Understanding Controls, Behaviors and Satisfaction in the Daylit Perimeter Office: A Daylight Design Case Study

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ABSTRACT

Daylight has the potential to positively impact occupants and reduce energy consumption in buildings if utilized correctly (Edwards & Torcellini, 2002). However, unintended negative outcomes can arise from unsuccessful daylighting schemes. Common issues, such as glare and heat gain, are important architectural considerations in design of the building envelope, but less studied are corresponding interior design considerations (such as furniture layout and access to controls) and associated occupant interactions and appraisals. The purpose of the current study is to expose some of the key issues related to the occupant use of daylight and daylight control in perimeter offices, to discuss the contributing design process factors, and to suggest possible improvements to the design process including an increased role for interior designers. The research methodology followed a case study approach and included post-occupancy evaluation (POE) questionnaires, interviews, and observations of a single higher education building with intentionally daylit perimeter offices. We discovered that the building in question was passed between three separate design teams throughout the design process, which may have contributed to the lack of integration between the architectural daylight design and the interior furniture and daylighting control fit-out. More than 50% of total respondents (n = 35) reported obstructed blind controls due to poor furniture design and layout. Of these, nearly 60% of occupants modified their office environment to gain access to blind controls. Ultimately, findings of this study demonstrate the importance of an integrated, multidisciplinary approach to daylighting design, one that considers both the specific building context and the human response.

Introduction

Daylighting, a fundamental sustainable and passive design strategy, can be employed as both the primary means of ambient light and as an energy efficiency strategy within interior environments (Bodart & Herde, 2002; Edwards & Torcellini, 2002; Ruck et al., 2000). Daylight has the potential to positively impact occupants if utilized correctly. Benefits of natural daylight within interior environments include increased occupant satisfaction, psychological and physiological health benefits, and increased productivity (Edwards & Torcellini, 2002; Heschong, 2002; Leslie, 2001; Ulrich & Zimring, 2004).

The Whole Building Design Guide defines daylighting as “the controlled admission of natural light into a space through windows to reduce or eliminate electric lighting” (Ander, 2008). Despite the many benefits of daylighting, an occupant’s lack of ability to control or manipulate the daylight within their environment may lead to increased energy usage from electric lighting and eliminate positive outcomes related to the presence of daylight and views (Escuyer & Fontoynont, 2001; Moore, Carter, & Slater, 2003; Veitch & Gifford, 1996). Spaces that are unsuccessfully daylit, whether they lack user controls, allow excessive glare, or contribute to heat gain, can result in adverse effects upon occupant performance and overall satisfaction (Edwards & Torcellini, 2002).

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within their office environment and to analyze the design process factors that contributed to these occupant behaviors. In particular, this study examines a building that intentionally implemented a daylighting scheme and manual window blind controls for occupants, but the furniture placement in many of the offices prevents occupants from accessing the window blinds. The following hypothesis guided the case study development: the inability to control daylight with window blinds impacts behaviors and satisfaction in daylit offices. Four research questions further explore the hypothesis: (1) have occupants manipulated spatial elements to gain access to blind controls, and if so, how and why; (2) does orientation impact occupant behaviors and satisfaction; (3) is there a correlation between satisfaction and how often occupants manipulate their blinds; (4) what design process factors contributed to these issues? A literature review suggests that little or no information is available that examines this particular phenomenon of inaccessible blind controls, due to furniture placement.

This paper is divided into three primary sections. First, the study is framed within the context of a practice model, Integrated Energy Design (IED) (Brown & Cole, 2006), and a theoretical environmental and behavior (E–B) model developed by Zeisel, Hyde, & Levkoff (1994). Second, a literature review introduces the primary areas of inquiry. The third section of this paper discusses the methodology, key findings from the case study, design implications, and relates these findings to the field of interior design.

Theoretical Frameworks
Successful daylighting design ultimately requires a multidisciplinary approach with “integration between architecture, interiors, lighting design, facility management, and end-user” (Theodorson, 2009). Brown and Cole’s IED offers a practice model that integrates four aspects of building design—climate, building, systems, and use—in an effort to achieve high performance buildings. The model is relevant to this study as it recognizes the importance of adopting an integrated perspective, one that includes occupant use patterns, early in the design process. The intent is to align “use issues” such as schedules, user activities, comfort criteria, and programmatic considerations, with the other quadrants to achieve synergistic building design strategies. The current study expands the scope of “use issues” by investigating user behaviors and use patterns specific to daylighting controls (manual blinds).

There is an intricate relationship among design goals, building performance criteria, design decisions, user behaviors and corresponding environmental outcomes. The basic design decision of furniture placement in the case study building resulted in unexpected environmental adaptations and user behaviors. Zeisel et al. (1994) eloquently state the significance of design decisions.

While designing and constructing a building results in a static physical object, the way people perceive it, use, react to and in other ways interact with the object takes place over time. The apparently static design decisions that interior designers, architects and facility operators make therefore lead to dynamic results. Such Environment-Behavior interactions can have either beneficial or dysfunctional side effects... (p.6).

This complex relationship among the design, the user, and the building can be further explored and supported through an integrated design approach, which takes the end users’ needs into account early in the design process (Figure 1). A truly integrated design approach should “synthesize climate, use, loads and systems resulting in a more comfortable and productive environment, and a building that is more energy-efficient than current best practices” (Brown & Cole, 2006).

