Thermal Comfort and Window Proximity as They Relate to Perceived Employee Performance and Satisfaction

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OFARTS

Advisor Denise Guerin

August, 2010

Acknowledgements

To all of the wonderful individuals that I worked with at the University of Minnesota and who helped make this work possible. My advisor, Denise Guerin who was always available to give her advice and expertise and who made my time working towards completing my thesis fun and exciting, I give my sincere thanks. To Caren Martin and Hye-Young Kim who were a part of my committee, I thank them for helping guide me in completing my thesis as well as being there for support. To Stef Truzpc and all the other wonderful graduate students I met along the way, I thank them for their support and commiseration on the lengthy process that we went through together.

Lastly to my family, Justin, Peyton, William, Grace and my parents, Carol and Doug Watson, thank you for your support and love while I spent many hours away from all of you working on completing my work.

Dedication

I would like to dedicate this work to my parents, who were wonderful examples of what it takes to accomplish your dreams and always supported me through every aspect of my life. Also to my husband Justin and my children, Peyton, William, and Grace who helped make this possible.

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Chapter 1 Introduction

Purpose of the Study

The purpose of this research is to determine the relationship between thermal comfort and workstation window proximity with employees' perceived performance and satisfaction in a corporate environment. Interior designers need to consider the impact that the design of employees' workstation has on their perceived performance and satisfaction in order to create a more successful and profitable solution for the interior designers' clients. This study examined the new corporate headquarters for Medtronic's Cardiac Rhythm Disease Management (CRDM) business unit in Mounds View, Minnesota. Medtronic was chosen for this particular study due to the large numbers of employees who work in this facility and the ability to generalize findings to other similar corporations. In addition, it is a relatively new building where the majority of employees have been in the facility long enough to no longer have bias about the novelty of a new space. This study focuses specifically on the effect thermal comfort and workstation window proximity has on an individual's perceived performance using the Human Ecosystem Theory (HET) as a theoretical framework.

Rationale

No matter where a corporation is located or who is responsible for the design of the corporation's offices, all businesses share a common construct, which is; the relationship between the cost of their employees and the effect their performance has on the businesses' bottom line. Employee performance is the second most costly part of doing business regardless the focus of the company (Chilton & Baldry, 1997), which are

areas of concern for any business no matter the size or location. What adds unnecessary cost for businesses is employee turnover, retention, illness, job-related illnesses, stress, headaches, distractions, and related issues. Within the designed environment, there are many features that are known to effect employee performance such as daylighting, artificial lighting, temperature, furnishings, and indoor air quality (Fischer et al., 2004). In relation to the built environment, performance is also affected by other elements including employees' satisfaction with their physical environment and social environment, such as their relationships with colleagues or their managers; tasks; the benefits they receive; the amenities provided by their employer; their commute to work; and a number of other factors (Fischer et al., 2004, Van der Voordt, 2004). As shown in Figure 1, these relationships are related to employee performance and satisfaction. Although all of the areas listed have been shown to affect employee performance and satisfaction, this study is limited to the physical environment and, within that, the individual workstation.

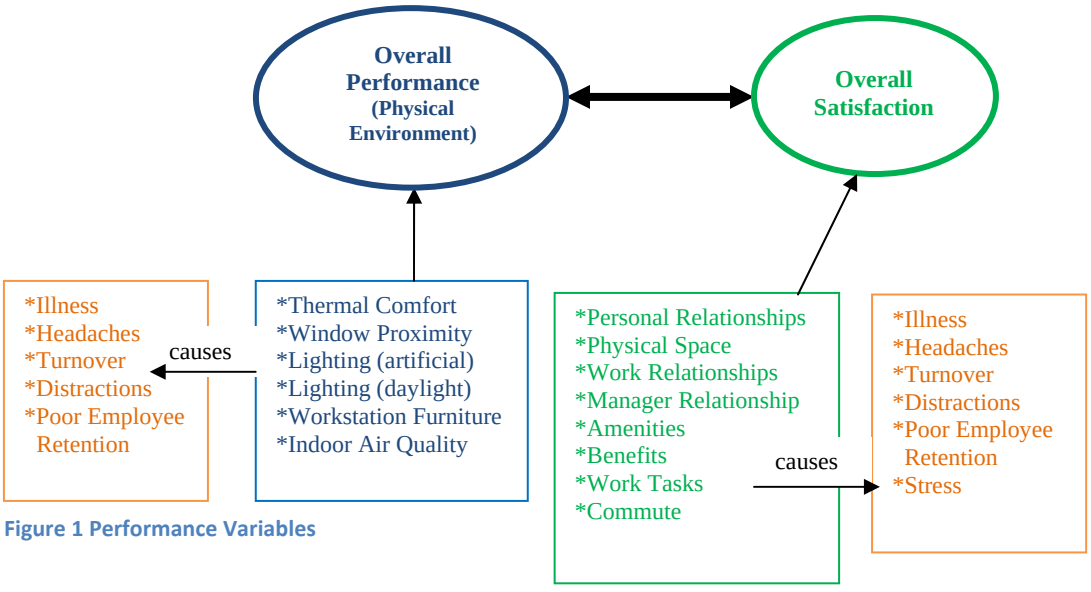


Figure 1 Performance Variables

Because of the large numbers of variables that can affect employee performance and satisfaction, it is important for interior designers to understand how individual variables affect the end users of the space, specifically variables that are within the designer's control. With a better understanding of how these variables affect employee performance, interior designers can make informed decisions on which variables are most important to spend project dollars to ensure the highest level of employee performance and satisfaction for their clients. Researchers are accountable to not only look at how the overall work environment affects performance and satisfaction, but also to research individual workstation variables and the strength of their relationships to performance, which can have a direct affect on a company's economic success.

Figure 2 Medtronic Mounds View Campus (Koyama Photography)

Background

Medtronic is the world's largest medical technology company; it is based in Minnesota with multiple buildings spread across the Twin Cities (Minneapolis/St. Paul). They specialize in technologies that help individuals with chronic illnesses lead more normal lives (Medtronic, 2010). They are best known for the invention of the external, battery-powered pacemaker in 1957 by company co-founder, Earl Bakken. Currently, the

Cardiac Rhythm Disease Management (CRDM) group remains their biggest business unit in the organization despite an expansion into spinal and biologics, neuromodulation, diabetes, and surgical technologies. In December of 2005, Medtronic broke ground on the construction of a new facility for the CRDM group in Mounds View, Minnesota. The purpose of this new facility was to bring together a business unit that was spread across six different buildings in the northern suburbs of Minneapolis. The campus consists of three, eight-story towers including a five-story, on-site parking facility for employees. The design of the campus was created to integrate the exterior and interior environments so there is a seamless transition between environments. The intent of the orientation of the buildings on the site allows for a reduced energy load and creates visual connectivity among the buildings that are all physically connected by "glass links" spanning seven of the eight-stories and housing conference rooms and meeting spaces (Figure 4). The interior is further integrated with the exterior environment by full height glass windows on all three building structures, which has become a major design feature in many new office construction projects, despite the fact that the extreme levels of glass provided often causes more issues than benefits (Muehleisen, 2010). Although the exterior of the buildings was designed to blend with its natural surroundings, it is balanced by the use of industrial finishes such as glass and concrete that are similar to the materials Medtronic uses in their medical devices.

Figure 3 shows the typical layout of the floors in all three buildings and the zones where employees in the open-office environment are located in relation to the window walls. On each floor, the plan for the employees' personal workstations was to have an open, modern, and efficient aesthetic space that would accommodate many different job types and work styles while also "…reflect(ing) the needs and aspirations and desires of the employees who work within the space" (Steve Mahle, former President of Medtronic's CRDM group, StarTribune, 2008). This was accomplished by the use of two different workstations that have slightly different layouts. Both stations provide users with adaptable features, privacy, and the ability to collaborate with team members when needed. As seen in Figure 5, both workstations use a u-shape layout with overhead file and tower storage. Type A provides users with less connected work surface but adds a movable round table for easy collaboration with an employees from other workstations. The tower storage unit is also flush with the panel unlike typical B where it is rotated providing more privacy. The openness of A creates an open and welcoming station for

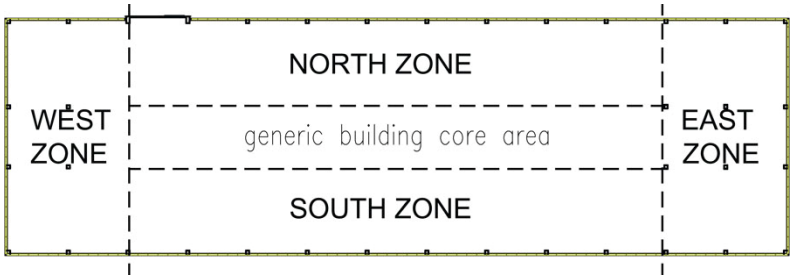


Figure 3. Typical Floor Plan


Figure 4. Mounds View Campus Site View

visitors, which also increases the possibility for distractions to the users. It may also be more prone to glare issues because of its open layout. Type B workstation provides more work surface and no separate table, so does not lend itself as well to collaboration. Both workstation types provide an adjustable height work surface so users can work in their preferred position of sitting or standing. Although the two workstation options offer employees some flexibility to support their work habits, employees were not given the option of selecting the station in which they would prefer to work. The vice president of the business group determined the workstation type for an entire business unit. Currently, when groups are relocated to a new area, the group either has to accept the existing workstation configuration or, as an entire business unit, agree to change to the alternative workstation configuration. Since the cost of the change is assigned to that business unit, the vice president of the business unit has to give the initial approval to change the workstation configuration. This inability of individual employees to choose what type of station they feel best matches their work style could cause perceived performance issues if they prefer the opposite station than that assigned. Employees' satisfaction and evaluation of their workstation is related to their perception of their own abilities or 'self-schema' (p. 131) to get their job done as efficiently as possible (Fischer et al., 2004), which in turn is crucial to the quality of work output of employees (Gensler, 2008).

Figure 5. Typical Workstation Types

Problem Statement

Despite interior designers' goal to create an environment that supports many different types of employees within a facility, it is difficult to know how those spaces help or hinder employee's perceived performance and satisfaction without a post-occupancy evaluation (POE) of the space. Failing to participate in a POE once a design is complete may impede modifying design features that negatively affect employee performance and satisfaction and lead to repeating mistakes in designs for future clients. Research consistently supports the reality that the physical environment affects both employee satisfaction and perceived performance (Vischer, 2007).

Specifically, with the abundant use of windows in the three towers that make up the CRDM campus, there are significant opportunities for both positive and negative issues to arise with employees' comfort while working in this facility. On the positive side, the views and natural daylight that are available to almost every employee within the building can help reduce stress (Vischer, 2007) and have been shown, in other studies, to create a higher level of satisfaction (Veitch, 2007). However, the large number of windows create the potential for large amounts of heat gain or loss, as well as potential glare on work surfaces and computer screens that can create eye fatigue or lead to discomfort or unpleasant feelings while at work (Kim et al., 2010).

For example, Medtronic's CRDM campus was initially occupied with no window coverings on any of the exterior windows. This decision was made by the design team so employees could take advantage of the view to the outdoors, add visual connectivity of the three buildings, and make sure that the views of the building from the exterior were

consistent for passersby. Without the ability to control the amount of light and heat coming into the building from direct sunlight, different spaces of the building were uncomfortable work environments for employees. The amount of light and heat that was coming into employees' workstations affected their ability to get their work done, so the employees taped paper onto the windows to control light, heat gain, and glare. Medtronic had to invest in motorized window treatments after the building was occupied. t was not possible to conduct this study prior to installation of window treatments as the timing of this research occurred after installation, there continues to be concern from employees and the leadership that there are ongoing issues related to the thermal environment of the facility even with the recent addition of window treatments. Therefore, if more POE studies were done and shared with other designers, mistakes like these could save money in the future for clients and create better work environments for employees upon occupation of a facility.

This study investigated how thermal comfort and workstation proximity to a window affects employee perceived performance and satisfaction at the CRDM facility.

Research Questions

Research questions of this study are the following:

Research Question 1: Is there a relationship between the interior designed environment, its components, and employee perceived performance and satisfaction?

Research Question 2: Is there a relationship between the thermal comfort and employee perceived performance?

Research Question 3: Is there a relationship between window proximity and employee perceived performance?

Research Question 3a: Is there a relationship between view when seated and employee perceived performance?

Research Question 4: Is there a relationship between overall electric lighting levels including the amount of light, desk (task) light, and visual comfort, and employee perceived performance?

The main focus of this research is on employee perceived performance. However, as literature has shown that performance is related to satisfaction, there is a secondary focus on overall satisfaction levels as related to these criteria.

Significance of the Study

This research will help Medtronic determine if thermal comfort and window proximity within the Mounds View facilities affect the employees' ability to successfully complete their daily work within the provided workstations provided to them. It will also allow Medtronic to remedy some physical environment issues that affect performance so they can improve performance and thereby increase satisfaction. Additionally, this research will help other organizations better understand design considerations for the workstations they provide for employees, make the best investment decisions possible in the work environment design, and receive the benefits of increased performance, specifically other companies who have used the same design approach as Medtronic such

as Best Buy who is also headquartered in the Twin Cities and used the same design firm for their corporate office design. Lastly, this research will help companies better understand the needs of their employees as they relate to the work environment.

Previous research also shows that the work environment has a considerable effect on financial gains or losses of the organization, as well as its external image. Successful workplace design has been shown to have a positive correlation with business performance. Looking at just an increase in profit, Gensler (2008) found that as workplace performance index increases, profit increases seven to fourteen points across all industries. However, many large organizations and interior designers do not take advantage of the findings of employee performance research in their practice.

While research shows that a company's work environment can affect its image and profitability (Veitch et al., 2007; Harter et al., 2002), many companies do not perform their own POEs to determine the impact that the work environment has on employee performance. Without these POEs, many companies will not know how to improve overall work environments going forward and will likely repeat the same mistakes when building new facilities and possibly limit their employees' performance as a result. A well-designed and executed POE can increase employee performance, employee image, and ultimately, contribute additional profit to a company's bottom line. It could also inform the evidence-based practice of interior design, architecture, and facilities management.

The more information available to design practitioners to help them understand how their designs and decisions affect those who actually live and work in these spaces,

the better the design and the greater is the potential for improving quality of life. Limited research has been done on the physical work environment's impact on employee performance. Roelofsen (2002) supports this despite the fact that there is a consensus in the field that improving work environments (on a larger scale than just speech privacy) would increase performance throughout most divisions within an organization (Herman Miller, 2008; Herman Miller, 2007; Van der Voordt, 2004; Vischer, 2007).

Ultimately, the work environment will influence and have an effect on employee performance as well as satisfaction, but researchers have failed to adequately support this relationship by failing to look just at the individual's workstation. This study will fill some of the gaps in knowledge about perceived employee performance as they relate to the workstation.

Chapter 2 Literature Review

The relevant literature reviewed in this chapter include the overall corporate landscape within new facility design; the physical work environment that employees are submersed in everyday and how it relates to their well-being; employee perceptions on their performance; employee satisfaction; relevant studies about thermal comfort and window proximity; relationships between gender, age, thermal comfort, and glare; and the use of POE in workspace assessment.

The corporate landscape literature reveals the current lack of understanding by employers as to what parts of the interior environment contribute to or diminish employee performance. Closely related to corporate landscape, this study examines how the employees' perception of their work environments affects not only their satisfaction but performance as well. Another component of this research is an exploration of research on thermal comfort and window proximity and how those variables affect employee perceptions. From these studies, relationships between gender and age were found and explored within the current research study. Lastly, the overall history of the use of POE in workspace assessment was explored and how these evaluations have been used to assess overall satisfaction and performance. A theoretical model of human ecosystem theory is discussed in relation to this study.

Based on all of this research, the study mainly looked at performance perceptions in relation to the Medtronic facilities. However, satisfaction was discussed and explored due to the proven relationship with performance.

Conceptual Definitions of the Study

It is important to provide operational definitions of the physical environment and other terms used in the literature review.

- "Employee" refers to any user of the space who is employed by an organization for more than six months and is considered full time by the organization.
- "Work environment" refers to all parts of the built interior of the building.
- "Workstation" refers to all components that make up an individual's work space.
- "Open-plan" refers to office design where minimal walls are built for employee offices.
- "Occupancy" refers to the time in which the owner of the building takes over the space from the contractor and moves into the space.
- "Performance" refers to the quality of work being produced and having the power to produce one's work.
- "Thermal Comfort" refers to state of mind that expresses satisfaction with the surrounding environment (ASHRAE Standard 55).
- "Employee Satisfaction" refers to the amount that the work environment fulfills the wants and needs of the individual (Van der Voordt, 2004).
- "Overhead General Electric" refers to ambient artificial lighting.

Performance and satisfaction have been found to affect business' economic success, i.e., the bottom line. Employee performance and satisfaction as related to the

physical environment, specifically, access to window views, thermal comfort, and general electric lighting, may have an effect on the employees of Medtronic in either a positive or negative manner. It is necessary for Medtronic to understand potential interactions of these variables with their employees.

With such diverse variables it will be important to use a comprehensive framework to organize them according to a theoretical approach. Use of the Human Ecosystem Theory (HET) will accomplish this organization as it looks at each environment that the user interacts with and how each interacts with each other.

Theoretical Framework:

An appropriate theoretical framework for this study is the Human Ecosystem Theory (HET). Human ecology, as it is generally known, is the complete view of individuals or groups and how individuals or groups interact with their surroundings, including the physical, biological, and social environments that surround everyday activities (Bubolz, Eicher, & Sontag, 1979). The basic definition of an ecosystem as used in science is a system formed by the interaction of a community of organisms with their environment (dictionary.com, 2008). This concept was first used in the form of the ecosystem theory in 1942 by Raymond Lindeman (Lee, 2007) who defined an ecosystem as "…the system composed of physical-chemical-biological processes active within a space-time unit of any magnitude" (Lindeman, 1942, p. 400) related to organisms in ecology.

Kantor and Lehr (1975) used a similar theoretical approach when studying the family unit. They contend that while it is important to look at a family as a system, it is

important to also understand that this system is not just one single unit but three subsystems that affect one another. Kantor and Lehr (1975) labeled the subsystems of the family as the family unit subsystem, the interpersonal subsystem, and the personal subsystem. Like Lindeman (1942), this concept divides a single system in three distinct subsystems. Although these systems are not defined or named exactly as in the HET, there are similarities that connect it to each of these frameworks and later appeared in research conducted by Bubolz et al. (1979) as the human ecosystem theory. Bubolz et al. (1979) took the basic ideas surrounding an ecosystem and translated them into a framework to use when studying humans' interactions with their environments on both the micro and macro levels.

