Spatial Factors Related to Occupants' Behavioral Beliefs About Window and Blind Use in Multifamily Residential Buildings

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Abstract

Occupant behavior is one of the factors that impact the buildings' energy consumption. Occupants interact with building systems to adjust their indoor environmental conditions to meet their comfort levels. Occupants' behavior to control those multiple conditions have been studied in isolation. Previous research highlighted the impact that contextual factors, such as interior design, have on occupants' energy-related behaviors. This study focused on psychological, contextual, and environmental reasons leading to energy-related occupants' behavior. It investigates the impact of spatial factors: orientation, floor level, space type, and furniture layout on occupants' behavioral beliefs about operating windows and adjusting blinds. Results revealed a significant relationship between the spatial factors and occupants' behavioral beliefs about operating windows and adjusting blinds. It is recommended to consider occupants' behavioral beliefs related to the spatial factors in the preliminary stages of the design process to contribute to efficient space planning and thus enhance the building's energy performance.

Introduction

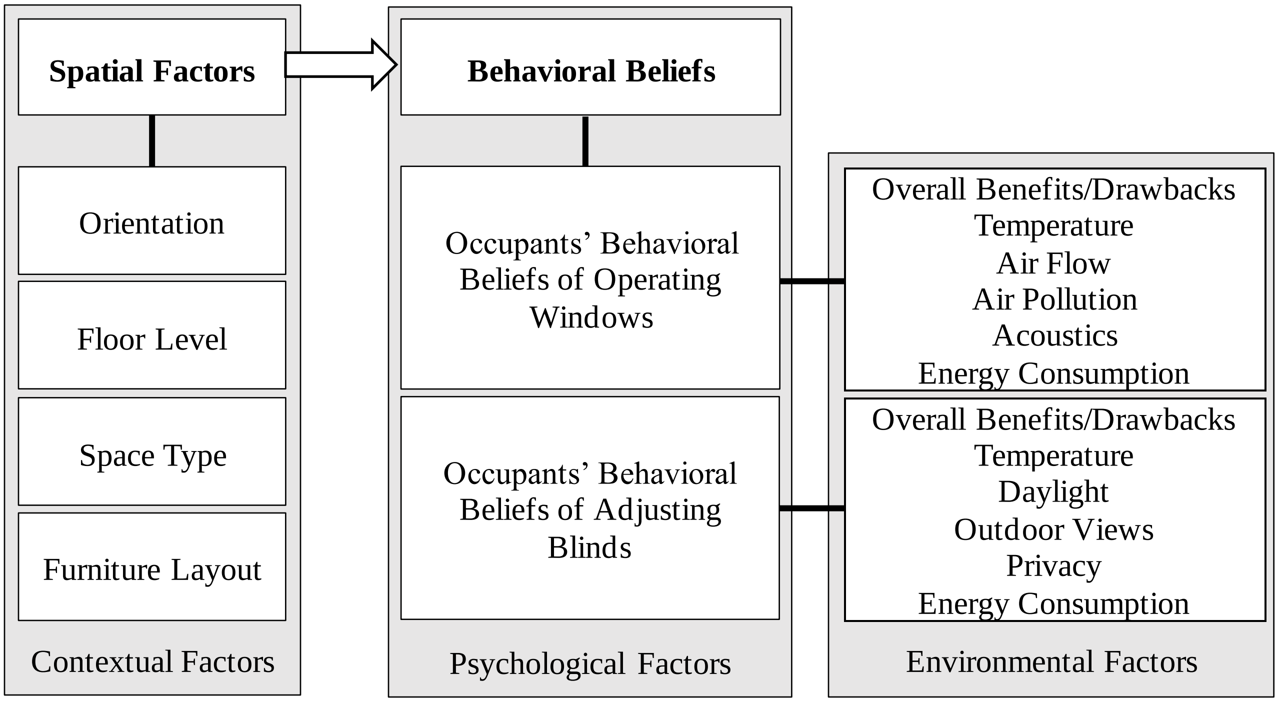
Buildings contribute to global greenhouse gas emissions and energy consumption. More than 40% of the end-use in residential buildings in the United States is a result of space heating, air conditioning, and lighting (EPA, 2015). Indoor environmental conditions such as thermal comfort, visual comfort, acoustical comfort, and indoor air quality affect the occupants' health, comfort, well-being, and satisfaction (Bae et al., 2017). Occupants interact with passive and active building systems to control their indoor environmental conditions. Examples of occupant-building interaction include adjusting the HVAC thermostat, turning the light on/off, operating windows, and adjusting blinds (Hong et al., 2016). Occupants are continuously experiencing multiple indoor environmental conditions, however, occupants' perception and behavior to control those conditions have been studied in isolation. In addition, many studies lacked a theoretical foundation and failed to link occupants' perceptions to actions (Schweiker et al., 2020).

Occupant-building interaction is closely related to the building's energy consumption (Yan et al., 2017). Literature review showed that analysis of occupants' behavior has been overlooked which resulted in inaccurate building performance predictions (Delzendeh et al., 2017). Also, previous research suggested that future research investigate the influence of interior design features on occupant-building interaction (Delzendeh et al., 2017; Yan et al., 2015). There is an increasing number of studies focusing on occupants' energy-related behaviors related to spatial factors (Marín-Restrepo et al., 2020; Uddin et al., 2022). However, there is still a lack of research that addresses the influence of spatial factors on occupants' adaptive behaviors such as operating windows and adjusting blinds in the residential environment.

The theory of planned behavior proved that human behavioral beliefs are one of the considerations that guide human behavior (Ajzen, 1991). It explained that behavioral beliefs are determined by the consequences and experiences that are likely to be associated with specific behavior. The theory of planned behavior proved that behavioral beliefs affect the attitude and thus the intention to perform a behavior (Ajzen, 1991). Therefore, it is important to study the occupants' behavioral beliefs related to the advantages and disadvantages of operating windows and adjusting blinds as those beliefs will be related to their interaction with building systems. Occupants interact with building systems to control their indoor environment including the indoor air quality, thermal, acoustical, and visual conditions. Those environmental conditions are influenced by spatial factors. Hence, this research studied the relationship between spatial factors (i.e., orientation, floor level, space type, and furniture layout) and the occupants' behavioral beliefs with a focus on adaptive behaviors such as operating windows and adjusting blinds related to those behaviors in residential units as shown in Figure 1.

Figure 1

Study Framework



The research hypotheses are as follows:

1- Spatial factors (i.e., orientation, floor level, and space type) have a significant relationship with occupants' behavioral beliefs about operating windows.
2- Spatial factors (i.e., orientation, floor level, and space type) have a significant relationship with occupants' behavioral beliefs about adjusting blinds.

The research also examined the research questions below:

1- How do spatial factors (i.e., furniture layout) relate to occupants' behavioral beliefs about operating windows?
2- How do spatial factors (i.e., furniture layout) relate to occupants' behavioral beliefs about adjusting blinds?

Literature Review and Theoretical Background

The literature review was conducted to understand concepts of sustainable interior design and the relation between design and occupant behavior. It also discussed occupant-building interaction and the representation of energy-related behavior in building energy simulation software. Finally, it addressed interior design and occupant behavior as a gap in research that needs further investigation.

Sustainable Interior Design

The term "sustainable interior design" was addressed by Moxon (2012) who wrote the "Sustainability in Interior Design" book in which he focused on four key issues: energy, water, materials, and construction methods. Moxon's approach to the low-energy design included adopting passive design strategies, specifying energy-efficient appliances, and incorporating renewable energy sources. Passive design can reduce energy consumption by manipulating the building's orientation, form, and layout. Also, passive design has been used immensely in designing and specifying building envelope structures and materials that enhance energy performance. Interior design is an integral part of the passive solar architecture (Moxon, 2012).

Interior design complements the exterior building design and refines the passive solar features in residential buildings to create a comfortable living environment (Breen, 1981). However, a spatial analysis conducted by McLain-Kark (1985) revealed that passive design elements such as windows when combined with orientation can cause interior space planning problems. Problems such as activity zones, circulation, and furniture arrangements contributed to passive solar homeowners' dissatisfaction.

Design for Sustainable Behavior

The concept of “Design for Sustainable Behavior” (DfSB) emerged in the field of product design. Lockton et al. (2008) addressed that all design influences users’ behavior. They suggested that designers can influence the way that user’s intestate with a product or a system and thus make the user more efficient and reduce the waste of resources. Lockton (2008) used the term ‘Design with Intent’ (DwI) to describe the approach that he suggests designing for sustainable behavior. Lockton et al. (2010a) started developing their design tool kit for influencing user behavior through design. The DwI tool is composed of eight lenses representing different fields of research: architectural, error-proofing, interaction, ludic, perceptual, cognitive, Machiavellian, and security (Lockton et al., 2010b).

Daae (2014) described the DfSD as the intersection between sustainability, user-centered design, and behavioral psychology. The concept of motivating sustainable behavior through design was adopted by building-occupant interaction research. The individual’s awareness and motivation were two approaches found to be useful in influencing occupants’ energy behavior (Crocker & Lehmann, 2013). However, most of the previous research that discusses DfSB in the built environment focuses on equipment use. For example, the study of Withanage et al. (2016) focused on energy overuse failure modes caused by high energy consumption habits and lack of energy awareness. In addition, Chiu et al. (2020) study analyzed energy consumption behaviors using the theory of planned behavior (TBP) and created behavioral interventions to help reduce energy consumption.