Zeisel et al.’s (1994) explanation of E–B interactions, in conjunction with the IED process establishes the theoretical framework for the current study. These models serve as the lens through which user interactions with the daylight controls and interior environment are understood.
The Integrated Energy Design (IED) model is useful in demonstrating the importance of the building use patterns and occupant needs in relation to the overall energy outcomes and the integrated design process.

Figure 1. The Integrated Energy Design (IED) process (Brown & Cole, 2006).

The E–B model is valuable in understanding the relationship between the static interior environment and dynamic occupant interactions. The IED model is useful in demonstrating the importance of the building use patterns and occupant needs in relation to the overall energy outcomes and the integrated design process. The following sections illuminate the importance of these topics in relation to the overarching goals of the perimeter daylit office. The issue of blind control remains the common thread throughout each theme. The case study findings provide an example of issues that can arise when the integration of these design decisions are not fully realized.

Review of Literature

The review of literature is divided into the following areas of inquiry: (1) daylit environments, (2) the purpose of perimeter offices, and (3) user preference and need for control.

The first subsection, relating to daylight design considerations, defines key terms and provides a summary of the differing daylight characteristics associated with climatic conditions, variable sky conditions and differences among building orientation. After the primary daylight characteristics are defined, a brief overview of preferred occupant luminous conditions and shading conditions is presented.

Definitions: Daylighting, Illuminance, Luminance, and Glare

Illuminance can be described as the total amount of light falling on a given surface (IESNA Handbook, 2000). Illuminance values are often measured horizontally at desk height, as this is the level at which occupants typically work (Estes, Schreppler, & Newsom, 2004). Luminance is defined as “the photometric quantity most closely associated with one’s perception of brightness. It usually refers to the amount of light that reaches the eye of the observer measured in units of luminous intensity (candelas) per unit area (m²)” (IESNA Handbook, 2000). In other words, luminance describes the light we actually see. Different colors and reflectance values of materials and surfaces affect the overall luminance value. A high contrast of luminance values within a space can lead to glare problems, which is particularly difficult for both older individuals and office workers utilizing a computer screen (Chain, Dumortier, & Fontoymont, 2001; Osterhaus, 2005). Ander (2008) notes that “glare, or excessive brightness contrast within the field of view, is an aspect of lighting that can cause discomfort to occupants. The human eye can function quite well over a wide range of luminous environments, but does not function well if extreme levels of brightness are present in the same field of view.” Issues with glare are specifically addressed within the case study results.

Climatic Considerations

Strategies and requirements for daylighting implementation differ based on a building’s specific site location, latitude and climate. The frequency of clear, partly cloudy, and overcast sky conditions can all render differing daylight characteristics and should be taken into consideration when designing for daylight.
During clear and partly cloudy conditions, each of the four cardinal orientations offers a light source that contrasts in both character and illuminance levels.

Similarly, climate variation establishes thermal considerations that are important to take into account when incorporating daylighting. For instance, a building designed for daylight utilization in Seattle, Washington (latitude 47.62°N), renowned for its rainy winters, would not perform well if it were transplanted to a much sunnier climate such as Miami, Florida (latitude 25.76°N) (Reinhart, Mardaljevic, & Rogers, 2006).

Differences among Orientation

During clear and partly cloudy conditions, each of the four cardinal orientations offers a light source that contrasts in both character and illuminance levels. The northern skydome provides relatively dim, diffuse, and bluish light. The south differs significantly, offering direct sunlight in addition to skydome light. The result is a bright, dynamic condition, and excess heat gain if not properly shaded. East and west have a variety of conditions: A combination of sun and skydome (Theodorson & Day, 2010).

The National Institute of Building Sciences (NIBS) Executive Order 13423 (2010) for daylighting recommends north-facing windows as the first choice for daylighting orientation. South-facing windows are recommended as the second choice, with the caveat that designers utilize fixed overhangs to block direct sunlight. The building in the current meets recommendations for daylight orientation, as it is elongated in the east-west direction (Baker & Steemers, 2002; NIBS, 2010).

Preferred Luminous Conditions and Window Shading Configurations

The literature suggests a wide range of acceptable illuminance levels for occupants. Individuals may prefer differing illuminance levels based on a variety of factors including task type, climatic conditions, seasonal characteristics or even cultural differences (Begemann et al., 1997; Nicol, Wilson, & Chiancarella, 2006).

Several researchers have explored blind use patterns in relations to window orientation, time of day, sky condition, season, latitude, and workstation position (Galasiu & Veitch, 2006). Blinds are a crucial design feature needed to control glare and overheating in daylight environments. The variability of the luminous conditions between orientations requires different shading treatments and considerations. Horizontal blinds are recommended for control of the high sun (south) conditions, while vertical blinds are used to intercept low sun angles on the east, west, and where needed, on the north.

Rubin, Collins, and Tibbott (1978) conducted a study in which they recorded the blind positions of perimeter offices in six buildings over three separate 10-day periods in October, February, and July. The photographs of the building facades illustrated that most occupants preferred blind configurations that were independent of the sun position or seasonal climatic conditions. One of the study’s most significant findings was that shading configuration differences did exist among orientation; north-facing office windows were left open more frequently than those on the south side which suggested an awareness of sunlight penetration and heat gain within offices.

Rea (1984) conducted a similar study in Ottawa, Canada, which investigated the effect of window orientation, time of day, and weather conditions on the use of the blinds. The blind configurations were recorded on a cloudy day in April and a clear day in May. Results revealed that the position of the blinds typically did not change throughout the day, but did vary between clear or cloudy sky conditions.

