

Green Roof Exposure and Office Workers' Mental Health: Work-related Distress, Mental  
Fatigue, and Perceived Restoration

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## ABSTRACT

More than half of the world's population works full time and spends about one-third of their weekdays at workplaces (International Labor Organization, 2022). Mental disorders are one of the health problems that have emerged among working populations (World Health Organization, 2022). Previous empirical research and theories demonstrated that nature exposure positively impacts human health and wellbeing (Kaplan and Kaplan 1989). Green roofs can be one of the most easily accessible nature places for office workers in city centers. This study examines the relationship between green roofs and work-related distress, mental fatigue, and restoration. An online survey of 179 employees was used to evaluate the relationship between exposure to six different green roofs and employee work-related distress, mental fatigue, and mental restoration. The results show that the average time spent on green roofs and the frequency of visits have statistically significant relationships with the mental restoration.

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## GENERAL AUDIENCE ABSTRACT

More than half of the world's population works full time and spends about one-third of their weekdays at workplaces (International Labor Organization, 2022). Mental health issues are one of the health problems that have emerged among employees (World Health Organization, 2022). Previous research and theories demonstrated that nature contributes to human health and wellbeing in a very positive way (Kaplan and Kaplan 1989). This study investigates the relationship between green roofs and work-related stress and mental fatigue.

This study evaluates employees' perceived stress and mental fatigue at work, their perception of onsite green roofs, and the restorative capacity of workplace green roofs using a 32-item online survey. 179 employees from four companies with at least one onsite green roof each answered the survey. The results showed that the average time spent on green roofs per visit, the frequency of visits, employees' attitudes and perceptions towards workplace green roofs, the organization's relevance with nature, the presence of diverse species on the green roof, and employees' knowledge about green roofs are related to the perceived restoration capacity of the green roof.

The study contributes to understanding the relationship between the restorative capacity of green roofs and work-related psychosocial outcomes, employees' green roof use patterns, preferences, and green roof design attributes. Green roof designers, the green roof industry, and business owners can benefit from the study findings and implications to create more restorative green roofs, as well as happier and healthier workplaces.

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## CHAPTER 1. INTRODUCTION

In dense and big cities, green areas mostly exist separate from daily life, while high-rise buildings are the most dominant elements of the environment. However, humans have had an invisible and innate attachment to nature since the beginning of life (Joye & de Block, 2011; Kellert, 1993; Levy, 2003; Wilson, 1984). We are the part of nature that becomes separated from our daily environment (Turner et al., 2004). The Biophilia hypothesis explains this connection in a very spiritual way (Kellert, 1993). Other scientific literature, such as Attention Restoration and Stress Reduction theories, also supports this idea by stating that nature has a healing effect on human health and positively affects human well-being (Kaplan & Kaplan, 1989; Ulrich, 1983).

According to Kaplan and Kaplan (1989), our immediate surroundings/everyday nature also have an impact on us. In other words, nature affects human beings positively, and people do not have to travel great distances to nature in state or national parks to experience that benefit. The high degree of benefit also comes from the nearby nature, such as nearby parks or gardens adjacent to living spaces.

More than half of the U.S. population works full-time (Bureau of Labor Statistics, 2021) and spends a great deal of time in their workplaces, and work environment is therefore critical to employee health and well-being. Green roofs are one of the options for nearby nature in cities, especially for office workers who often do not see urban greenery during work hours. This dissertation examines workplace green roofs and their impact on employee stress, mental fatigue, and well-being.

The following sections in this chapter begin with the research problem of how we can positively impact employee health and well-being using nature's healing effect and green

roof design elements. Second, the objectives are presented, and the research questions are explained. Next, the contribution of this research to the literature is discussed. The chapter concludes with the structure of the research.

### **1.1 Research Problem and Purpose of Research**

Green interventions in workplaces impact not only the mental health status of employees (An et al., 2016; Leather et al., 1998; Loder, 2014) but also affect work attitudes, job satisfaction, and behaviors (Hartig et al., 2014; R. Kaplan, 1993; Sop Shin, 2007). Since green interventions influence the work-relevant outcomes mentioned below, how can we determine which outcome is the most influenced?

First, there is insufficient evidence regarding the relationship between a green roof and work-relevant attitudes and behaviors in the literature. Even if researchers mention the existence of that relationship, they do not provide deep explanations through their studies. In addition, there are some studies on the health and nature relationship, but they do not evaluate the process or the mediators in detail; mainly, they evaluate this relationship using urban green spaces such as parks or residential gardens. However, the evaluation of green roofs or other green infrastructure types are not very common. As several empirical studies and theories support the hypothesis that green space exposure is associated with health outcomes, work-related psychosocial outcomes were used in this study to assess the relationships between green roofs and work-related mental health outcomes. This research aims to identify the restorative capacity of green roofs on employee mental fatigue and work-related stress for happier and healthier workplaces.



## 1.2 Research Questions

This research aims to fill the literature gap regarding green roofs' influence on human health and well-being in potentially stressful environments. According to Kaplan and Kaplan (R. Kaplan & Kaplan, 1989), any adjacent or nearby vegetated area can be considered nearby natural environments regarding health benefits. From that point of view, green roofs are considered nearby nature. This study evaluated employees' perceived stress and mental fatigue at work and their perception of onsite green roofs.

