   |   |
| Human sensi-tivity |  |  |

**Figure 29-RADIANCE images of luminance ratio, type B (#1624), 5:00 PM, December 21st, intermediate.**

## 4.4.3. Luminance ratio between the TV point and patient eye

### 4.4.3.1. Comparison between type A and B in SE and NW

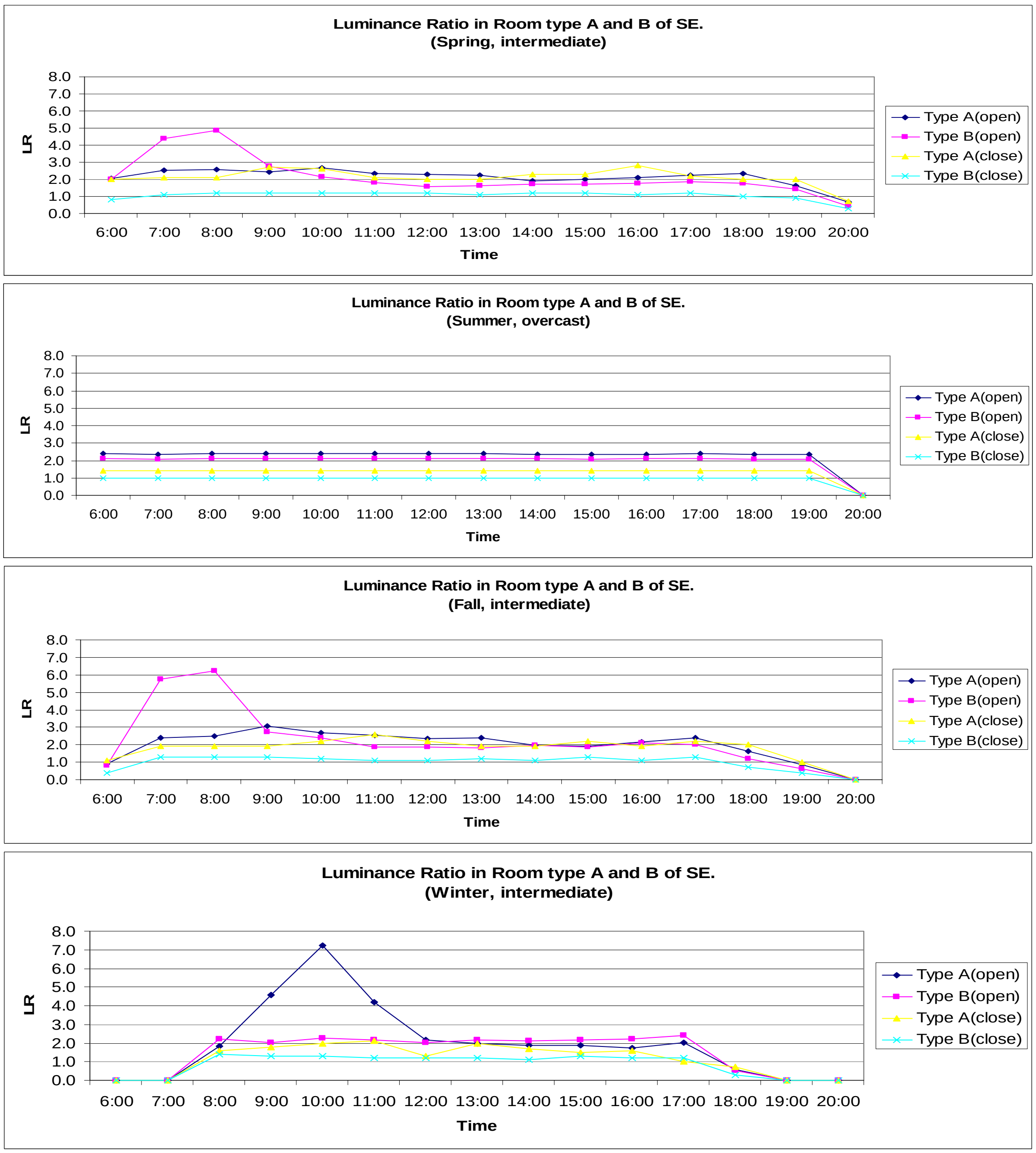



**Figure 30-Comparison between type A and B in SE.**

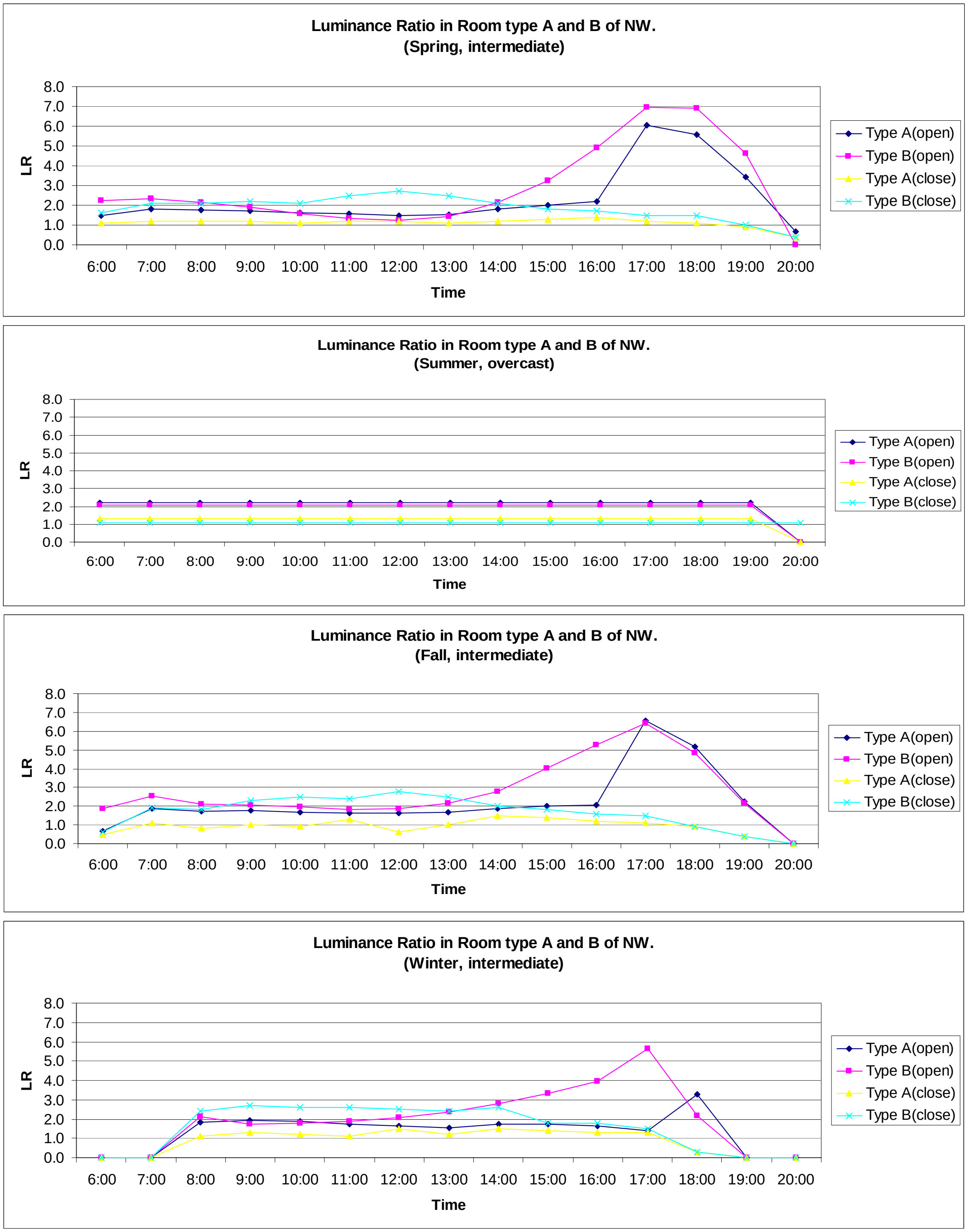



**Figure 31-Comparison between type A and B in NW.**

In Figures 30 and 31, the various seasonal solar locations make different LR between Type A and B in SE and NW orientations each. The both types have moderate LR in the all seasons. All Luminance Rations are lower than 1:10 that is recommended luminance ratio.[8] In SE, the type A has relatively high LR over 5 in the morning during spring and fall. And, the type B has the LR over 7 at 10:00 in fall.

In Figure 31, the changing patterns of LR in the type A and B of NW is almost same. It looks proportionally related. Because they are facing NW, they have high LRs in the evening in the all seasons. Those are sustained just for 1or 2 hours.

As a result, there is no significant difference between the two types in SE and NW each. Moreover, all LR values are lower than the recommended LR, 1:10.

#### 4.4.3.2. Comparison between SE and NW of type A and type B

In Figures 32 and 33, overall SE facing rooms have relatively high LR in the morning and NW facing rooms do in the evening.

All values are not over the recommended max. LR values, and the relatively high LR values at a certain time is not sustained over 2 hours. On the contrary, all luminance ratios are controllable with the vertical blinds and can be moderate. As a result, there are no significant differences between types and orientations in luminance ratios.

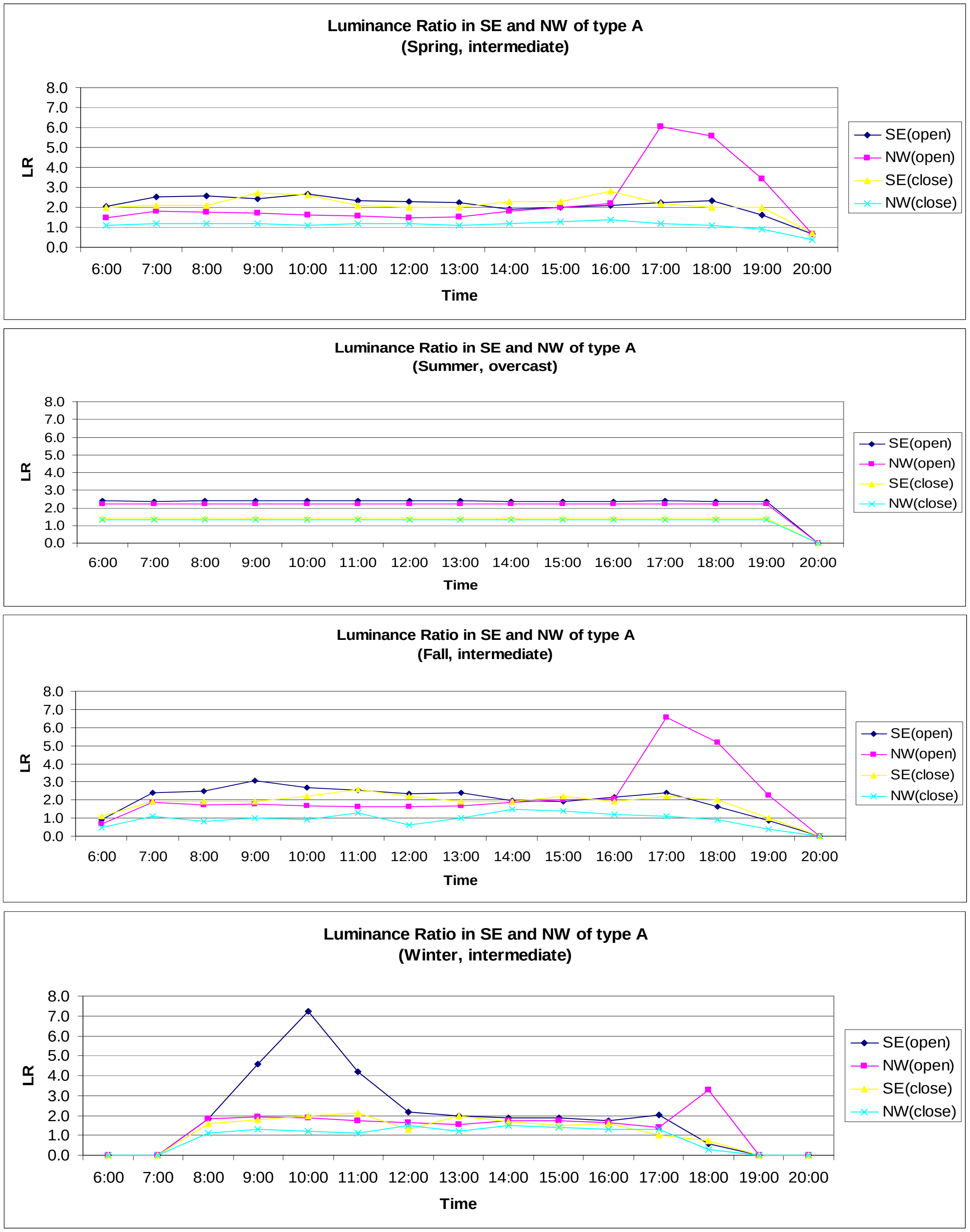
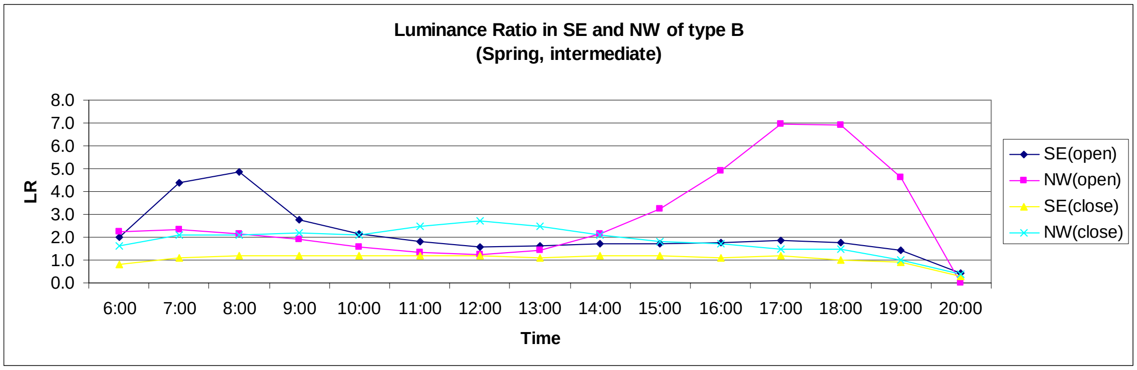
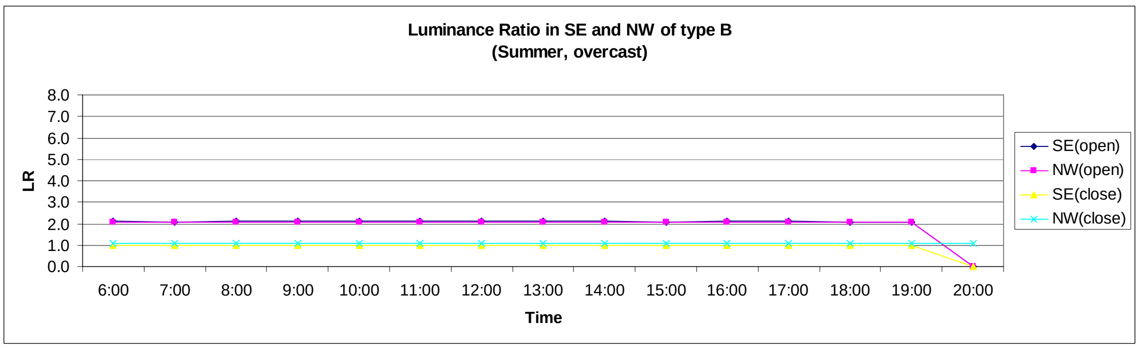
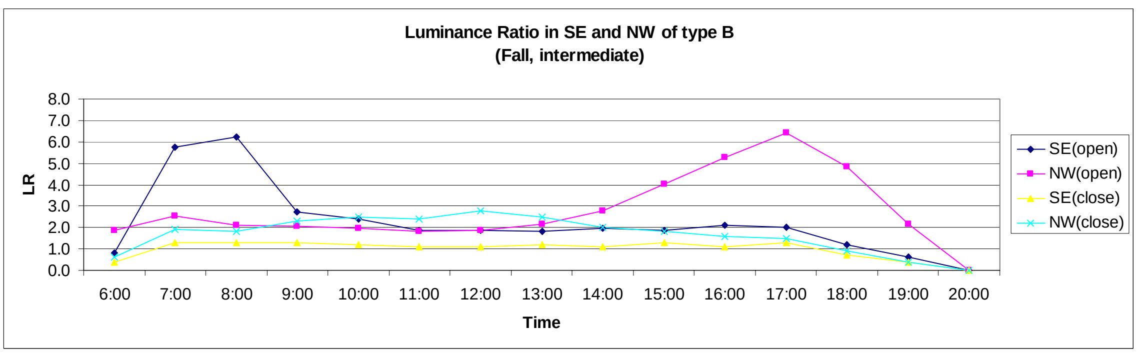



**Figure 32-Comparison between SE and NW of type A.**



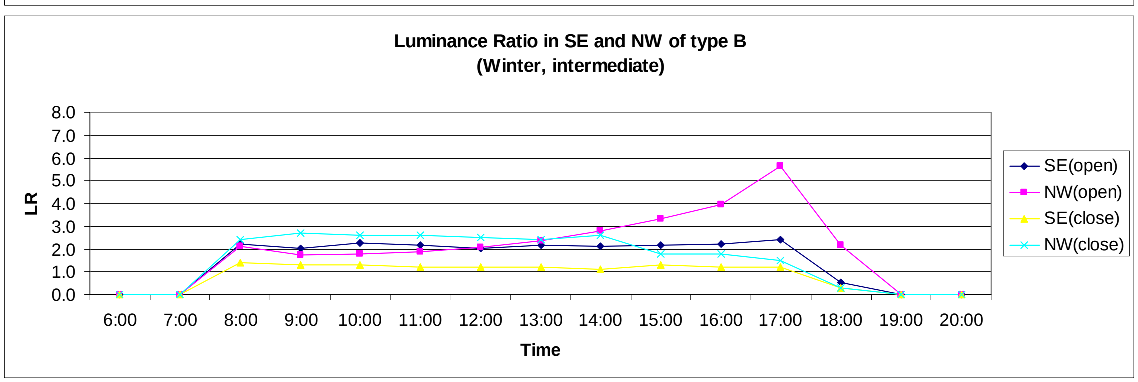




**Figure 33-Comparison between SE and NW of type B.**

Figure 34 shows the effect of the blinds closed on reducing the luminance ratio.

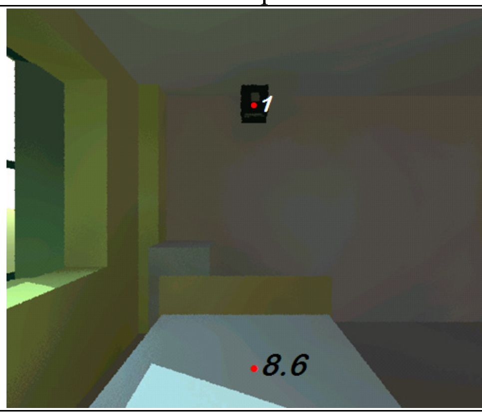
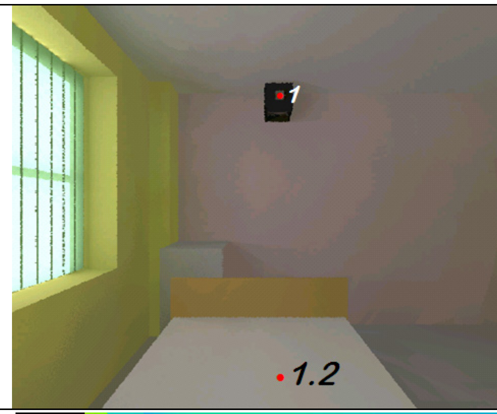
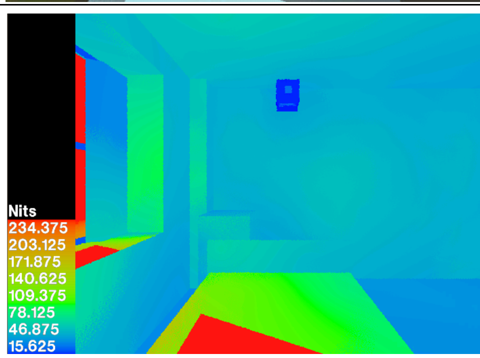
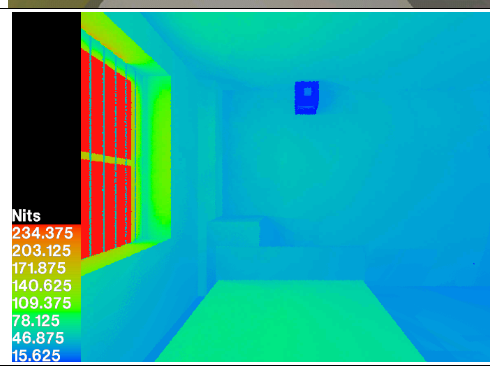
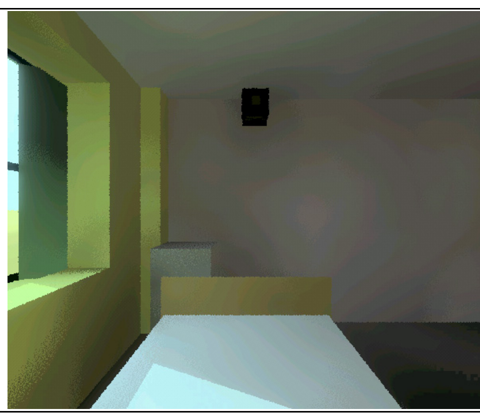
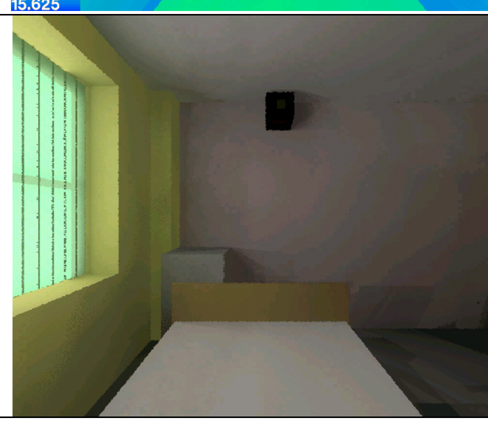
<table>
<tr><td></td><td colspan="2">Type B(#1624), 17:00 , December 21st. Intermediate</td></tr>
<tr><td></td><td>Blinds opened</td><td>Blinds closed</td></tr>
<tr><td>LR</td><td>
</td><td>
</td></tr>
<tr><td>False color</td><td>
</td><td>
</td></tr>
<tr><td>Human sensi-tivity</td><td></td><td></td></tr>
</table>

**Figure 34- RADIANCE image of luminance ratio, type B(#1624), 5:00 PM, December 21st, intermediate.**

## 4.4.4. Average illuminance

### 4.4.4.1. Comparison between type A and B in SE and NW

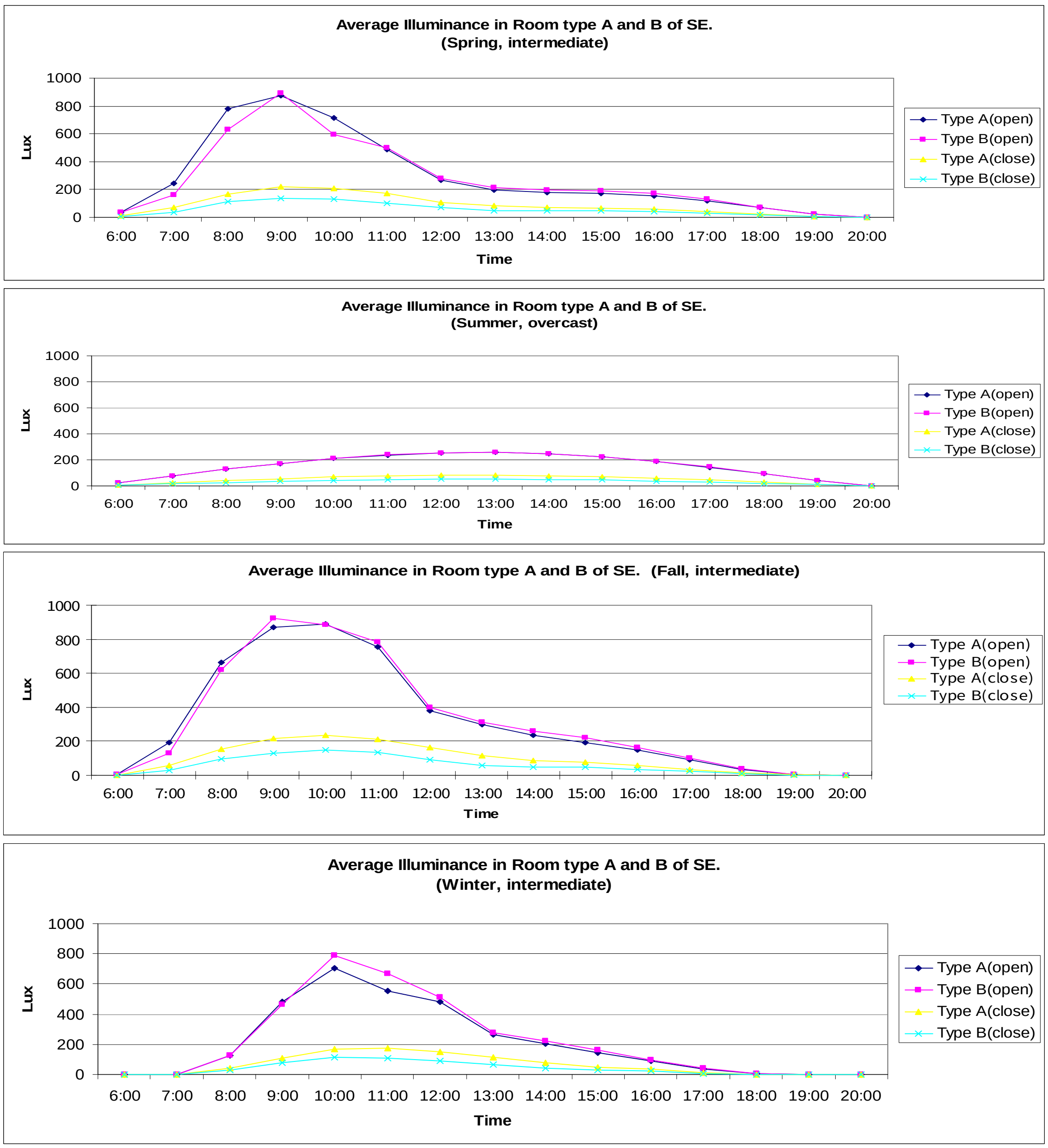



**Figure 35-Comparison between type A and B in SE.**

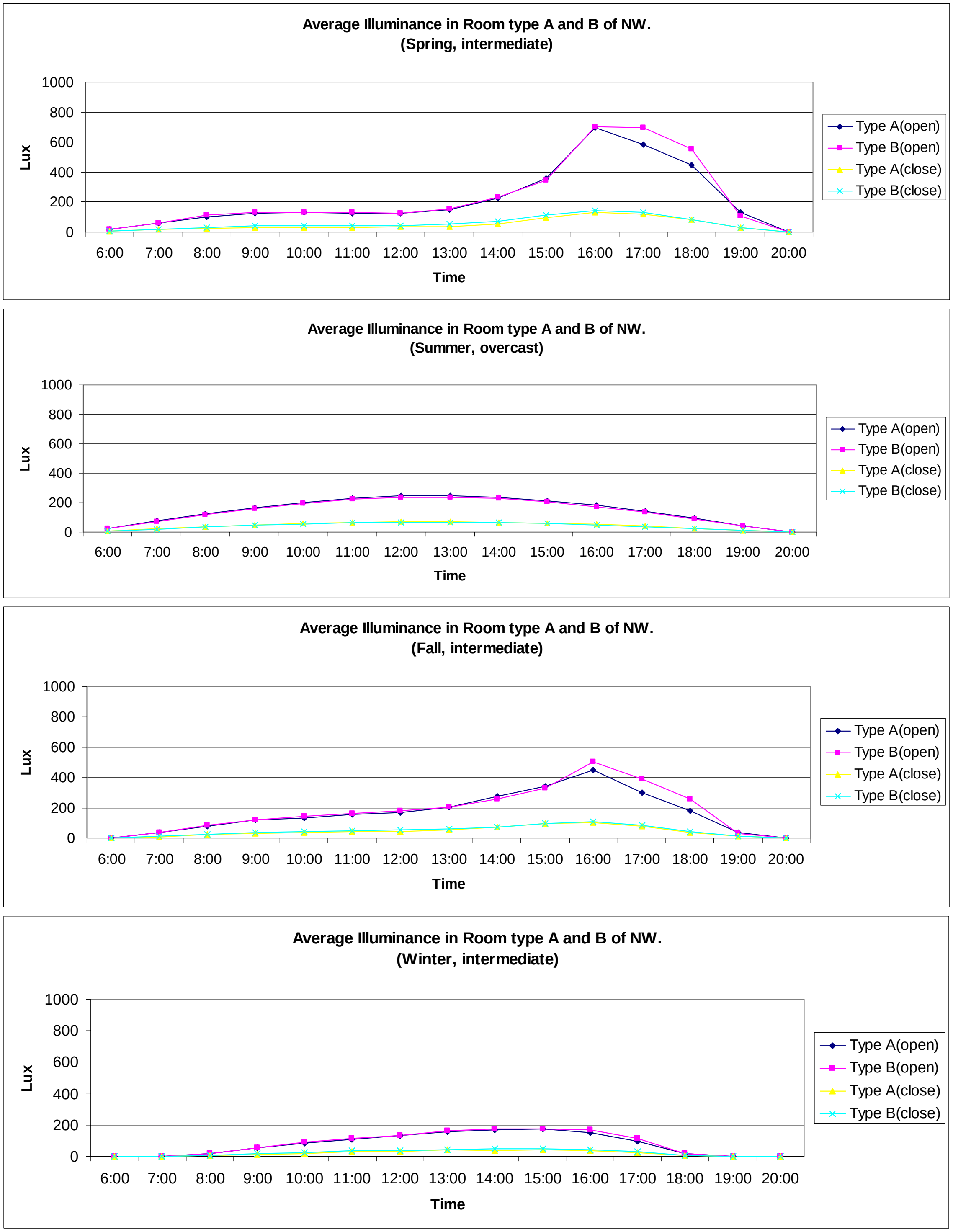



**Figure 36-Comparison between type A and B in NW.**

#### 4.4.4.2. Comparison between SE and NW of type A and type B

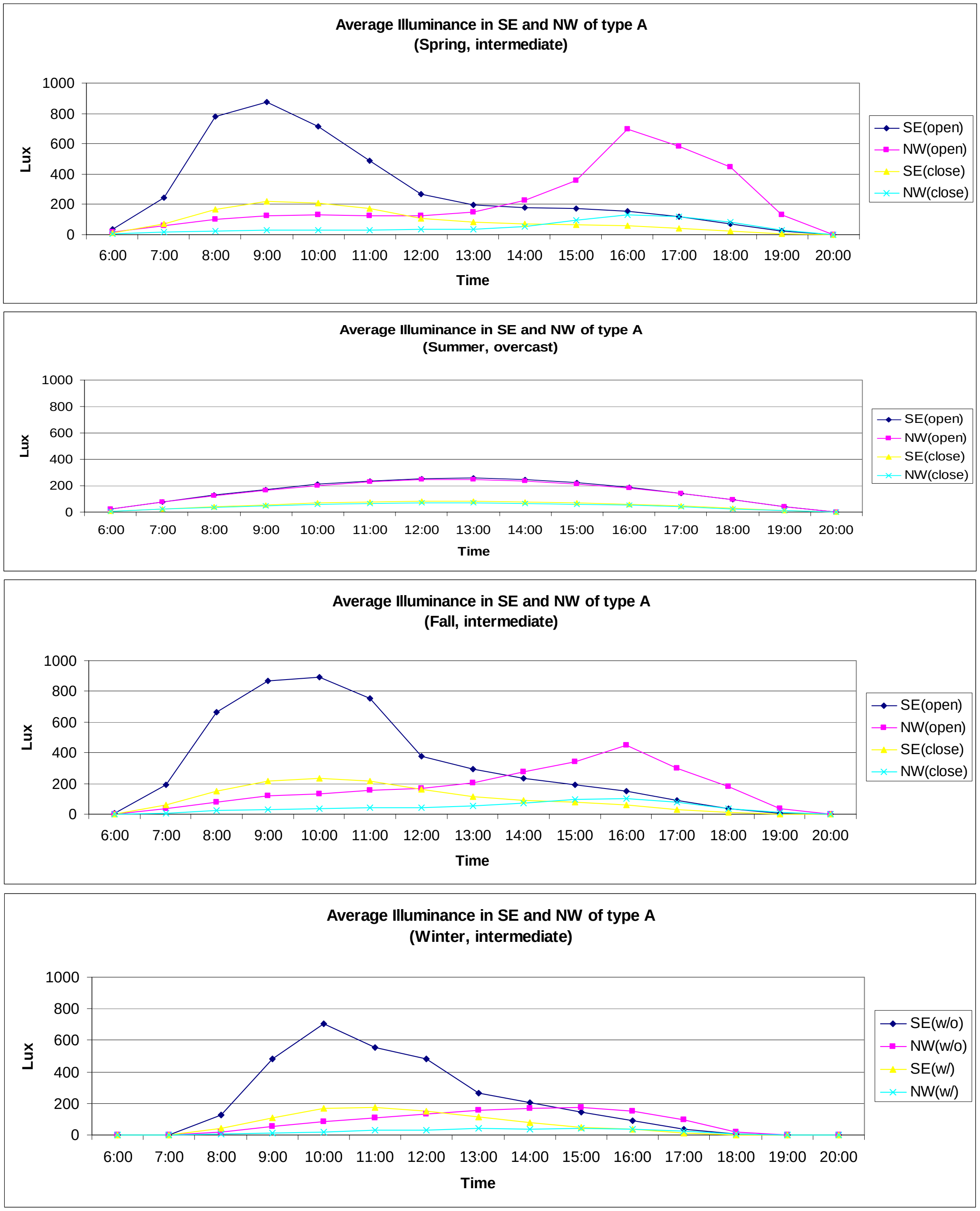



**Figure 37-Comparison between SE and NW of type A.**

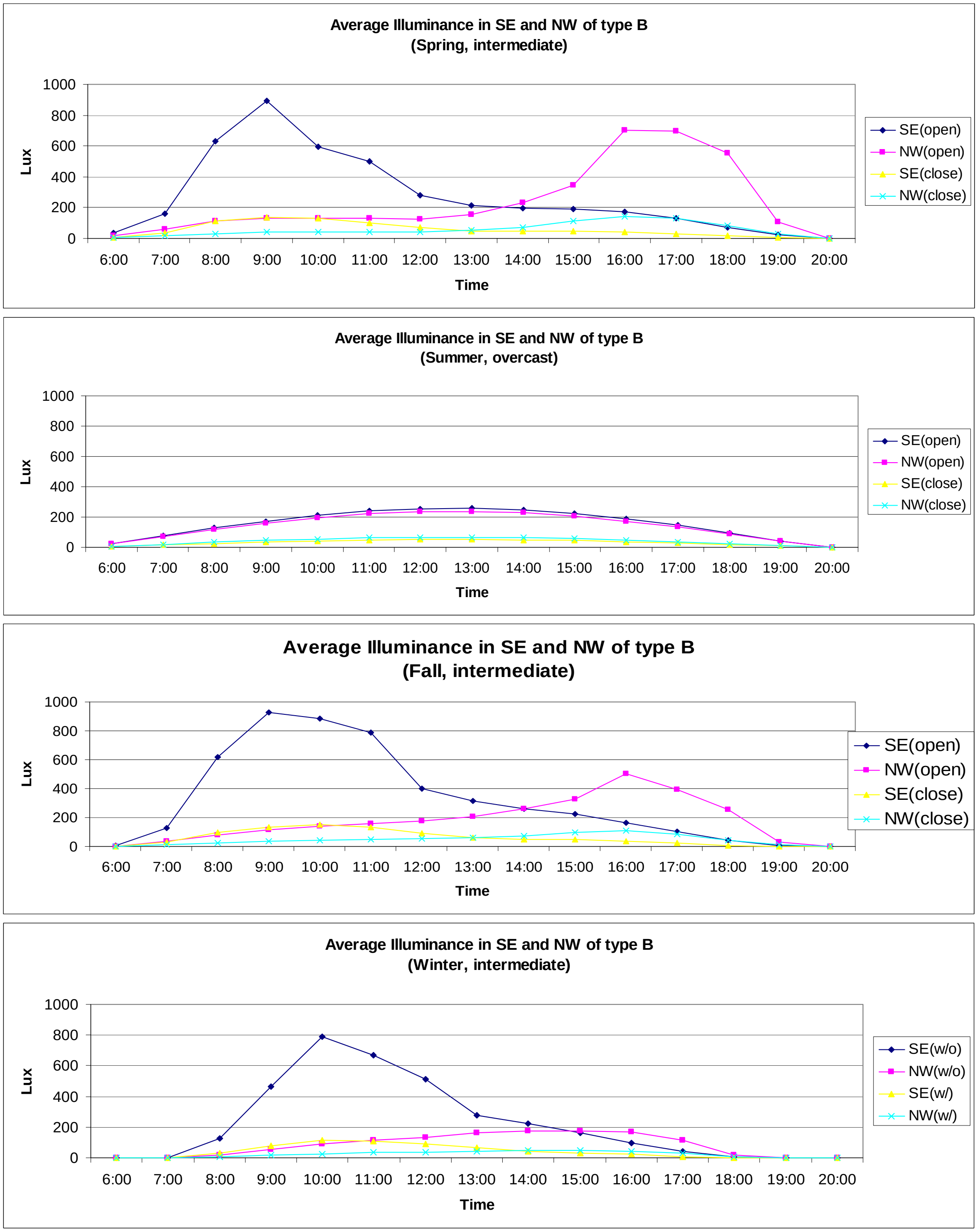



**Figure 38-Comparison between SE and NW of type B.**

As shown in Figures 35 and 36, there is no significant difference in average illuminance between Type A and B in each orientation of SE and NW. Because of a same orientation, the changing patterns of average illuminance are almost same between the two.

In Figures 37 and 38, SE facing room has higher illuminance than CIBSE recommended reading lighting level (300 lux) for a patient room.  Even though, NW facing room has slightly higher than SE facing room in Illuminance in the afternoon, the illuminance of SE facing room is extremely high in the morning time. Those phenomenons are expected to be happened in the whole year except in overcast season, summer. In summer, illuminance levels are lower than the CIBSE recommended reading lighting level that it may need a separated electric luminaries.

With vertical blinds, excessive illuminace can be controlled to be reduced up to the level lower than 200 lux.

## 4.4.5. Diversity of Illuminance (DI)

### 4.4.5.1. Comparison between type A and B in SE and NW

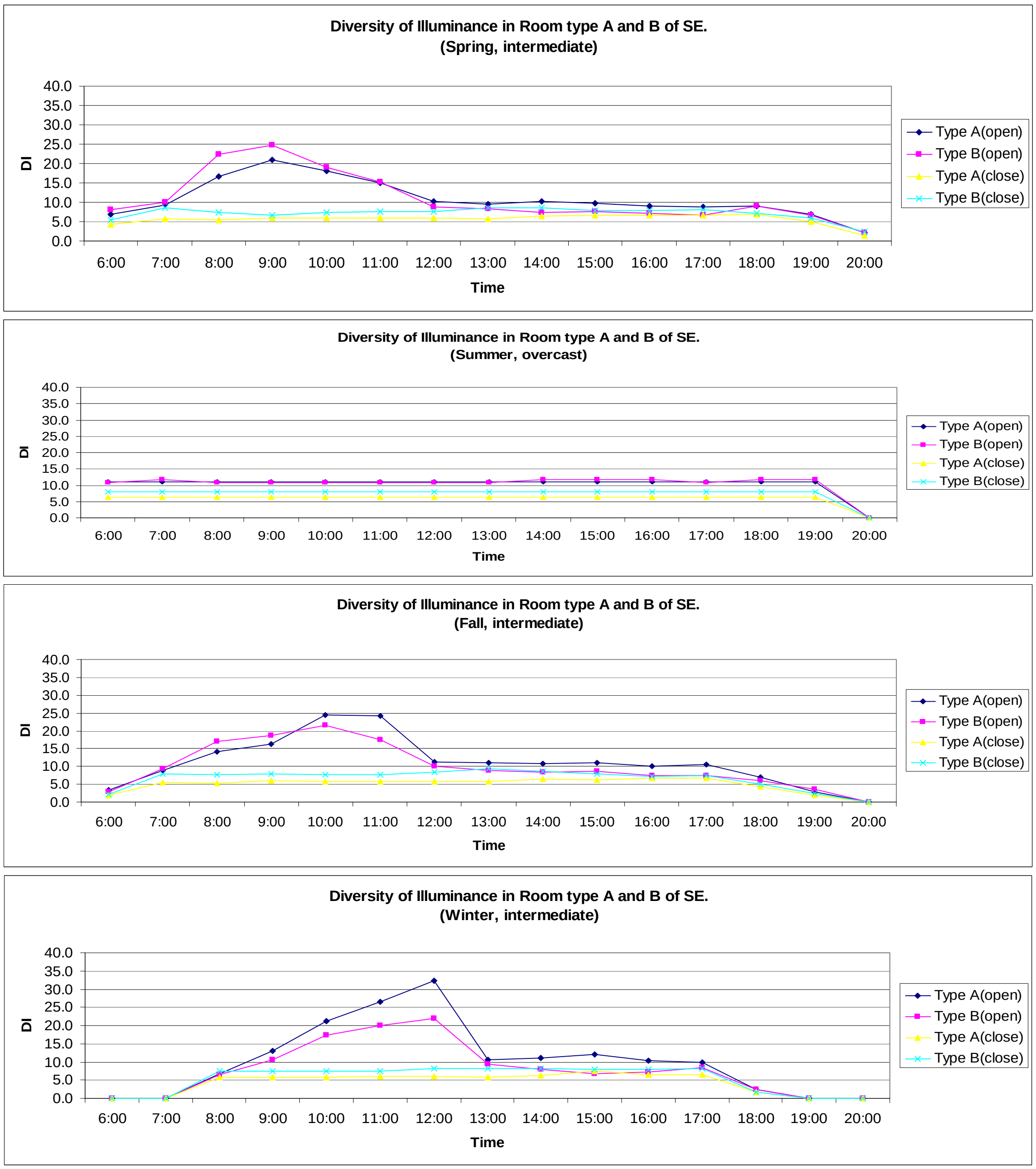



**Figure 39-Comparison between type A and B in SE.**

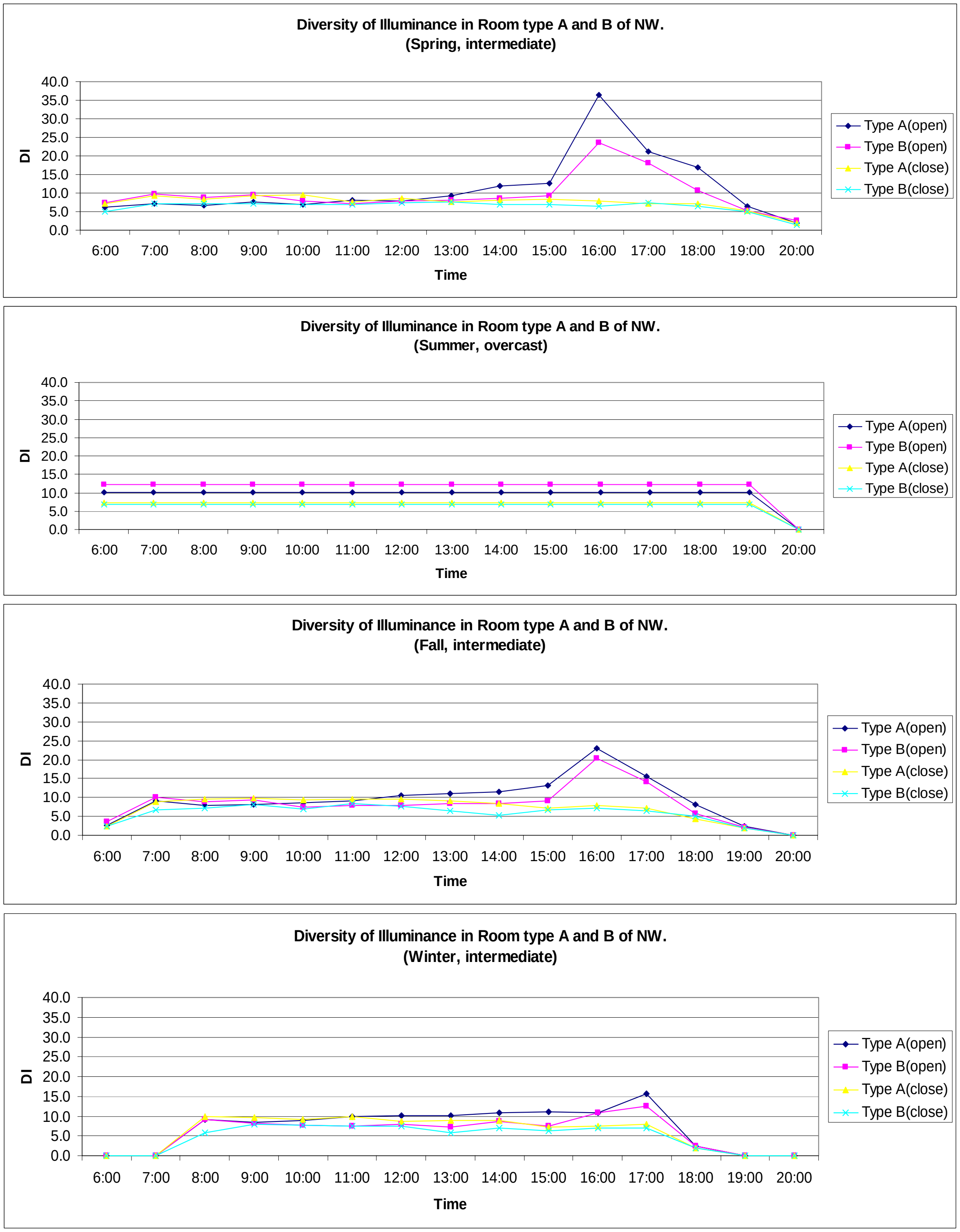



**Figure 40-Comparison between type A and B in NW.**

### 4.4.5.2. Comparison between SE and NW of type A and B

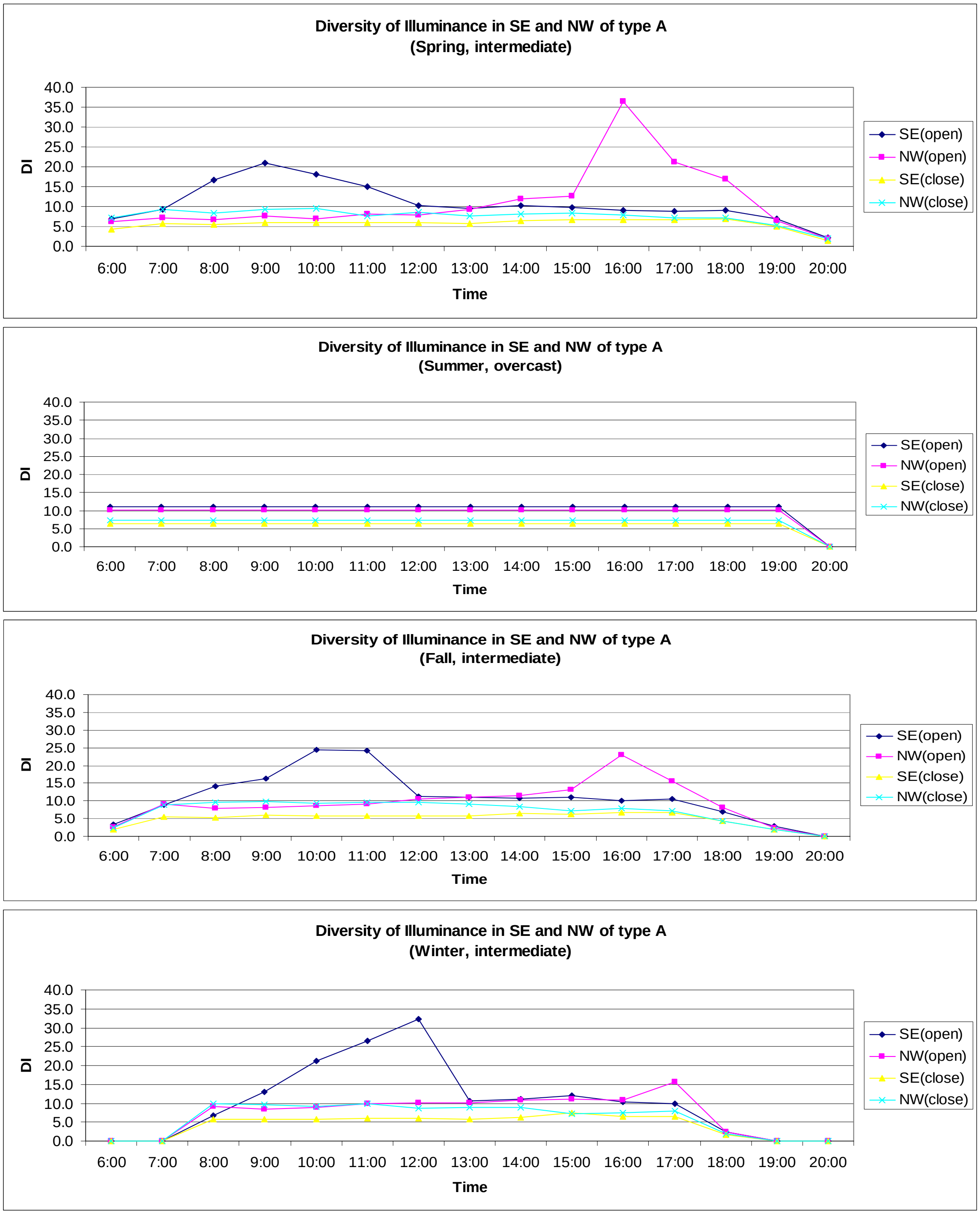



**Figure 41-Comparison between SE and NW of type A.**

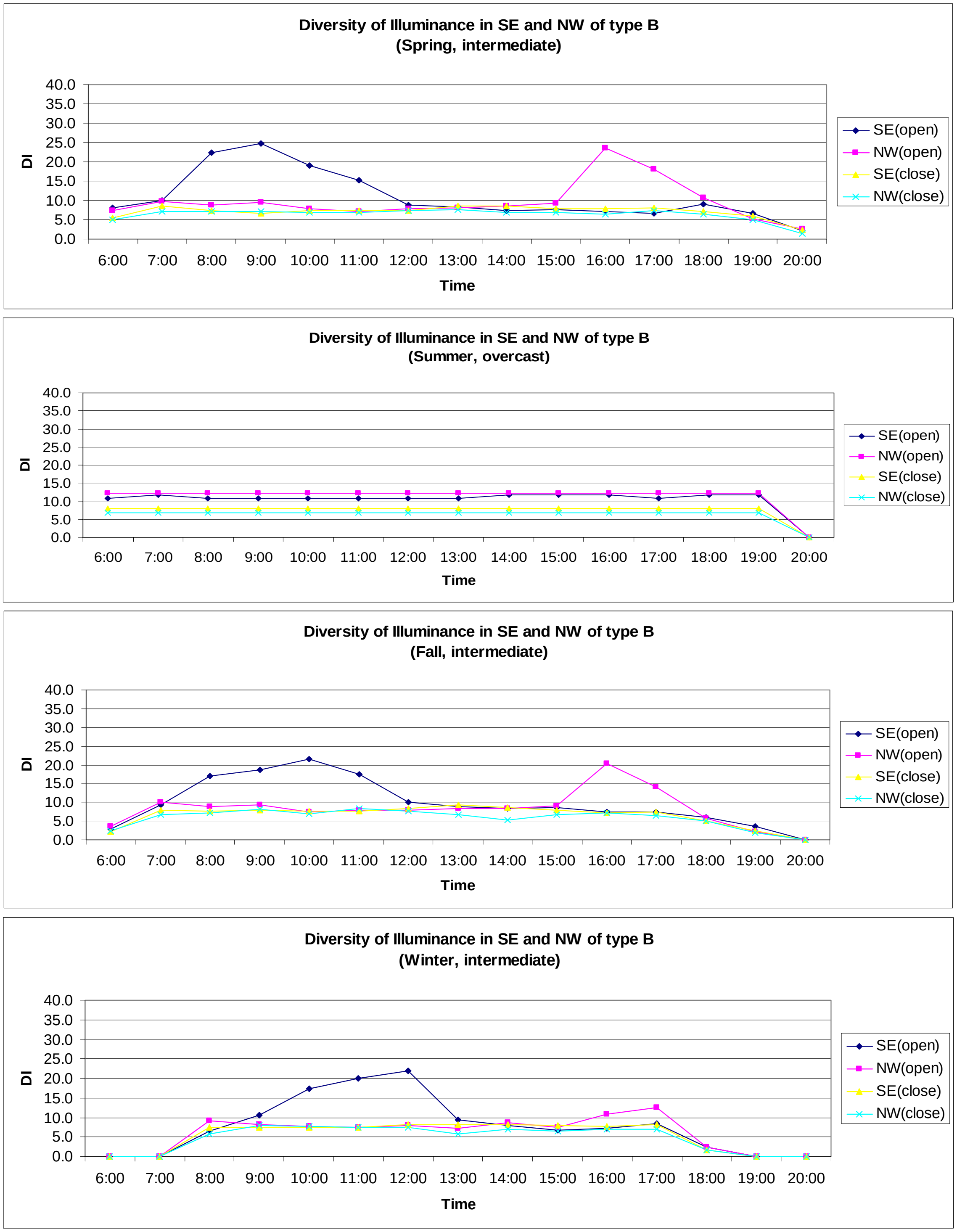



**Figure 42-Comparison between SE and NW of type B.**

The changing patterns of diversity of illuminance are very similar between the two types of each orientation because it is much related with illuminance level (Figures 39 and 40). Overall the values of diversity of illuminace are higher than the maximum recommend value, 5 by CIBSE without using blinds.

In Figures 41 and 42, the SE facing patient rooms have higher diversity of illuminances than the NW facing in the morning for the all season except for summer. On the contrary, the NW facing rooms have higher values than the SE in the afternoon.

With the blinds closed in a patient room, the diversity of illuminance is reduced to lower than 10 but, higher than 5. Even though it is not met with the recommended value, the diversity of illuminance can be drastically reduced and become moderate. Moreover, the difference of the diversity of illuminance between the two orientations is greatly reduced with closed blinds. Therefore, all patient rooms may have similar values of the diversity of illuminance. In addition, patients can prevent visual discomfort by controlling the blinds as they desire to meet their particular preferences.