Ultimately, each of these studies exhibits a wide range of individual preferences for shading configurations and luminous conditions. Orientation, sky conditions, and occupant habits may all contribute to varying occupant preferences. It is important to outline the diverse spectrum of lighting and shading preferences for two reasons. First, these studies confirm the need for individual daylight controls. Second, these studies indicate a large variation among preferred lighting conditions. A lack of personal controls to satisfy occupants’ preferred lighting levels.
There are many programmatic and behavioral reasons why one might need individual control of daylight in the interior workplace environment.

Purpose of the Perimeter Daylit Office

The primary goal of a perimeter daylight office is to provide both daylight and views for occupants. Employers' motivation for providing daylit offices lies in the potential positive employee outcomes including increased job satisfaction, increased productivity, and health benefits (Townsend, 2006). From a practical standpoint, employers benefit from more satisfied and more productive workers. In addition, a healthier employee translates into fewer sick days and paid leave (Boyce, Hunter, & Howlett, 2003).

Daylight, Views, Satisfaction, and Health

A link exists between daylight, views, satisfaction, and health (Boyce et al., 2003; Frumkin, 2003; Heerwagen, Johnson, Brothers, & Rosenfeld, 1998). Robbins (1986) states that full spectrum light, originating from daylight, affects humans both psychologically and physiologically. Occupants in daylit offices consistently report an increase in general well-being over those in traditionally fluorescent-lit office buildings. Studies have shown that daylighting has the potential to decrease the occurrence of headaches, Seasonal Affective Disorder (SAD), and eyestrain (Edwards & Torcellini, 2002; Franta & Anstead, 1994; Rashid & Zimring, 2008).

Stress, a common condition in the workplace, can have serious effects on both the psyche and the body. Windows and natural views in an office environment serve to reduce stress and eyestrain (Heerwagen et al., 1998). Facilitating the need for contact with the outside and natural environment is one of the most important psychological benefits of daylighting (Robbins, 1986). Studies have suggested that many of the health benefits gained in daylit environments involve the presence of views. However, these favorable human impacts cannot be realized if inaccessible blind controls prevent window access, required for both daylight and views.

The Issue of Control

There are many programmatic and behavioral reasons why one might need individual control of daylight in the interior workplace environment. First, the very nature of daylight—intense, dynamic, and variable—generally requires the occupant to respond to the ever-changing conditions. Second, modification of the daylight source is necessary to support critical visual tasks performed in office settings: light level preferences, glare mitigation, digital output, and so on. Third, occupants may have personal needs surrounding views, privacy, and health. For instance, individuals suffering from common migraines may require a closed blind position more frequently than others may.

Veitch, Hine, and Gifford (1993) studied various issues related to lighting, in an attempt to better understand the typical user. Researchers distributed a survey to a large number of university undergraduates. The results indicated that daylighting was important to the majority of respondents, and access to control over lighting conditions was highly valued. Furthermore, many participants believed that “fluorescent lighting was detrimental to one’s health ... and natural daylight is superior to electric light” (p. 15).

A study conducted by Newsham, Veitch, Arsenault, and Duval (2004), observed 118 participants who worked for a single day under one of four lighting designs. The participants went through a period without access to lighting control, followed by a second period where participants had access to individual light dimming controls. Subjects completed various clerical tasks and responded to a questionnaire of psychological perceptions about their experiences during both observation periods. Those who made use of the controls to change their lighting environment showed the largest improvement in the satisfaction surveys, while those who made no use of the lighting controls showed little or no change in their satisfaction indices.

Whereas the previous studies have suggested a high variability among individual lighting and shading...
Due to the dynamic nature of daylight, occupants need the ability to control daylight.

Summary of Main Points
The following list outlines the primary concepts presented in the literature review.

1. People value daylight and views.
2. Individuals exhibit a wide range of daylight level preferences.
3. The presence of daylight and views within the office can have both positive and negative effects on occupants’ health.
4. Occupants desire control of lighting conditions (electric and daylight), and due to the dynamic nature of daylight, occupants need the ability to control daylight.

Although occupants may have a wide range of luminous preferences, control of the daylight source is of the utmost importance. While a plethora of studies exist surrounding daylight, there are many gaps within the literature that led to the development of this study.

First, most studies deal with control and satisfaction of electric light, not daylight. Daylight has unique characteristics that vary from electric light with regard to the occupant and luminous environment. Second, there is limited research available investigating how and why occupants operate blinds. Third, there is a lack of literature involving control, occupant behaviors, and spatial elements, such as furniture, within daylit environments. Furthermore, the literature review suggests that little or no research examines the phenomenon central to this study—inaccessible blind controls due to furniture placement.

Methodology
This investigation employs a case study of a single academic building with offices. Varying research strategies are used to identify multiple data sources, which included exterior photo documentation, post-occupancy evaluation (POE) questionnaires, and occupant and facility management interviews. For the purposes of the current study, POE is defined as, “an appraisal of the degree to which a designed setting satisfies and supports explicit and implicit human needs and values of those for whom a building is designed” (Friedman, Zimring & Zube, 1978, p. 20). This study built upon previously reported research methods developed by Integrated Design Lab | Inland Northwest to specifically study issues of daylight and occupancy in schools and offices (Day & Theodorson, 2010; Theodorson, 2009; Theodorson & Day, 2010, 2011).