Human ecosystem theory follows the same general definition as an ecosystem when applied to research and has been used by many different academic areas, such as social ecologists, sociologists, anthropologists, environmental psychologists, landscape architects, marketing, and interior designers (Cordell & Bergstrom, 1999). The main focus of this theory uses the basic definition of an ecosystem and places the human as the organism and at the center of the environments in which one lives and interacts (Guerin, 1988), similar to the use of the three subsystems defined by Kantor and Lehr (1975) where the family is placed at the center of its own subsystems.

In research conducted by Pickett et al. (1997) on urban ecosystems, the two frameworks of science and social science are combined and challenge the sciences to explore the idea that it is necessary for humans to be a central factor in any ecosystem, including the sciences. Emphasizing the connection that humans have to any natural

ecosystem is already well-documented and is seen through the remnants left behind. Science can learn from the use of HET in the social sciences (Pickett et al., 1997).

Theory Discussion

Within the assumptions of HET are the human(s) and three environments: human constructed environment (HCE), natural environment (NE), and human behavioral environment (HBE). Because of the flexibility of this theory, it is applicable to many different units of analysis, from an individual to an entire population. For example, the human can be either an individual placed at the center of one's own personal environment, an employee and his/her workstation, or a group, such as a department of employees that share similar experiences, goals, and interests. In the classic study by Bubolz et al. (1979), the HCE is defined as the environment that is modified or built by humans; NE is defined as the environment as formed by nature; HBE is defined as the social environment including the psychological needs of each individual.

More specifically, NE would consist of the weather, amount of sunlight, wind, outside temperature. HCE consists of buildings, furniture, artificial lighting, air temperature within the building, and clothing or anything constructed by humans. HBE consists of perceptions, culture, values, and morals. The human can be looked at

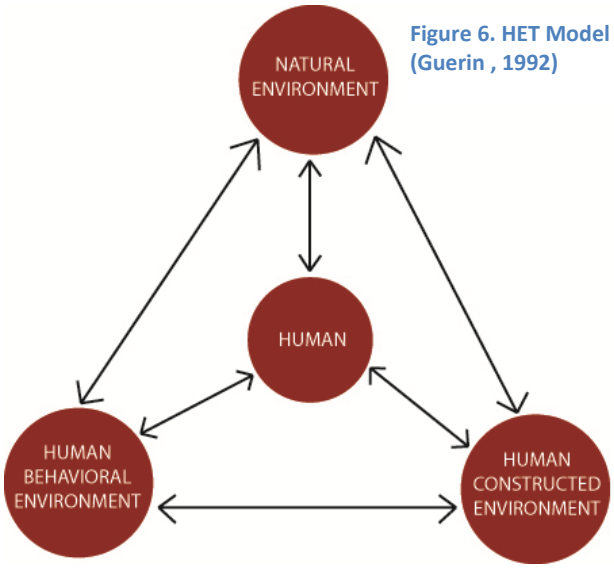
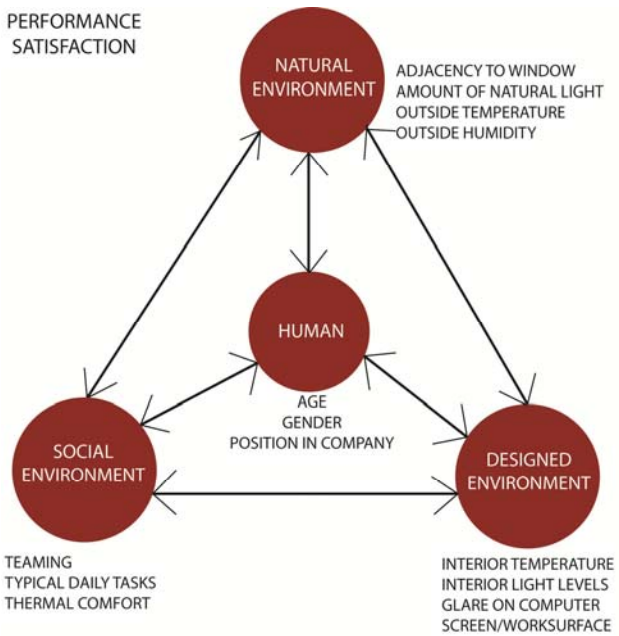


Figure 6. HET Model (Guerin , 1992)

in terms of age and gender either individually or as a unit. The main proposition of this theory is that each of these environments interacts with each other in some way and effect the way in which interactions take place. The components of all three can also interact back and forth among any or all of the components (Guerin, 1988), and directly and/or indirectly affect the human(s) or each environment. Workspace, lighting, and temperature can and do have interactions between variables and are factors that impact performance or satisfaction with one's environment (Van der Voordt, 2004). Interaction occurs when any one part of an environment manipulates or controls another part of the ecosystem and is therefore manipulated or controlled in turn (Bubolz, et al., 1979). This idea of interaction was first coined as interface in family behavioral studies as when one subsystem is affected and in turn causes an interface or interaction with at least one other subsystem (Kantor et al., 1975). An added element of interaction is the idea that environments interact both in cooperation and in opposition to each other. Strain can sometimes be seen in a situation where contradictory goals occur between two competing environments (Kantor et al., 1975).

Figure 7. HET with Performance Variables



Another component of this theory that is typically seen across most studies is the visual model that was developed to illustrate the

relationships among the assumptions, propositions, and constructs. The most common model used is shown in Figure 6, which was developed by Guerin (1992). Each circle represents one of the environments with the human surrounded by these environments. The arrows illustrate the interaction that occurs among all of the environments and the human and how those interactions can and do go both directions. Adjusting the sizes of the circles is used to show the emphasis placed on each environment for a particular study or omitted altogether if not part of the focus of the study. In addition, the interaction arrows may be omitted if a relationship is not included in a study. Later work by Guerin (2009) incorporates newer language that more accurately expresses these environments. The HBE is now the Social Environment (SE), and the HCE is renamed as the Designed Environment (DE); the NE remains unchanged (Figure 7).

HET is an appropriate way of organizing the variables of this study as it accounts for each environment that is measured to determine the effect of interior design. Not only does HET take into account each environment, but it also looks at the interactions that occur between one environment and the human, or among multiple environments and the human. It also shows that inconsistencies can occur when each environment is not working in concert with the other. Most importantly, the focus of HET is how these constructs affect the human at the center of all the environments. It explains the way in which human actions, cultures, values, and behavior impact how individuals, groups, or entire organizations interact with their environments (Butzer, 1982).

Although there is ample research that has looked at the total work environment and its effects on employee performance, there are few studies that focus on the

individual workstation itself. This study will focus on how thermal comfort and proximity to a window affects employee perceived performance.

Within the confines of this study, the environment of the workstation is categorized similar to the human ecological theory. Figure 7 shows how the components of HET fit within this model and the variables that relate to each construct of the theory; the NE, SE, DE, and HO. The SE consists of personal perceptions, ability to complete typical daily tasks, either individual or group work. DE consists of the amount of glare on work surfaces and computer screens produced from artificial lighting, daylighting, and the overall light levels of the space, the interior temperature and humidity of the space, and the size of the window.

The windows within the Medtronic facility are floor to ceiling, allowing for high amounts of daylight into the space. NE consists of the adjacency to windows, the amount of natural light, and the outside temperature and humidity. Within Medtronic, most employees have some access to windows as all workstations are set up along the perimeter with offices and conference spaces in the core. The HO consists of the age, gender, and position of the individual within the company (which was not considered in this study.

In this study, the NE interacts with the DE in the way that individuals are able to complete their work based on the amount of natural or artificial light as well as the location and layout of the workstation itself. The quality of the different components of the DE will also affect the user of the workstation through the overall functionality of the space, the adjustability of the space based on changing NE variables, and the flexibility of

the space to suit personal preferences. Within Medtronic, the workstation does not allow for much flexibility to control the temperature, light levels (both artificial and natural), or proximity to a window. Many interactions occur at the same time and a causal relationship has not been established. While it is possible for one environment to affect another in a singular way potentially setting off a chain of events, interaction does not have to happen in that way and may not be typical of this study. Each of these environments continually interacts with each other throughout a typical work day, as do the environments and the users of the space. These interactions can either positively or negatively affect employees' perceived performance and/or satisfaction.

Corporate Landscape

Large corporations spend millions of dollars on designing and building new office complexes but rarely do they complete post-occupancy evaluations to determine if the money invested is well spent or gives the return of added employee performance expected from the new design. Most corporations want to achieve a high level of employee performance at as low as cost as possible (Van der Voordt, 2004) but fail to monitor how the decisions they make really affect performance. Another mistake made by many organizations and facility managers is just looking at office space as a place to "house their employees" (Veitch et al., 2007) rather than as an asset to improve performance if designed correctly.

In recent years, employee performance has shown a decline while companies continue to add to their information technology expenses to keep up with ever changing technology that should help to increase employee performance (Smith-Jackson, 2009).

However, technology alone has been unable to support a greater increase in performance, making it important for researchers, designers, and facility managers to understand the other elements of the workspace that affect perceived performance.

Medtronic recently spent $95 million on a new campus to consolidate over 3,000 employees in their Cardiac Rhythm Disease Management group from various facilities around the Twin Cities into one campus consisting of three buildings (see Figure 4). With this large investment, it is important for Medtronic to know if design components, specifically employee workstations, enhance or hinder employee perceived performance. This knowledge can provide Medtronic with tools to quickly make necessary modifications and avoid mistakes in the future as they continue to grow and expand.

In addition, little research has been done on the effect of the workstation on employee perceived performance. Since this is the space where employees potentially spend 80% of their day (Hochanadel, 1995), it is important to understand how it affects their perceived performance. Research has also shown companies that are rated as top performing by their employees in at least eight success factors (industry leader, financial strength, development of top performing products and services, innovative, promotes work/life balance, well respected management, high employee retention, and community and environmental connection) typically have high levels of employee job satisfaction (Gensler, 2008). Medtronic is a company that epitomizes the above qualities and is known for high employee satisfaction. However, Medtronic has not looked at how their employee's perceived performance affects their ability to do their work in the best manner possible in their current and new facilities. This knowledge could help increase

satisfaction levels and add to Medtronic's reputation as not only an industry leader in medical devices but also in workplace design.

When designing interiors for corporations like Medtronic's new CRDM campus, most interior designers search for cost saving approaches. Some leave out important user needs that might take away from the overall design aesthetic they are trying to create. This design approach ignores the issue that on-going employee costs are much higher than any initial building costs or the exclusion of certain environmental necessities (Roelofsen, 2002). While a single employee's drop in production does not have a large effect on the organization as a whole, it does not take much of a loss in performance of each employee to result in a great loss to the entire organization (Roelofsen, 2002). Business owners and managers are better off investing in design of the work environment as a cost effective way to prevent performance losses in their employees. Tucker and Smith (2008) state, "employee satisfaction leads to better service and added value, which therefore influences customer satisfaction, and consequently leads to profit and growth within the organization" (p. 205). Studies are beginning to illustrate the correlation between business performance and perceived performance for business owners and facility managers, but not enough organizations or interior designers are using this research to aid in the design and evaluation of multi-million dollar office complexes.

Another issue many businesses need to consider is the fact that they are in the service industry whether they are a retailer, hospitality provider, or a large corporation. All companies offer a service of some sort to their customers, but tend to forget what effect the work environment has on their external marketing message. Bitner's (1992)

Servicescapes framework looks at the lack of emphasis on the work environment by organizations in the service industry (including office buildings) and how that affects employees, how customers perceive a space, and how customers' perceptions can affect their working relationship with the company. Bitner (1992) classifies avoidance and approach behaviors that customers may exhibit when entering a work environment and how employee perceptions of that environment influence interactions with customers and may affect the customer's perceptions in the same way, potentially negatively influencing a company's bottom line.

The physical and social work environments have the potential of negatively or positively influencing employees who work in the environment. Any employee who comes in contact with a customer or business partner has the ability to affect the business relationship in a positive or negative way based on his/her personal emotions. For example, if an employee is fatigued or has a headache due to the glare in the workstation and goes into a meeting or presentation with a client or customer, that interaction can give a poor impression of the company to the customer based on the physical state of the employee. Again, this demonstrates the importance of employers understanding how work environments affect their employees in relation to both perceived performance and satisfaction.

Work Environment & Relationship to Employee Performance and Satisfaction

Office layout and the way individuals work in their work environments have changed dramatically over the years, especially with the introduction and continued dependence on the computer. Open office workspace, an office environment that uses

work systems with moveable panels instead of built walls, have become the standard layout for most large corporate offices today due to the flexibility and cost effectiveness of this design. With a transition from employees in private offices to open office workspaces, many new challenges have evolved for interior designers and facility managers.

As a result, it is increasingly important to understand the effects the work environment can have on a corporation's employees. Bitner (1992) found that the work environment can affect an employee's ability to do his/her work based on different ambient variables such as lighting, temperature, color, and layout. In Bittner's study, the theory of Servicescapes was examined and related to multiple public service businesses such as hotels, retail stores, restaurants, hospitals, and professional buildings (corporate offices).

As part of this theory, Bitner (1992) discussed the fact that organizational behavior studies exclude the customer/consumer and focus solely on the employee, while marketing studies tend to do the opposite, by just focusing on the consumer. Servicescapes look at both of these groups and how the environment has an impact on each group in different ways. The research points out that the physical setting has the ability to either promote or interfere with employee accomplishments, external marketing plans, and organizational goals. Bitner (1992) further states that, "objective environmental factors are perceived by both customers and employees and that both groups may respond cognitively, emotionally, and physiologically to the environment" (p. 59). This supports the implication that the design of an employee's workstation can

have an effect on an individual's perceived performance and satisfaction. Tucker and Smith (2008) emphasize this connection illustrating that employee satisfaction indirectly impacts profit and growth due to their direct connection with the customers of the business. When employees are working productively and have a high level of satisfaction, this will result in a higher level of service to their customers that will add to a greater level of customer satisfaction and lead to greater financial support from the customers, directly affecting profit (Figure 6). A study conducted by an architectural and design firm, Gensler (2008), supports this concept stating,

> …the physical work environment is an asset with a specific and quantifiable impact on business success… top performing companies, those with higher profits, better employee engagement, and stronger market and brand position, have significantly higher performing work environments than average companies. (p. 9)

Gensler rated companies using eight, pre-determined success factors: leadership in the industry, financial strength, development and creation of top quality products or services, innovation, promotion of work/life balance, superiority in management capabilities, ability to attract and retain talent, and responsibility to the community and environment. A company was considered top-performing if Gensler gave it a score of seven of the eight success factors. This is an diagnosis that Gensler found support for from the research they practice on a regular basis in its design solutions for commercial interiors. Gensler reinforces the idea of a framework that more designers and architects should take these success factors into consideration in their designs. Figure 8 shows the cycle process that organizations experience and how employee satisfaction is closely related to an organization's own profit and growth, which relates to findings in Gensler's description of top-performing companies.

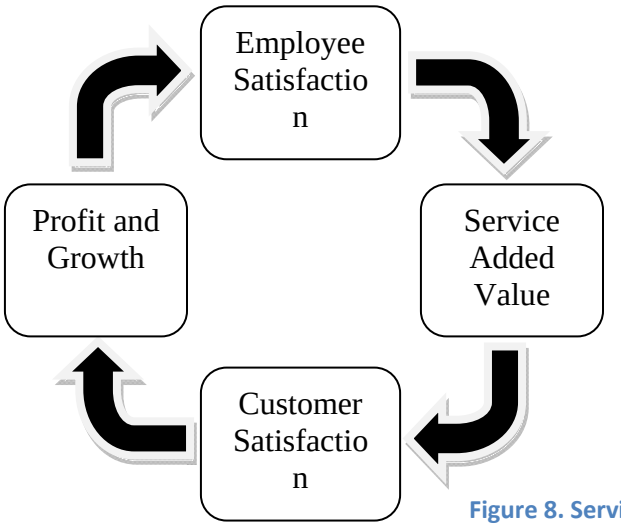


Figure 8. Service Profit Change (Tranfield & Akhlaghi, 1995; Tucker & Smith, 2008)

Employee Perceived Performance

In addition to the many variables related to and definitions of satisfaction, there are numerous ways that an organization can measure its counterpart, performance. However, some strategies are more difficult or cost prohibitive than others to incorporate in the facility design. According to Van der Voordt (2004), performance can be measured in five ways;

1. Labor performance (i.e., the actual quantity of words that can be typed in a certain period of time);
2. Perceived performance;
3. Actual time spent to complete a task;
4. Absenteeism because of illness; and

5. Intangible variables (i.e., problem solving skills or knowledge about a particular subject).

Several of these measures are time consuming and costly ways to collect data. Physically logging labor performance, or measuring the actual time spent to complete a task, or identifying the primary intangible variables that can affect performance, are all difficult for corporations to track. Human resources would have a list of the number of sick days taken by employees; however, because of privacy issues would not be able to find out what was the actual nature of the illness and if it was directly related to the physical environment unless the information was voluntarily given by the employee.

Measuring perceived performance becomes the most cost effective and easiest method of learning how the work environment affects performance. However, most organizations do not take advantage of their ability to obtain this information using the fairly straightforward method of POE and surveys/questionnaires. Some researchers question the reliability of self reporting of an individual's own perception of performance since she/he may try to answer questions in the most acceptable manner possible (Van der Voordt. 2004).

User perceptions and workplace performance have also been areas of continued research for facilities management. Tucker and Smith (2008) looked at the factors behind the increasing number of employees' satisfaction or dissatisfaction with the workplace and how that affects retention, absenteeism, level of complaints, and performance. They identified the main areas related to perceived performance as personal control, privacy, interior planning, color, windows, and lighting. As part of this study, the researchers did

a review of literature of each of the areas they recognized as key areas affecting performance.

Within this review, they found that employees who had a view of nature had a higher level of satisfaction with the workplace and also experienced a restorative quality from these views to better complete their work (Tucker & Smith, 2008). They failed, though, to look at the effect of thermal comfort on performance and did not cite it as having an effect on perceived performance or satisfaction. This lack of inclusion of thermal comfort illustrates a need for additional research in this area.

Employee Satisfaction

As stated previously, satisfaction is comprised of many different variables that can have an effect on perceived performance. Because the link between satisfaction and performance is so strong, it is important for researchers, designers, facilities managers, and individual organizations to have a good understanding of what is meant and affected by satisfaction. Figure 9 expands on the information detailed in Figure 1 by taking a more in depth look at the variables that influence satisfaction in the work environment.