## 4.4.6. Uniformity of Illuminance (UI)

### 4.4.6.1. Comparison between type A and B in SE and NW

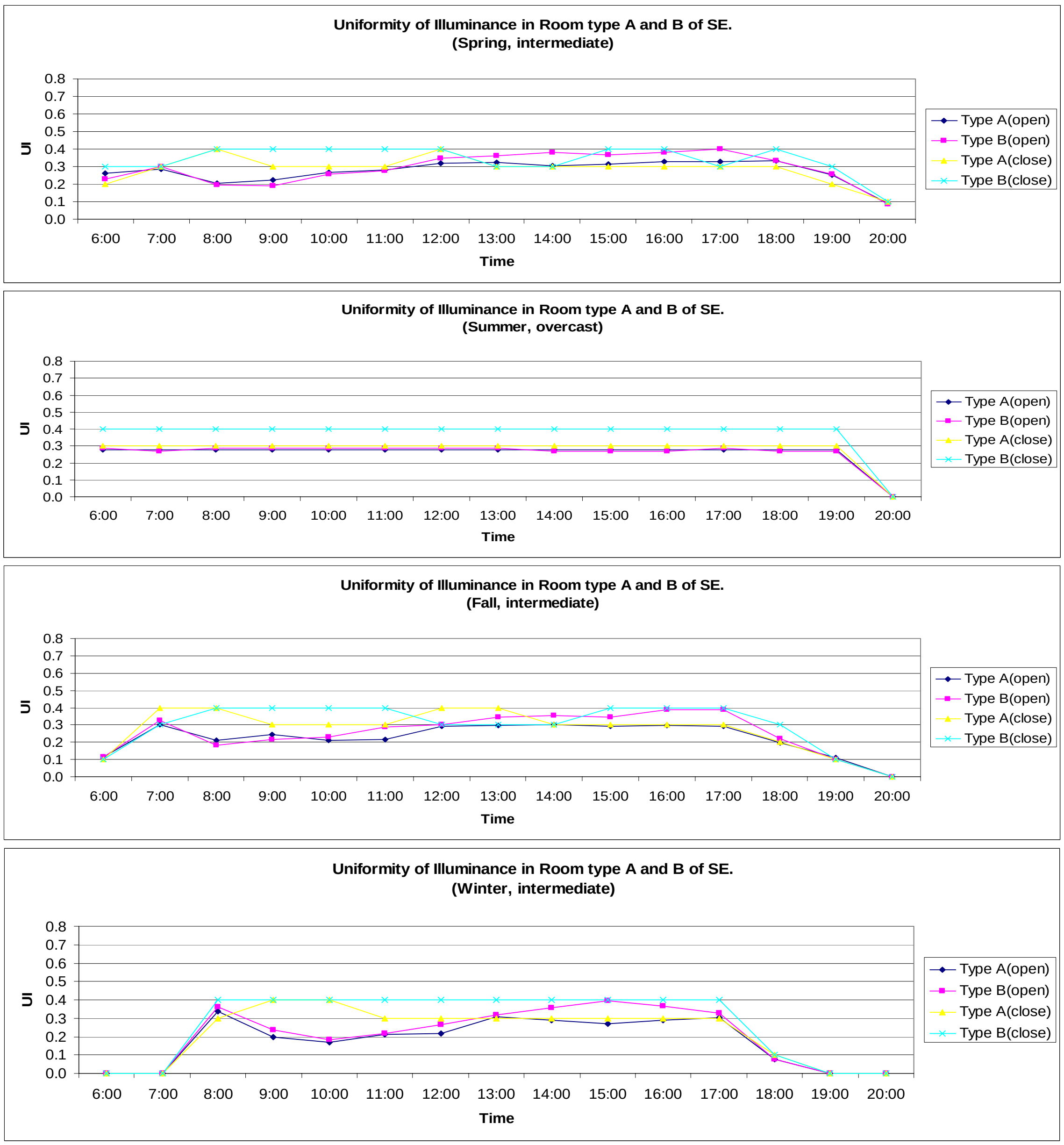



**Figure 43-Comparison between type A and B in SE.**

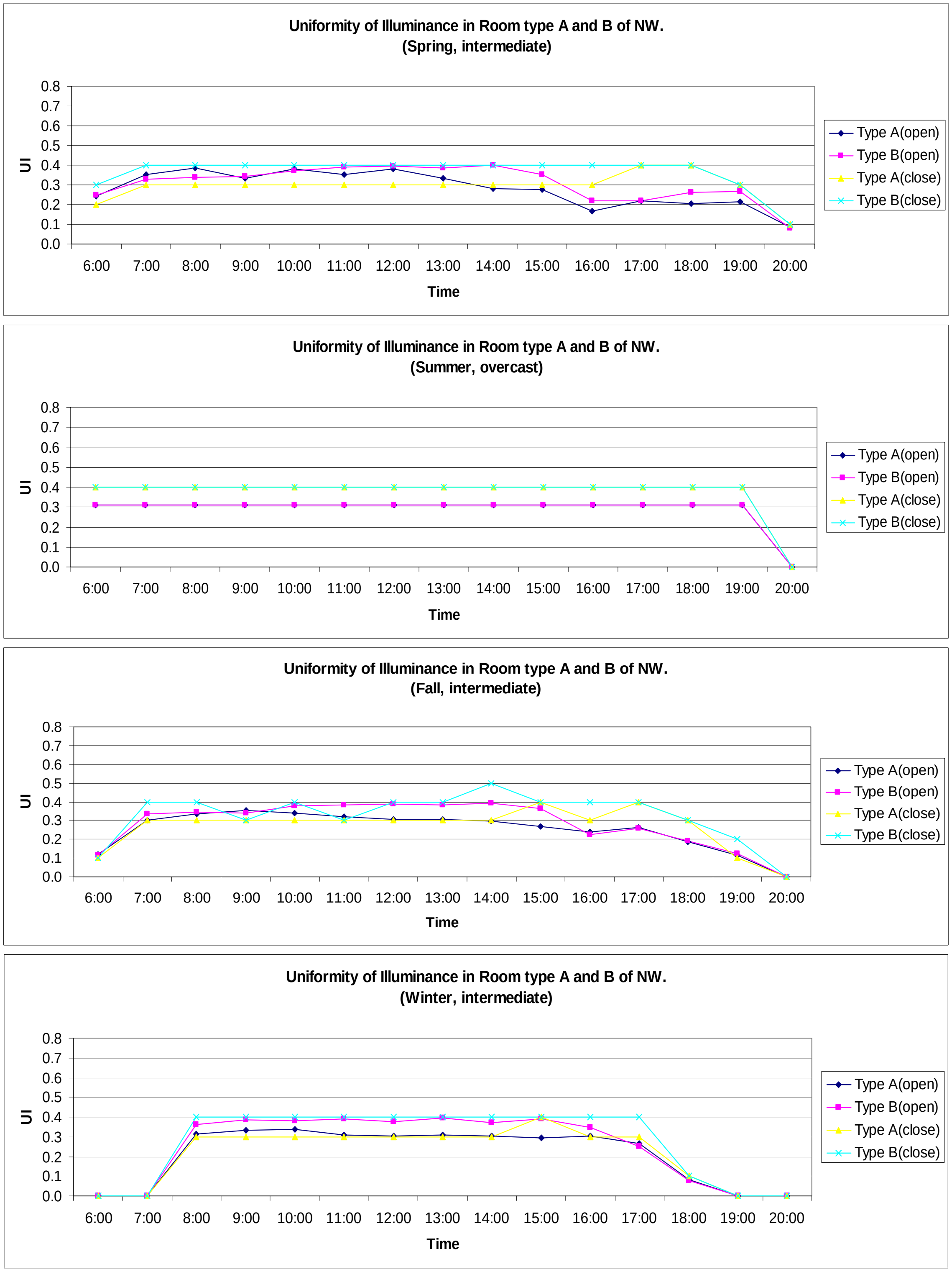



**Figure 44-Comparison between type A and B in NW.**

#### 4.4.6.2. Comparison between SE and NW of type A and type B

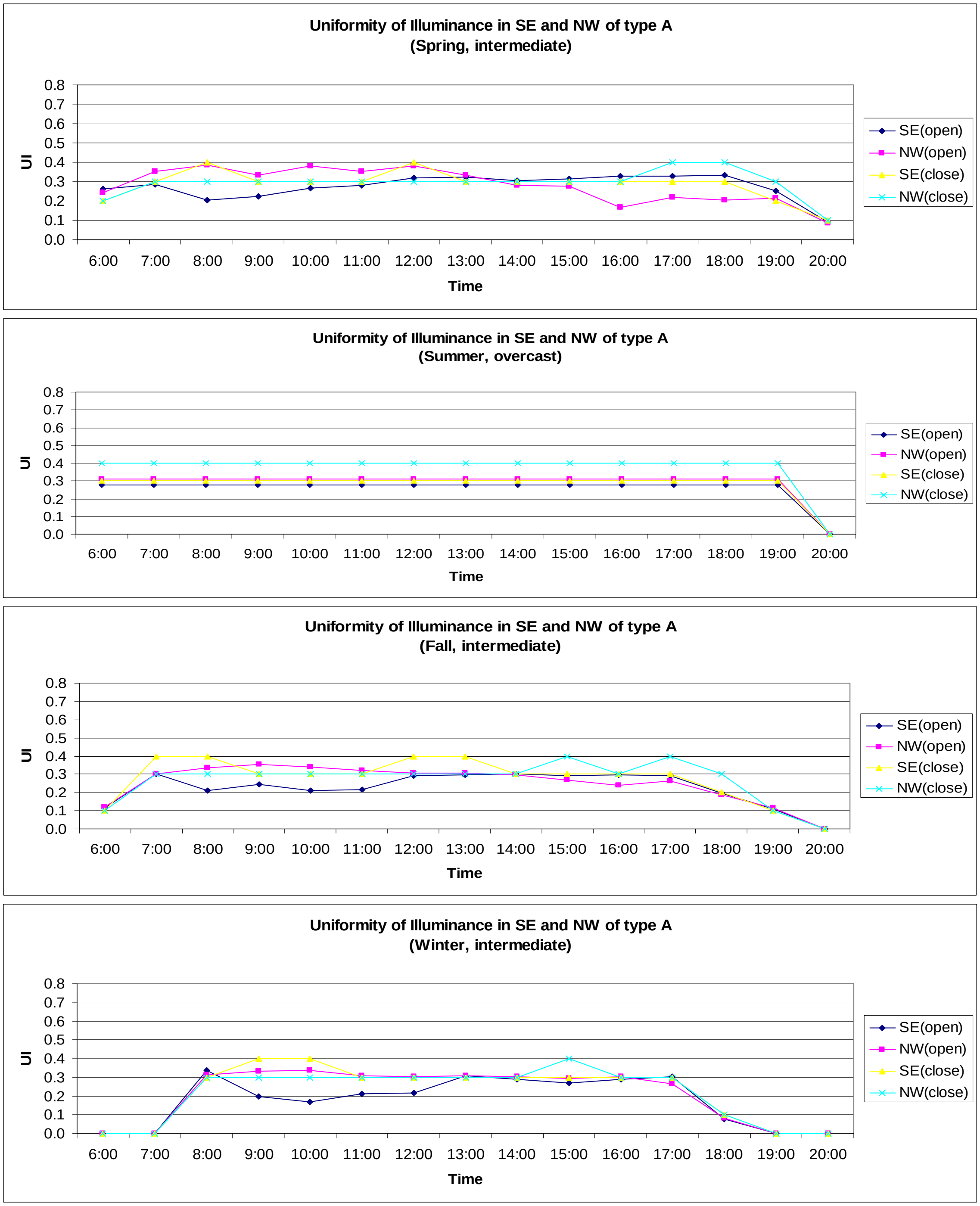



**Figure 45-Comparison between SE and NW of type A.**

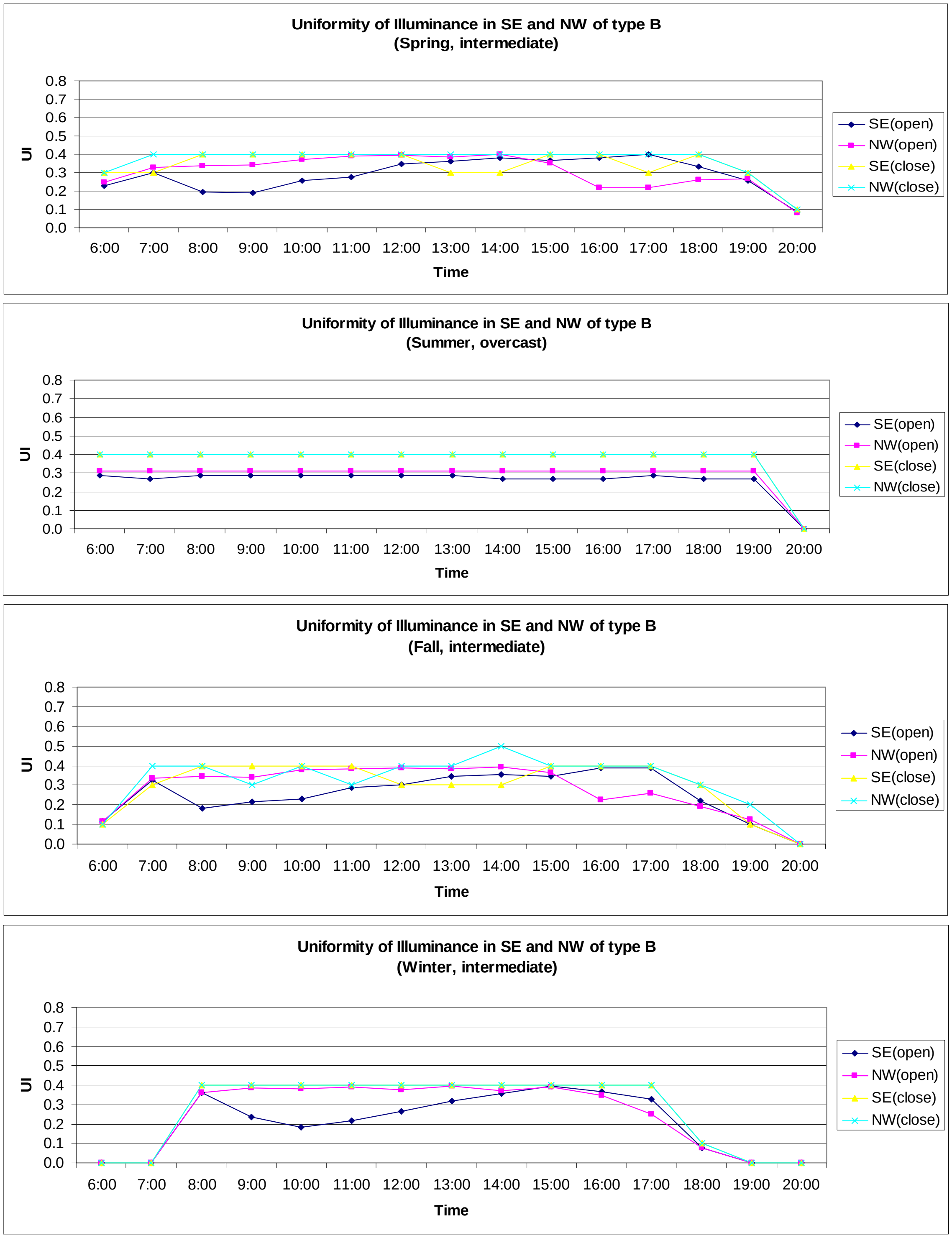



**Figure 46-Comparison between SE and NW of type B.**

As Figures 43, 44, 45 and 46 show, all values of the uniformity of illuminance (UI) are very similar in all types and orientations.

Overall the values of the uniformity of illuminace are between 0.3 and 0.4 with the blinds opened. Even though the blinds may be closed, the values of the uniformity of illuminance are almost the same as the values with the blinds opened.

All UI values are lower than the minimum recommended value of 0.8 by CIBSE. Because of the diffusion created by the blinds in patient rooms, the uniformity of illuminance is slightly increased from 0.3 to 0.4 with the blinds closed. But, the values are not significantly changed.

As a result, the uniformity of illuminance is always lower than the minimum recommended 0.8 and averages between 0.3 to 0.4. Because a patient room has only one side window, there is a limit to distribute daylight uniformly in the indoor area. Such an indoor environment may have negative effects on patients' visual comfort during their stay.

### 4.4.7. Contours of the critical values of DI and UI between "Blinds opened" and "Blinds closed" in each season

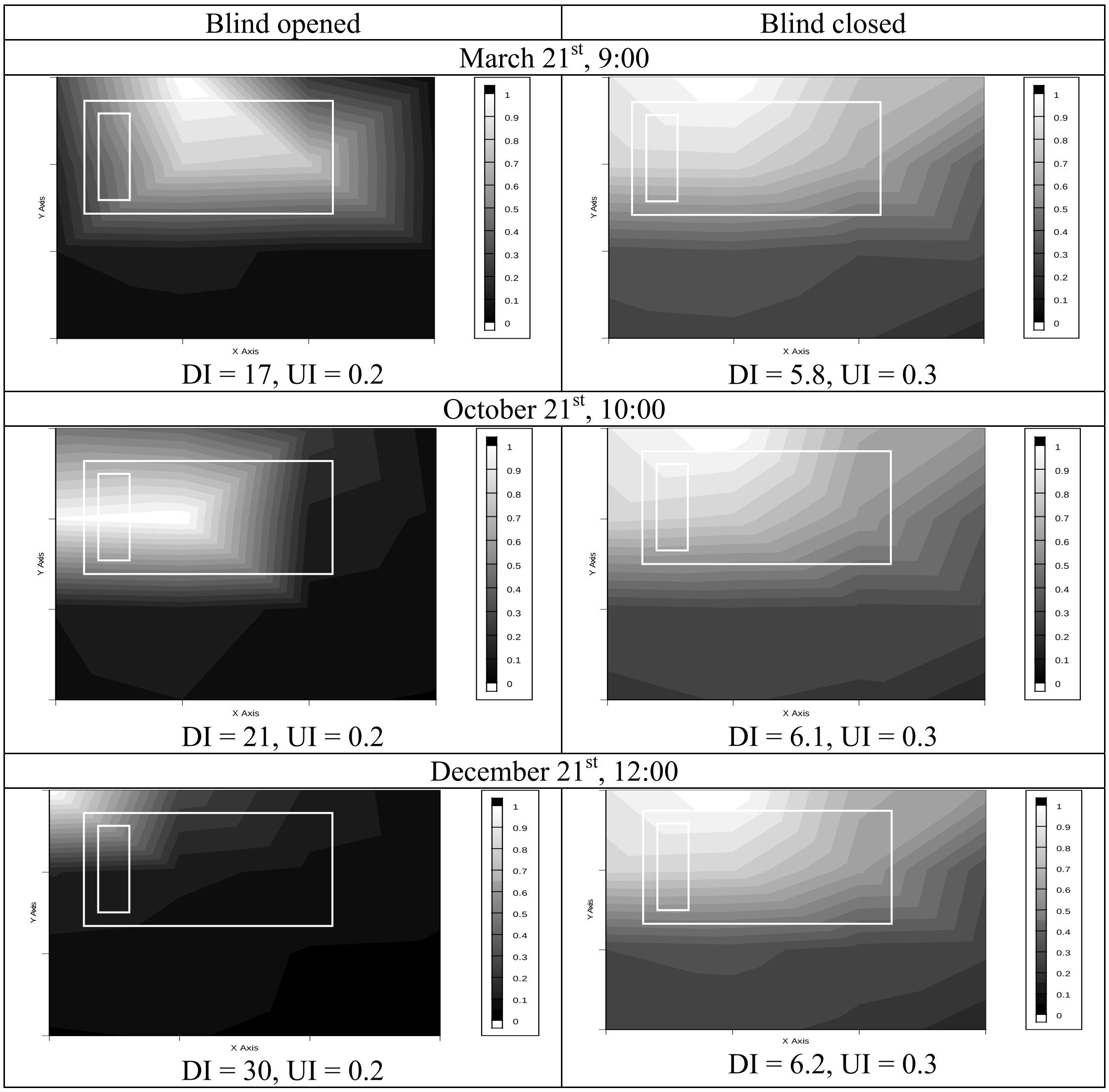



**Figure 47-Comparisons of contour of DI and UI between the blinds opened and closed (type A, SE).**

As Figure 47 shows, the blinds are effective in reducing the value of the diversity of illuminance near the maximum recommended value, 5. But, the blinds are relatively not so effective in increasing the value of UI (See Appendix II for more contours).

Overall, the blinds improve the visual comfort in patient rooms as they are controlled as the patient desires.

## 4.5. STATISTICAL ANALYSIS OF INHA UNIVERSITY HOSPITAL

In this study, the data of patient ALOS that are less than 3 days at least are excluded because such temporary stays cannot be regarded as being influenced by daylight.

### 4.5.1. Comparisons of each type in a same orientation

In Table 32, the result of ANOVA for comparing each type of each orientation shows no significant difference. Overall average numbers of samples are over 15 except in summer season. In the ALOS on 8$^{th}$ floor, the genecology ward, summer shows significant differences between the two types. But, the numbers of samples are too small to judge the significance. Conventionally, the valid number of sample is over 15 to 20 at least. In Tables 32 and 33, the scale of ALOS is “Days”.

| Floor | ORI. | Type | Spring ALOS (N)* | Spring Sig. | Summer ALOS | Summer Sig. | Fall ALOS | Fall Sig. | Winter ALOS | Winter Sig. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | 5.33 (29) | 0.114 | 5.14 (4) | 0.587 | 4.79 (25) | 0.405 | 5.58 (33) | 0.362 |
| | | B | 4.53 (26) | | 6 (5) | | 5.12 (5.12) | | 5.12 (31) | |
| | NW | A | 5.25 (36) | 0.309 | 4.22 (5) | 0.023 | 4.83 (18) | 0.171 | 4.75 (33) | 0.208 |
| | | B | 7.7 (24) | | 6.64 (8) | | 5.51 (27) | | 5.26 (35) | |
| 11th | SE | A | 7.19 (19) | 0.368 | 4 (3) | 0.248 | 5.22 (14) | 0.175 | 6.32 (23) | 0.457 |
| | | B | 6.13 (23) | | 8 (8) | | 6.96 (16) | | 7.33 (22) | |
| | NW | A | 6.96 (14) | 0.669 | 5.57 (4) | 0.304 | 7.09 (14) | 0.600 | 9.65 (10) | 0.722 |
| | | B | 6.44 (15) | | 7.33 (4) | | 8.03 (18) | | 10.56 (15) | |
| 12th | SE | A | 6 (20) | 0.697 | 4 (2) | 0.301 | 5.19 (13) | 0.343 | 4.83 (21) | 0.182 |
| | | B | 5.51 (25) | | 7.5 (2) | | 6.97 (17) | | 8.49 (27) | |
| | NW | A | 6.12 (20) | 0.706 | 3.8 (6) | 0.393 | 6.58 (16) | 0.676 | 8.63 (19) | 0.889 |
| | | B | 5.76 (25) | | 4.5 (4) | | 7.41 (16) | | 8.06 (20) | |
| 16th | SE | A | 8.56 (20) | 0.164 | 23.25 (2) | 0.181 | 7.6 (6) | 0.057 | 5.66 (23) | 0.624 |
| | | B | 6.33 (26) | | 5 (3) | | 4.86 (17) | | 6.2 (15) | |
| | NW | A | 7.11 (27) | 0.258 | 5.9 (6) | 0.511 | 5.77 (16) | 0.621 | 6.77 (21) | 0.264 |
| | | B | 6.07 (34) | | 7.27 (7) | | 5.37 (21) | | 5.54 (31) | |

**Table 32-Statistical analysis of each type of patient rooms in a same orientation (*N: Number of samples).**

### 4.5.2. Comparisons of each orientation in a same type of patient rooms

| Floor | Type | Ori. | Spring | | Summer | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **ALOS (N)** | **Sig.** | **ALOS (N)** | **Sig.** | **ALOS (N)** | **Sig.** | **ALOS (N)** | **Sig.** |
| 8th | A | SE | 5.33 (29) | 0.888 | 5.14 (4) | 0.498 | 4.79 (25) | 0.915 | 5.58 (33) | 0.183 |
| | | NW | 5.25 (36) | | 4.22 (5) | | 4.83 (18) | | 4.75 (33) | |
| | B | SE | 4.53 (26) | 0.015 | 6 (5) | 0.576 | 5.12 (20) | 0.377 | 5.12 (31) | 0.779 |
| | | NW | 7.7 (24) | | 6.64 (8) | | 5.51 (27) | | 5.23 (35) | |
| 11th | A | SE | 7.19 (19) | 0.868 | 4 (3) | 0.138 | 5.22 (14) | 0.048 | 6.32 (23) | 0.074 |
| | | NW | 6.96 (14) | | 5.57 (4) | | 7.09 (14) | | 9.65 (10) | |
| | B | SE | 6.13 (23) | 0.768 | 8 (8) | 0.837 | 6.96 (16) | 0.484 | 7.33 (22) | 0.088 |
| | | NW | 6.44 (15) | | 7.33 (4) | | 8.03(18) | | 10.56 (15) | |
| 12th | A | SE | 5.91 (21) | 0.864 | 3 (1) | 0.577 | 5.04 (14) | 0.098 | 4.83 (21) | 0.251 |
| | | NW | 6.12 (20) | | 3.8 (6) | | 6.58 (16) | | 8.63 (19) | |
| | B | SE | 5.45 (25) | 0.754 | 9 (2) | 0.08 | 6.77 (19) | 0.771 | 7.75 (32) | 0.538 |
| | | NW | 5.76 (25) | | 4.5 (4) | | 7.41 (16) | | 9.64 (28) | |
| 16th | A | SE | 8.2 (24) | 0.474 | 23.25 (15) | 0.061 | 7.6 (6) | 0.201 | 5.66 (23) | 0.073 |
| | | NW | 7.11 (27) | | 5.9 (31) | | 5.77 (16) | | 6.77 (21) | |
| | B | SE | 6.33 (26) | 0.763 | 5 (3) | 0.414 | 4.86 (17) | 0.521 | 6.2 (15) | 0.582 |
| | | NW | 6.07 (34) | | 7.27 (7) | | 5.37 (21) | | 5.74 (31) | |

**Table 33-Statistical analysis of each orientation in a same type of patient rooms.**

The result of ANOVA for comparing each orientation of each type of patient rooms shows partially significant difference. In spring, comparison between SE and NW in type B of 8th floor has significance. And in fall and winter, Type A of 11th floor, 12th floor, and 16th floor have significance in each ALOS comparison (Table 33).

In a different manner, the results of ANOVA analysis in each orientation of a same type of patient rooms have several significant differences. One to three ANOVA in each season shows significant difference with the exception of summer when there are no differences between SE and NW in daylight environments.

## 4.6. SUMMARY

The result of ANOVA shows that 6 comparisons are significant or marginal significant among 32 comparisons. The common thing of the six significant comparisons is the ALOS of SE is shorter than that of NW. The rest of total, 26 comparisons show there is no significant difference. This implies that the ALOS of each comparison can be regarded as the same value from the view point of statistics. Among the six, two are significant, and four are marginally significant (Table 34). All significant ALOS comparisons are shown in spring, fall, and winter when there are differences in light variables depending on the orientation. When the sky is overcast during summer, the light variables are almost the same in the two orientations.

| Type | Season | Floor | Ward | Orientation | ALOS (days) | N | Significance |
|---|---|---|---|---|---|---|---|
| A | Fall | 11th | Surgery | SE | 5.22 | 14 | **0.048** (<0.05) |
| | | | | NW | 7.09 | 14 | |
| | | 12th | Otorhino. | SE | 5.04 | 14 | 0.098 (<0.10) |
| | | | | NW | 6.58 | 16 | |
| | Winter | 11th | Surgery | SE | 6.32 | 23 | 0.074 (<0.10) |
| | | | | NW | 9.65 | 10 | |
| | | 16th | Internal | SE | 5.66 | 23 | 0.073 (<0.10) |
| | | | | NW | 6.77 | 21 | |
| B | Spring | 8th | Genecology | SE | 4.53 | 26 | **0.015** (<0.05) |
| | | | | NW | 7.7 | 24 | |
| | Winter | 11th | Surgery | SE | 7.33 | 22 | 0.088 (<0.10) |
| | | | | NW | 10.56 | 15 | |

**Table 34-Summary of significant ANOVA results.**

Tables 35 and 36 show the summary of indoor daylight variables of Inha University Hospital. The values are calculated from seasonal average from 8:00 AM to 6:00 PM because light levels are fairly low before 8:00 AM and after 6:00 PM.

| Variable | Reco-mmend | Blinds | Spring | | Summer | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | SE | NW | SE | NW | SE | NW | SE | NW |
| DF (%) | Min. 1% | Opened | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 |
| | | Closed | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| LR (TV wall) | Max. 40 | Opened | 20.9 | 7 | 7.4 | 7.3 | 19.5 | 7.2 | 17.1 | 7.1 |
| | | Closed | 9.6 | 7.5 | 7.6 | 7.4 | 11.4 | 6.7 | 6.6 | 6.5 |
| LR (Eye & TV) | Max. 10 | Opened | 2.3 | 2.5 | 2.4 | 2.2 | 2.3 | 2.5 | 2.7 | 2.8 |
| | | Closed | 2.3 | 1.2 | 1.4 | 1.3 | 2.1 | 1.1 | 1.6 | 1.2 |
| Illum.(lux) | Min. 300 | Opened | 366 | 279 | 195 | 188 | 414 | 218 | 282 | 105 |
| | | Closed | 112 | 61 | 63 | 61 | 124 | 55 | 86 | 26 |
| DI | Max. 5 | Opened | 12.5 | 10.3 | 10.8 | 10.7 | 13.7 | 11.5 | 14.8 | 9.8 |
| | | Closed | 6.2 | 8.1 | 6.3 | 6.2 | 5.9 | 8.4 | 5.8 | 8.2 |
| UI | Max. 0.8 | Opened | 0.29 | 0.3 | 0.28 | 0.31 | 0.26 | 0.29 | 0.24 | 0.29 |
| | | Closed | 0.32 | 0.32 | 0.3 | 0.4 | 0.32 | 0.32 | 0.3 | 0.29 |

**Table 35-Summary of the average values of indoor daylight variables in type A from 8:00 AM to 6:00 PM.**

| Variable | Reco-mmend | Blinds | Spring | | Summer | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | SE | NW | SE | NW | SE | NW | SE | NW |
| DF (%) | Min. 1% | Opened | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| | | Closed | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| LR (TV wall) | Max. 40 | Opened | 24.9 | 11.8 | 9.1 | 9.3 | 24.8 | 15.2 | 29.9 | 15.3 |
| | | Closed | 16.8 | 9.8 | 9.7 | 9.5 | 11.7 | 10 | 14.9 | 9.6 |
| LR (Eye & TV) | Max. 10 | Opened | 2.1 | 3.1 | 2.1 | 2.1 | 2.4 | 3.2 | 2 | 2.7 |
| | | Closed | 1.2 | 2.1 | 1 | 1.1 | 1.2 | 2 | 1.2 | 2.1 |
| Illum.(lux) | Min. 300 | Opened | 353 | 301 | 196 | 181 | 428 | 238 | 306 | 112 |
| | | Closed | 71 | 72 | 49 | 51 | 75 | 61 | 54 | 31 |
| DI | Max. 5 | Opened | 12.4 | 10.9 | 11.2 | 12.3 | 12 | 9.8 | 10.8 | 8.1 |
| | | Closed | 7.7 | 7 | 6.3 | 7.4 | 5.9 | 7.4 | 5.8 | 7.2 |
| UI | Max. 0.8 | Opened | 0.32 | 0.33 | 0.28 | 0.31 | 0.3 | 0.33 | 0.28 | 0.34 |
| | | Closed | 0.37 | 0.4 | 0.4 | 0.4 | 0.36 | 0.38 | 0.37 | 0.37 |

**Table 36-Summary of the average values of indoor daylight variables in type B from 8:00 AM to 6:00 PM.**

| Type | Season | Variables | Floor / Time | SE | NW |
|---|---|---|---|---|---|
| A | Fall | ALOS (days) | 11th | 5.22 | 7.09 |
| | | | 12th | 5.04 | 6.58 |
| | | Average Illuminance (lux) | 8AM-6PM | 414 | 218 |
| | | | 8AM-1PM | 642 | 143 |
| | | | 2PM-6PM | 141 | 308 |
| | Winter | ALOS (days) | 11th | 6.32 | 9.65 |
| | | | 16th | 5.66 | 6.77 |
| | | Average Illuminance (lux) | 8AM-6PM | 282 | 105 |
| | | | 8AM-1PM | 436 | 128 |
| | | | 2PM-6PM | 96 | 120 |
| B | Spring | ALOS (days) | 8th | 4.53 | 7.7 |
| | | Average Illuminance (lux) | 8AM-6PM | 353 | 301 |
| | | | 8AM-1PM | 519 | 131 |
| | | | 2PM-6PM | 153 | 305 |
| | Winter | ALOS (days) | 11th | 7.33 | 10.56 |
| | | Average Illuminance (lux) | 8AM-6PM | 306 | 112 |
| | | | 8AM-1PM | 473 | 96 |
| | | | 2PM-6PM | 106 | 131 |

**Table 37-Significant ALOS comparisons and average illuminance between SE and NW**

According to Tables 35 and 36, daylight factors (DF), luminance ratios (LR) on the TV wall, and luminance ratios (LR) between the TV point and patient eye have almost no differences between the two orientations, SE and NW. Moreover, the values of LRs are lower than the recommended values. With the blinds closed, the values are reduced and are no longer near the recommended values.

The uniformity of illuminance (UI) and diversity of illuminance (DI) are always higher than the recommended, maximum 5 and minimum 0.8 each in the two orientations. The values of UI and DI can be controlled as patients desire if they have visual discomfort due to high DI and UI. However, the values of UI and DI which can be controlled have almost no significant differences between the two orientations.

According to Tables 74, 75, 76 and 77 in Appendix III, the average values of light variables between 8:00 AM and 1:00 PM, and 2:00 PM and 6:00 PM have almost the same changing patterns except within illuminance. The most distinguished difference between SE and NW is the illuminance. In Tables 35 and 36, the values of illuminance in the SE are much higher than that in NW during the spring, fall and winter seasons. Table 37 summarizes the significant ALOS and the values of illuminance between the SE and the NW. All (marginally) significant data show the ALOS of SE to be shorter than that of NW. The illuminance of SE is much higher than that of NW before 1:00 PM, and the NW has slightly higher illuminance between 2:00 PM and 6:00 PM. But, the difference in the first is larger than in the second. It means that patients in the SE facing rooms can control illuminance more variously as they desire than in the NW facing. As a result of using blinds, patients in the SE facing rooms can control illuminance more variously as they desire than in the NW facing rooms. It may remove stressors caused by daylight and be beneficial to patient physiological conditions.

Therefore, in the case of Inha University Hospital, ALOS seems to be greatly related to illuminance in patient rooms than other light variables. And, based on the fact that there is higher illuminance in the SE especially between 8:00 AM and 1:00 PM, patient rooms which are brightened in the morning may also have positive effects on the patient Average Length of Stay (ALOS).

# 5. RESEARCH DESCRIPTION OF ST. JOSEPH REGIONAL HEALTH CENTER

## 5.1. ST. JOSEPH REGIONAL HEALTH CENTER

St. Joseph Regional Health Center (Figures 48 and 49) is dedicated to providing comprehensive rehabilitation services for patients suffering from neurological, brain injury, stroke, and general rehabilitation injuries. The facility offers a 60-bed specialty hospital and a 75-bed nursing facility with complete therapy services aimed at helping each individual reach his or her maximum potential. This facility was built in 1968, and an extension to the building was built in 1990.

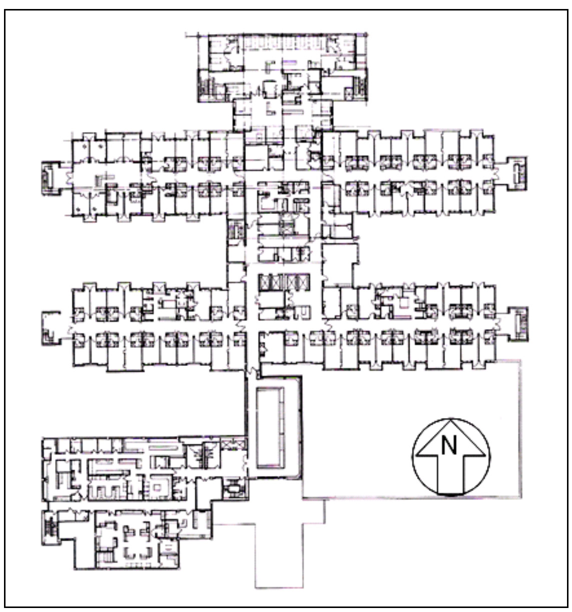



**Figure 48-Floor plan of Inha University Hospital.**

**Figure 49-Exterior view of St. Joseph Regional Health Center.**

| Location | Ward |
|---|---|
| 2nd floor , SW wing | Medical |
| 3rd floor, SW wing | Orthopedics |

**Table 38-Study targeted patient wards of St. Joseph Regional Health Center.**

| Ward | Definition |
|---|---|
| Medical | The diagnosis and treatment of any ailment in adults that is not associated with a specific ward. |
| Orthopedics | The branch of medicine that deals with the prevention or correction of injuries or disorders of the skeletal system and associated muscles, joints, and ligaments. |

**Table 39-Definition of wards.**

In this study, the 2nd and 3rd floors of the southwest wing of the building are chosen. Tables 38 and 39 summarize the wards of this facility and those descriptions.[41]

### 5.1.1. Location and climatic conditions in Bryan, Texas

St. Joseph regional health center is located in Bryan, Texas (Latitude : 30.66 ºN, Longitude : 96.36 ºW). (Time Zone: Central (Standard Time: GST -6 hours, DST: GMT -5 hours).

Bryan is located 2-3 mile away from College Station, Texas. Because there is no significant difference in location between College Station and Bryan, the College Station weather file is used in this study.

The summer in Bryan is long, extremely hot and dry with monthly average highs ranging from 74.2°F to 83.4°F (23.4°C-28.6°C). The highest average temperature in summer is 97°F (38.3°C). The summer is long and last from May until early September. July and August are the hottest months. Winter in Bryan, which generally lasts from December to February, is relatively cool and humid. In January, the coldest month, daily average temperatures range from 38.7°F to 58.5°F (3.72°C-14.7°C). The lowest temperature is 12°F (-11°C). Table 40 summarizes the climate properties of Bryan, Texas. Solar radiation is highest in June and lowest in December (Figure 50). Table 41 shows the turbidity of Bryan throughout whole year.

Energy-10 Weather File Summary

Inchon,

File Name: C:₩Weather Data₩korea weather data₩KR-INCHON-471120.ET1

Comment:

Latitude: 37.483

Longitude: 126.633

Elevation: 230 ft

Design Day Dry Bulb (Winter 99.0%): 6.0 °F

Design Day Dry Bulb (Winter 97.5%): 6.0 °F

Design Day Dry Bulb (Summer 2.5%): 90.0 °F

Design Day Wet Bulb (Summer 2.5%): 76.0 °F

| Month | TAA | TMXA | TMNA | TMX | TMN | TWBA | RH | WSA | HS | HDD | CDD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 26.7 | 34.0 | 19.3 | 48.0 | 6.0 | 23.2 | 62.5 | 9.4 | 637 | 1190 | 0 |
| February | 29.7 | 37.2 | 21.6 | 51.0 | 12.0 | 26.1 | 65.2 | 9.6 | 922 | 997 | 0 |
| March | 39.1 | 46.7 | 31.2 | 59.0 | 21.0 | 34.8 | 66.8 | 9.8 | 1176 | 807 | 0 |
| April | 50.8 | 58.6 | 42.2 | 74.0 | 32.0 | 45.8 | 70.0 | 9.4 | 1456 | 439 | 1 |
| May | 60.7 | 68.4 | 52.1 | 79.0 | 44.0 | 55.1 | 71.6 | 8.3 | 1467 | 161 | 13 |
| June | 67.7 | 74.5 | 60.1 | 83.0 | 53.0 | 63.0 | 78.8 | 6.7 | 1459 | 15 | 84 |
| July | 74.7 | 80.4 | 68.2 | 94.0 | 61.0 | 70.4 | 82.4 | 7.4 | 1149 | 0 | 288 |
| August | 77.0 | 82.7 | 70.5 | 91.0 | 63.0 | 72.2 | 80.8 | 6.9 | 1134 | 0 | 360 |
| September | 68.5 | 76.4 | 60.0 | 87.0 | 50.0 | 63.2 | 76.4 | 6.3 | 1139 | 19 | 115 |
| October | 58.1 | 66.5 | 49.2 | 78.0 | 35.0 | 52.3 | 70.6 | 6.7 | 956 | 226 | 3 |
| November | 44.4 | 52.4 | 36.1 | 64.0 | 22.0 | 39.7 | 67.8 | 9.0 | 673 | 622 | 0 |
| December | 32.2 | 39.4 | 24.4 | 52.0 | 11.0 | 28.3 | 64.4 | 9.2 | 537 | 1027 | 0 |
| Year | 52.5 | 59.8 | 44.6 | 94.0 | 6.0 | 47.8 | 71.4 | 8.2 | 1059 | 5501 | 863 |

TAA Average Dry Bulb Temperature, °F

TMXA Average Daily Maximum Dry Bulb Temperature, °F

TMNA Average Daily Minimum Dry Bulb Temperature, °F

TMX Maximum Dry Bulb Temperature, °F

TMN Minimum Dry Bulb Temperature, °F

TWBA Average Wet Bulb Temperature, °F

WSA Average Wind Speed, MPH

HS Average Daily Horizontal Solar Radiation, Btu/ft? RH Relative Humidity, %

HDD Heating Degree Days, Base 65.0 °F

CDD Cooling Degree Days, Base 65.0 °F

**Table 40-Summary of weather data for College Station-Bryan, Texas (Weather Maker v.1.01).**

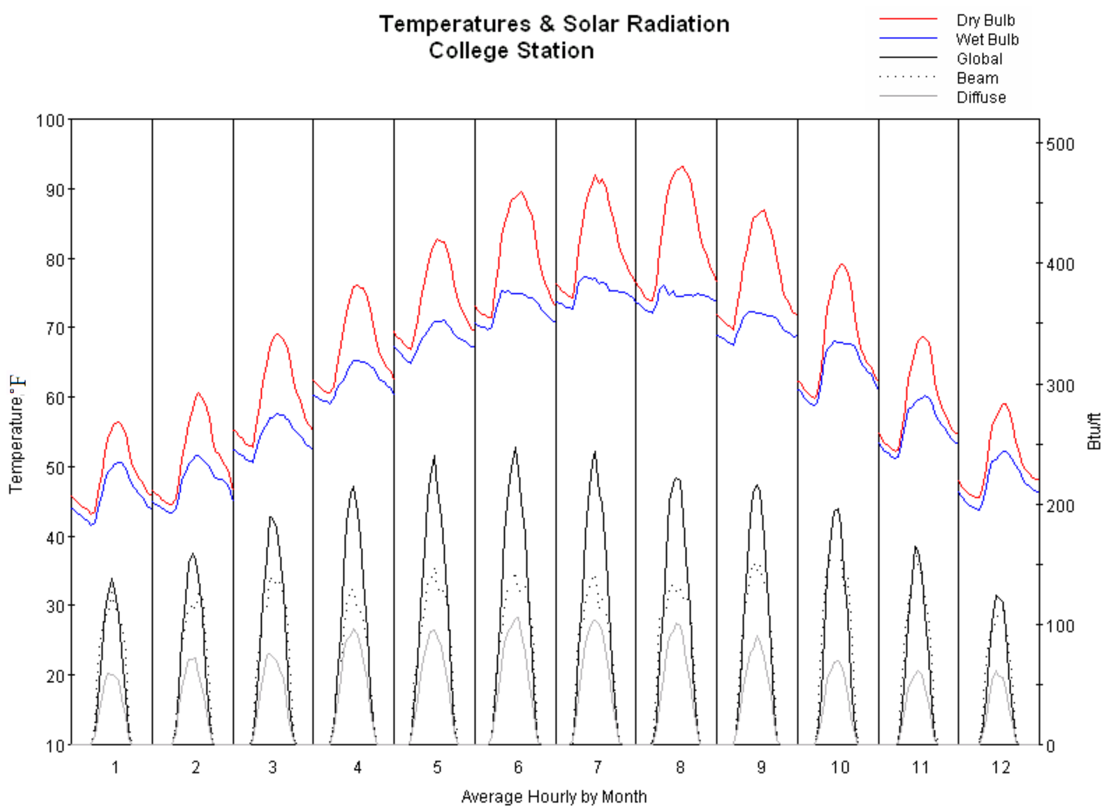



**Figure 50-Hourly temperature and solar radiation in College Station-Bryan, Texas (Weather Maker v.1.01).**

| Month | Bryan |
|---|---|
| January | 3 |
| February | 3.5 |
| March | 3.5 |
| April | 4 |
| May | 4 |
| June | 4.5 |
| July | 4.5 |
| August | 5 |
| September | 5 |
| October | 4 |
| November | 3.5 |
| December | 3.5 |

**Table 41-Turbidity of Bryan, Texas.**[38]

| Month | Percentage of cloud | CIE sky condition |
|---|---|---|
| Jan | 48.4 % | Intermediate |
| Feb | 41.8 % | Intermediate |
| Mar | 34.7 % | Intermediate |
| Apr | 33.9 % | Intermediate |
| May | 32.7 % | Intermediate |
| Jun | 27.4 % | Clear |
| Jul | 15.9 % | Clear |
| Aug | 11.5 % | Clear |
| Sep | 25.1 % | Clear |
| Oct | 38.5 % | Intermediate |
| Nov | 45.3 % | Intermediate |
| Dec | 45.9 % | Intermediate |

**Table 42-Annual average percentage of cloud in sky condition, College Station-Bryan, Texas, 2004 (ESL, 2004) [44]**

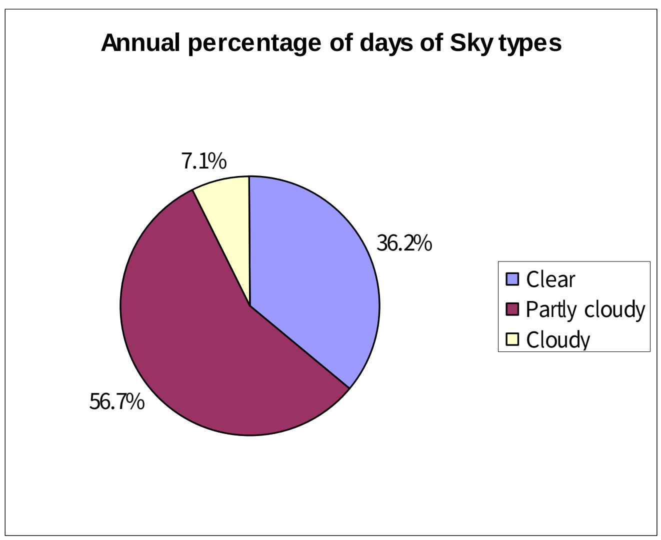



**Figure 51-Percentage of types of sky condition, College Station-Bryan, Texas, 2004 (ESL,2004) [44]**

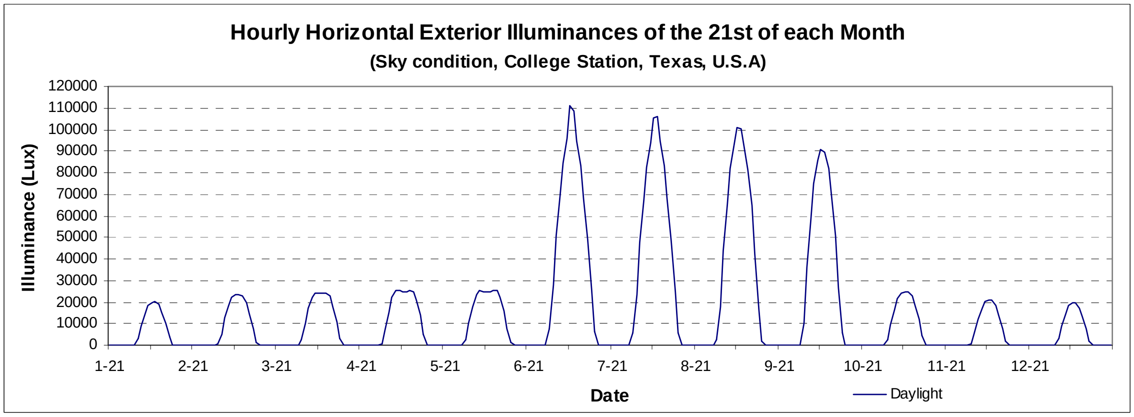



**Figure 52-Calculated hourly horizontal exterior illuminances of the 21st of each month, College Station, Texas based on climate data and CIE sky conditions (RADIANCE).**

As Table 42 shows, the average amount of cloud coverage in the sky of College Station and Bryan, Texas, during 2004 is from 11.5% to 48.4%. As the CIE sky condition shows, the average amount of cloud data is categorized into two types; intermediate and clear sky conditions. From June to September, there are clear skies, and other months have intermediate skies. Depending on the hourly exterior illuminance data, three seasons are categorized: Horizontal Exterior Illuminances (HEI) in spring (March, April, May) and fall (October, November, December, January, February) are between 20000 and 30000 lux, and HEI in summer (June, July, August, & September) is over 90000 lux. The intermediate sky occurred 56% of the time and the clear sky occurred about 36% of the time in 2004 (Figure 51). Figure 52 shows calculated hourly exterior illuminances of the 21st of each month, College Station, Texas, U.S.A. based on climate data and the CIE sky condition.

## 5.2. ANALYSIS OF INDOOR DAYLIGHT ENVIRONMENT IN ST. JOSEPH REGIONAL HEALTH CENTER

### 5.2.1. Reflectance

The reflectance of material surfaces in patient rooms at St. Joseph Regional Health Center is investigated. The reflectance of wall, floor, and bed are higher than the recommended surface reflectance by IESNA (Table 43).

| | **Site** | **RADIANCE** | | **Physical Scale model** | **Recommended reflectance (IESNA, 1995)** [43] |
|---|---|---|---|---|---|
| Wall | 0.65 | 0.65 | | 0.622 | 0.4-0.6 |
| Floor | 0.65 | 0.65 | | 0.622 | 0.2-0.4 |
| Ceiling | 0.82 | 0.82 | | 0.846 | 0.7-0.8 |
| Bed | 0.84 | 0.84 | | 0.846 | 0.25-0.45 |
| Curtain | 0.33 | 0.33 | | 0.335 | 0.25-0.45 |
| Furniture | 0.12 | 0.12 | | 0.126 | 0.25-0.45 |
| Transmittance of curtain | 0 % | n/a | | n/a | n/a |
| Transmittance of glazing | 32.8 % | 32.8 % | 100 % | 100% | n/a |

**Table 43- Reflectance values of materials in site, RADIANCE, and scale model in St. Joseph Regional Health Center.**

### 5.2.2. Properties of a patient room

The properties of patient rooms are shown in Table 44 and Figure 53. The patient room has a tall window that cannot be opened. All of the walls and ceilings are concrete, and the windows are insulated double glass.

| | **Property** |
|---|---|
| Window area | 2.2 $m^2$ |
| Glass type | Double (insulated) |
| UV coating | N/A |
| Window/wall ratio | 0.171 |
| Window/floor ratio | 0.299 |

**Table 44-Properties of windows in St. Joseph Regional Health Center.**

**Figure 53-Interior view of a patient room in St. Joseph Regional Health center.**

Patient rooms in St. Joseph Regional Health Center are designed symmetrically with 2 types. Thus, patient beds are located head to head and foot to foot with a wall between two rooms creating a mirror image. In this study, the patient rooms are categorized into type A and type B depending on patient head orientations (Figure 54).

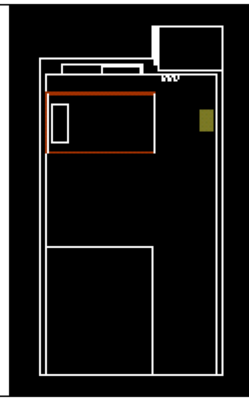
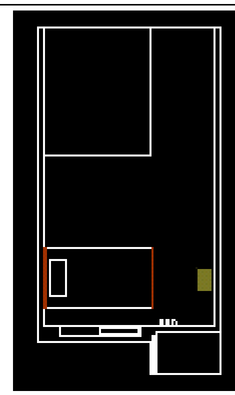
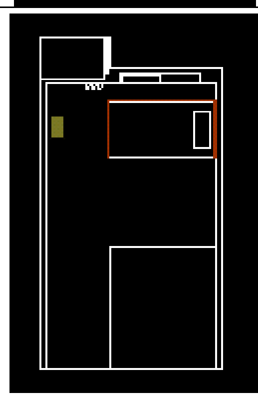
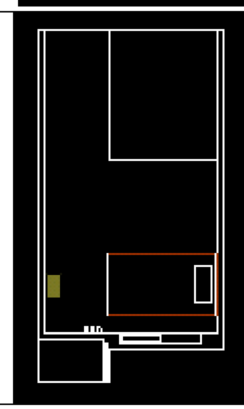
| | North | South |
|---|---|---|
| Type A |  |  |
| Type B |  |  |

**Figure 54-Type A and B in patient rooms.**

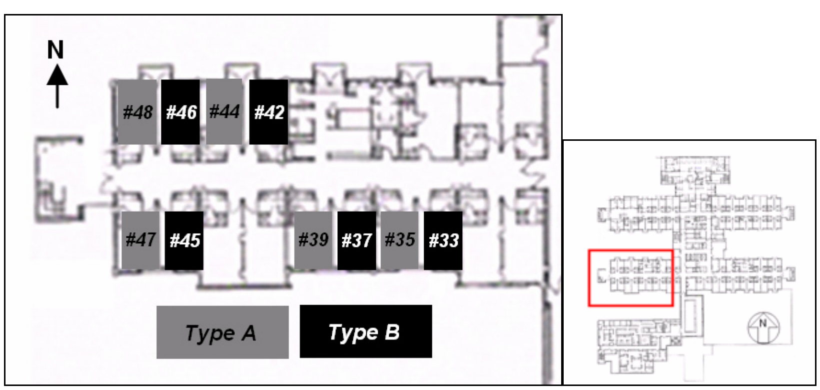



**Figure 55- Types of ptient rooms in a ward of the southwest wing of the building.**

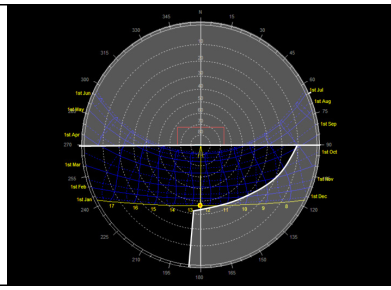
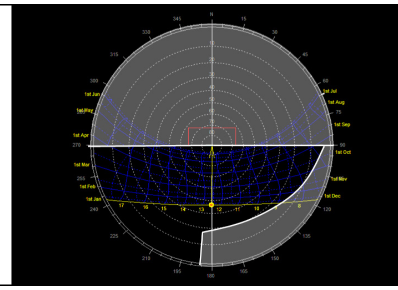
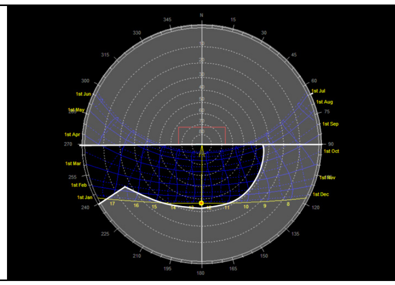
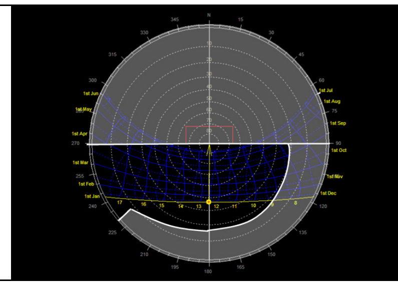
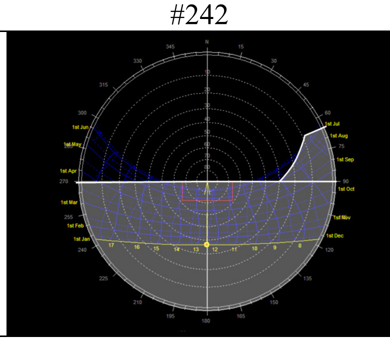
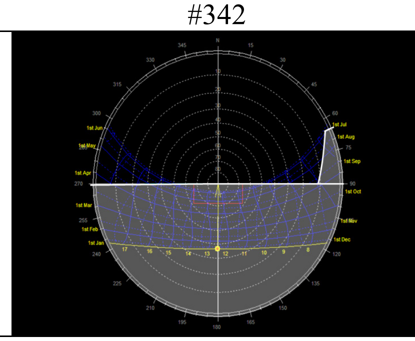
| | **2nd floor** | **3rd floor** |
|---|---|---|
| | # 247 | #347 |
| South |  |  |
| | #233 | #333 |
| South |  |  |
| | #242 | #342 |
| North |  |  |

**Figure 56-Shading mask in patient rooms (Ecotect v.5.20).**

The research targeted wards of this study are Medical (2nd floor at the southwest wing) and Orthopedics (3rd floor at the southwest wing) in the southwest wing of the building as Figure 55 shows.

In Figure 56, the south facing patient rooms on the second floor have direct daylight in the morning until dusk annually except during the hot summer season. The south facing rooms on the third floor have direct daylight all day long even in the summer. The north facing patient rooms on the second and third floors have daylight only in the morning and at dusk.

**Figure 57- A view from a patient laid on the bed.**

The window view is not seen from a patient who lies on the bed because the long vertical long window is located in the corner of the room near the foot of the bed (Figure 57).

### 5.2.3. Discrepancy between RADIANCE and on-site measurement

To test the value of the illuminance level, on-site measurement and RADIANCE are used. To verify the output value from RADIANCE, a scale model was used with the RADIANCE model without glazing components, simulating the window glass in St. Joseph Regional Health Center.

The sensor height is placed on 0.95m height from the floor. This is the height of a table for patients and is where visual behaviors most often occur. Physical scale model measurements are conducted in the same location to compare the data between RADIANCE and the scale model.

On-site measurements and scale model measurements are conducted under the overcast sky conditions. The same reflectance of site materials is assigned in the material of RADIANCE model and the scale model (Table 45).

| | **On-Site measurement** | **Desktop RADIANCE** | **Scale model measurement** |
|---|---|---|---|
| Sky condition | Overcast and very cloudy | CIE Overcast | Overcast and very cloudy |
| Data Scale | Lux | | |
| Simulation Mode | n/a | Batch to ACS II | n/a |
| Ambient Bounce | n/a | 5 | n/a |
| Turbidity | n/a | 4 | n/a |

**Table 45-Setting data of on-site measurement, RADIANCE, and scale model measurement.**

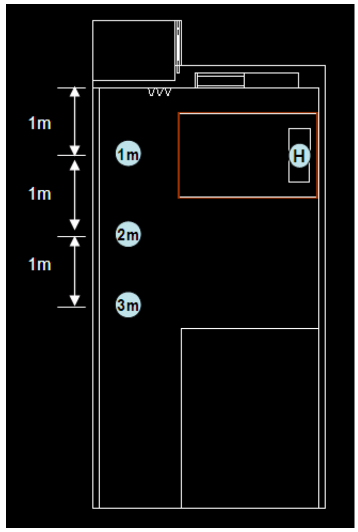


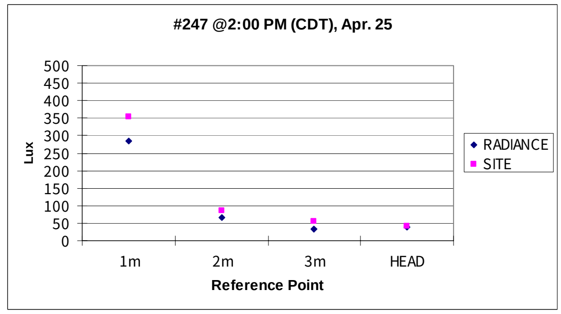

**Figure 58-Placements of reference point in a patient room.**

The reference points are four at the height of 95 cm from the floor as Figure 58 shows. The distance among the points in front of the window is 1m.

**Figure 59-Overcast sky condition, south (left) & north skies in Bryan, Texas, at 3:00 PM (CDT), Apr. 25, 2005.**

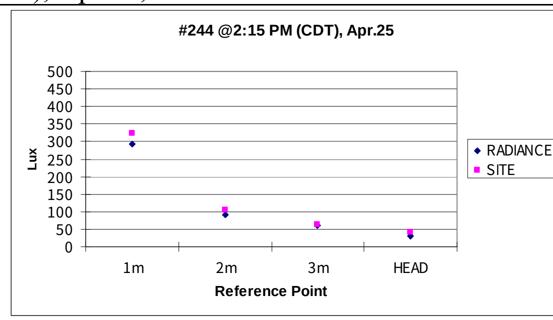
#247 @ 2:00 PM (CDT), Apr.25, Overcast

| #247 | RAD. | SITE | Discrep.* |
|---|---|---|---|
| 1m | 285 | 353 | 19.1% |
| 2m | 66 | 84 | 21.9% |
| 3m | 32 | 54 | 40.5% |
| HEAD | 37 | 42 | 10.9% |
| | | Ave. | 23.1% |
| HEI | 17708 | 22856 | 22.5% |



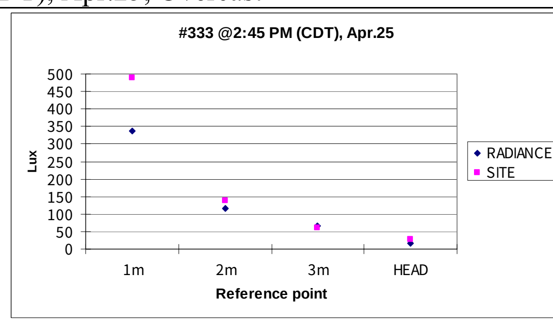

#244@ 2:15 PM (CDT), Apr.25, Overcast

| #244 | RAD. | SITE | Discrep. |
|---|---|---|---|
| 1m | 292 | 322 | 9.3% |
| 2m | 92 | 105 | 12.9% |
| 3m | 62 | 63 | 2.0% |
| HEAD | 31 | 41 | 24.9% |
| | | Ave. | 12.3% |
| HEI | 17533 | 25725 | 31.8% |




#333 @ 2:45 PM (CDT), Apr.25, Overcast

| #333 | RAD. | SITE | Discrep. |
|---|---|---|---|
| 1m | 337 | 488 | 30.9% |
| 2m | 116 | 138 | 16.4% |
| 3m | 66 | 61 | 8.7% |
| HEAD | 17 | 27 | 38.7% |
| | | Ave. | 23.7% |
| HEI | 16921 | 25630 | 34.0% |




#342 @ 3:00 PM (CDT), Apr.25, Overcast

| #342 | RAD. | SITE | Discrep. |
|---|---|---|---|
| 1m | 273 | 370 | 26.1% |
| 2m | 74 | 120 | 38.5% |
| 3m | 35 | 59 | 41.0% |
| HEAD | 30 | 34 | 11.5% |
| | | Ave. | 29.3% |
| HEI | 16921 | 23580 | 28.2% |

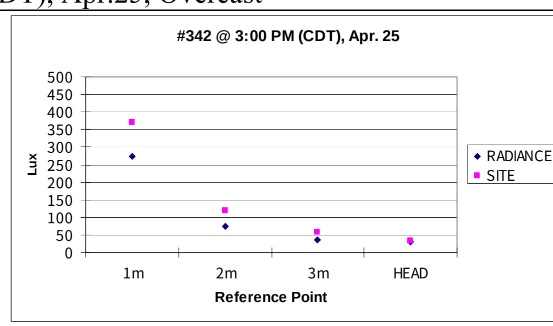



**Table 46-Comparison of illuminance levels between on-site measurement and RADIANCE (*Discrep. : Discrepancy=(RAD.-SITE)/SITE ).**

The measurements are conducted under the overcast sky (Figure 59). In Table 46, illuminance between the scale model and RADIANCE shows almost the exact same trend having very similar discrepancies between each other under the overcast sky condition, the orientation does not influence the indoor illuminance.