Observations include photograph documentation of north-, south-, and west-facing offices from the exterior of the building. The protocol for the exterior photograph documentation follows a similar methodology to the Rea (1984) and Rubin et al. (1978) studies previously mentioned. The exterior photograph method was pretested prior to the official start. The camera type, best exposure settings, and image sequence were tested and defined before the study. Photographs were taken every two hours from 8:30 a.m. to 4:30 p.m. to document actual blind adjustment frequency and positions as adjusted by occupants. In total, five measurements were taken per day. Corresponding photographs of the sky were also taken for each data collection time period and were later corroborated with the National Climatic Data Center values for observed cloud cover (NOAA, 2010). Sky conditions varied from sunny to rainy. Questionnaire responses and photographs were collected simultaneously over a period of 2 weeks, approximately 1 month after the fall equinox, October 25 to November 4, 2010.

All individuals holding offices within the case study building received an online questionnaire, and respondents without exterior windows were removed from the analysis. Questions were framed to elicit responses regarding occupants’ access to blind controls, occupant satisfaction surrounding the office and daylight environment, occupant needs, reported occupant behaviors and demographics.
Multiple data types were collected to strengthen validity and triangulate responses. For instance, the exterior photographs recorded the dynamic relationship between the occupants and blinds, while the climate data and time stamps made it possible to understand if user interactions were related to sky conditions. In addition, questionnaire responses (what occupants reported about blind use) were compared to the actual blind use as recorded by the exterior photographs. Interviews provided a deeper understanding of why certain behaviors occurred, which were either discovered through the blinds photographs or questionnaire responses.

Case Study Building Background
The case study building, located in Spokane, Washington, was completed in 2008. The design intent was to create a sustainable, energy-efficient building with natural daylighting features. The building houses faculty offices on four of five floors, which are located on the south, north and west perimeters; however, the majority of offices are located on the north side of the building (Figure 2).

Architectural daylighting strategies slightly vary between orientation: external sunshading appears on the southern exposure only, and windows on...
This paper investigates a very specific phenomenon of inaccessible blind controls, due to furniture placement, through a case study.

Figure 3. Inaccessible blind controls diagram

The south side vary in size while windows on the north and west façade are identical. Vertical blinds are used throughout, regardless of office orientation. It is important to note the design process of the case study building. The design team that developed the schematic design for the building was not the same design team that carried out the building through construction documents and construction administration. More importantly, the interior designer that specified the blinds and furniture was not involved in the schematic design, when the daylighting strategies were conceived. In the end, the interiors were configured in mirrored layouts, which resulted in a spatial and furniture configuration that denied occupant access to blind controls in every other office (Figure 3).

Overall, 35 of 133 occupants responded to the questionnaire. Multiple follow-up reminder e-mails were sent to the building occupants over a period of 2 weeks in attempt to recruit additional survey participants. Respondents include 34 females (97%) and 1 male (3%). The majority of participants were between the ages of 46 and 60 (58%), another (17%) were above the age of 61 years, (17%) were between the ages of 35 to 45 years, and the remaining (8%) were below the age of 34 years. The questionnaire results include responses from north-facing (20), west-facing (5), and south-facing (10) offices. The majority of classrooms are located on the east side of the building, so there are very few offices on the east perimeter.

After survey responses were evaluated, e-mail interviews were conducted with nine individuals. The researcher purposefully selected one individual from each building orientation (3) and each level of control (3) from the pool of questionnaire respondents who agreed to participate in follow-up interviews. There was a 100% response rate for the follow-up e-mail questions. The e-mail interviews were intended to elicit why and how explanations to specific questionnaire responses in an open-ended fashion. For example, occupants that modified their environments were asked why and how they chose to do so. The e-mail interviews were not meant to be comprehensive or exhaustive of the daylight responses for the entire case study building, but rather indicative of specific questionnaire responses and appraisals.

Analysis

Data were collected from many sources for this case study. Descriptive statistics were produced for questionnaire responses, which included mean, standard deviation, minimum and maximum values. t tests were used to determine statistical significance for satisfaction means for two separate groupings: (1) occupants with control (including those who added extensions or switched blinds upon move-in) versus occupants without access to blind controls; and (2) occupants on the north side of the building versus those on the south and west. An alpha level of 0.05 was used for all statistical tests (for a confidence level of 95%).

Photographs of interior blind positions were first coded, and corresponding occlusion values were then calculated. For the purposes of this study, blind occlusion is defined as the total percentage of blinds obstructing any given window (Foster & Oreszczyn, 2001). The values for blind and slat positions ranged from (1) to (5). Each value represented a percentage of total blind occlusion (Figure 4).

For example (1) represented fully open blinds, or 0% occluded; (2) represented a blind and slat position equivalent to 33% occluded (this condition never
actually occurred in this study); (3) represented all blinds closed and slats rotated 90°, or blinds pulled half-closed and slats fully rotated, which were both equivalent to 50% occluded; (4) represented blinds closed and slats rotated at 45°, equivalent to 75% occluded; and finally a (5) was recorded as a fully closed condition (blinds and slats) or 100% blind occlusion. Once all windows were coded, an overall blind occlusion mean was calculated for the entire façade.

Interview responses were grouped by both orientation and access to control, and served as narrative explanations to specific findings within the questionnaire results. The WSU Office of Research Assurances determined that this study met the criteria for Exempt Research at 45 CFR 46.101(b)(2).