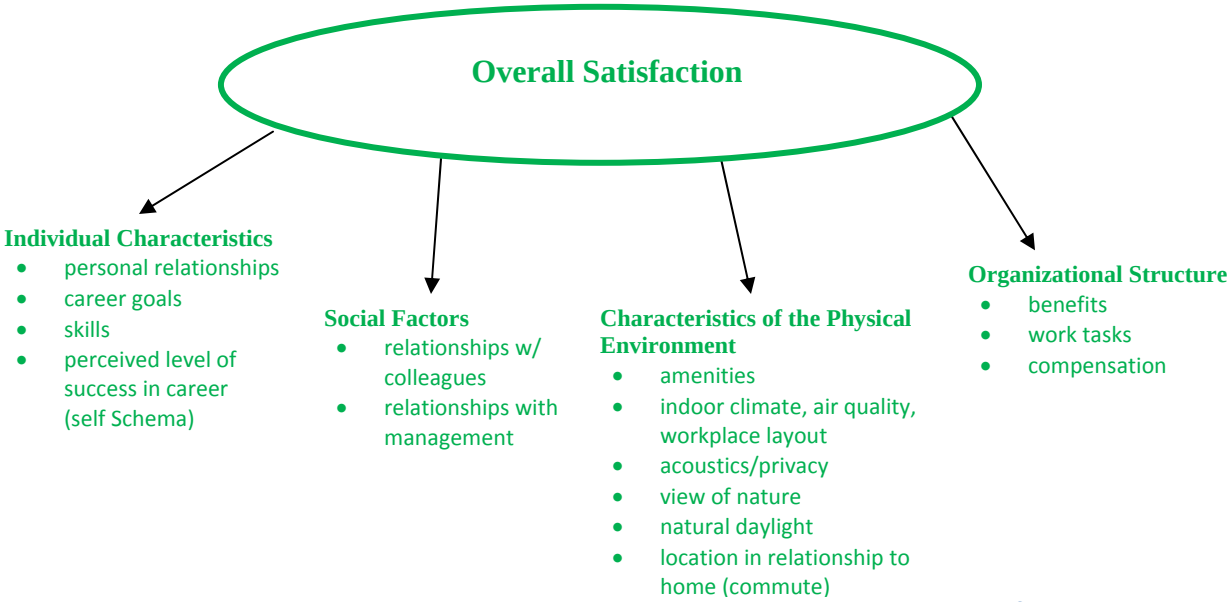


Figure 9.Satisfaction Model

Satisfaction is comprised of four categories that consist of individual characteristics of the employee, social factors, characteristics of the physical environment, and the organizational structure of the corporation/company (Van der Voordt, 2004; Clemens-Croome, 2000). Individual characteristics include personal relationships that individuals have outside of the working environment, career goals, whether or not the individual feels that person is accomplishing those goals, and overall skill level. Social factors include individuals' relationship with colleagues or with the management, specifically the direct manager.

Characteristics of the physical environment include the amenities that are provided to employees, the indoor climate (thermal comfort, humidity), lighting, air quality, workplace layout (proximity to a window), and the location of the office in relation to an individual's home, specifically the length of their commute. Lastly, the organizational structure includes the benefits employees receive from their employers as well as their specific work tasks and compensation. Any one of these variables can affect

an individual's satisfaction but combinations of these variables can also work together to affect satisfaction. Many of these variables are out of the control of the employer or employee, which makes it all the more important for organizations to have an idea of the overall satisfaction level of their employees to better understand their perceived performance.

In a study conducted by Veitch et al. (2007), the researchers looked at the variables related to satisfaction in open-plan environments, such as privacy, ventilation, and lighting. They predicted that these three variables are positively related to overall environmental satisfaction, which in turn is related to job satisfaction. The initial study included data from three office buildings, then, two years later included six additional office buildings. The study looked at both public and private organizations to have a greater ability to generalize any findings from the research. They had a participation rate of approximately 90%. Participants were approached while working in their workstations and asked if they were willing to participate in the study at that time. If they agreed, they were taken to another location to complete a questionnaire while the researchers took physical measurements of their workstations. The results of the study supported the researchers' hypotheses, including the relationship of satisfaction in the work environment to privacy, ventilation, and lighting contribute to satisfaction with the work environment and that these variables are positively related to overall environmental satisfaction and job satisfaction. The study used the model in Figure 10 to illustrate the relationship between environmental satisfaction and job satisfaction. While it shows similarities to the model in Figure 9 of this study, it does not look at the relationship of

satisfaction and perceived employee performance. The researchers stated that this model (Figure 10) "is needed in order to make practical recommendations to designers about open-plan office design choices to promote employee satisfaction" (p. 187).

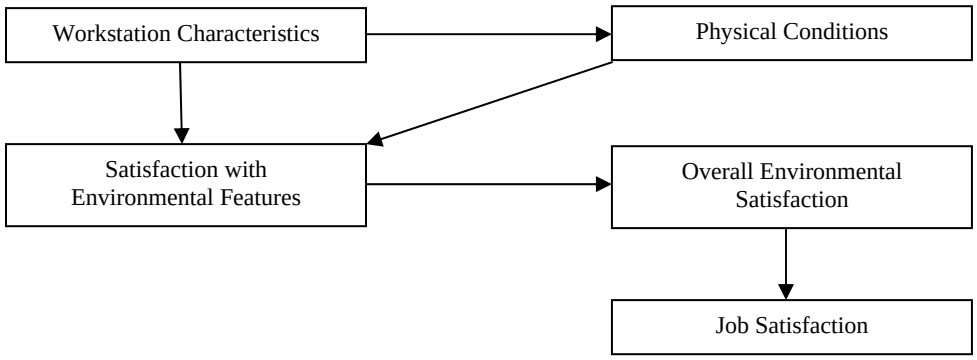


Figure 10. Conceptual Model COPE Project (Veitch et al., 2007)

Thermal Comfort and Window Proximity

The perception that the "one-size-fits-all" office works for all work types, is one that can no longer exist in the open-office environment. The idea that all individuals can perform their best in the exact same environment and with the exact same temperature is a focus of current research (Barber, 2008). In 2005, Knoll worked with DYG, Inc. (a research leader in social, cultural, and demographic research) to conduct a nationwide phone survey with white-collar employees to learn about their preferences in the work environment. They asked questions about preferences for different work styles and what elements within their work environment affect their perceived performance. Respondents were asked to rate 15 different office characteristics either as a high impact, moderate impact, some impact, or low impact on their performance. Across all groups that were part of the study, 70% said that climate control, or thermal comfort, has a high level of

impact on their performance. Seventy-eight percent also identified control over the heating, ventilation, and air conditioning (HVAC) as having a high impact on their performance. However, this study does not detail the size of the sample population, making it difficult to verify the generalizability of the study. The findings suggest that additional study of this relationship is warranted.

Wang, Federspiel, and Arends (2005) estimate possible performance costs to corporations due to thermal comfort (a building that is either "too hot" or "too cold") at between $12-$125 billion annually. As stated earlier, studies of thermal research have reached a level of consensus on the factors that contribute to thermal temperature dissatisfaction or satisfaction as air temperature, humidity, force of air flow, radiant temperatures, individual metabolic rates, and clothing level (Huang & Xu, 2006; Wang, et al., 2005).

Similarly, Olesen and Seelen (1993) classify thermal comfort elements as activity level, clothing weight or layers, HVAC velocity, and air humidity. They also give support to the idea that thermal comfort can have different levels of influence on an individual and does not require total body comfort or discomfort level. The researchers state that dissatisfaction can come from an adverse warm or cold experience to one particular part of the body, which they term as "local thermal discomfort" (Olesen& Seelen, 1993, p. 546). They reason that to achieve complete levels of satisfaction of thermal comfort, no localized thermal discomfort must exist. Because of the complexity of the factors behind thermal comfort in an office setting, it is imperative for corporations

to understand how perceived control of temperature affects perceived employee performance.

In their study, Wang et al. (2005) looked at satisfaction levels with thermal temperature in a building during winter and summer from a randomly selected group of employees using a five-point scale. They analyzed the complaint records for the same company captured through a computerized maintenance system used to track maintenance issues. Anytime employees submit a complaint concerning the thermal temperature of his/her work environment it is recorded in this system. Time, date, and location of complaints are also captured as part of the maintenance process, so this information can be used to compare different building areas, time of day, and time of year. Because of privacy considerations, the data collected were not about individual employees but about general areas in a building. The researchers compared at the building level between complaint reports and the survey results. They found that the higher the complaint rate as it related to temperature issues in a building, the higher the level of overall employee dissatisfaction within the same building, ultimately resulting in higher operating costs for that building due to a higher number of maintenance calls and unproductive workers.

While the study gives some interesting insight into the relationship between thermal comfort satisfaction and complaint rates, the researchers recognize that their sample size and regional focus may have limited their ability to generalize their findings. They also began this study relating thermal comfort to productivity in the workplace stating that, “it not only deteriorates occupants’ performance and organizational

productivity but also increases building maintenance and operating cost" (Wang et al., 2005, p. 13). However, the researchers did not circle back to that relationship in their study. This gap illustrates the need for a better understanding of how thermal temperature affects the performance of employees working in an environment.

Using a different approach, research by Newsham, Veitch, and Charles (2008) found that the location and proximity to a window have an effect on thermal comfort no matter the neutral temperature of the environment. In the study, the researchers looked at 779 workstations across nine different buildings. First, detailed measurements of each workstation were taken by an investigator using a chart-a-chair approach. The chair that is used in the workstation by the employee was removed and replaced with a chair that had environmental sensors designed into it. The sensors recorded the level of humidity, light, sound/noise, air pollutants, and air movement. At the same time, an investigator was taking measurements of the workstations, such as height of panels, location in building, adjacency to a window, window size, and workstation layout. During the time these measurements were taken, the workstation users were asked to use a nearby station and complete a questionnaire that asked them about their overall satisfaction with their workstations. A focus of the questionnaire was satisfaction with ventilation, the subject of most interest to this study.

The results found that individuals that were adjacent to a window or had their own windows were three times more likely to be very dissatisfied compared to those that were 15 feet away from a window. Individuals that experienced a temperature variance of 5°C from the neutral temperature were two times less likely to be satisfied. However, the

further the temperature went above or below 5°C, the more likely the employees were dissatisfied with their space. Newsham, et al. (2008) explains the outcomes by the fact that people in close proximity to windows tend to experience more extreme temperatures depending on the season.

The researchers also noted that for benefits gained from proximity to a window to outweigh the negative aspects will depend on the individual and that person's preferences, as well as the type of work done. This research shows that a relationship exists between the overall comforts of employees workstations, specifically with thermal temperature and performance with a workstation; however, as with all studies, more research is needed to fully understand and substantiate this relationship. Furthermore, it seems there are multiple variables that influence employees' perception of their performance and affect their thermal comfort, such as temperature, control of temperature, proximity to a window, layout of the workstation, and individual workstation components (panel height, task chair type, and location within the building) (Smith-Jackson et al., 2009; Veitch et al., 2007; Yildirim et al., 2007).

In a review of the literature, Haynes (2007) found many studies establishing a correlation between environmental conditions such as temperature and air quality with performance, but that the high correlation values ($r = .92$ to $.99$) do not prove causation. A key point that was affirmed in the review was the fact that there are many unexpected variables that can affect employees' perceptions of not only satisfaction with their environment but also their perceptions of their level of performance.

Some of the potential variables highlighted in the research studies reviewed by Haynes were personal control, design intent, building depth, work groups of employees, and responsiveness. These "killer" variables as termed by Haynes (2007) have made it difficult for researchers to get an accurate view of what really affects employee perceptions of their work environments. While the review was unable to find one single approach to measure the relationship between the office environment and employee performance, Haynes states that there are some common variables to consider in the design and continued maintenance of office environments, which include building temperature or thermal comfort. The extensive literature review by Haynes (2007) also supports the need for additional research to better understand the relationship between perceived employee performance, thermal comfort, and proximity to a window.

Thermal Comfort, Gender, and Age

When designing for people within the office environment, it is important to take their genders and ages into consideration as both have shown to have an effect on users' perceptions. As individuals age, their ability to see different levels of contrast decreases; it is thought that this increase in contrast sensitivity begins somewhere after age 50 (Harrison et al., 1993). Research has also shown that there is a significant decrease in overall visual function as one ages (Ivers et al., 2000). In their study on visual function, Ives et al. (2000) found that there was a strong deterioration of visual acuity and contrast sensitivity in older adults with a mean age of 66.4 years for women and 65.9 years for men. Although the study tested both individuals with and without visual disabilities such as cataracts. When visually-impaired individuals were taken out of the study, a significant

deterioration was still evident among the remaining participants. Overall, the study found "poor scores in visual acuity, contrast sensitivity, disability glare and visual field tests [that] might predict problems with visual function in elderly people (Ives et al., 2000, p 46)." The researchers suggest that the findings indicate a need for other corrective solutions for these individuals, outside of corrective lenses, in the form of appropriate lighting to help improve the quality of life for this group. These findings indicate that employers need to take this group into consideration due to the increasing age of today's workforce.

Age has also been shown to have a relationship with thermal comfort. A study conducted in 19 different centers for older people in Hong Kong found that occupants over the age of 60 most likely have varying expectations on the thermo-neutrality of the environment (Wong et al., 2009). The study showed that as individuals age, their air temperature comfort zone continually gets higher by approximately 1-2 degrees.

While some researcher consider the relationship between gender and thermal comfort as relatively small, recent studies have indicated a more significant relationship between the two. Research reported that females (who range in age) have a significantly higher dissatisfaction with their thermal comfort than males in the same environment (Karjalainen, 2007; Wong et al., 2009). Recent research has indicated that females prefer higher room temperatures than males and show a higher level of dissatisfaction with indoor air temperatures than males (Karjalainen, 2007). Since opinions of the relationship between thermal comfort and gender still vary, it is important to continue to

explore the potential connection so designers know how to better accommodate work environments for all users.

Use of Post Occupancy Evaluation in Workplace Assessment

Post occupancy evaluation (POE) is used by interior designers, architects, the construction industry, and facility managers as a tool to evaluate buildings after the end-users occupy the newly designed space (Hadjri & Crozier, 2009) and "focuses on assessment of client satisfaction and functional 'fit' with the specific space… and the occupants needs" (Zimmerman & Martin, 2001, p. 169). Although there are many definitions that are currently used to describe POE, it is not used as often as possible because of the hurdles often associated with it. POE can be a time-consuming and expensive process. Architecture firms typically do not include POE services as part of their basic contract but as an additional service if their clients decide they want to conduct one after occupancy (Hadjri & Crozier, 2009). In addition to offering POEs as an additional service, many architecture firms are hesitant to conduct the survey and risk potential lawsuits in case their findings demonstrate a flawed design (Hadjri & Crozier, 2009). Another struggle with integrating POE in practice is that many organizations do not see them as a benefit to their current business but rather as a benefit to future clients of designers or architects and therefore do not want to pay to benefit another organization (Bordass & Leaman, 2005).

While research and interest in POE remain high from building owners and facility managers (Bordass & Leaman, 2005), studies show that only a small percentage of organizations actually take part in a POE at all. In a survey of 160 organizations, only

7% carried out any kind of survey, and, of those that did participate in a POE, it was generally three years post-occupancy (Roberts, 2001). Waiting that long after completion of a project to conduct a POE, it is assumed that a POE would uncover problems and issues needing to be addressed within the workspace. Technology advances would direct some change at a minimum, and often employee instigated changes to the workplace would have already occurred. Even with a general consensus that POEs expose new possibilities for design and have the potential to reduce operating costs and increase performance of occupants, many managers feel it is not their responsibility to provide this information to a broader audience (Bordass & Leaman, 2005).

When organizations use the POE process, the steps illustrated in Figure 11 are followed. First, client goals are identified by the designer and agreed upon with the client. Based on those goals, performance criteria are established such as health, safety, and security performance; functionality of spaces; or performance levels of users. Once a design is complete and users occupy the space, an object or process is chosen for observation that results in the actual findings or performance measures. This gives the facilitators of the POE the ability to make a comparison between the original performance criteria and the actual performance measures. The evaluator is responsible for assessing the results based on the performance criteria. Once the final results are collected, organizations have the information they need to effectively make adjustments to the space based on quantifiable data rather than just suppositions (Preiser & Vischer, 2005).

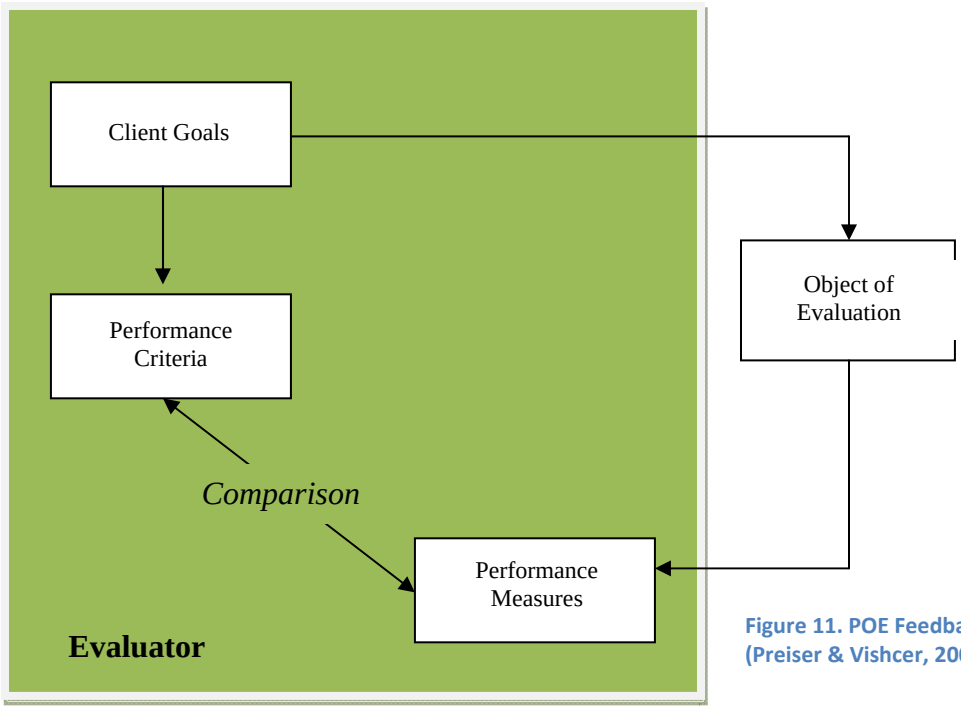


Figure 11. POE Feedback System (Preiser & Vishcer, 2005)

In a case study of an international energy company, Chilton and Baldry (1997) used a POE survey to examine the current workspace environment to help the organization reduce real estate costs associated with the building. The study focused on 350 employees who were part of a "re-engineering" of the work environment by changing from individual workspaces (high partitions with high levels of privacy and acoustic separation) to an open-office setting. After the change in workplace was complete and employees were in their new locations and office type, a questionnaire was distributed to employees to better understand their perceptions after the reorganization.