Illuminances between site-measurement and Radiance are relatively close in value to each other in 2m, 3m, and head reference points with less than 10% discrepancy. Comparing the graphs shows almost the same trends at each reference point. However, in the illuminance on 1m reference point of rooms, on-site measurement showed larger values than RADIANCE with over 20% discrepancy. There are some possible reasons for the discrepancy. Because the illuminance on 1m point may be sensitive to sky conditions, it may have caused a large discrepancy in 1m point between on-site measurement and RADIANCE.

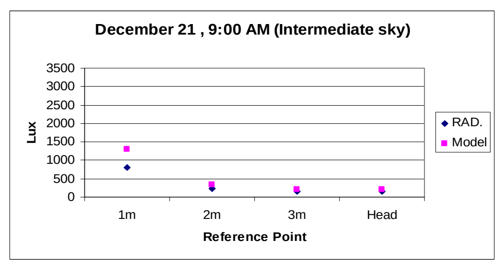
With dirt and other unrecognizable exterior variables of the building's exterior, the actual reflectance may be affected depending on various conditions. Those components may have caused the discrepancy. Another possible reason is the difference between the CIE overcast condition and the actual sky condition. The CIE overcast condition is considered 70% or more cloud coverage. The CIE overcast condition may be different than the actual sky conditions on the date of the measurement.

### 5.2.4. Discrepancy between RADIANCE and scale model measurement

The comparisons of illuminance between RADIANCE and the scale model measurements are conducted with the selected RADIANCE models, room #347 for the south orientation, which are relatively isolated from other buildings, even more so than other patient rooms which can disturb the daylight entering the rooms.

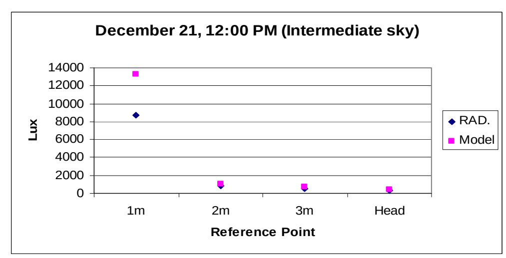
December 21, 9:00 AM

| Lux | RAD. (lux) | Model (lux) | Discrep.* |
|---|---|---|---|
| 1m | 802 | 1286 | 60.4% |
| 2m | 243 | 336 | 38.5% |
| 3m | 149 | 198 | 32.9% |
| Head | 144 | 200 | 39.2% |
| | | Ave. | 42.8% |
| HEI** | 9136 | 13040 | 42.7% |




December 21, 12:00 PM

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 8696 | 13320 | 53.2% |
| 2m | 790 | 1025 | 29.7% |
| 3m | 541 | 721 | 33.4% |
| Head | 333 | 457 | 37.1% |
| | | Ave. | 38.3% |
| HEI | 19725 | 27980 | 41.9% |




December 21, 3:00 PM

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 1761 | 2920 | 65.8% |
| 2m | 428 | 581 | 35.8% |
| 3m | 227 | 298 | 31.2% |
| Head | 296 | 360 | 21.8% |
| | | Ave. | 38.7% |
| HEI | 13337 | 17898 | 34.2% |

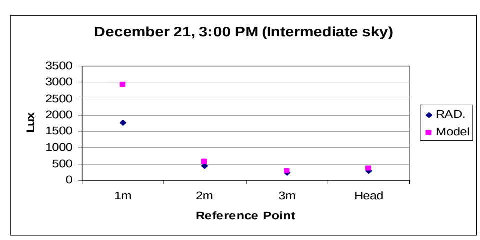
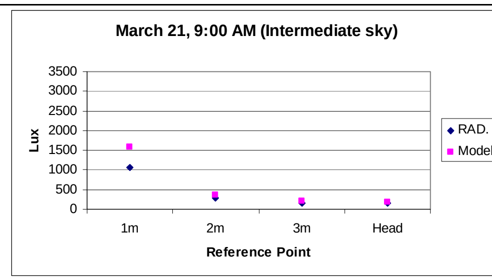



**Table 47-Comparison of illuminance levels between RADIANCE (#347) and scale model measurement, (December 21, Intermediate sky). (Discrep.*: Discrepancy=(RAD.-Model)/RAD.), HEI**: Horizontal Exterior Illuminance).**

**Figure 60-Intermediate on the scale model measurement date (Location : A parking lot of Southwest pkwy circle apartment, College Station, Texas, 12:00 PM, May 9, 2005).**

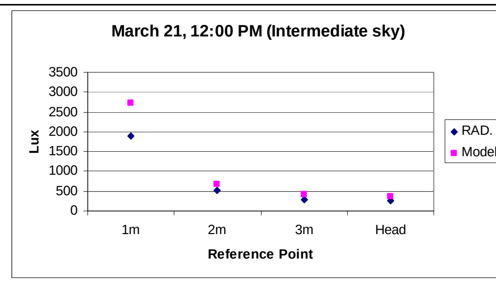
March 21, 9:00 AM

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 1056 | 1587 | 50.3% |
| 2m | 290 | 360 | 24.3% |
| 3m | 163 | 210 | 28.6% |
| Head | 143 | 183 | 27.8% |
| | | Ave. | 32.7% |
| HEI | 11883 | 15283 | 28.6% |




March 21, 12:00 PM

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 1880 | 2730 | 45.2% |
| 2m | 510 | 680 | 33.3% |
| 3m | 294 | 420 | 42.6% |
| Head | 271 | 365 | 34.9% |
| | | Ave. | 39.0% |
| HEI | 21212 | 29980 | 41.3% |




March 21, 3:00 PM

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 1682 | 2480 | 47.4% |
| 2m | 461 | 602 | 30.6% |
| 3m | 252 | 331 | 31.4% |
| Head | 286 | 360 | 26.1% |
| | | Ave. | 33.9% |
| HEI | 13957 | 18540 | 32.8% |

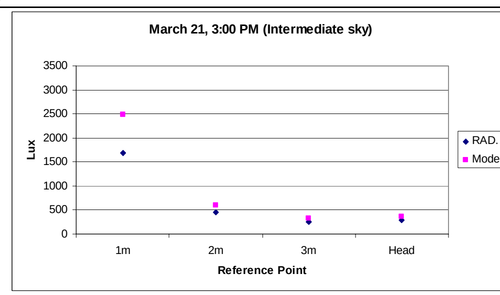



**Table 48-Comparison of illuminance levels between RADIANCE (#347) and scale model measurement, (March 21, Intermediate sky).**

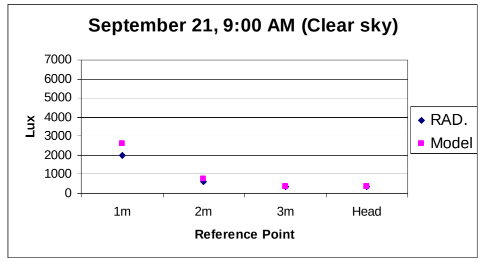
The intermediate sky for the measurements is shown in Figure 60. According to Tables 47 and 48, the discrepancy between RADIANCE and Scale model measurements, the values of the second are higher than RADIANCE by 20% to 50%. It is because the CIE intermediate sky is different than actual intermediate sky conditions. One HEI value cannot cover the diversity of the intermediate sky that covers 30 % to 70 % of the sky with clouds.

**Figure 61-Clear sky condition on the scale model measurement date (Location : The roof of Langford, Texas A&M University, College Station, Texas, 3:00 PM, Apr. 15, 2005).**

In the measurements under the clear sky, the discrepancy depends on each HEI variance for each case. The discrepancies of HEI are 9% to 16% between the scale model and RADIANCE. Because of higher HEI in the scale model measurements, all illuminances on the reference points in the model are higher than in RADIANCE averaging between 15% to 26% (Table 49).

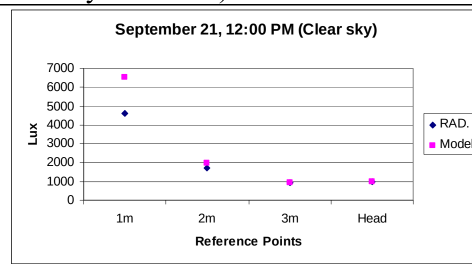
September 21, 9:00 AM (Clear sky condition)

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 1993 | 2621 | 31.5% |
| 2m | 611 | 762 | 24.7% |
| 3m | 345 | 377 | 9.3% |
| Head | 339 | 360 | 6.2% |
| | | Ave. | 18.0% |
| HEI | 58493 | 65120 | 11.3% |




September 21, 12:00 PM (Clear sky condition)

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 4631 | 6508 | 40.5% |
| 2m | 1713 | 1973 | 15.2% |
| 3m | 934 | 910 | 2.6% |
| Head | 1009 | 982 | 2.7% |
| | | Ave. | 15.2% |
| HEI | 90571 | 105100 | 16.0% |




September 21, 3:00 PM (Clear sky condition)

| Lux | RAD. | Model | Discrep. |
|---|---|---|---|
| 1m | 3215 | 4633 | 44.1% |
| 2m | 1121 | 1452 | 29.5% |
| 3m | 609 | 638 | 4.7% |
| Head | 1001 | 1258 | 25.7% |
| | | Ave. | 26.0% |
| HEI | 69382 | 75880 | 9.4% |

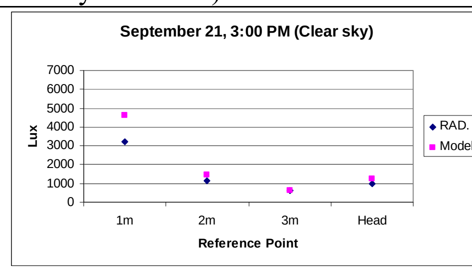



**Table 49-Comparison of illuminance levels between RADIANCE (#347) and scale model measurement (September 21, Clear sky).**

The discrepancies between the scale model measurements and the RADIANCE calculation are due to the following reasons.

Trees and other buildings surrounded the places where the scale model measurements are conducted. One measurement under the intermediate sky was conducted in a parking area, College Station, Texas, and the other measurement under the clear sky is done on the roof floor of Langford A Building, Texas A&M University, College Station, Texas (Figure 61). These measurements create different environments of models, which are calculated by RADIANCE.

Another possible reason for the discrepancy is the difference between CIE sky condition and the actual sky condition. The CIE intermediate condition is 30% to 70% cloud coverage, and the clear sky condition is less than 30% cloud coverage. Thus, the horizontal exterior illuminance (HEI) of RADIANCE is not identical with the actual HEI values.  And, the RADIANCE calculation is more sensitive to the reflectance of the building exterior. With dirt and other unrecognizable exterior variables of the building's exterior, the actual reflectance may be varied depending on conditions. Those components may cause discrepancies between the two (Figure 62).

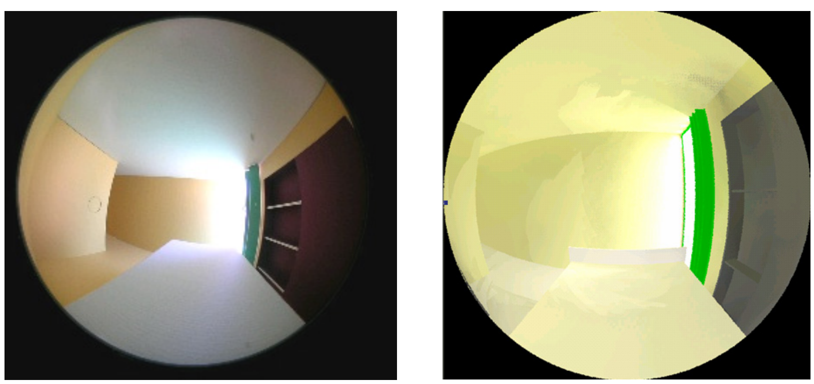


**Figure 62-Images of the scale model (left)  and RADIANCE model of room #346 at St. Joseph Regional Health Center.**

### 5.2.5. Comparison between the 2nd and 3rd floors

First, 2nd and 3rd floors should be compared to check the difference in illuminance and daylight factors because the research targeted wards are located on the 2nd and 3rd floor in the southwest wing of St. Joseph Regional Health Center Building. This can be influenced by surrounding buildings and affect the daylighting environment.

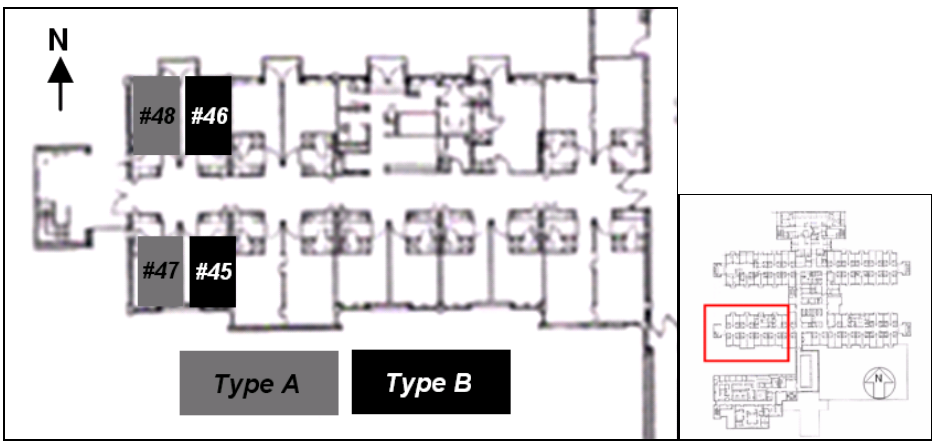



**Figure 63-Types of patient rooms in a ward.**

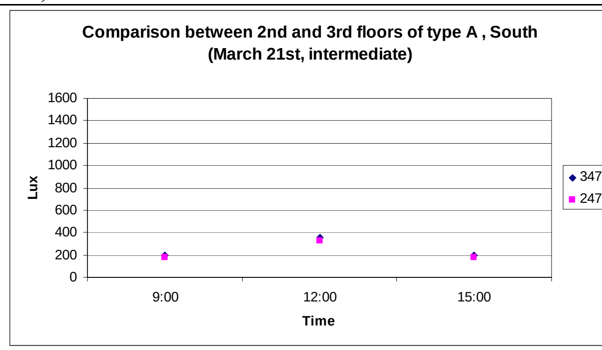
The comparison analysis between the 2nd and 3rd floors is conducted using the representative four rooms on each floor. The study is performed between the two rooms which are located at the same position on 2nd and 3rd floors. Each representative type of a patient room at a particular orientation is selected to be analyzed at every floor (Figure 63).

| RADIANCE (HEI - Lux) | 9:00 | 12:00 | 15:00 |
|---|---|---|---|
| March | 14196 | 22966 | 20686 |
| July | 22339 | 24628 | 25721 |
| October | 12524 | 21920 | 15992 |
| December | 5016 | 14769 | 9935 |

**Table 50-Horizontal exterior illuminance (lux) by RADIANCE.**

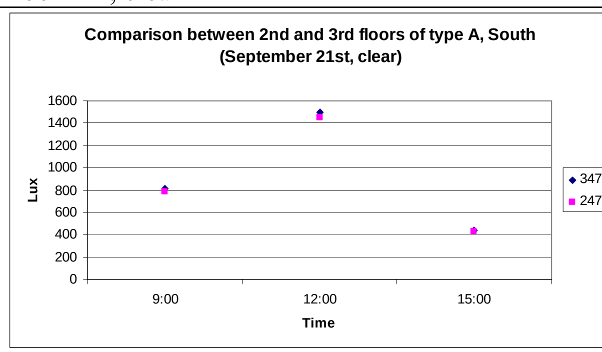
March 21st, intermediate

| Time | 347 (lux) | 247 (lux) | Discrep (lux,(%))* |
|---|---|---|---|
| 9:00 | 195 | 173 | 22 (11%) |
| 12:00 | 355 | 329 | 26 (7%) |
| 15:00 | 195 | 181 | 14 (7%) |
| | | Ave. | 20 (8%) |




September 21st, clear

| Time | 347 | 247 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 818 | 782 | 36 (4%) |
| 12:00 | 1494 | 1451 | 43 (3%) |
| 15:00 | 444 | 433 | 10 (2%) |
| | | Ave. | 30 (3%) |




December 21st, intermediate

| Time | 347 | 247 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 103 | 73 | 30 (29%) |
| 12:00 | 486 | 442 | 44 (9%) |
| 15:00 | 240 | 224 | 16 (7%) |
| | | Ave. | 30 (15%) |

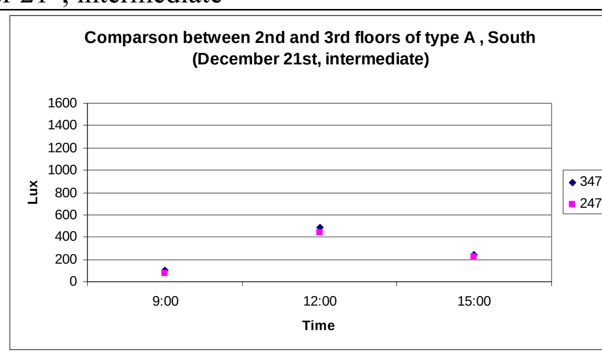
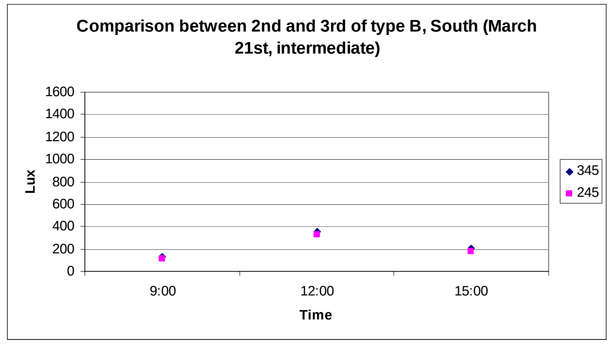



**Table 51-Comparison between #347 and #247 (type A, South) (*Discrepancy (%) = [Value (3rd floor) - Value(2nd floor)] / Value (3rd floor).**

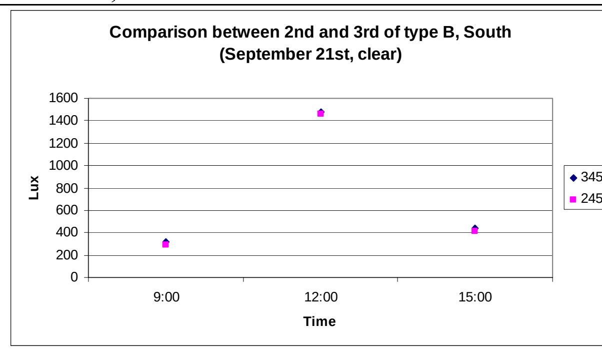
March 21st, intermediate

| Time | 345 | 245 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 133 | 114 | 19 (14%) |
| 12:00 | 354 | 330 | 24 (7%) |
| 15:00 | 203 | 178 | 25 (12%) |
| | | Ave. | 23 (11%) |




September 21st, clear

| Time | 345 | 245 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 315 | 288 | 27 (8%) |
| 12:00 | 1482 | 1464 | 17 (1%) |
| 15:00 | 438 | 412 | 27 (6%) |
| | | Ave. | 24 (5%) |




December 21st, intermediate

| Time | 345 | 245 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 158 | 72 | 86 (54%) |
| 12:00 | 480 | 442 | 38 (8%) |
| 15:00 | 348 | 327 | 21 (6%) |
| | | Ave. | 48 (23%) |

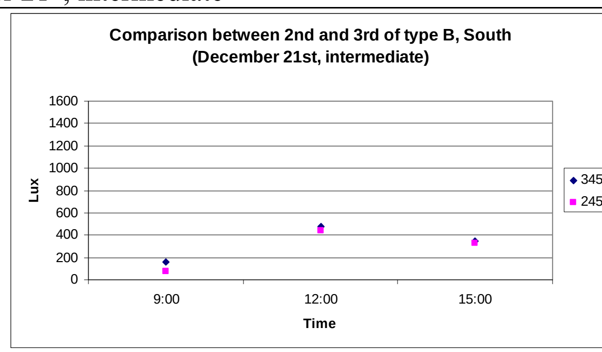
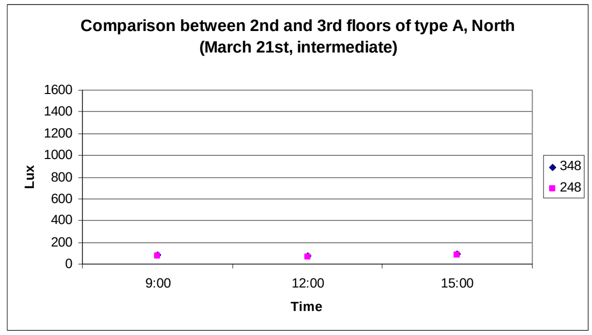



**Table 52-Comparison between #345 and #245 (type B, South).**

The calculations are conducted with the same HEI by RADIANCE (Table 50). In type A and B of the south orientation, overall illuminances of the rooms on the 3rd floor have higher illuminances than those of the 2nd floor. The overall average discrepancy is between 20% and 50%. The illuminance patterns of change are similar between the two depending on the HEI values (Tables 51 and 52). Because other buildings around the southwest wing block daylight from low altitude sunlight in the morning, in December, the rooms on the 2nd floor have much lower illuminances than on the 3rd floor.

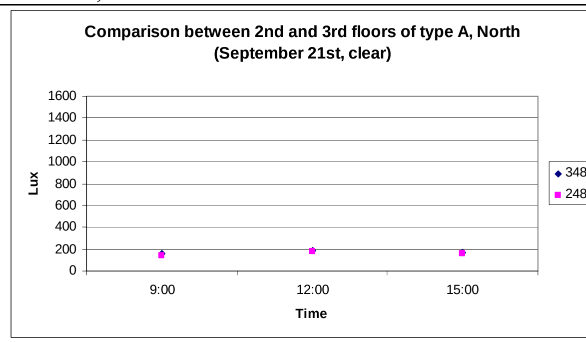
March 21st, intermediate

| Time | 348 | 248 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 88 | 73 | 15 (17%) |
| 12:00 | 72 | 68 | 4 (6%) |
| 15:00 | 91 | 83 | 8 (9%) |
| | | Ave. | 9 (10%) |




September 21st, clear

| Time | 348 | 248 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 159 | 143 | 16 (10%) |
| 12:00 | 187 | 182 | 5 (3%) |
| 15:00 | 170 | 160 | 10 (6%) |
| | | Ave. | 10 (6%) |




December 21st, intermediate

| Time | 348 | 248 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 48 | 40 | 7 (15%) |
| 12:00 | 71 | 68 | 4 (5%) |
| 15:00 | 61 | 58 | 3 (5%) |
| | | Ave. | 5 (8%) |

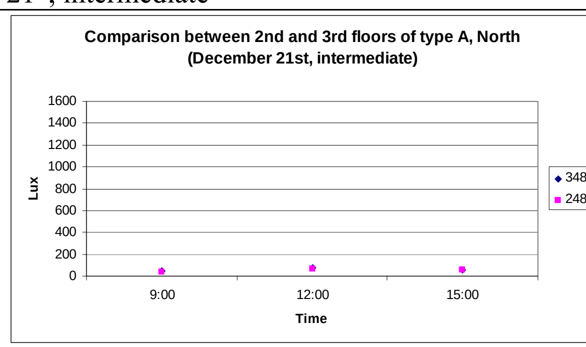
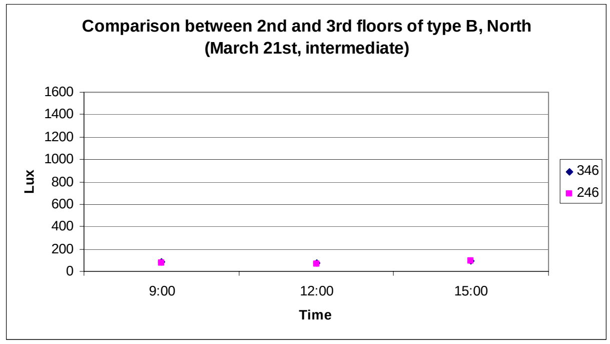



**Table 53-Comparison between #348 and #248 (type A, North).**

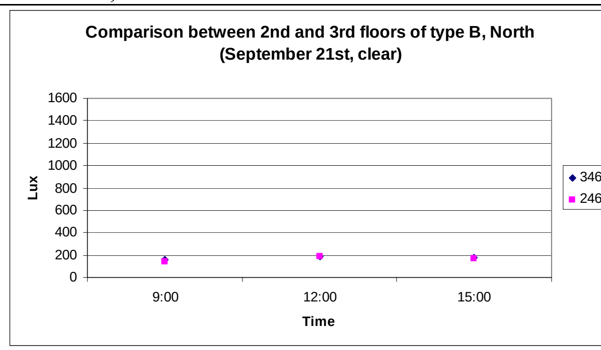
March 21st, intermediate

| Time | 346 | 246 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 85 | 71 | 14 (17%) |
| 12:00 | 72 | 69 | 3 (4%) |
| 15:00 | 95 | 90 | 5 (6%) |
| | | Ave. | 7 (9%) |




September 21st, clear

| Time | 346 | 246 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 158 | 144 | 14 (9%) |
| 12:00 | 190 | 185 | 4 (2%) |
| 15:00 | 176 | 166 | 10 (5%) |
| | | Ave. | 9 (5%) |




December 21st, intermediate

| Time | 346 | 246 | Discrep (lux,(%)) |
|---|---|---|---|
| 9:00 | 46 | 40 | 6 (13%) |
| 12:00 | 74 | 70 | 4 (5%) |
| 15:00 | 65 | 62 | 3 (5%) |
| | | Ave. | 4 (8%) |

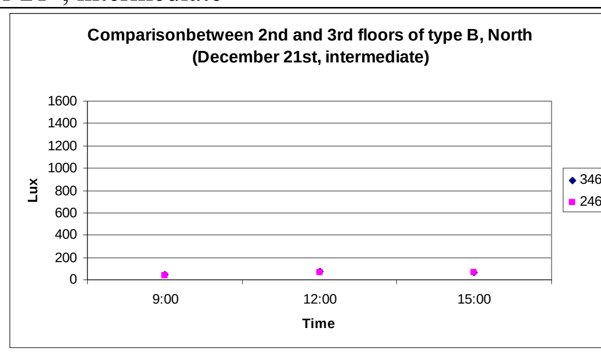



**Table 54-Comparison between #346 and #246 (type B, North).**

In type A and B of the northern orientation, overall illuminances of the rooms on the 3rd floor are slightly higher than those of the 2nd floor. The overall average discrepancy is below 10%. The illuminance patterns of change are similar between the two depending on the HEI values (Tables 53 and 54). Because north facing patient rooms receive both indirect and diffused light from the sun, the illuminance changing pattern is not sensitively related with the direct sunlight and sky condition.

As a result, illuminances of south facing rooms have a large discrepancy between 2nd and 3rd floors at 20% to 50%. Those are larger than in north facing rooms which have little discrepancy between the two floors, below 10 %.

### 5.2.6. Comparison among the same floor rooms

The comparisons of illuminances among the rooms are performed to determine the differences among them on each floor in terms of type and orientation.

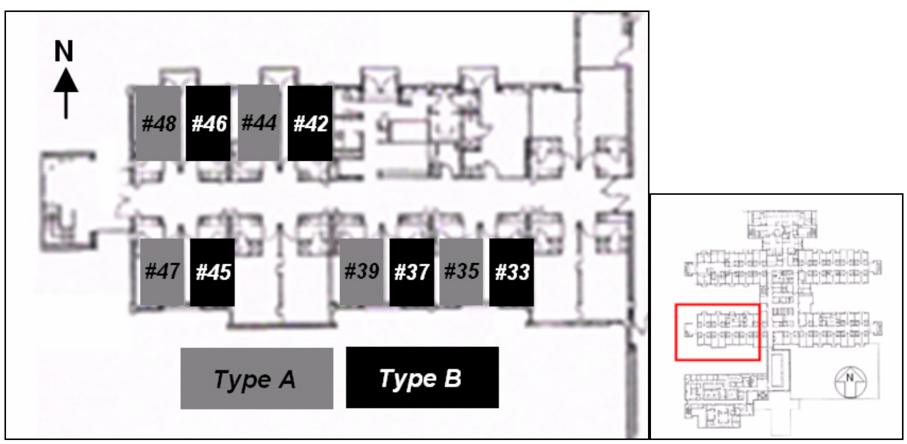
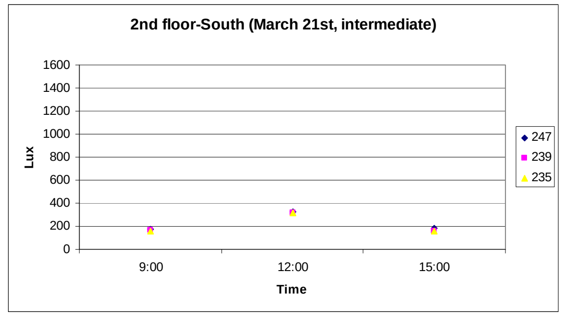



**Figure 64- Types of patient rooms in a ward.**

The comparison analysis is conducted among the rooms that are of the same types and orientations on each 2nd and 3rd floors (Figure 64).

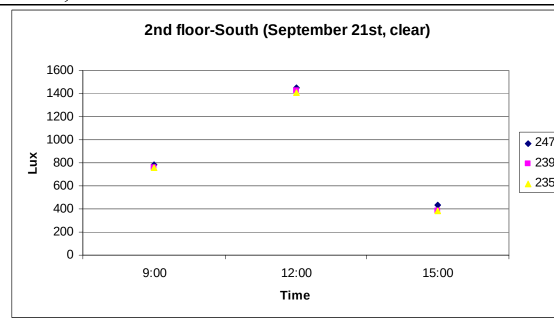
March 21st, intermediate

| Time | 247 (lux) | 239 (lux) | 235 (lux) | Discrep. (lux)* |
|---|---|---|---|---|
| 9:00 | 173 | 165 | 162 | 11 |
| 12:00 | 329 | 320 | 319 | 10 |
| 15:00 | 181 | 161 | 162 | 19 |
| | | | Ave. | 14 |




September 21st, clear

| Time | 247 | 239 | 235 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 782 | 757 | 756 | 27 |
| 12:00 | 1451 | 1426 | 1407 | 44 |
| 15:00 | 433 | 385 | 382 | 52 |
| | | | Ave. | 41 |




December 21st, intermediate

| Time | 247 | 239 | 235 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 73 | 66 | 58 | 15 |
| 12:00 | 442 | 430 | 423 | 19 |
| 15:00 | 224 | 200 | 200 | 24 |
| | | | Ave. | 19 |

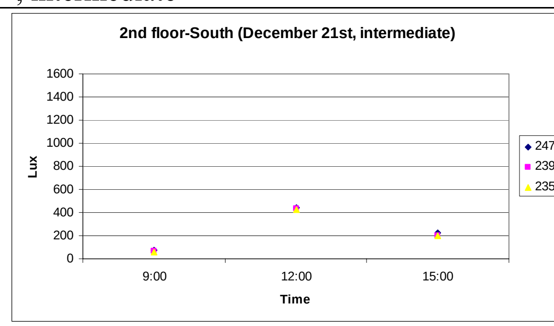
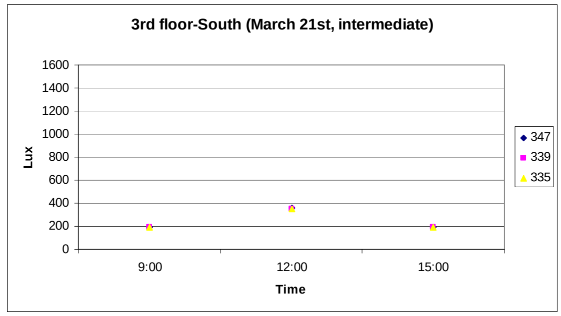



**Table 55-Comparison among the patient rooms (type A, South, 2nd floor) (*Discrepancy (lux) = max. value – min. value in each time).**

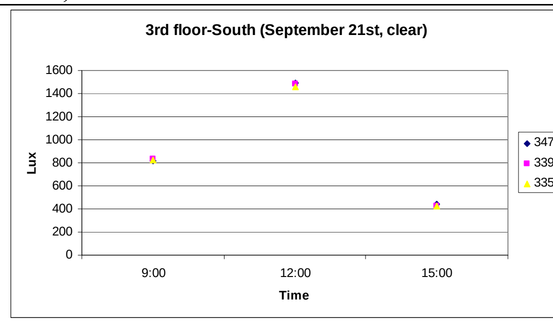
March 21st, intermediate

| Time | 347 | 339 | 335 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 133 | 132 | 130 | 3 |
| 12:00 | 354 | 356 | 348 | 6 |
| 15:00 | 203 | 197 | 196 | 7 |
| | | | Ave. | 5 |




September 21st, clear

| Time | 347 | 339 | 335 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 315 | 316 | 311 | 5 |
| 12:00 | 1482 | 1481 | 1471 | 11 |
| 15:00 | 438 | 420 | 429 | 10 |
| | | | Ave. | 8 |




December 21st, intermediate

| Time | 347 | 339 | 335 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 158 | 155 | 156 | 2 |
| 12:00 | 480 | 480 | 483 | -3 |
| 15:00 | 348 | 345 | 345 | 3 |
| | | | Ave. | 1 |

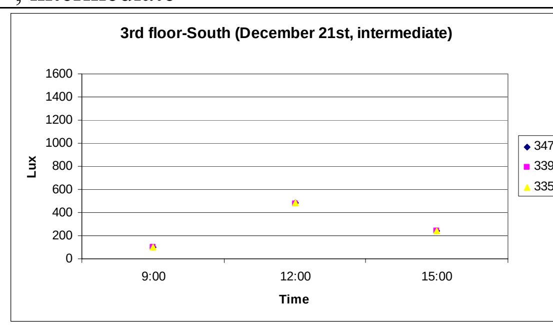
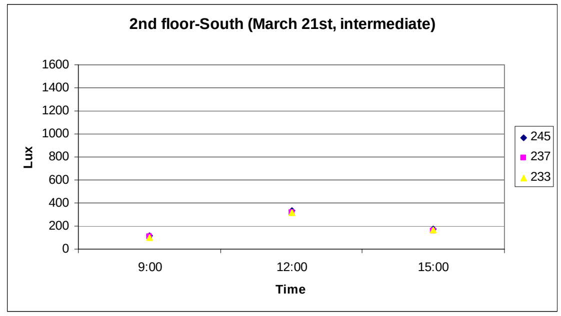



**Table 56-Comparison among the patient rooms (type A, South, 3rd floor).**

In Tables 55 and 56, the overall average illuminance discrepancy among the patient rooms of type A, south on the 2nd and 3rd floors is about 20 and 5 lux each under the intermediate sky condition, and about 40 and 8 lux each under the clear sky condition. As a room is located near the inside corner of the building, the illuminance value is slightly diminished by influences of the other portion of the building. As a result, #239 and #339 patient rooms are appropriate to use as a representative sample to demonstrate the properties of indoor daylight environments for type A, the south on the 2nd and 3rd floors each.

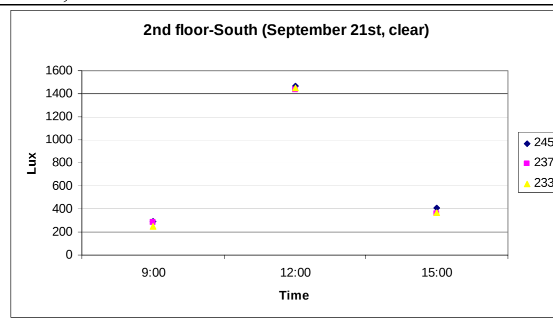
March 21st, intermediate

| Time | 245 | 237 | 233 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 114 | 107 | 97 | 17 |
| 12:00 | 330 | 320 | 319 | 11 |
| 15:00 | 178 | 157 | 163 | 15 |
| | | | Ave. | 15 |




September 21st, clear

| Time | 245 | 237 | 233 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 288 | 283 | 250 | 39 |
| 12:00 | 1464 | 1436 | 1448 | 16 |
| 15:00 | 412 | 355 | 369 | 43 |
| | | | Ave. | 33 |




December 21st, intermediate

| Time | 245 | 237 | 233 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 72 | 69 | 55 | 17 |
| 12:00 | 442 | 439 | 432 | 9 |
| 15:00 | 327 | 311 | 308 | 20 |
| | | | Ave. | 15 |

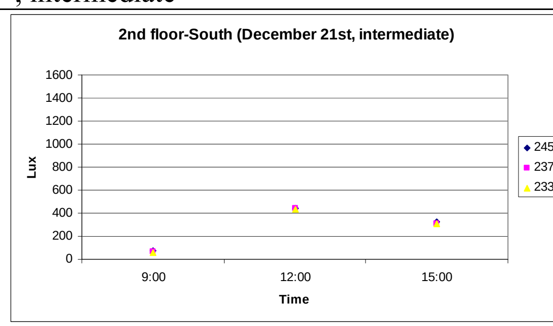
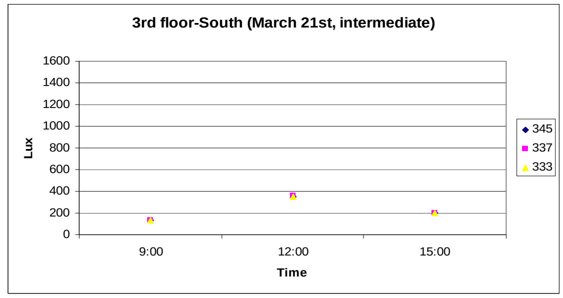



**Table 57-Comparison among the patient rooms (type B, South, 2nd floor).**

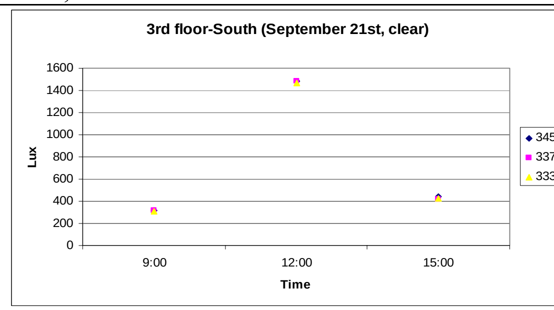
March 21st, intermediate

| Time | 345 | 337 | 333 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 133 | 132 | 130 | 3 |
| 12:00 | 354 | 356 | 348 | 6 |
| 15:00 | 203 | 197 | 196 | 7 |
| | | | Ave. | 5 |




September 21st, clear

| Time | 345 | 337 | 333 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 315 | 316 | 311 | 5 |
| 12:00 | 1482 | 1481 | 1471 | 11 |
| 15:00 | 438 | 420 | 429 | 10 |
| | | | Ave. | 8 |




December 21st, intermediate

| Time | 345 | 337 | 333 | Discrep. (lux) |
|---|---|---|---|---|
| 9:00 | 158 | 155 | 156 | 2 |
| 12:00 | 480 | 480 | 483 | -3 |
| 15:00 | 348 | 345 | 345 | 3 |
| | | | Ave. | 1 |

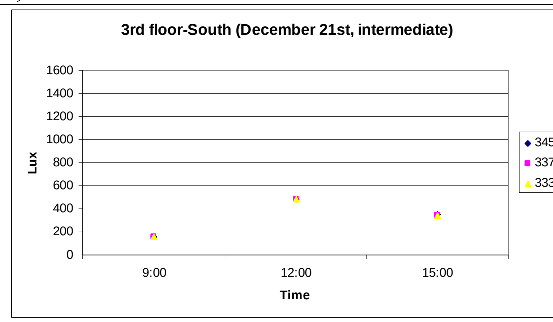
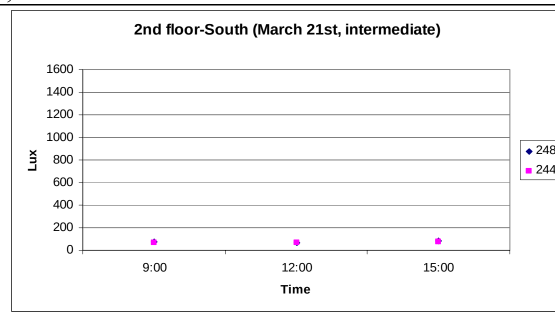



**Table 58-Comparison among the patient rooms (type B, South, 3rd floor).**

In Tables 57 and 58, the overall average illuminance discrepancy among the patient rooms of type A, south on the 2nd and 3rd floors is about 15 and 5 lux each under intermediate sky condition, and about 33 and 8 lux each under the clear sky condition. As a room is located near the inside corner of the building, the illuminance value is slightly diminished by the influences the other portion of the building. As a result, #237 and #337 patient rooms are appropriate to use as a representative sample to demonstrate the properties of indoor daylight environments for type B, the south on the 2nd and 3rd floors each.

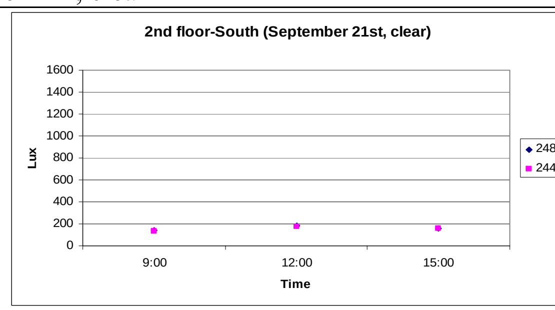
March 21st, intermediate

| Time | 248 | 244 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 73 | 69 | 4 |
| 12:00 | 68 | 67 | 2 |
| 15:00 | 83 | 79 | 5 |
| | | Ave. | 3 |




September 21st, clear

| Time | 248 | 244 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 143 | 136 | 7 |
| 12:00 | 182 | 176 | 6 |
| 15:00 | 160 | 155 | 6 |
| | | Ave. | 6 |




December 21st, intermediate

| Time | 248 | 244 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 40 | 39 | 2 |
| 12:00 | 68 | 66 | 2 |
| 15:00 | 58 | 55 | 3 |
| | | Ave. | 2 |

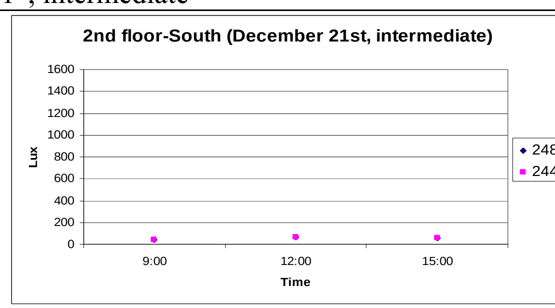
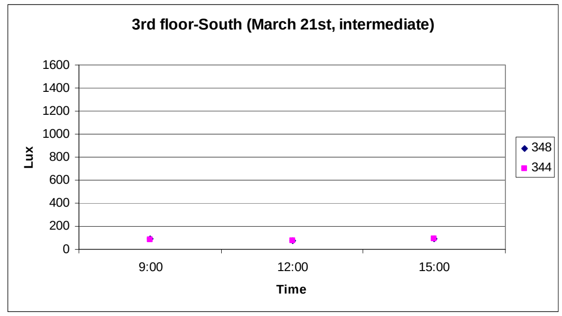



**Table 59-Comparison among the patient rooms (type A, North, 2nd floor).**

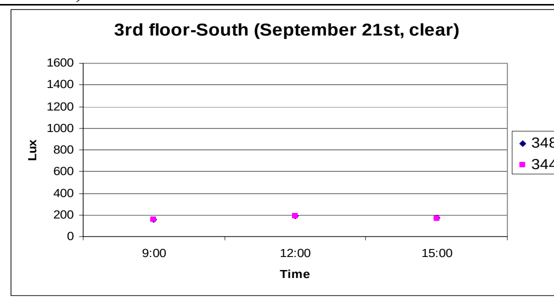
March 21st, intermediate

| Time | 348 | 344 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 88 | 87 | 1 |
| 12:00 | 72 | 72 | 0 |
| 15:00 | 91 | 90 | 2 |
| | | Ave. | 1 |




September 21st, clear

| Time | 348 | 344 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 159 | 155 | 4 |
| 12:00 | 187 | 188 | -1 |
| 15:00 | 170 | 165 | 5 |
| | | Ave. | 3 |




December 21st, intermediate

| Time | 348 | 344 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 48 | 47 | 1 |
| 12:00 | 71 | 70 | 1 |
| 15:00 | 61 | 60 | 0 |
| | | Ave. | 0 |

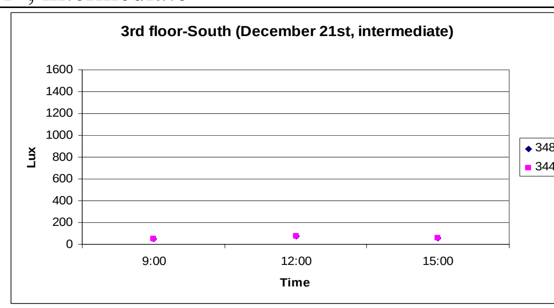
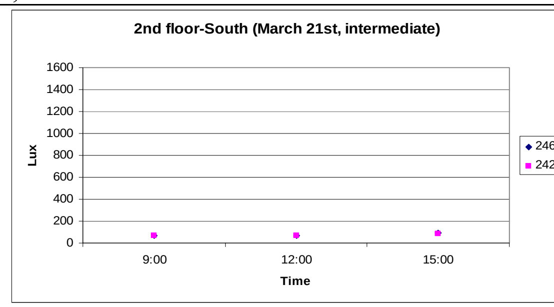



**Table 60-Comparison among the patient rooms (type A, North, 3rd floor).**

In Tables 59 and 60, the overall average illuminance discrepancy among the patient rooms of type A, south on the 2nd and 3rd floors is about 3 and 1 lux each under intermediate sky conditions, and about 6 and 3 lux each under clear sky conditions. As a room is located near the inside corner of the building, the illuminance value is slightly diminished from the influences other portions of the building. As a result, rooms #244 and #344 are appropriate to use as a representative sample to demonstrate the properties of indoor daylight environments for type A, the north on the $2^{nd}$ and $3^{rd}$ floors each.

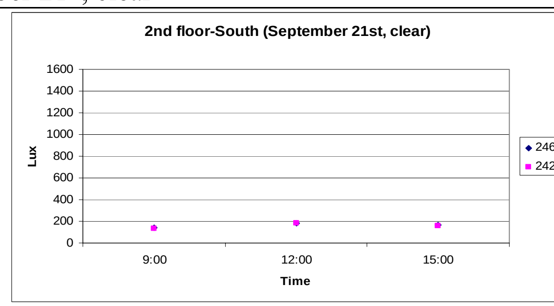
March $21^{st}$, intermediate

| Time | 246 | 242 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 71 | 68 | 3 |
| 12:00 | 69 | 68 | 2 |
| 15:00 | 90 | 84 | 6 |
| | | Ave. | 4 |




September $21^{st}$, clear

| Time | 246 | 242 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 144 | 136 | 8 |
| 12:00 | 185 | 182 | 3 |
| 15:00 | 166 | 159 | 7 |
| | | Ave. | 6 |




December $21^{st}$, intermediate

| Time | 246 | 242 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 40 | 40 | 1 |
| 12:00 | 70 | 69 | 1 |
| 15:00 | 62 | 57 | 5 |
| | | Ave. | 2 |

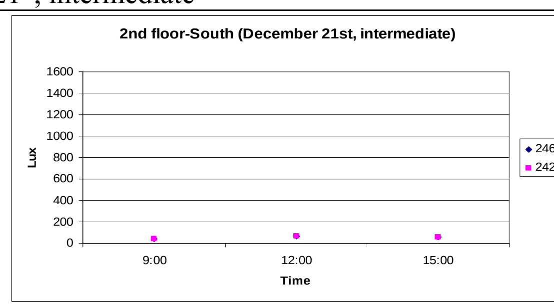
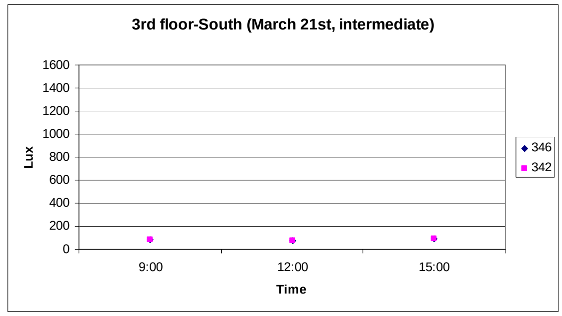



**Table 61-Comparison among the patient rooms (type B, North, 2nd floor).**

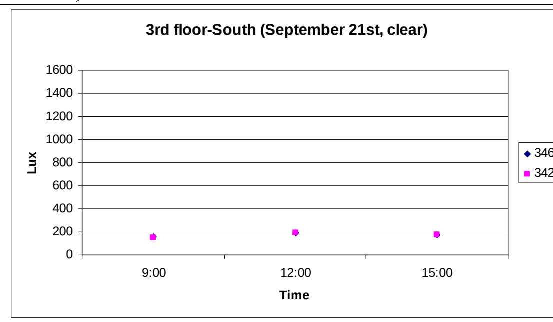
March 21st, intermediate

| Time | 346 | 342 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 85 | 83 | 1 |
| 12:00 | 72 | 72 | 0 |
| 15:00 | 95 | 94 | 1 |
| | | Ave. | 1 |




September 21st, clear

| Time | 346 | 342 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 158 | 153 | 5 |
| 12:00 | 190 | 189 | 1 |
| 15:00 | 176 | 174 | 2 |
| | | Ave. | 3 |




December 21st, intermediate

| Time | 346 | 342 | Discrep. (lux) |
|---|---|---|---|
| 9:00 | 46 | 47 | 0 |
| 12:00 | 74 | 74 | 0 |
| 15:00 | 65 | 64 | 1 |
| | | Ave. | 0 |

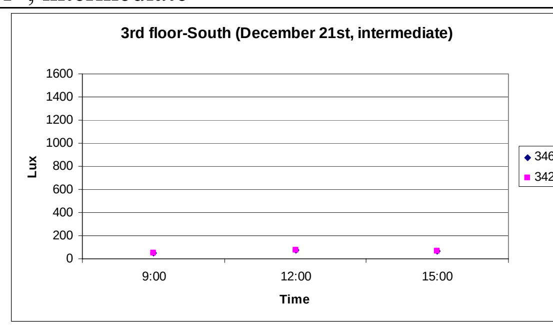



**Table 62-Comparison among the patient rooms (type B, North, 3rd floor).**

In Tables 61 and 62, the overall average illuminance discrepancy among the patient rooms of type A, south on the 2nd and 3rd floors is about 4 and 1 lux each under intermediate sky conditions, and about 6 and 3 lux each under clear sky conditions. As a room is located near the inside corner of the building, the illuminance value is slightly diminished from influences of other portions of the building. As a result, #242 and #342 patient rooms are appropriate to use as a representative sample to demonstrate the properties of indoor daylight environments for type B, the north on the 2nd and 3rd floors each.

## 5.3. ANALYSIS OF DAYLIGHT VARIABLES

There are a great deal of similarities in changing patterns in the light variables; luminance ratio, illuminance, diversity and uniformity of illuminance in the types and orientations on each floor, the 2nd and 3rd. For that reason, all analysis results are the same for the two floors. The results of the variable analysis of the 3rd floor are discussed in this section. The results of the 2nd floor can be seen in Appendix IV.