Results and Discussion

This paper investigates a very specific phenomenon of inaccessible blind controls, due to furniture placement, through a case study. This section first reports the results as they relate to the hypothesis and research questions. The case study findings are then further discussed in relation to the overarching themes as reported in the literature review. Lastly, unexpected results, revolving around health and view responses, are discussed in relation to occupant satisfaction, behaviors, and relevant literature.

Hypothesis and Research Questions

Hypothesis: the inability to control daylight impacts behaviors and satisfaction in daylit offices.

It was found through questionnaire responses that behaviors and satisfaction appraisals for some occupants were in fact affected by their inability to control the blinds and daylight source. For instance, when asked “I can easily access my daylight controls,” those without access to controls were the least satisfied, and individuals with access to blind controls were the most satisfied; this was a statistically significant finding. These results are consistent with the literature surrounding lighting and controls (Newsham et al., 2004; Veitch et al., 1993); in both of these studies participants with access to lighting controls demonstrated higher satisfaction responses. Table 1 outlines findings from the t tests; significant findings are given in bold within the table. Results from all t tests are included to provide additional insight into the results; however, some questions are more relevant than others for each of the two groupings examined. For the following results, the question designations listed below (i.e., Q1, Q2, etc.) correspond with the satisfaction responses reported for each of the subsequent graphs and tables.

Q1: I am pleased with the visual appearance of the office
Table 1. Satisfaction marginal means, standard deviations, and t-test results: Grouping 1 (occupant with blind control vs. occupants with no blind control)

<table>
<thead>
<tr>
<th>Question</th>
<th>Grouping 1</th>
<th>t-test (95% CI)</th>
<th>M</th>
<th>S.D.</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Have control</td>
<td>$t(33) = 1.27, p = 0.10$</td>
<td>5.65</td>
<td>0.93</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>5.22</td>
<td>0.67</td>
<td>9</td>
</tr>
<tr>
<td>Q2</td>
<td>Have control</td>
<td>$t(33) = 1.86, p = 0.03^*$</td>
<td>5.42</td>
<td>0.70</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>4.66</td>
<td>1.73</td>
<td>9</td>
</tr>
<tr>
<td>Q3</td>
<td>Have control</td>
<td>$t(12) = 1.17, p = 0.13$</td>
<td>4.00</td>
<td>1.22</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>3.00</td>
<td>1.73</td>
<td>9</td>
</tr>
<tr>
<td>Q4</td>
<td>Have control</td>
<td>$t(13) = 0.23, p = 0.40$</td>
<td>4.83</td>
<td>1.15</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>4.66</td>
<td>1.32</td>
<td>9</td>
</tr>
<tr>
<td>Q5</td>
<td>Have control</td>
<td>$t(33) = 1.12, p = 0.14$</td>
<td>5.03</td>
<td>1.31</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>5.56</td>
<td>0.72</td>
<td>9</td>
</tr>
<tr>
<td>Q6</td>
<td>Have control</td>
<td>$t(18) = 0.31, p = 0.37$</td>
<td>5.00</td>
<td>1.45</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>5.22</td>
<td>0.97</td>
<td>9</td>
</tr>
<tr>
<td>Q7</td>
<td>Have control</td>
<td>$t(26) = 0.76, p = 0.23$</td>
<td>4.68</td>
<td>1.76</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>4.11</td>
<td>1.83</td>
<td>9</td>
</tr>
<tr>
<td>Q8</td>
<td>Have control</td>
<td>$t(20) = 0.52, p = 0.30$</td>
<td>5.62</td>
<td>1.04</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>5.33</td>
<td>1.58</td>
<td>9</td>
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<tr>
<td>Q9</td>
<td>Have control</td>
<td>$t(33) = 0.96, p = 0.17$</td>
<td>4.69</td>
<td>1.49</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>5.22</td>
<td>1.20</td>
<td>9</td>
</tr>
<tr>
<td>Q10</td>
<td>Have control</td>
<td>$t(33) = 3.54, p &lt; 0.01^*$</td>
<td>4.78</td>
<td>1.84</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>No access to blind controls</td>
<td></td>
<td>2.44</td>
<td>1.13</td>
<td>9</td>
</tr>
</tbody>
</table>

Note: Likert scale used for satisfaction responses: 1 very strongly disagree; 2 strongly disagree; 3 disagree; 4 neither disagree or agree; 5 agree; 6 strongly agree; 7 very strongly agree.

Q2: I am pleased with the comfort of my personal office furniture (desk, chair, computer, equipment, etc.)

Q3: I am satisfied with the adjustability and movability of my office furniture

Q4: I am pleased with the colors and textures of the flooring, furnishings, and surface finishes in my office

Q5: I am satisfied with the level of visual privacy I have from the exterior window

Q6: I am satisfied with the level of visual privacy from interior window by door

Q7: I am satisfied with the quality of my view

Q8: I am satisfied with daylight in my space

Q9: The computer screen is legible and does not have reflections

Q10: I can easily access my daylight controls (blind controls)

Satisfaction assessments were further divided into three overarching categories: (a) access to controls; (b) no access to control, but modified environment; and (c) no control, but did not modify environment when broken up by overall means (Figure 5).

All occupants reported a uniformly positive level of satisfaction with their daylit environment, regardless
It is noteworthy to mention that the inability to access blind controls in some of the offices affected both occupant satisfaction and behaviors independent of daylight.

Figure 5. Occupant satisfaction means by level of control.

![Occupant Satisfaction Means by Level of Control Graph]

Research Question 1: Have occupants manipulated spatial elements to gain access to blind controls, and if so, how and why?