The results of the survey found that the overall satisfaction of the employees surveyed was between 33% and 37%. Eighty percent of employees stated they had a high level of dissatisfaction with the acoustics in the new workspace, despite efforts to plan for

acoustics in the design process. Participants indicated that the major concern with their individual spaces was the size of their work area, the physical worksurface color, and space for filing. Participants were satisfied with group work and teaming areas due to an increase of community within the work environment. The survey found that they were most dissatisfied with their individual work areas. While this POE did not give the owners, designers, or researchers the answers that they were expecting, it did give them a better understanding of how their employees worked and their overall perceptions of the space. The company may not be able to give employees individual enclosed offices as they had previously, but they could put strategies into place that reinforce the areas of the new design that satisfied employees are satisfied with and implement strategies to enhance work performance in the new open-plan environment, which will benefit both the company and the employees.

In a similar case study, Walbe, Ornstein, et al. (1999) used the POE process to evaluate employee workspace in a building in San Paulo, Brazil. The building was designed for use by multiple tenants, whether they were located in a section of a single floor or across multiple floors within the building. This study focused on the organization that occupied the largest amount of space in the building, is a Brazilian-American industrial company. The company has multiple types of workspaces within their space including public areas, meeting and reception areas, private offices, and open integrated offices. The researchers used a representative sample for the questionnaires, and distributed them in proportion to gender and position of the workspace in relationship to windows and layout of the space. The response rate was 68%.

Researchers estimated that it took participants approximately 20 minutes to complete the survey. Findings of the survey indicated that 55% of employees consider the work environment 'agreeable' with an additional 11% who find it 'very agreeable.' When asked about environmental conditions, 66% of the participants said that they were 'good' with an additional 8% reporting 'excellent' conditions. The overall conclusions of the study were that the employees were in general satisfied with their work environment and the building as a whole. However, they found that the most common area that employees felt needed improving was the amount of privacy (60 instances cited) and washrooms (55 instances cited). Knowing this information gives the organization the opportunity to respond to the items that employees believe are the highest priority for change as well providing the organization with a better understanding of the overall work environment for the employees.

Although the basic process of POE is widely accepted, some researchers have found that it does not cover the full spectrum of the design process. Way (2005) proposed a new, in-depth process of POE called "Soft Landings." This process gives added levels of responsibility to the contractor and designer of the space that is typically not a part of basic POE processes. Soft Landings is similar to the Leadership in Energy and Environmental Design (LEED) certification process where buildings can gain points through having a dedicated commissioning agent. The Soft Landings process designates a team that is on site to observe during the initial occupation. The new space, and a review of the space continues periodically over the first three years (Way, 2005). While this process gives more support to the involvement of many cross-functional groups that are a

part of the design process, it has not been widely used yet as a form of POE but may be the direction of future POE studies.

Chapter 3: Methods

This chapter explains the methods used to collect the data for this study. The sample of the population used in the study, the instrument, and the procedure that was followed during the administration of the instrument are discussed.

The purpose of this study was to examine the relationship between employees' perceived performance and satisfaction and the thermal environment in which they work, including window proximity. The study focused on the CRDM business unit of Medtronic Inc. on their Mounds View, Minnesota campus. Data were collected using a questionnaire that was distributed to all employees within the CRDM campus.

Population and Sample

This study attempted to obtain the full population of interest, which is full-time employees from the CRDM campus in Mounds View who have been employed in this facility for a minimum of six months. The time period of six months was determined to allow employees to acclimate to their new environment and no longer have a bias about the new location because of higher satisfaction levels with a newly built or experienced environment (Van der Voordt, 2004; Zagreus, Arends, & Lehrer, 2004). Question four in the questionnaire asked participants how long they have worked in one of the Mounds View buildings. If a participant selected less than six months, they were sent to the end 'thank you' message. The questionnaire was sent out to all employees in all three buildings with a total of 3,000 employees. Of these, there are approximately 840 individuals located in private offices (who were not the focus of this study) so the actual sample size was 2,160.

Instrument

The instrument used in this study is a questionnaire distributed through Zoomerang™. A copy of this instrument is included in Appendix A. Questions are based on the questions developed by Guerin and Bridgeman (2009) for the Center for Sustainable Building Research (CSBR) at the University of Minnesota for POE of sustainable office buildings. Questions were altered minimally to better fit the research goals of this study as well as some alterations by Medtronic to better accommodate their corporate goals. A full discussion of the alterations made by Medtronic is presented in the limitations section of this research.

The main focus of the questions was on employees' perceived performance; questions on overall satisfaction were also included because personal satisfaction variables have been linked to higher ratings of employees' performance perception (Van der Voordt, 2004). Individuals who are satisfied with their workspace are more likely to have a higher self-schema of professional success (higher performance level) of their work (Fischer et al., 2004). Therefore, satisfaction became an important variable for inclusion in the questionnaire.

The questionnaire consisted of a total of 36 questions that focused on the variables detailed in the next section as well as demographic information. The first 11 questions focused on demographic information to help determine gender differences and general location of each individual within the floor plan. Participants could also write comments. Employees responded to the questions using a 7-point Likert-type scale, in which they reported on the level a specific design attribute hindered performance (1) or

enhanced performance (7). For satisfaction questions, employees chose from very dissatisfied (1) to very satisfied (7) for each design attribute listed.

The questionnaire was exempted by the University of Minnesota's Institutional Review Board (IRB) in accordance with the process. After exemption by the IRB, eligible participants were sent an email introducing them to the purpose, benefits, and risks of the study; after they consented, they could access the questionnaire link. They were given seven days to respond. A reminder email was sent as a follow-up two days after the initial email. All email messages were written in collaboration with the Medtronic Internal Communications group as well as the Mounds View Facilities group. All communication is included in Appendix B and was approved by the IRB prior to any communication sent to employees. Participants were also offered the option of entering in a drawing to receive one of (10) $10 gift certificates to Target by entering their email address when prompted at the end of the survey to help increase response rate. The amount of $10 was selected so that the reward was not too large to coerce employees to participate and was determined by the primary researcher with the assistance of the IRB. Twenty-five percent of respondents submitted their email address for entry into the drawing. The questionnaire was closed seven days after the initial email was sent to employees with an overall response rate of 31%.

The results of this study were shared with Medtronic. It was recommended by the researcher that Medtronic report the results to the participants and whether or not any changes will be implemented due to the findings. These steps increase the likelihood that

employees will participate in future company research (Van der Voordt, 2004). It was unknown at the time of this report whether or not the results were shared with employees.

Variables

The variables that are a part of this study are explained in the following section and categorized by research questions one, two, three, and four. Table 1 links the theoretical construct from the HET to the variables and the research question. The independent variables in this study are, employee characteristics, thermal comfort, lighting levels, lighting (glare), and proximity to a window. The dependent variables are perceived performance and satisfaction. The general research questions from chapter 1 are separated here for ease of clarity and discussion.

Research Question One

Research Question 1a*: Is there a relationship between the interior environment (DE), its components, and employee perceived performance?*
Research Question 1b: *Is there a relationship between the interior environment (DE), its components, and employee satisfaction?*

The variables that are related to overall interior environment and employee's perceived performance and satisfaction are thermal comfort, lighting levels (natural and electric), view (independent variables), and perceived performance or satisfaction (dependant variables). Table 1 and 2 detail the theoretical constructs of the research questions as well as the questions used in the questionnaire and measure of the variables. Satisfaction levels were only a part of research question one, as perceived performance was the main focus of the research. For example, in the first line of Table 1, the designed environment (DE) and the natural environment (NE) interact within the whole interior environment to affect the social environment (SE) variable of performance.

Theoretical Construct (DE or NE)	Dependent Variable (SE)	Independent Variable	Question (Measure)
DE	Performance	Whole Interior Environment	The overall effect of the whole interior environment (hinders/enhances)
DE	Performance	Electric Lighting	The overall effect of general overhead electric lighting in your workstation (hinders/enhances)
NE	Performance	Natural Daylighting	The overall effect of natural daylighting conditions in your workstation (hinders/enhances)
DE	Performance	View	The overall effect of window views in your workstation (hinders/enhances)
DE	Performance	Thermal Comfort	The overall thermal comfort in your workstation (hinders/enhances)

Table 1. Research Question 1a: Performance Variables

Theoretical Construct (DE or NE)	Dependent Variable (SE)	Independent Variable	Question (Measure)
DE/NE	Satisfaction	Whole Interior Environment	Your overall satisfaction with the interior environment (very dissatisfied/very satisfied)
DE	Satisfaction	Electric Lighting	Your overall satisfaction with the general overhead electric lighting in your workstation (very dissatisfied/very satisfied)
NE	Satisfaction	Natural Daylighting	The overall effect of natural daylighting conditions in your workstation (very dissatisfied/very satisfied)
DE/NE	Satisfaction	View	The overall effect of window views in your workstation (very dissatisfied/very satisfied)
DE	Satisfaction	Thermal Comfort	The overall thermal comfort in your workstation (very dissatisfied/very satisfied)

Table 2. Research Question 1b:Satisfaction Variables

Research Question Two

***Research Question 2**: Is there a relationship between thermal comfort and employee perceived performance?*

The independent variables that are related to thermal comfort are temperature and air velocity (Table 3). The descriptive variables for this question include the participant's demographic information as well the floor, zone, work station type that were captured as part of the survey (see Table 6).

Theoretical Construct	Dependent Variable	Independent Variable	Question (Measure)
DE	Performance	Temperature	The temperature in your workstation (hinders/enhances)
DE	Performance	Air Velocity	The air velocity (hinders/enhances)

Table 3. Research Question 2

Research Question Three

***Research Question 3**: Is there a relationship between window proximity and employee perceived performance?*

The variables that are related to the effect of window proximity on an individual's perceived performance level are exterior view when seated, exterior view when standing, amount of natural daylight and control of daylight (independent variables) (Table 4). This question also is related to the floor, zone, and workstation type (see Table 6).

Theoretical Construct	Dependent Variable	Independent Variable	Question (Measure)
DE/NE	Performance	Exterior View Seated	The extent to which you have an external window view when seated (hinders/enhances)
DE/NE	Performance	Exterior View Standing	The extent to which you have an external window view when standing (hinders/enhances)
NE	Performance	Natural Daylighting	The amount of natural daylighting in your workstation (hinders/enhances)
NE/DE	Performance	Control of Daylight	The ability to control or block the natural daylight in your workstation (hinders/enhances)

Table 4. Research Question 3

Research Question Four

***Research Question 4**: Is there a relationship between overhead electric lighting levels and employee perceived performance?*

The variables that are related to overhead electric lighting levels and employee perceived performance are control of light levels, electric lighting levels, and visual comfort (Table 5). This question also is related to the floor, zone, and workstation type (see Table 6).

Theoretical Construct	Dependent Variable	Independent Variable	Question (Measure)
DE	Performance	Control of Light Levels	The extent to which you can control the desk (task) light at your workstation (hinders/enhances)
DE	Performance	Electric Lighting Levels	The amount of electric lighting in your workstation (hinders/enhances)
DE/NE	Performance	Visual Comfort	The visual comfort of daylighting and electric lighting (minimized glare, prevention of distraction reflection, appropriate contrast) in your workstation (hinders/enhances)

Table 5. Research Question 4

Demographics

Additional variables were considered as a part of the study related to individual information of each participant. Because of the differences in building location and potential location within each building, the questionnaire included general demographic information that determine the relationship among variables (Table 6) to help explain the findings of the research questions.

Theoretical Construct	Dependent Variable	Independent Variable	Question (Measure)
DE	Performance & Satisfaction	Workstation Location	In what building is your workstation currently located (north, central, south)
DE	Performance & Satisfaction	Workstation Type	Of the two workstation photos above, which one do you have (typical A, typical B, neither)
DE	Performance & Satisfaction	Zone	Please refer to the floor plan image above, in which zone is your workstation (north, south, east, west)
HO	Performance & Satisfaction	Tenure	How long have you worked in this building (less than 6 months, 6m to 1 yr, 1-2yrs, 2+ yrs)
HO	Performance & Satisfaction	Work Hours	In a typical week, how many hours do you spend in the building (less than 20, 20-30, 31-40, 40+)
HO	Performance & Satisfaction	Age	What is your age (range 18-90+)
HO	Performance & Satisfaction	Gender	What is your gender (male, female)
SE	Performance & Satisfaction	Hours in Workstation	What percentage of time per week do you spend in your personal workstation (less than 20%, 25-50%, 51-75%, more than 75%)
SE	Performance & Satisfaction	Floor	What floor do you work on (first through eighth)
SE	Performance & Satisfaction	Time at Computer	Of the time spent in your personal workstation, what percentage of time is spent at your computer (less than 20%, 25-50%, 51-75%, more than 75%)

Table 6. Demographic Questionnaire Measures

Analysis

The analysis used a three-way ANOVA assumption to examine the variance among building locations (north, central, and south), floor within the building (first floor through eighth floor), and zone (north, south, east, and west). Because the sample population within each of these zones was typically small (n between 2 and 55), creating results that were not statistically significant, an additional two-way ANOVA analysis was done. This reduced the factors to building location (north, central, and south) and zone (north, south, east, and west). Lastly, a one-way ANOVA analysis was done reducing the factors to zone (north, south, east, and west) within all buildings. Only the one-way ANOVA tests were used to compare means as no other tests showed any significant differences. The three-way ANOVA results were used only to obtain mean values and standard deviation information, not as a comparative analysis. Results are reported in Chapter 4 of this research.

Limitations

The main limitations of the study were in the form of the changes made to the survey instrument by Medtronic. Thermal comfort is dependent on and defined as air velocity, air temperature, and relative humidity (Wong et al., 2010). Due to sensitivities within the organization, the questions pertaining to humidity were omitted at the direction of the executives at Medtronic. Due to this omission, a full understanding of the thermal environment of Medtronic cannot be assessed within this research.

Additional limitations of the study include self-reporting by employees so responses could biased. Since this study focuses on perceived performance, some

individuals could answer the questions more favorably in terms of the amount of work they are able to complete than the amount of work they actually are able to complete, to appear more socially acceptable in their response (Van der Voordt, 2004).

This study focuses on a specific building type on a corporate campus within the state of Minnesota so the findings may not be generalizable to other commercial buildings or office types such as healthcare facilities, complexes that have a lower amount of exterior windows, different climates, etc. Minnesota's climate may have an effect on the interior environment that is not typical in other locations across the country (e.g., extended winter snow cover increases reflected daylight in buildings), so the results should be considered as reference for projects in similar climates. Also, the survey was also conducted at the beginning of April when there was no snow on the ground. If this questionnaire was done during the winter, employee responses would reflect the most extreme results in relation to glare when sun reflection is at its highest for this region. It may be useful for Medtronic to conduct this survey again during the winter to get additional information about different levels of glare throughout the entire year and their effects on perceived performance and satisfaction increase or decrease during the different seasons.

Color has been shown to affect user perceptions of thermal comfort due to the psychological associations individuals have with warm and cool colors (Tucker & Smith, 2008). However, color psychology was not a part of this study, so it is possible that color of the interior environment could be an extraneous variable in the findings that may have influenced participants without their direct knowledge.

Some research has connected one's own self-image in relation to one's perception of performance and the overall work environment. Research found that individuals with a higher level of perceived success in their career tend to rate their overall work environment and performance higher than those with a lower level of perceived success or failure (Fischer et al., 2004). This study did not look at individuals' self perception of their perceived success or failure in their career in relation to their perception of performance or the work environment. However, it may be beneficial for future research to take these variables into consideration as part a part of the POE process.

Chapter 4 Results

This chapter presents the results of the questionnaire and discusses the analysis of the data.

Descriptive Analysis

The majority of responses came from employees in the South building (45%), who have been in their workspaces for more than two years (50%), are in a Typical B workstation configuration (64%), and are approximately 45-54 years old (32%).

In the North (27%) and Central (29%) buildings, participation was evenly distributed between employees in the two buildings. The smallest group participation was individuals who have worked in their space for six months to one year (8%). The gender of participants was almost equal, with 53% female participants and 47% male participants. The distribution for age range for participants was 18-24 (3%), 25-34 (21%), 35-44 (29%), 45-54 (32%), and 55-64 (15%). One percent of respondents selected the age range of 90+, but it is unclear if this was an accidental selection as Medtronic does not have any full-time employees in that age range.

The floor location of participants was somewhat evenly distributed across all eight floors of the building with 7% on the first, 15% on the second, 16% on the third, 10% on the forth, 10% on the fifth, 14% on the sixth, 12% on the seventh, and 15% on the eighth. While participation was evenly distributed between floors, most respondents were located within the north and south zones of their specific floor with 33% in the north zone and 31% in the south zone (see Figure 12). These results reflect the overall distribution of employees among floors and within each floor. For example, as shown in Figure 12, the buildings run on a north-south axis with most employees located on the north and south of the buildings.

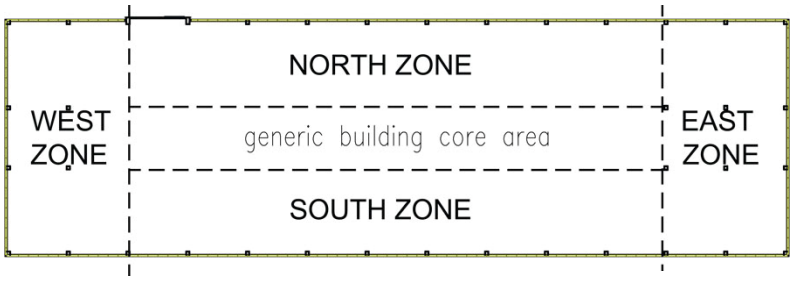


Figure 12. Typical Floor Layout

The survey results indicate that employees typically spend the majority of their work week within the Medtronic facilities. Participants indicated that they spend 40 or more hours within the facilities (68%) followed by those spending 31-40 hours a week (27%). The responses of the participants also reflect research (Hochanadel, 1995) that employees spend the majority of their time at their personal workstation with 45% of participants spending 75% or more of their time at their workstation followed by 37% who spend 51-75% of their time spent at their personal workstation. Of the time spent at their workstation, 80% of the respondents indicated that they spent 75% or more of the time spent in their workstation working on their computers with 16% spending 51-75% working on their computers.

There were no interpretations or meanings of the response scales given to employees who participated in the study; however, the following gives a general interpretation of the responses, which were requested by Medtronic. Each scale is identical in interpretation but numbers are not equal intervals but balanced interpretive scales, one point intervals at the highest and lowest levels and two point intervals in the middle. This reflects similar scales as found in Guerin, 2010 which allows comparison of interpretative meaning between studies.