### 5.3.1. Daylight Factor (DF)

For the Daylight Factor and illuminance calculation, sixteen grids in a patient room were used (Figure 65). Daylight factors of type A and B patient rooms are shown in Figures 66 and 67. Daylight Factors of both types have the same numerical pattern reducing DF as the rooms near the building's inner corner. The overall discrepancy between the two types on the 2nd floor is DF 0.01%. On the 3rd floor, there is no difference between the two types (Table 63). As a result, the DF difference between the two types on each floor can be negligible. All DF of the rooms do not meet the recommended minimum DF in hospitals, 1%, by Markus.[9]

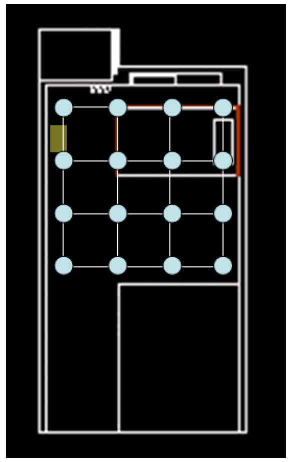


**Figure 65- Reference grids for DF and Illuminance calculation.**

| Type | Patient room | DF | Type | Patient room | DF |
|---|---|---|---|---|---|
| A (2nd floor) | 247 / 248 | 0.72% | B (2nd floor) | 245/246 | 0.71% |
| | 244 | 0.70% | | 242 | 0.69% |
| | 239 | 0.68% | | 237 | 0.67% |
| | 235 | 0.65% | | 233 | 0.65% |
| A (3rd floor) | 347/348 | 0.81% | B (3rd floor) | 345/346 | 0.81% |
| | 344 | 0.81% | | 342 | 0.80% |
| | 339 | 0.80% | | 337 | 0.80% |
| | 335 | 0.79% | | 333 | 0.79% |

**Table 63-DF of patient rooms of type A and B.**

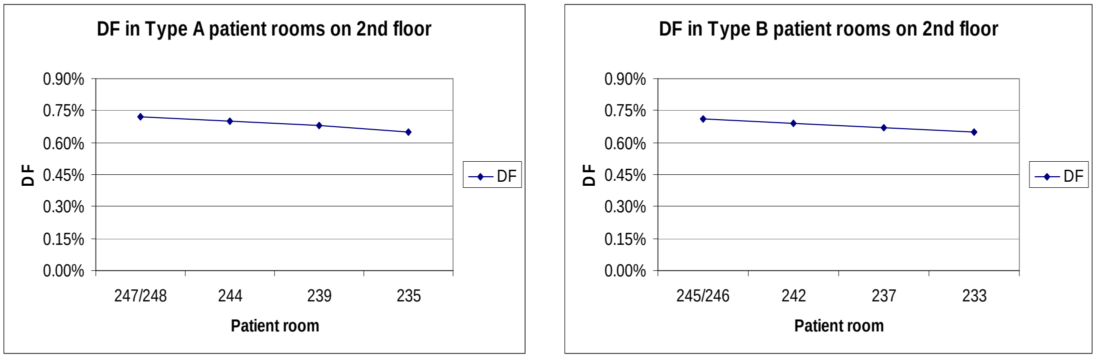



**Figure 66-DF of patient rooms of type A (left) and B, 2nd floor.**

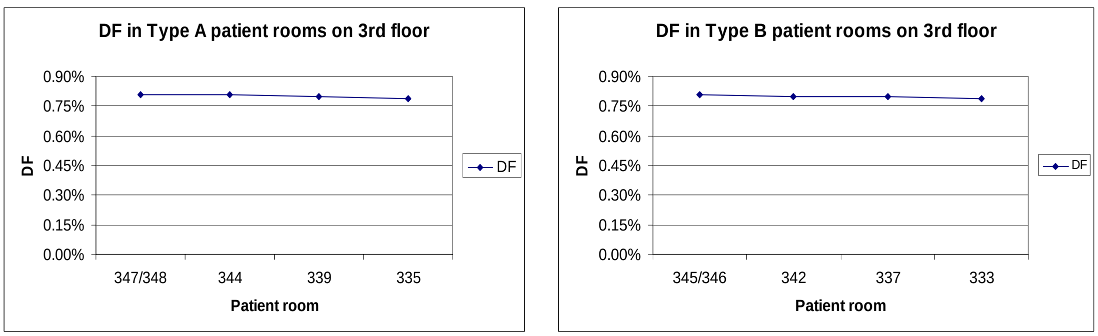



**Figure 67-DF of patient rooms of type A (left) and B, 3rd floor.**

## 5.3.2. Luminance ratio on TV wall

### 5.3.2.1. Comparison between type A and B in the south and the north, 3rd floor

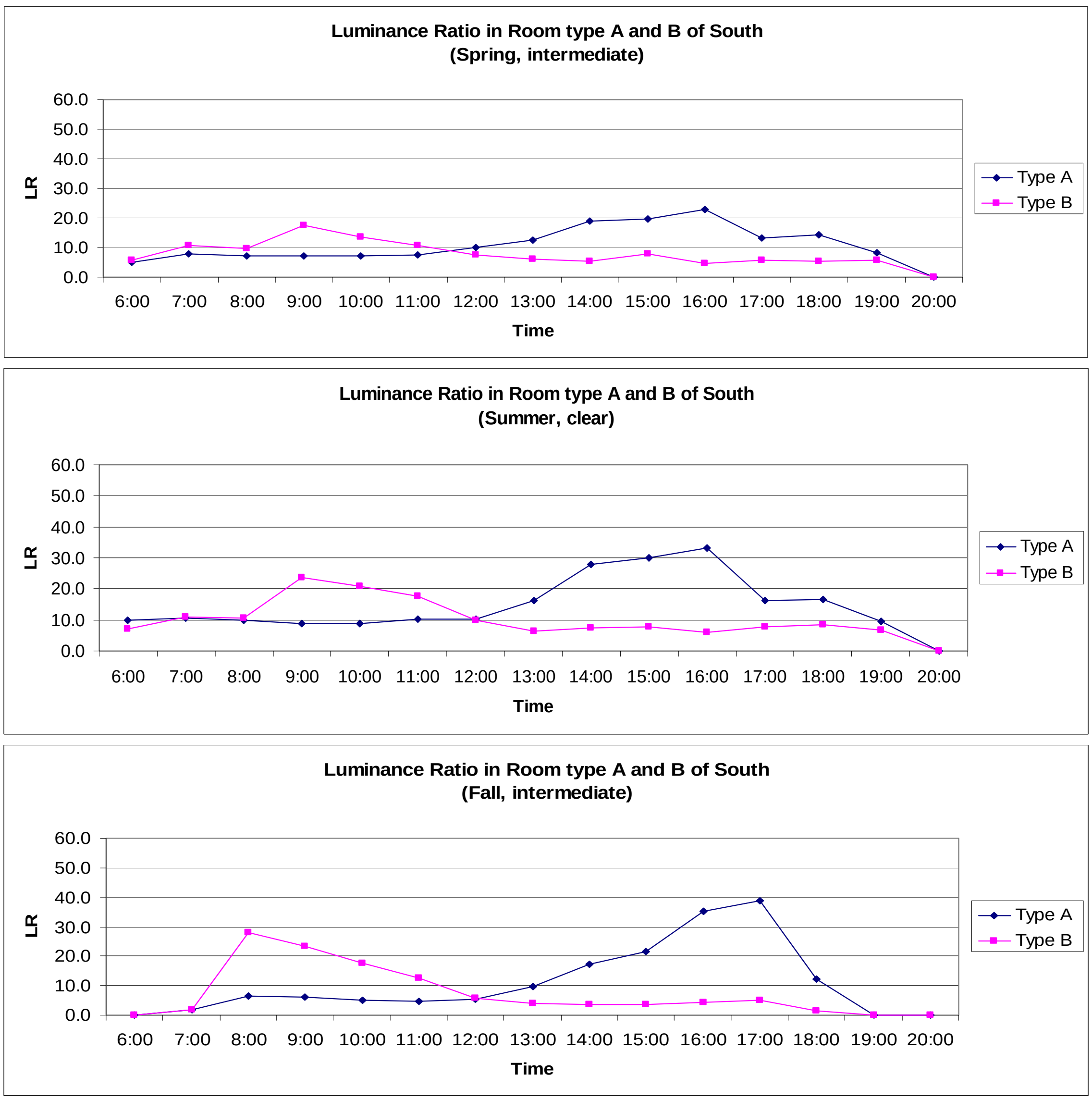



**Figure 68- Comparison between type A and B in the south, 3rd floor.**

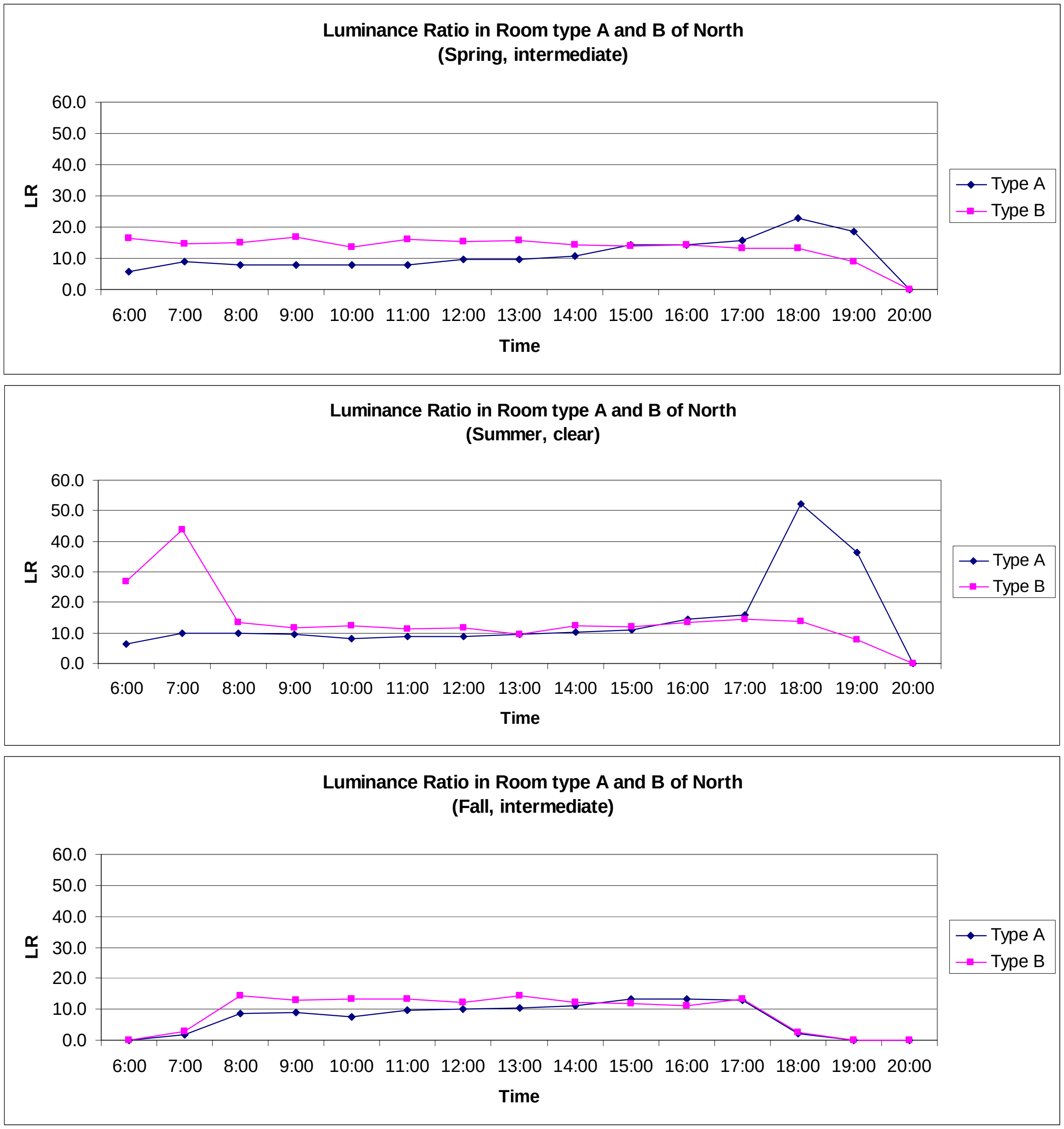



**Figure 69-Comparison between type A and B in the north, 3rd floor.**

In Figure 68, the south facing floor commonly shows higher luminance ratios in type B in the morning and in type A in the afternoon. It is because the TV walls face opposite orientations in each type of room. Whether a season has intermediate or clear sky conditions, the maximum LR is not more than 40:1 that is the maximum allowable amount according to the guide lines of Stein.[8] Such a phenomenon disturbs patient visual comfort in their rooms.

In Figure 69, in all seasons, LRs are moderate lower than 20:1. But in summer, LR is high at over 50:1 between 7:00 and 18:00 in type A and B each only in summer. However, because it temporarily happened for 1 hour, it has no significant effects on patients' visual discomfort. As a result, the LR of the two types can be regarded as the same.

#### 5.3.2.2. Comparison between the south and the north of type A and type B, 3rd floor

In Figure 70, in all seasons, the LR of a south facing room is higher than that of a north facing room in the afternoon except in summer. The maximum LR of a south facing room is not over 40:1. But the maximum LR of a north facing room is higher than 50:1 in summer.

Figure 71 shows that in all seasons, the LR of type B on the 3rd floor is lower than 20:1. Only in the morning during summer is the LR of a north facing room over 40:1.

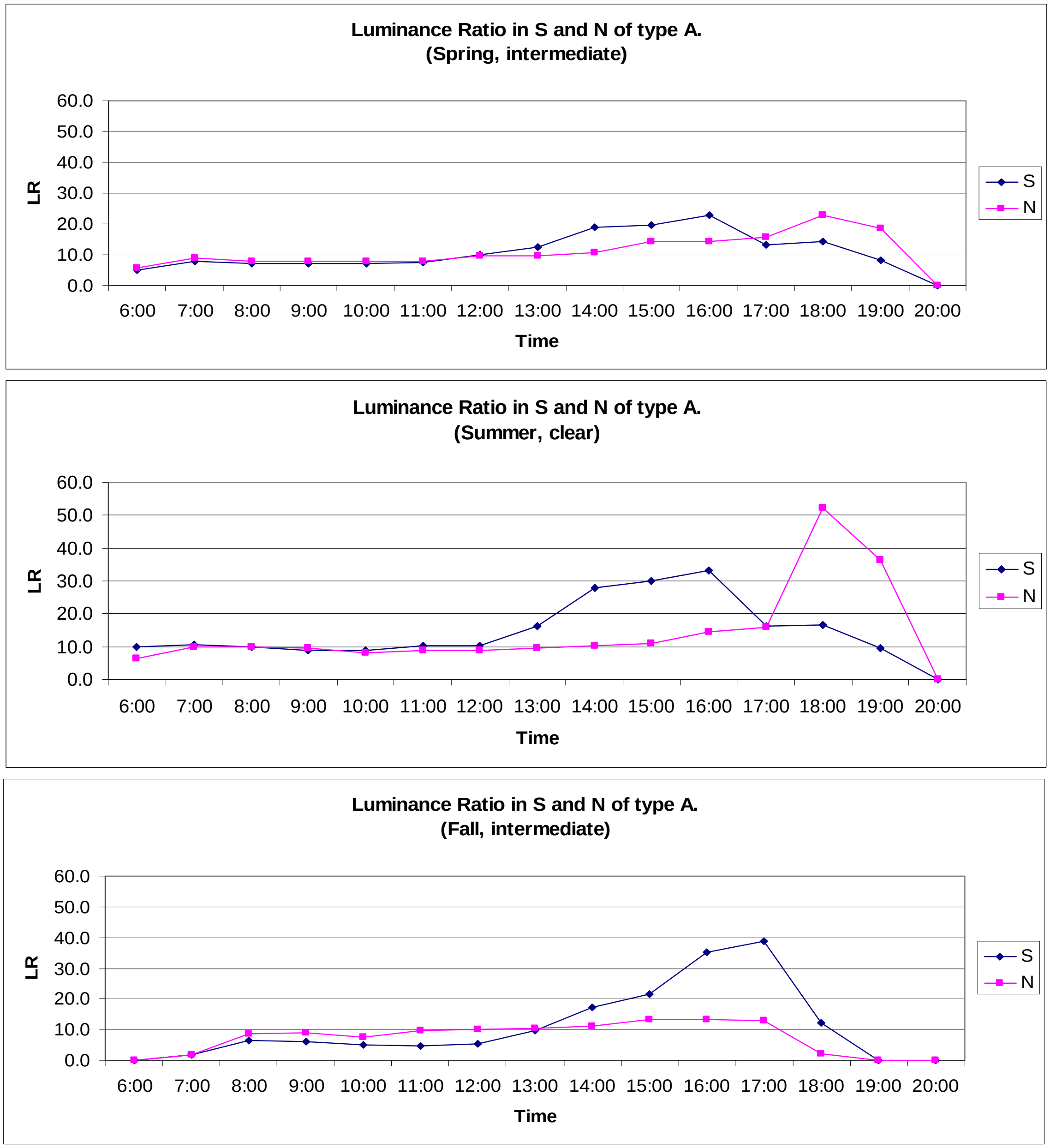



**Figure 70-Comparison between the south and the north of type A, 3rd floor.**

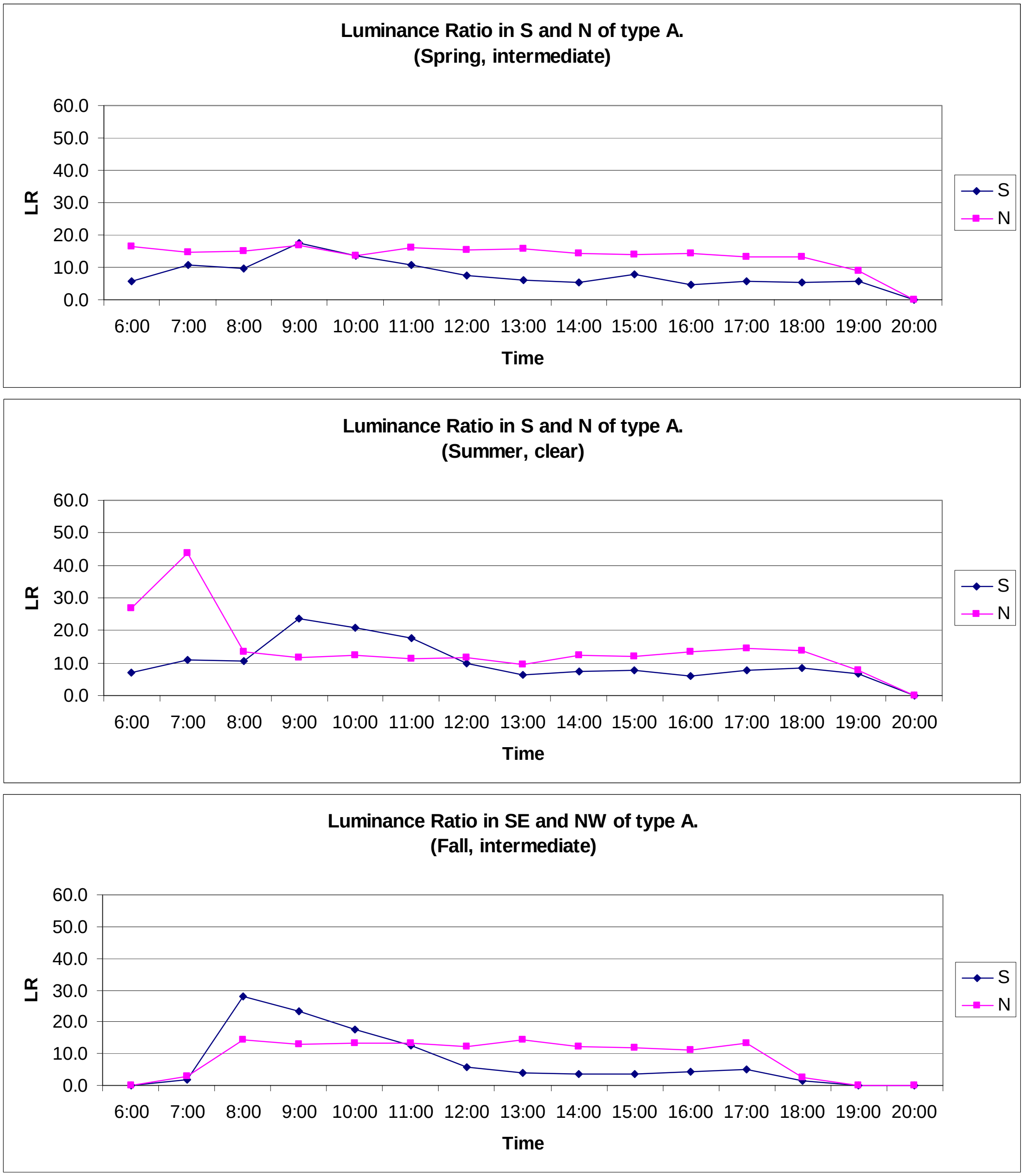



**Figure 71-Comparison between the south and the north of type B, 3rd floor.**

Figure 72 shows the sampled critical values of the luminance ration in September and July on the TV wall.

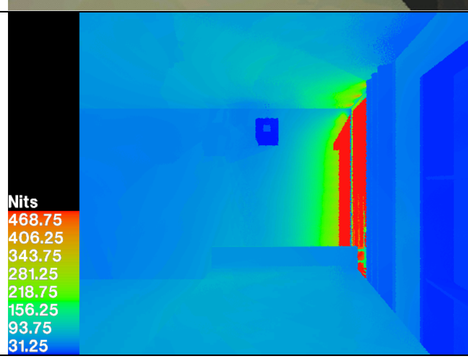
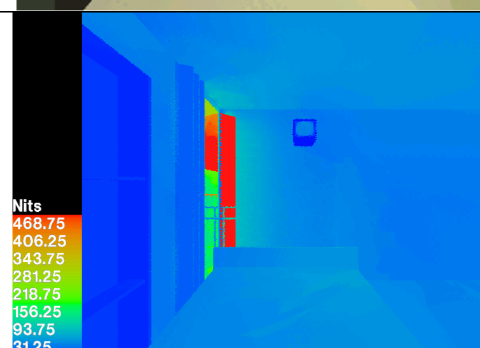
| | #339, Type A, South, 4:00 PM (CST), Sep. 21$^{st}$, Clear | #344, Type A, North, 6:00 PM (CST), Jul. 21$^{st}$, Clear |
|---|---|---|
| LR |  |  |
| False color |  |  |
| Human sensitivity |  |  |

**Figure 72- RADIANCE images of luminance ratio on the TV wall.**

### 5.3.3. Luminance ratio between the TV point and patient eye

#### 5.3.3.1. Comparison between type A and B in the south and the north, 3rd floor

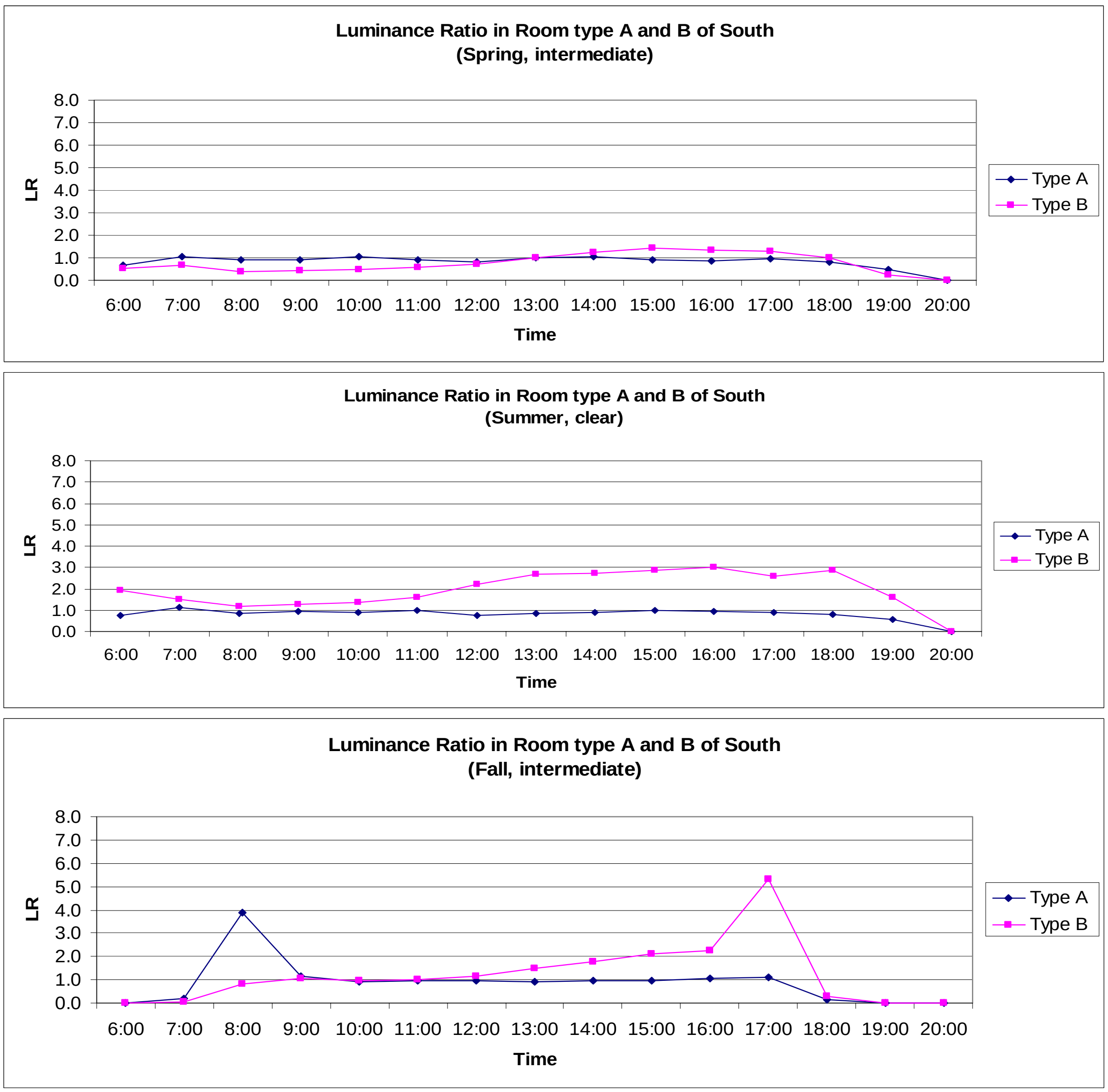



**Figure 73-Comparison between type A and B in the south, 3rd floor.**

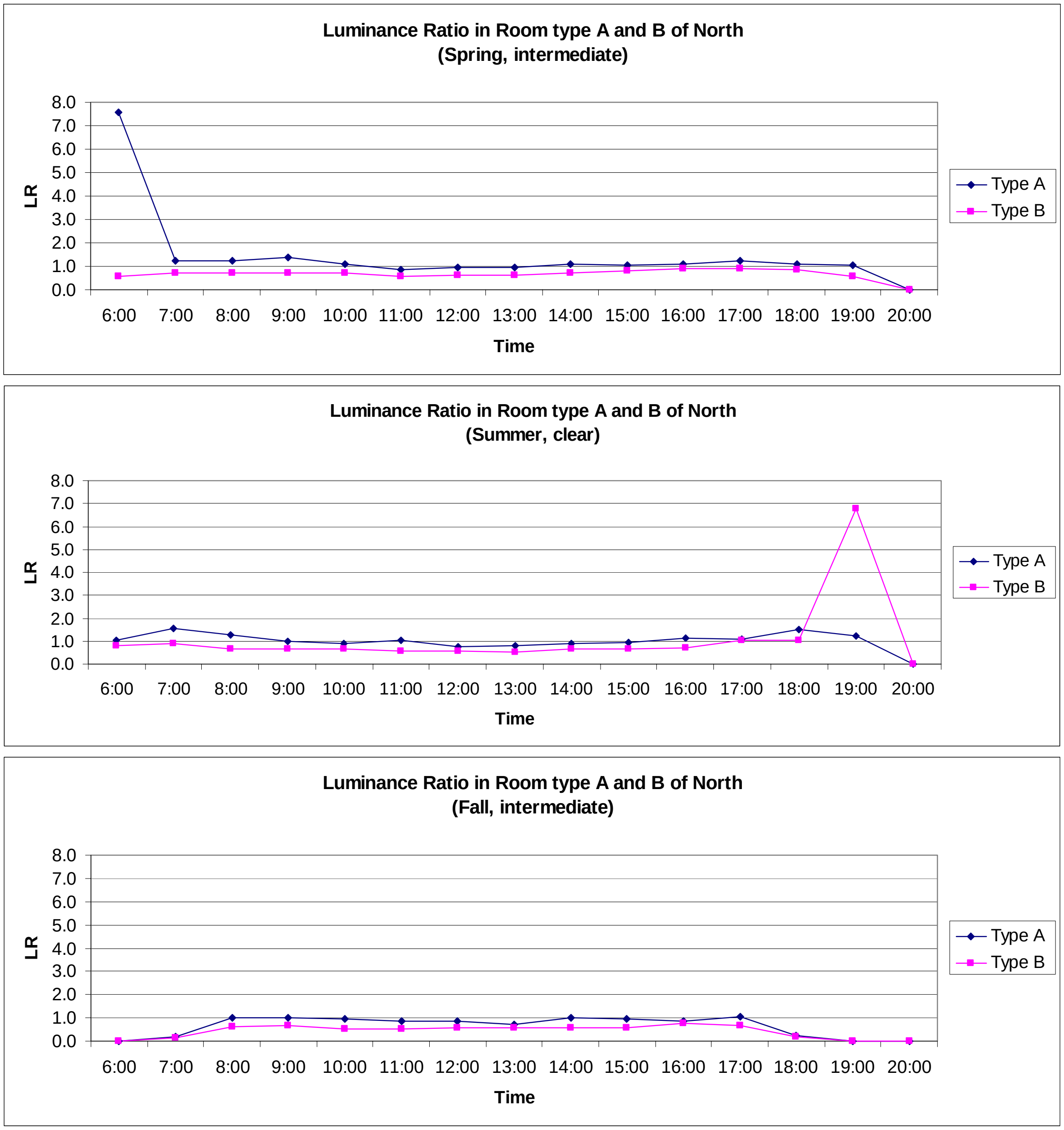
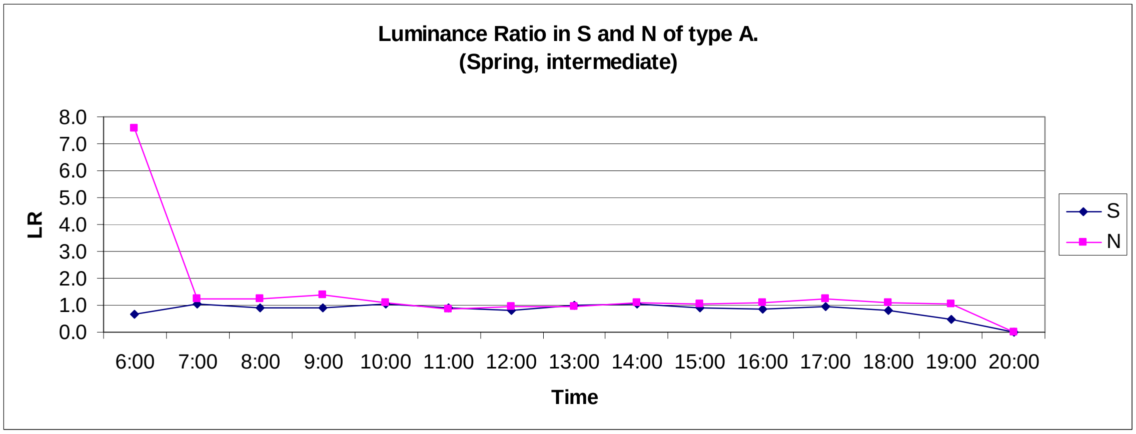
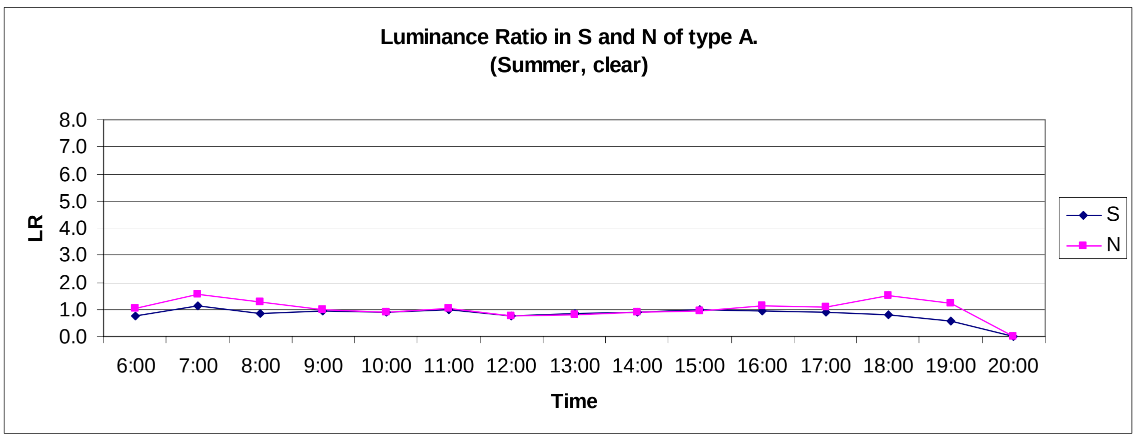



**Figure 74-Comparison between type A and B in the north, 3rd floor.**

#### 5.3.3.2. Comparison between the south and the north in type A and type B, 3rd floor



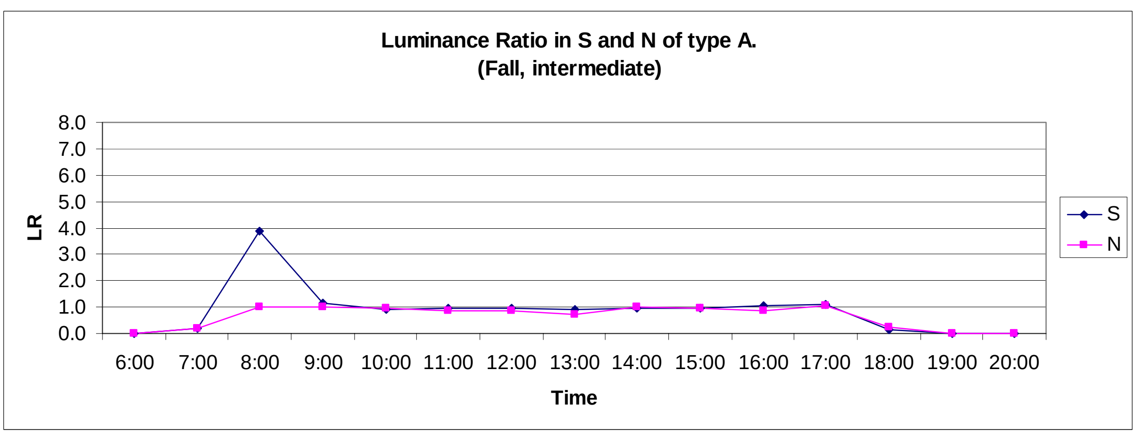




**Figure 75-Comparison between the south and the north of type A, 3rd floor.**

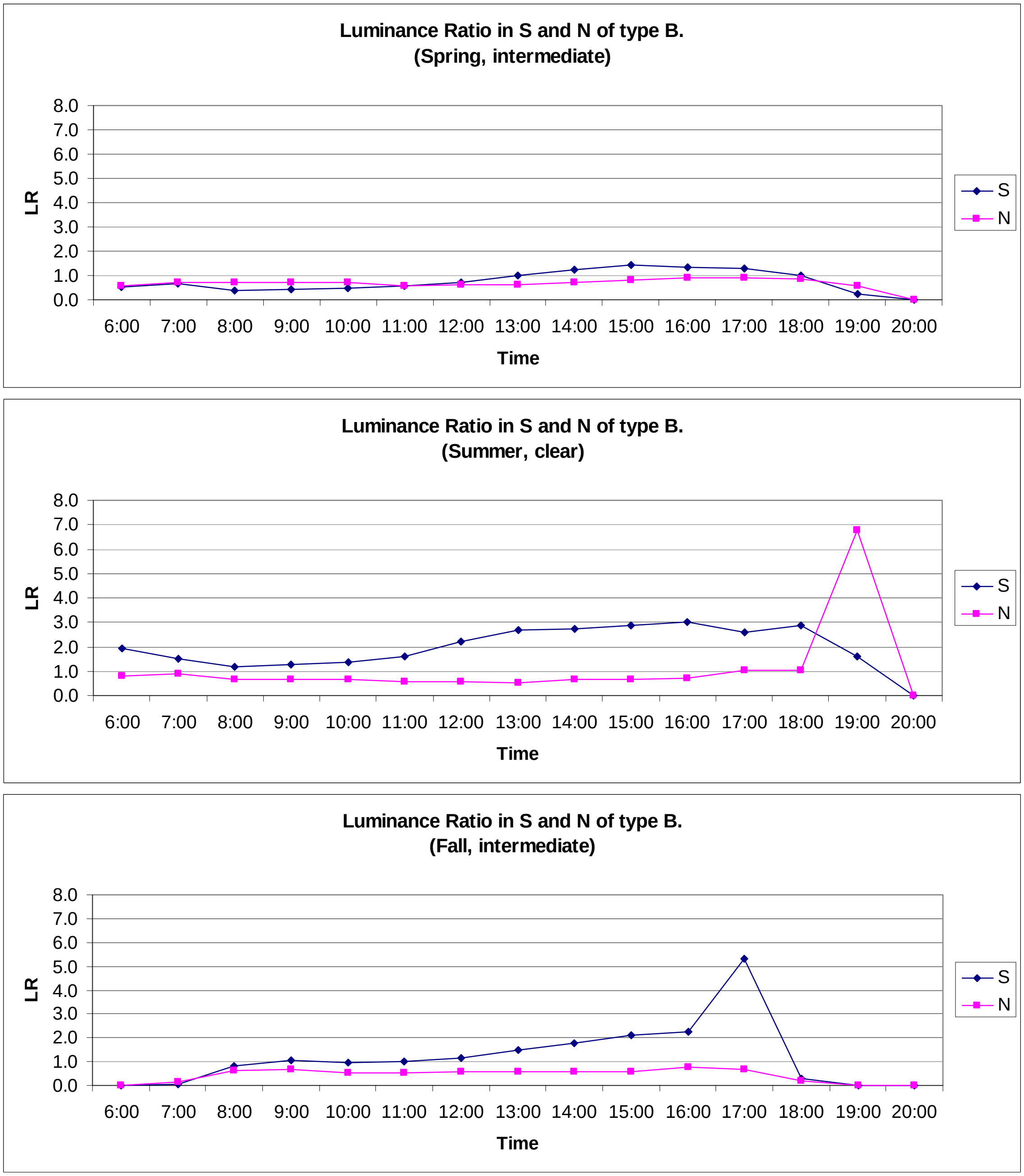



**Figure 76-Comparison between the south and the north of type B, 3rd floor.**

The various seasonal solar locations create different LRs between Type A and B in the southern orientation. The types have moderate LR during all seasons.

According to Figures 73, 74, 75 and 76, there are no significant differences between the two orientations in Type A and B during the all seasons. The overall LR is not over that of the recommended LR value (1:10).[8] There is a high LR from the north in the evening during summer. But, it only temporarily happened for about 1 hour. Overall, there is no significant difference between the two orientations and the two types each. Figure 77 shows a sample critical value of the luminance ratio between the TV point and human eye in July.

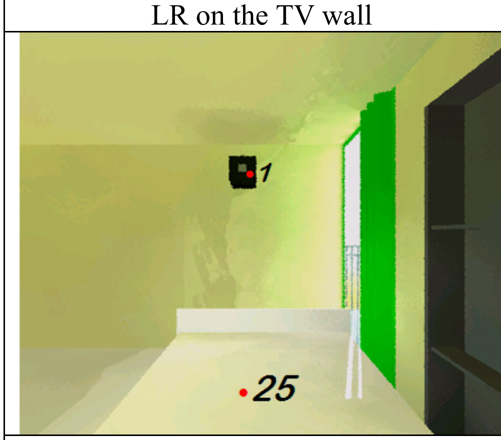
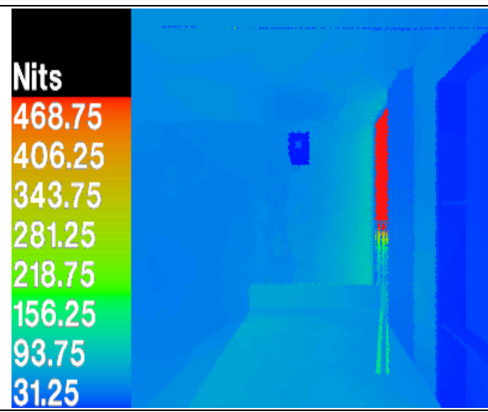
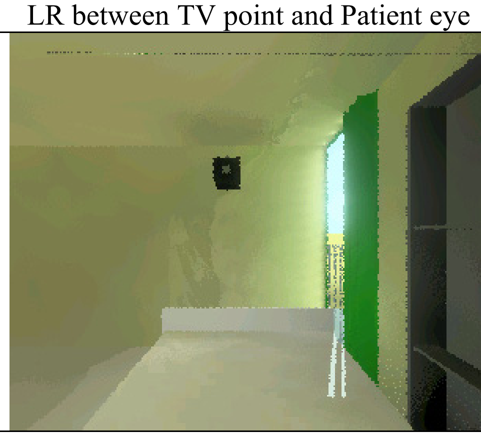
| LR on the TV wall | False color |
|---|---|
|   |   |
| LR between TV point and Patient eye | |
|  | |

**Figure 77-RADIANCE images of luminance ratio, #342, Type B, North (5:00 PM (CST), July 21st, clear).**

### 5.3.4. Average illuminance

#### 5.3.4.1. Comparison between type A and B in the south and the north, 3rd floor

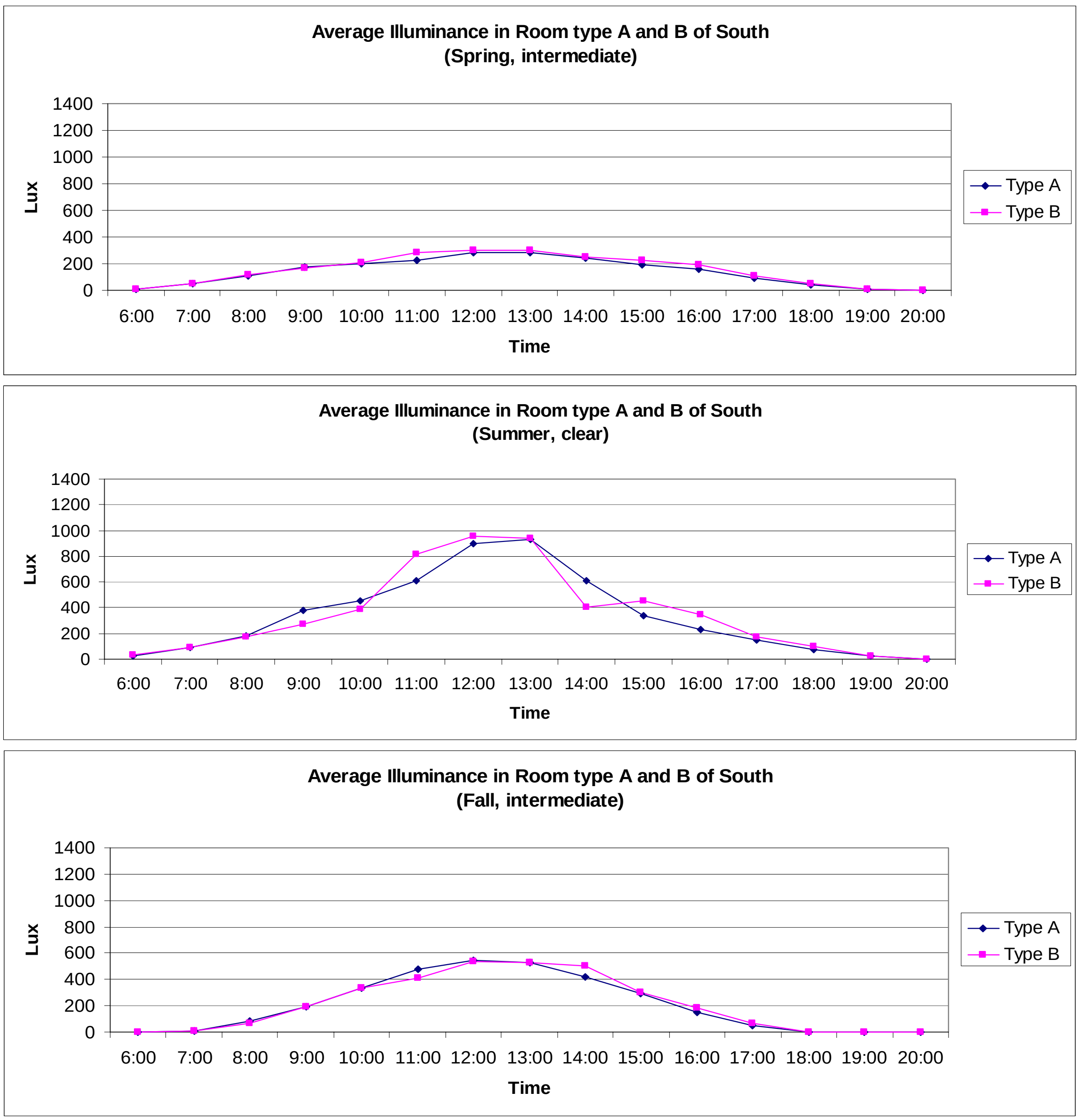



**Figure 78-Comparison between type A and B in the south, 3rd floor.**

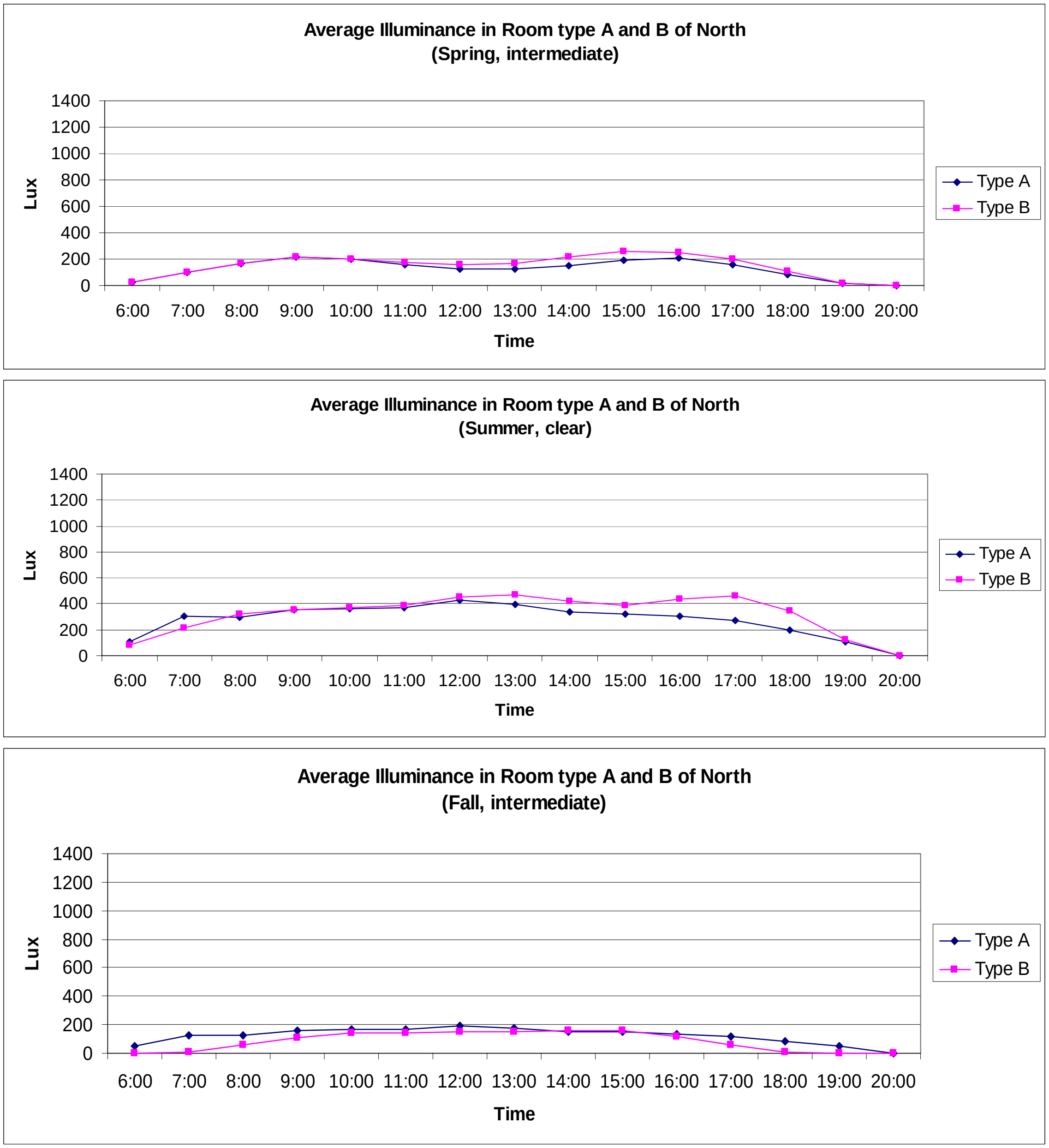



**Figure 79-Comparison between type A and B in the north, 3rd floor.**

There is no significant difference in average illuminance between Type A and B in each orientation, south and north (Figures 78 and 79). Those have almost same patterns depending on the seasons and sky conditions.

### 5.3.4.2. Comparison between the south and the north of type A and type B, 3rd floor

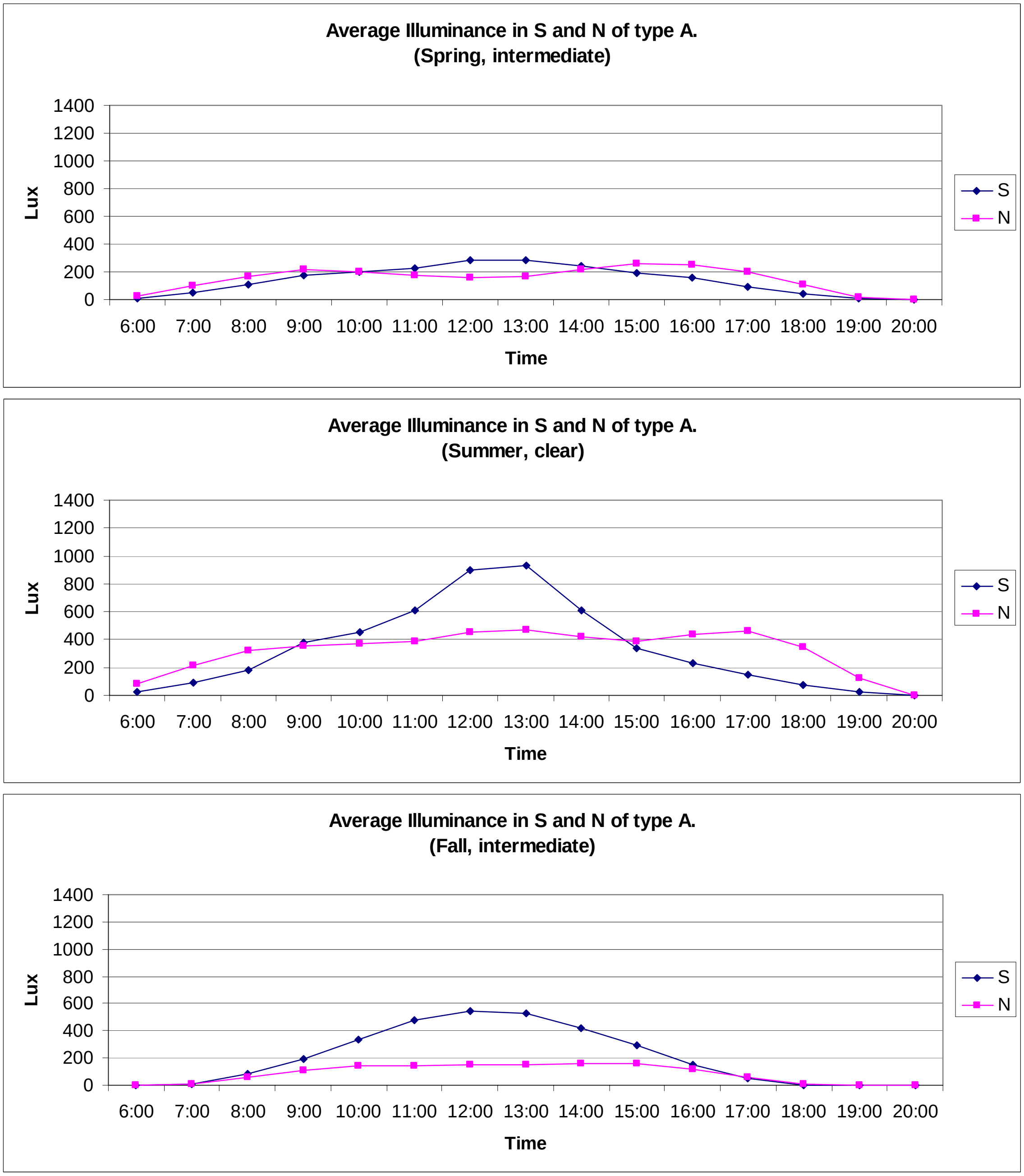



**Figure 80-Comparison between the south and the north of type A, 3rd floor.**

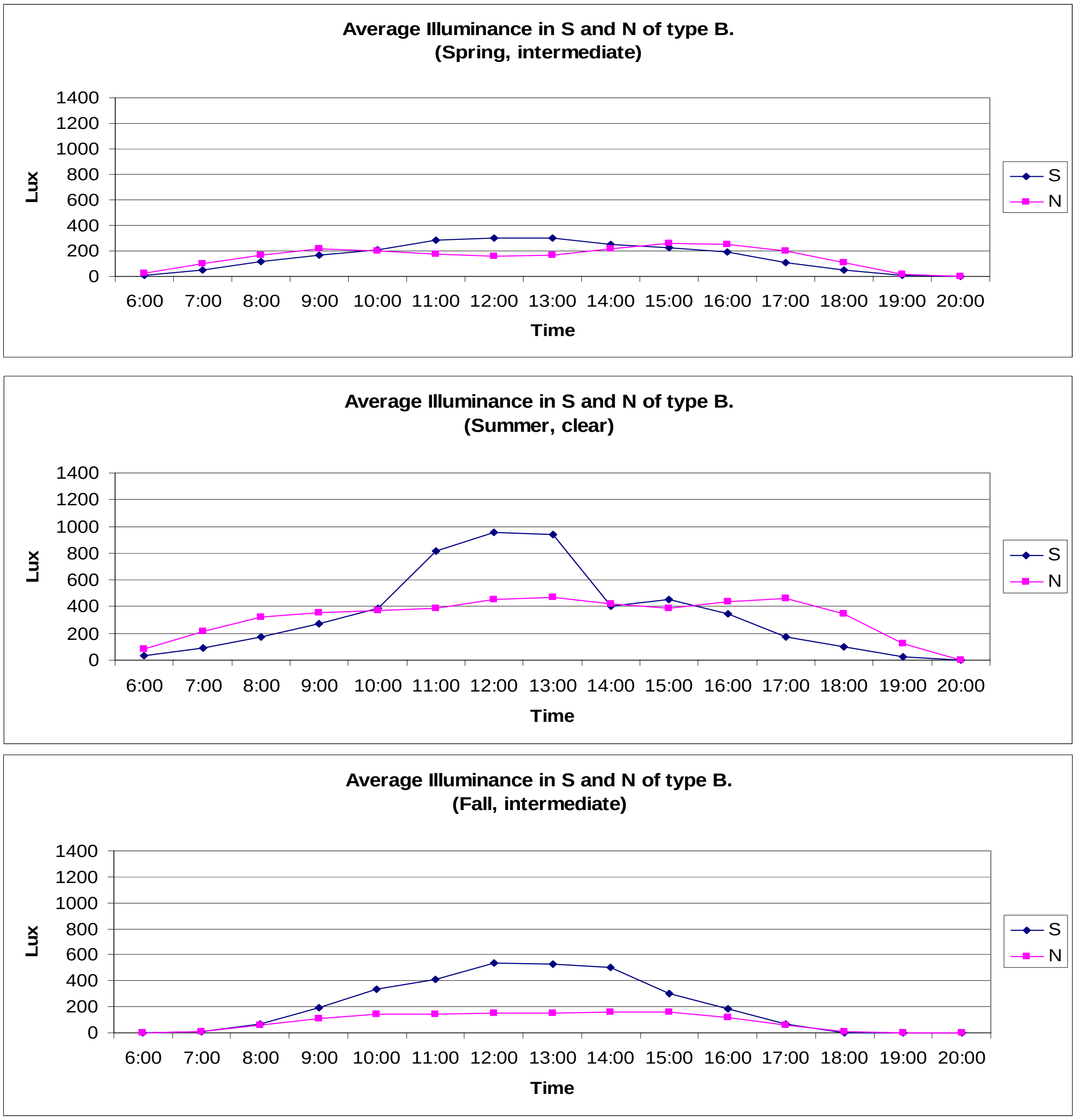
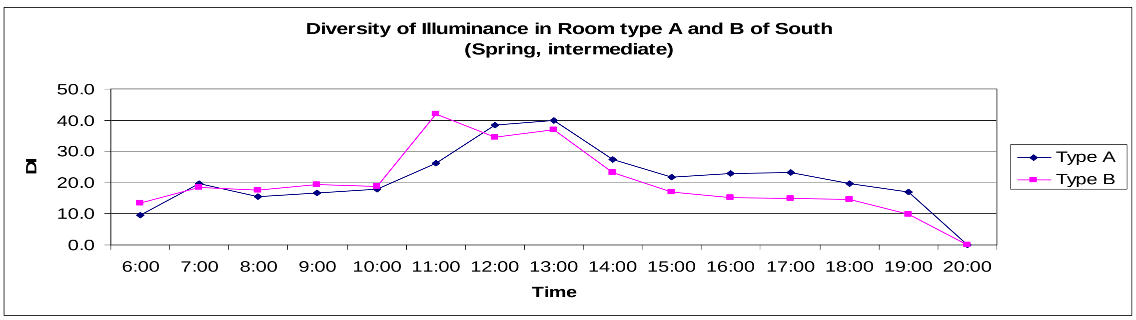


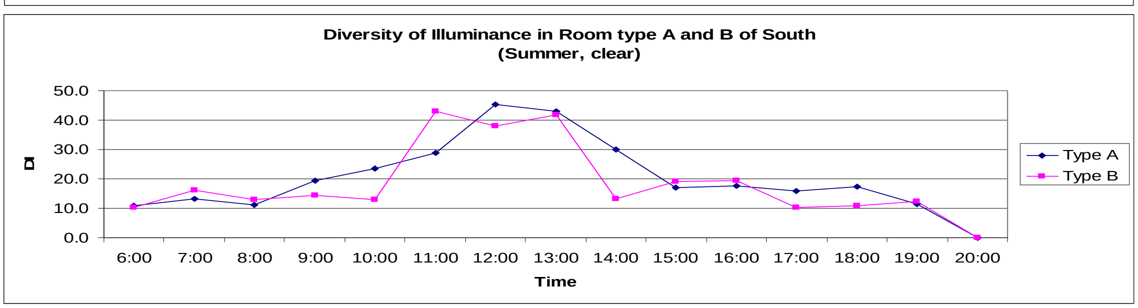

**Figure 81-Comparison between the south and the north of type B, 3rd floor.**

According to CIBSE, the recommended illuminance is 100 lux for general lighting and 300 lux for reading in a patient room. The south facing rooms have excessive illuminance compared to the north facing rooms (Figures 80 and 81). Because the north facing rooms have no direct sunlight, diffused light are entered and makes moderate illuminance level. As a result, the south facing rooms have much higher illuminance levels and more possibilities to make visual discomfort by the light.

### 5.3.5. Diversity of Illuminance (DI)

#### 5.3.5.1. Comparison between type A and B in the south and the north, 3rd floor



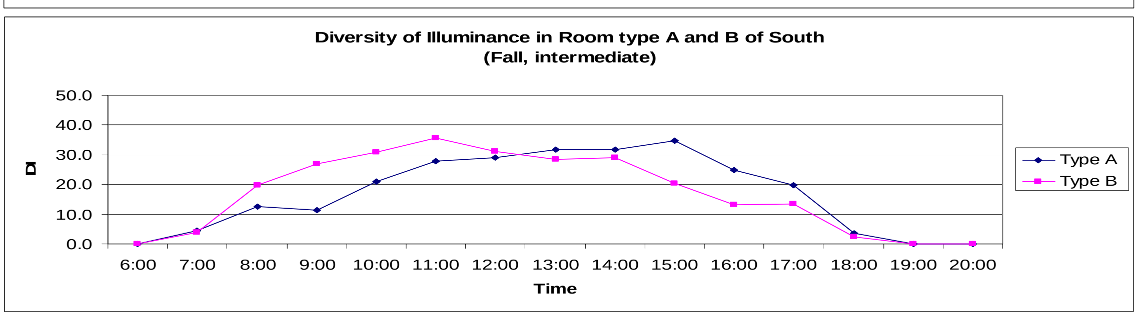




**Figure 82-Comparison between type A and B of the south, 3rd floor.**

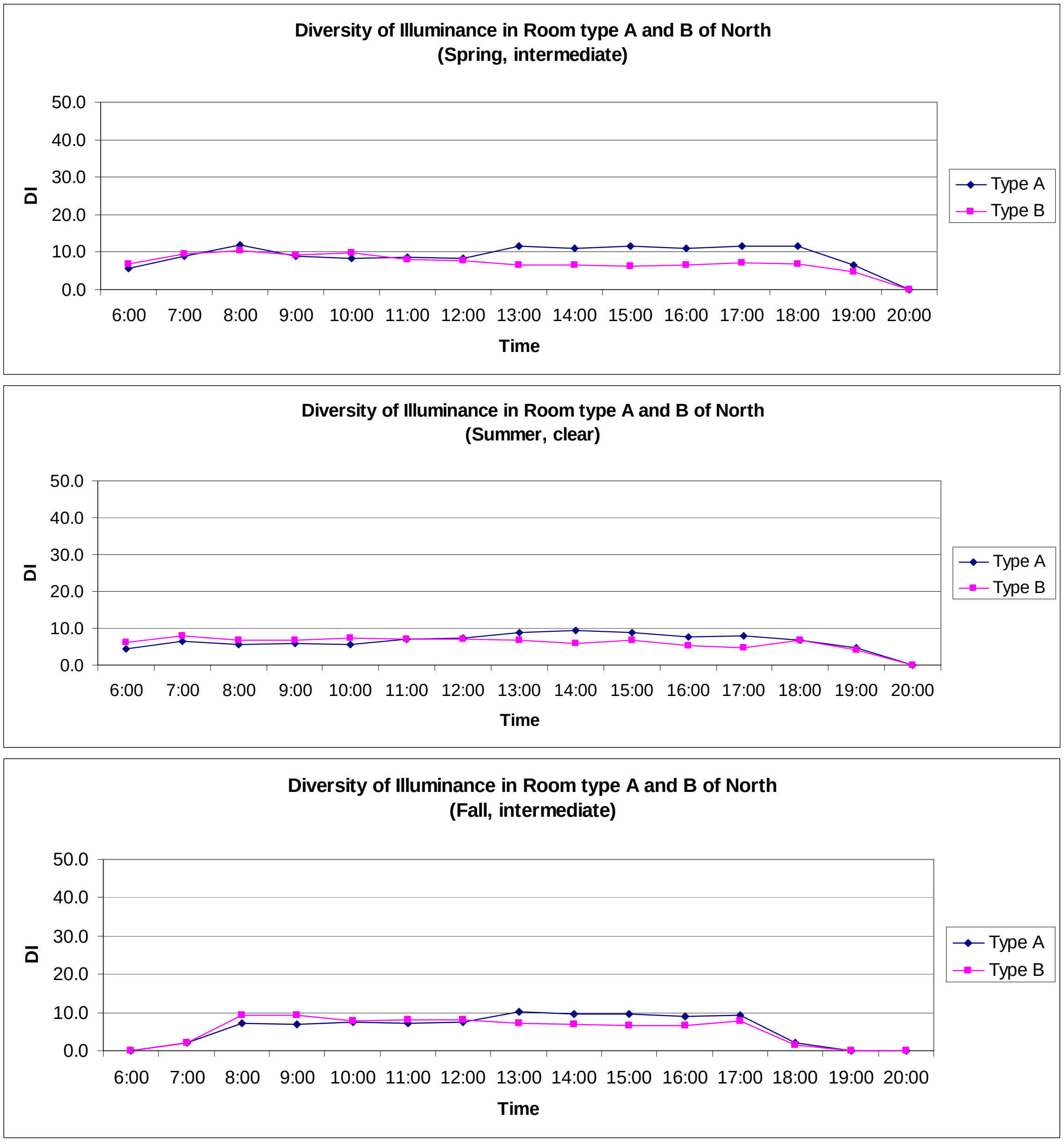



**Figure 83-Comparison between type A and B of the north, 3rd floor.**

During all seasons, the diversity of illuminance in both types is over 5. The changing patterns of DI are much similar between the two types of each orientation (Figures 82 and 83).