The issue of control was explored in response to the first research question. Over 54% of respondents reported obstructed blind controls. Of these, 63% of occupants modified their office to gain access to controls. Individuals who modified their environment either added longer cords or extensions to blind controls or asked maintenance to switch blind controls to the opposite side of the window (reversed control location). Two other occupants reported that they had instead modified their behaviors. One occupant climbed on top of their desk to change the blind position, while the other, a shorter occupant, crawled under the desk. The remaining 37% without access to blind controls did nothing to their office to reach the inaccessible controls. These differences in occupant behavior were noted and further addressed in the follow-up interviews.

One respondent without access to controls, who did not modify their environment, stated, “I would definitely change blind position more often if they were a tad easier to reach. I am noticing this much [more] since change of season (summer—sun is high and I don’t need to adjust, winter—sun is lower and comes directly into office) and sometimes I leave them closed more often than I like because it’s hard to reach.” A second response revealed that the occupant did not change the environment, but rather had to modify their behavior to reach the blinds, “It is nearly impossible to reach the blinds in my office. I either have to crawl under my desk or crawl over it!” The third individual was less bothered by the inaccessibility to controls as they “always leave them open for maximum daylight and view anyway.” This finding is surprising as this particular occupant was located on the south side of the building. The fact that this individual...
always left the blinds open suggests a high acceptance or tolerance for the variability of daylight and glare.

Respondents who did modify their environment in some way were also asked additional interview questions. When asked why they initially decided to modify their office, one occupant simply stated, “I couldn’t reach the blind controls without climbing on my desk—therefore I added extensions.” Another interview response uncovered that the occupant had not modified their environment to gain access to blind controls, but rather to move away from the vent. “I moved the desk unit away from the window about two feet to get out of the venting draft in the ceiling and away from the cold window in the winter.” For the most part, access to controls was important to most occupants, and those without control claimed that they would use their blinds more frequently if they could access them easily.

Research Question 2: Does orientation impact occupant behaviors and satisfaction? Behavioral responses were explored through overall blind occlusion values throughout the study period.

Descriptive statistics revealed differences and variance in all mean satisfaction appraisals when questionnaire responses were divided by orientation. Even though responses varied, most occupant assessments still remained highly positive (Figure 6).

Occupants on the north side were least satisfied with access to blind controls and the quality of their view. The lower satisfaction appraisals for access to blind controls may be explained by two factors: (1) there were more occurrences of occupants without control on the north side; and (2) the majority of occupants on the north only had one window while occupants on the south side had two to three windows each. The lower satisfaction levels on the north for privacy and view were also expected. The quality of view and level of privacy are highest on the west side, lowest on the north side, and somewhere in between on the south. The occupants on the north view the south façade and offices of the adjacent building. Similarly, the occupants of the adjacent building are able to look directly into the offices of the north side academic building occupants.

The questionnaire responses revealed that glare was a common environmental outcome related to daylight in the case study building. One question within the survey, “the computer screen is legible and does not have reflections,” probed at issues and perceptions of glare within the office. The responses were categorized by office orientation. Although occupants remained mostly positive, reports of glare did vary by orientation, and the occupants on the south and west façades represented the least satisfied groups. Additional t tests verified a significant difference between glare assessments and orientation, $t(33) = 3.06$, $p < .01$, as north occupants reported less instances of glare than those on the south and west (Table 2).

Over 14% of respondents chose to include additional complaints of glare within the optional open-ended...
sections of the questionnaire. In the follow-up interviews, one occupant clearly expressed concern, “I have a HUGE problem with the shiny metal window frame...very stupid on a south-facing window. I have had to cover the frame in places to prevent the glare.” Varying interior daylight strategies, such as horizontal blinds on the south facade, may have helped to mitigate instances of glare.

The exterior photographs documented a higher rate of total blind occlusion on the south facade, which is consistent with the higher reported instance of glare on the south facade in the questionnaire responses (Figure 7).

### Table 2. Satisfaction marginal means, standard deviations, and t-test results: Grouping 2 (north orientation vs. south and west orientation)

<table>
<thead>
<tr>
<th>Grouping 2</th>
<th>Test (95% CI)</th>
<th>M</th>
<th>S.D.</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>t(33) = 0.44, p = 0.33</td>
<td>5.60</td>
<td>0.75</td>
<td>20</td>
</tr>
<tr>
<td>Q2</td>
<td>t(33) = 0.18, p = 0.43</td>
<td>5.20</td>
<td>1.32</td>
<td>20</td>
</tr>
<tr>
<td>Q3</td>
<td>t(22) = 0.53, p = 0.30</td>
<td>4.25</td>
<td>1.67</td>
<td>20</td>
</tr>
<tr>
<td>Q4</td>
<td>t(23) = 0.43, p = 0.34</td>
<td>4.80</td>
<td>1.01</td>
<td>19</td>
</tr>
<tr>
<td>Q5</td>
<td>t(33) = 0.69, p = 0.25</td>
<td>5.05</td>
<td>1.10</td>
<td>20</td>
</tr>
<tr>
<td>Q6</td>
<td>t(28) = 1.73, p = 0.04*</td>
<td>4.85</td>
<td>1.42</td>
<td>20</td>
</tr>
<tr>
<td>Q7</td>
<td>t(21) = 2.65, p = 0.007*</td>
<td>3.73</td>
<td>1.64</td>
<td>19</td>
</tr>
<tr>
<td>Q8</td>
<td>t(29) = 0.49, p = 0.31</td>
<td>5.53</td>
<td>1.25</td>
<td>15</td>
</tr>
<tr>
<td>Q9</td>
<td>t(33) = 3.06, p &lt; 0.01*</td>
<td>4.07</td>
<td>1.53</td>
<td>20</td>
</tr>
<tr>
<td>Q10</td>
<td>t(33) = 2.08, p = 0.02*</td>
<td>4.93</td>
<td>1.67</td>
<td>15</td>
</tr>
</tbody>
</table>

Note: Likert scale used for satisfaction responses: 1 very strongly disagree; 2 strongly disagree; 3 disagree; 4 neither disagree or agree; 5 agree; 6 strongly agree; 7 very strongly agree.