Performance

- 6.1 – 7.0 Enhances work performance
- 4.1 – 6.0 Somewhat enhances work performance
- 2.0 – 4.0 Somewhat hinders work performance
- 1.0 – 1.9 Hinders work performance

Satisfaction

- 4.1 – 7.0 Satisfied
- 4.1 – 5.0 Somewhat satisfied
- 3.0 – 4.0 Somewhat dissatisfied
- 1.0 – 2.9 Dissatisfied

Overall Employee Performance and Overall Employee Satisfaction

Research Questions 1a and 1b

There were 10 questions that asked employees to rate their overall perceived performance and satisfaction as related to the interior environment. Questions looked at the components of the interior environment and how the effects of window views in workstations, natural daylighting in workstation, overhead electric lighting in workstations, thermal comfort in workstations, and interior environment relate to

perceived performance and satisfaction. Mean responses indicate that most participants have positive associations with the variables tested in this research. Overall thermal comfort has the lowest mean value for performance (4.5), while window views has the lowest mean value for satisfaction (4.62).

Table 7. Overall results of Mounds View Campus

	Performance			Satisfaction		
Variable	**Mean**	**SD**	**Interpretation**	**Mean**	**SD**	**Interpretation**
Overall Interior Environment	4.81	1.35	Somewhat enhances work performance	4.97	1.43	Somewhat Satisfied
Overall Thermal Comfort	4.50	1.38	Somewhat enhances work performance	4.63	1.56	Somewhat Satisfied
Overall General Electric Lighting	4.76	1.30	Somewhat enhances work performance	5.07	1.47	Satisfied
Overall Natural Daylighting	4.70	1.59	Somewhat enhances work performance	4.65	1.84	Somewhat Satisfied
Overall View	4.80	1.45	Somewhat enhances work performance	4.62	1.87	Somewhat Satisfied

*Note: 7-point rating scale

Figure 13. Overall results of Mounds View Campus

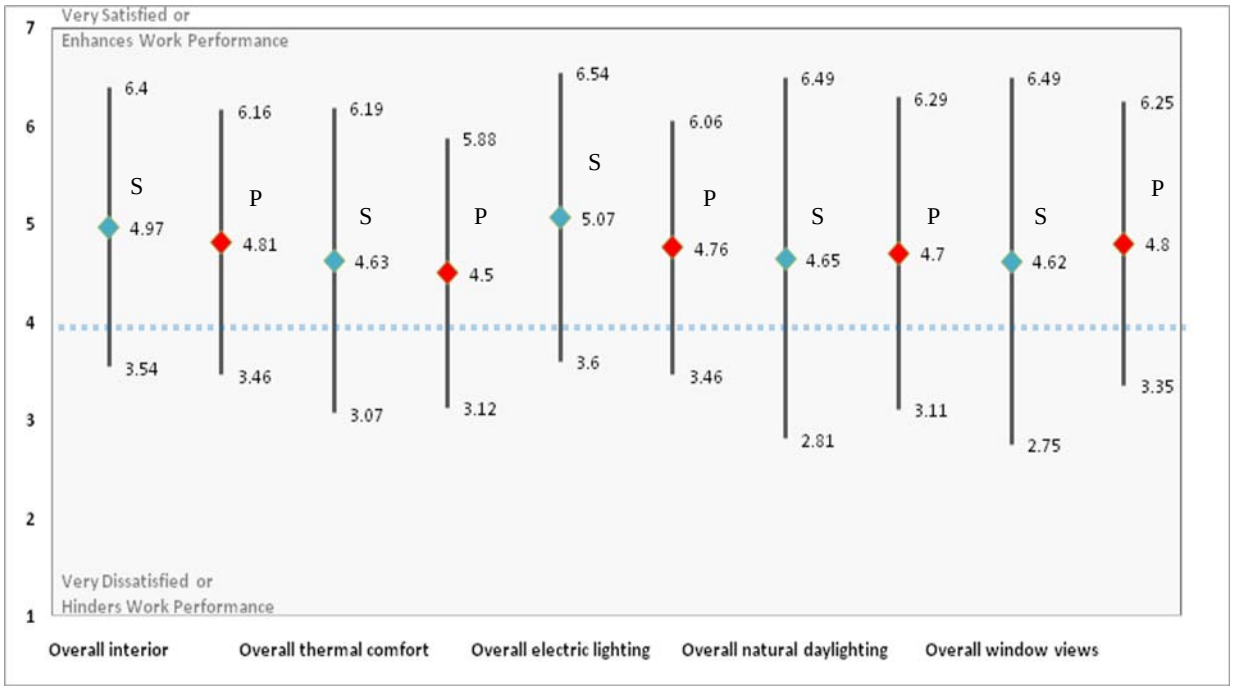


Table 7 and Figure 13 show that employees are somewhat satisfied with the overall interior environment, thermal comfort in their workstations, the effect of natural daylighting in their workstations, effect of window views in their workstations, and satisfied with the general electric overhead lighting in their workstations. They indicate that overall the same elements somewhat enhance their performance.

Overall, findings in regards to performance showed that the employees of the Mounds View campus believe that the environment somewhat enhances their work performance. In regards to the question of the overall environment's affect on performance, the mean response was 4.81, indicating that the majority (62%) of

respondents believe that the overall environment somewhat enhances their performance. Sixty-two percent of respondents answered that the whole environment somewhat enhances to enhances their performance, while only 15% indicated a negative effect on performance. Just over half of respondents (51%) indicated that overall the thermal comfort in their workstation somewhat enhances (mean 4.5) their performance, while 24% indicated that thermal comfort hinders their work performance and 26% believe thermal comfort neither enhances or hinders their performance. Overhead electric lighting responses show a high level of somewhat enhancing to enhancing work performance with 79% of respondents indicating a positive effect. Respondents felt that the effects of daylight and views in their workstation somewhat enhanced (M=4.8) their performance (53%), while daylighting conditions also somewhat enhanced (M=4.7) their performance (56%).

Results showed that the majority of employees are satisfied with the overall interior environment. The mean level of satisfaction for this question is 4.97. The majority of respondents reported that they are satisfied with their environment (34%), while dissatisfaction with the overall interior environment was lower (27%).

Employee satisfaction with their overall thermal comfort was more evenly distributed across the satisfaction spectrum; however, the largest percentage of participants indicated they are satisfied with the thermal comfort of their work environment (58% very satisfied to somewhat satisfied). Despite a high level of

satisfaction with the thermal environment, 25% of participants indicated they have some level of dissatisfaction with their thermal comfort.

The majority of participants indicated that their overall satisfaction with overhead electric lighting in the facility was somewhat satisfied (72%). Some respondents (15%) indicated some level of dissatisfaction with the overall electric lighting. Employee responses for satisfaction level of natural daylighting in their workstation show positive satisfaction levels at 59% with negative satisfaction levels at 27%.

Over half of participants indicated they are satisfied with the window views from their workstation (56%). Twenty-nine percent of participants indicated dissatisfaction with their window view. Positive responses to the effect of the windows are typified by this participant's response, "I think having windows is very pleasing to almost everyone. I love being able to look outside and see what it's doing. It's a beautiful building; however, I do think they should have thought about the sun glaring in heating it up and hurting our eyes. Even the blinds don't help that much when the sun is shining at certain times of the year!" Respondents with more negative feelings about window views shared similar response, "[I] would like a better view. Sometimes it is too dark in my cube and it'd be nice to have more light and other times the sun reflects badly off the other building and it's extremely glaringly bright." Results from the overall questions indicate similar perceptions of employee satisfaction and performance in mean scores. This is an expected result with the strong connection between employee satisfaction and performance perceptions as discussed earlier in the literature review. One participant's

response to the survey may sum up these similar employee perceptions in relation to the overall environment, “this is the most comfortable office space I have ever worked in where an open floor plan was used.”

Thermal Comfort Effect on Performance

Employee perceived performance was measured by two questions in relation to thermal comfort. Forty-five percent of participants indicated the temperature in their workstations enhances their performance (mean 4.31), while 27% indicate the temperature hinders their performance. Forty-five percent of participants also indicated that the air velocity in their workstations enhances their performance (mean 4.38, Table 8 Figure 14), while 23% indicated the air velocity hinders their performance. These results indicate an overall perception that thermal comfort somewhat enhances employee performance in the Mounds View campus. While these findings suggest an overall positive perception about the thermal environment, there were some negative comments from respondents. “The temperature changes drastically when clouds come in during the summer. If they are out too long, I have to put on a sweater. When they go away, I sweat; during the summer months (May-Aug) the temperature is very warm, makes for a difficult work environment.”

Figure 14. Mean Values of Thermal Comfort & Performance

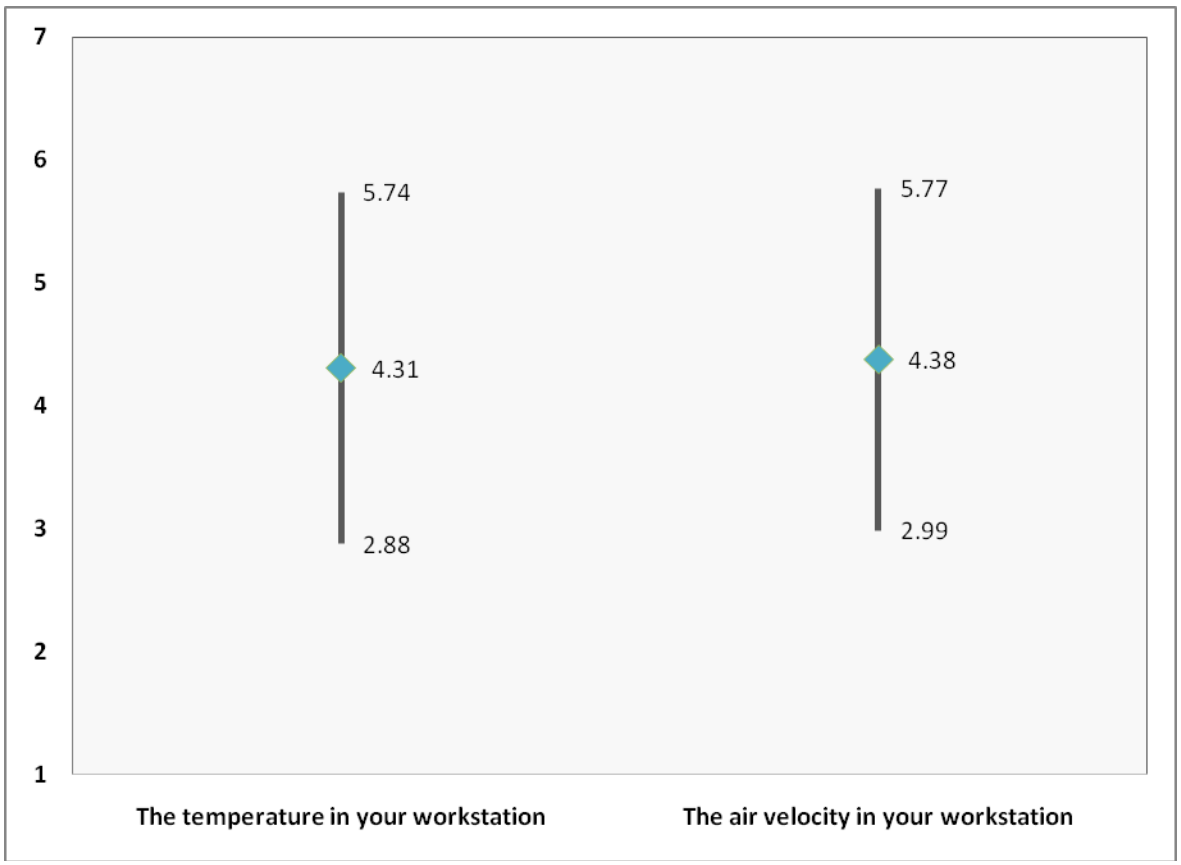


Table 8. Mean Values of Thermal Comfort & Performance

Question	Mean Score	Standard Deviation	Interpretation
Q.25 Temperature	4.31	1.43	Somewhat enhances work performance
Q.30 Air Velocity	4.38	1.39	Somewhat enhances work performance

*Note: 7-point rating scale

Window Proximity Effect on Performance

Employee perceived performance was measured with four questions in relation to proximity to a window: the extent to which you have an external window view when standing (mean 5.13), the extent to which you have an external window view when seated

(mean 4.40), the amount of natural daylighting in the workstation (mean 4.71), and the ability to control or block the natural daylight in your workstation (mean 3.88). Responses to most of these questions indicate an overall perception that window proximity somewhat enhances employee perceived performance in relation to external view when seated (41% enhances, 24% hinders) and standing (65% enhances, 12% hinders). The majority (57%) of respondents indicated that the amount of daylighting in their workstation enhances their performance while only 20 believe that it hinders their performance (Table 9, Figure 15). However, the mean score for the ability to control or block the natural daylight indicates a perception of somewhat hindering work performance (36%). Only 31% of respondents indicated the control or ability to block daylight enhances their work performance while many respondents commented on their inability to control the blinds in their work environment saying, "it would be nice to have a ability to control the height of the blinds as most days the blinds could be down 1/3 of the way and still block the sun but allow natural light in."

Figure 15. Mean Values of Window Proximity & Performance

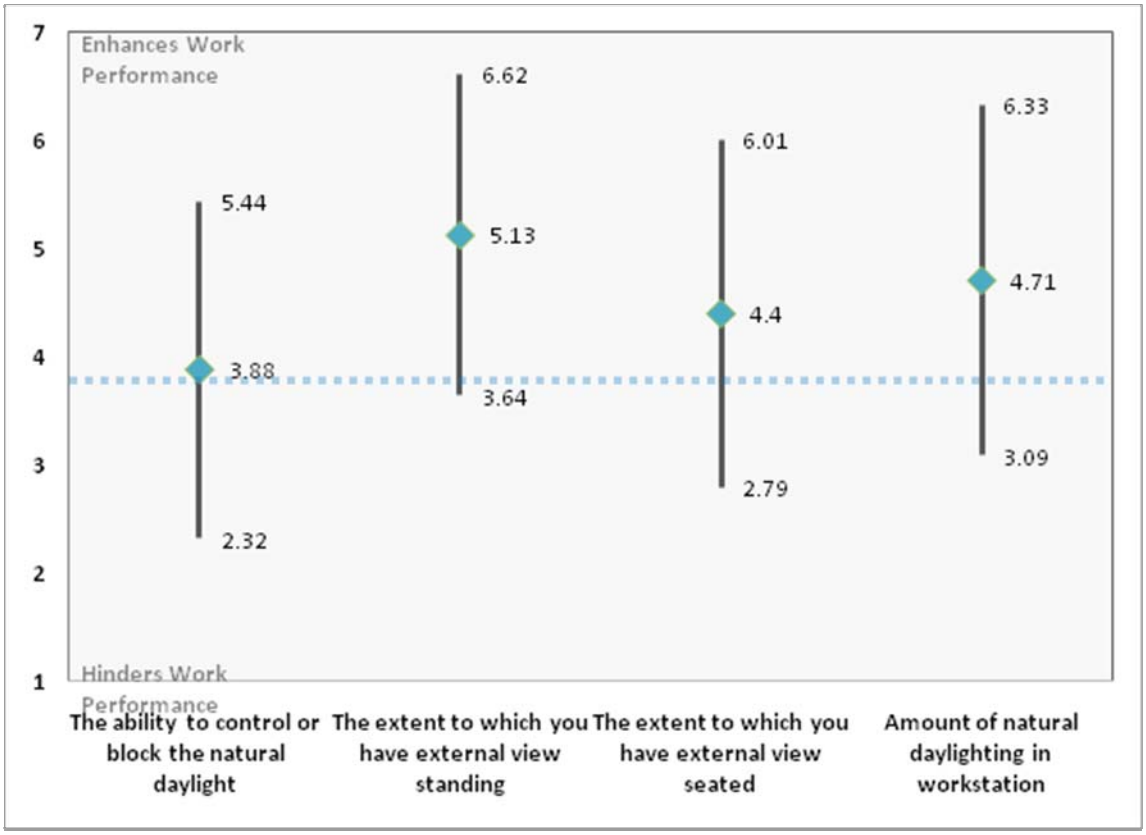


Table 9. Mean Values of Window Proximity & Performance

Question	Mean Score	Standard Deviation	Interpretation
Q.26 Control/Block natural daylight	3.88	1.56	Somewhat hinders work performance
Q.27 External view standing	5.13	1.49	Somewhat enhances work performance
Q. 29 External view seated	4.40	1.61	Somewhat enhances work performance
Q.31 Amount of natural daylighting	4.71	1.62	Somewhat enhances work performance

*Note: 7-point rating scale

Electric Lighting Levels and Glare and Effects on Performance

Employee perceived performance was measured with three questions in relation to lighting levels. Fifty-three percent of respondents indicated that the amount of electric

lighting in their workstations (mean 4.62) somewhat enhances their work performance (16% hinders). Forty seven percent indicated that the visual comfort of daylighting and electric lighting in their workstations (mean 4.38) enhances their work performance (27% hinders), and 42% indicated that the extent to which they can control the desk light at their workstations (mean 4.30) somewhat enhances their work performance (24% hinders). Responses to these questions indicate an overall perception that lighting levels somewhat enhance work performance (Figure 16, Table 10). However several respondents agreed that the desk light does not provide enough light and an under-counter solution would have been preferable, “The Koncept task light doesn't do much. I would much more prefer an under the counter task light attached to the sliding door cabinet to enhance lighting in that area.”