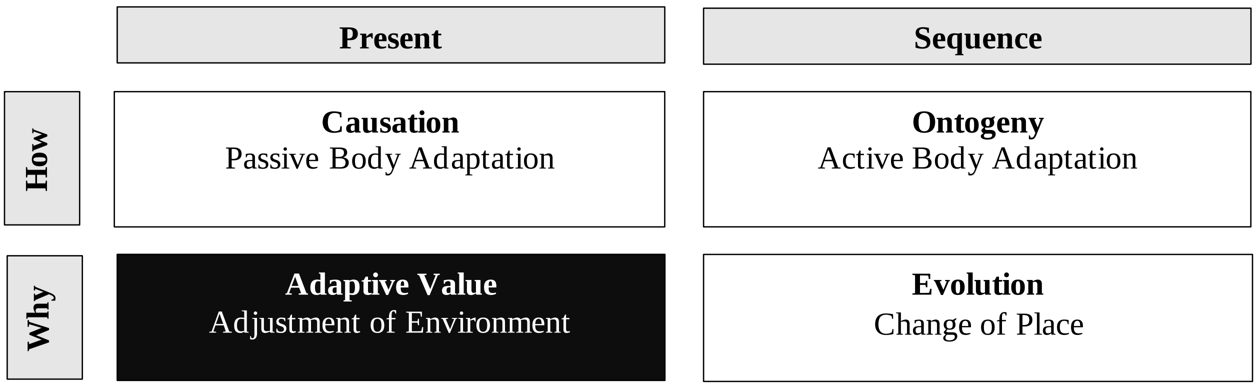
Karjalainen (2016) argues that “buildings are not used as the designers intended”. He said that designers design buildings in a specific way and expect occupants to understand how the building systems function. Designers also assume that occupants understand the impact that their behavior has on the building's energy consumption and adopt pro-environmental behavior when they interact with building systems. However, research has shown that those assumptions do not always align with real-world situations. Two main strategies were adopted by researchers to reduce buildings’ energy consumption. The first strategy recommends building-design approaches that diminish the influence of occupants’ behavior on the buildings’ energy performance. The second strategy aims to design buildings in a way that helps modify energy-related occupant behavior (O’brien, 2013; Karjalainen, 2016)

Energy-Related Occupant Behavior

Occupant energy-related behavior is defined by Schweiker (2010) as “occupant behavior can be defined as a human being’s unconscious and conscious actions to control the physical parameters of the surrounding built environment based on the comparison of the perceived environment to the sum of past experiences”. Figure 2 shows the four types of occupant behavior by Schweiker’s (2010). This classification was inspired by “Tinbergen’s Four Questions” which focused on the biological study of behavior (Schweiker, 2010). Tinbergen (1963) called them; causation, ontogeny, survival value, and evolution. Accordingly, the four types of occupant behavior described by Schweiker (2010) are passive body adaptation, active body adaptation, adjustment of environment, and change of place.

Figure 2

Energy-Related Behavior Demonstrated Based on Schweiker (2010) Occupant Behavior Classification



The research review conducted by Delzendeh et al. (2017) showed that much attention has been given to technical factors of the building energy analysis, however, the human factors were only represented in the form of fixed schedules and patterns of behaviors. This way of representation failed to mimic actual adaptive occupant behavior and results in inaccurate predicted results of the building's energy analysis.

Occupant health and well-being are related to Indoor Environmental Quality (IEQ). Weerasinghe et al. (2020) conducted a literature review of journal articles and theses that study the impact of occupant comfort-related parameters on the occupants' decision to interact with building systems. Their study showed that opening/closing windows, adjusting thermostats, lowering blinds, and turning lights on/off are among the most common occupant-building interactions that influence building energy consumption.

Window and Blind Use

More attention has been given to studying occupants' interaction with windows and blinds in an office setting compared to residential settings (Fabi et al., 2012; Van Den Wymelenberg, 2012). However, studying occupants' behavior of opening and closing windows in residential buildings dates to 1951 when Dick and Thomas studied the ventilation in occupied houses and proved that the number of open windows is related to the outdoor temperature. Afterward, more studies were conducted using different methods including questionnaires, observations, and measurements to study more variables related to occupants' interaction with windows (Brundrett, 1977; Dubrul, 1988; Johnson & Long, 2005; Andersen et al., 2009; Guerra-Santin & Itard, 2010; Cali et al., 2016). Some of the findings of this research referred to the building characteristics such as the dwelling type, room type, and orientation as factors that influence the occupants' behavior of opening and closing windows.

The investigation of occupants' interaction with blinds started in the late-1970s with a focus on office settings (Rubin et al.,1978; Rea, 1984; Inoue, et al., 1988; Lindsay, 1989; Lindsay & Littlefair, 1992). In 2013, a survey on Canadian households' control of indoor climate was conducted and occupants indicated that privacy, security, daylighting, solar radiation, and outdoor views were the main reasons for them to interact with blinds (Veitch et al., 2013). Also, Bennet et al. (2014) monitored blind use in a multi-unit residential building high-rise condominium in Canada and the results of the study indicated that blind use can be a potential energy saver. In 2019, Pereira and Ramos indicated that the occupants' motivation to interact with building systems including blinds is related to the room and environmental parameters. In addition, Nazmy and Kim (2021) conducted an observational study of the spatial and temporal factors that influence the occupants' blind use in residential buildings. Results of this study showed that the day and time of observation were found to impact the occupants’ blind use patterns. Occupants’ blind use patterns were also correlated with spatial factors such as the floor level and orientation of the residential unit.

Occupant Behavior and Spatial Factors

Fabi et al. (2012) described occupant behavior as a complex process. They named the internal and external factors influencing behavior “drivers.” They divided those “drivers” into five groups: physiological, psychological, social, physical environmental, and contextual factors. One of the five groups was psychological factors such as lifestyle and perception. Another group was contextual factors that moderate occupants' behaviors in a space such as the interior design including furniture layout, connection to the outdoors, and visibility of energy use (Goldstein et al., 2011; O'Brien & Gunay, 2014; Schweiker et al., 2018). They argued that it is important to provide the occupants with the flexibility to change their position when needed. They also recommend that the space planning and furniture layout are designed with conscious attention to occupant behavior. The occupants' actual behaviors may differ from the assumptions made during the design stage and studying occupants' behaviors can contribute to efficient space planning and accurate prediction of buildings' performance (Wagner et al., 2018).

Delzendeh et al. (2017) research review revealed that occupants’ behavior gained attention in residential settings, and this is reflected in the number of case studies on this topic. Most studies focused on specific occupants’ interaction at a time and window opening behavior is more studied compared to blind use behavior. They identified domains of research to advance the buildings’ energy analysis. One of those identified domains was interior design and specifically the space layout and fixtures and fittings. Based on their research review, they indicated that the influence of interior design aspects on occupants' energy-related behavior did not receive much attention in previous research until recently.

Marín-Restrepo et al. (2020) described spatial factors as action moderators for building-occupant interaction in office buildings. They categorized spatial layout into 1- open space, 2- shared enclosed space, and 3- individual space. They also considered the control element orientation its distance to the occupant. Their study's results indicated that the operation of windows and blinds was strongly related to spatial factors. A more recent study was performed by Mo and Zhao (2022) which related the high energy consumption in residential buildings to the occupants' interaction with home systems. They conducted a spatial analysis at the scale of the region and geographical location which showed its impact on the occupants' energy-use related activities. They suggest that these results could inform residential building energy strategies and policies.

Occupant Behavior and Building Energy Simulation

Asadi et al. (2017) conducted a literature review that focused on the relationship between indoor environmental quality (IEQ), building energy consumption, and occupant behavior. Their study revealed that most previous research did not consider the four factors (i.e., thermal comfort; visual comfort; acoustical comfort; indoor air quality) of IEQ at the same time and focused on measuring and/or simulating only one or two. This research pointed out that the human psychological parameter results in uncertainty when it comes to simulating occupant behavior.

Hoes et al. (2009) proved that occupant behavior impacts the whole building energy simulations by creating an occupant behavioral model. Additionally, they recommended that occupant behavior should be assessed in detail, especially for specific buildings where users have close interaction with the building systems. However, a literature review showed that the human dimension was incorporated in a simplified way in building energy simulation due to its complexity (D’Oca et al., 2018).

Nazmy (2020) developed a conceptual framework for adaptive occupant behavior. The framework was based on the Drivers – Needs – Actions – Systems ontology that was developed to standardize the building-occupant interaction representation (Hong, et al., 2015a; Hong, et al, 2015b; D’Oca et al., 2017). Nazmy’s framework consisted of four components: building systems, indoor environmental quality criteria, theory of planned behavior constructs, and individual and spatial factors. The spatial factors identified in this framework were: site characteristics, building features, space planning, and furniture layout. The researcher used the framework to develop an agent-based model that represents energy-related behavior.

Uddin et al. (2022) developed a hybrid occupant behavior model by integrating Agent-Based Modeling (ABM), Systems Dynamics (SD), and Building Information Modeling (BIM). The ABM was based on the theory of reasoned action. The SD was used to represent events and problems. The BIM was used to represent the interior layout of the space. The model was validated using data collected by sensors. The model considered the distance between the occupant and the switch location. It also included other factors such as the circulation path, direction, and presence of any obstacles. The model proved that the interior layout adjustment can improve buildings’ energy performance by 14.9%.

Theory of Planned Behavior and Occupant-Building Interaction

The theory of planned behavior is a well-established psychological theory that is used to predict the human decision process (Ajzen, 1991; Ajzen, 2020). The theory links human behavior to their beliefs. It proved that behavioral, normative, and control beliefs guide the individual’s attitude, subjective norm, and perceived behavioral control which in turn shape the behavioral intention of an individual to perform a behavior (Ajzen, 1991). The theory of planned behavior was used as a theoretical framework for environmental psychology research which focuses on occupant-building interactions such as window, shading, lighting, and temperature controls (Bavaresco et al., 2020; Heydarian et al., 2020).

Summary of the Research Gaps

A thorough review of the literature reveals that building designers and researchers have worked diligently to study and implement passive design strategies to reduce energy use and increase building sustainability. While passive design strategies achieve the building's goal of sustainability, sometimes occupants' comfort and satisfaction are compromised. Researchers agreed that interior design contributes to the passive design strategies and more attention should be given to the relationship between interior design and passive building systems such as windows and blinds to avoid occupants' dissatisfaction with their indoor environmental conditions.