* p < .05

### Overall Blind Occlusion

Existing literature typically presents blind occlusion by facade (Foster & Oreszczyn, 2001). This is because there are many differences in the way individuals choose to operate their blinds, and presenting mean occlusion data for an entire facade is a way to generalize these individual differences. Blind occlusion means varied per orientation for the case study building: north 28%, west 53%, south 70%. During sunny sky conditions, blind occlusion values increased on the south side, while blind occlusion means decreased on the north side. This may be explained by glare conditions on the south and desire for more daylight on the north during sunny sky conditions. There was
The presence of daylight and views within the office can have both positive and negative effects on occupants’ health: occupants noted daylight and views as vital to their well-being and mental focus.

Figure 7. Blind occlusion means by orientation.

HOURLY BLIND OCCLUSION PERCENTAGES BY FACADE

<table>
<thead>
<tr>
<th>TIME AND DATE</th>
<th>NORTH</th>
<th>WEST</th>
<th>SOUTH</th>
<th>Cloudy</th>
<th>Sunny</th>
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</thead>
<tbody>
<tr>
<td>10.27.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.28.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>11.02.10</td>
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<td>11.03.10</td>
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<td>11.03.10</td>
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</tbody>
</table>

no significant correlation between weather response and blind occlusion values for the west façade. The mean level of occlusion is highest on the south-facing façade, which is to be expected and consistent with current literature (Foster & Oreszczyn, 2001).

Research Question 3: Is there a correlation between satisfaction and how often occupants manipulate their blinds?

Data for this question were evaluated for questionnaire responses and actual exterior photograph documentation. First, self-reported blind adjustment frequency was compared to satisfaction assessments. Pearson $r$ analyses revealed correlations in only three of the satisfaction categories. A moderate positive correlation ($r^2 = 0.59, p < .01$) existed between blind adjustment frequency and the satisfaction responses geared toward glare assessment; this suggests individuals who report changing blinds more frequently to mitigate glare also report a lower satisfaction rating. Alternatively, privacy and view responses suggest that occupants who operate blinds more frequently were more satisfied with view and privacy. These correlations do not denote a causal relationship, but rather signify a notable link between the two given variables (Gay, Mills, & Airasian, 2008). These findings further validate the need for occupant daylight controls. Significant correlations were not found between any of the other satisfaction categories and self-reported blind adjustment frequency.

Satisfaction responses were also evaluated in relation to actual blind adjustment frequency (documented by exterior photographs). Blind patterns were isolated for those individuals that provided office room numbers on the questionnaire, and satisfaction responses were compared to blind change frequency for those offices only. No significant differences were found between observed blind change frequency and any of the measured satisfaction appraisals.

Research Question 4: What design process factors contributed to these issues?

The findings of this study demonstrate the importance of an integrated, multidisciplinary approach to daylighting design, one that considers both the specific building context and the human response. Early interviews with the Capital Planning Department and Facilities Manager revealed that the design process was not an integrated one, as the project was passed between multiple design teams throughout the design process. It was also reported that an interior designer was not included in the design team during the design development of the building.

Design issues, such as the inability for occupants to change clothes within their office, indicate a missed opportunity for coordination between the design team and user early in the design process. Reported instances of glare may also reflect a lack of coordination between the architectural daylighting strategies
Alternatively, inaccessible controls and reports of frequent glare suggest instances of stress and increased difficulty when faced with light-related health problems such as migraines or frequent headaches.

and interior daylight environment. Incorporating a design process as described in the IED model, previously discussed in this paper, may have mitigated some of the design issues that emerged in this study. The Integrated Design Process (IDP)... allows participants to establish performance goals and a vision for the project that is understood and supported by everyone. Such goals can serve as the basis for a design process based upon an integrated analysis of how different building systems can work together and thereby identify synergies among structural, mechanical and electrical systems that are conventionally designed in isolation. (Cole, Robinson, Brown, & O’Shea, 2008, p. 327)

Additional Findings as Related to Blind Control, Satisfaction, and Health

Even though the research questions were not related to health, questionnaire and interview responses illuminated specific behaviors surrounding the blind control, or lack thereof, that were directly related to occupant health. This section is dedicated to reporting some of these unexpected results.

The online questionnaire gave participants the option to discuss any light-related health issues at their discretion. Three individuals reported cases of migraines and two reported cases of SAD. Other light-related health conditions reported included (1) thyroid eye disease (causes double vision), (2) cataracts, (3) sleep disorders, (4) light sensitivity, and (5) headaches.