Figure 16. Mean Values of Lighting Levels & Performance

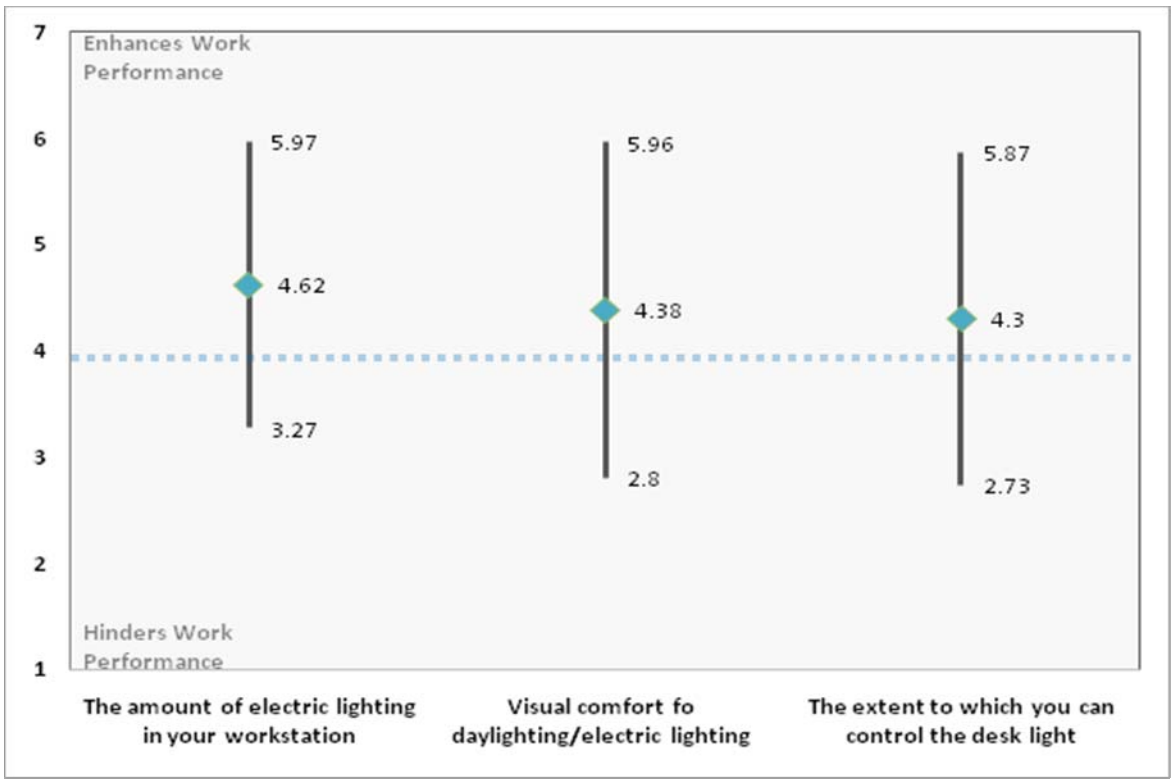


Table 10. Mean Values of Lighting Levels & Performance

Question	Mean Score	Standard Deviation	Interpretation
Q.28 Amount of electric lighting	4.62	1.35	Somewhat enhances work performance
Q.33 Visual Comfort	4.38	1.58	Somewhat enhances work performance
Q.32 Control desk light	4.30	1.57	Somewhat enhances work performance

*Note: 7-point rating scale

Open-Ended Questions

An additional element of the survey was the ability for participants to answer open-ended questions throughout the survey to provide additional information within a section or overall comments at the end of the survey. No prompts were provided to

participants on how to answer the questions, although the responses were able to be grouped in similar categories to illustrate reoccurring themes, concerns, or subjects. Comments were categorized into workstation, location, noise, distractions, privacy, control, air velocity, humidity, general building comments, general building design comments, natural lighting, electric lighting, overall lighting, temperature, sunlight and glare, view, existing blinds, miscellaneous and general comments, and design of the survey. These categories were further grouped into like categories workstation/location, noise/distractions/privacy/control, air velocity, humidity, general building and design, natural/electric/overall lighting, temperature, sunlight and glare, view/blinds, miscellaneous/general comments, and design of the survey to simplify reporting of results. Overall, respondents commented most frequently on sunlight and glare with 100% of those comments being negative about how the sunlight and glare affects them while at work. This was followed by frequency of comments about temperature, lighting issues, noise, privacy, distractions, and control. While sunlight, glare, temperature, and lighting were all a part of the questionnaire, noise, privacy, distractions, and control were not included in this research. These issues were subjects that the participants continually commented on and are recommended as part of future studies.

One interesting observation in relation to the open-ended comments was that when respondents talked negatively about light coming from the outdoors they used the words sun or sunlight 100% of the time. However, when speaking positively about light coming from the outdoors they used the words natural light or daylight almost 100% of the time. Further research should be done to see why these positive and negative

associations were common with Medtronic employees and if it has any connection with how those references are used by management.

Overall Perceived Performance and the Interior Environment

To answer Research Question 1a, "is there a relationship between the interior environment (DE), its components, and employee perceived performance," a one-way ANOVA was conducted to compare the effect of building zone (north, south, east, west) and building location (North, Central, South) with overall perceived performance. There was no significant difference in mean scores between overall perceived performance and zone location by building (Table 11, 12, 13).

Table 11. Overall Perceived Performance North Building and Zone Location

Performance		**North Zone**	**South Zone**	**East Zone**	**West Zone**	**1-Way ANOVA**
Overall thermal comfort	Mean	4.58	4.51	4.40	4.48	.762
	SD	1.39	1.47	1.32	1.32	
	N	179	151	96	88	
Overall window views	Mean	4.71	4.87	4.91	4.83	.665
	SD	1.47	1.30	1.62	1.42	
	N	180	151	96	87	
Overall natural daylighting	Mean	4.68	4.67	4.99	4.59	.306
	SD	1.56	1.55	1..65	1.60	
	N	179	150	96	86	
Overall general electric lighting	Mean	4.65	4.94	4.83	4.66	.174
	SD	1.28	1.33	1.21	1.33	
	N	177	151	96	83	
Overall whole interior environ.	Mean	4.69	4.93	4.95	4.72	.263
	SD	1.36	1.44	1.25	1.29	
	N	177	149	95	86	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 12. Overall Perceived Performance Central Building and Zone Location

Performance		North Zone	South Zone	East Zone	West Zone	1-Way ANOVA
Overall thermal comfort	Mean	4.58	4.51	4.40	4.48	.762
	SD	1.39	1.47	1.32	1.32	
	N	179	151	96	88	
Overall window views	Mean	4.71	4.87	4.91	4.83	.665
	SD	1.47	1.30	1.62	1.42	
	N	180	151	96	87	
Overall natural daylighting	Mean	4.68	4.67	4.99	4.59	.306
	SD	1.56	1.55	1..65	1.60	
	N	179	150	96	86	
Overall general electric lighting	Mean	4.65	4.94	4.83	4.66	.174
	SD	1.28	1.33	1.21	1.33	
	N	177	151	96	83	
Overall whole interior environ.	Mean	4.69	4.93	4.95	4.72	.263
	SD	1.36	1.44	1.25	1.29	
	N	177	149	95	86	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 13. Overall Perceived Performance South Building and Zone Location

Performance		North Zone	South Zone	East Zone	West Zone	1-Way ANOVA
Overall thermal comfort	Mean	4.58	4.51	4.40	4.48	.762
	SD	1.39	1.47	1.32	1.32	
	N	179	151	96	88	
Overall window views	Mean	4.71	4.87	4.91	4.83	.665
	SD	1.47	1.30	1.62	1.42	
	N	180	151	96	87	
Overall natural daylighting	Mean	4.68	4.67	4.99	4.59	.306
	SD	1.56	1.55	1..65	1.60	
	N	179	150	96	86	
Overall general electric ligthing	Mean	4.65	4.94	4.83	4.66	.174
	SD	1.28	1.33	1.21	1.33	
	N	177	151	96	83	
Overall whole interior environ.	Mean	4.69	4.93	4.95	4.72	.263
	SD	1.36	1.44	1.25	1.29	
	N	177	149	95	86	

*Mean difference is significant at the 0.05 level (P<0.05)

Next a one-way ANOVA was conducted to compare the effect of overall zone location between buildings with overall performance measures. Employee performance

perceptions showed a significant effect of zone location on the overall effect of electric overhead lighting at the p<0.05 level of zone conditions [F(2,174) = 5.585, p = .032). Post hoc comparisons using the Tukey and LSD tests indicate that the mean score for the south building north zone (M = 4.88, SD = 1.32) was significantly higher than the central building north zone (M = 4.25, SD = 1.42). These results suggest that there is a higher level of performance perceptions in the south building north zone than the central building north zone (Table 14). It is unclear as to why this difference occurred in these zones. Additional research is needed to gain a better understand of the difference.

Table 14a. Overall Performance Perceptions of Interior Environment in Zones Between Buildings

Performance		**North Building North Zone**	**Central Building North Zone**	**South Building North Zone**	**1-Way ANOVA**
Overall thermal comfort	Mean	4.61	4.45	4.65	.734
	SD	1.39	1.52	1.30	
	N	77	47	55	
Overall window views	Mean	4.81	4.42	4.84	.296
	SD	1.44	1.54	1.44	
	N	77	48	55	
Overall natural dayligthing	Mean	4.78	4.52	4.69	.674
	SD	1.49	1.56	1.65	
	N	76	48	55	
Overall general electric	Mean	4.74	4.25	4.88	.032*
	SD	1.10	1.42	1.32	
	N	77	48	52	
Overall whole environment	Mean	4.74	4.44	4.85	.294
	SD	1.37	1.47	1.21	
	N	77	48	52	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 14b. Overall Performance Perceptions of Interior Environment in Zones Between Buildings, Post Hoc Results

ANOVA

	Sum of Squares	Df	Mean Square	F	Sig
Between groups	11.170	2	5.585	3.507	.032
Within groups	277.113	174	1.593		
Total	288.282	176			

To answer research question 1b, "is there a relationship between the interior environment (DE), its components, and employee satisfaction," a one-way ANOVA was conducted to compare the effect of overall zone location between buildings with overall satisfaction measures. Employee satisfaction showed a significant effect of zone location on natural daylighting conditions within the workstation at the $p<0.05$ level of zone conditions [$F(2, 171) = 3.398$, $p = .036$]. Post hoc comparisons using the LSD test indicate that the mean score for the north building north zone ($M = 5.09$, $SD = 1.68$) was significantly higher than the central building north zone ($M = 4.33$, $SD = 1.98$) and the south building north zone ($M = 4.39$, $SD = 1.95$). These results suggest that there is a higher level of overall satisfaction in relation to natural daylighting in the north building north zone than in the central and south buildings north zone (Table 15). This finding could be due to the location of the buildings on the site, as the north building north zone has a clear view to the outside. The south building north zone and central building north zone both look at either the north or central buildings which causes shading on the adjacent buildings (south building north zone faces the central building and the central building north zone faces the north building, see Figure 17).

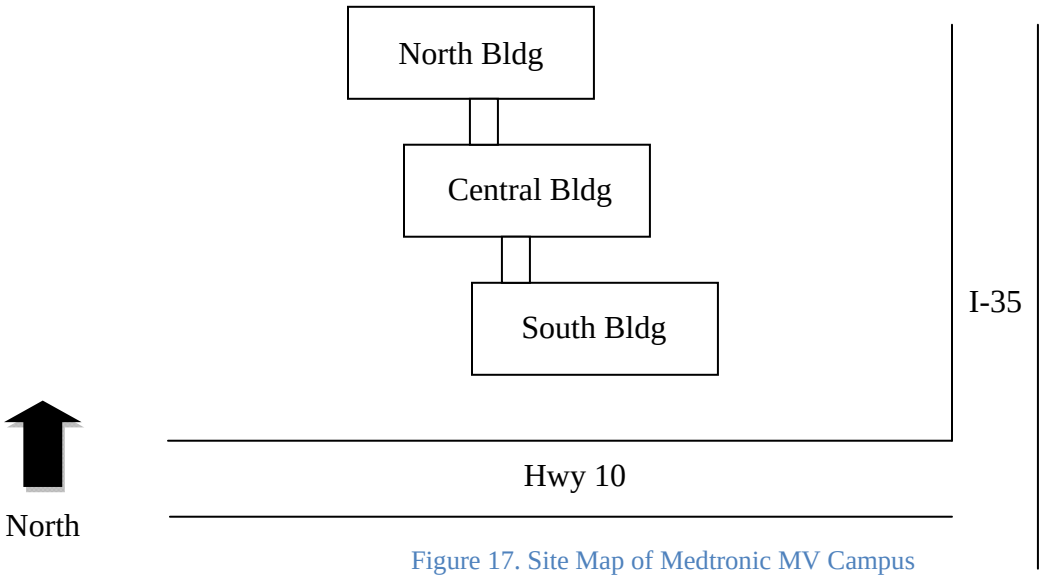


Figure 17. Site Map of Medtronic MV Campus

It is interesting to note that this same condition did not significantly affect overall satisfaction levels with window views. Further inquiry into this finding would be needed to understand the different affects on building location on the site and external views and access to natural light.

Table 15a. Overall Satisfaction of Natural Daylighting in Zones Between Buildings

Satisfaction		North Building North Zone	Central Building North Zone	South Building North Zone	1-Way ANOVA
Overall interior environment	Mean	4.99	4.54	4.88	.261
	SD	1.34	1.58	1.60	
	N	77	48	56	
Overall thermal comfort	Mean	4.90	4.54	4.75	.456
	SD	1.56	1.58	1.46	
	N	77	48	56	
Overall electric lighting	Mean	5.26	4.62	5.09	.062
	SD	1.29	1.71	1.47	
	N	77	48	56	
Overall natural daylighting conditions	Mean	5.09	4.33	4.39	.036*
	SD	1.68	1.98	1.95	
	N	76	48	56	
Overall window views	Mean	4.66	4.10	4.50	.295
	SD	1.90	2.01	1.95	
	N	77	48	56	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 15b. Overall Satisfaction of Natural Daylighting in Zones Between Buildings, Post Hoc Results

ANOVA

	Sum of Squares	Df	Mean Square	F	Sig
Between groups	23.282	2	11.641	3.398	.036
Within groups	606.379	177	3.426		
Total	629.661	179			

Employee satisfaction also showed a significant effect of zone location between buildings on the overall interior environment at the p<0.05 level of zone conditions [F(2,151) = 3.108, p = .048]. Post hoc comparisons using the Tukey test indicate that the mean score for the north building south zone (M = 4.64, SD = 1.48) was significantly

lower than the south building south zone (M = 5.37, SD = 1.46). These results suggest that there is a higher level of satisfaction of the overall interior environment in the south building south zone than in the north building south zone (Table 16). This was a surprising finding as the south building south zone gets direct sunlight into the open office area, while the north building south zone is shaded by the central building. However, it should be noted that the sample size varied between zones.

Table 16a. Overall Satisfaction of Interior Environment in Zones Between Buildings

Satisfaction		**North Building South Zone**	**Central Building South Zone**	**South Building South Zone**	**1-Way ANOVA**
Overall interior environment	Mean	4.64	5.14	5.37	.048*
	SD	1.48	1.31	1.46	
	N	33	37	84	
Overall thermal comfort	Mean	4.58	4.70	4.75	.878
	SD	1.79	1.37	1.73	
	N	33	37	84	
Overall electric lighting	Mean	5.03	5.43	5.25	.523
	SD	1.49	1.30	1.54	
	N	33	37	84	
Overall natural daylighting conditions	Mean	4.36	4.73	4.80	.507
	SD	2.11	1.63	1.78	
	N	33	37	84	
Overall window views	Mean	4.21	4.86	4.71	.251
	SD	2.11	1.18	1.77	
	N	33	37	84	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 16b. Overall Satisfaction of Interior Environment in Zones Between Buildings, Post Hoc Results

ANOVA

	Sum of Squares	Df	Mean Square	F	Sig
Between groups	12.740	2	6.370	3.108	.048
Within groups	309.520	151	2.050		
Total	322.260	153			

Thermal Comfort, Zone Location, and Perceived Performance

To answer research question two; "is there a relationship between the thermal comfort and employee perceived performance," a one-way ANOVA was conducted to compare the effect of building zone, not considering building (North, Central, South) or floor (first through eighth), on thermal comfort and perceived performance in the north, south, west, and east zones (see Table 17). This analysis looked at research questions 2a (is there a relationship between temperature and employee perceived performance) and 2b (is there a relationship between air velocity and employee perceived performance). However, 2c (is there a relationship between humidity and employee perceived performance) could not be answered due to the omission of humidity from the questionnaire by Medtronic. Responses given to the overall effect of thermal comfort on performance was used as a baseline for findings of the other variables of temperature and air velocity. It was assumed that if overall performance perceptions were positive (enhanced performance) then the individual variables should also be positive (enhance performance).

There was no significant difference in mean scores between thermal comfort on perceived performance (overall thermal comfort, temperature, and air velocity) and building zone when the building and floor location are not considered.

Table 17. Thermal Comfort and Effect on Performance by Zone Location

Performance		**North Zone**	**South Zone**	**East Zone**	**West Zone**	**1-Way ANOVA**
Overall Thermal Comfort	Mean	4.58	4.51	4.40	4.48	.762
	SD	1.39	1.47	1.32	1.32	
	N	177	151	96	88	
Temperature	Mean	4.36	4.30	4.32	4.26	.943
	SD	1.41	1.55	1.32	1.42	
	N	179	149	96	90	
Air Velocity	Mean	4.36	4.37	4.48	4.39	9.16
	SD	1.50	1.41	1.27	1.30	
	N	179	148	96	90	

*Mean difference is significant at the 0.05 level (P<0.05)

Note: Humidity was omitted from research at the request of Medtronic

Another one-way ANOVA was conducted to compare the effect of zone difference within each building separately (North, Central, South) on thermal comfort and perceived performance in the north, south, west, and east zones. There was no significant difference in mean scores between thermal comfort on perceived performance and zone within each separate building (Table 18). The results within each separate building were also identical. Table 7 shows the results for all three individual buildings.

Table 18. Thermal Comfort and Effect on Performance by Zone Location within all Individual Buildings

Performance		North Zone	South Zone	East Zone	West Zone	1-Way ANOVA
Overall Thermal Comfort	Mean	4.58	4.51	4.40	4.48	.762
	SD	1.39	1.47	1.32	1.32	
	N	177	151	96	88	
Temperature	Mean	4.36	4.30	4.32	4.26	.943
	SD	1.41	1.55	1.32	1.42	
	N	179	149	96	90	
Air Velocity	Mean	4.36	4.37	4.48	4.39	9.16
	SD	1.50	1.41	1.27	1.30	
	N	179	148	96	90	

*Mean difference is significant at the 0.05 level (P<0.05)

Lastly, a one-way ANOVA was conducted to compare the effect of each zone's relationship as a whole, regardless of building location, on thermal comfort and performance in the north, south, east, and west zones. There was no significant difference in mean scores between overall zone location (regardless of building) and thermal comfort on perceived performance (Tables 19, 20, 21, 22).