Researchers also found that design can be used to raise the awareness and motivation of users to adopt sustainable behavior. Some studies addressed the concept of "Design for Sustainable Behavior" and "Design with Intent". Those concepts aimed to incorporate users' behavior in the design process and agreed that behavioral psychology needs to be taken into consideration to encourage sustainable behavior through design, however, they focused on equipment use and did not specifically address the relationship between spatial design, occupant behavior, and energy efficiency.

Occupant-building interaction including window and blind use is gaining increasing attention in the literature. The reason being is the discrepancy between the predicted versus the actual energy consumption indicates that buildings are not being used as the designers intended. Researchers developed energy-related occupant behavior models to improve the realism and accuracy of building energy performance simulation, but the existing models lack a clear representation of the influence that spatial factors have on the occupants' behavioral beliefs when it comes to interacting with buildings systems to adjust the indoor environmental conditions to reach their comfort levels.

Research Methods

A field survey was designed and conducted to collect data about occupants' energy-related behavioral beliefs and space-use patterns in residential units.

Research Setting

Three multifamily residential buildings were located in East Lansing, Michigan, USA. According to the 2021 International Energy Conservation Code (IECC, 2021), Ingham County is within the climate zone 5A which is cool and humid. The Fahrenheit-based 5-year-average (2017 to 2021) heating degree days with a base temperature of 65 F were 6505 and the cooling degree days with a base temperature of 65 F were 959 (BizEE, 2022). This unit of analysis was selected for this study because it was considered a geographical representation of multifamily residential buildings and included features and characteristics that facilitated the investigation of the study variables (orientation, floor level, space types, and furniture layout). First, the selected buildings were constructed in 2016 and consisted of four occupiable levels above the grade level. The buildings had a variety of apartment configurations which included one- and two-bedroom apartments. The apartments are fully furnished and have a consistent furniture layout as shown in Figure 3.

Figure 3

Interior Shots of the Apartments Studied in this Research

Note. Photo Credit by Chris Buller, MSU Residence Education and Housing Services.

Almost 50% of the apartments were facing the north orientation and the other 50% were facing the south orientation. The apartments with a north orientation overlook a parking lot and those with a south orientation overlook a lawn area as shown in Figure 4 and Figure 5

Figure 4

Exterior Façades of the Multifamily Residential Buildings Studied in this Research

Note. Photo Credit by Authors.

Figure 5

Image Showing the Relationship between the Buildings and Site.

Note. Image Source : https://www.google.com/maps

The different apartment orientations, the variety of outdoor views, the multiple floor levels, and the similar furniture layout made this unit of analysis an appropriate one for this study that focuses on spatial factors. Also, the geographic location of the buildings allowed the researcher to conduct the survey during the summer and winter.

Research Participants

The population of the study is the buildings' tenants who were undergraduate and graduate students' families. Students and their families were diverse in their age, income, race, ethnicity, and cultural background. The sample frame included all the heads of households of each of the 189 apartments. The base sample size of 93 responses was calculated with a 5% precision and a 95% confidence level (PSU 2014).

Research Instrument

The questionnaire used was designed based on the theory of planned behavior (Ajzen, 2006). The questionnaire investigates occupants' behavioral beliefs towards two adaptive behaviors to control indoor environmental conditions. The first behavior is operating windows which can affect the indoor temperature, air quality, and acoustics. The second behavior is adjusting blinds which affect the indoor daylight, outdoor views, and temperature.

The theory of planned behavior demonstrated that beliefs about the expected outcomes associated with the specific behavior drive human actual behavior. Accordingly, sample questionnaire items shown in Figure 6 were used to collect data about occupants' behavioral beliefs about operating windows and adjusting blinds. The behavioral beliefs construct was measured using indoor environmental quality variables associated with operating windows such as thermal comfort, visual comfort, acoustical comfort, indoor air quality, and perception of energy consumption. To measure the behavioral beliefs, we asked a series of questions such as "What do you think are the benefits (or drawbacks) of operating windows (or adjusting blinds) in the living room area (or bedroom area) in summer (or winter)?" We asked the respondents to select all that apply from the list of six items, including "operating windows has no drawbacks (or benefits)," "It causes an undesired (or desired) change in temperature," "It causes an undesired (or desired) change in airflow," "It raises (or eliminates) air pollution concerns," "It raises (or eliminates) noise concerns," "It wastes (or saves) energy,". Also, we asked respondents to select all that apply from the list of six items, including "adjusting blinds has no drawbacks (or benefits)," "It causes an undesired (or desired) change in temperature," "It causes an undesired (or desired) change in the amount of daylight," "It hinders (or allows) access to outdoor views," "It raises (or eliminates) privacy concerns," "It wastes (or saves) energy,". The variables of six binary items are also shown in Figure 6.

Figure 6

Sample Questionnaire Items

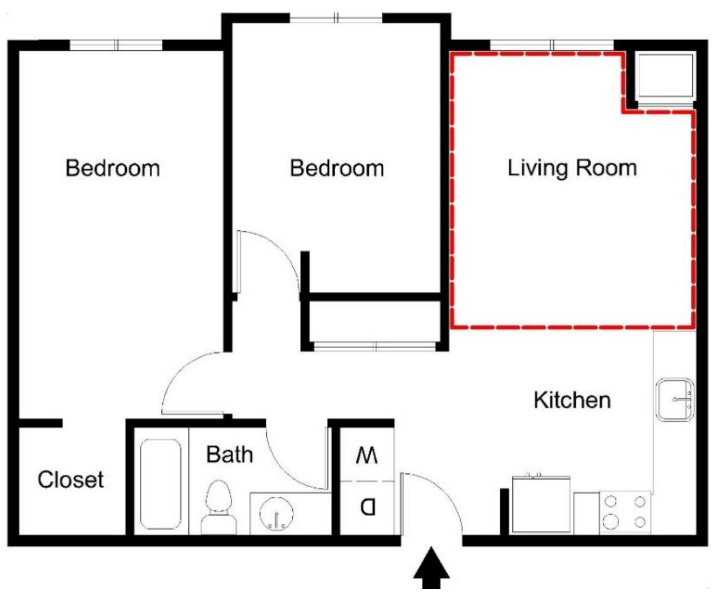
Negative Behavioral Beliefs of Operating Windows	**What do you think are the benefits of operating windows in the <u>living area</u> in summer?** (Please select all that apply) ☐ Operating windows has no drawbacks ☐ It causes an undesired change in temperature ☐ It causes an undesired change in airflow ☐ It raises pollution concerns ☐ It raises noise concerns ☐ It wastes energy, please explain why: ☐ If other, please specify:
Positive Behavioral Beliefs of Operating Windows	**What do you think are the benefits of operating windows in the <u>living area</u> in summer?** (Please select all that apply) ☐ Operating windows has no benefits ☐ It causes a desired change in temperature ☐ It causes a desired change in airflow ☐ It eliminates air pollution concerns ☐ It brings in outdoor pleasant sounds ☐ It saves energy, please explain why: ☐ If other, please specify:

In addition, qualitative data were collected using the heat maps which were set up using the Qualtrics platform. The floor plan of each apartment type was saved as an image and inserted in one of the questionnaire items as shown in Figure 7. The living and sleeping areas were highlighted with a red border and customized regions were added to help report the results that are relevant to the areas under study. We asked respondents to select the option that best describes their apartment from the list of four items, including “Apartment overlooking the green area,” “Apartment overlooking the parking lot,” “Corner apartment overlooking the green area,” “Corner apartment overlooking the parking lot." This filtering question allowed the Qualtrics software to display the apartment layout that corresponds to the respondents' answers in the following question. Then, respondents were asked to click on the area on the drawing that indicated their preferred spot where they spend most of their time in the sleeping area (or living area) in summer (or in winter). Afterward, we asked participants to respond to an open-ended question and explain if their preference for the spot that they selected in the previous question is related in any way to its location from the windows.

Figure 7

Sample Heat Map and Open-Ended Questions

The drawing below shows the floor plan of your apartment. Please click on the area on the drawing that indicates your preferred spot where you spend most of your time in the **living area** in summer.



Can you please explain if your preference of the spot that you selected in the previous question is related in any way to its location from the windows?

To ensure content validity, The behavioral beliefs about the behaviors under study were described based on the action, target, context, and time. For example, the occupants perform an action which was operating a window that is the target in a specific context, which was one of the cases was the sleeping area or the living area. In addition, the research focused on behaviors during the daytime, and in two different seasons which were summer and winter.

Since the biased selection of participants and history may be two confounding variables that might pose a threat to the internal validity of the self-reported questionnaire, therefore, the survey was distributed among all potential participants to eliminate preexisting biases such as age, nationality, etc. Also, since recently performed behavior is easier to recall than those that were performed a long time ago, the survey was conducted in the summer and winter seasons so that occupants can respond to the survey questions according to the present season.

Regarding external validity, the self-representation bias was reduced by ensuring the confidentiality of the responses and exemplifying the importance of the true responses to benefit the research. Also, the reactive effects of experimental arrangement are eliminated in this study because the participants were asked to give information about behavior that they do in their everyday life in their natural setting, which is the apartment that they live in.

Research Data Collection Procedures

The data collection was conducted two times during the summer and winter seasons of 2019 and 2020. The residential buildings were occupied by a state university's students, so the research residents were contacted through the State university's Registrar's Office. The respondents were also encouraged to share the link to the survey with their family members who are living with them in the same apartment. The same data collection procedures were adopted in both summer and winter surveys. This research adopted the mixed-mode survey design (Dillman et al., 2014) to increase the response rate and reduce coverage error. The first online survey invitation was sent to the occupants followed by two email reminders after one and two weeks after the date of the initial invitation. Two weeks later, the paper-based survey was mailed to the occupants followed by a postcard reminder within a week of that date. The postcard reminder included the URL and a QR code to encourage occupants to respond to the online survey. The respondents received a $5 Amazon gift card as an incentive for completing the survey.