The satisfaction responses from the questionnaire indicate a highly positive appraisal of daylight, and 100% of interview respondents claimed to value daylight and views. Some individuals were willing to tolerate glare in exchange for the view and access to daylight. The presence of daylight and views within the office can have both positive and negative effects on occupants’ health: occupants noted daylight and views as vital to their well-being and mental focus. Alternatively, inaccessible controls and reports of frequent glare suggest instances of stress and increased difficulty when faced with light-related health problems such as migraines or frequent headaches. This case study found that occupants chose to open blinds to daylight and views for psychological benefits (stress relief, well-being, connection to the outdoors), while others needed to close blinds for physiological concerns (migraines, cataracts, headaches). The inability to open or close the blinds for these issues was a problem for some occupants.

The follow-up e-mail interview questions were not designed to lead occupants to discuss health factors, but many chose to do so anyway. Several individuals in this building are faculty members in a medical profession, so respondents may be more aware of health-related issues. For example, “[I] highly value daylight anywhere! I have worked with only electric lights and find I feel more tired, have difficulty concentrating, and [used to] avoid meeting with people in my office—I have worked night shift under artificial light and experienced similar effects....” Another occupant notes “daylight is vital to my mental well-being. Electric light would not be the same.” Other comments included, “connection with the out of doors is essential for progression in time; my windows overlook a planted tree garden (south west corner of campus) so my eyes drift away from my monitor and out the window to contemplate and change focal length; I have worked in offices without a window and the chance to glance outside. I do not find it a satisfying environment. The blue skies/sunlight brighten my mood personally.” The interview responses indicate a high appreciation for daylight and views, and most responses report psychological benefits from either daylight or views (i.e. “brighten my mood,” stress relief, “connection with the outdoors”).

Many individuals claimed to open the blinds for stress relief and mental well-being. However, one occupant stated that they closed the blinds to daylight on occasion because the light bothered them when they had a migraine. Similar actions were noted for individuals with headaches, glare issues, and light sensitivity. These findings suggest that occupants chose to
open blinds to daylight and views for psychological benefits, while others needed to close blinds for physiological concerns; this further substantiates the importance of access to blind controls.

Conclusion and Design Implications

In this particular building, it is clear that there were some missteps in the design process that could have been easily avoided through an integrated design approach and better understanding of the occupant needs and behaviors. It would have been beneficial to have an interior designer involved early in the design process, or at least to have the same designer work on the project in all design stages. There was an opportunity for increased coordination between the architectural building envelope daylighting strategies (window placement) and the interior furniture layout, occupant needs, and interior daylight levels during early building conception and schematic design.

Design Implications

There were several design challenges uncovered through the current study that could have been easily avoided through a “daylight” commissioning process. Daylight commissioning is rarely performed, but would be an effective way to ensure daylight controls and strategies were working properly before building occupation. Additional client interviews and daylight modeling, early in the design process, may have also reduced some of the negative impacts discovered in this case study. Varying interior daylight strategies, such as horizontal blinds on the south facade, may have helped to mitigate instances of glare (NIBS, 2010). Also, while the luminance values of interior finishes were not measured in this case study, reported challenges with glare confirm the importance of thoughtful material selection and integration within any daylighting scheme.

Generalizability and Limitations

It is important to mention the limitations and generalizability issues related to this case study. First, the sample population was almost completely female (97%), and the majority of respondents were over the age of 46 (75%). Ideally, most study populations should be more evenly distributed between male and female participants. Also, it is known that eyes begin to change as individuals’ age, and people over the age of 40 need more light for detail-oriented tasks (Osterhaus, 2005). Older individuals also tend to have more frequent issues with glare. This study cannot prove or disprove that there were more reports of glare due to the age of participants, but it is certainly a possibility.

Additional limitations to this study include the absence of offices on the east facade, a fairly low survey response rate (29%), and the study only looked at responses and blind patterns for one period of time. Findings may have been strengthened if measurements were taken seasonally. Also, the questionnaire results included responses from north-facing (20), west-facing (5), and south-facing offices (10), which does not represent an evenly distributed sample. Finally, reported health issues may have been higher in this study as most of the respondents were faculty members in a health-related profession.

Future Study

Further research is needed surrounding the interactions between the occupant and daylight controls. Future studies could investigate specific occupant expectations and preferences in daylit spaces. The IED model previously discussed presents an opportunity for additional research surrounding occupant use patterns and corresponding energy implications. Ultimately, interior designers have the opportunity to enhance an individual’s health, work satisfaction, and overall well-being through correctly implemented daylight strategies (Boyce et al., 2003; Edwards & Torcellini, 2002; Franta & Anstead, 1994). The introduction of daylight into an interior environment requires controls and alters occupants’ behaviors: people have a dynamic relationship with daylight by necessity. It is this relationship that ultimately determines the degree of success of the design intent.
and underlies the importance of understanding the dynamic quality of the daylight source, both diurnally and seasonally. Occupant control of the daylight source is particularly important; when blind controls were inaccessible, the majority of occupants were required to manipulate their environment or their behavior. The B–E and IED models are integral in conceiving the theoretical framework for the current study; both models illustrate the importance of the relationship that exists between dynamic daylight, the static interior environment, and corresponding occupant interactions.

A truly integrated design approach, coupled with an understanding of the dynamic quality of daylight and building specific patterns of occupation, may have mitigated some of the daylight control issues discovered through this case study. These results will hopefully empower interior designers to become more involved with the project design team earlier in the design process. All passive design strategies—especially daylighting and ventilation—would benefit from increased interior design involvement and integration.

References


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