#### 5.3.5.2. Comparison between the south and the north of type A and type B, 3rd floor

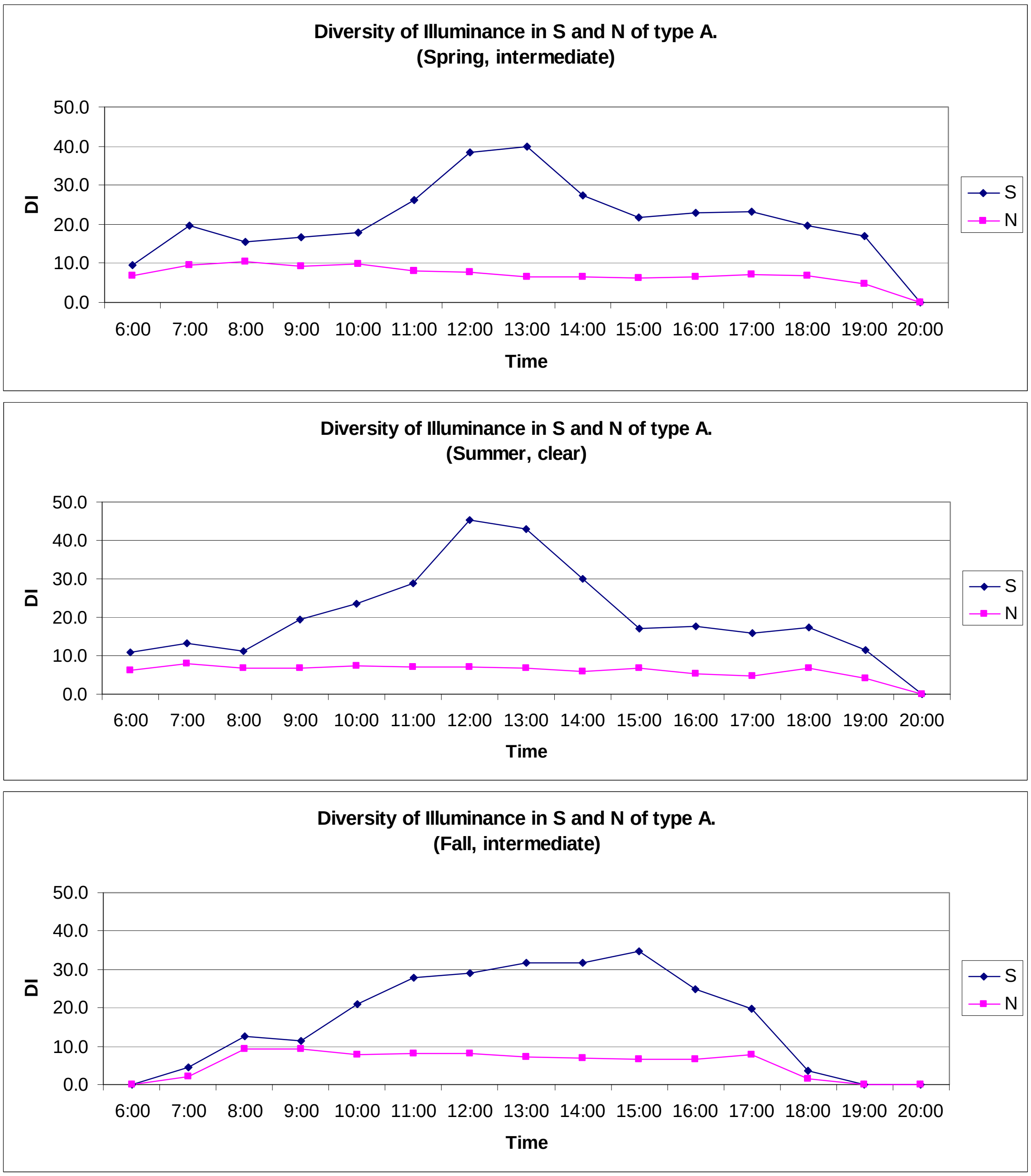



**Figure 84-Comparison between the south and the north of type A, 3rd floor.**

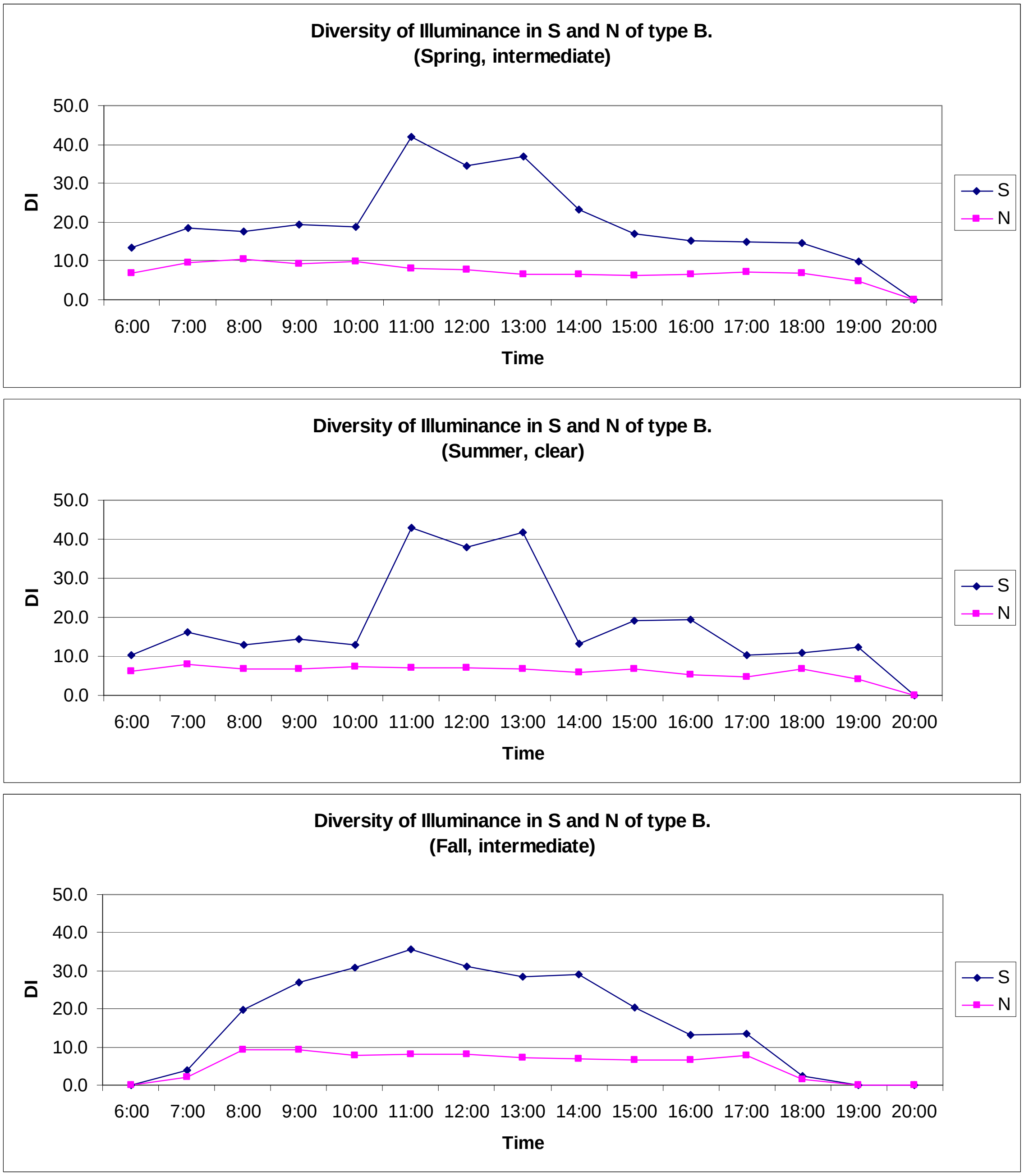



**Figure 85-Comparison between the south and the north of type B, 3rd floor.**

In Figures 84 and 85, the south facing rooms have much higher DI than the north facing. The excessive values are over 5. As a result, patients in south facing rooms may have much visual discomfort. On the contrary, the DI of the north facing rooms is slightly higher than and close to the recommended value, 5.

### 5.3.6. Uniformity of Illuminance (UI)

#### 5.3.6.1. Comparison between type A and B in the south and the north, 3rd floor

During all seasons, the uniformity of illuminance in both types is lower than the minimum recommended value, 0.8. The changing patterns of UI are much similar between the two types of each orientation (Figures 86 and 87). There is no difference in the uniformity of illuminance between the two types of each orientation.

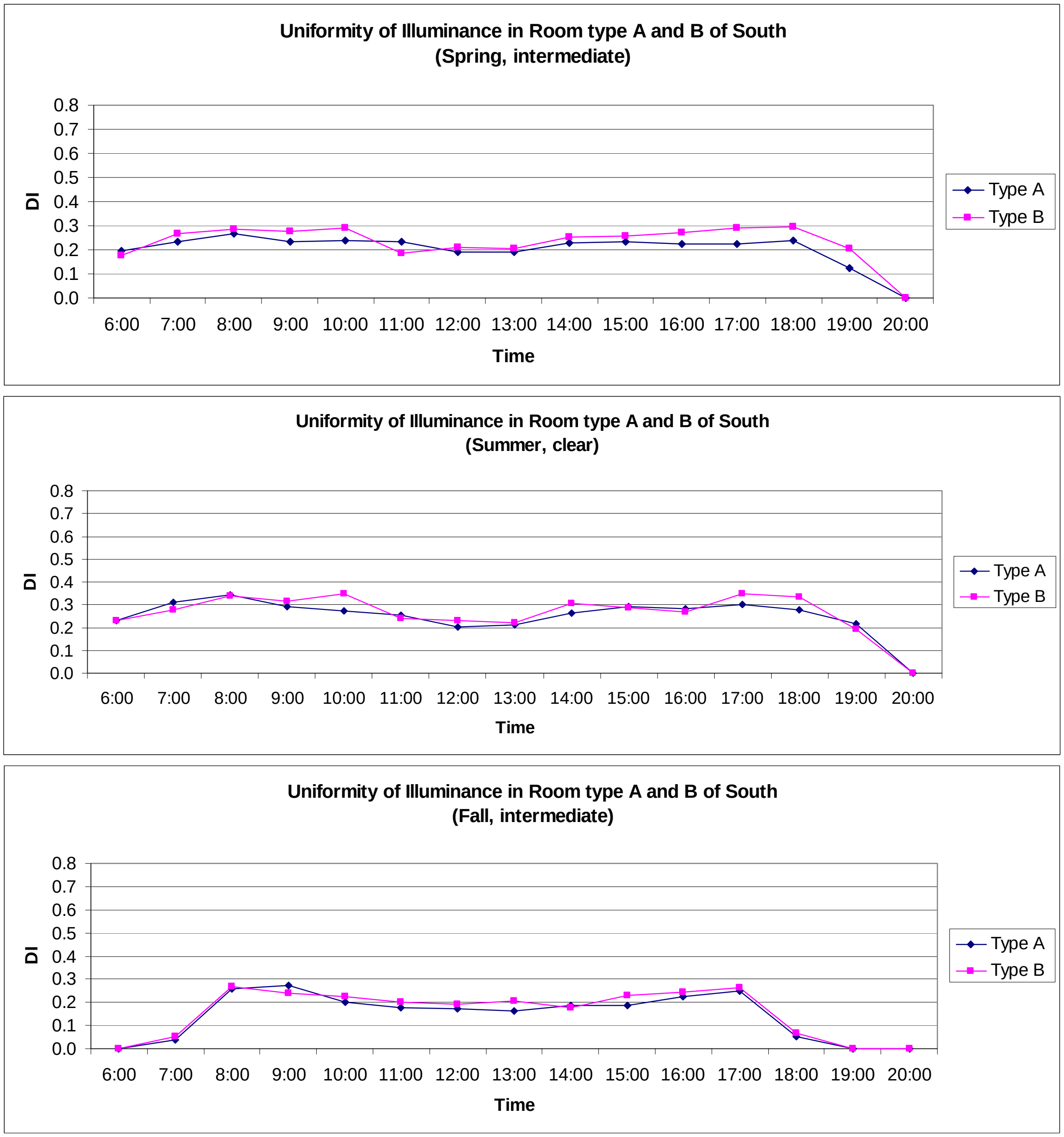



**Figure 86-Comparison between type A and B in the south, 3rd floor.**

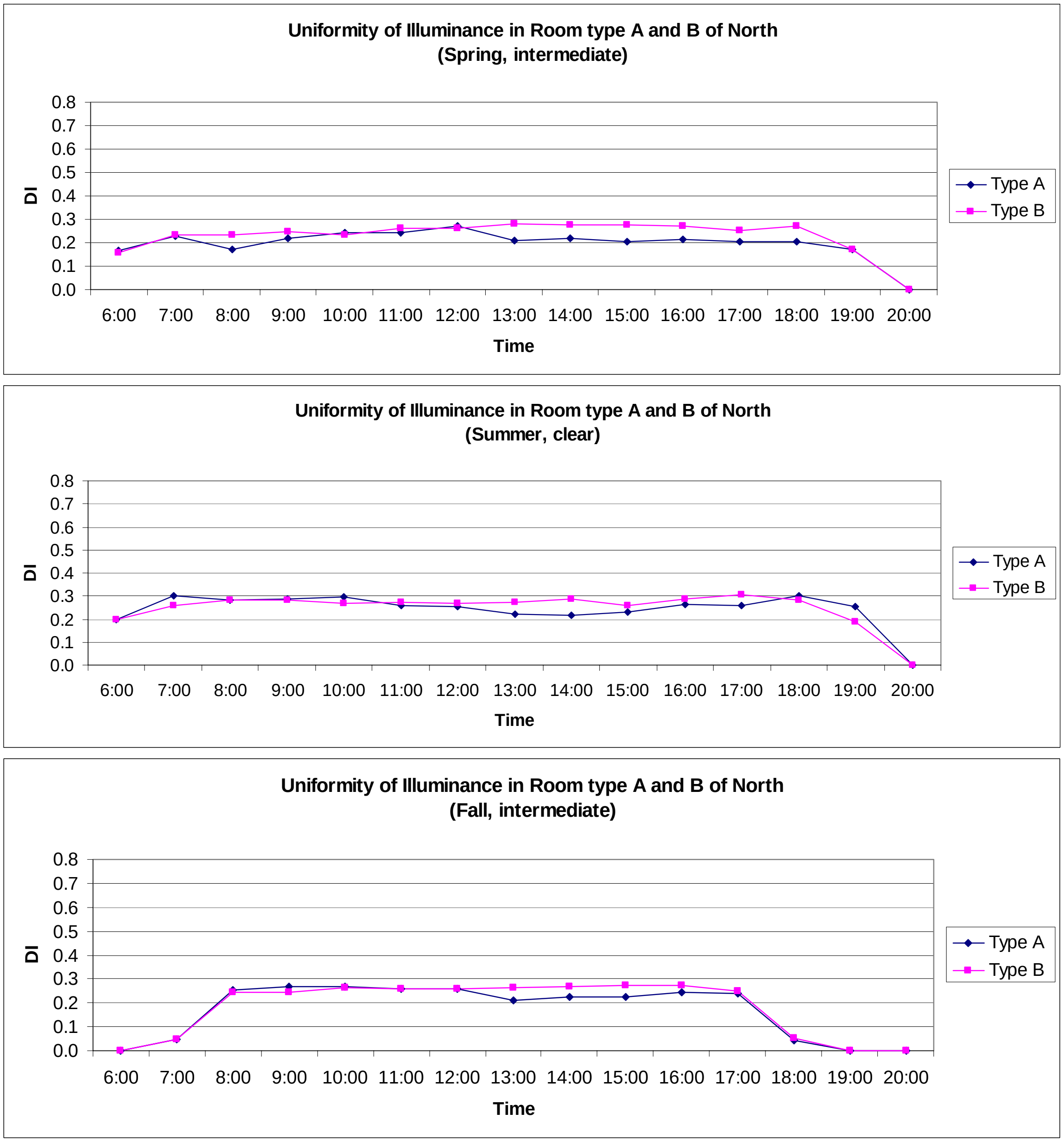
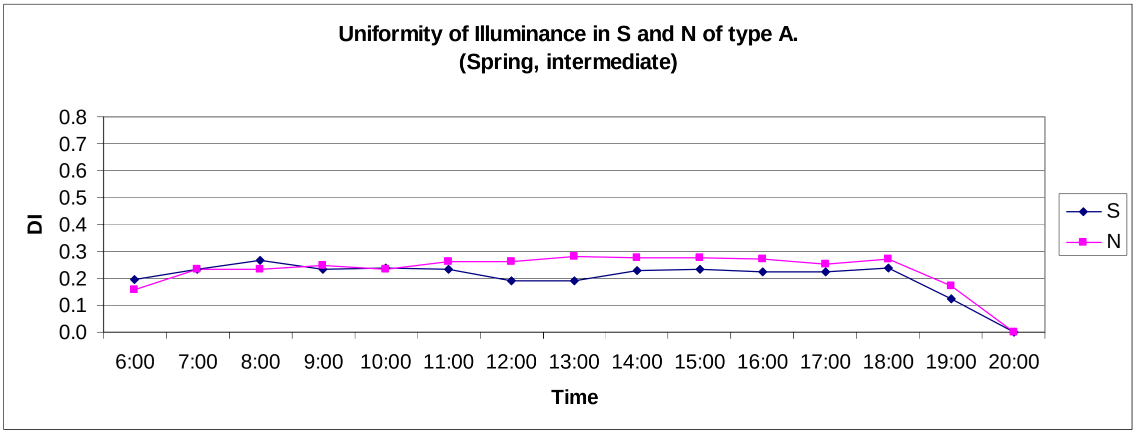
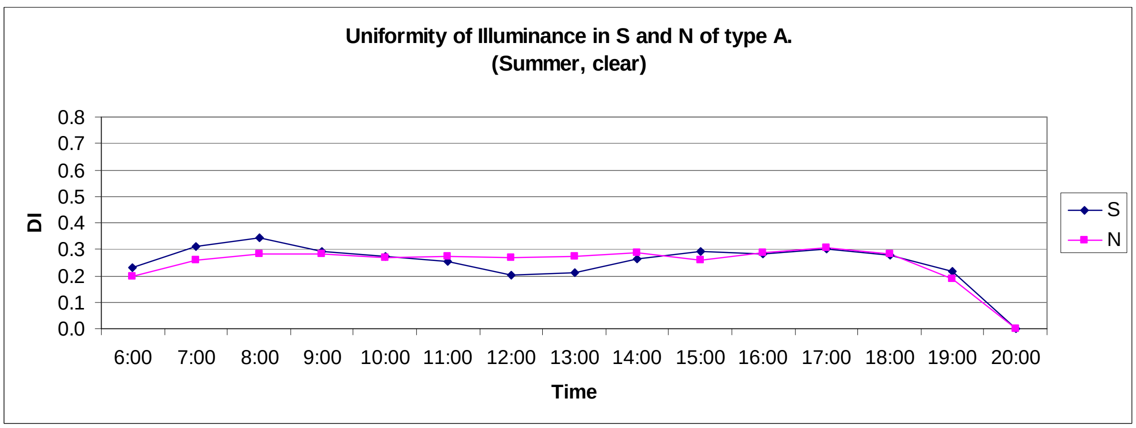



**Figure 87-Comparison between type A and B in the north, 3rd floor.**

### 5.3.6.2. Comparison between the south and the north of type A and type B, 3rd floor



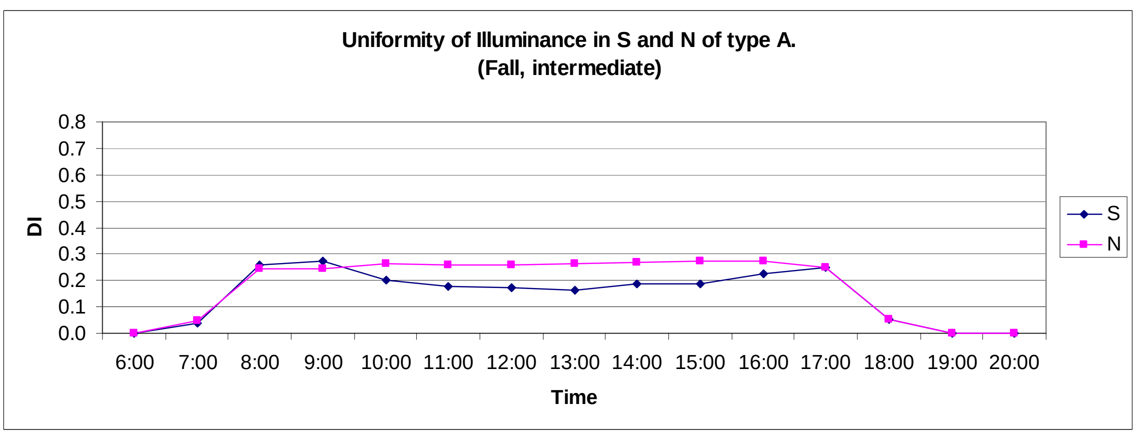




**Figure 88-Comparison between the south and the north of type A, 3rd floor.**

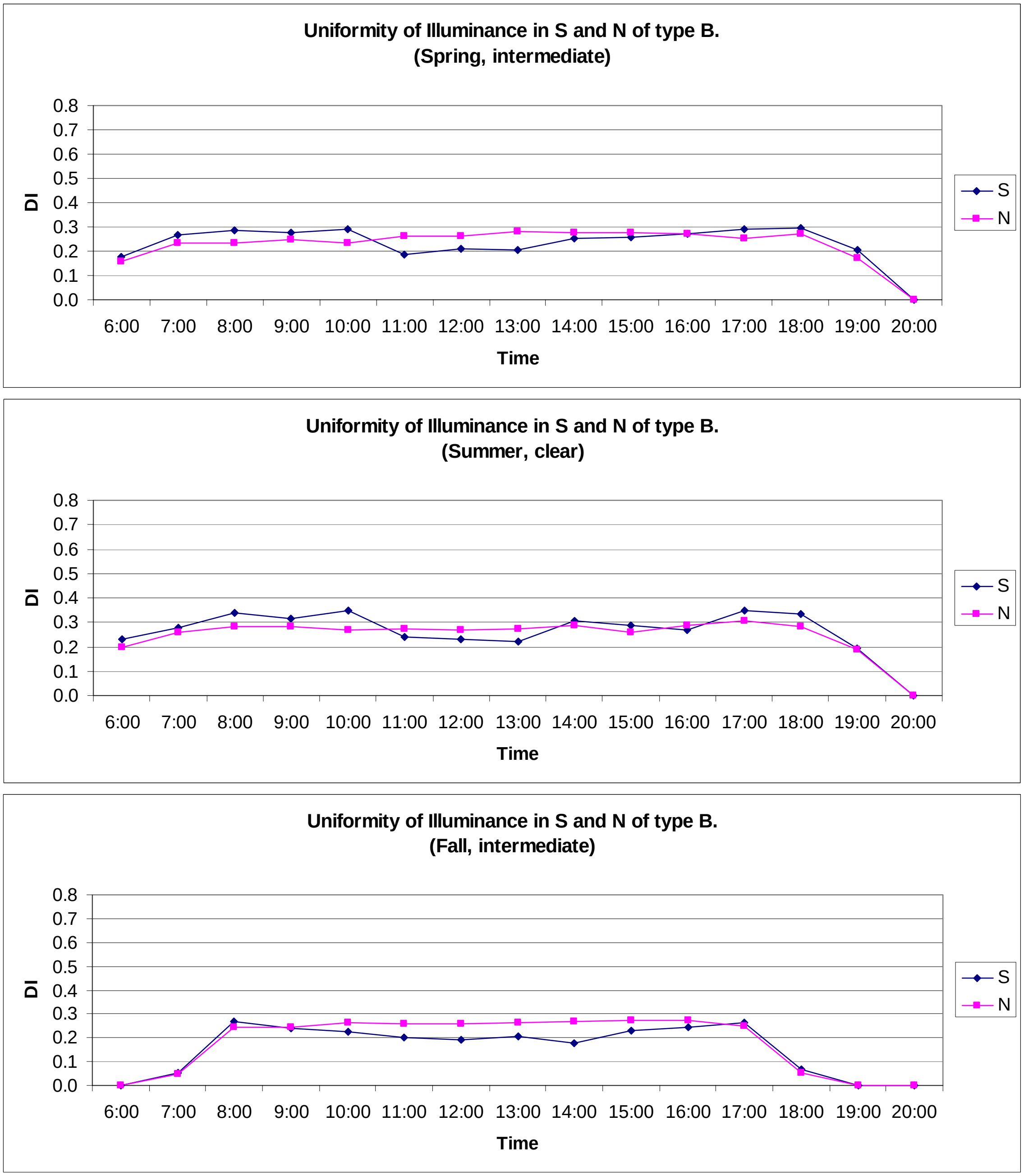



**Figure 89-Comparison between the south and the north of type B, 3rd floor.**

In Figures 88 and 89, there is no difference in the uniformity of illuminance between the two orientations of each type. All values are around 0.4 which is lower than the minimum recommended value, 0.8. Because of the side window, there may be a limit of distributing daylight uniformly in patient rooms.

### 5.3.7. Contours of critical values of diversity and uniformity of illuminance between the south and the north (3rd floor)

As Figure 90 shows, the south facing rooms have higher DI than the north. Because of direct sunrays in the south facing rooms, the light is concentrated around the window area. This is the main reason why there are higher DI values in the south facing rooms. The values of UI show no significant difference between the two orientations. (More contours can be seen in Appendix II.)

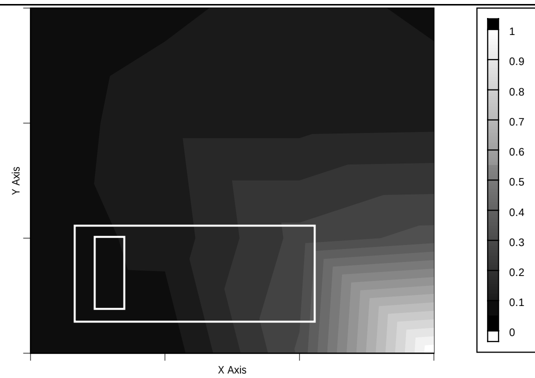
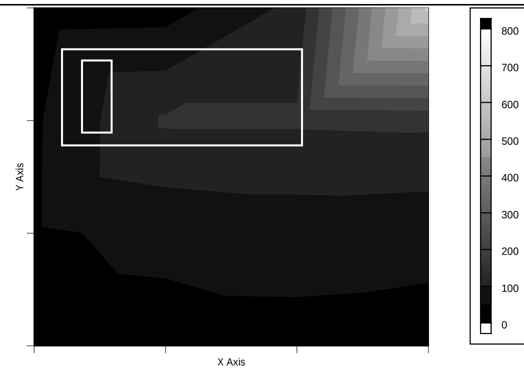
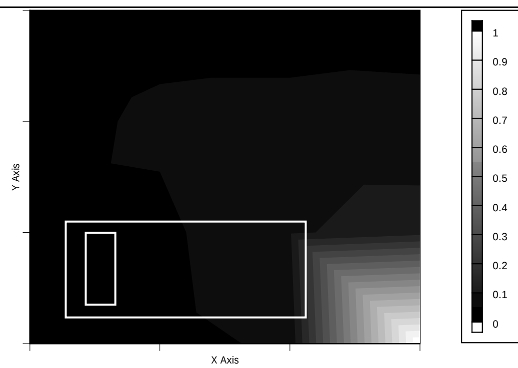
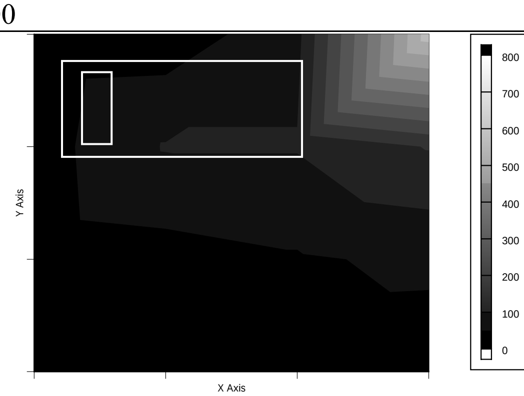
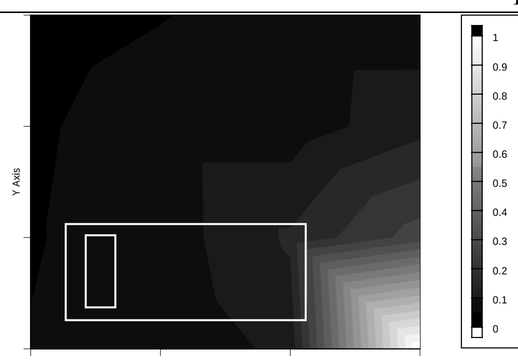
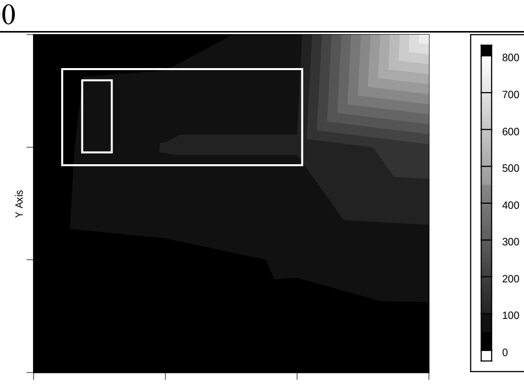
| South | North |
| --- | --- |
| 9:00 | |
|  DI=16.8, UI=0.2 |  DI=9.2, UI=0.2 |
| 12:00 | |
|  DI=38.5, UI=0.2 |  DI=7.6, UI=0.2 |
| 15:00 | |
|  DI=21.6, UI=0.2 |  DI=6.3, UI=0.2 |

**Figure 90-Comparisons of contour of DI and UI between the south and the north of type A, 3rd floor, March 21st.**

### 5.3.8. Indoor light environment with a curtain closed

One of major properties in a patient room of St. Joseph Regional Health Center is that the curtain has 0% transmittance of light. As a result, a patient has just two options to control daylight; close or open the curtain. There is a limit to control the daylight level variously as a patient desires. If a patient has visual discomfort with excessive daylight, he has nothing but to close the curtain and turn on the electric light (Figures 91 and 92).

**Figure 91-A curtain of a patient room at St. Joseph Regional Health Center.**

**Figure 92-A patient room with electric lights.**

As Figure 91 shows, when a curtain is closed, there is a little daylight admitted through the margin between the curtain and the wall. The daylight is not so available in a patient room.

| | | | | |
|---|---|---|---|---|
| 55 lux | 267 | 221 | 247 | 181 |
| 108 | 158 | 329 | 371 | 445 |
| 117 | 169 | 315 | 386 | 418 |
| 66 | 132 | 227 | 282 | 300 |

**Table 64-Illuminance levels of the electric light on the 16-reference grids at the height of 95cm from the floor (#346, type B, North).**

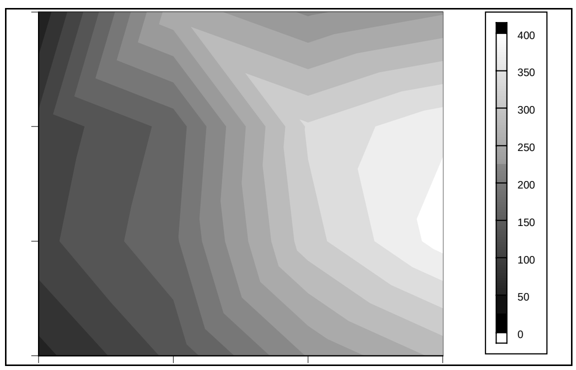



**Figure 93-Illuminance level (lux) contour of the electric lights.**

Table 64 and Figure 93 show the illuminance levels of the electric lights in the patient room of St. Joseph Regional Health Center with the curtain closed. The electric light illuminance is average 240 lux measured from 16 reference grids, and the diversity of illuminance is 8.1. The lighting environment is proper compared to the recommended guidelines. So, if patients in this hospital close the curtain to block daylight, the most of daylight are blocked and the light environment is almost same by the electric light.

## 5.4. STATISTICAL ANALYSIS OF INHA UNIVERSITY HOSPITAL

### 5.4.1. Comparison of each type in a same orientation

In Table 65, the results of ANOVA for comparing each type of orientation shows no significant difference between the two types having a similar orientation. All significances in each ANOVA are over 0.10 (10%) that means there is a marginally significant difference.

| Floor | ORI. | Type | Spring | | Summer | | Fall | |
|---|---|---|---|---|---|---|---|---|
| | | | ALOS (N. of samples) | Sig. | ALOS (N. of samples) | Sig. | ALOS (N. of samples) | Sig. |
| 2nd (Medical) | South | A | 6.75 (28) | 0.788 | 6.46 (40) | 0.187 | 5.39 (54) | 0.420 |
| | | B | 6.53 (34) | | 7.66 (38) | | 5.81 (49) | |
| | North | A | 6.44 (20) | 0.903 | 6.72 (29) | 0.884 | 6.12 (34) | 0.954 |
| | | B | 6.28 (23) | | 6.89 (26) | | 6.06 (34) | |
| 3rd (Orthopedic) | South | A | 5.33 (27) | 0.544 | 5.00 (47) | 0.604 | 5.33 (56) | 0.101 |
| | | B | 5.74 (34) | | 5.37 (54) | | 4.46 (50) | |
| | North | A | 4.9 (25) | 0.570 | 6.40 (20) | 0.273 | 5.47 (31) | 0.818 |
| | | B | 5.33 (19) | | 5.22 (25) | | 5.28 (37) | |

**Table 65-Statistical analysis of each type of patient room in a same orientation.**

### 5.4.2. Comparison of each orientation in a same type of patient rooms

In Table 66, the results of ANOVA for comparing each orientation of each type of patient room shows no significant difference between the ANOVA of each orientation in the same type of patient room. There is only one ANOVA that shows marginally significant difference which is found in the type A of the orthopedic division during summer. The significance is 0.088 (< 0.10).

| Floor | Type | Orient. | Spring | | Summer | | Fall | |
|---|---|---|---|---|---|---|---|---|
| | | | **ALOS** | **Sig.** | **ALOS** | **Sig.** | **ALOS** | **Sig.** |
| 2nd (Medical) | A | South | 6.75 (28) | 0.805 | 6.46 (40) | 0.796 | 5.39 (54) | 0.215 |
| | | North | 6.44 (20) | | 6.72 (29) | | 6.12 (34) | |
| | B | South | 6.53 (34) | 0.755 | 7.66 (38) | 0.465 | 5.81 (49) | 0.781 |
| | | North | 6.28 (23) | | 6.89 (26) | | 6.06 (34) | |
| 3rd (Orthopedic) | A | South | 5.33 (27) | 0.481 | 5.00 (47) | **0.088** | 5.33 (56) | 0.844 |
| | | North | 4.90 (25) | | 6.40 (20) | | 5.47 (31) | |
| | B | South | 5.74 (34) | 0.622 | 5.37 (54) | 0.878 | 4.46 (50) | 0.130 |
| | | North | 5.33 (19) | | 5.22 (25) | | 5.28 (37) | |

**Table 66-Statistical analysis of each orientation in a same type of patient rooms.**

Two significant details in patient rooms at St. Joseph Regional Health Center are the windows, which are located at the corner wall far from the patient head area, and the curtain of which transparency is 0%. Even though there exist possibilities to change the indoor daylight environment, the curtain prohibits a patient from changing the level of daylight. For examples, if a patient experiences visual discomfort from glare by direct or indirect daylight, he is forced to cover the whole window with the curtain or just leave it open without covering it at all. The curtain consists of thick fabric that cannot control the level of daylight except by completely blocking it. This curtain is different from other types of curtains like Venetian blinds that can control the level of daylight as the occupant desires.

As a result, even though there is a huge difference in indoor daylight environments between the two orientations, the south and the north, of patient rooms, the curtain and the corner window may make it difficult for a patient to pursue the varieties of daylight environment as they desire. According to the comparison of ALOS between the two orientations, the only marginal significant ANOVA of type A of the 3$^{rd}$ floor during the summer in Table 66, shows that the south ALOS is shorter than the north.

## 5.5. QUESTIONNAIRE SURVEY

### 5.5.1. Survey description

The questionnaire surveys are conducted in the St. Joseph Regional Health Center, Bryan, Texas with patients who stays in the Medical and the orthopedic wards. This survey was completed by patients who willingly volunteered to answer the questions of the survey. It was conducted at 2:00 PM, April 27, 2005 and at 1:30 PM, June 1, 2005 under clear sky conditions. The total number of samples is 14 in the north and south facing patient rooms of medical and orthopedic wards.

The questionnaire survey consisted of 36 questions. Among them, there are fourteen objective questions, and the rest of them are 7 point scale (-3 to 3) with strength of satisfaction pertaining to their indoor environment related with the existing lighting conditions.

### 5.5.2. Survey results

#### 5.5.2.1. Objective questions

| | No. of samples | % |
|---|---|---|
| Number of samples | 14 | 100 |
| 1.Sex | | |
| Male | 5 | 36 |
| Female | 9 | 64 |
| 2.Age | | |
| 20s | 3 | 21 |
| 30s | 4 | 29 |
| 40s | 1 | 7 |
| 50s | 3 | 21 |
| +60s | 3 | 21 |
| 3.Length of stays (Days) | | |
| 1~2 day(s) | 6 | 43 |
| 3~4 days | 6 | 43 |
| 5~6 days | 2 | 14 |
| 4.Ward | | |
| Medical | 10 | 70 |
| Orthopedic | 4 | 30 |
| 5.Preferred lighting | | |
| Daylight | 9 | 57 |
| Electric light | 0 | 0 |
| Both | 6 | 43 |
| 6.Most preferable daylight | | |
| Daylight in the morning | 9 | 64 |
| Daylight at noon | 3 | 29 |
| Daylight in the evening | 1 | 7 |
| 7. How long time to use a curtain | | |
| Less than 1 hour | 1 | 7 |
| 1 to 2 hours | 2 | 14 |
| 3 to 5 hours | 3 | 21 |
| 6 to 8 hours | 4 | 29 |
| 9 hours or more | 4 | 29 |

**Table 67-Survey results (Question 1 to 7).**

| | | |
|---|---|---|
| 8.The reason to use the curtain | | |
| Too much daylight | 3 | 21 |
| Privacy | 9 | 64 |
| Nothing | 2 | 14 |
| 9.Most preferred season | | |
| Spring | 12 | 86 |
| Summer | 1 | 7 |
| Fall | 0 | 0 |
| Winter | 1 | 7 |
| 10.Controllable equipment over the lighting | | |
| Lighting switch | 14 | 100 |
| Light Dimmer | 0 | 0 |
| Desk light | 0 | 0 |
| Window curtain | 14 | 100 |
| 11.Sensitivity to glare | | |
| Yes | 3 | 21 |
| No | 11 | 79 |
| 12.Eyeglasses | | |
| Corrective glasses for near-sighted | 7 | 50 |
| Corrective glasses for far-sighted | 1 | 7 |
| Sunglasses | 2 | 14 |
| No glasses | 4 | 29 |
| 13. Reason of visual discomfort | | |
| Direct daylight | 9 | 64 |
| The electric light on the ceiling | 3 | 21 |
| Diffused daylight | 0 | 0 |
| The electric light on the bed head | 1 | 7 |
| Reflected daylight on the wall | 1 | 7 |
| 14. Most important to the physical well-bing | | |
| Daylight | 7 | 50 |
| Electric light | 1 | 7 |
| Humidity | 0 | 0 |
| Thermal condition | 4 | 29 |
| Window view | 0 | 0 |
| Noise level | 2 | 14 |

**Table 68-Survey results (Question 8 to 14).**

Objective questions were answered based on each person's actual condition and preference regardless of his/her indoor environment. According to the survey result Tables 67 and 68, 60 % of patients say they prefer daylight rather than electric light, and

40% prefer both of daylight and electric light. Therefore, the survey shows that daylight is more preferable than other types of light, even though 70% of participants feel visual discomfort by direct daylight. The excessive daylight has negative effects on patients. In spite of their positive responses towards daylight, 65% of patients used their curtain to have some privacy, and only 20% used it to block daylight. 100% of the participants had an electric lighting switch and a window curtain switch to control their lighting environment.

As a result, people have a tendency to prefer daylight over electric light. But, because of their need for privacy, they used their curtains regardless of natural lighting conditions. Consequently, whether daylight is appropriate or excessive, the lighting is blocked by the thick fabric curtain.

### 5.5.3. Seven point scale questions

In the seven point scale survey, “3” indicated the most positive response and “-3” indicated the most negative response. In the case of a moderate response, “0” is used.

In Table 69, most people in the survey think the window size is moderate, not so positive and not so negative. The patients think the daylight contributes toward upgrading the overall room environment more than electric light. They also answered slightly positive on the question of how the lighting quality affected their recovery.

The average points are 1.85 in the questions asked whether daylight contributed towards upgrading the overall room environment and atmosphere. The patients responded also that they have visual comfort in electric light as well.

Regarding the window, patient's felt moderate and slightly negative on the window position (0.25 point) and view (-0.35 point) respectively. Overall concerning thermal comfort, thermal control, and other room facilities, patient's thought moderately or positively (Table 70).

| No. | Question | Very dim (-3), Moderate (0), Very bright (+3) |
|---|---|---|
| | | Average point |
| 15. | How do you feel daylight in this room? | 0.65 |
| 16. | How do you feel the electric lights in this room? | 0.55 |
| | | Very small(-3), Moderate (0), Very large (+3) |
| | | Average point |
| 17. | How do you feel the window size in this room? | 0.55 |
| | | Very dissatisfied(-3), Moderate (0), Very satisfied (+3) |
| | | Average point |
| 18. | How satisfied are you with the visual comfort of daylight in this room (e.g., glare, reflections)? | 1.20 |
| 19. | How satisfied are you with controlling of daylight in this room? | 0.40 |
| 20. | Does daylight contribute toward upgrading the overall room environment and atmosphere in this room? | 1.85 |
| 21. | How satisfied are you with the visual comfort of the electric lights in this room (e.g., glare, reflections)? | 1.80 |
| 22. | How satisfied are you with controlling of the electric lights in this room? | 1.05 |
| 23. | Do the electric lights contribute toward upgrading the overall room environment and atmosphere in this room? | 0.25 |

**Table 69-Survey results (Question 15 to 23).**

| | | Very dissatisfied(-3), Moderate (0), Very satisfied (+3) |
|---|---|---|
| | | Average point |
| 24. | Overall, does the lighting quality enhance or interfere with your health recovery? | 0.75 |
| 25. | How satisfied are you with the window view in this room? | -0.35 |
| No. | Question | Very dissatisfied(-3), Neutral(0), Very satisfied (+3) |
| | | Average point |
| 26. | Does the window in this room provide sufficient privacy? | 1.80 |
| 27. | How satisfied are you with the position of the window in this room? | 0.25 |
| 28. | How satisfied are you with the temperature in this room? | 1.00 |
| 29. | How satisfied are you with controlling of the temperature in this room? | 0.90 |
| 30. | Overall, does the thermal comfort in this room enhance or interfere with your health recovery? | 1.45 |
| 31. | How satisfied are you with the noise level in this room? | 1.35 |
| 32. | How satisfied are you with the placement of the bed in this room? | 1.35 |
| 33. | How satisfied are you with the colors and textures of ceiling, flooring, furniture and surface finishes in this room? | 1.35 |
| 34. | How satisfied are you with the amount of light in this room? | 1.15 |
| 35. | All things considered, how satisfied are you with this room? | 2.05 |
| 36. | How satisfied are you with the building overall? | 1.90 |

**Table 70-Survey results (Question 24 to 36).**

## 5.6. SUMMARY

The result of ANOVA shows that only 1 comparison is marginal significant among 12 comparisons. The marginal significant comparison shows the north ALOS is shorter than the south. The rest of total comparisons show there is no significant difference in ALOS. It means the ALOS of each comparison can be regarded as same values from the view point of statistics.

Tables 71 and 72 show the summary of indoor daylight variables of St. Joseph Regional Health Center. The values are calculated from seasonal average from 8:00 AM to 6:00 PM because there is little light before 8:00 AM and after 6:00 PM. Because the changing patterns of daylight of the 2$^{nd}$ floor and the 3$^{rd}$ floor are much similar with each other, Tables 71 and 72 summarize the daylight environment of the 3$^{rd}$ floor.

| Type A | Ori. | DF (%) | LR (TV wall) | LR (TV & Eye) | Illum. (lux) | DI | UI |
|---|---|---|---|---|---|---|---|
| Spring | South | 0.68 | 11.3 | 1 | 301 | 9.9 | 0.2 |
| | North | 0.70 | 12.8 | 0.9 | 154 | 8.4 | 0.3 |
| Summer | South | 0.68 | 13 | 0.8 | 697 | 11.8 | 0.3 |
| | North | 0.70 | 15.7 | 0.8 | 318 | 8 | 0.3 |
| Fall | South | 0.68 | 14.5 | 0.9 | 346 | 15.3 | 0.2 |
| | North | 0.70 | 10.7 | 0.7 | 103 | 7.7 | 0.2 |

**Table 71-Summary of the average values of indoor daylight variables in type A (3$^{rd}$ floor) from 8:00 AM to 6:00 PM.**

| Type B | Ori. | DF (%) | LR (TV wall) | LR (TV & Eye) | Illum. (lux) | DI | UI |
|---|---|---|---|---|---|---|---|
| Spring | South | 0.67 | 4.8 | 1.5 | 335 | 11.7 | 0.3 |
| | North | 0.69 | 16.4 | 0.8 | 166 | 7.9 | 0.3 |
| Summer | South | 0.67 | 7.3 | 1.1 | 635 | 13.7 | 0.3 |
| | North | 0.69 | 13.4 | 0.7 | 342 | 6.7 | 0.3 |
| Fall | South | 0.67 | 5.3 | 1.5 | 354 | 13.7 | 0.2 |
| | North | 0.69 | 13.2 | 0.6 | 104 | 7.4 | 0.2 |

**Table 72-Summary of the average values of indoor daylight variables in type B (3rd floor) from 8:00 AM to 6:00 PM.**

| Type | Season | Variables | South | North | Floor / Time |
|---|---|---|---|---|---|
| A | Summer | ALOS (days) | 5 | 6.4 | 3rd |
| | | Average Illuminance (lux) | 697 | 318 | 8AM-6PM |

**Table 73-Significant ALOS comparison and average illuminance, 3rd floor.**

As seen in Tables 71 and 72, daylight factor (DF), luminance ratio (LR) between TV point and patient eye, and uniformity of illuminance (UI) have almost no differences between the two orientations. In the luminance ratio on the TV wall, the north facing rooms have higher values than the south. This may be due to the fact that direct sunlight is reflected on the wall and this reduces the ratio in the south facing room. But, the luminance ratios are much lower than the recommended value, 40. And the south facing rooms have higher illuminance values than the north. The uniformity of illuminance (UI) is equal in the two orientations and lower than the minimum recommended value, 0.8. All diversity of illuminance (DI) values are higher than the maximum recommended values, 5, and that of the south is higher than that of the north. In this hospital, the significant difference of ALOS between the two orientations happened only at type A room on the 3rd floor in summer. As Table 73 shows, the most significant difference in indoor daylight variables between the two orientations is the average illuminance.

In the patient room of St. Joseph Regional Health Center, the only thing that can block the excessive daylight levels is a thick fabric curtain that has no transmittance. So, indoor daylight level cannot be controlled as a patient desires with the curtain. According to the survey result, 70% of patients answered excessive direct daylight levels make visual discomfort. And, most of them think daylight contributes towards upgrading the overall room environment. Therefore, daylight should be well controlled as patients desire to optimize the indoor daylight environment. However, if there is a little glare in a room, a patient should close the curtain without any choice and turn on the electric lights to maintain the proper light level.

Moreover, because this hospital was designed as buildings face to each other through windows. The building occupants can see the inside of the opposite building if they want. In the survey, 64% of patients said they closed the curtain because of privacy in the survey. As a result, because of their need for privacy, patients use their curtains regardless of daylighting conditions. Consequently, whether daylight is appropriate or excessive, the lighting is blocked by the thick fabric curtain. Such a privacy problem and the thick fabric curtain lead patients to close the curtain and to use the electric light whether it is day or night.

As a result, these situations may make the indoor light environment of patient rooms almost same in the all types and orientations, and prohibit the positive effects of natural daylight on the patient ALOS.

# 6. CONCLUSIONS AND RECOMMENDATIONS

The goal of this study was to analyze a significant relationship between indoor daylight environments and patient's Average Length of Stay (ALOS) in two healthcare facilities. To meet this goal, this study focused on investigating several lighting variables by the effects of daylighting in each patient room which faces a different orientation, and by analyzing the seasonal ALOS depending on each orientation.

In the case of Inha University Hospital, a large window in a patient room admits a lot of luminance and illuminance to the southeast and northwest orientations. As a result, the variables; average illuminance, diversity of illuminance and uniformity of illuminance are higher or lower the recommended guidelines by CIBSE. Southeast facing rooms have especially higher values of each analyzed variable than those of northwest facing rooms. This means there are more possibilities that a patient in southwest facing room may be exposed to visual discomfort like glare. While a NW facing room is even brighter and has higher illuminance than a SE facing room in the after noon, a SE room has higher illuminance in the morning. In spite of that, according to statistically analyzed ALOS of patients, 6 (18.8%) comparisons among the 32 cases that compared SE and NW rooms in each type of patient room in each season shows ALOS of southeast facing rooms are shorter than other rooms. The results are from the data of spring, fall, and winter when there is an intermediate sky. In summer, the overcast season, the analyses results show that there are differences between the ALOS of the two orientations. Because all rooms of every orientation have almost the same daylighting environment under overcast skies, there is no difference in the light variable between SE and NW. This may be the reason why there is no difference in ALOS between the two orientations. Above all, a patient room at Inha University Hospital has vertical blinds on the window. It makes it possible for a patient to control the daylighting variables as they desire to prevent themselves from visual discomfort such as glare. As a result, it may be helpful to patient physiological conditions and make positive effects on patient average length of stay.

In the case of St. Joseph Regional Health Center, a 2.3m high window in a patient room admits a lot of luminance and illuminance to the south and north oriented rooms. As a result, the variables; luminance ratio on TV wall, average illuminance, and diversity of illuminance in south facing rooms are over the recommended guidelines by CIBSE. On the contrary, in north facing rooms, average illuminance and luminance ratios on TV walls and on TV points are lower than the guidelines. South facing rooms have an especially higher value of each analyzed variable than those of the north facing types. In summer when it is a clear sky condition, the discrepancies in the variables between the two orientations are greater. This indicates there are more possibilities that a patient in a south facing room may be exposed to visual discomfort like glare. The south facing rooms have more daylighing and are brighter than the north facing rooms. The results of the ALOS analysis show there are only one set of ALOS comparison among 12 sets to show marginally significant difference in summer. The south facing rooms show less ALOS than the north. Compared to the case of Inha University Hospital, the number of ALOS comparison sets showing significant difference is small in St. Joseph Regional Health Center. Most different facility component between the two hospitals is a thick fabric curtain in patient rooms at St. Joseph Regional Health Center which creates almost 0% light transmittance. The curtain of the hospital makes it difficult on the patient by limiting a patient's control on the indoor daylight environment. As a result, the curtain may reduce the possibility to makes difference in indoor daylight environment between the patient rooms of the two orientations.

## 6.1. CONCLUSIONS

This study began with three hypotheses, which gave way to the test results listed below :

1) There may be a relationship between indoor daylight environments and ALOS(Average Length of Stay). According to the results of the two cases of Inha University Hospital and St. Joseph Regional Health Center, 18.8% and 8% of ALOS comparison sets of each hospital show positive relationships between the ALOS and brighter light environments.

2) Seasonal weather differences cause different indoor daylighting levels and may influence the length of patient hospitalization. Depending on the sky conditions in each season, the indoor lighting levels changed and caused different indoor light environments between patient rooms facing two different orientations. Some results of

the comparison analysis of ALOS of Inha University Hospital show that significantly reduced ALOS occurred in spring, fall and winter even though there existed different indoor daylight environments between the patient rooms facing various orientations.

3) Overall patient satisfaction and feeling about patient rooms may be related with indoor daylight environments. According to the results of the questionnaire survey in St. Joseph Regional Health Center, most people sampled positively replied to the role of daylight in indoor daylight environments for their specific patient bedroom.

Besides the conclusions from the test results of the hypothesis, this study also could reach the following conclusions.

First, bright daylighting environments are preferred by patients, and may have positive effects on patients' ALOS. As the results of the survey in this study show, over 70% of patients prefer daylight over electric lights. Moreover, 18.8% of the comparison of ALOS analysis of Inha University Hospital shows that patients' ALOS in the brighter orientation, SE facing rooms, is shorter than in the northwest facing rooms.

Second, visual discomfort by excessive daylight and glare can be prevented by proper shading devices such as a curtain and vertical (or horizontal) blinds. Using such a device, high luminance ratios, diversity, and illuminance can be controlled to the recommended values by CIBSE and IESNA.

Third, more controllable shading devices which meet the patient's desires may have more positive effects on patients' physiological condition. In the case of Inha University Hospital, Inchon, Korea, 6 comparison sets of the 32 sets show that the patients in the SE facing rooms have higher illuminance levels and have shorter ALOS than in the NW. Patients in this case could choose from a variety of light levels with controllable blinds in brighter environments. But, in the case of St. Joseph Regional Health Center, Bryan, Texas, only one comparison set among 12 sets shows that the patients in the south facing rooms where there are higher illuminance levels have shorter ALOS than in the north. In St. Joseph Regional Health Center, because of the thick fabric curtains, patients have very limited control. They can either open or close it.

Finally, the high illuminance in the morning may be more beneficial than in the afternoon. Based on the analyses results of Inha University Hospital, the SE facing rooms have higher illuminance than the NW in the morning, and vice versa in the afternoon. But the difference of illuminance between the two orientations in the morning is greater than in the afternoon. The morning light may positively affect the human circadian rhythm.

## 6.2. RECOMMENDATIONS

Based on the previously stated results and conclusions, the following recommendations are made for effective indoor daylight environments for patients' visual comfort and positive physiological settings.

First, avoid excessive glare which affects visual discomfort, indicated by an excessive luminance ratio and illuminance, by providing proper sun-shading devices in patients' rooms. If indoor and outdoor sun-shading devices are utilized together in patient rooms the effective visual comfort environment will have greater positive healing effects on the patients.

Second, indoor curtains and blinds should be controlled as the patient desires. According to previously described statistics, different people have different preferences for daylight in their rooms, especially while they are ill. Some people may prefer darkness while others prefer lighter situations. If their indoor daylight environments are not satisfied, patients will potentially experience greater stress levels and a longer length of stay at the hospital.

Third, healthcare facilities should be designed so that the window of a patient room does not allow views into other windows or patient rooms. Most patients are highly sensitive to their privacy. The results of the survey at St. Joseph's Hospital indicated that patients primarily use curtains to avoid intrusive eyes of patients and visitors from windows directly across from their rooms. These privacy issues occurred regardless of whether daylight levels were high or low. Such a "face-to-face" design of patient rooms may reduce patients' opportunities to experience daylight which can positively affects their physiological condition.

To increase the validity and confidence about the positive effects of daylight on human physiological conditions further studies are necessary which provide more samples, facilities, and other variables. As explained in the first section, this study began with some limits and assumptions, since there may be some properties about daylight that are yet unknown.

There are also other variables that may affect patients' physiological conditions; thermal condition, indoor air quality, etc. Those should also be considered to the degree of effects as indoor environment qualities. Moreover, one hospital in Korea and one in the U.S.A. were chosen in this study. Based on their different cultures, the preferences of light environments may be different and their physiological reactions may be different.

Therefore, further studies are necessary and should be applied to the design of healthcare facilities for an optimal environment for patient health. The effects of those studies would be invaluable for patients who are eager to regain their health.