Research Data Analysis Plan

Descriptive statistics were conducted to sort out the demographic and socioeconomic characteristics of the respondents. It was also used to sort the responses based on the nominal independent variable (spatial factors) which consisted of three categories: orientation, floor level, and space type. The occupants' behavioral beliefs were measured using six dichotomous dependent variables, each consisting of two categories: yes and no. The binary logistic regression was used to analyze the relationship between the spatial factors and the occupants' behavioral beliefs about operating windows and adjusting blinds through indoor environmental conditions. Also, qualitative analysis was used to explain the occupants' behavioral beliefs about operating windows and adjusting blinds using thematic analysis of open-ended questions and heat maps.

Results

Participants Profiles

A total number of 104 and 101 responses were collected from the summer and winter surveys, respectively. The response rate exceeded 50% in both rounds of data collection. Table 1 shows that more than half of the respondents were between 25- and 34 years old. The rest of the respondents were in the age range of 18-24 and 35-44 years old. Both genders equally participated in this survey in both seasons. About 42% of the respondents to the summer survey were males and 57% were females. Similarly, about 44% of the respondents to the winter survey were males and 56% were females. Most of the respondents were Asian/ Asian American and White/Caucasian/ European. Also, some of the respondents were Black/African American, Arab/Middle Eastern, Latin American/Hispanic, and African. Since the three buildings under study are family housing, most of the respondents indicated that there were at least two adults and almost half of them had children living with them.

Table 1

Age, Gender, and Race of Survey Respondents

		Summer Survey		Winter Survey	
		Frequency	Percent	Frequency	Percent
Variable	Age				
Valid	Prefer not to answer	2	1.9	1	1.0
	18-24 years old	11	10.6	19	18.8
	25-34 years old	64	61.5	60	59.4
	35-44 years old	25	24.0	17	16.8
	55-64 years old	1	1.0	4	4.0
	Total	103	99.0	101	100.0
Missing	System	1	1.0	0	0.0
Total		104	100.0	101	100.0
Variable	Gender				
Valid	Prefer not to answer	4	3.8	1	1.0
	Male	42	40.4	44	43.6
	Female	57	54.8	56	55.4
	Total	103	99.0	101	100.0
Missing	System	1	1.0	0	0.0
Total		104	100.0	101	100.0
Variable	Race				
Valid	Prefer not to answer	4	3.8	4	4.0
	American Indian or Alaska Native or Indigenous or First Nations	1	1.0	1	1.0
	Asian or Asian American	57	54.8	52	51.5
	Black or African American	5	4.8	4	4.0
	White or Caucasian or European American	25	24.0	1	1.0
	Arab or Middle Eastern	5	4.8	24	23.8
	Latin American or Hispanic	4	3.8	9	8.9
	African	1	1.0	3	3.0
	Mixed	1	1.0	2	2.0
	Total	103	99.0	1	1.0
Missing	System	1	1.0	101	100.0
Total		104	100.0	101	100.0

Table 2 shows that about 14% of the respondents were doctorate students or candidates. Most of the respondents held either bachelor’s or master’s degrees. The rest of them had a high school degree, associate degree, or professional degree. About two-thirds of the respondents were students at a State University and the other third were either their spouses or domestic partners.

About 60% of the respondents' average household income was less than $36,000 and the others had higher income levels as shown in Table 6.

Table 2

Education, Affiliation, and Income of Survey Respondents

		Summer Survey		Winter Survey	
		Frequency	Percent	Frequency	Percent
Variable	Highest Education Degree				
Valid	Prefer not to answer	1	1.0	0	0.0
	High school degree or equivalent	5	4.8	4	4.0
	Some college, no degree	7	6.7	10	9.9
	Associate degree	5	4.8	4	4.0
	Bachelor's degree	20	19.2	24	23.8
	Master's degree	47	45.2	44	43.6
	Professional degree	4	3.8	2	2.0
	Doctorate	14	13.5	13	12.9
	Total	103	99.0	101	100.0
Missing	System	1	1.0	0	0.0
Total		104	100.0	101	100.0
Variable	Affiliation to a State University				
Valid	Prefer not to answer	2	1.9	1	1.0
	Student yourself	65	62.5	71	70.3
	Spouse or domestic partner of a student	33	31.7	25	24.8
	Child of a student	1	1.0	2	2.0
	Staff	1	1.0	0	0.0
	Total	102	98.1	99	98.0
Missing	System	2	1.9	2	2.0
Total		104	100.0	101	100.0
Variable	Average Household Income				
Valid	$0	14	13.5	13	12.9
	$ 1- $ 12,000	10	9.6	12	11.9
	$ 12,001- $ 24,000	32	30.8	34	33.7
	$ 24,001- $ 36,000	20	19.2	21	20.8
	$ 36,001- $ 48,000	7	6.7	5	5.0
	$ 48,001- $ 60,00	10	9.6	10	9.9
	$ 60,001- $ 72,000	5	4.8	2	2.0
	$ 72,001- $ 84,000	2	1.9	1	1.0
	$ 96,000 or mor	3	2.9	2	2.0
	Total	103	99.0	100	99.0
Missing	System	1	1.0	1	1.0
Total		104	100.0	101	100.0

Housing Characteristics

Besides the demographic and socioeconomic characteristics presented above, the housing characteristics were an important aspect of this study and are presented in Table 3. The apartment orientation was one of the factors that were studied, and the respondents were almost equally divided in which about half of them were occupying apartments facing the north and overlooking a parking lot and the others were occupying apartments facing the south and overlooking a green area. The floor level was another factor studied in this research and the respondents were almost equally divided in which about a quarter of them was occupying apartments on the first, second, third, and fourth floors. Occupants' move-in dates to the apartments varied. Some respondents occupied their apartments since the building was constructed in the Fall of 2016, while other respondents moved in the Spring of 2020 right before the study was conducted. This means most of the respondents have been living in their current homes for at least one year.

Table 3

Apartments' Orientation, Floor Level, and Move-in Date of Survey Respondents

		Summer Survey		Winter Survey	
		Frequency	Percent	Frequency	Percent
Variable	Apartments' Orientation				
Valid	North	57	54.8	54	53.5
	South	47	45.2	47	46.5
	Total	104	100.0	101	100.0
Missing	System	0	0.0	0	0.0
Total		104	100.0	101	101
Variable	Apartments' Floor Level				
Valid	First Floor	19	18.3	17	16.8
	Second Floor	33	31.7	37	36.6
	Third Floor	29	27.9	29	28.7
	Fourth Floor	23	22.1	18	17.8
	Total	104	100.0	100	100.0
Missing	System	0	0.0	0	0.0
Total		104	100.0	101	100.0
Variable	*Move-in Date*				
Valid	Fall 2016	21	20.2	21	20.8
	Spring 2017	3	2.9	1	1.0
	Summer 2017	3	2.9	2	2.0
	Fall 2017	21	20.2	18	17.8
	Spring 2018	7	6.7	2	2.0
	Summer 2018	4	3.8	2	2.0
	Fall 2018	29	27.9	31	30.7
	Spring 2019	4	3.8	0	0.0
	Summer 2019	0	0.0	0	0.0
	Fall 2019	12	11.5	20	19.8
	Spring 2020	0	0.0	4	4.0
	Total	104	100.0	101	100.0
Missing	System	0	0.0	0	0.0
Total		104	100.0	101	100.0

Results of the Binary Logistic Regression

The binary logistic regression was conducted to explain the relationships between spatial factors (i.e., orientation, floor level, space type) and occupants' behavioral beliefs about operating windows and adjusting blinds. Three assumptions were checked before running the binary logistic regression. First, the construct studied (occupants' behavioral beliefs) was measured using six binominal variables with two categories (yes or no). Second, casewise diagnostics were used to identify all the outliers outside three standard deviations. Results showed that there are no significant outliers in the data series. Finally, the Variance Inflation Factor (VIF) and tolerance are the two indicators that were computed to measure the impact of collinearity on the analysis. Results showed that the VIF was lower than 10 and the tolerance was higher than 0.01 for all independent variables, so multicollinearity is not a threat to the analysis.

Tables 4-11 show the results of the binary logistic regression. Each table includes the three independent variables (i.e., orientation, floor level, and space type). The rows corresponding to each independent variable display the results of the statistical analysis for each of the six variables indicated in Figure 6. The significant results are highlighted in grey.

Table 4 shows that, in the summer months, the odds ratio for those who occupy an apartment facing the north orientation to believe that operating windows had no drawbacks is 0.556. This suggests that occupants of north-facing apartments were 0.556 times less likely to believe that operating windows have no drawbacks compared to those who occupy south-facing apartments. However, it was 2.737 times more likely that those who occupy an apartment on the first floor believe that operating windows has no drawbacks compared to occupants living in apartments at higher floor levels. Table 5 shows that it was 0.276 times less likely that those who occupy an apartment on the first floor believe that operating windows have no benefits compared to those who occupy apartments at higher floor levels. Also, it was 2.963 times more likely that those who occupy an apartment on the first floor believe that operating windows bring in outdoor pleasant sounds compared to occupants living in apartments at higher floor levels. In addition, it was 0.244 times less likely that occupants believe that operating windows improves the indoor air temperature in the sleeping area compared to the living area. Also, it was 1.822 times more likely that occupants believe that operating windows bring in outdoor pleasant sounds in the sleeping area compared to the living area.