Table 19. Thermal Comfort and Effect on Performance North Zone Location

Performance		North Building North Zone	Central Building North Zone	South Building North Zone	1-Way ANOVA
Overall Thermal Comfort	Mean	4.61	4.45	4.65	.734
	SD	1.39	1.51	1.30	
	N	77	47	55	
Temperature	Mean	4.49	4.11	4.39	.339
	SD	1.36	1.43	1.46	
	N	77	46	56	
Air Velocity	Mean	4.48	4.22	4.36	.609
	SD	1.46	1.43	1.49	
	N	77	46	56	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 20. Thermal Comfort and Effect on Performance South Zone Location

Performance		**North Building South Zone**	**Central Building South Zone**	**South Building South Zone**	**1-Way ANOVA**
Overall Thermal Comfort	Mean	4.55	4.58	4.49	.951
	SD	1.55	1.13	1.57	
	N	31	36	83	
Temperature	Mean	4.39	4.39	4.25	.859
	SD	1.65	1.30	1.61	
	N	31	36	81	
Air Velocity	Mean	4.35	4.44	4.34	.931
	SD	1.47	1.23	1.48	
	N	31	36	80	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 21. Thermal Comfort and Effect on Performance East Zone Location

Performance		**North Building East Zone**	**Central Building East Zone**	**South Building East Zone**	**1-Way ANOVA**
Overall Thermal Comfort	Mean	3.92	4.39	4.45	.460
	SD	1.50	1.41	1.25	
	N	12	33	51	
Temperature	Mean	4.17	4.40	4.29	.854
	SD	1.40	1.36	1.29	
	N	12	35	49	
Air Velocity	Mean	3.92	4.71	4.43	.165
	SD	1.00	1.43	1.20	
	N	12	35	49	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 22. Thermal Comfort and Effect on Performance West Zone Location

Performance		North Building West Zone	Central Building West Zone	South Building West Zone	1-Way ANOVA
Overall Thermal Comfort	Mean	4.54	4.56	4.36	.813
	SD	1.47	1.05	1.44	
	N	24	27	36	
Temperature	Mean	4.56	4.21	4.14	.498
	SD	1.42	1.13	1.59	
	N	24	28	36	
Air Velocity	Mean	4.48	4.50	4.31	.803
	SD	1.23	1.17	1.43	
	N	25	28	36	

*Mean difference is significant at the 0.05 level (P<0.05)

Proximity to a Window, Perceived Performance, and Zone location

To answer research question 3, "is there a relationship between window proximity and employee perceived performance," a one-way ANOVA was conducted to compare the effect of building zone, not considering building (North, Central, South) or floor (first through eighth), on window proximity and perceived performance in the north, south, east, and west zones. This analysis looked at questions 3a (is there a relationship between view when seated and employee perceived performance), 3b (is there a relationship between view when standing and employee perceived performance), 3c (is there a relationship between amount of natural daylight and employee perceived performance), and 3d (is there a relationship between the ability to control or block the natural daylight and employee perceived performance).

Employee performance perception showed a significant effect of zone location (not considering building or floor) on external view when sitting at the $p<0.05$ level for the zone conditions [$F(3,505) = 5.077$, $p = .002$). Post hoc comparisons using the Tukey

test indicated that the mean score for the north zone (M = 4.09, SD = 1.61) was significantly lower than the east zone (M = 4.75, SD = 1.78). This test also indicated that the mean score for the north zone (M = 4.09, SD = 1.61), was significantly lower than the mean score of the west zone (M = 4.72, SD = 1.53). However the south (M = 4.36, SD = 1.43) zone did not significantly differ from the other zones (Table 23). These results suggest that the east and west zones have higher level of perceived performance in relation to external view when seated. However it should be noted that sample size varied between zone locations.

Table 23a. Proximity to a Window and Effect on Performance in Zone Location

Performance		**North Zone**	**South Zone**	**East Zone**	**West Zone**	**1-Way ANOVA**
Ability to control/block dayligthing	Mean	3.81	4.09	3.94	3.58	.089
	SD	1.56	1.55	1.54	1.57	
	N	177	148	95	90	
External view when standing	Mean	5.05	5.09	5.47	5.10	.116
	SD	1.50	1.45	1.39	1.46	
	N	177	148	95	89	
External view when seated	Mean	4.09	4.36	4.75	4.72	.002*
	SD	1.61	1.43	1.78	1.53	
	N	176	147	96	90	
Amount of Natural Daylighting	Mean	4.58	4.86	4.95	4.49	.090
	SD	1.61	1.50	1.68	1.66	
	N	180	156	101	94	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 23b. Proximity to a Window and Effect on Performance in Zone Location, Post Hoc Results

ANOVA

	Sum of Squares	Df	Mean Square	F	Sig
Between groups	38.137	3	12.712	5.077	.002
Within groups	1264.492	505	2.504		
Total	1302.629	508			

Electric Lighting Levels and Effect on Performance

To answer research question 4, "is there a relationship between overhead electric lighting levels and employee perceived performance," a one-way ANOVA was conducted to compare the effect of overall zone location (not considering building or floor) with electric lighting levels. This analysis looked at questions 4a (is there a relationship between the ability to control the desk/task light and employee perceived performance), 4b (is there a relationship between the amount of electric lighting and employee perceived performance), and 4c (is there a relationship between the visual comfort of light levels and employee perceived performance).

Employee performance perceptions showed a significant effect of zone location (excluding building and floor) on the extent to which individuals can control the desk (task) light at their workstation at a $p<0.05$ level of zone conditions [$F(3,524) = 2.666$, $p=.047$]. Post hoc comparisons using the LSD test indicate that the mean score for the north zone ($M = 4.13$, $SD = 1.65$) was significantly lower than the south zone ($M = 4.54$, $SD = 1.51$). Additionally the mean score for the west zone ($M = 4.10$, $SD = 1.38$) was significantly lower than the south zone. These results suggest that there is a higher level

of perceived performance in relation to the extent to which an individual can control their desk (task) light in the south zone than in the north or west zone (Table 24). These results could be due to the possibility that the south zone does not need to use their desk lamp as often due to the increased amount of natural daylight that is available to them therefore creating less of a need to control the light.

Table 24a. Perceived Performance of Desk Light Control within Zones

Performance		**North Zone**	**South Zone**	**East Zone**	**West Zone**	**1-Way ANOVA**
Control of desk light	Mean	4.13	4.54	4.42	4.10	.047*
	SD	1.65	1.51	1.59	1.38	
	N	180	155	100	93	

*Mean difference is significant at the 0.05 level (P<0.05)

Table 24b. Perceived Performance of Desk Light Control within Zones, Post Hoc Results

ANOVA

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig**
Between groups	19.353	3	6.451	2.666	.047
Within groups	1352.889	524	2.419		
Total	1287.119	527			

Discussion

The next chapter will discuss these findings in more detail as they relate to the research questions and the HET.

Chapter 5 Conclusion

This study examined the effects of thermal comfort, window proximity, and electric lighting on perceived employee performance perceptions and employee satisfaction at the Medtronic Mounds View, Minnesota Campus. This chapter reviews the main findings; the fit with the theoretical model; and the implications of the results for Medtronic, for the practice of interior design in relation to office design, and for education in relation to office design. It also examines areas of additional research for the future.

Overview of Main Findings

The result of statistical analysis on Research Question 1a, "is there a relationship between the interior environment (DE), its components, and employee perceived performance," showed that there was no relationship between interior environment and performance when comparing the buildings individually. However, when zones across all floors and all buildings were compared, there was a significant relationship between perceived performance and electric lighting levels. These results suggest that there is a higher level of performance perceptions in the south building north zone than the central building north zone.

The results of statistical analysis for overall performance measured showed a significant difference in mean scores of perceived performance and overhead electric lighting between the north zone south building and the north zone central building. The results indicate that there is a higher mean score in the south building north zone than the central building north zone. It is unclear as to why these results would show a significant

difference as these zones have the same electric lighting conditions and similar natural lighting conditions with their relationship with the other buildings and orientation on the site. There were also similar sample sizes in both zones with an adequate sample size for reliable results (N = 48, N = 52). Additional research would need to be conducted to find out why there is a perceived difference in these zones.

The results of statistical analysis of Research Question 1b, "is there a relationship between the interior environment (DE), its components, and employee satisfaction," indicated that overall employee satisfaction levels showed that there was a significant difference between satisfaction levels between the north zone in each building (north, central, south). The north building had a higher mean score for satisfaction of natural daylighting in the space. The north zone in the central and south buildings still show a mean score above neither satisfied nor dissatisfied but not at the same level as the north zone in the north building. This difference in satisfaction may be due to how the buildings are positioned on the site. The long sides of the buildings run parallel to Hwy 10 in Mounds View, situated east to west and staggered with one another. The north building is on the north side of the site; with the south building adjacent to Hwy 10 on the south of the site and central in the middle of the two (see Figure 17). The south and central buildings are connected to the central building with seven levels of "bridges." Because of this orientation of the buildings on the site and their relationship to each other, access to natural light and views differs between north zones within the different buildings. The north building north zone is able to get clear access to natural light without any other elements impeding or blocking its entrance into the space. The south

and central buildings' north zones are both shadowed by another building as well as broken up by the building bridges. While it seems plausible that this difference in access to natural light is the cause in satisfaction level difference, the findings indicate a relationship, but it may not be causal. Additional research would need to be conducted to confirm this causal relationship.

The statistical results also showed a significant difference in mean scores in satisfaction levels between the north building north zone and south building south zone. The study showed that employees in the south building south zone have a higher level of satisfaction than the employees in the north building north zone. This finding was an unanticipated result considering both the location of the buildings on the site (see Figure 18) and the findings from the access to natural daylight satisfaction results. Employees in the south zone of the south building are exposed to direct sunlight at all times of the year, creating a situation of glare and heat gain in that area. There were enough initial complaints about those issues after the building was first occupied that lead to Medtronic installing expensive daylight sensing automatic shades in all buildings south zones. The results of this study may indicate that the shades have improved the issues in these areas creating a more desirable work environment than other areas where shades were not installed. Additional research would need to be conducted to examine this possibility further.

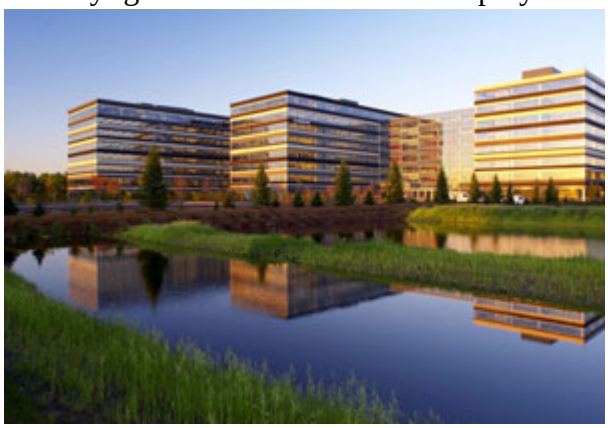


Figure 18 Site view of Medtronic Mounds View

Findings from Research Question Two; “is there a relationship between thermal comfort and employee perceived performance”, showed that there was no significant difference in employee perceptions of performance in relation to thermal comfort. The analysis was conducted looking at overall zone difference, not considering building or floor, zone difference in each building, and overall zone difference as a whole. There was no significance of thermal comfort found. However, it is unclear if that would be the case if humidity had been tested in addition to temperature and air velocity. Buildings with full height window walls for exterior walls must engineer to ensure that the building systems are able to keep up with the demands that can be put on them in harsh climates similar to Minnesota (extreme temperatures in summer and winter months). The results from the Medtronic campus indicate that there is an adequate amount of temperature control from the facilities heating, ventilation, & and air-conditioning (HVAC) systems to regulate temperature and air velocity across all buildings and zones.

The result of statistical analysis on Research Question 3, “is there a relationship between window proximity and employee perceived performance,” showed that there was a significant effect of zone location (not considering building or floor) on perceived performance from external view when seated between the east/west zones and the north zone. The north zone had a lower mean score for enhancing perceived performance indicating that the west and east zones may be more conducive to higher levels of perceived performance. However, these results do not indicate a reason behind the difference in perceptions between zones, only that one exists. Further research would need to be done to understand what in particular it is about these zones that caused the

dissimilar results. An assumption for the reason for these results is that the percentage of individuals on the east or west window walls is larger than those on the south or north, therefore making an even comparison difficult.

The results for Research Question Three also indicate that although it is beneficial to have a window view when standing it is also important to employees to have visual access to the outside while seated at their desk. Research has shown that views to the outdoors and daylight can lead to an increase in concentrated task performance (Lee, 2007), which is also supported in the findings of this study. While it is unclear exactly how much of an increase in performance views to the outdoors can create, Medtronic employees' indicated a desire for views to the outside while they are seated at their desks rather than just when standing at their desks. This could be accomplished by lower panel heights within the open work environment or adding glass panel sections into the workstations of the north zones. Although adjustments may help views when seated, it may be essential to look at the possible effects these alterations could have on privacy and noise control in relation to seated views. These were issues that Medtronic employees made written comments about in the open-ended question sections of the survey. Most of the comments spoke about inadequate privacy and limited or no noise control. These variables were not tested in this research but could potentially be more related to perceived performance levels. It is also possible that the results of the seated view are higher than the seated view because employees expect to have a view when standing with office design today, so it is taken for granted and not seen as high of a

benefit at it once was. If a follow up question was asked in a survey about this subject it may help determine what employee expectations are for open-office design.

The result of statistical analysis on Research Question 4, "is there a relationship between overhead lighting levels and employee perceived performance," showed a significant difference in mean scores of perceived performance and control of the desk (task) light. Results indicate that there is a higher level of perceived performance in the south zone of all buildings than the north or west zones related to the extent to which employees can control their desk light at their workstation. While control of desk lights typically is not dependent on where they are within the building, since all desk lamps provided to employees are the same, it may be that employees in different zones use their desk lights more often than employees in other zones. Employees in the south zone get more natural light in their areas than the other three zones in the buildings. Because of this, employees in the south zone may not need to use their desk light as often and therefore do not have negative perceptions about their ability to increase light levels in their workstation. There were many negative comments in the open-ended question section of the survey where respondents negatively describe desk lights provided to them, and some stated they have brought in their own light fixtures due to the inadequacy of the workstation desk light. However, this is an assumption made by the researcher and would need further exploration to give support to the supposition.

The most impactful finding of the research is that few of the variables tested indicated a statistically significant difference in either satisfaction levels or perceived

performance levels. And of these variables that are statistically significant, they typically were still in the positive range for satisfaction or perceived performance.

Fit with Theoretical Model

This study used the HET to explain how employee (Human) perceived performance (Social Environment) was affected by thermal comfort (Designed Environment) and window proximity (Natural Environment). An additional measure of satisfaction (Social Environment) was added due to the close association between satisfaction and performance in employee perceptions. Thermal comfort was measured by air velocity and temperature. Window proximity was measured by access to natural daylight and external views when standing and seated. Perceived performance and satisfaction levels were completed as self measures by participants of the study. The findings from this study support the theoretical model and relationships between environments. There were significant results found in both the natural and designed environments in relation to lighting levels. Access to daylight has an effect and interacts with the need or use of electric lighting. This research supports the position that the social environment is connected to the natural and designed environments within interior environments. Consequently, this model can be used

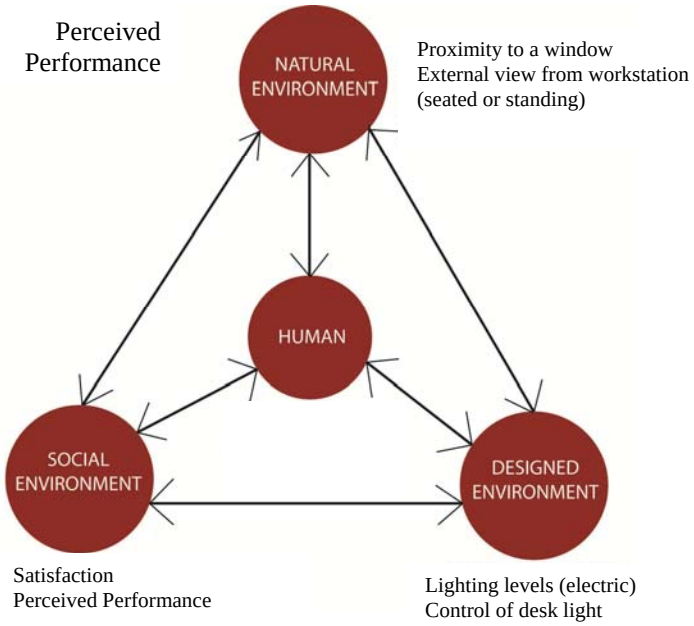


Figure 19. Theoretical Model

to validate the relationship between employee perceptions about satisfaction and performance in relation to the work environment, including both external aspects (NE) of the environment as well as interior elements (DE).

The results of the research show that there are interactions occurring between the SE, DE, NE, and the employees (HO). Proximity to a window, view when seated or standing, electric lighting, and control of desk light were all variables in either the DE or NE that were effected or interacted with the SE and HO in either a positive or negative way. Moreover, they also indicated when there was not a significant relationship between the DE and the HO. No emphasis was placed on gender or age in the study as it relates to the HO. An analysis was conducted to examine a potential relationship but no significant results were found. The findings of the research support the use of the human ecosystem model as a theoretical foundation for testing how employees interact with their environment (Figure 19).

Implications for Medtronic, Inc.

The results of this study should be seen as an overall success for Medtronic regarding the buildings on their Mounds View campus. There were few statistically significant results from the survey indicating that overall employees are satisfied with their workstation environment as it relates to thermal comfort and window proximity as well as an overall perception that their workstation enhances their level of work performance. Results indicate that the design of the workstation environment and its interaction with larger facility systems has been successful overall, based on the variables examined (thermal comfort, proximity to a window including view, and overhead light

levels). There are a few variables (thermal comfort, overhead light levels, and view) that may benefit from further investigation to discover the cause of the difference in satisfaction or performance perceptions. As discussed in the overall results section, there are also areas within different buildings and zones that show a significant difference in either satisfaction or perceived performance levels related to access to daylighting, views when seated, overhead electric lighting levels, and ability to control desk light.

It may benefit Medtronic to further investigate the differences in daylighting and views in the north and east zones in all buildings, first to understand if the decrease in satisfaction and perceived performance levels is due to elements that are fixable, such as need for additional window shades, change in panel height or opacity, or if they are elements that need to be taken into consideration for future construction of office space. For example, changing the orientation of the buildings on the site is not possible for the current buildings, but building orientation that most effectively supports satisfaction and employee performance could be considered for future office construction. Medtronic may also want to investigate the importance to views in relation to the interior environment. If the interior environment is the same across all areas of the different buildings and across all floors, then why are there differences in performance or satisfaction perception? May this difference be caused by access to view alone? Also, where there are differences between zones related to electric lighting, it would be beneficial to further investigate why differences occurred. If lighting and fixtures are consistent across all buildings, floors, and zones, then it would be assumed that satisfaction and performance levels would be the same across all buildings, floors, and

zones. Medtronic needs to look at why these differences are occurring and what is the cause, i.e. lamp rotation schedule, lamp type being used in identical light fixtures, or the time of day that the individual in using the electric/artificial lighting.

Because of the focused scope of this study, not all elements that can have an effect on satisfaction and performance perceptions were investigated. In addition to the areas of interest within this study, there were additional areas of concern indicated by employees about their workstations. Answers to the open-ended questions section of the research indicated additional design elements that Medtronic may want to consider in future research. Noise, distractions, and privacy were the subject of many responses to open-ended questions within the questionnaire. Responses indicated a lack of ability to make private work-related calls or conferences. Managers expressed a concern for conducting some of the more private side of their work out in the open for others to hear or see.