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# APPENDIX I

# RESULTS OF ANOVA

**RESULTS OF ANOVA (Statistical analysis)**

**1. Inha University Hospital**

1) ANOVA between type A and type B in a same orientation

Spring, $8^{th}$ floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 29 | 5.33 | 6.12 | 0.39 | 4.54 | 6.12 | 3 | 15 |
| Type B | 26 | 4.53 | 1.94 | 0.30 | 3.94 | 5.13 | 3 | 11 |
| Total | 55 | 4.96 | 2.40 | 0.25 | 4.46 | 5.46 | 3 | 15 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 14.46 | 1 | 14.460 | 2.547 | 0.114 |
| Within Groups | 505.36 | 53 | 5.678 | | |
| Total | 519.82 | 54 | | | |

Spring, 8th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 36 | 5.25 | 3.31 | 0.43 | 4.40 | 6.10 | 3 | 18 |
| Type B | 24 | 7.70 | 8.12 | 1.28 | 5.10 | 10.30 | 3 | 46 |
| Total | 60 | 6.23 | 5.83 | 0.58 | 5.07 | 7.39 | 3 | 46 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 144.06 | 1 | 144.060 | 4.385 | 0.309 |
| Within Groups | 3219.65 | 58 | 32.854 | | |
| Total | 3363.71 | 59 | | | |

Spring,11th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 19 | 7.19 | 5.71 | 1.03 | 5.10 | 9.29 | 3 | 26 |
| Type B | 23 | 6.13 | 3.99 | 0.65 | 4.82 | 7.44 | 3 | 21 |
| Total | 42 | 6.61 | 4.83 | 0.58 | 5.45 | 7.77 | 3 | 26 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 19.25 | 1 | 19.254 | 0.822 | 0.368 |
| Within Groups | 1569.18 | 40 | 23.421 | | |
| Total | 1588.43 | 41 | | | |

Spring,11$^{th}$ floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 14 | 6.96 | 4.34 | 0.89 | 5.13 | 8.79 | 3 | 21 |
| Type B | 15 | 6.44 | 4.09 | 0.82 | 4.75 | 8.13 | 3 | 16 |
| Total | 29 | 6.69 | 4.18 | 0.60 | 5.49 | 7.89 | 3 | 21 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 3.29 | 1 | 3.290 | 0.185 | 0.669 |
| Within Groups | 835.12 | 27 | 17.768 | | |
| Total | 838.41 | 28 | | | |

Spring, 12$^{th}$ floor, 12 SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 20 | 6.00 | 5.21 | 0.91 | 4.15 | 7.85 | 2 | 29 |
| Type B | 25 | 5.51 | 5.43 | 0.85 | 3.80 | 7.23 | 2 | 32 |
| Total | 45 | 5.73 | 5.30 | 0.62 | 4.50 | 6.96 | 2 | 32 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4.35 | 1 | 4.351 | 0.153 | 0.697 |
| Within Groups | 2046.24 | 43 | 28.420 | | |
| Total | 2050.59 | 44 | | | |

Spring, 12th floor, 12 NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 20 | 6.12 | 4.78 | 0.82 | 4.45 | 7.78 | 3 | 23 |
| Type B | 25 | 5.76 | 3.41 | 0.53 | 4.70 | 6.83 | 3 | 16 |
| Total | 45 | 5.92 | 4.06 | 0.47 | 4.99 | 6.85 | 3 | 23 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.38 | 1 | 2.378 | 0.143 | 0.706 |
| Within Groups | 1231.15 | 43 | 16.637 | | |
| Total | 1233.53 | 44 | | | |

Spring, 16th floor, 16 SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 20 | 8.56 | 9.62 | 1.65 | 5.20 | 11.92 | 3 | 50 |
| Type B | 26 | 6.33 | 3.58 | 0.55 | 5.22 | 7.43 | 3 | 21 |
| Total | 46 | 7.31 | 6.97 | 0.79 | 5.73 | 8.89 | 3 | 50 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 94.70 | 1 | 94.695 | 1.976 | 0.164 |
| Within Groups | 3593.82 | 44 | 47.918 | | |
| Total | 3688.52 | 45 | | | |

Spring, 16th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 27 | 7.11 | 4.60 | 0.69 | 5.73 | 8.49 | 3 | 22 |
| Type B | 34 | 6.07 | 4.53 | 0.61 | 4.86 | 7.28 | 3 | 28 |
| Total | 61 | 6.53 | 4.57 | 0.45 | 5.63 | 7.44 | 3 | 28 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 26.97 | 1 | 26.970 | 1.296 | 0.258 |
| Within Groups | 2060.16 | 59 | 20.810 | | |
| Total | 2087.13 | 60 | | | |

Summer, 8th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 4 | 5.14 | 3.76 | 1.42 | 1.66 | 8.62 | 3 | 13 |
| Type B | 5 | 6.00 | 2.40 | 0.80 | 4.16 | 7.84 | 3 | 10 |
| Total | 9 | 5.63 | 2.99 | 0.75 | 4.03 | 7.22 | 3 | 13 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.89 | 1 | 2.893 | 0.309 | 0.587 |
| Within Groups | 130.86 | 7 | 9.347 | | |
| Total | 133.75 | 8 | | | |

Summer, 8th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 5 | 4.22 | 1.20 | 0.40 | 3.30 | 5.15 | 3 | 6 |
| Type B | 8 | 6.64 | 2.79 | 0.75 | 5.03 | 8.25 | 3 | 11 |
| Total | 13 | 5.70 | 2.57 | 0.54 | 4.59 | 6.81 | 3 | 11 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 32.10 | 1 | 32.100 | 5.978 | 0.023 |
| Within Groups | 112.77 | 11 | 5.370 | | |
| Total | 144.87 | 12 | | | |

Summer, 11th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 3 | 4.00 | 0.00 | 0.00 | 4.00 | 4.00 | 4 | 4 |
| Type B | 8 | 8.00 | 7.34 | 1.96 | 3.76 | 12.24 | 3 | 26 |
| Total | 11 | 6.95 | 6.49 | 1.49 | 3.82 | 10.08 | 3 | 26 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 58.95 | 1 | 58.947 | 1.432 | 0.248 |
| Within Groups | 700.00 | 9 | 41.176 | | |
| Total | 758.95 | 10 | | | |

Summer, 11th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 4 | 5.57 | 2.15 | 0.81 | 3.58 | 7.56 | 3 | 10 |
| Type B | 4 | 7.33 | 3.67 | 1.50 | 3.48 | 11.18 | 4 | 13 |
| Total | 8 | 6.38 | 2.96 | 0.82 | 4.60 | 8.17 | 3 | 13 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 10.03 | 1 | 10.029 | 1.161 | 0.304 |
| Within Groups | 95.05 | 6 | 8.641 | | |
| Total | 105.08 | 7 | | | |

Summer, 12th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 2 | 4.00 | 1.00 | 0.58 | 1.52 | 6.48 | 3 | 5 |
| Type B | 2 | 7.50 | 5.07 | 2.53 | -0.56 | 15.56 | 3 | 14 |
| Total | 4 | 6.00 | 4.08 | 1.54 | 2.22 | 9.78 | 3 | 14 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 21.00 | 1 | 21.000 | 1.329 | 0.301 |
| Within Groups | 79.00 | 2 | 15.800 | | |
| Total | 100.00 | 3 | | | |

Summer, 12$^{th}$ floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 6 | 3.80 | 1.32 | 0.42 | 2.86 | 4.74 | 3 | 6 |
| Type B | 4 | 4.50 | 1.87 | 0.76 | 2.54 | 6.46 | 3 | 8 |
| Total | 10 | 4.06 | 1.53 | 0.38 | 3.25 | 4.88 | 3 | 8 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.84 | 1 | 1.838 | 0.777 | 0.393 |
| Within Groups | 33.10 | 8 | 2.364 | | |
| Total | 34.94 | 9 | | | |

Summer, 16$^{th}$ floor, 16 SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 2 | 23.25 | 27.87 | 13.94 | -21.10 | 67.60 | 3 | 64 |
| Type B | 3 | 5.00 | 2.12 | 0.95 | 2.37 | 7.63 | 3 | 8 |
| Total | 5 | 13.11 | 19.65 | 6.55 | -1.99 | 28.22 | 3 | 64 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 740.14 | 1 | 740.139 | 2.206 | 0.181 |
| Within Groups | 2348.75 | 3 | 335.536 | | |
| Total | 3088.89 | 4 | | | |

Summer, 16th floor, 16 NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 6 | 5.90 | 3.07 | 0.97 | 3.70 | 8.10 | 3 | 12 |
| Type B | 7 | 7.27 | 5.76 | 1.74 | 3.40 | 11.14 | 3 | 22 |
| Total | 13 | 6.62 | 4.62 | 1.01 | 4.52 | 8.72 | 3 | 22 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 9.87 | 1 | 9.871 | 0.450 | 0.511 |
| Within Groups | 417.08 | 11 | 21.952 | | |
| Total | 426.95 | 12 | | | |

Fall, 8th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 25 | 4.79 | 1.68 | 0.26 | 4.26 | 5.31 | 3 | 9 |
| Type B | 20 | 5.12 | 1.77 | 0.30 | 4.50 | 5.74 | 3 | 10 |
| Total | 45 | 4.93 | 1.72 | 0.20 | 4.54 | 5.33 | 3 | 10 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.07 | 1 | 2.070 | 0.701 | 0.405 |
| Within Groups | 218.60 | 43 | 2.954 | | |
| Total | 220.67 | 44 | | | |

Fall, 8th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 18 | 4.83 | 2.09 | 0.38 | 4.05 | 5.61 | 3 | 11 |
| Type B | 27 | 5.51 | 2.07 | 0.31 | 4.89 | 6.13 | 3 | 11 |
| Total | 45 | 5.24 | 2.09 | 0.24 | 4.76 | 5.72 | 3 | 11 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 8.27 | 1 | 8.269 | 1.914 | 0.171 |
| Within Groups | 315.41 | 43 | 4.321 | | |
| Total | 323.68 | 44 | | | |

Fall, 11th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 14 | 5.22 | 2.66 | 0.56 | 4.07 | 6.37 | 3 | 15 |
| Type B | 16 | 6.96 | 5.55 | 1.07 | 4.77 | 9.16 | 3 | 22 |
| Total | 30 | 6.16 | 4.51 | 0.64 | 4.88 | 7.44 | 3 | 22 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 37.84 | 1 | 37.844 | 1.898 | 0.175 |
| Within Groups | 956.88 | 28 | 19.935 | | |
| Total | 994.72 | 29 | | | |

Fall, 11th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 14 | 7.09 | 7.19 | 1.50 | 3.98 | 10.19 | 3 | 28 |
| Type B | 18 | 8.03 | 5.88 | 1.07 | 5.84 | 10.23 | 3 | 24 |
| Total | 32 | 7.62 | 6.43 | 0.88 | 5.85 | 9.40 | 3 | 28 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 11.66 | 1 | 11.660 | 0.278 | 0.600 |
| Within Groups | 2138.79 | 30 | 41.937 | | |
| Total | 2150.45 | 31 | | | |

Fall, 12th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 13 | 5.19 | 4.01 | 0.87 | 3.37 | 7.01 | 3 | 19 |
| Type B | 17 | 6.97 | 7.75 | 1.44 | 4.02 | 9.91 | 3 | 40 |
| Total | 30 | 6.22 | 6.46 | 0.91 | 4.39 | 8.05 | 3 | 40 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 38.38 | 1 | 38.376 | 0.919 | 0.343 |
| Within Groups | 2004.20 | 28 | 41.754 | | |
| Total | 2042.58 | 29 | | | |

Fall, 12$^{th}$ floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 16 | 6.58 | 4.63 | 0.91 | 4.71 | 8.45 | 3 | 22 |
| Type B | 16 | 7.41 | 9.00 | 1.73 | 3.85 | 10.97 | 3 | 46 |
| Total | 32 | 7.00 | 7.14 | 0.98 | 5.03 | 8.97 | 3 | 46 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 9.14 | 1 | 9.135 | 0.176 | 0.676 |
| Within Groups | 2640.86 | 30 | 51.782 | | |
| Total | 2650.00 | 31 | | | |

Fall, 16$^{th}$ floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 6 | 7.60 | 5.74 | 1.81 | 3.49 | 11.71 | 3 | 22 |
| Type B | 17 | 4.86 | 2.91 | 0.54 | 3.75 | 5.97 | 3 | 16 |
| Total | 23 | 5.56 | 3.94 | 0.63 | 4.29 | 6.84 | 3 | 22 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 55.74 | 1 | 55.741 | 3.863 | 0.057 |
| Within Groups | 533.85 | 21 | 14.428 | | |
| Total | 589.59 | 22 | | | |

Fall, 16th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 16 | 5.77 | 2.75 | 0.54 | 4.66 | 6.88 | 3 | 13 |
| Type B | 21 | 5.37 | 3.33 | 0.56 | 4.23 | 6.51 | 3 | 20 |
| Total | 37 | 5.54 | 3.07 | 0.39 | 4.75 | 6.33 | 3 | 20 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.36 | 1 | 2.361 | 0.247 | 0.621 |
| Within Groups | 564.79 | 35 | 9.573 | | |
| Total | 567.15 | 36 | | | |

Winter, 8th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 33 | 5.58 | 2.47 | 0.33 | 4.91 | 6.25 | 3 | 15 |
| Type B | 31 | 5.12 | 2.75 | 0.38 | 4.35 | 5.89 | 3 | 16 |
| Total | 64 | 5.36 | 2.60 | 0.25 | 4.86 | 5.86 | 3 | 16 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 5.70 | 1 | 5.701 | 0.839 | 0.362 |
| Within Groups | 706.68 | 62 | 6.795 | | |
| Total | 712.38 | 63 | | | |

Winter, 8th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 33 | 4.75 | 1.75 | 0.24 | 4.27 | 5.22 | 3 | 10 |
| Type B | 35 | 5.26 | 2.47 | 0.32 | 4.61 | 5.91 | 3 | 14 |
| Total | 68 | 5.01 | 2.16 | 0.20 | 4.61 | 5.41 | 3 | 14 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 7.43 | 1 | 7.434 | 1.607 | 0.208 |
| Within Groups | 513.56 | 66 | 4.627 | | |
| Total | 520.99 | 67 | | | |

Winter, 11th floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 23 | 6.32 | 5.00 | 0.81 | 4.67 | 7.96 | 3 | 24 |
| Type B | 22 | 7.33 | 6.64 | 1.11 | 5.09 | 9.58 | 3 | 28 |
| Total | 45 | 6.81 | 5.84 | 0.68 | 5.46 | 8.16 | 3 | 28 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 19.14 | 1 | 19.141 | 0.558 | 0.457 |
| Within Groups | 2468.21 | 43 | 34.281 | | |
| Total | 2487.35 | 44 | | | |

Winter, 11$^{th}$ floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 10 | 9.65 | 8.51 | 2.06 | 5.27 | 14.02 | 3 | 34 |
| Type B | 15 | 10.56 | 7.81 | 1.56 | 7.34 | 13.78 | 3 | 34 |
| Total | 25 | 10.19 | 8.01 | 1.24 | 7.70 | 12.69 | 3 | 34 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 8.43 | 1 | 8.434 | 0.129 | 0.722 |
| Within Groups | 2620.04 | 23 | 65.501 | | |
| Total | 2628.48 | 24 | | | |

Winter, 12$^{th}$ floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 21 | 4.83 | 2.76 | 0.47 | 3.88 | 5.78 | 3 | 17 |
| Type B | 27 | 8.49 | 15.86 | 2.36 | 3.72 | 13.25 | 3 | 107 |
| Total | 48 | 6.89 | 12.11 | 1.35 | 4.19 | 9.58 | 3 | 107 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 263.77 | 1 | 263.772 | 1.816 | 0.182 |
| Within Groups | 11330.22 | 46 | 145.259 | | |
| Total | 11593.99 | 47 | | | |

Winter, 12$^{th}$ floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 19 | 8.63 | 19.17 | 3.39 | 1.71 | 15.54 | 3 | 112 |
| Type B | 20 | 8.06 | 13.25 | 2.27 | 3.44 | 12.68 | 3 | 80 |
| Total | 39 | 8.33 | 16.26 | 2.00 | 4.34 | 12.33 | 3 | 112 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 5.28 | 1 | 5.284 | 0.020 | 0.889 |
| Within Groups | 17187.38 | 37 | 268.553 | | |
| Total | 17192.67 | 38 | | | |

Winter, 16$^{th}$ floor, SE

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 23 | 5.66 | 3.84 | 0.62 | 4.40 | 6.92 | 3 | 21 |
| Type B | 15 | 6.20 | 4.88 | 0.98 | 4.18 | 8.22 | 3 | 27 |
| Total | 38 | 5.87 | 4.25 | 0.54 | 4.80 | 6.94 | 3 | 27 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4.43 | 1 | 4.431 | 0.242 | 0.624 |
| Within Groups | 1116.55 | 36 | 18.304 | | |
| Total | 1120.98 | 37 | | | |

Winter, 16th floor, NW

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Type A | 21 | 6.77 | 4.76 | 0.80 | 5.14 | 8.41 | 3 | 23 |
| Type B | 31 | 5.54 | 5.18 | 0.72 | 4.10 | 6.98 | 3 | 39 |
| Total | 52 | 6.03 | 5.02 | 0.54 | 4.96 | 7.11 | 3 | 39 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 31.80 | 1 | 31.802 | 1.264 | 0.264 |
| Within Groups | 2139.09 | 50 | 25.166 | | |
| Total | 2170.90 | 51 | | | |

2) ANOVA between the SE and the NW in a same type

Spring, 8th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 29 | 5.33 | 2.72 | 0.39 | 4.54 | 6.12 | 3 | 15 |
| NW | 36 | 5.25 | 3.31 | 0.43 | 4.40 | 6.10 | 3 | 18 |
| Total | 65 | 5.29 | 3.04 | 0.29 | 4.71 | 5.87 | 3 | 18 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.19 | 1 | 0.19 | 0.020 | 0.888 |
| Within Groups | 991.92 | 63 | 9.36 | | |
| Total | 992.10 | 64 | | | |

Spring, 8th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 26 | 4.53 | 1.94 | 0.30 | 3.94 | 5.13 | 3 | 11 |
| NW | 24 | 7.70 | 8.12 | 1.28 | 5.10 | 10.30 | 3 | 46 |
| Total | 50 | 6.06 | 5.99 | 0.66 | 4.75 | 7.37 | 3 | 46 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 207.60 | 1 | 207.60 | 6.153 | 0.015 |
| Within Groups | 2733.10 | 48 | 33.74 | | |
| Total | 2940.70 | 49 | | | |

Spring, 11th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 19 | 7.19 | 5.71 | 1.03 | 5.10 | 9.29 | 3 | 26 |
| NW | 14 | 6.96 | 4.34 | 0.89 | 5.13 | 8.79 | 3 | 21 |
| Total | 33 | 7.09 | 5.11 | 0.69 | 5.71 | 8.47 | 3 | 26 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.75 | 1 | 0.75 | 0.028 | 0.868 |
| Within Groups | 1411.80 | 31 | 26.64 | | |
| Total | 1412.55 | 32 | | | |

Spring, 11th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 23 | 6.13 | 3.99 | 0.65 | 4.82 | 7.44 | 3 | 21 |
| NW | 15 | 6.44 | 4.09 | 0.82 | 4.75 | 8.13 | 3 | 16 |
| Total | 38 | 6.25 | 4.00 | 0.50 | 5.25 | 7.26 | 3 | 21 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.43 | 1 | 1.43 | 0.088 | 0.768 |
| Within Groups | 992.50 | 36 | 16.27 | | |
| Total | 993.94 | 37 | | | |

Spring, 12th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 21 | 5.91 | 5.07 | 0.86 | 4.17 | 7.65 | 2 | 29 |
| NW | 20 | 6.12 | 4.78 | 0.82 | 4.45 | 7.78 | 3 | 23 |
| Total | 41 | 6.01 | 4.89 | 0.59 | 4.84 | 7.19 | 2 | 29 |

ANOVA

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.71 | 1 | 0.71 | 0.029 | 0.864 |
| Within Groups | 1626.27 | 39 | 24.27 | | |
| Total | 1626.99 | 40 | | | |

Spring, 12th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 25 | 5.45 | 5.37 | 0.83 | 3.78 | 7.13 | 2 | 32 |
| NW | 25 | 5.76 | 3.41 | 0.53 | 4.70 | 6.83 | 3 | 16 |
| Total | 50 | 5.61 | 4.48 | 0.49 | 4.64 | 6.58 | 2 | 32 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.01 | 1 | 2.01 | 0.099 | 0.754 |
| Within Groups | 1662.02 | 48 | 20.27 | | |
| Total | 1664.04 | 49 | | | |

Spring, 16th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 24 | 8.20 | 8.91 | 1.41 | 5.35 | 11.05 | 3 | 50 |
| NW | 27 | 7.11 | 4.60 | 0.69 | 5.73 | 8.49 | 3 | 22 |
| Total | 51 | 7.62 | 6.95 | 0.75 | 6.13 | 9.12 | 3 | 50 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 25.11 | 1 | 25.11 | 0.518 | 0.474 |
| Within Groups | 4026.84 | 49 | 48.52 | | |
| Total | 4051.95 | 50 | | | |

Spring, 16th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 26 | 6.33 | 3.58 | 0.55 | 5.22 | 7.43 | 3 | 21 |
| NW | 34 | 6.07 | 4.53 | 0.61 | 4.86 | 7.28 | 3 | 28 |
| Total | 60 | 6.18 | 4.13 | 0.41 | 5.36 | 7.00 | 3 | 28 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.57 | 1 | 1.57 | 0.091 | 0.763 |
| Within Groups | 1667.16 | 58 | 17.19 | | |
| Total | 1668.73 | 59 | | | |

Summer, 8th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 4 | 5.14 | 3.76 | 1.42 | 1.66 | 8.62 | 3 | 13 |
| NW | 5 | 4.22 | 1.20 | 0.40 | 3.30 | 5.15 | 3 | 6 |
| Total | 9 | 4.63 | 2.58 | 0.64 | 3.25 | 6.00 | 3 | 13 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 3.34 | 1 | 3.34 | 0.485 | 0.498 |
| Within Groups | 96.41 | 7 | 6.89 | | |
| Total | 99.75 | 8 | | | |

Summer, 8th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 5 | 6.00 | 2.40 | 0.80 | 4.16 | 7.84 | 3 | 10 |
| NW | 8 | 6.64 | 2.79 | 0.75 | 5.03 | 8.25 | 3 | 11 |
| Total | 13 | 6.39 | 2.61 | 0.54 | 5.26 | 7.52 | 3 | 11 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.26 | 1 | 2.26 | 0.323 | 0.576 |
| Within Groups | 147.21 | 11 | 7.01 | | |
| Total | 149.48 | 12 | | | |

Summer, 11th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 3 | 4.00 | 0.00 | 0.00 | 4.00 | 4.00 | 4 | 4 |
| NW | 4 | 5.57 | 2.15 | 0.81 | 3.58 | 7.56 | 3 | 10 |
| Total | 7 | 4.92 | 1.78 | 0.51 | 3.78 | 6.05 | 3 | 10 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 7.20 | 1 | 7.20 | 2.599 | 0.138 |
| Within Groups | 27.71 | 5 | 2.77 | | |
| Total | 34.92 | 6 | | | |

Summer, 11th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 8 | 8.00 | 7.34 | 1.96 | 3.76 | 12.24 | 3 | 26 |
| NW | 4 | 7.33 | 3.67 | 1.50 | 3.48 | 11.18 | 4 | 13 |
| Total | 12 | 7.80 | 6.36 | 1.42 | 4.82 | 10.78 | 3 | 26 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.87 | 1 | 1.87 | 0.044 | 0.837 |
| Within Groups | 767.33 | 10 | 42.63 | | |
| Total | 769.20 | 11 | | | |

Summer, 12th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 1 | 3.00 | . | . | . | . | 3 | 3 |
| NW | 6 | 3.80 | 1.32 | 0.42 | 2.86 | 4.74 | 3 | 6 |
| Total | 7 | 3.73 | 1.27 | 0.38 | 2.87 | 4.58 | 3 | 6 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.58 | 1 | 0.58 | 0.336 | 0.577 |
| Within Groups | 15.60 | 5 | 1.73 | | |
| Total | 16.18 | 6 | | | |

Summer, 12th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 2 | 9.00 | 5.00 | 2.89 | -3.42 | 21.42 | 4 | 14 |
| NW | 4 | 4.50 | 1.87 | 0.76 | 2.54 | 6.46 | 3 | 8 |
| Total | 6 | 6.00 | 3.67 | 1.22 | 3.18 | 8.82 | 3 | 14 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 40.50 | 1 | 40.50 | 4.200 | 0.080 |
| Within Groups | 67.50 | 4 | 9.64 | | |
| Total | 108.00 | 5 | | | |

Summer, 16th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 3 | 5.00 | 2.12 | 0.95 | 2.37 | 7.63 | 3 | 8 |
| NW | 7 | 7.27 | 5.76 | 1.74 | 3.40 | 11.14 | 3 | 22 |
| Total | 10 | 6.56 | 4.95 | 1.24 | 3.92 | 9.20 | 3 | 22 |

ANOVA

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 17.76 | 1 | 17.76 | 0.710 | 0.414 |
| Within Groups | 350.18 | 8 | 25.01 | | |
| Total | 367.94 | 9 | | | |

Fall, 8th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 25 | 4.79 | 1.68 | 0.26 | 4.26 | 5.31 | 3 | 9 |
| NW | 18 | 4.83 | 2.09 | 0.38 | 4.05 | 5.61 | 3 | 11 |
| Total | 43 | 4.81 | 1.84 | 0.22 | 4.37 | 5.24 | 3 | 11 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.04 | 1 | 0.04 | 0.012 | 0.915 |
| Within Groups | 241.24 | 41 | 3.45 | | |
| Total | 241.28 | 42 | | | |

Fall, 8th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 20 | 5.12 | 1.77 | 0.30 | 4.50 | 5.74 | 3 | 10 |
| NW | 27 | 5.51 | 2.07 | 0.31 | 4.89 | 6.13 | 3 | 11 |
| Total | 47 | 5.34 | 1.95 | 0.22 | 4.91 | 5.78 | 3 | 11 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 3.00 | 1 | 3.00 | 0.789 | 0.377 |
| Within Groups | 292.77 | 45 | 3.80 | | |
| Total | 295.77 | 46 | | | |

Fall, 11th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 14 | 5.22 | 2.66 | 0.56 | 4.07 | 6.37 | 3 | 15 |
| NW | 14 | 7.09 | 7.19 | 1.50 | 3.98 | 10.19 | 3 | 28 |
| Total | 28 | 6.15 | 5.44 | 0.80 | 4.54 | 7.77 | 3 | 28 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 40.20 | 1 | 40.20 | 1.369 | 0.048 |
| Within Groups | 1291.74 | 26 | 29.36 | | |
| Total | 1331.93 | 27 | | | |

Fall, 11th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 16 | 6.96 | 5.55 | 1.07 | 4.77 | 9.16 | 3 | 22 |
| NW | 18 | 8.03 | 5.88 | 1.07 | 5.84 | 10.23 | 3 | 24 |
| Total | 34 | 7.53 | 5.70 | 0.76 | 6.01 | 9.04 | 3 | 24 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 16.28 | 1 | 16.28 | 0.496 | 0.484 |
| Within Groups | 1803.93 | 32 | 32.80 | | |
| Total | 1820.21 | 33 | | | |

Fall, 12th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 14 | 5.04 | 3.86 | 0.80 | 3.38 | 6.71 | 3 | 19 |
| NW | 16 | 6.58 | 4.63 | 0.91 | 4.71 | 8.45 | 3 | 22 |
| Total | 30 | 5.86 | 4.31 | 0.62 | 4.62 | 7.10 | 3 | 22 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 28.70 | 1 | 28.70 | 1.562 | 0.098 |
| Within Groups | 863.30 | 28 | 18.37 | | |
| Total | 892.00 | 29 | | | |

Fall, 12$^{th}$ floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 19 | 6.77 | 7.53 | 1.35 | 4.01 | 9.53 | 3 | 40 |
| NW | 16 | 7.41 | 9.00 | 1.73 | 3.85 | 10.97 | 3 | 46 |
| Total | 35 | 7.07 | 8.18 | 1.07 | 4.92 | 9.22 | 3 | 46 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 5.79 | 1 | 5.79 | 0.085 | 0.771 |
| Within Groups | 3803.94 | 33 | 67.93 | | |
| Total | 3809.72 | 34 | | | |

Fall , 16$^{th}$ floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 6 | 7.60 | 5.74 | 1.81 | 3.49 | 11.71 | 3 | 22 |
| NW | 16 | 5.77 | 2.75 | 0.54 | 4.66 | 6.88 | 3 | 13 |
| Total | 22 | 6.28 | 3.81 | 0.64 | 4.99 | 7.57 | 3 | 22 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 24.21 | 1 | 24.21 | 1.697 | 0.201 |
| Within Groups | 485.02 | 20 | 14.27 | | |
| Total | 509.22 | 21 | | | |

Fall , 16$^{th}$ floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 17 | 4.86 | 2.91 | 0.54 | 3.75 | 5.97 | 3 | 16 |
| NW | 21 | 5.37 | 3.33 | 0.56 | 4.23 | 6.51 | 3 | 20 |
| Total | 38 | 5.14 | 3.13 | 0.39 | 4.36 | 5.92 | 3 | 20 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4.11 | 1 | 4.11 | 0.416 | 0.521 |
| Within Groups | 613.62 | 36 | 9.90 | | |
| Total | 617.73 | 37 | | | |

Fall , 8$^{th}$ floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 33 | 5.58 | 2.47 | 0.33 | 4.91 | 6.25 | 3 | 15 |
| NW | 33 | 4.75 | 1.75 | 0.24 | 4.27 | 5.22 | 3 | 10 |
| Total | 66 | 5.16 | 2.17 | 0.21 | 4.75 | 5.57 | 3 | 15 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 19.24 | 1 | 19.24 | 4.207 | 0.183 |
| Within Groups | 493.82 | 64 | 4.57 | | |
| Total | 513.05 | 65 | | | |

Fall , 8$^{th}$ floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 31 | 5.12 | 2.75 | 0.38 | 4.35 | 5.89 | 3 | 16 |
| NW | 35 | 5.26 | 2.47 | 0.32 | 4.61 | 5.91 | 3 | 14 |
| Total | 66 | 5.19 | 2.59 | 0.25 | 4.70 | 5.69 | 3 | 16 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.54 | 1 | 0.54 | 0.079 | 0.779 |
| Within Groups | 726.41 | 64 | 6.79 | | |
| Total | 726.95 | 65 | | | |

Winter, 11$^{th}$ floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 23 | 6.32 | 5.00 | 0.81 | 4.67 | 7.96 | 3 | 24 |
| NW | 10 | 9.65 | 8.51 | 2.06 | 5.27 | 14.02 | 3 | 34 |
| Total | 33 | 7.35 | 6.40 | 0.86 | 5.62 | 9.08 | 3 | 34 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 130.34 | 1 | 130.34 | 3.318 | 0.074 |
| Within Groups | 2082.09 | 31 | 39.28 | | |
| Total | 2212.44 | 32 | | | |

Winter, 11th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 22 | 7.33 | 6.64 | 1.11 | 5.09 | 9.58 | 3 | 28 |
| NW | 15 | 10.56 | 7.81 | 1.56 | 7.34 | 13.78 | 3 | 34 |
| Total | 37 | 8.66 | 7.26 | 0.93 | 6.80 | 10.51 | 3 | 34 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 153.61 | 1 | 153.61 | 3.015 | 0.088 |
| Within Groups | 3006.16 | 35 | 50.95 | | |
| Total | 3159.77 | 36 | | | |

Winter, 12th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 21 | 4.83 | 2.76 | 0.47 | 3.88 | 5.78 | 3 | 17 |
| NW | 19 | 8.63 | 19.17 | 3.39 | 1.71 | 15.54 | 3 | 112 |
| Total | 40 | 6.64 | 13.43 | 1.64 | 3.37 | 9.92 | 3 | 112 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 240.93 | 1 | 240.93 | 1.344 | 0.251 |
| Within Groups | 11656.47 | 38 | 179.33 | | |
| Total | 11897.40 | 39 | | | |

Winter, 12th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 32 | 7.75 | 14.70 | 2.02 | 3.70 | 11.81 | 3 | 107 |
| NW | 28 | 9.64 | 15.79 | 2.30 | 5.00 | 14.28 | 3 | 80 |
| Total | 60 | 8.64 | 15.18 | 1.52 | 5.63 | 11.65 | 3 | 107 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 88.38 | 1 | 88.38 | 0.381 | 0.538 |
| Within Groups | 22714.66 | 58 | 231.78 | | |
| Total | 22803.04 | 59 | | | |

Winter, 16th floor, Type A

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 23 | 5.66 | 3.84 | 0.62 | 4.40 | 6.92 | 3 | 21 |
| NW | 21 | 6.77 | 4.76 | 0.80 | 5.14 | 8.41 | 3 | 23 |
| Total | 44 | 6.19 | 4.31 | 0.50 | 5.19 | 7.20 | 3 | 23 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 22.59 | 1 | 22.59 | 1.220 | 0.073 |
| Within Groups | 1314.72 | 42 | 18.52 | | |
| Total | 1337.32 | 43 | | | |

Winter, 16th floor, Type B

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| SE | 15 | 6.20 | 4.88 | 0.98 | 4.18 | 8.22 | 3 | 27 |
| NW | 31 | 5.51 | 5.23 | 0.73 | 4.04 | 6.98 | 3 | 39 |
| Total | 46 | 5.74 | 5.09 | 0.58 | 4.57 | 6.90 | 3 | 39 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 7.99 | 1 | 7.99 | 0.305 | 0.582 |
| Within Groups | 1938.75 | 44 | 26.20 | | |
| Total | 1946.74 | 45 | | | |

**2. St. Joseph Regional Health Center**

1) ANOVA between type A and type B in a same orientation

Spring, 2nd floor, South

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 28 | 6.75 | 3.49 | 0.66 | 5.39 | 8.10 | 3.06 | 17.60 |
| B | 34 | 6.53 | 2.87 | 0.49 | 5.53 | 7.53 | 3.00 | 15.58 |
| Total | 62 | 6.63 | 3.14 | 0.40 | 5.83 | 7.42 | 3.00 | 17.60 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.7 | 1 | 0.728 | 0.073 | 0.788 |
| Within Groups | 600.5 | 60 | 10.008 | | |
| Total | 601.2 | 61 | | | |

Spring, 2nd floor, North

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 20 | 6.44 | 5.22 | 1.17 | 3.99 | 8.88 | 3.11 | 25.98 |
| B | 23 | 6.28 | 3.18 | 0.66 | 4.90 | 7.65 | 3.08 | 17.13 |
| Total | 43 | 6.35 | 4.20 | 0.64 | 5.06 | 7.64 | 3.08 | 25.98 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.3 | 1 | 0.273 | 0.015 | 0.903 |
| Within Groups | 739.8 | 41 | 18.045 | | |
| Total | 740.1 | 42 | | | |

Spring, 3rd floor, South

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 27 | 5.33 | 2.28 | 0.44 | 4.43 | 6.24 | 3.01 | 11.21 |
| B | 34 | 5.74 | 2.81 | 0.48 | 4.76 | 6.72 | 3.00 | 15.82 |
| Total | 61 | 5.56 | 2.58 | 0.33 | 4.90 | 6.22 | 3.00 | 15.82 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.5 | 1 | 2.498 | 0.372 | 0.544 |
| Within Groups | 395.7 | 59 | 6.707 | | |
| Total | 398.2 | 60 | | | |

Spring, 3rd floor, North

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 25 | 4.90 | 2.05 | 0.41 | 4.06 | 5.75 | 3.00 | 11.11 |
| B | 19 | 5.33 | 2.93 | 0.67 | 3.92 | 6.75 | 3.00 | 13.14 |
| Total | 44 | 5.09 | 2.45 | 0.37 | 4.35 | 5.83 | 3.00 | 13.14 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.0 | 1 | 2.001 | 0.329 | 0.570 |
| Within Groups | 255.8 | 42 | 6.089 | | |
| Total | 257.8 | 43 | | | |

Summer, 2nd floor, South

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 40 | 6.46 | 3.87 | 0.61 | 5.23 | 7.70 | 3.00 | 17.86 |
| B | 38 | 7.66 | 4.07 | 0.66 | 6.32 | 9.00 | 3.02 | 17.90 |
| Total | 78 | 7.05 | 3.99 | 0.45 | 6.15 | 7.95 | 3.00 | 17.90 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 28.0 | 1 | 27.954 | 1.774 | 0.187 |
| Within Groups | 1197.4 | 76 | 15.756 | | |
| Total | 1225.4 | 77 | | | |

Summer, 2nd floor, North

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 29 | 6.72 | 4.41 | 0.82 | 5.05 | 8.40 | 3.03 | 22.04 |
| B | 26 | 6.89 | 4.16 | 0.82 | 5.21 | 8.57 | 3.02 | 19.16 |
| Total | 55 | 6.80 | 4.25 | 0.57 | 5.65 | 7.95 | 3.02 | 22.04 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.4 | 1 | 0.393 | 0.021 | 0.884 |
| Within Groups | 976.4 | 53 | 18.422 | | |
| Total | 976.8 | 54 | | | |

Summer, 3rd floor, South

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 47 | 5.00 | 2.54 | 0.37 | 4.25 | 5.75 | 3.00 | 16.63 |
| B | 54 | 5.37 | 4.18 | 0.57 | 4.23 | 6.51 | 3.00 | 28.07 |
| Total | 101 | 5.20 | 3.50 | 0.35 | 4.50 | 5.89 | 3.00 | 28.07 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 3.3 | 1 | 3.348 | 0.271 | 0.604 |
| Within Groups | 1221.3 | 99 | 12.337 | | |
| Total | 1224.7 | 100 | | | |

Summer, 3rd floor, North

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 20 | 6.40 | 3.95 | 0.88 | 4.55 | 8.25 | 3.01 | 18.98 |
| B | 25 | 5.22 | 3.15 | 0.63 | 3.92 | 6.52 | 3.04 | 16.59 |
| Total | 45 | 5.74 | 3.54 | 0.53 | 4.68 | 6.81 | 3.01 | 18.98 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 15.4 | 1 | 15.381 | 1.235 | 0.273 |
| Within Groups | 535.4 | 43 | 12.450 | | |
| Total | 550.7 | 44 | | | |

Fall, 2nd floor, South

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 54 | 5.39 | 2.29 | 0.31 | 4.76 | 6.01 | 3.00 | 16.07 |
| B | 49 | 5.81 | 3.01 | 0.43 | 4.95 | 6.68 | 3.02 | 18.80 |
| Total | 103 | 5.59 | 2.65 | 0.26 | 5.07 | 6.11 | 3.00 | 18.80 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4.6 | 1 | 4.638 | 0.656 | 0.420 |
| Within Groups | 713.7 | 101 | 7.067 | | |
| Total | 718.4 | 102 | | | |

Fall, 2nd floor, North

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 34 | 6.12 | 3.20 | 0.55 | 5.00 | 7.24 | 3.23 | 18.69 |
| B | 34 | 6.06 | 5.03 | 0.86 | 4.30 | 7.82 | 3.07 | 27.85 |
| Total | 68 | 6.09 | 4.19 | 0.51 | 5.08 | 7.10 | 3.07 | 27.85 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.1 | 1 | 0.060 | 0.003 | 0.954 |
| Within Groups | 1175.0 | 66 | 17.803 | | |
| Total | 1175.0 | 67 | | | |

Fall, 3rd floor, South

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 56 | 5.33 | 2.90 | 0.39 | 4.56 | 6.11 | 3.00 | 20.33 |
| B | 50 | 4.46 | 1.56 | 0.22 | 4.01 | 4.90 | 3.00 | 9.96 |
| Total | 106 | 4.92 | 2.40 | 0.23 | 4.46 | 5.38 | 3.00 | 20.33 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 20.3 | 1 | 20.265 | 3.617 | 0.600 |
| Within Groups | 582.7 | 104 | 5.603 | | |
| Total | 602.9 | 105 | | | |

Fall, 3$^{rd}$ floor, North

| Type | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| A | 31 | 5.47 | 3.46 | 0.62 | 4.20 | 6.74 | 3.04 | 18.90 |
| B | 37 | 5.28 | 3.35 | 0.55 | 4.16 | 6.39 | 3.01 | 20.94 |
| Total | 68 | 5.37 | 3.37 | 0.41 | 4.55 | 6.18 | 3.01 | 20.94 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.6 | 1 | 0.618 | 0.054 | 0.818 |
| Within Groups | 762.4 | 66 | 11.551 | | |
| Total | 763.0 | 67 | | | |

2) ANOVA between the south and the north in a same orientation

Spring, 2nd floor, Type A

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 28 | 6.75 | 3.49 | 0.66 | 5.39 | 8.10 | 3.06 | 17.60 |
| N | 20 | 6.44 | 5.22 | 1.17 | 3.99 | 8.88 | 3.11 | 25.98 |
| Total | 48 | 6.62 | 4.25 | 0.61 | 5.38 | 7.85 | 3.06 | 25.98 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.1 | 1 | 1.129 | 0.061 | 0.805 |
| Within Groups | 846.2 | 46 | 18.397 | | |
| Total | 847.4 | 47 | | | |

Spring, 2nd floor, Type B

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 34 | 6.53 | 2.87 | 0.49 | 5.53 | 7.53 | 3.00 | 15.58 |
| N | 23 | 6.28 | 3.18 | 0.66 | 4.90 | 7.65 | 3.08 | 17.13 |
| Total | 57 | 6.43 | 2.97 | 0.39 | 5.64 | 7.22 | 3.00 | 17.13 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.9 | 1 | 0.880 | 0.098 | 0.755 |
| Within Groups | 494.0 | 55 | 8.983 | | |
| Total | 494.9 | 56 | | | |

Spring, 3rd floor, Type A

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 27 | 5.33 | 2.28 | 0.44 | 4.43 | 6.24 | 3.01 | 11.21 |
| N | 25 | 4.90 | 2.05 | 0.41 | 4.06 | 5.75 | 3.00 | 11.11 |
| Total | 52 | 5.13 | 2.17 | 0.30 | 4.52 | 5.73 | 3.00 | 11.21 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.4 | 1 | 2.383 | 0.503 | 0.481 |
| Within Groups | 236.9 | 50 | 4.738 | | |
| Total | 239.3 | 51 | | | |

Spring, 3rd floor, Type B

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 34 | 5.74 | 2.81 | 0.48 | 4.76 | 6.72 | 3.00 | 15.82 |
| N | 19 | 5.33 | 2.93 | 0.67 | 3.92 | 6.75 | 3.00 | 13.14 |
| Total | 53 | 5.59 | 2.83 | 0.39 | 4.81 | 6.38 | 3.00 | 15.82 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.0 | 1 | 2.002 | 0.246 | 0.622 |
| Within Groups | 414.6 | 51 | 8.129 | | |
| Total | 416.6 | 52 | | | |

Summer, 2nd floor, Type A

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 40 | 6.46 | 3.87 | 0.61 | 5.23 | 7.70 | 3.00 | 17.86 |
| N | 29 | 6.72 | 4.41 | 0.82 | 5.05 | 8.40 | 3.03 | 22.04 |
| Total | 69 | 6.57 | 4.08 | 0.49 | 5.59 | 7.55 | 3.00 | 22.04 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.1 | 1 | 1.129 | 0.067 | 0.796 |
| Within Groups | 1128.2 | 67 | 16.839 | | |
| Total | 1129.4 | 68 | | | |

Summer, 2nd floor, Type B

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 38 | 7.66 | 4.07 | 0.66 | 6.32 | 9.00 | 3.02 | 17.90 |
| N | 26 | 6.89 | 4.16 | 0.82 | 5.21 | 8.57 | 3.02 | 19.16 |
| Total | 64 | 7.35 | 4.09 | 0.51 | 6.33 | 8.37 | 3.02 | 19.16 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 9.1 | 1 | 9.135 | 0.542 | 0.465 |
| Within Groups | 1045.6 | 62 | 16.864 | | |
| Total | 1054.7 | 63 | | | |

Summer, 3rd floor, Type A

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 47 | 5.00 | 2.54 | 0.37 | 4.25 | 5.75 | 3.00 | 16.63 |
| N | 20 | 6.40 | 3.95 | 0.88 | 4.55 | 8.25 | 3.01 | 18.98 |
| Total | 67 | 5.42 | 3.07 | 0.37 | 4.67 | 6.17 | 3.00 | 18.98 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 27.4 | 1 | 27.377 | 2.995 | 0.088 |
| Within Groups | 594.1 | 65 | 9.140 | | |
| Total | 621.5 | 66 | | | |

Summer, 3rd floor, Type B

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 54 | 5.37 | 4.18 | 0.57 | 4.23 | 6.51 | 3.00 | 28.07 |
| N | 25 | 5.22 | 3.15 | 0.63 | 3.92 | 6.52 | 3.04 | 16.59 |
| Total | 79 | 5.32 | 3.86 | 0.43 | 4.45 | 6.18 | 3.00 | 28.07 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.4 | 1 | 0.358 | 0.024 | 0.878 |
| Within Groups | 1162.6 | 77 | 15.099 | | |
| Total | 1163.0 | 78 | | | |

Fall, 2$^{nd}$ floor, Type A

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 54 | 5.39 | 2.29 | 0.31 | 4.76 | 6.01 | 3.00 | 16.07 |
| N | 34 | 6.12 | 3.20 | 0.55 | 5.00 | 7.24 | 3.23 | 18.69 |
| Total | 88 | 5.67 | 2.69 | 0.29 | 5.10 | 6.24 | 3.00 | 18.69 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 11.2 | 1 | 11.165 | 1.558 | 0.215 |
| Within Groups | 616.4 | 86 | 7.168 | | |
| Total | 627.6 | 87 | | | |

Fall, 2$^{nd}$ floor, Type B

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 49 | 5.81 | 3.01 | 0.43 | 4.95 | 6.68 | 3.02 | 18.80 |
| N | 34 | 6.06 | 5.03 | 0.86 | 4.30 | 7.82 | 3.07 | 27.85 |
| Total | 83 | 5.91 | 3.94 | 0.43 | 5.05 | 6.77 | 3.02 | 27.85 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.2 | 1 | 1.228 | 0.078 | 0.781 |
| Within Groups | 1272.3 | 81 | 15.707 | | |
| Total | 1273.5 | 82 | | | |

Fall, $3^{rd}$ floor, Type A

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 56 | 5.33 | 2.90 | 0.39 | 4.56 | 6.11 | 3.00 | 20.33 |
| N | 31 | 5.47 | 3.46 | 0.62 | 4.20 | 6.74 | 3.04 | 18.90 |
| Total | 87 | 5.38 | 3.09 | 0.33 | 4.72 | 6.04 | 3.00 | 20.33 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.4 | 1 | 0.377 | 0.039 | 0.844 |
| Within Groups | 822.1 | 85 | 9.672 | | |
| Total | 822.5 | 86 | | | |

Fall, $3^{rd}$ floor, Type B

| Orientation | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| S | 50 | 4.46 | 1.56 | 0.22 | 4.01 | 4.90 | 3.00 | 9.96 |
| N | 37 | 5.28 | 3.35 | 0.55 | 4.16 | 6.39 | 3.01 | 20.94 |
| Total | 87 | 4.81 | 2.50 | 0.27 | 4.27 | 5.34 | 3.00 | 20.94 |

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 14.4 | 1 | 14.362 | 2.334 | 0.130 |
| Within Groups | 522.9 | 85 | 6.152 | | |
| Total | 537.3 | 86 | | | |

# APPENDIX II

# CONTOUR IMAGES OF U.I. AND D.I.

## 1. Inha University Hospital

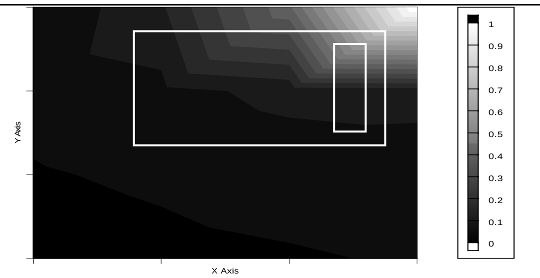
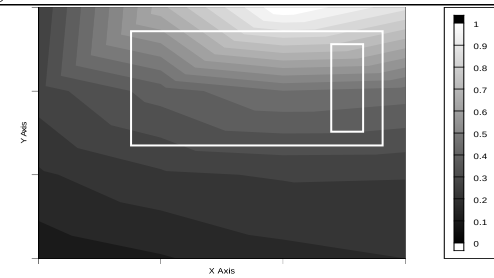
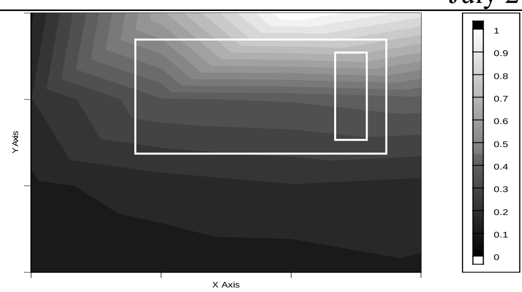
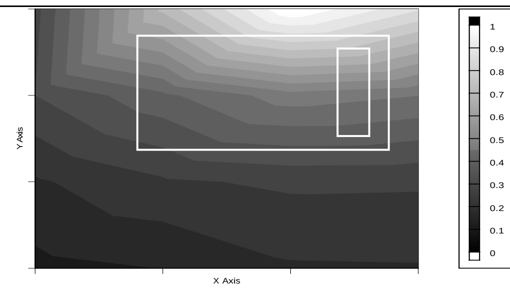
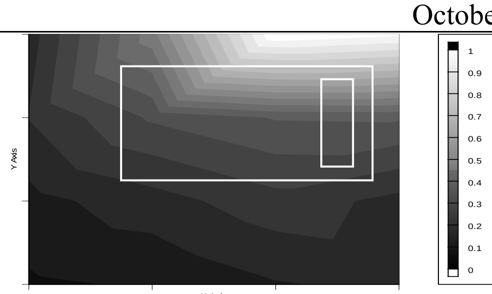
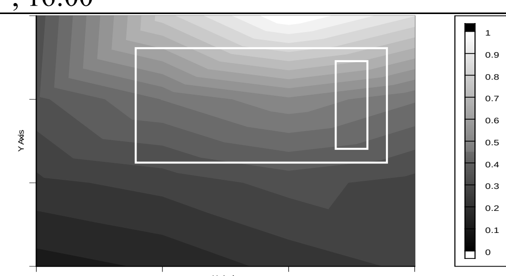
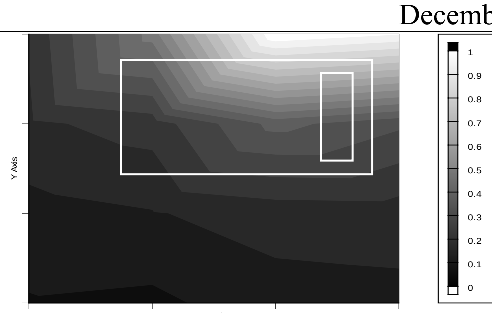
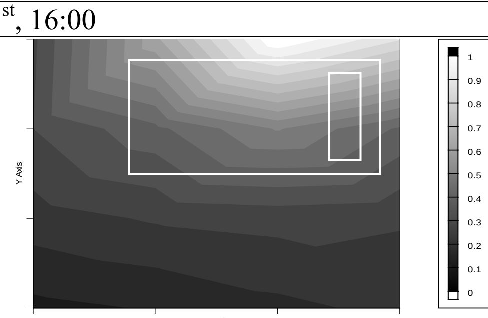
| Blinds opened | Blinds closed |
|---|---|
| March 21st, 16:00 | |
|  |  |
| DI = 37, UI = 0.2 | DI = 8.6, UI = 0.3 |
| July 21st, 12:00 | |
|  |  |
| DI = 10, UI = 0.3 | DI = 7.04, UI= 0.4 |
| October 21st, 16:00 | |
|  |  |
| DI = 11, UI = 0.3 | DI = 7.9, UI = 0.3 |
| December 21st, 16:00 | |
|  |  |
| DI = 11.3, 0, UI = 0.3 | DI = 7.4, UI =0.4 |

**Figure 94-Comparisons of contour of DI and UI between the blinds opened and closed (Type A, NW) of Inha University Hospital.**

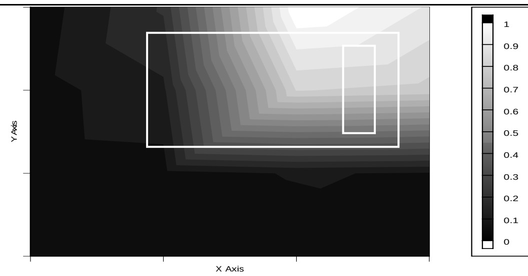
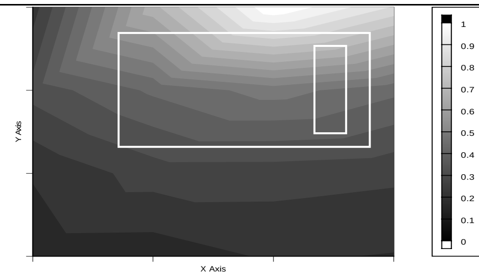
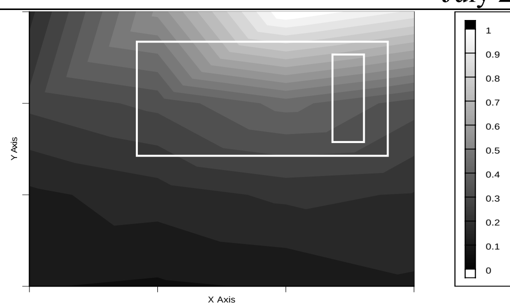
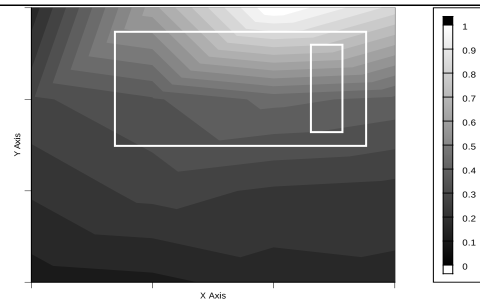
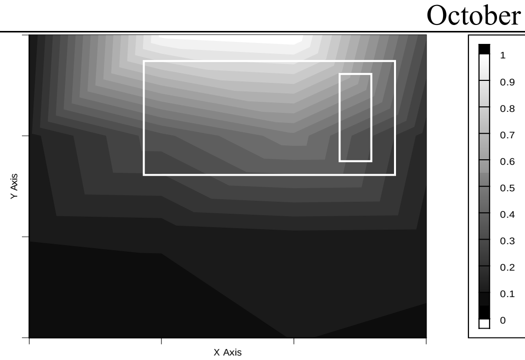
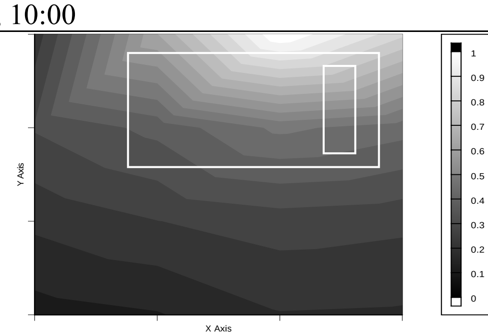
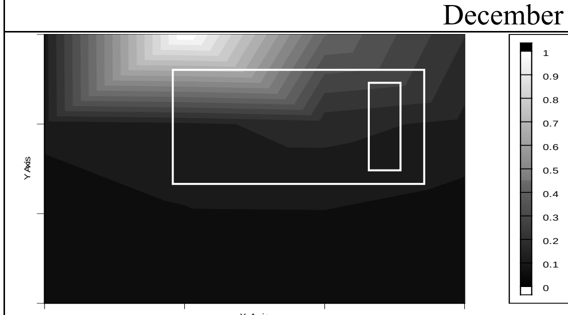
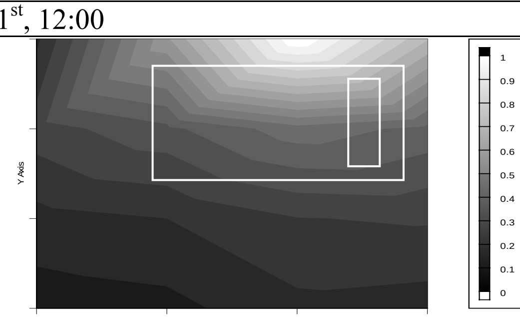
| Blinds opened | Blinds closed |
|---|---|
| March 21st, 9:00 | |
|  DI = 19.2, UI = 0.2 |  DI = 5.9, UI = 0.4 |
| July 21st, 12:00 | |
|  DI = 10.89, UI = 0.3 |  DI = 7.0, UI = 0.4 |
| October 21st, 10:00 | |
|  DI = 17.2, UI = 0.2 |  DI = 7.78, UI = 0.3 |
| December 21st, 12:00 | |
|  DI = 18.4, UI = 0.2 |  DI = 8.1, UI = 0.4 |

**Figure 95-Comparisons of contour of DI and UI between the blinds opened and closed (Type B, SE) of Inha University Hospital.**

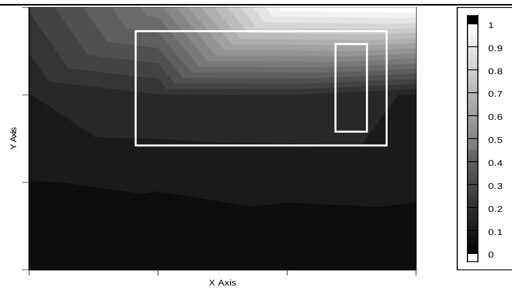
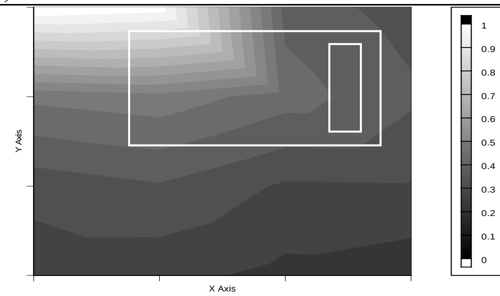
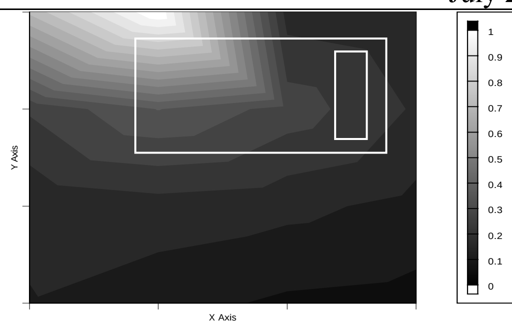
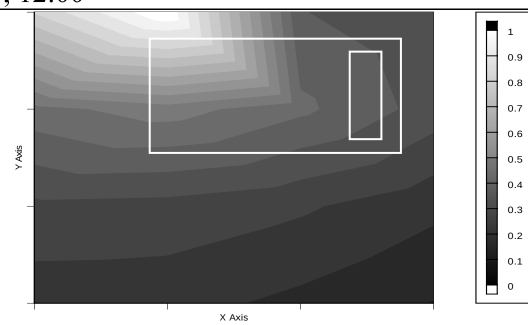
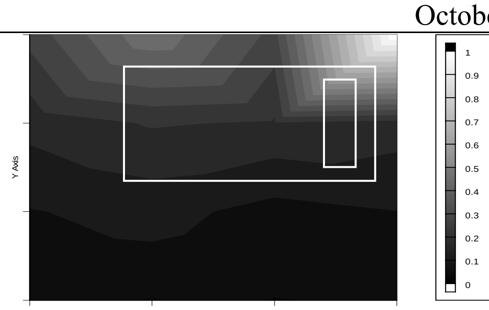
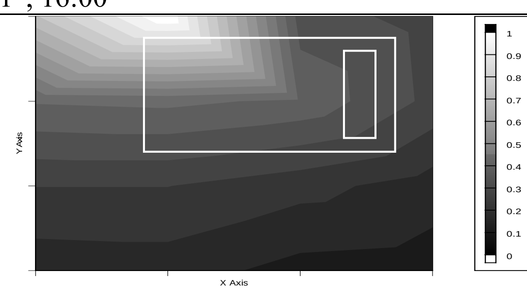
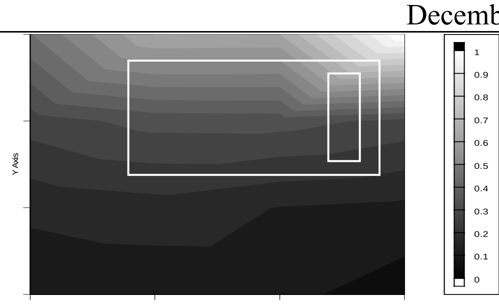
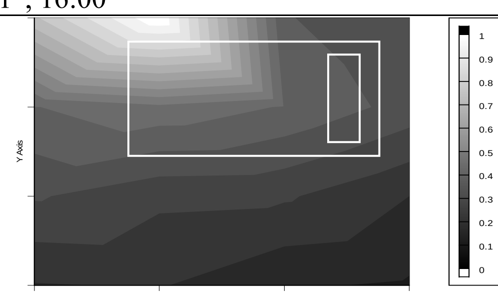
| Blinds opened | Blinds closed |
|---|---|
| March 21st, 16:00 | |
|  DI = 18.3, UI = 0.2 |  DI = 4.6, UI = 0.5 |
| July 21st, 12:00 | |
|  DI = 10.8, UI = 0.3 |  DI = 6.77, UI = 0.4 |
| October 21st, 16:00 | |
|  DI = 20, UI = 0.2 |  DI = 8.1, UI = 0.4 |
| December 21st, 16:00 | |
|  DI = 13.8, UI = 0.4 |  DI = 6.9, UI = 0.4 |