Table 4

Binary Logistic Regression Results for Occupants' Negative Behavioral Beliefs of Operating Windows from Summer Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No Drawbacks	-.588	.297	3.915	1	.048	.556	.310	.994
	Undesired Temp.	.006	.319	.000	1	.986	1.006	.538	1.878
	Undesired Air Flow	.088	.464	.036	1	.850	1.092	.439	2.713
	Undesired Air Poll.	.221	.596	.138	1	.710	1.248	.388	4.016
	Undesired Acoustics	.582	.325	3.206	1	.073	1.789	.946	3.383
	Wastes Energy	.006	.458	.000	1	.989	1.006	.410	2.467
First Floor Compared to Second, Third, and Fourth Floors	No Drawbacks	1.007	.435	5.358	1	.021	2.737	1.167	6.418
	Undesired Temp.	.504	.456	1.221	1	.269	1.656	.677	4.051
	Undesired Air Flow	1.540	1.042	2.184	1	.139	4.664	.605	35.960
	Undesired Air Poll.	-.497	.695	.512	1	.474	.608	.156	2.374
	Undesired Acoustics	-.197	.418	.223	1	.637	.821	.362	1.861
	Wastes Energy	-.401	.552	.528	1	.467	.670	.227	1.975
Sleeping Area Compared to Living Area	No Drawbacks	-.317	.293	1.173	1	.279	.728	.410	1.293
	Undesired Temp.	.433	.319	1.839	1	.175	1.542	.825	2.883
	Undesired Air Flow	.102	.464	.048	1	.827	1.107	.446	2.749
	Undesired Air Poll.	-.030	.596	.003	1	.960	.970	.302	3.121
	Undesired Acoustics	-.345	.325	1.126	1	.289	.708	.374	1.340
	Wastes Energy	.837	.482	3.021	1	.082	2.310	.899	5.937

Table 5

Binary Logistic Regression Results for Occupants' Positive Behavioral Beliefs of Operating Windows from Summer Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No Benefits	-.582	.445	1.708	1	.191	.559	.234	1.337
	Desired Temp.	.027	.345	.006	1	.937	1.028	.523	2.021
	Desired Air Flow	.248	.300	.685	1	.408	1.281	.712	2.305
	Desired Air Poll.	.216	.353	.374	1	.541	1.241	.621	2.481
	Desired Acoustics	.538	.316	2.889	1	.089	1.712	.921	3.182
	Saves Energy	.060	.486	.015	1	.902	1.062	.410	2.751
First Floor Compared to Second, Third, and Fourth Floors	No Benefits	-1.288	.459	7.864	1	.005	.276	.112	.679
	Desired Temp.	.024	.460	.003	1	.959	1.024	.416	2.520
	Desired Air Flow	.441	.381	1.342	1	.247	1.554	.737	3.277
	Desired Air Poll.	.192	.489	.155	1	.694	1.212	.465	3.157
	Desired Acoustics	1.086	.516	4.427	1	.035	2.963	1.077	8.152
	Saves Energy	1.406	1.046	1.809	1	.179	4.081	.526	31.679
Sleeping Area Compared to Living Area	No Benefits	-1.288	.459	7.864	1	.005	.276	.112	.679
	Desired Temp.	.024	.460	.003	1	.959	1.024	.416	2.520
	Desired Air Flow	.441	.381	1.342	1	.247	1.554	.737	3.277
	Desired Air Poll.	.192	.489	.155	1	.694	1.212	.465	3.157
	Desired Acoustics	1.086	.516	4.427	1	.035	2.963	1.077	8.152
	Saves Energy	1.406	1.046	1.809	1	.179	4.081	.526	31.679

Table 6 shows that, in the summer months, the odds ratio for those who occupy an apartment on the first floor believe that adjusting blinds caused an undesired change in the amount of daylight is 5.181. This suggests that occupants living in an apartment on the first floor were 5.181 times more likely to believe that adjusting blinds caused an undesired change in the amount of daylight compared to those who occupy apartments at higher floor levels. However, it was 0.356 times less likely that those who occupy an apartment on the first floor believe that adjusting blinds causes a privacy concern compared to those who occupy apartments at higher floor levels. Also, it was 0.093 times less likely that those who occupy an apartment on the first floor believe that adjusting blinds results in more energy consumption compared to those who occupy apartments at higher floor levels. Table 7 shows that it was 1.813 times more likely that those who occupy an apartment facing the north orientation believe that adjusting blinds causes the desired change in the amount of daylight compared to those who occupy an apartment facing the south orientation. Also, it was 5.197 times more likely that occupants living in an apartment on the first floor believe that adjusting blinds causes a desired change in the indoor temperature compared to those who occupy apartments at higher floor levels.

Table 6

Binary Logistic Regression Results for Occupants' Negative Behavioral Beliefs of Adjusting Blinds from Summer Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No Drawbacks	-.244	.292	.697	1	.404	.783	.442	1.390
	Undesired Temp.	.372	.627	.352		.553	1.451	.425	4.953
	Undesired Daylight	-.146	.355	.169		.681	.864	.431	1.733
	Undesired Views	.491	.374	1.722	1	.189	1.634	.785	3.403
	Privacy Concerns	.235	.323	.527	1	.468	1.264	.671	2.382
	Wastes Energy	-1.458	1.122	1.686	1	.194	.233	.026	2.101
First Floor Compared to Second, Third, and Fourth Floors	No Drawbacks	.563	.407	1.912	1	.167	1.756	.791	3.899
	Undesired Temp.	18.534	6775	.000	1	.998	111968	.000	.
	Undesired Daylight	1.645	.751	4.797	1	.029	5.181	1.189	22.578
	Undesired Views	.967	.638	2.298	1	.130	2.631	.753	9.193
	Privacy Concerns	-1.034	.387	7.147	1	.008	.356	.167	.759
	Wastes Energy	-2.372	.895	7.019	1	.008	.093	.016	.539
Sleeping Area Compared to Living Area	No Drawbacks	-.218	.290	.567	1	.452	.804	.455	1.420
	Undesired Temp.	.191	.627	.093	1	.761	1.210	.354	4.136
	Undesired Daylight	-.250	.353	.500	1	.479	.779	.390	1.556
	Undesired Views	.547	.379	2.078	1	.149	1.728	.821	3.634
	Privacy Concerns	.128	.323	.158	1	.691	1.137	.604	2.139
	Wastes Energy	-.011	.862	.000	1	.990	.989	.182	5.358

Table 7

Binary Logistic Regression Results for Occupants' Positive Behavioral Beliefs of Adjusting Blinds from Summer Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No benefits	-.810	.696	1.354	1	.245	.445	.114	1.741
	Desired Temp.	.586	.355	2.722		.099	1.796	.896	3.602
	Desired Daylight	.595	.296	4.040		.044	1.813	1.015	3.239
	Desired Views	-.029	.283	.010	1	.920	.972	.558	1.693
	Improved Privacy	-.402	.298	1.819	1	.177	.669	.373	1.200
	Saves Energy	.837	.650	1.662	1	.197	2.310	.647	8.253
First Floor Compared to Second, Third, and Fourth Floors	No benefits	-1.046	.660	2.509	1	.113	.351	.096	1.282
	Desired Temp.	1.648	.752	4.805	1	.028	5.197	1.191	22.684
	Desired Daylight	-.107	.386	.077	1	.781	.898	.422	1.913
	Desired Views	.143	.371	.149	1	.700	1.154	.557	2.389
	Improved Privacy	-.190	.381	.249	1	.618	.827	.392	1.745
	Saves Energy	-1.108	.663	2.796	1	.094	.330	.090	1.210
Sleeping Area Compared to Living Area	No benefits	-.228	.630	.131	1	.718	.796	.232	2.736
	Desired Temp.	-.121	.354	.116	1	.733	.886	.443	1.774
	Desired Daylight	-.117	.292	.160	1	.689	.890	.503	1.576
	Desired Views	.533	.282	3.572	1	.059	1.704	.980	2.962
	Improved Privacy	-.277	.295	.878	1	.349	.758	.425	1.352
	Saves Energy	.156	.630	.061	1	.804	1.169	.340	4.019

Table 8 shows that, in the winter months, the odds ratio for those who occupy an apartment facing the north orientation to believe that operating windows raised noise concerns was 0.418. This suggests that occupants of an apartment facing the north orientation were 0.418 times less likely to believe that operating windows raised noise concerns compared to those who occupy apartments facing the south orientation. Also, it was 0.383 times less likely that occupants believe that operating windows raised noise concerns in the sleeping area compared to the living area. Table 9 did not show any significant results regarding occupants' positive behavioral beliefs about operating windows in the winter season.

Table 8

Binary Logistic Regression Results for Occupants' Negative Behavioral Beliefs of Operating Windows from Winter Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No Drawbacks	.526	.325	2.622	1	.105	1.693	.895	3.202
	Undesired Temp.	-.276	.288	.923		.337	.758	.431	1.333
	Undesired Air Flow	.487	.402	1.466		.226	1.627	.740	3.579
	Undesired Air Poll.	.351	.691	.258	1	.612	1.420	.366	5.507
	Undesired Acoustics	-.873	.425	4.215	1	.040	.418	.181	.961
	Wastes Energy	.103	.477	.047	1	.829	1.108	.435	2.824
First Floor Compared to Second, Third, and Fourth Floors	No Drawbacks	-.288	.413	.488	1	.485	.749	.334	1.683
	Undesired Temp.	.060	.382	.024	1	.876	1.061	.502	2.246
	Undesired Air Flow	.085	.536	.025	1	.874	1.089	.381	3.116
	Undesired Air Poll.	-.312	.831	.141	1	.707	.732	.143	3.733
	Undesired Acoustics	-.780	.483	2.609	1	.106	.458	.178	1.181
	Wastes Energy	-.552	.561	.971	1	.324	.576	.192	1.727
Sleeping Area Compared to Living Area	No Drawbacks	.156	.323	.234	1	.629	1.169	.621	2.202
	Undesired Temp.	-.041	.286	.020	1	.886	.960	.548	1.681
	Undesired Air Flow	.317	.400	.628	1	.428	1.373	.627	3.009
	Undesired Air Poll.	-.234	.687	.116	1	.733	.791	.206	3.041
	Undesired Acoustics	-.960	.418	5.273	1	.022	.383	.169	.869
	Wastes Energy	-.452	.481	.882	1	.348	.636	.248	1.634