Another issue of concern for employees is the new shade system that was installed in the south zones of the building. The lack of personal control and inability to change the shades to suit their needs was an area of concern for all employees who addressed the shades in their comments. The question concerning the ability to control or block natural daylight in their workstation had the lowest and only mean score ($M = 3.88$) in the "somewhat hinders performance" interpretation indicating that the solution may not be well suited to its current application. The shades were also listed as a source of increased distraction as it was indicated consistently that they are raised and lowered

throughout the day multiple times. Some participants indicated that they have made their own shade systems because the ones recently installed are undependable.

Another area of concern that was repeatedly mentioned by respondents was the inability to control lighting after typical office hours. As shown in the results of the questionnaire, 68% of respondents spend more than 40 hours a week in the buildings indicating that there are many individuals in the building during off hours. Electric lighting on timers that turn off after 6 pm were stated as an area of distraction as well as increasing the inability to complete work. It may make sense to supply additional task lights to employees so they have control of lighting levels within their workstations when facility lights need to be turned off to conserve energy and save on cost.

While most areas addressed in the study did not show statistically different responses between buildings and zone, the mean scores for all satisfaction and performance questions ranged from 5.13 on the high side and 3.88 on the low side, with the majority falling in the 4.97 to 4.31 range. This indicates that overall employees feel that the workstation somewhat enhances their performance or they are somewhat satisfied with their workstation. Some of the suggestions above may be items to address that will help improve mean scores to satisfied or enhances performance.

Implications for Practice

The results of this research support the need for interior designers to better understand the recommendations they give to clients and the outcomes of their designs. The findings of this research show that while the overall design of the Medtronic facility has been successful for the most part, there are variables that could be better understood

by designers and architects, as well as how those variables interact with each other and with employees.

At the beginning of projects, interior designers and architects need to work with the client to develop specific design goals and it is important for practitioners to help guide clients in this development. Once goals are determined by the design team, a list of priorities should be developed to help facilitate the decision making processes when design solutions present conflicts in achieving design goals, for instance budget versus sustainable design. Designers should understand appropriate baselines for satisfaction and performance levels for employees and make design decisions based on those ideas, which also need to be consistent with their clients' needs and goals. This process would help designers have a better understanding of their own goals for the project as well as the clients. This will also help eliminate surprises in the end result of the project if the client was aware of all of the potential outcomes (positive and negative) due to decisions made during the project. In many cases, failed designs are not due to poor design but to client expectations that are different from what the designer implements.

If the client is actively involved in the entire design process and aware of the effects of decisions they make, then they are more likely to support the end result of the design with their employees and sell every aspect of it. Designers could also help clients develop methods to communicate design decisions to employees to help them better understand why certain decisions were made. For example, in the case of Medtronic, if the health of their employees is a top priority and a design goal for the project, then low workstation partitions may have been selected above privacy due to the health benefits of

views to the outdoors for employees. If Medtronic had moved employees into their new workstations and facility with communication about all of the health benefits to them as well as recognizing what they are giving up, it may help employees understand the decision better and accept losing some of the benefits of a private office to the benefits of open-office environments.

Another area that design firms should take into consideration is the development of research-based positions within their own organizations. If firms were to designate interior designers and/or architects who are focused on compiling and conducting research on their firm's behalf (research on both their own projects and general design research), they will make information more readily available to their colleagues/employees to use in projects. This practice would help the firm become more desirable to both potential clients as well as give them a area of differentiation in the marketplace. Firms would also have the opportunity to publish their own studies and POE's of their projects helping establish them as a leader in the field similar to the practice of Gensler, a large and well respected design firm that publishes their own research.

If these ideas where incorporated more often in practice, interior designers could better serve their clients and help add to the body of knowledge of interior design that is predominately supported by academia at this time. Additionally, evidence-based design would help designers better promote their designs to their clients and give them knowledge to make impactful decisions that are able to support the economic well-being of the company while supporting the health and well-being of employees.

Implications for Education

For interior designers to better support the needs of their clients, it is important that a foundation is set in interior design education. The biggest element in interior design education to emphasize in the curriculum is the practice of evidence-based design. New practitioners leave higher education with the basics of how to look at their projects critically but most lose it very quickly once practicing due to the limited emphasis on project research. The University of Minnesota has recently begun an evidence-based design class for graduate level interior design students as well as for practitioners to help facilitate a better understanding of the concept of this type of design. Healthcare and casino designs are the best examples of design industries that have taken advantage of evidence-based design, but it does not seem to have made it to many of the other commercial design types, specifically within office designs. If it was a requirement to have a focused class on evidence-based design required by the Council for Interior Design Accreditation (CIDA, the accrediting organization for interior design programs at universities and colleges), instead of just an area that is incorporated into curriculum, evidence-based design might become more prevalent in practice and more widely used. During this class faculty could potentially be able to present case studies to students to help them better understand how the POE process works and how best to incorporate it into their practice.

During school, many design students are taught to think creatively and out-of-the-box and not always consider real world applications in their design decisions. They get so caught up in the aesthetic portion of their design that they often lose sight of the

practicality or function of their designs. In the case of Medtronic, the designers focused on the appearance of the buildings from the exterior of the buildings that the effect of the design on the interior of the space may have been put at a lesser level of priority. If these principles were required in a class focused on cause and effect, such as evidence based design, then design priorities can be better balanced.

Implications for Research

To better answer the questions explored by this research, future research issues are identified for both Medtronic and academia. While the overall response rate for this study was relatively high, it may be beneficial for Medtronic to conduct their own environmental study. By doing a full environmental study of their buildings, they not only get the benefit of better understanding their facilities and how they affect their employees, but they would also be able to use the learning across all their facilities located around the world. Even making changes and additions to existing environments based on findings from any studies conducted, it is never possible to create an ideal situation for every individual, as needs vary so greatly from person-to-person. However, giving employees an opportunity to voice their concerns may help to increase their level of ownership over any changes that occur as well as feel like they matter in such a large organization like Medtronic.

There are also areas within the findings of this study that Medtronic may want to expand on the level of understanding. The discrepancy between electric lighting between the north zones in the south and central buildings needs to be addressed. They may want to determine if this is due to individual lights going out in these zones or if there is a yet

unidentified issue in those areas, as discussed earlier. It may also be beneficial to do a study on the shade system that was installed in the south zones and whether or not they are the right solution for this application and if additional shades are needed in other zones of the buildings.

Further research in academia would be to compare the results of this study with similar companies in other locations around the United States. It may be possible that the employees at Medtronic are a relatively homogeneous group causing similar response across locations in the different buildings. It would be interesting to see if similar results would occur in similar building types across different geographic locations and companies. The assumption is that the results would vary, especially based on geographical location and associated climate.

In addition to comparing offices in different locations across the United States, it may also be a benefit to determine if the time of year that the research was conducted was actually the most appropriate time to collect the data. Due to time constraints of this study the data was collected in April when the insolation levels (the amount of sunlight hitting the earth's surface [Apricus, 2010]) in Minneapolis Minnesota are approximately 4.55. These levels rise and fall throughout the year depending on the location of the sun. At its lowest, insolation levels are at 1.34 in December and rise to 5.86 in June. To better understand how employees work throughout the year, it may be beneficial to repeat the survey during these different times of year to get a better idea of how the amount of sun exposure affects employees and their performance and satisfaction perceptions.

It would be valuable to understand why performance and satisfaction levels were so high in this study as it relates to view when seated. Most individuals in this setting are not able to see a view to the outside when seated, however they indicated that they are satisfied and believe that their exterior views enhance their performance. As discussed in the literature view, past research has shown that view to the exterior has a high impact on performance perceptions and satisfaction levels, but that was not supported in these findings. Have office workers begun to adapt to the new open office plan and are happy to just have access to natural light, without the view itself? Or has view just become less important to employees than it once was?

While this study generally indicated that the DE was considered positively by the employees at the Medtronic Mounds View Campus, there are still many areas of research needed to gain a better understanding of the design of the facility and its impact on the company's employees that spend 75% or more of their time in these buildings. Other researchers could investigate these same variables with different methods and see if the same results occur as found in this study.

Every POE study that is conducted contributes to the body of knowledge for interior designers, architects, facilities managers, and company owners. This study helps to add to that body of knowledge. Gaining a better understanding of how the environment affects employee perceived performance and satisfaction will only increase the quality of facility designs and functionality creating a more sustainable and healthy work environment for every occupant of the space. Because Medtronic is such a large company, the fact that they conducted a successful POE study, may help to influence

other similar companies to do the same and follow suit. Positive results from this study will also help support the potential not only other companies following this example, but interior designers and architects may realize that they can be confident in their designs and offer POE studies more often to their clients. This study also helps bring a model of how a POE process might be initiated in an organization, taking small steps to starts by focusing on just the workstation first and then extending to a wider scope of design issues over time.

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Appendix A

Questionnaire/Survey

Post-Occupancy Evaluation

Consent Form

You are invited to be in a research study because you are employed by Medtronic and work at the Mounds View Campus. Please read this form and ask any questions you may have before agreeing to complete the survey. This study is being conducted by a graduate student at the University of Minnesota.

Background Information
The purpose of this study is to assess your perception of how your work performance is affected by your workstation and the physical environment surrounding it.

Procedures
If you agree to be in this study, please complete the online questionnaire and submit it to the University as directed in the questionnaire. If you would like to be entered into a drawing for one of ten gift cards, simply provide your email address when prompted at the completion of the survey.

Risks and Benefits of Being in the Study
There is no greater than minimal risk to participation in the study. The benefits are that you will be adding to knowledge about office design.

Confidentiality
The records of this study will be kept private. In any sort of report we might publish, the University of Minnesota will not include any information that will make it possible to identify you. Research records will be stored securely, and only researchers will have access to the records. Medtronic will not have access to these records.

Voluntary Nature of the Study
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. You are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions
The researcher conducting this study is Kari Ihle. You may ask any questions you have before you begin the survey. If you have questions later, you are encouraged to contact Kari Ihle at 612.281.5759 or ihlex011@umn.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), you are encouraged to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

Page 1 - Question 1 - Yes or No [M

Answer YES to provide your consent and complete the questionnaire.

○ Yes

- ○ No

Page 2 - Heading

Directions:
There are several sections in this questionnaire for you to complete. Completion of the entire questionnaire is important to the understanding of how the Mounds View facility meets your needs. All data are confidential, and no personal identification will be used except to note your approximate location in the building, which helps us determine how the design meets your needs. No individual data will be shared with Medtronic.

Definition of Terms Used:
Workstation is your individual work area/desk.
Workplace is your overall work environment.
Building is the physical structure you work in and its surrounding grounds.
Facility is the building, site, and interior environment.

Page 3 - Question 2 - Choice - Multiple Answers (Bullets)

In what building is your workstation currently located?

- ❑ North
- ❑ Central
- ❑ South

Page 3 - Image

Workstation Types

Page 3 - Question 3 - Choice - Multiple Answers (Bullets) [M

Of the two workstation photo's above, which one do you have?

- ❑ Typical A
- ❑ Typical B
- ❑ Private Hardwall Office [Skip to End]

Page 4 - Question 4 - Choice - One Answer (Bullets) [M

How long have you worked in this building?

- ○ Less than 6 months [Skip to End]

- ○ 6 months to 1 year
- ○ 1-2 years
- ○ Over 2 years

Page 4 - Question 5 - Choice - One Answer (Bullets)

In a typical week, how many hours do you spend in the building?

- ○ Less than 20
- ○ 20-30
- ○ 31-40
- ○ More than 40

Page 4 - Question 6 - Choice - One Answer (Bullets)

What percentage of time per week do you spend in your personal workstation?

- ○ Less than 25%
- ○ 25-50%
- ○ 51-75%
- ○ More than 75%

Page 4 - Question 7 - Choice - One Answer (Bullets)

Of the time spent in your personal workstation, what percentage of time is spent at your computer?

- ○ Less than 25%
- ○ 25-50%
- ○ 51-75%
- ○ More than 75%

Page 4 - Question 8 - Choice - Multiple Answers (Bullets)

What is your age?

- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ 65-74
- ☐ 75-84
- ☐ 85-90
- ☐ 90+

Page 4 - Question 9 - Choice - One Answer (Bullets)

What is your gender?

- ❍ Male
- ❍ Female

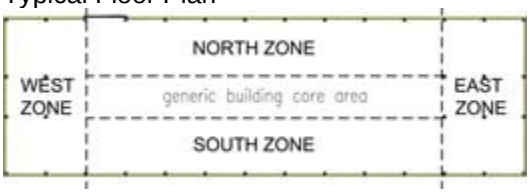
Page 4 - Question 10 - Choice - One Answer (Bullets)

What floor do you work on?

- ❍ First
- ❍ Second
- ❍ Third
- ❍ Fourth
- ❍ Fifth
- ❍ Sixth
- ❍ Seventh
- ❍ Eighth

Page 4 - Image

Typical Floor Plan



Page 4 - Question 11 - Choice - One Answer (Bullets)

Please refer to the floor plan image above, in which zone is your workstation?

- ❍ North Zone
- ❍ South Zone
- ❍ East Zone
- ❍ West Zone

Page 4 - Question 12 - Open Ended - Comments Box

Please provide additional comments about any of the above questions.

Page 5 - Heading

Following is a series of statements about your overall level of satisfaction with your workstation.

Page 5 - Question 13 - Rating Scale - One Answer (Horizontal)

Your overall satisfaction with the interior environment:

Very Dissatisfied	2	3	4	5	6	Very Satisfied
❍	❍	❍	❍	❍	❍	❍

Page 5 - Question 14 - Rating Scale - One Answer (Horizontal)

The overall thermal comfort in your workstation (temperature, air velocity, humidity):

Very Dissatisied	2	3	4	5	6	Very Satisfied
❍	❍	❍	❍	❍	❍	❍

Page 5 - Question 15 - Rating Scale - One Answer (Horizontal)

Your overall satisfaction with the general overhead electric lighting in your workstation:

Very Dissatisfied	2	3	4	5	6	Very Satisfied
❍	❍	❍	❍	❍	❍	❍

Page 5 - Question 16 - Rating Scale - One Answer (Horizontal)

The overall effect of natural daylighting in your workstation:

Very Dissatisfied	2	3	4	5	6	Very Satisfied
❍	❍	❍	❍	❍	❍	❍

Page 5 - Question 17 - Rating Scale - One Answer (Horizontal)

The overall effect of window views in your workstation:

Very Dissatisfied	2	3	4	5	6	Very Satisfied
❍	❍	❍	❍	❍	❍	❍

Page 5 - Question 18 - Open Ended - Comments Box

Please provide additional comments about any of the above questions.

Page 6 - Heading

Following are statements about the effect of the workstation on your work performance.

Page 6 - Question 19 - Rating Scale - One Answer (Horizontal)

The overall thermal comfort (temperature, air velocity, humidity) in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 6 - Question 20 - Rating Scale - One Answer (Horizontal)

The overall effect of window views in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 6 - Question 21 - Rating Scale - One Answer (Horizontal)

The overall effect of natural daylighting conditions in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 6 - Question 22 - Rating Scale - One Answer (Horizontal)

The overall effect of electric general overhead lighting in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 6 - Question 23 - Rating Scale - One Answer (Horizontal)

The overall effect of the whole interior environment:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 6 - Question 24 - Open Ended - Comments Box

Please provide additional comments about any of the above questions.

Page 6 - Heading

You have completed about 1/2 of the questionnaire; keep going!

Page 7 - Heading

Following are statements about how your workstation effects your work performance.

Page 7 - Question 25 - Rating Scale - One Answer (Horizontal)

The temperature (i.e., hot or cold) in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 7 - Question 26 - Rating Scale - One Answer (Horizontal)

The ability to control or block the natural daylight in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 7 - Question 27 - Rating Scale - One Answer (Horizontal)

The extent to which you have an external window view when standing:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 7 - Question 28 - Rating Scale - One Answer (Horizontal)

The amount of electric lighting in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 7 - Question 29 - Rating Scale - One Answer (Horizontal)

The extent to which you have an external window view when seated:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 7 - Question 30 - Rating Scale - One Answer (Horizontal)

The air velocity (i.e., drafty or stagnant) in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 8 - Question 31 - Rating Scale - One Answer (Horizontal)

The amount of natural daylighting in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 8 - Question 32 - Rating Scale - One Answer (Horizontal)

The extent to which you can control the desk (task) light at your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 8 - Question 33 - Rating Scale - One Answer (Horizontal)

The visual comfort of daylighting and electric lighting (i.e., minimized glare, prevention of distracting reflections, appropriate contrast) in your workstation:

Hinders Work Performance	2	3	4	5	6	Enhances Work Performance
❍	❍	❍	❍	❍	❍	❍

Page 8 - Question 34 - Open Ended - Comments Box

Please provide additional comments about any of the above questions.

Page 9 - Question 35 - Open Ended - Comments Box

Please provide any other final comments you have before completing the survey.

Page 9 - Heading

Thank you for completing the survey!

Thank You Page

Thank you for completing this survey!

As a token of appreciation, you may email your contact information (name and email address) to ihlex011@umn.edu to be entered into a drawing for one of ten $10 gift certificates to Target.

Your information will not be used to identify your responses in the survey, nor to contact you for any other reason than to inform you of the results of the drawing. Your personal information will also not be shared with Medtronic in any way.

If you have any questions or concerns, please contact Kari Ihle at ihlex011@umn.edu

Thank you again for your time and participation.

Appendix B

Emails sent to employees

INITIAL EMAIL INVITING EMPLOYEES TO PARTICIPATE

Dear Medtronic Mounds View Employees-

A local University of Minnesota graduate student is conducting a survey to assess perception of work performance and the physical environment in open office space. **Note that the survey does not include hardwall private offices.** Concentrating on the Mounds View Campus due to the LEED (Leadership in Energy and Environmental Design) principles incorporated into the overall design. Please click on the link below to take the survey. It should take no longer than ten minutes to complete. All responses to the survey are confidential.

Your responses will be compiled and used for research purposes at the University of Minnesota's College of Design. Information gathered from this survey will also be shared with the Medtronic Facilities Operations team. Medtronic will not see individual responses of participants.

In appreciation of your time, ten gift cards will be randomly awarded to survey respondents. Simply provide your e-mail address when prompted to enter at the completion of the survey.

Thank you in advance for your participation.

<Insert link here>

FOLLOW-UP EMAIL REMINDING EMPLOYEES TO PARTICIPATE

Dear Medtronic Mounds View Employees –

A reminder of an opportunity to participate in a University of MN graduate student's survey to assess perception of work performance and the physical environment at the Mounds View Campus. The survey will be available for only two more days. Remember the results will be kept completely confidential, and Medtronic will not see any individual responses.

Thank you in advance for your participation.

<Insert link here>