**Figure 96-Comparisons of contour of DI and UI between the blinds opened and closed (Type B, NW) of Inha University Hospital.**

## 2. St. Joseph Regional Health Center

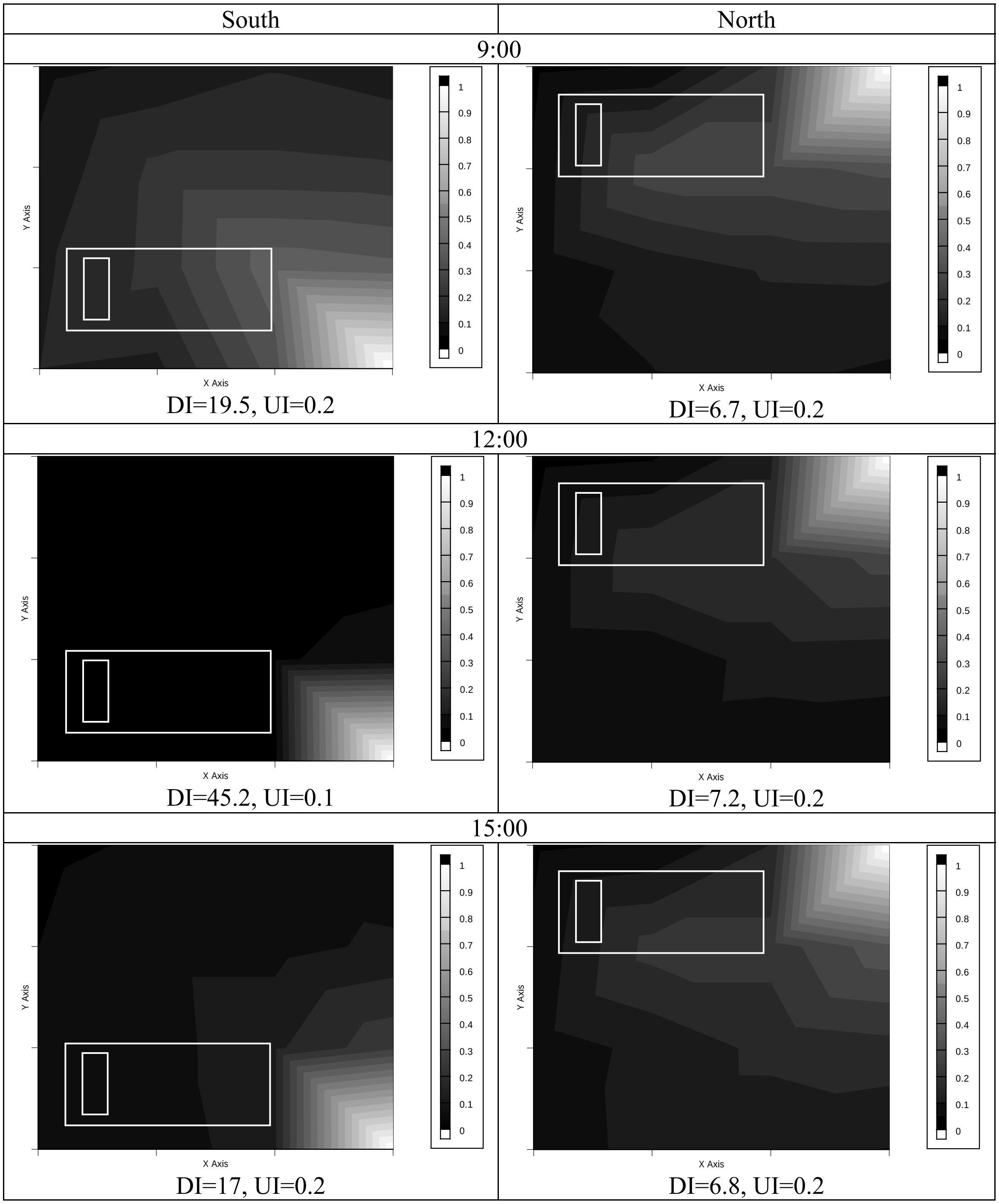
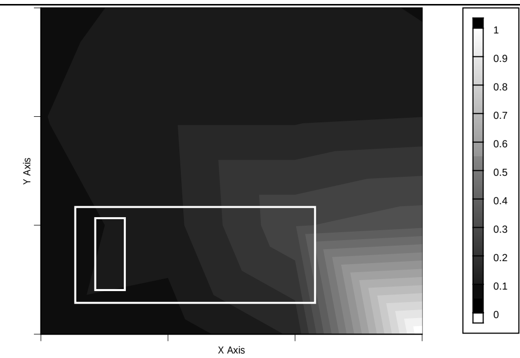
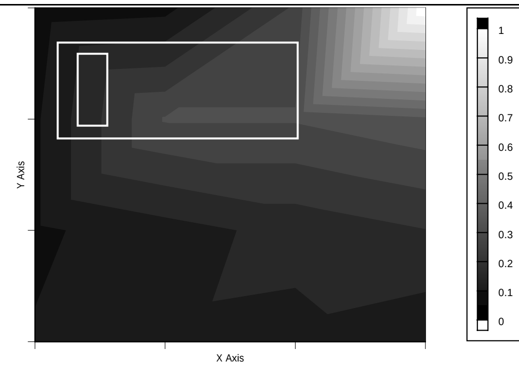
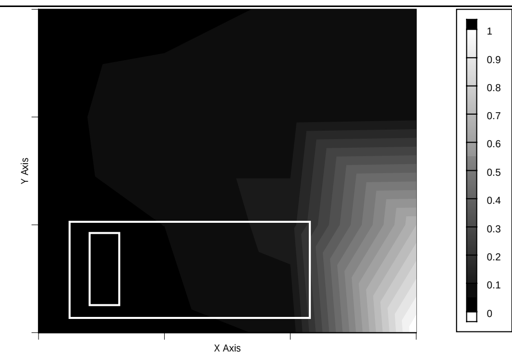
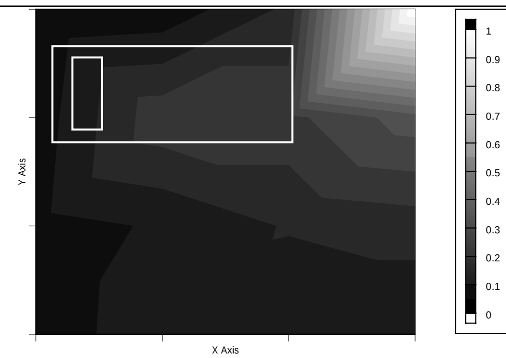


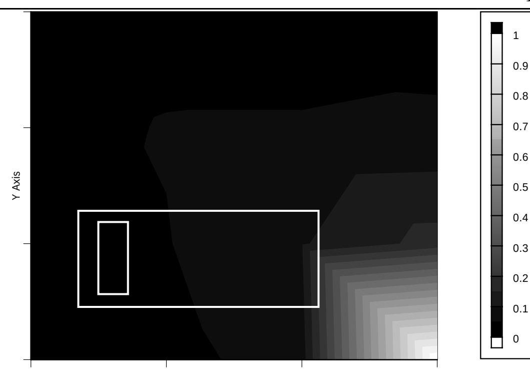

**Figure 97-Comparisons of contour of DI and UI between the south and the north of type A, September 21st.**

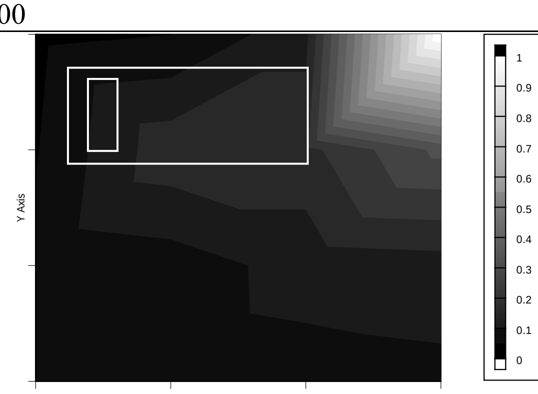
<table>
<tr><th>South</th><th>North</th></tr>
<tr><td colspan="2">9:00</td></tr>
<tr><td>

DI=11.4, UI=0.3</td><td>

DI=9.2, UI=0.3</td></tr>
<tr><td colspan="2">12:00</td></tr>
<tr><td>

DI=29.1, UI=0.2</td><td>

DI=7.9, UI=0.3</td></tr>
<tr><td colspan="2">15:00</td></tr>
<tr><td>

DI=34.7, UI=0.2</td><td>

DI=6.6, UI=0.2</td></tr>
</table>

**Figure 98-Comparisons of contour of DI and UI between the south and the north of type A, December 21st.**

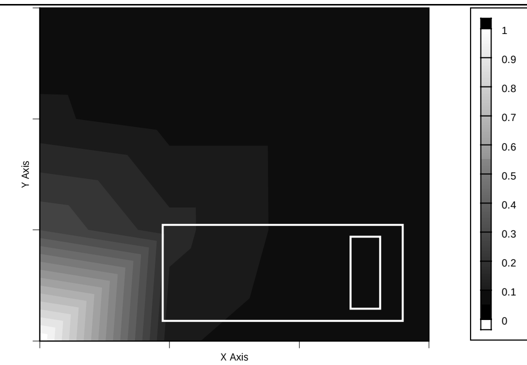
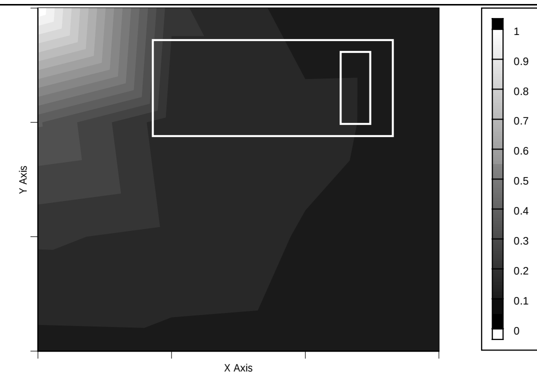
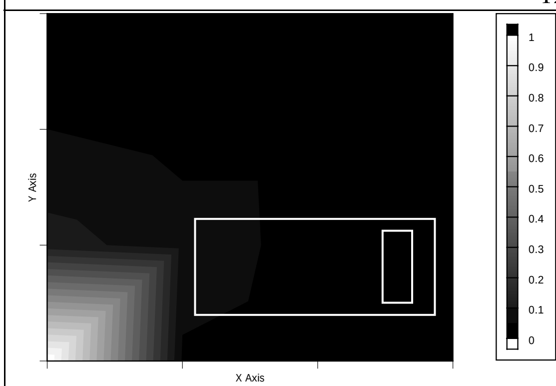
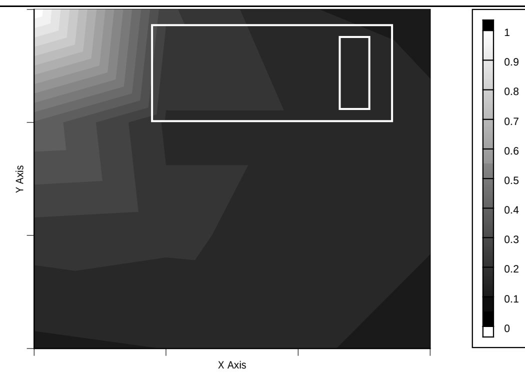
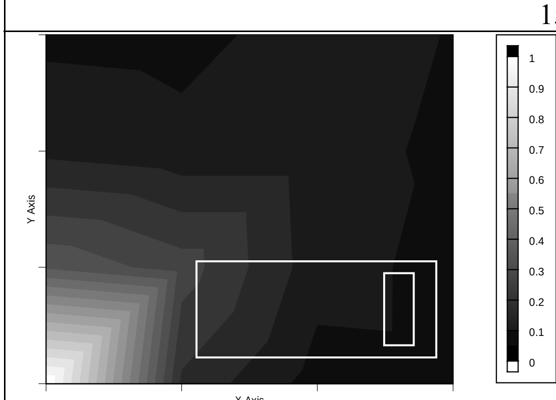
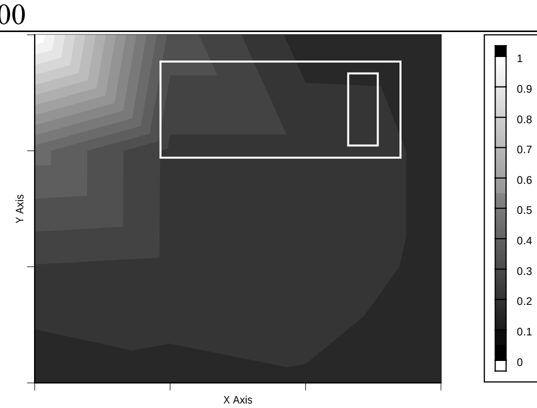
| South | North |
|---|---|
| 9:00 | |
| <br>DI=19.3, UI=0.2 | <br>DI=9.2, UI=0.3 |
| 12:00 | |
| <br>DI=34.5, UI=0.2 | <br>DI=7.6, UI=0.3 |
| 15:00 | |
| <br>DI=16.9, UI=0.2 | <br>DI=6.3, UI=0.3 |

**Figure 99-Comparisons of contour of DI and UI between the south and the north of type B, March 21st.**

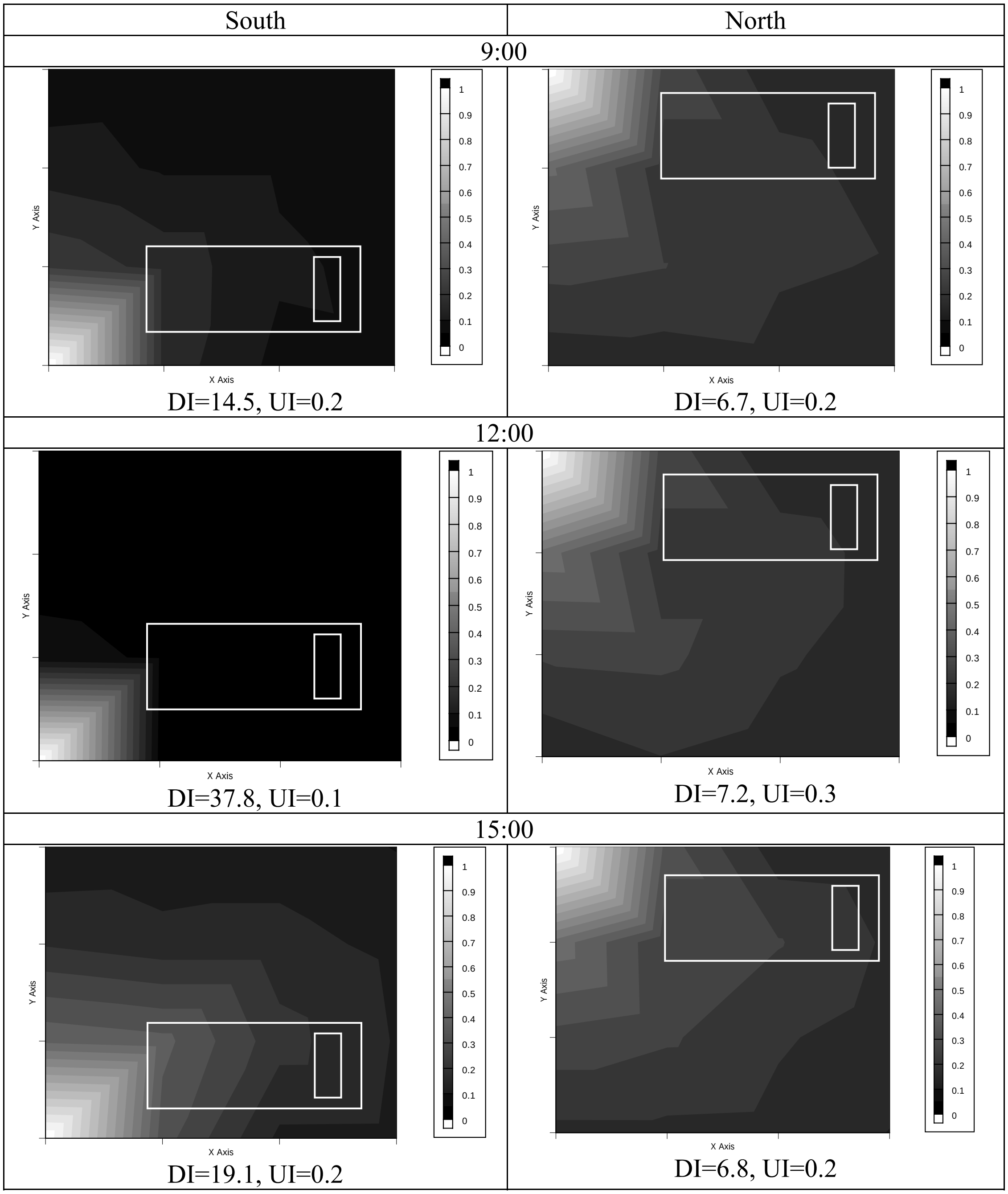



**Figure 100-Comparisons of contour of DI and UI between the south and the north of type B, September 21st.**

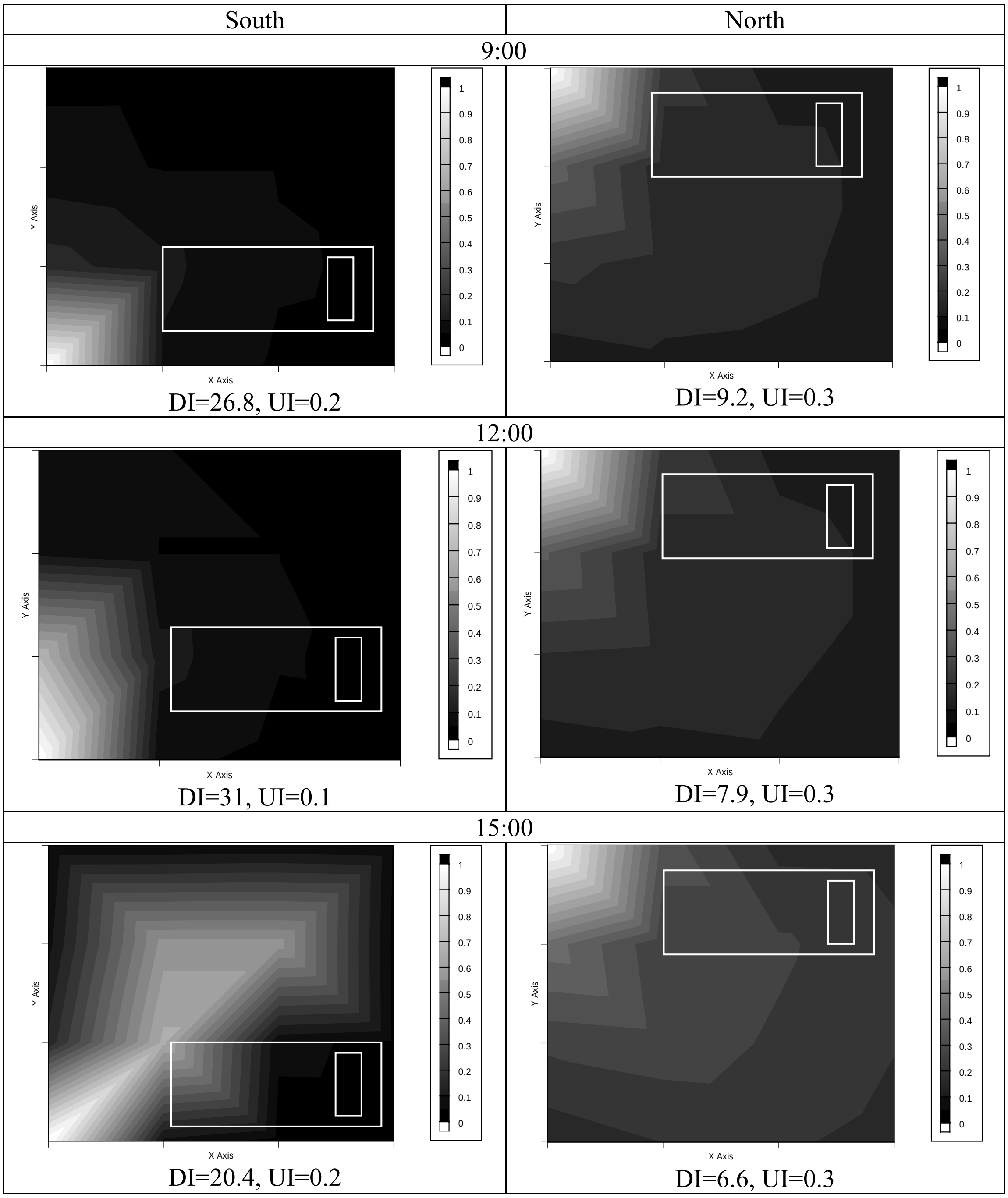



**Figure 101-Comparisons of contour of DI and UI between the south and the north of type B, December 21st.**

# APPENDIX III

# SUMMARY OF THE AVERAGE VALUES OF INDOOR DAYLIGHT VARIABLES OF INHA UNIVERSITY HOSPITAL

| | Blinds | Spring | | Summer | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|
| | | SE | NW | SE | NW | SE | NW | SE | NW |
| DF (%) | Opened | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 |
| | Closed | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| LR (TV wall) | Opened | 21.3 | 6.9 | 7.4 | 7.3 | 17.8 | 7.4 | 14.6 | 7 |
| | Closed | 8.5 | 7.1 | 7.6 | 7.4 | 10.6 | 6.9 | 5.6 | 6.4 |
| LR (Eye & TV) | Opened | 2.4 | 1.6 | 2.4 | 2.2 | 2.6 | 1.7 | 3.7 | 1.8 |
| | Closed | 2.3 | 1.2 | 1.4 | 1.3 | 2.1 | 0.9 | 1.8 | 1.2 |
| Illum.(lux) | Opened | 554 | 126 | 209 | 202 | 642 | 143 | 436 | 128 |
| | Closed | 161 | 31 | 68 | 65 | 183 | 37 | 92 | 23 |
| DI | Opened | 15.1 | 7.8 | 10.8 | 10.7 | 16.8 | 9.2 | 18.4 | 9.5 |
| | Closed | 5.8 | 8.5 | 6.3 | 6.2 | 5.7 | 9.5 | 5.9 | 9.3 |
| UI | Opened | 0.27 | 0.36 | 0.28 | 0.31 | 0.24 | 0.33 | 0.24 | 0.32 |
| | Closed | 0.33 | 0.3 | 0.3 | 0.4 | 0.35 | 0.3 | 0.3 | 0.3 |

**Table 74-Summary of the average values of indoor daylight variables in type A from 8:00 AM to 1:00 PM of Inha University Hospital.**

| | Blinds | Spring | | Summer | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|
| | | SE | NW | SE | NW | SE | NW | SE | NW |
| DF (%) | Opened | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 |
| | Closed | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| LR (TV wall) | Opened | 20.3 | 7 | 7.4 | 7.3 | 21.5 | 7.5 | 20 | 7.6 |
| | Closed | 9.2 | 6.8 | 7.6 | 7.4 | 11 | 7.1 | 6.4 | 6.8 |
| LR (Eye & TV) | Opened | 2.1 | 3.5 | 2.4 | 2.2 | 2 | 3.5 | 3.7 | 1.8 |
| | Closed | 2.3 | 1.2 | 1.4 | 1.3 | 2 | 1.2 | 1.8 | 1.2 |
| Illum.(lux) | Opened | 140 | 462 | 178 | 172 | 141 | 308 | 96 | 120 |
| | Closed | 53 | 97 | 58 | 55 | 54 | 77 | 30 | 35 |
| DI | Opened | 9.4 | 19.8 | 10.8 | 10.7 | 9.9 | 14.2 | 9.2 | 10.2 |
| | Closed | 6.7 | 7.7 | 6.3 | 6.2 | 6.1 | 7 | 5.7 | 6.7 |
| UI | Opened | 0.32 | 0.34 | 0.28 | 0.31 | 0.28 | 0.32 | 0.25 | 0.32 |
| | Closed | 0.32 | 0.3 | 0.3 | 0.4 | 0.33 | 0.3 | 0.33 | 0.3 |

**Table 75-Summary of the average values of indoor daylight variables in type A from 2:00 PM to 6:00 PM of Inha University Hospital.**

| | Blinds | Spring | | Summer | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|
| | | SE | NW | SE | NW | SE | NW | SE | NW |
| DF (%) | Opened | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| | Closed | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| LR (TV wall) | Opened | 26.4 | 8.9 | 9.1 | 9.3 | 26.3 | 9.7 | 35.3 | 8.1 |
| | Closed | 17.8 | 8.6 | 9.7 | 9.5 | 14 | 10.7 | 16.6 | 9.7 |
| LR (Eye & TV) | Opened | 2.4 | 1.6 | 2.1 | 2.1 | 2.8 | 2 | 2.1 | 2 |
| | Closed | 1.2 | 2.4 | 1 | 1.1 | 1.2 | 2.4 | 1.3 | 2.5 |
| Illum.(lux) | Opened | 519 | 131 | 210 | 201 | 654 | 147 | 473 | 96 |
| | Closed | 100 | 41 | 56 | 55 | 110 | 45 | 81 | 27 |
| DI | Opened | 16.4 | 8.3 | 10.8 | 12.3 | 15.6 | 8.4 | 14.3 | 7.9 |
| | Closed | 7.5 | 7.2 | 8.1 | 6.8 | 8.1 | 7.5 | 7.7 | 7.1 |
| UI | Opened | 0.27 | 0.37 | 0.29 | 0.31 | 0.26 | 0.37 | 0.26 | 0.38 |
| | Closed | 0.38 | 0.4 | 0.4 | 0.4 | 0.37 | 0.37 | 0.4 | 0.4 |

**Table 76-Summary of the average values of indoor daylight variables in type B from 8:00 AM to 1:00 PM of Inha University Hospital.**

| | Blinds | Spring | | Summer | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|
| | | SE | NW | SE | NW | SE | NW | SE | NW |
| DF (%) | Opened | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| | Closed | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| LR (TV wall) | Opened | 23 | 8.6 | 9.1 | 9.3 | 23 | 9.1 | 35.3 | 8.1 |
| | Closed | 18.3 | 9.3 | 9.7 | 9.5 | 14 | 10 | 16.8 | 9.7 |
| LR (Eye & TV) | Opened | 18 | 4.8 | 2.1 | 2.1 | 1.8 | 4.7 | 1.9 | 3.6 |
| | Closed | 1.1 | 1.7 | 1 | 1.1 | 1.1 | 1.6 | 1 | 1.6 |
| Illum.(lux) | Opened | 153 | 305 | 179 | 176 | 158 | 348 | 106 | 131 |
| | Closed | 36 | 109 | 47 | 46 | 33 | 81 | 21 | 35 |
| DI | Opened | 7.9 | 14 | 11.7 | 12.3 | 7.6 | 11.6 | 6.5 | 8.4 |
| | Closed | 7.6 | 6.8 | 8.1 | 6.8 | 7.3 | 6.1 | 6.8 | 5.8 |
| UI | Opened | 0.37 | 0.38 | 0.27 | 0.31 | 0.26 | 0.37 | 0.3 | 0.38 |
| | Closed | 0.37 | 0.4 | 0.4 | 0.4 | 0.37 | 0.37 | 0.4 | 0.4 |