Table 9

Binary Logistic Regression Results for Occupants' Positive Behavioral Beliefs of Operating Windows from Winter Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No Benefits	.627	.411	2.320	1	.128	1.871	.836	4.192
	Desired Temp.	-.363	.290	1.573		.210	.695	.394	1.227
	Desired Air Flow	-.071	.297	.058		.810	.931	.521	1.666
	Desired Air Poll.	.042	.334	.016	1	.899	1.043	.542	2.008
	Desired Acoustics	.133	.439	.092	1	.762	1.142	.483	2.702
	Saves Energy	.974	.711	1.877	1	.171	2.649	.657	10.674
First Floor Compared to Second, Third, and Fourth Floors	No Benefits	.738	.648	1.295	1	.255	2.091	.587	7.447
	Desired Temp.	.140	.390	.129	1	.720	1.150	.536	2.470
	Desired Air Flow	-.350	.411	.723	1	.395	.705	.315	1.579
	Desired Air Poll.	-.348	.422	.681	1	.409	.706	.309	1.614
	Desired Acoustics	-.283	.547	.268	1	.604	.753	.258	2.201
	Saves Energy	-.676	.727	.865	1	.352	.508	.122	2.115
Sleeping Area Compared to Living Area	No Benefits	-.413	.410	1.015	1	.314	.662	.296	1.478
	Desired Temp.	-.205	.287	.512	1	.474	.815	.464	1.429
	Desired Air Flow	.000	.294	.000	1	1.000	1.000	.562	1.781
	Desired Air Poll.	.110	.331	.110	1	.741	1.116	.583	2.137
	Desired Acoustics	-.382	.441	.752	1	.386	.682	.288	1.619
	Saves Energy	.434	.667	.423	1	.516	1.543	.417	5.702

*$p \leq .05$. **$p \leq .01$. ***$p \leq .001$

Table 10 shows that, in the winter months, the odds ratio for those who occupy a north-facing apartment to believe that adjusting blinds had no drawbacks was 2.170. This suggests that those who occupy a north-facing apartment were 2.170 times more likely to believe that adjusting blinds had no drawbacks compared to those who occupy south-facing apartments. Also, it was

0.374 times less likely that occupants living in an apartment on the first floor believe that adjusting blinds hinders access to outdoor views compared to those who occupy apartments at higher floor levels. Also, it was 0.379 times less likely that those who occupy an apartment on the first floor believe that adjusting blinds raised privacy concerns compared to those who occupy apartments at higher floor levels. In addition, it was 0.446 times less likely that occupants believe that adjusting blinds caused an undesired change in the amount of daylight in the sleeping area compared to the living area. Table 11 shows that, in the winter months, it was 9.888 times more likely that those who occupy an apartment on the first floor believe that adjusting blinds caused a desired change in the indoor temperature compared to those who occupy apartments at higher floor levels.

Table 10

Binary Logistic Regression Results for Occupants' Negative Behavioral Beliefs of Adjusting Blinds from Winter Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No Drawbacks	.728	.291	6.251	1	.012	2.070	1.170	3.662
	Undesired Temp.	-.398	.451	.778		.378	.672	.278	1.626
	Undesired Daylight	-.166	.333	.247		.619	.847	.441	1.628
	Undesired Views	-1.223	.511	5.725	1	.017	.294	.108	.802
	Privacy Concerns	-.280	.317	.780	1	.377	.756	.406	1.406
	Wastes Energy	1.369	1.165	1.379	1	.240	3.930	.400	38.578
First Floor Compared to Second, Third, and Fourth Floors	No Drawbacks	-.116	.386	.091	1	.763	.890	.418	1.896
	Undesired Temp.	.334	.653	.261	1	.610	1.396	.388	5.022
	Undesired Daylight	.334	.653	.261	1	.610	1.396	.388	5.022
	Undesired Views	-1.058	.521	4.117	1	.042	.347	.125	.965
	Privacy Concerns	-1.052	.390	7.278	1	.007	.349	.163	.750
	Wastes Energy	17.631	6751.5	.000	1	.998	453833	.000	.
Sleeping Area Compared to Living Area	No Drawbacks	.000	.289	.000	1	1.000	1.000	.567	1.763
	Undesired Temp.	-.384	.442	.755	1	.385	.681	.287	1.619
	Undesired Daylight	-.808	.336	5.781	1	.016	.446	.231	.861
	Undesired Views	.608	.459	1.754	1	.185	1.836	.747	4.512
	Privacy Concerns	.097	.311	.097	1	.756	1.102	.598	2.028
	Wastes Energy	.000	1.017	.000	1	1.000	1.000	.136	7.339

Table 11

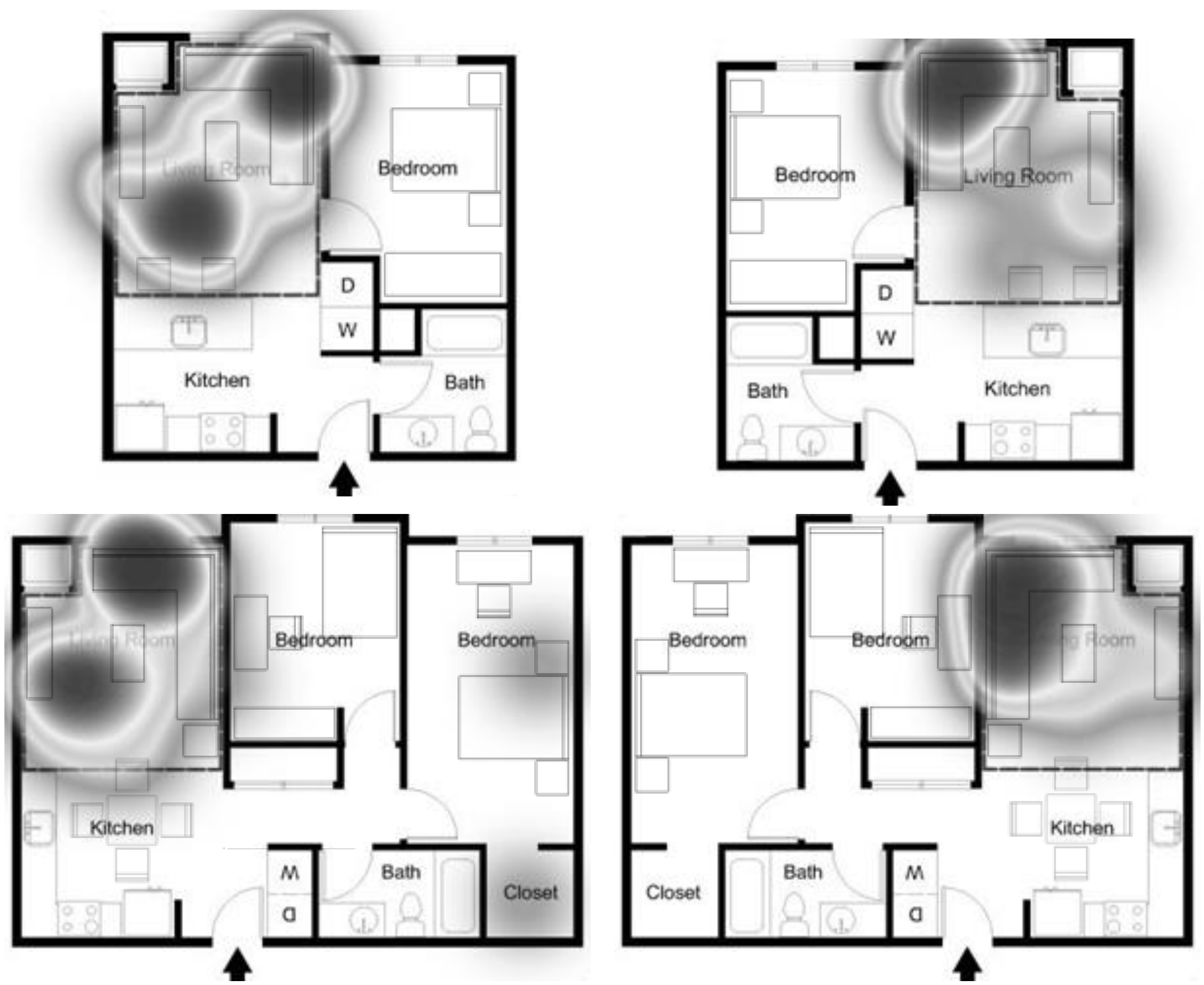
Binary Logistic Regression Results for Occupants' Positive Behavioral Beliefs of Adjusting Blinds from Winter Survey Responses

Independent Variable	Dependent Variable	B	SE B	Wald	df	Sig	Exp (B)	95% CI	
								LL	UL
North Orientation Compared to South Orientation	No benefits	1.817	1.109	2.684	1	.101	6.154	.700	54.109
	Desired Temp.	.496	.374	1.752		.186	1.642	.788	3.420
	Desired Daylight	-.465	.342	1.843		.175	.628	.321	1.229
	Desired Views	-.153	.286	.288	1	.591	.858	.490	1.501
	Improved Privacy	-.451	.321	1.970	1	.160	.637	.340	1.196
	Saves Energy	-.451	.321	1.970	1	.160	.637	.340	1.196
First Floor Compared to Second, Third, and Fourth Floors	No benefits	.229	1.125	.041	1	.839	1.257	.139	11.405
	Desired Temp.	2.291	1.037	4.884	1	.027	9.888	1.296	75.440
	Desired Daylight	.018	.450	.002	1	.968	1.018	.422	2.459
	Desired Views	-.429	.385	1.244	1	.265	.651	.306	1.384
	Improved Privacy	-.599	.400	2.242	1	.134	.550	.251	1.203
	Saves Energy	.035	.804	.002	1	.965	1.035	.214	5.007
Sleeping Area Compared to Living Area	No benefits	-.725	.885	.673	1	.412	.484	.086	2.741
	Desired Temp.	-.488	.377	1.675	1	.196	.614	.293	1.286
	Desired Daylight	-.058	.340	.029	1	.865	.944	.485	1.837
	Desired Views	.240	.283	.717	1	.397	1.271	.730	2.213
	Improved Privacy	.000	.314	.000	1	1.000	1.000	.540	1.850
	Saves Energy	.358	.603	.351	1	.553	1.430	.438	4.665

In addition to the quantitative data collected from occupants, heat maps were used to collect qualitative data about the occupants' preferred spots in sleeping and living areas during the summer and winter months and the results are displayed in Figure 8, Figure 9, Figure 10, and Figure 11. Also, opened ended questions were included in the questionnaire and thematic analysis was conducted to identify and interpret patterns of occupants' behavioral beliefs about operating windows and adjusting blinds related to the furniture layout as shown in Figure 12.