**Table 77-Summary of the average values of indoor daylight variables in type B from 2:00 PM to 6:00 PM**

# APPENDIX IV

## RESULTS OF INDOOR DAYLIGHT VARIABLE ANALYSIS OF

## ST. JOSEPH REGIONAL HEALTH CENTER

# 1. Luminance ratio on the TV wall on the 2nd floor

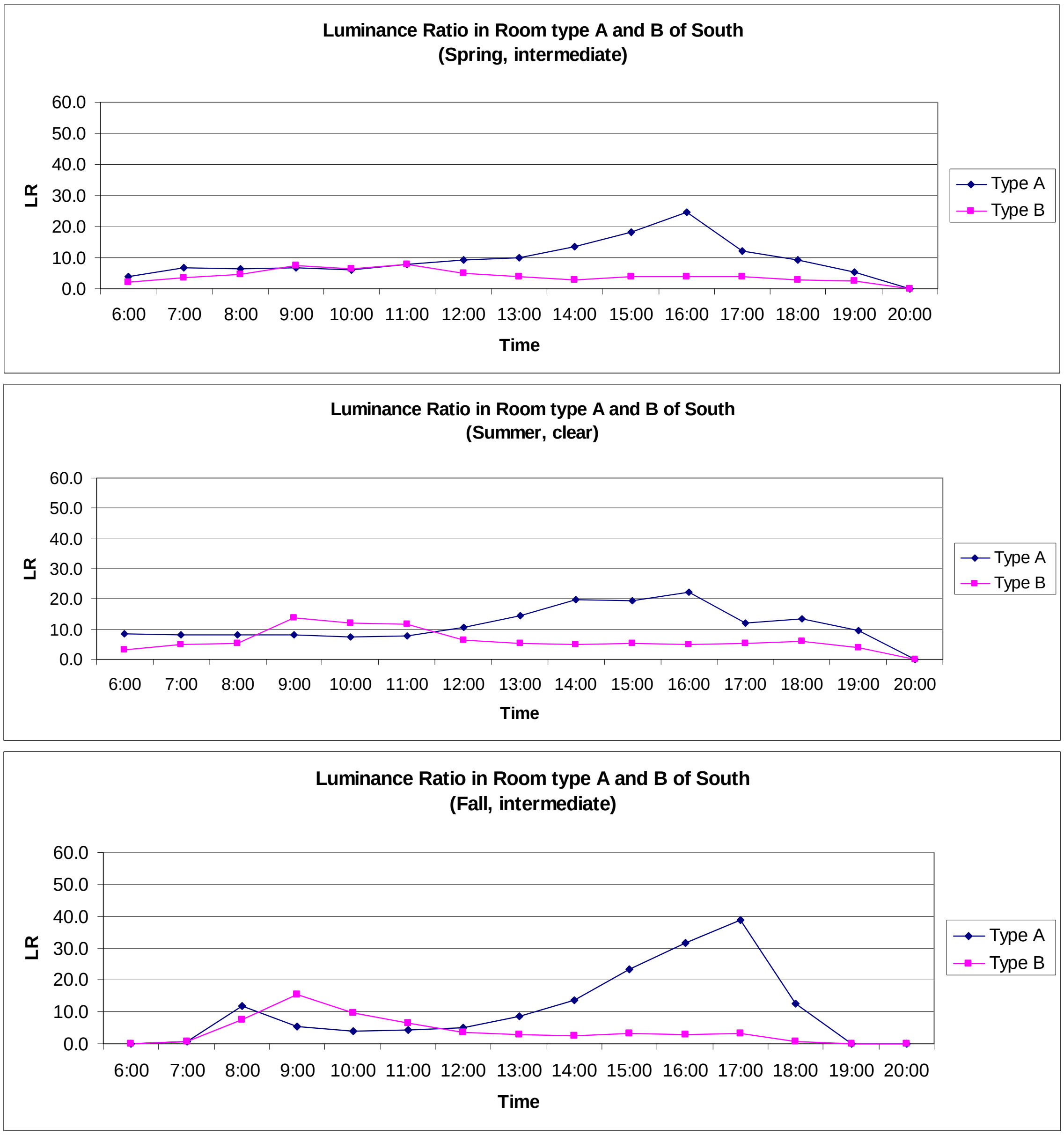



**Figure 102-Comparison of LR between type A and B in the south, 2nd floor.**

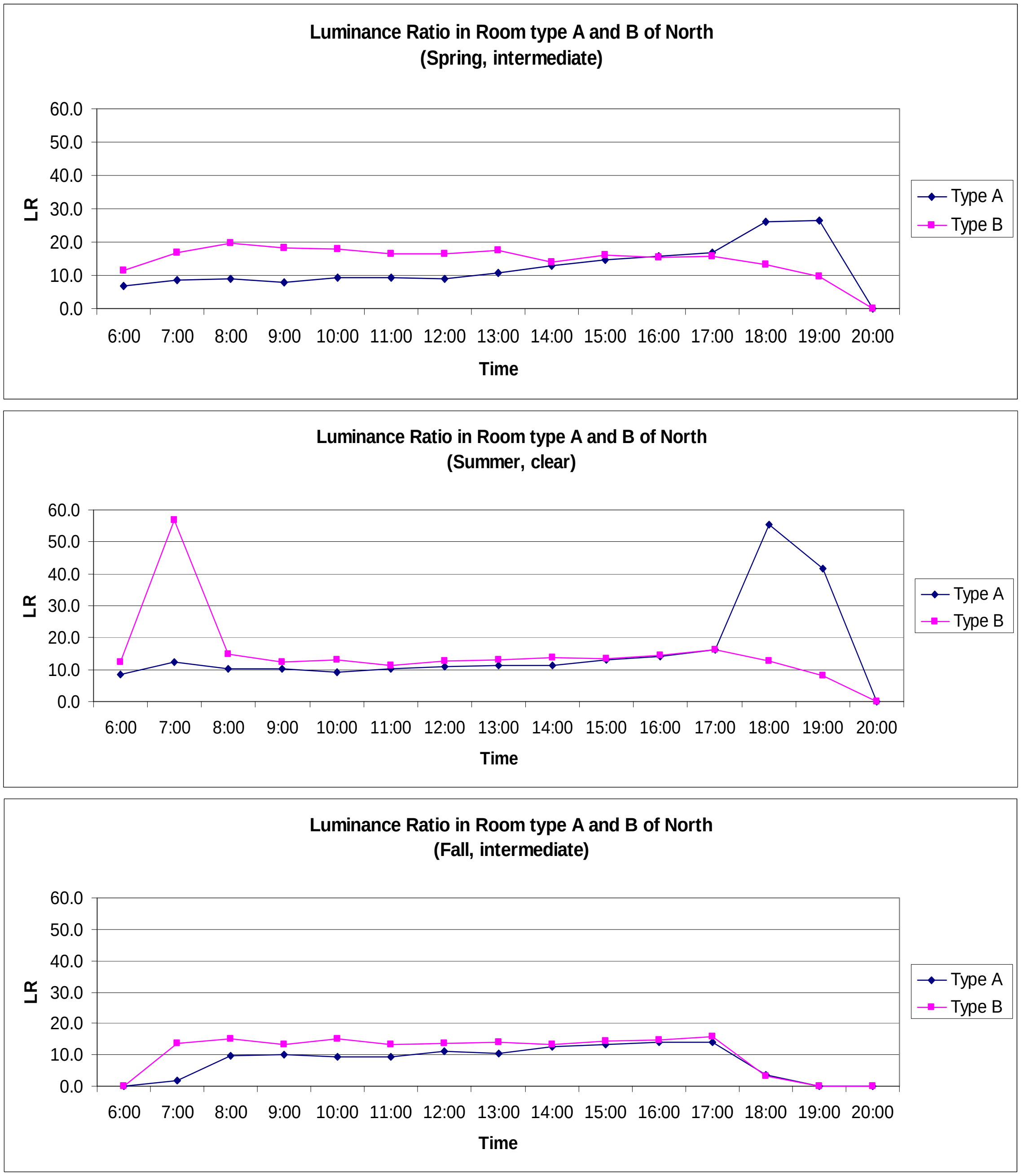



**Figure 103-Comparison between type A and B in the north, 2nd floor.**

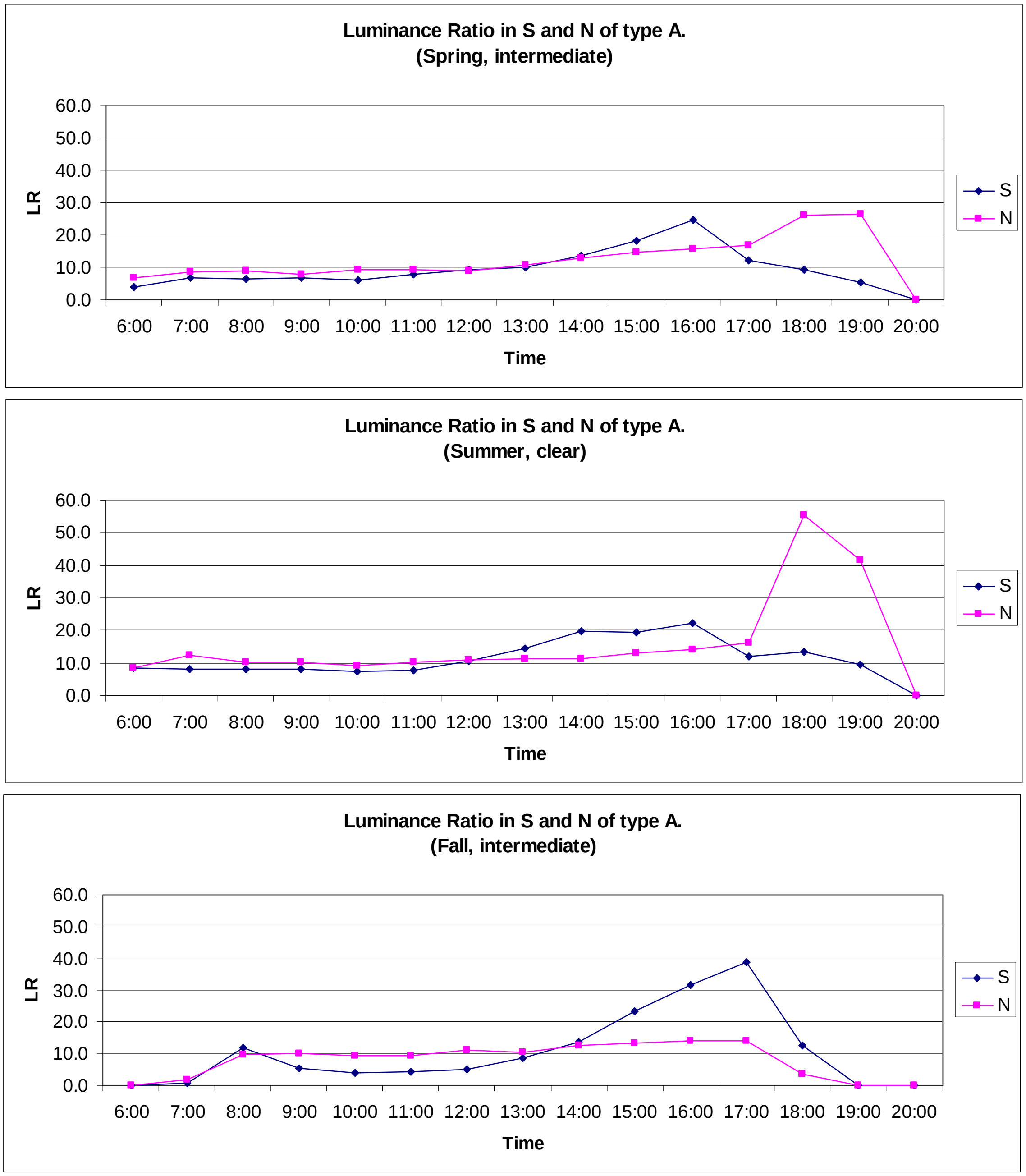



**Figure 104-Comparison between the south and the north of type A, 2nd floor.**

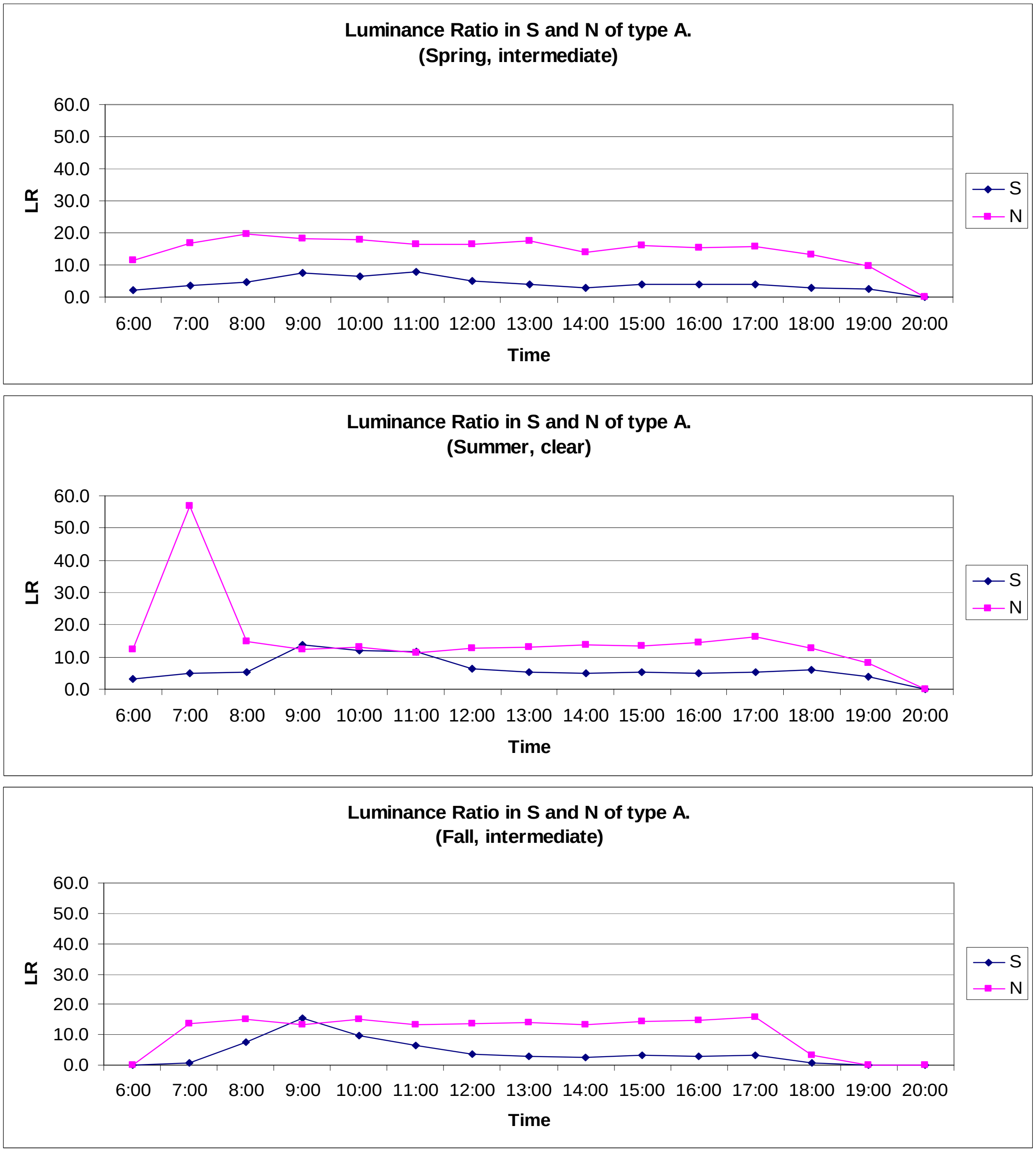



**Figure 105-Comparison between the south and the north of type B, 2nd floor.**

## 2. Luminance Ratio between Human eye and the TV point

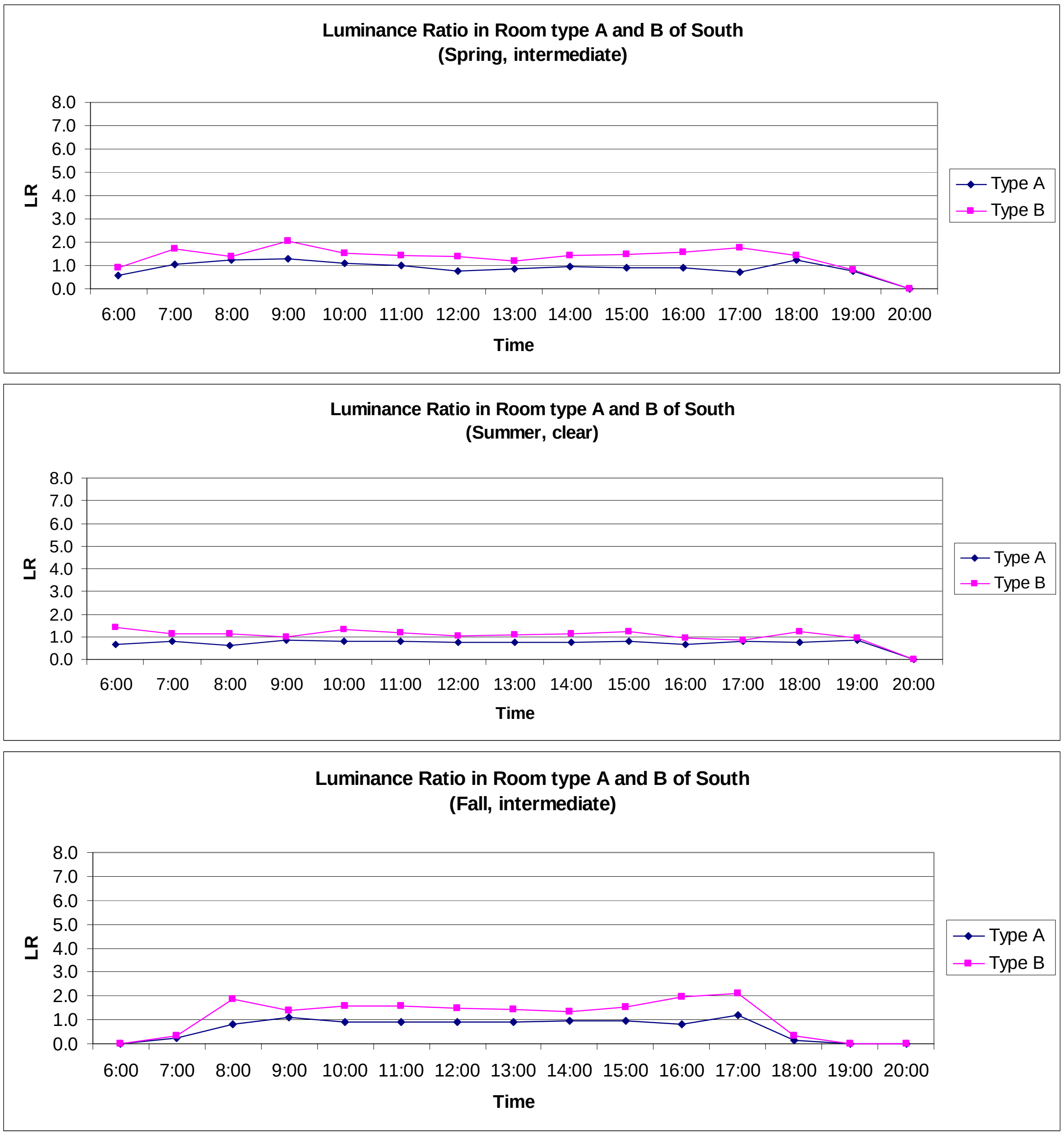



**Figure 106-Comparison between type A and B in the south, 2nd floor.**

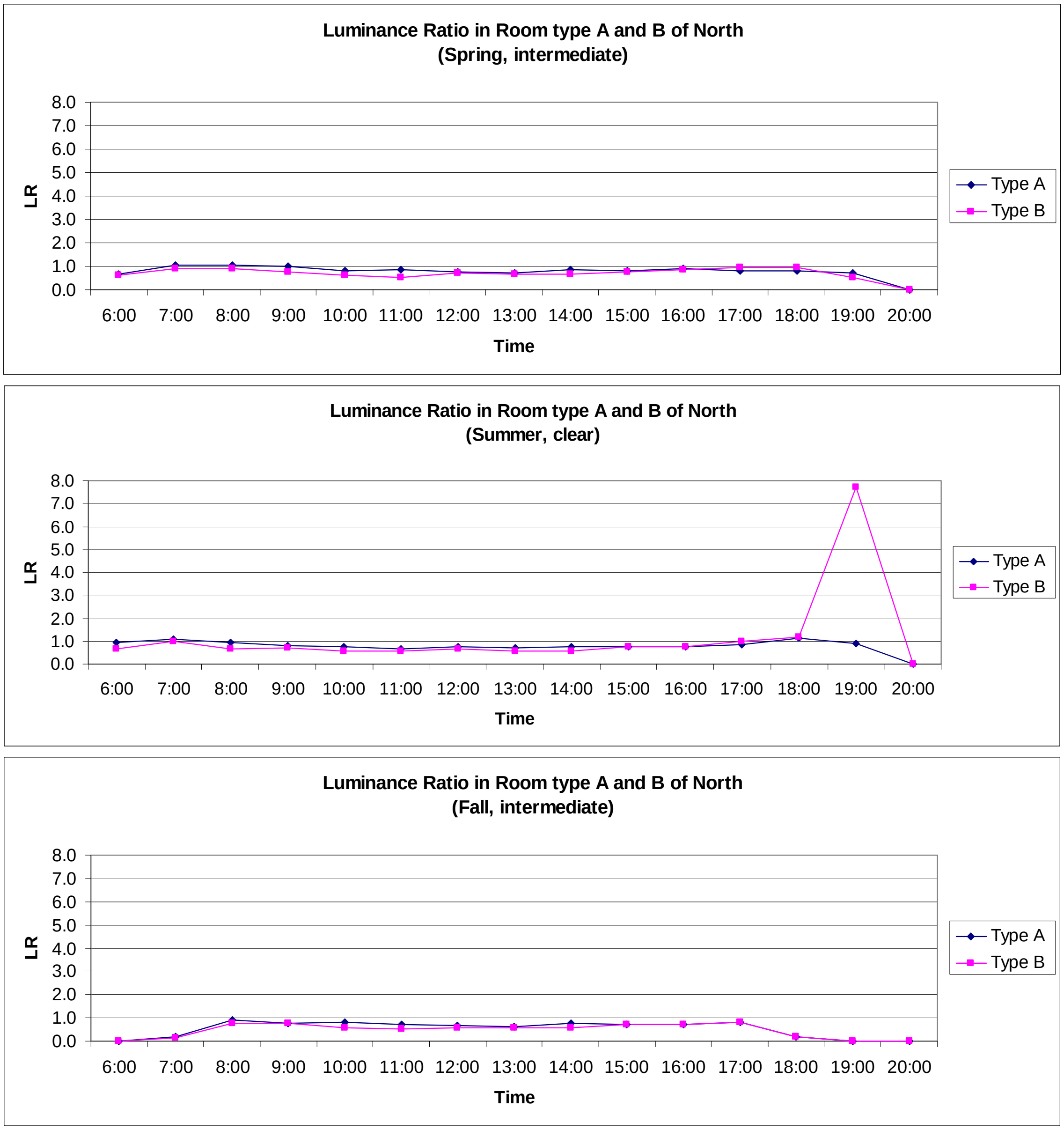



**Figure 107-Comparison between type A and B in the north, 2nd floor.**

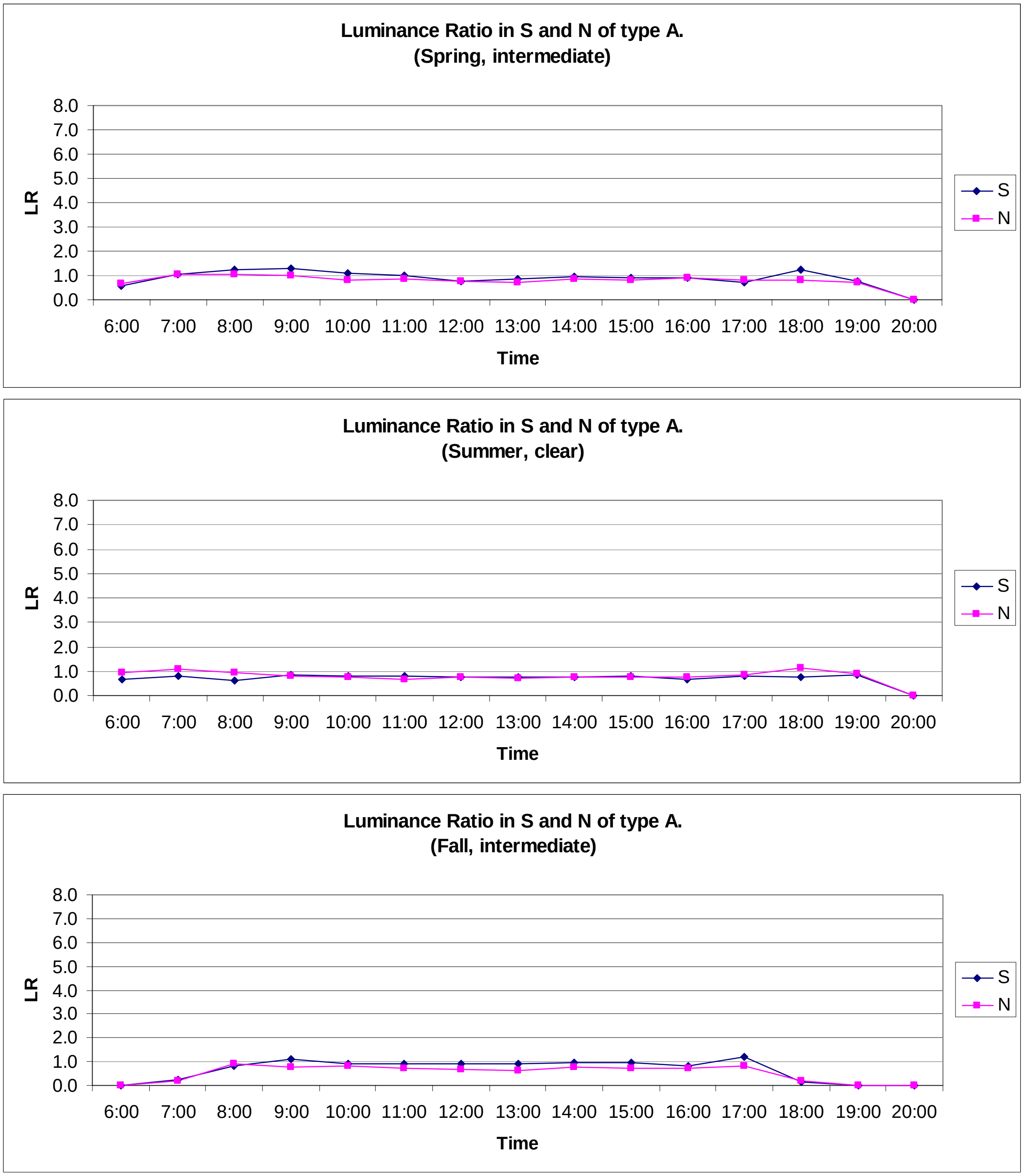



**Figure 108-Comparison between the south and the north of type A, 2nd floor.**

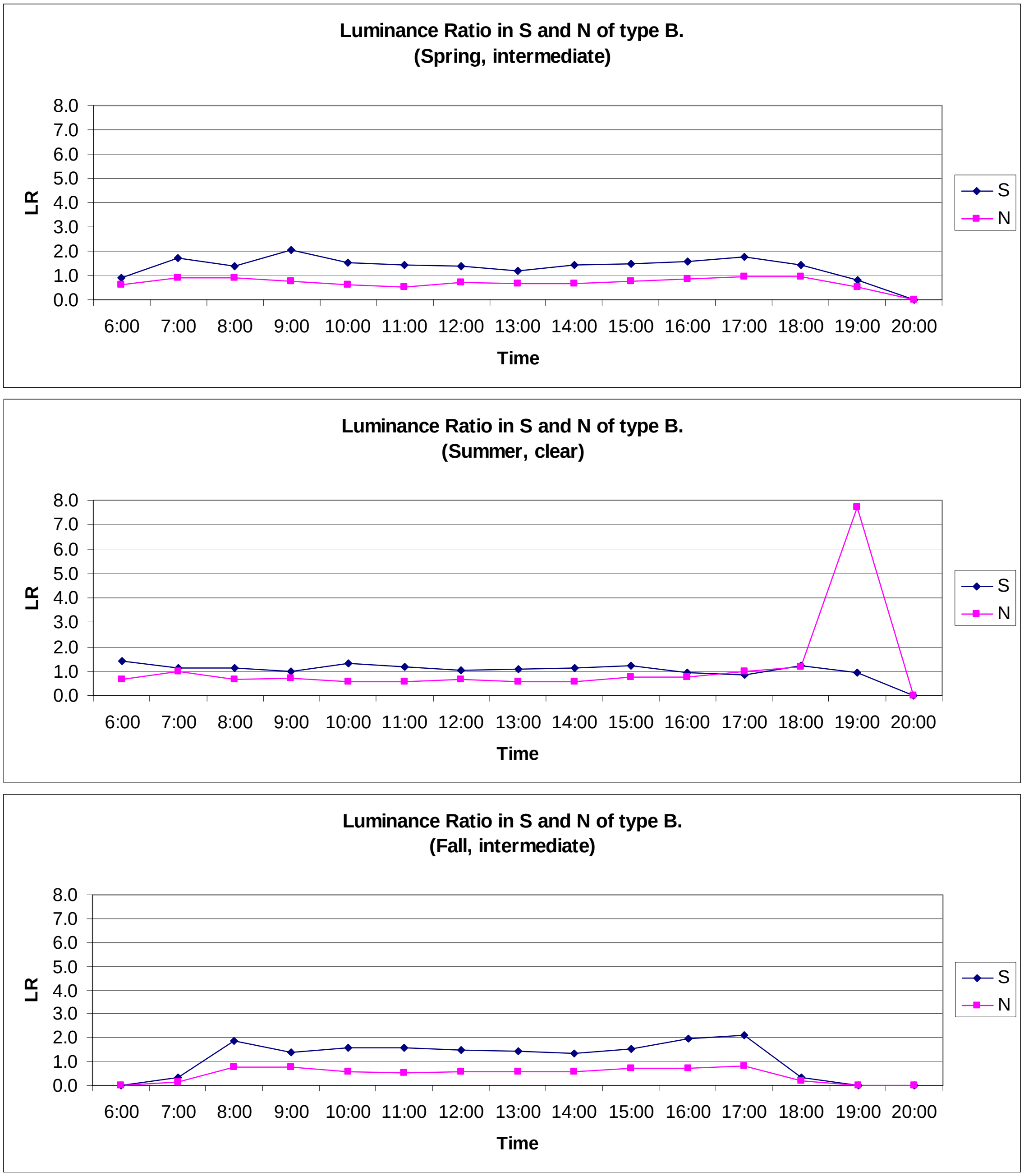



**Figure 109-Comparison between the south and the north of type B, 2nd floor.**

## 3. Average Illuminance

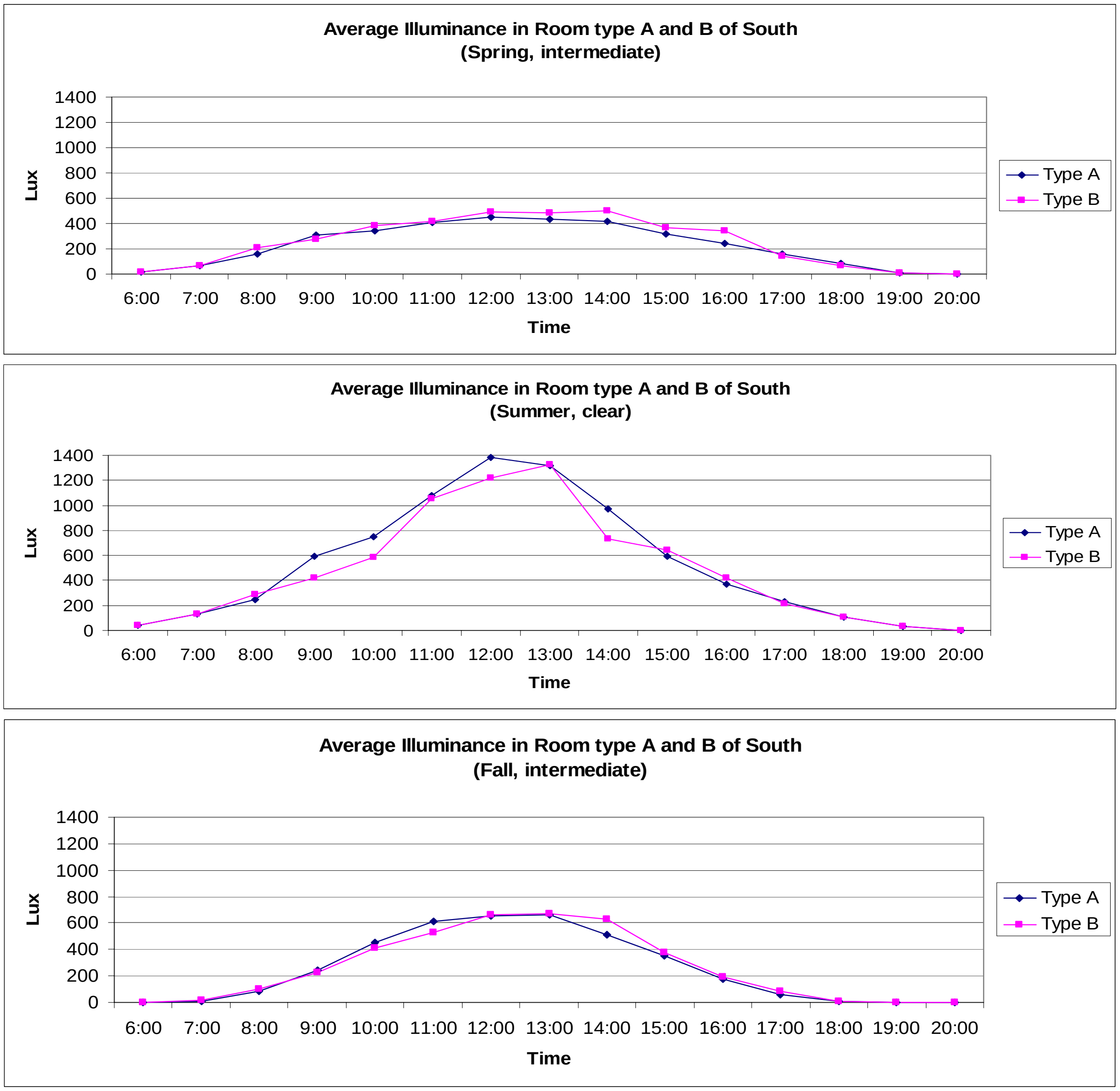



**Figure 110-Comparison between type A and B in the south, 2nd floor.**

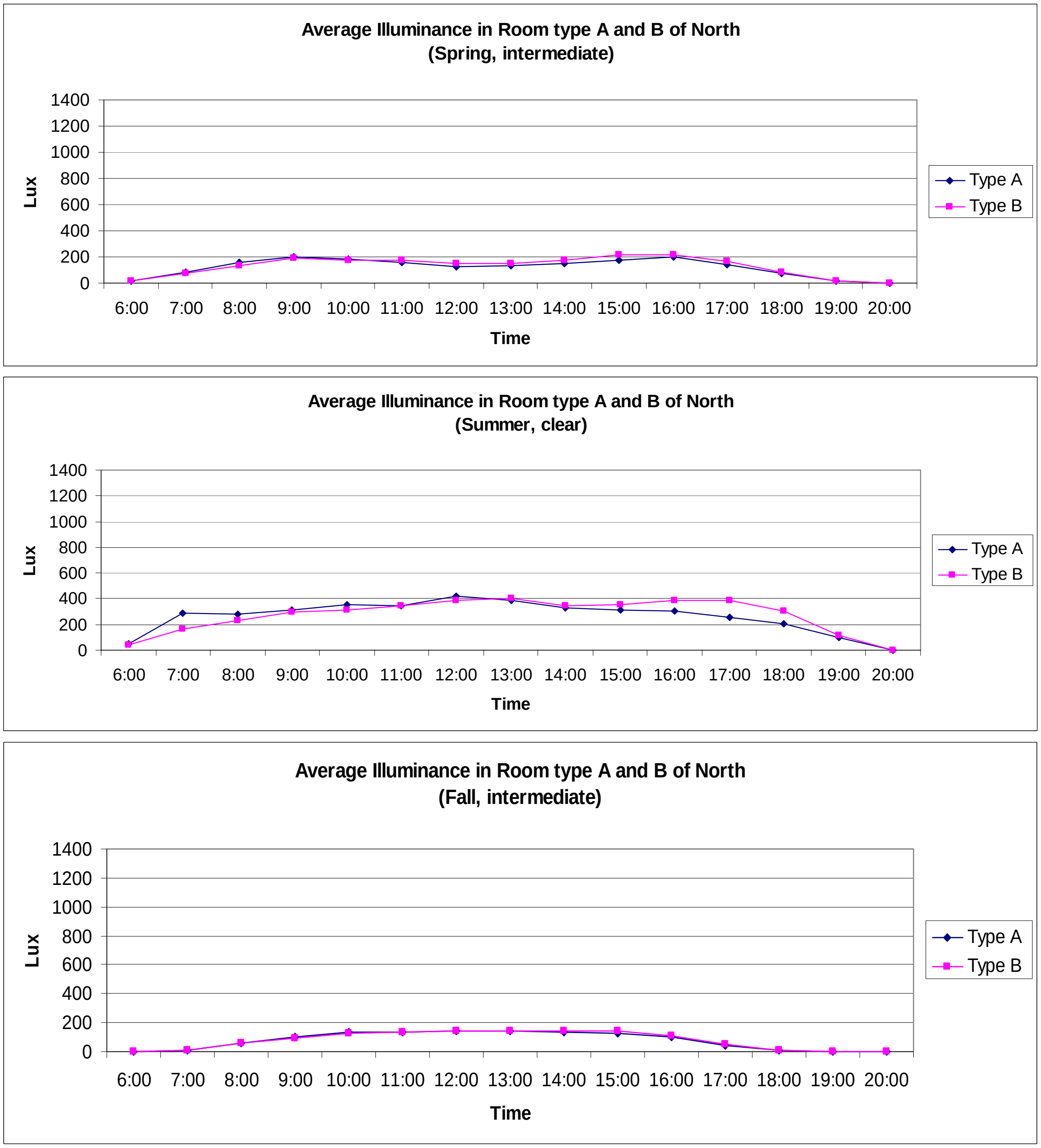



**Figure 111-Comparison between type A and B in the north, 2nd floor.**

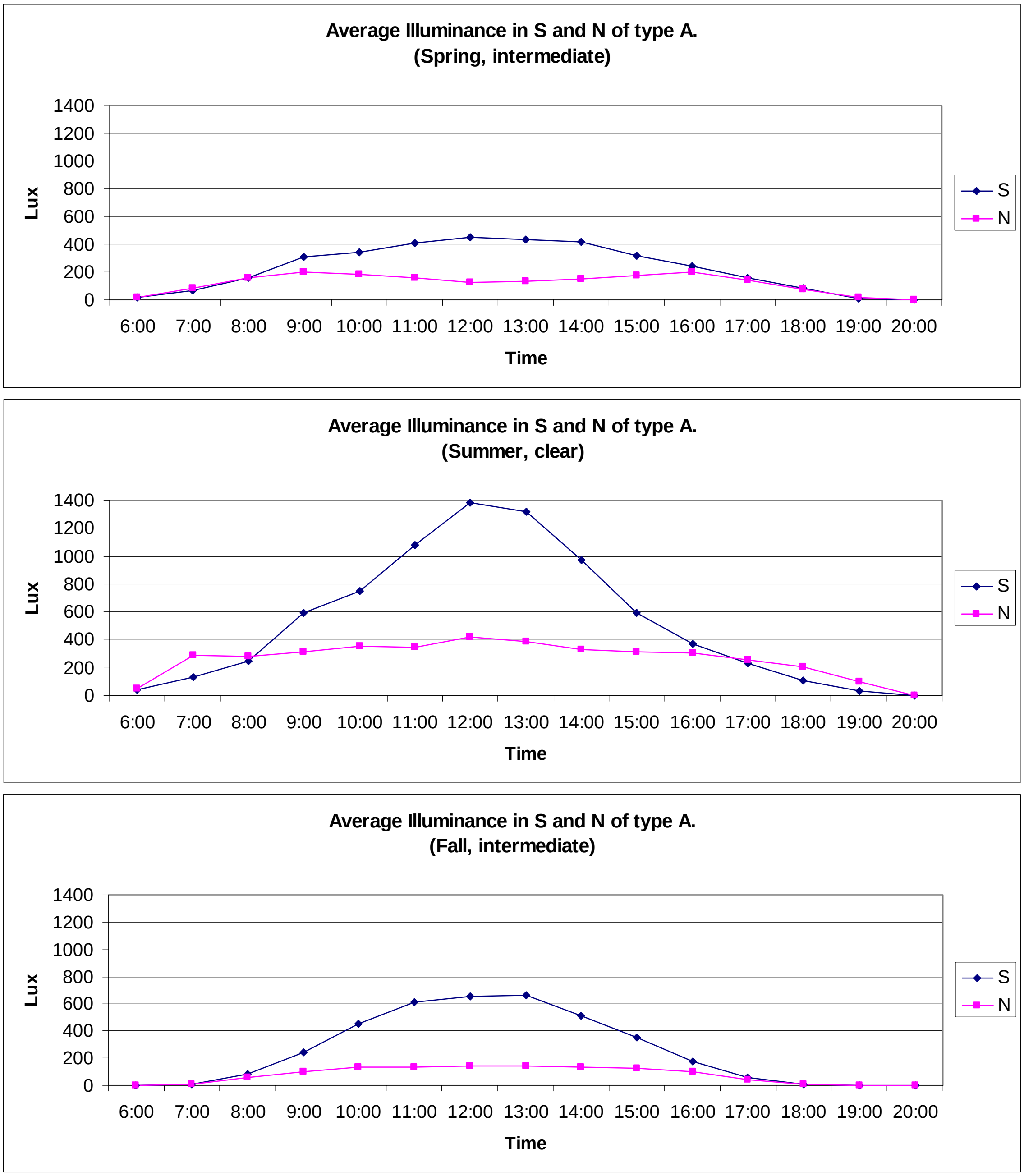



**Figure 112-Comparison between the south and the north of type A, 2nd floor.**

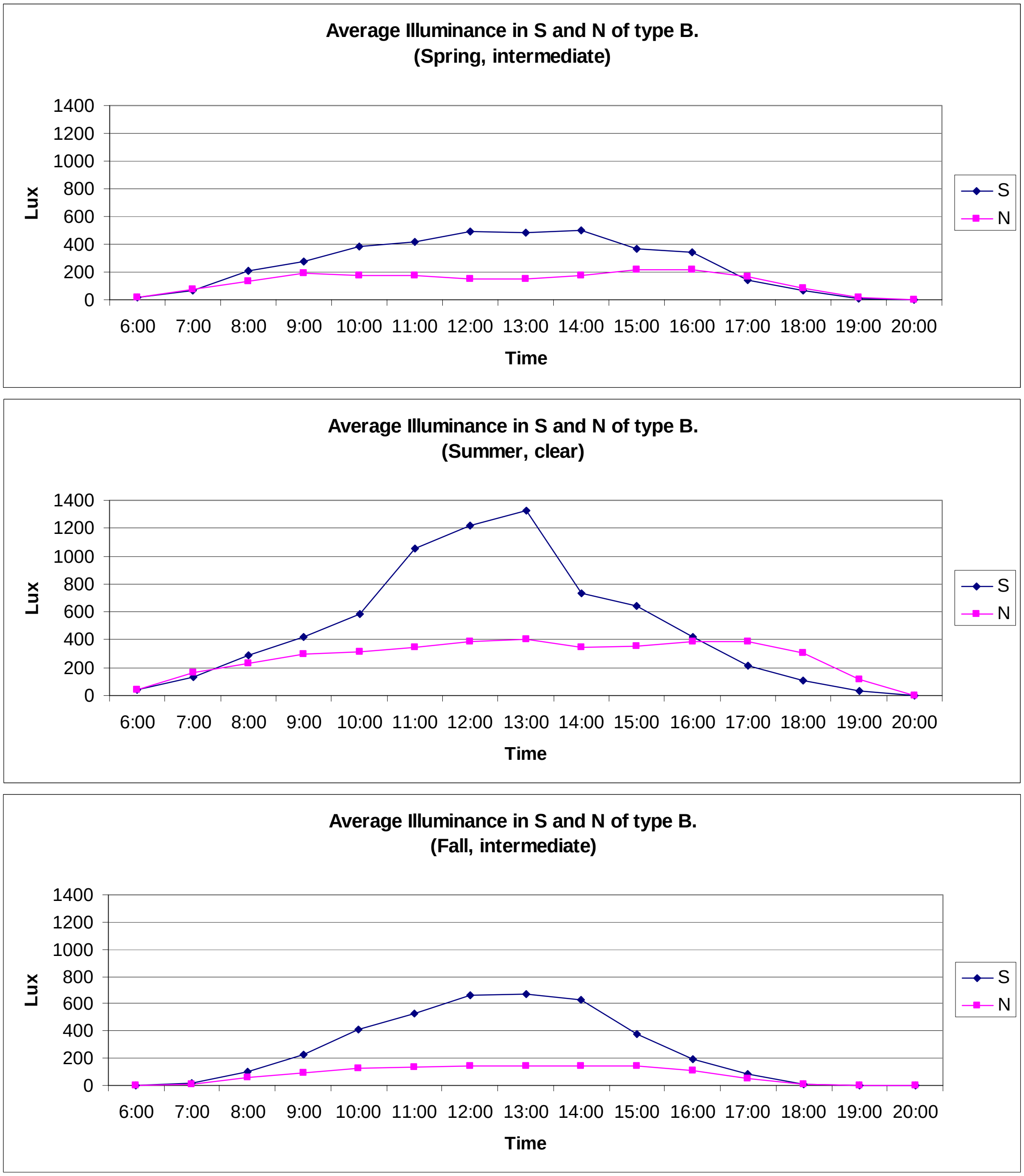



**Figure 113-Comparison between the south and the north of type B, 2nd floor.**

# 4. Diversity of Illuminance (DI)

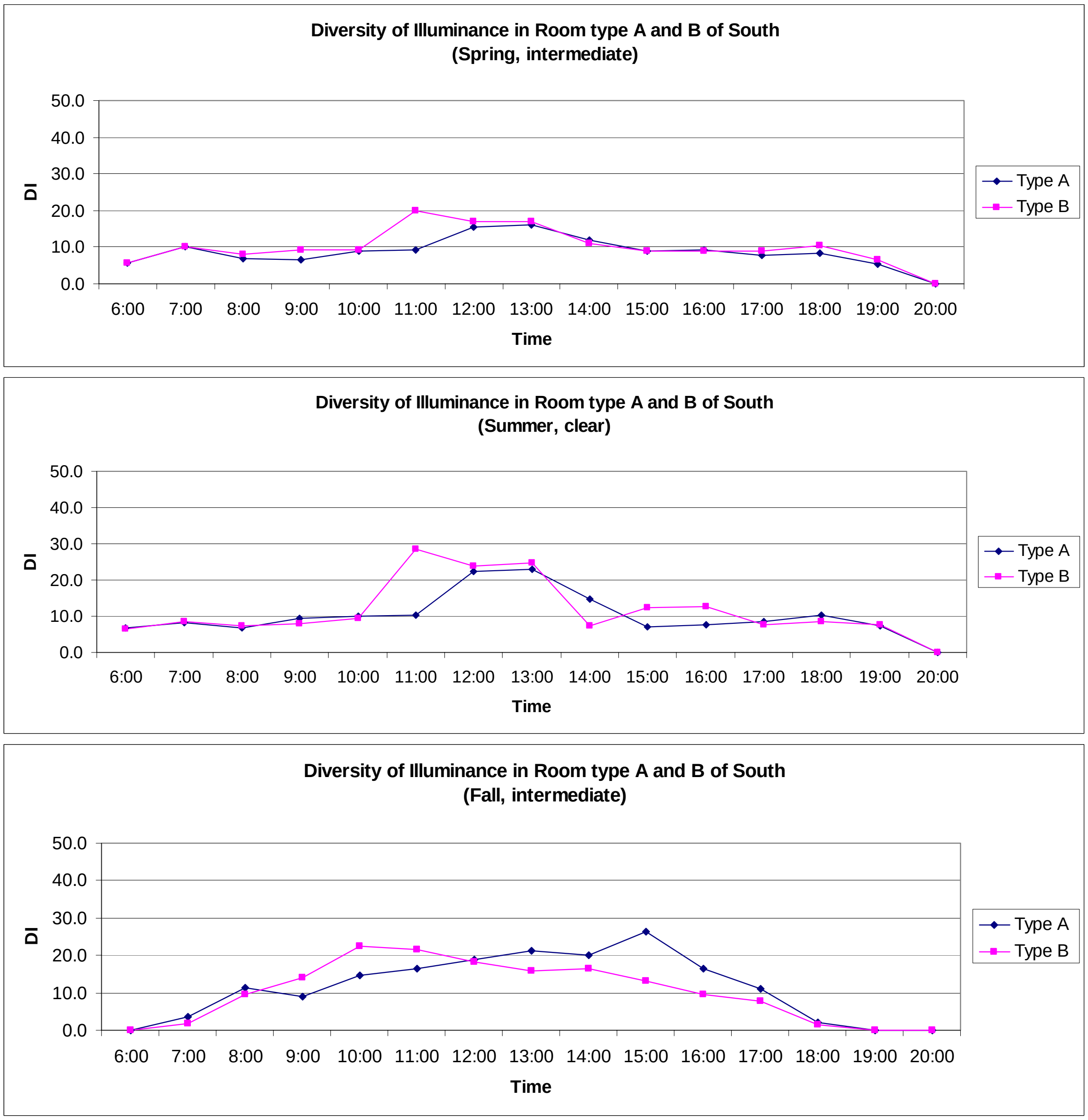



**Figure 114-Comparison between type A and B in the south, 2nd floor.**

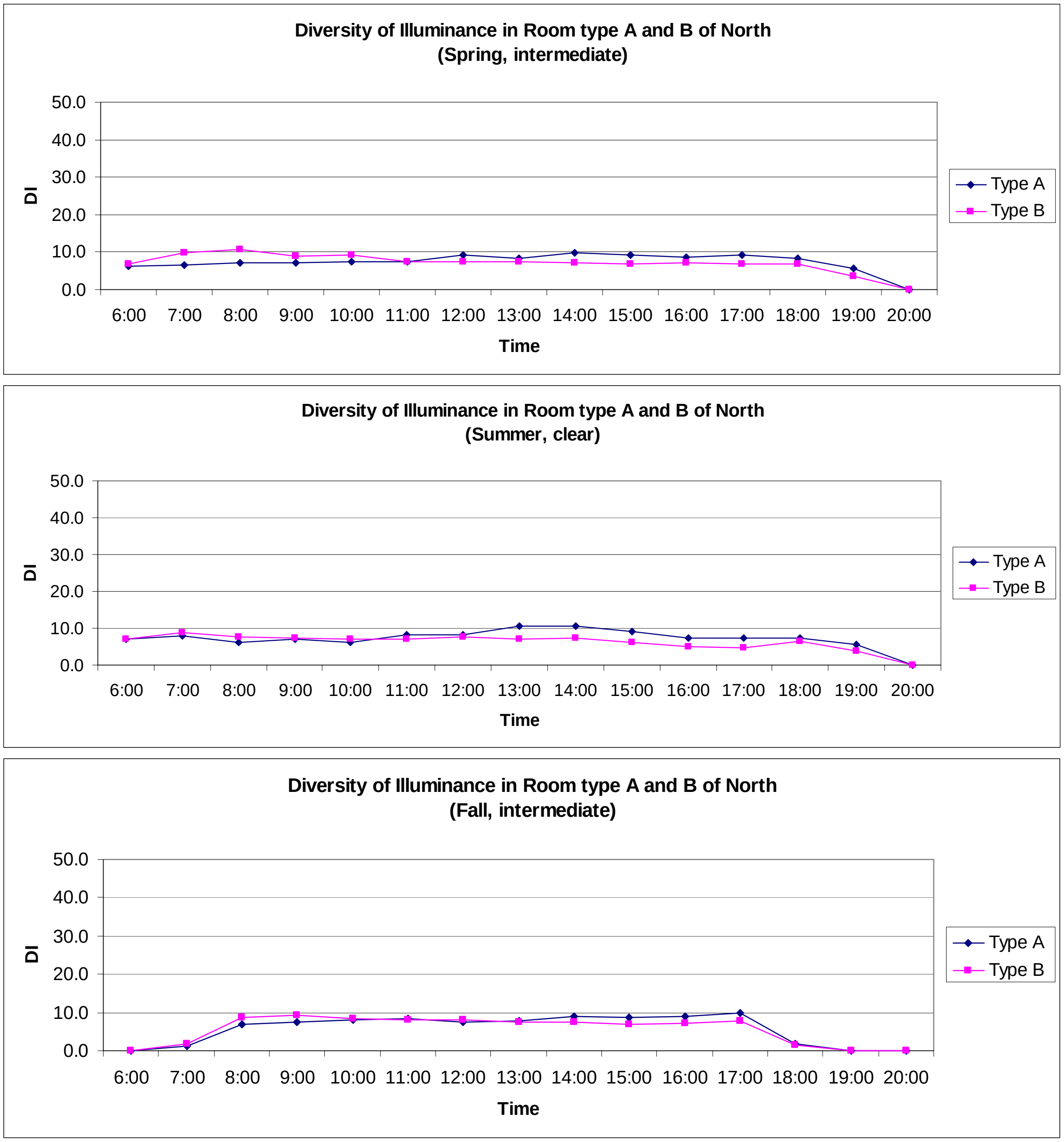



**Figure 115-Comparison between type A and B in the north, 2nd floor.**

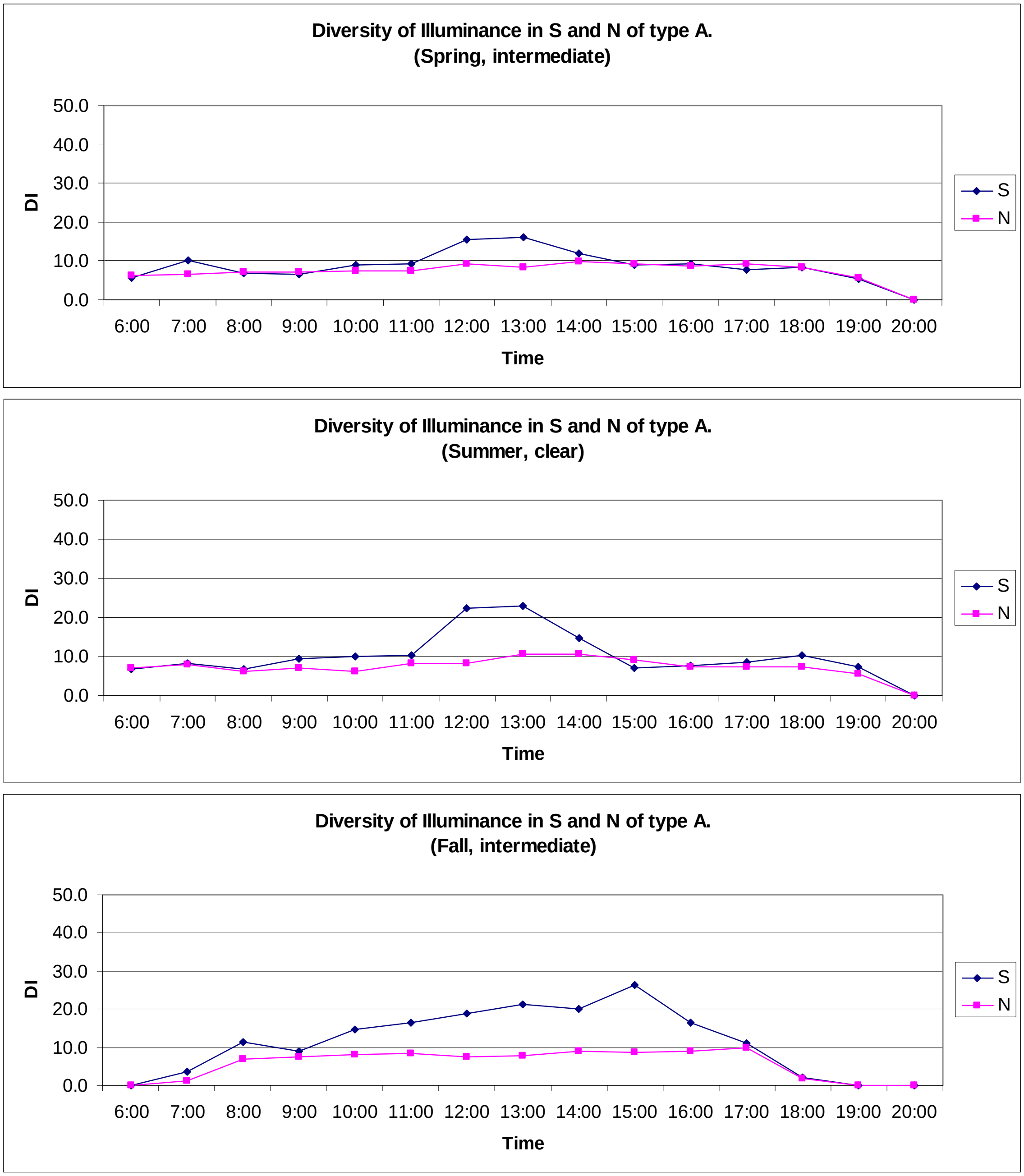
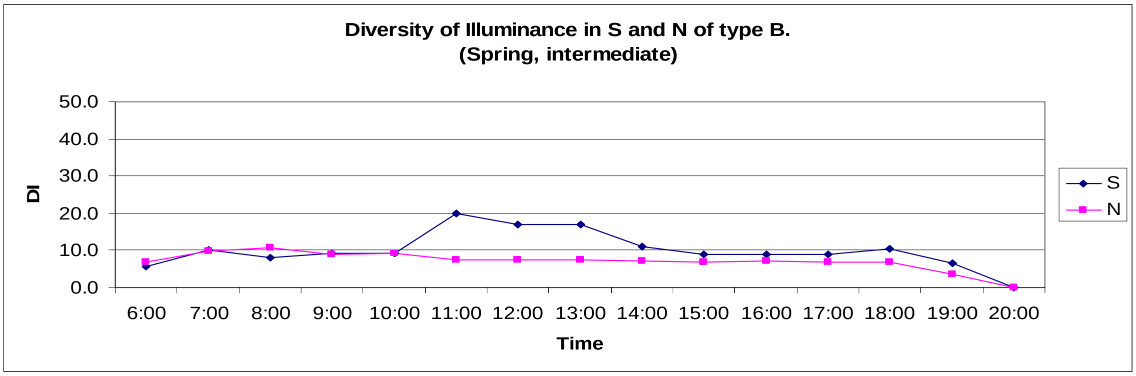
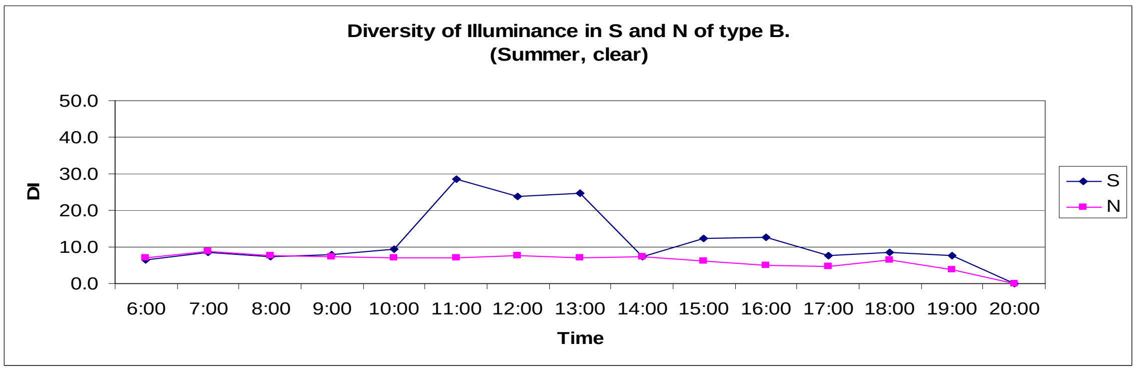



**Figure 116-Comparison between the south and the north of type A, 2nd floor.**



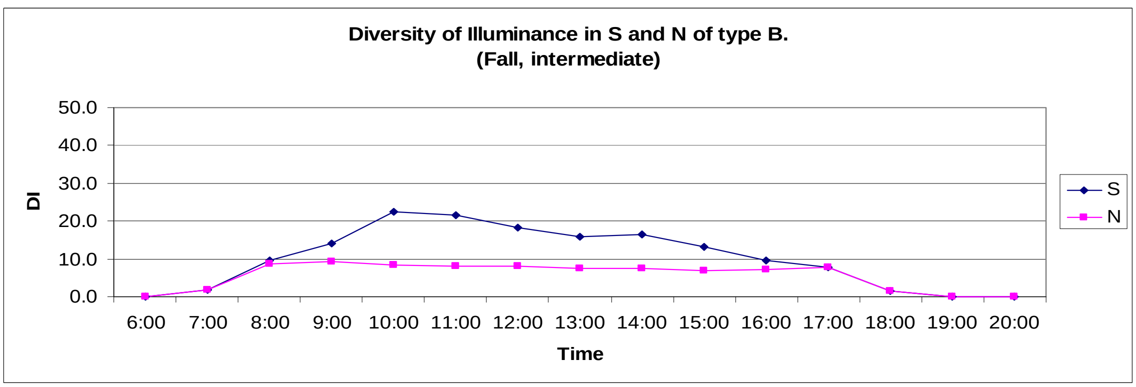
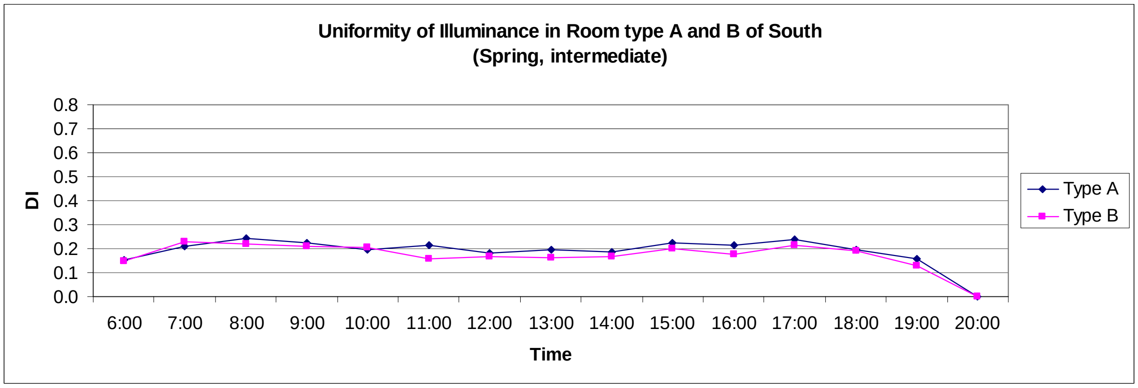
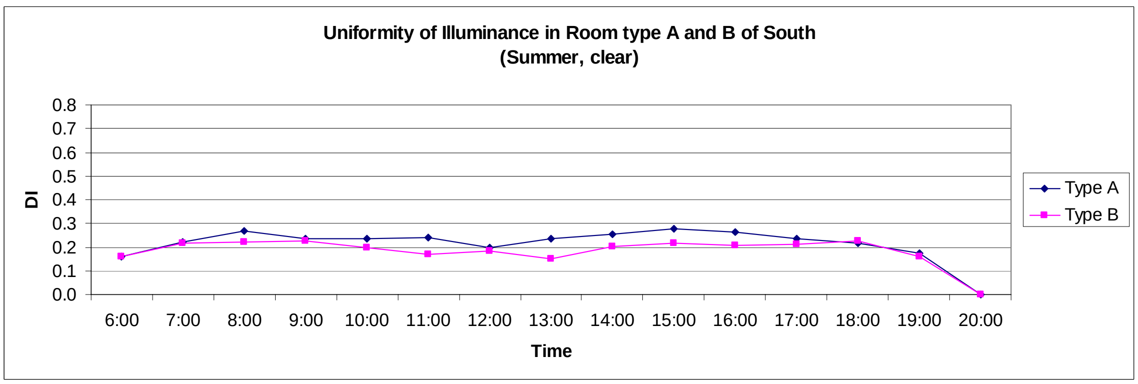




**Figure 117-Comparison between the south and the north of type B, 2nd floor.**

## 5. Uniformity of Illuminance (UI)



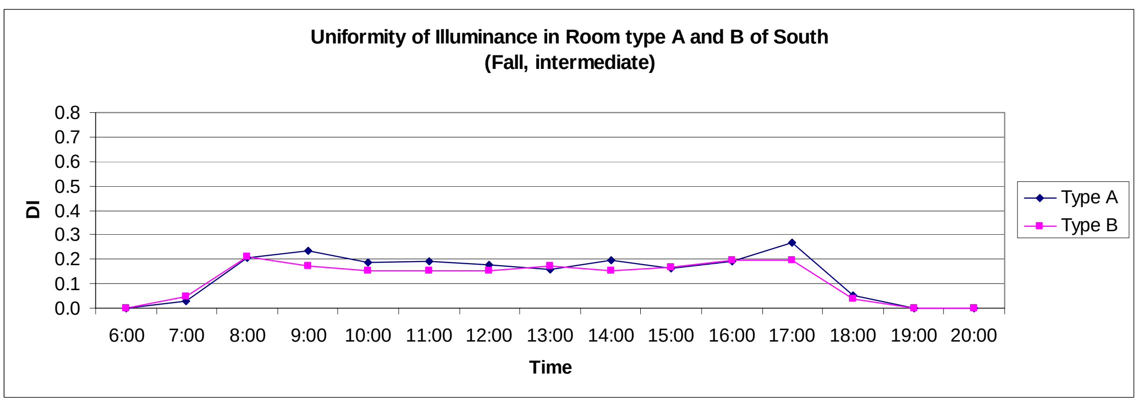




**Figure 118-Comparison between type A and B in the south, 2nd floor.**

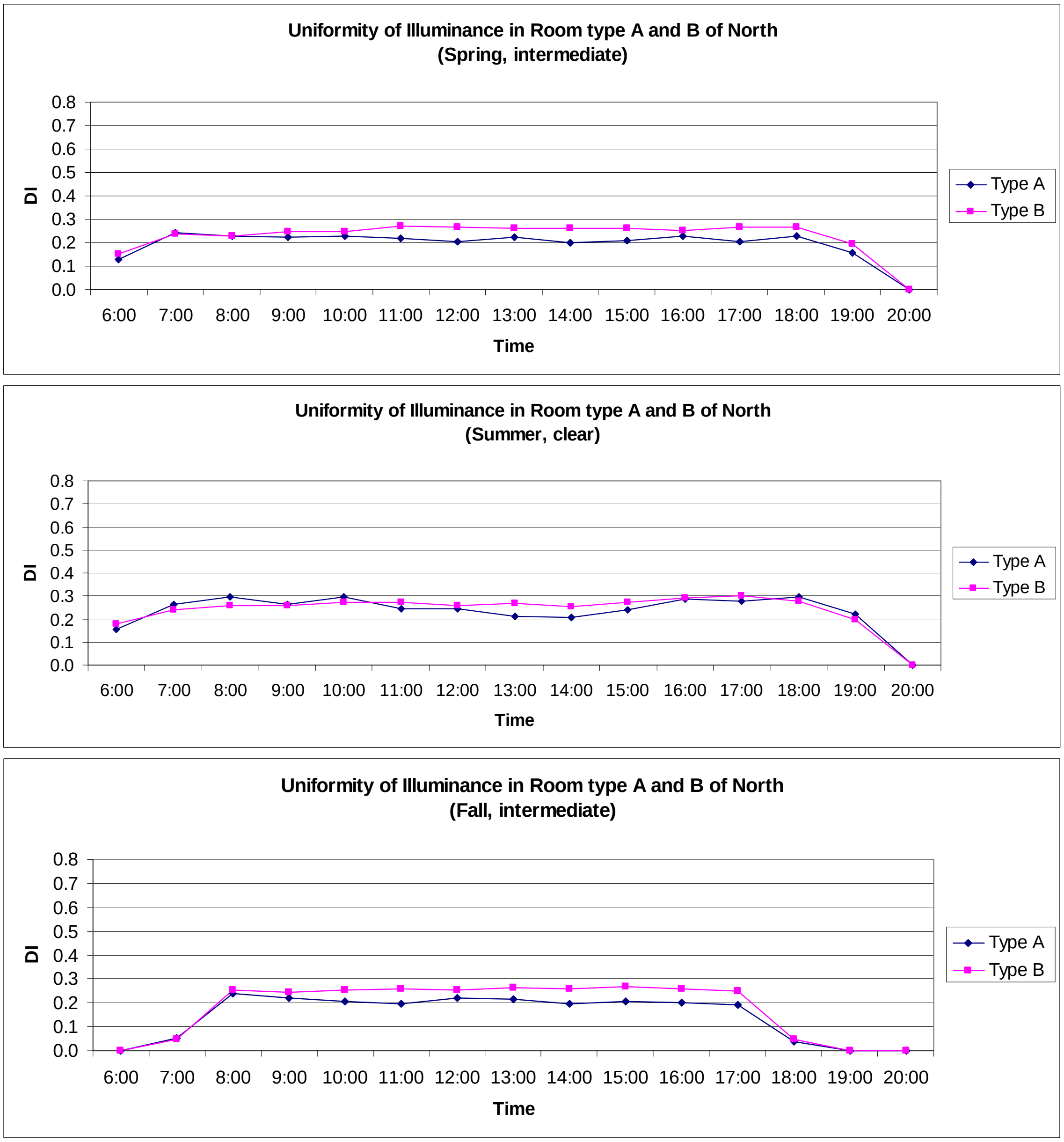



**Figure 119-Comparison between type A and B in the north, 2nd floor.**

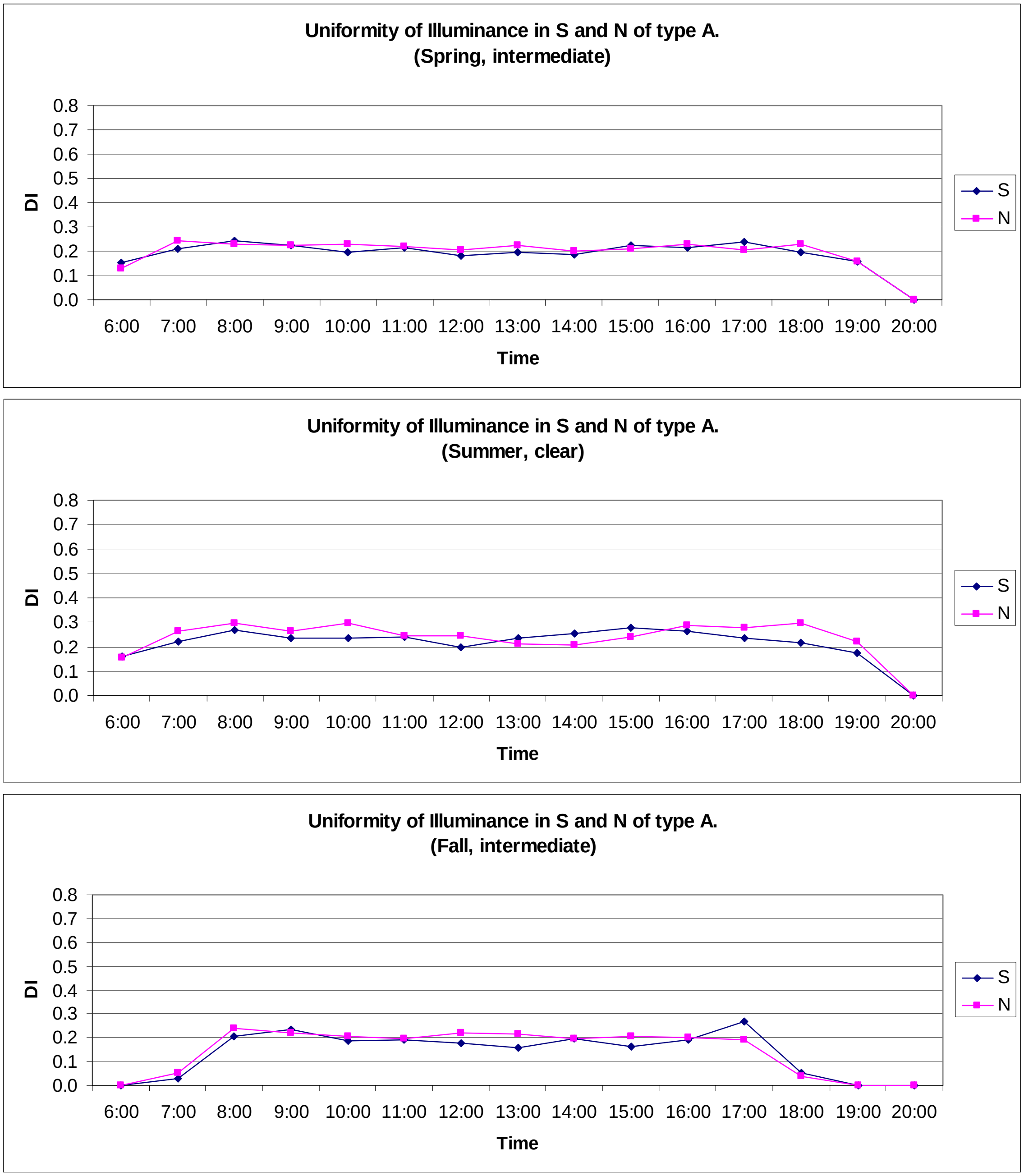



**Figure 120-Comparison between the south and the north of type A, 2nd floor.**

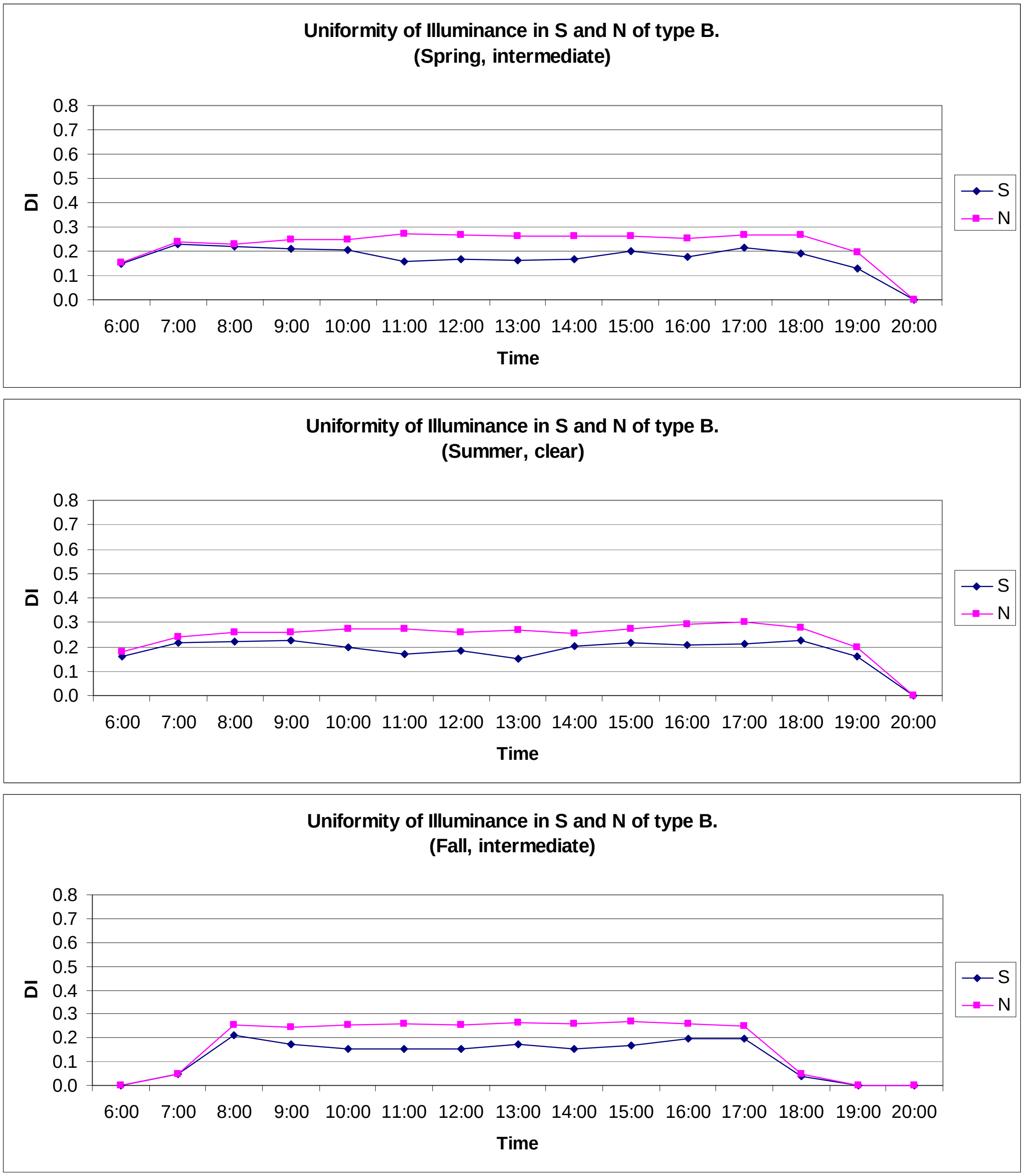



**Figure 121-Comparison between the south and the north of type B, 2nd floor.**

# APPENDIX V

# UNIX SCRIPT FOR CALCULATING ILLUMINANCE IN THE PATIENT ROOMS

```
#!/bin/bash
day=21  # The specific date of each month for calculating illuminance.

# The specific months for calculating illuminance.
for month in 1 2 3 4 5 6 7 8 9 10 11 12; do


# "turb" means turbidity.
if [ $month == 1 ]; then turb=2
  elif [ $month == 2 ]; then turb=2.5
    elif [ $month == 3 ]; then turb=3
       elif [ $month == 4 ]; then turb=3.5
          elif [ $month == 5 ]; then turb=4
            elif [ $month == 6 ]; then turb=4
              elif [ $month == 7 ]; then turb=4
                elif [ $month == 8 ]; then turb=4.5
                  elif [ $month == 9 ]; then turb=4.5
                    elif [ $month == 10 ]; then turb=3.5
                      elif [ $month == 11 ]; then turb=2.5
                        elif [ $month == 12 ]; then turb=2.5
 fi
    echo "$month"


   # Location of building (latitude, longitude, time & turbidity)
    coords="-a 37.30 -o -126.38 -m -135.00 -t "$turb""
    echo "$turb"


                   # The specific times for calculating illuminance.
                   for hour in  06 07 08 09 10 11 12 13 14 15 16 17 18 19 20; do


                             # sky condition +s(clear) +i(intermediate) -c(overcast).
                              skypar="$month $day $hour +i $coords"


                              # Generate the sky based on the above "sky condition" formula
                              and a building orientation.
                              gensky $skypar | xform -rz 120.00 > temp/sky_temp.rad
```

```
# Make an OCT file with material, geometry and glazing files.
oconv  mat/user/ST_ref.rad mat/user/ST_mass.rad mat/user/ST_insidewall2.rad \
mat/user/ST_inside_wall.rad mat/user/ST_curtain2.rad mat/user/Inha_shelf1.rad \\
mat/user/ST_floor.rad mat/user/ST_bed_bedfm.rad mat/user/Inha_coach.rad \
mat/user/ST_windowfm_2.rad mat/user/ST_ceiling.rad mat/user/Inha_mass.rad \
glz/vir/blue_low_e.rad \
  1603/new_1603_1_floor_m_st_ref.rad \
  1603/new_1603_1_floor_m_st_mass.rad \
  1603/new_1603_1_floor_m_st_insidewall2.rad \
  1603/new_1603_1_floor_m_st_inside_wall.rad \
  1603/new_1603_1_floor_m_st_curtain2.rad \
  1603/new_1603_1_floor_m_inha_shelf1.rad \
  1603/new_1603_1_floor_m_st_floor.rad \
  1603/new_1603_1_floor_m_st_bed_bedfm.rad \
  1603/new_1603_1_floor_m_inha_coach.rad \
  1603/new_1603_1_floor_m_st_windowfm_2.rad \
  1603/new_1603_1_floor_m_st_ceiling.rad \
  1603/new_1603_1_floor_g_blue_low_e_glass.rad \
  1603/new_1603_1_floor_m_inha_mass.rad temp/sky_temp.rad \
          sky.rad > octree/temp.oct


  #Calculation of tracing rays.
  rtrace -w -h -I+ -dp 512 -ar 19 -ms 1.5e+002 -ds .3 -dt .1 -dc .5 -dr 1 \
        -sj .7 -st .1 -ab 5 -aa .2 -ad 400 -as 64 -av 0.5 0.5 0.5 -lr 6 \
        -lw .002 -st .001 -dj .02 -av 0 0 0 -i \
           octree/temp.oct < 1603/floor/Grid_1621.pts \
         | rcalc -e '$1=179*(.265*$1+.670*$2+.065*$3)' \
            >> 1603/floor/#floor_inter_all_month.txt


done
done
```

# APPENDIX VI

# QUESTIONNAIRE SURVEY FORM

**INFORMATION SHEET**

**Study on the Relationship between indoor daylight environment and patient ALOS in Healthcare Architecture**

Date 02/09/2005

You are asked to participate in a research study regarding relationship between indoor daylight environment and patients' hospitalization in healthcare architecture. You were selected to be a possible participant, because you are a patient of a subject healthcare facility. A total of about 50 people have been asked to participate in this study. The primary purpose of this study is to explore the correlations between patients' hospitalization times and levels of indoor daylight in their rooms in healthcare facilities.

If you agree to participate in this study, you will be asked to complete the questionnaire survey. It will take about 10 to 15 minutes for you to fill out the questionnaire. There are no risks associated with this study. There is no compensation for the participants.

This study might be published later, but will not mention any names of participants. All information will be treated confidentially. Unless you specially request otherwise, participant names, or locations will not be identified in any information distributed about this project. All information will be coded. The collected data will be used only for this study. Research records will be stored securely and only Joon Ho Choi will have access to the records. Your decision, whether or not to participate, will not affect your current or future relations with Texas A&M University or St. Joseph Regional Health Center. If you decide to participate, you are free to refuse to answer any of the questions that may make you uncomfortable. You can withdraw at any time without your relations with the university, job, benefits, etc., being affected. You can contact Joon Ho Choi, joonhochoi@neo.tamu.edu, (979) 412-3293, or Dr. Liliana Beltran, Assistant Professor, College of Architecture lbeltran@archone.tamu.edu, (979) 845-6545 with any questions regarding this study.

This research study has been reviewed by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, please contact the institutional Review Board through Dr. Michael W. Buckley, Director of Research Compliance, Office of Vice President for Research at (979) 458-4067 (mwbuckley@tamu.edu).

You have read the above information. If you have questions, please feel free to contact us. We will provide additional information to answers to your satisfaction. Please confirm your willingness to participate by filling out the questionnaire and also keep a copy of this document for your records.

Thank you very much for your assistance with this project.

Regards,

Joon Ho Choi
M.S. candidate, Department of Architecture,
College of Architecture, Texas A&M University
College Station, TX 77843-3137
Tel: (979) 412-3293, email: joonhochoi@neo.tamu.edu

**GENERAL INFORMATION**

1. What is your gender? ☐ Female ☐ Male

2. How old are you?
☐ 20s ☐30s ☐40s ☐50s ☐60s ☐70s or over

3. How long have you stayed in this room? ______________________ days

4. What is the name of the ward where you are staying? _________________________ward

**OCCUPANTS' OPINION**

Please place a check (V) or numbers on each question to indicate how you evaluate the following statements.

5. What type of lighting do you prefer?
☐ Daylight ☐ Electric light ☐ Both ☐ None

6. Please rank in numerical order the following in terms of what is most preferable.
(1- most preferred, 3- least preferred)
( ) Daylight in the morning ( ) Daylight at noon ( ) Daylight in the afternoon

7. How long do you use the curtain for a day in this room?
☐Less than 1hour ☐1 to 2 hours ☐3 to 5 hours ☐6 to 8 hours ☐ 9 hours or more

8. What is the main reason to use the curtain?
☐Too much daylight ☐Privacy
☐Nothing ☐Others (specify)______________

9. Which seasonal daylight would be preferable?
Please rank in numerical order. (1-most preferable, 4-least preferable)
( ) Spring ( ) Summer ( ) Fall ( ) Winter

10. Which of the following controls do you have over the lighting in this room? (Check all that apply)
☐Light switch ☐Light dimmer ☐Desk light
☐Window blinds or curtain ☐None of the above
☐Other: (specify)__________________________

11. Do you consider yourself as sensitive to glare*? ☐ Yes ☐ No
(* Glare: Excessive brightness that may be caused by either direct of indirect viewing of a light source.)

12. Which type of eyeglasses do you use?

☐Corrective glasses for near-sighted ☐Corrective glasses for far-sighed
☐Sunglasses ☐No glasses
☐Other (specify)______________________

13. If you feel visual discomfort (glare, reflections, contrast, etc) by lighting, what are mainly disturbing you? Please rank in numerical order. (1-most disturbing, 6-least disturbing)

( ) Direct daylight ( ) The electric light on the ceiling
( ) Diffused daylight ( ) The electric light on the bed head
( ) Reflected daylight on the wall ( ) Others (specify)______________

14. Please rank in numerical order the following in terms of what is most important to your physical well-being in this room. (1- most important, 6-least important)

( ) Daylight ( ) Electric light
( ) Humidity ( ) Thermal condition
( ) Window view ( ) Noise level

Please place a check (V) on each line of boxes to indicate how much you agree with the following statements.

| | | Very dim | | | Moderate | | | Very bright |
|---|---|---|---|---|---|---|---|---|
| 15. | How do you feel daylight in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. | How do you feel the electric lights in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | | Very small | | | Moderate | | | Very large |
| 17. | How do you feel the window size in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | | Very dissatisfied | | | Moderate | | | Very satisfied |
| 18. | How satisfied are you with the visual comfort of daylight in this room (e.g., glare, reflections)? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. | How satisfied are you with controlling of daylight in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. | Does daylight contribute toward upgrading the overall room environment and atmosphere in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. | How satisfied are you with the visual comfort of the electric lights in this room (e.g., glare, reflections)? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | Very dissatisfied | | | Moderate | | | Very satisfied |
|---|---|---|---|---|---|---|---|---|
| 22. | How satisfied are you with controlling of the electric lights in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23. | Do the electric lights contribute toward upgrading the overall room environment and atmosphere in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24. | Overall, does the lighting quality enhance or interfere with your health recovery? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 25. | How satisfied are you with the window view in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 26. | Does the window in this room provide sufficient privacy? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 27. | How satisfied are you with the position of the window in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 28. | How satisfied are you with the temperature in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 29. | How satisfied are you with controlling of the temperature in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 30. | Overall, does the thermal comfort in this room enhance or interfere with your health recovery? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 31. | How satisfied are you with the noise level in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 32. | How satisfied are you with the placement of the bed in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 33. | How satisfied are you with the colors and textures of ceiling, flooring, furniture and surface finishes in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 34. | How satisfied are you with the amount of light in this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 35. | All things considered, how satisfied are you with this room? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 36. | How satisfied are you with the building overall? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**COMMENTS**

37. Please describe any other issues related to lighting that are important to you, and/or write any additional comments or recommendations about your hospital room or building overall.

**- Thank you for participating in this survey. -**

# APPENDIX VII

# GLOSSARY

1. candela (cd) : the unit of luminous intensity.
2. diffused lighting : lighting that is not predominantly incident from any particular direction.
3. glare : luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted that causes annoyance, discomfort, or loss in visual performance and visibility.
4. illuminance : the density of luminous flux incident on a surface at a point. The average luminous flux on an area is the quotient of the total flux incident on the surface to the area of the surface.
5. illumination : the act of illuminating or state of being illuminated. This term has been used for density of luminous flux on a surface (illuminance) and such use is to be deprecated.
6. luminance : the luminous intensity of any surface in a given direction per unit area of that surface as viewed from that direction. All things visible have some luminance. Units are candelas per square meter (SI),
7. luminance ratio : the ratio between the luminances of any two areas in the visual field.
8. luminous flux : the time rate of flow of light.
9. lux (lx) : the international system (SI) unit of illuminance. It is the illumination on a surface one square meter in area on which there is a uniformly distributed flxu of one lumen, or the illumination produced at a surface of which all points area at a distance of one meter from a inoform point source of one candela.
10. nits : the unit of luminous intensity, (same with candela)
11. reflectance of a surface : the ratio of the reflected flux to the incident flux.
12. transmittance : the ratio of the transmitted flux to the incident flux.

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Choi, J. H., D. W. Lee, B. S. Kim, and K. H. Lee. 2002. A Study on Urban Space Analysis Using Feng-Shui and Space Syntax. *Proceedings of the 8th International Congress of Ecology.* Seoul, Korea. pp.41.

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