Figure 8

Heat Maps for Occupants' Preferred Spots in the Living Area During Summer.



The occupants' responses showed that their preferred spots in living areas are related to the location of the sofa and dining table in the living area. The dark spots showed that occupants were comfortable sitting close to the window during the summer months.

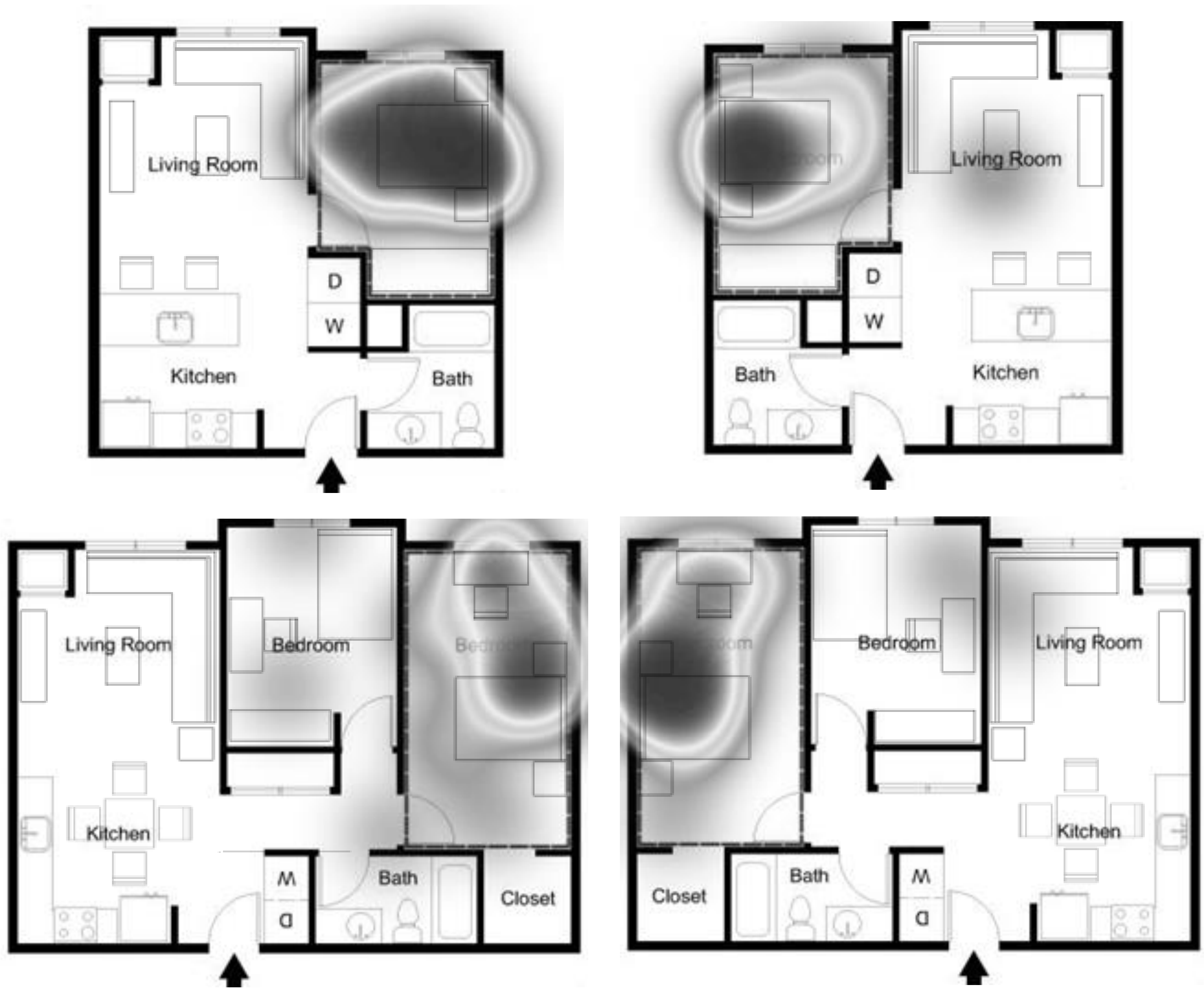
Figure 9

Heat Maps for Occupants' Preferred Spots in the Living Area During Winter.

The heat maps above showed that occupants' preferred spots were related to the furniture layout during winter. However, their preferred spots were more scattered in the space and not close to the window.

Figure 10

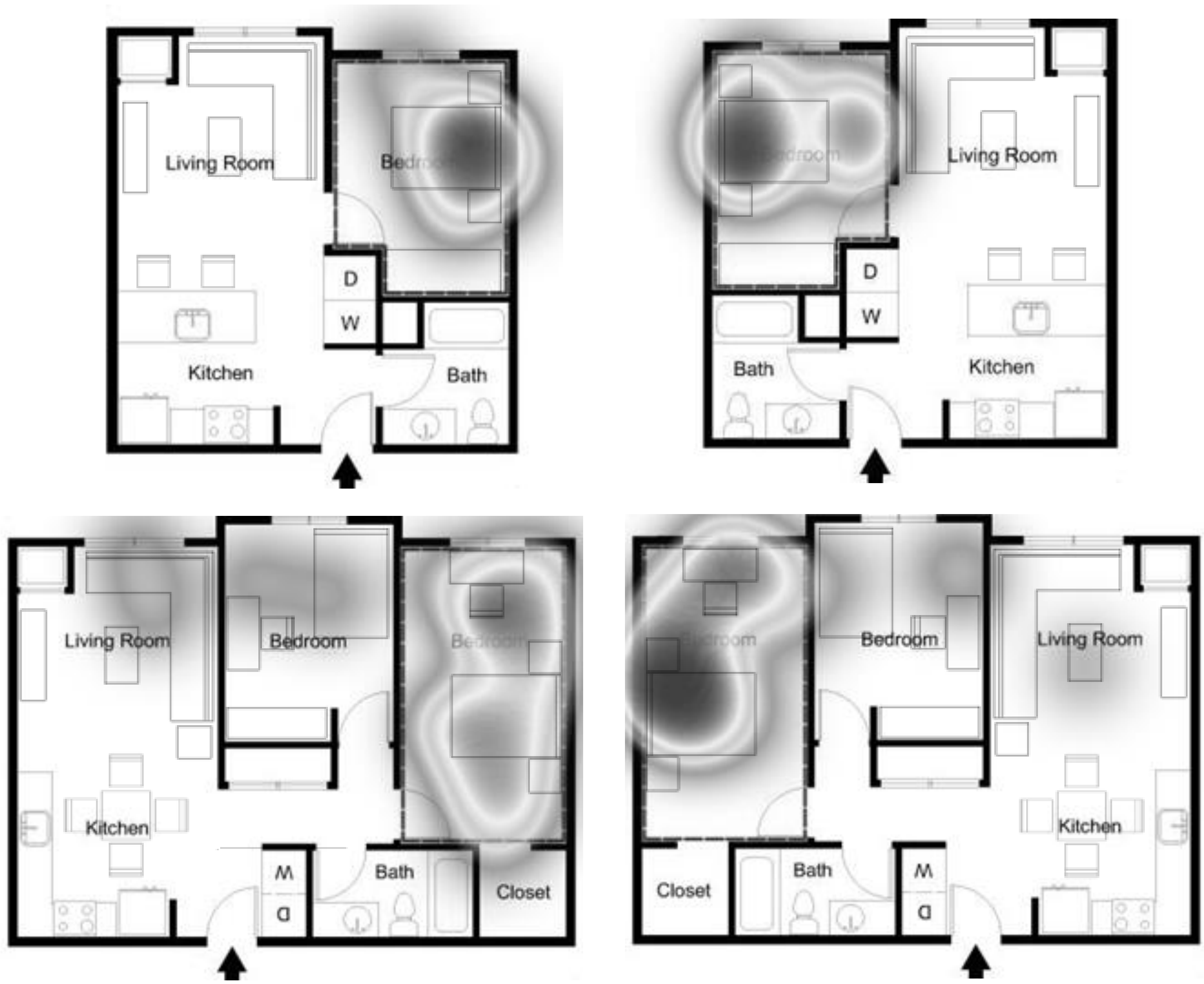
Heat Maps for Occupants' Preferred Spots in the Sleeping Area During Summer.



The occupants' preferred spots in the sleeping areas are more connected to the location of the furniture. The bedroom had a bed and a desk/chair for studying. The occupants' selected preferred spots were close to the window in the summer months.

Figure 11

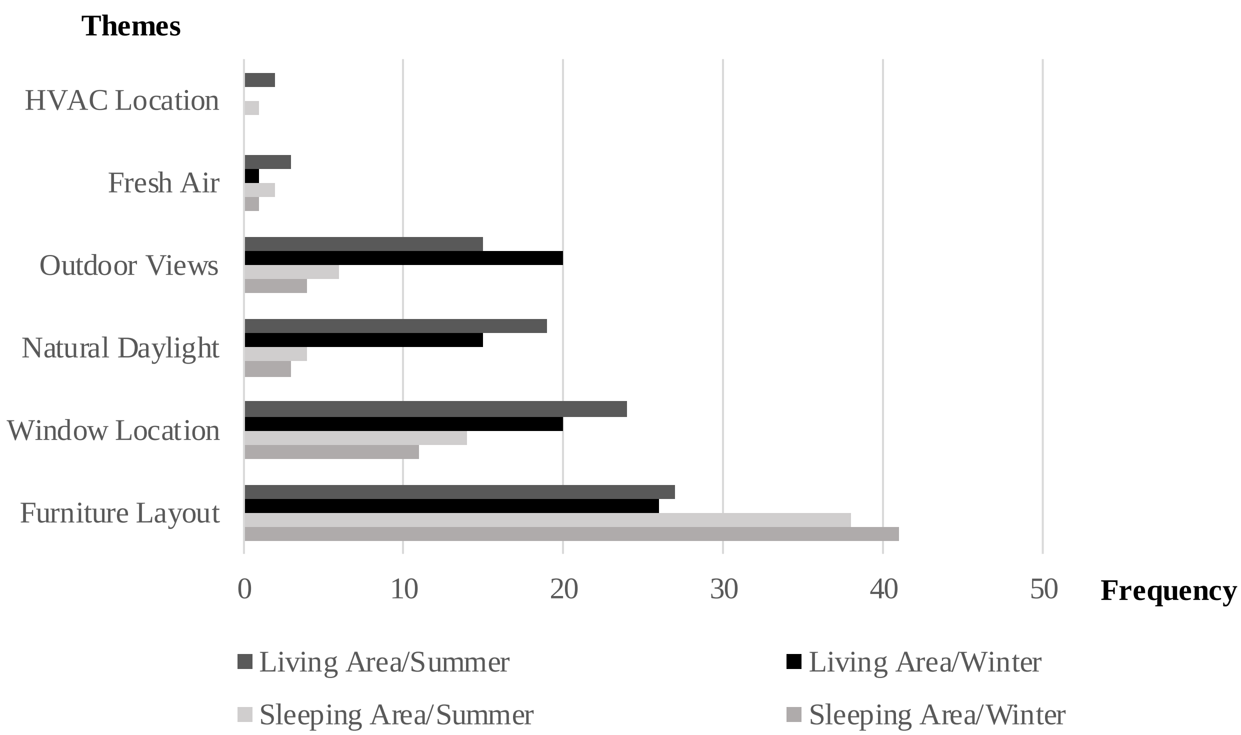
Heat Maps for Occupants' Preferred Spots in the Sleeping Area During Winter.



In the winter, the occupants' selected preferred spots were related to the furniture layout, while trying to stay away from the window. Besides the heat maps, occupants were asked to respond to open-ended questions and explain why they selected their preferred spots in living and sleeping areas during the summer and winter months.

Figure 12

Thematic Analysis of Occupants' Responses to Open-Ended Questions.



The bar chart presented in Figure 11 showed that the occupants' selection of their preferred spot in space is mostly related to the furniture layout. Occupants also indicated that their selection was related to the location of the window, especially in the living area as they could enjoy the natural daylight and have access to outdoor views.

Discussion

This research examined the relationship between spatial factors on occupants' beliefs about operating windows and adjusting blinds to control their indoor environmental conditions. The spatial factors identified were: 1- orientation 2- floor level 3- space type 4- furniture layout.

The binary logistic regression results (See Tables 4 to 11) revealed that occupants of north-facing apartments had significantly fewer negative beliefs toward operating windows in the summer and winter seasons. They also had significantly more positive beliefs toward adjusting their blinds to allow natural light into their spaces during summer. One of the possible justifications for this pattern is that occupants of northern exposed apartments are less concerned with the increase in the indoor temperature compared to occupants of southern exposed apartments. The results also revealed that occupants are aware of the heat gain in southern exposed apartments since the buildings are in the northern hemisphere.

First-floor unit occupants believed that the benefits of operating windows and adjusting blinds outweighed their drawbacks in both seasons. They had significantly more positive behavioral beliefs regarding adjusting blinds in summer and winter seasons to improve indoor air temperature. Also, results show that the first-floor units' occupants believed that adjusting blinds in the summer season results in an undesired amount of daylight in their apartments. These findings imply that the occupants of the first-floor units may prefer closing the blinds in the summer season to reduce the amount of heat gain and direct sunlight in their apartments. Privacy and noise are sometimes a concern in residential units; however, Figure 4 and 5 shows the site design that provides enough lawn space with trees that separates the apartments under study and neighboring units. Those features may have contributed to the occupants' positive behavioral beliefs toward operating windows and adjusting blinds.

Occupants indicated that they believed that operating windows in the sleeping area improve the indoor air temperature during summer and improve the acoustics in both seasons. They also did not have negative behavioral beliefs towards the amount of daylight that adjusting blinds causes in the winter season. These findings indicate that occupants attempt to keep their sleeping spaces cool and quiet, and they believe that operating windows and adjusting blinds help them in achieving their comfort goals.

The overall occupants' responses show more positive behavioral beliefs about adjusting blinds compared to operating windows. This pattern may relate to the location and the airtightness of the buildings. The building is in part of Michigan with a climate Zone 5A cold and humid and experiences mild summers and cold winters. The buildings were constructed in 2016 and with airtightness in consideration to avoid heat loss. Also, all apartments are centrally air-conditioned, and utilities are included in the rent. Airtightness and air-conditioning are two factors that had a negative relation to the occupants' behavior toward operation windows.

The heat maps and occupants' responses to the open-ended questions of the survey showed that the furniture layout is a primary factor influencing the occupants' selection of their preferred spot in living and sleeping areas. The rented apartments come with furniture and their limited square footage made it hard for occupants to make major rearranges of the furniture layout. Figures 8, 9, 10, and 11 show occupants' preferred spots in summer and winter in two different spaces which are the living and sleeping areas. The heat maps showed that occupants tend to pick a location closer to the window in summer. However, the placement of the sofa by the window in some apartments as shown in Figure 3 makes it hard for occupants to avoid sitting by the window in winter since other family members may be occupying other spaces.

The window was related to the occupants' selection of their preferred spot, especially in the living area during the summer season. In addition, occupants cared about the amount of natural daylight and access to outdoor views in the living area, and these factors were less important for them in the sleeping area. It is interesting to note that few occupants selected their preferred seating spot related to the HVAC registers. The indoor air quality was not one of the occupants' priorities or concerns. This may be due to the mixed-mode ventilation provided in the buildings being studied.

The results discussed above show that the three variables (i.e., orientation, floor level, and space type) are significantly related to the occupants' behaviors on the window and blind uses. It also confirmed that the furniture layout is related to occupants' beliefs about operating windows and adjusting blinds and this is shown in the space-use pattern and the proximity to the window location.

The findings of this study align with previous research that indicated spatial factors had an impact on occupants' motivation to interact with building systems including windows and blinds use (Fabi et al., 2012, Goldstein et al., 2011; O'Brien & Gunay, 2014; Schweiker et al., 2018). In addition, the occupants' responses revealed no significant difference between occupants' behavioral beliefs regarding the energy consumption associated with their interaction with windows and blinds and spatial factors. This finding supports Karjalainen's (2016) argument that buildings are not used as intended by designers and that the occupants do not understand the impact of the behavior on the buildings' energy performance.

Some limitations and suggestions for future research need to be considered. One of the limitations is the lack of surveys of the elderly. Since occupants' behavioral beliefs could differ across age ranges, therefore it is suggested that more elderly be included in the study sample of future studies. Also, data for behavioral beliefs were collected using multiple-choice questions to reduce the cognitive burden on the participants and increase the response rate and eliminate the possibility of missing data. However, this resulted in dichotomous questions which limited the opportunity to conduct more inferential statistics. Therefore, it is highly recommended that future research collects data using a liker scale. In addition, future studies can incorporate more items in the questionnaire and modify the wording to include open/close windows and open/close blinds instead of the term operate windows and adjust blinds to increase the internal reliability of the instrument. In addition, it is recommended to be able to match the participants of the winter and summer surveys to be able to compare their responses.

Conclusion

The literature review conducted in the study highlighted a lack of connection between the design, human, and technical aspects of high-performance buildings. It also emphasized that the design for sustainable behavior concepts addressed occupant behavior of equipment use, but not their adaptive behaviors such as operating windows and adjusting blinds. It also revealed that while occupant interaction with windows and blinds has been studied in different contexts, however, there is still a lack of connection between occupants' perceptions, beliefs, and behavior. It also showed that contextual factors influencing energy-related occupant behavior were not fully considered nor represented in building performance simulations.

Therefore, this study focused on spatial factors and the occupants' behavioral beliefs which is a construct of the theory of planned behavior. It attempted to establish a connection between the occupants' behavioral beliefs about the indoor environmental conditions associated with their behavior of operating windows and adjusting blinds and the spatial design. A survey was conducted to collect quantitative and qualitative data from occupants of a multifamily residential complex. The findings of the study proved that spatial factors such as orientation, floor level, space type, and furniture layout were related to occupants' behavioral beliefs about operating windows and adjusting blinds in residential buildings.

Thus, it is recommended to consider occupants' behavioral beliefs related to the spatial factors in the preliminary stages of the design process to contribute to efficient space planning and thus enhance the building's energy performance. This approach is also expected to contribute to occupants' motivation to adopt pro-environmental behaviors. It also revealed the need to educate occupants on their interaction with building systems and their influence on the buildings' performance. Also, this study provides a foundation for future studies to connect occupants' behavioral beliefs and behaviors. The incorporation of this information into the building energy simulation software may result in a more realistic representation of occupant behavior and a more accurate prediction of buildings' energy performance.

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