As a result of the research objectives mentioned above, four primary questions and three sub-questions were identified for the study. The information below explains how each research question contributed to the study and how participants were asked to respond.

- **Question 1: What is the impact of green roof use patterns on employees' mental fatigue and work-related distress?** This question seeks to determine if green roof use patterns are associated with mental fatigue and perceived work-related stress among employees. Examining employees' habits during work break periods and visits to the green roof are used to assess their exposure to the green roof. This question is critical in understanding whether green roof exposure can be used as a workplace resource to prevent the latter stage of mental fatigue and work-related stress in work settings. Mixed model analyses were conducted to answer this question.

- **Question 2: Is any level of nature exposure influencing the perceived restoration of an onsite green roof in workplaces?** This question helps to understand whether the duration of the visit or access (visual, physical, both) are influential factors affecting the restorative impact of green roofs. Findings from the analysis of this question help explain whether there is a healthy amount of nature access in workplaces for mental

restoration. Having several different time slots in the questions for determining the weekly and daily frequency of green roof visits among four different companies in this study is critical for that reason. Each weekly and daily frequency question is divided into four categories to find the most beneficial dose of green roof exposure for improved cognitive restoration for employees. There are also differences in how managements encourage employees to engage in activities on the green roof that affect how much time employees spend there. This question would be beneficial for companies in determining how to manage green roof access and why they should or should not encourage employee green roof visits during workdays. Mixed model analyses and Tukey post hoc tests were used to answer this question.

- **Question 3: Is mental fatigue or distress associated with perceived restoration?**

This question aims to determine whether a green roof's restorativeness level is associated with levels of distress and fatigue. This question is essential in understanding whether green roof exposure can be used as a workplace resource to prevent the latter stage of mental fatigue and work-related stress in work settings. For its analysis, mixed model analysis was used.

- **Question 4: What other factors possibly contribute to or interfere with the restorative value of green roofs?** This question examines what other factors besides employee work-related distress, mental fatigue, window view, and afterward roof exposure might affect the restorative impact of green roofs among employees. The study assessed the following factors as sub-research questions among all possible factors:

- **Question 4.1: Does attitude and perception towards green roofs contribute to the restorative impact of an onsite green roof?** Employee attitudes and knowledge about

green roofs' ecological and social benefits are examined in this question to determine if they could influence the restorative effects of visiting the roof. Evaluating this question might provide insight into the importance of environmental education among employees or users of green roofs for maximizing the benefits of natural interventions.

• **Question 4.2: Do a green roof's design and physical attributes influence the restorative effect?** This question examines how design, design elements, and functionality influence the restorative capacity of workplace green roofs. In addition, it can help promote more green roof adoption by identifying what design attributes (activities, spaces, or functions) are preferred. Content analysis is used to reveal commonalities among open-ended responses. Response to this question is analyzed using descriptive data analysis, which compares desired functions and design elements to the restorative capabilities of different green roofs. In addition to survey results, the researcher's observation was also used to answer this question.

• **Question 4.3: How do the differences between employee characteristics (i.e., demographic information, work type/work classification) influence the perceived restorative impact of green roofs?** This question would be beneficial in determining whether demographic factors are statistically related to green roof restorativeness. Demographics include gender, education levels, age groups, and years each employee has worked in that specific workplace. In addition to the attitudes associated with green roof use, the answer to this question might reveal how different demographic groups might experience the restorative benefits of green roofs.

### **1.3 Importance of the Study**

The positive impact of nature on people's health and well-being is a well-known fact proven by previous research. Forests, parks, and residential green areas in particular have been studied extensively, but green roofs' influence on people has yet to be widely explored. Additionally, even if workplaces are some of the most stressful environments in people's lives, they are not popular settings for these studies. This research will fill the gap in the current literature on Landscape Architecture, Environmental Psychology, Organizational Psychology, and Public Health relative to green roofs and their psychological impact.

Nature's restorative impact and stress-relieving effect are well-studied by several disciplines, such as Landscape Architecture, Psychology, and Geography. This study investigates the subject from a Landscape Architecture standpoint by considering Environmental Psychology and Organizational Psychology theories and models with the help of Public Health literature. Multidisciplinary approaches to solving problems allow a more holistic approach to be adopted, so this dissertation brings together literature from several different disciplines in order to provide the most comprehensive and multidisciplinary overview.

Another point of significance for this study is the methodological contribution to the literature. There are several scales in Environmental Psychology to determine the restorative capacity of natural areas. However, certain green infrastructure types, including green roofs, are different in some ways. In this study, a more appropriate restorativeness scale was created for green roof users, as the existing scales cannot be applied due to differences in experience.

Lastly, this study will provide businesses, especially those in dense business districts, with an opportunity to create happier, more productive work environments while complying with the sustainability-related building codes that are required in most states. Consequently, they can improve employee health as well as company performance while increasing worker productivity and reducing absenteeism.

#### **1.4 Study Organization**

This dissertation is organized into five chapters that broadly examine the relationship between the restorative value of onsite green roofs and their association with work-related distress and mental fatigue—as well as other associated factors—to improve the restorative value of green roofs on employees.

In Chapter 1, Introduction, the background of the study and the research approach are briefly introduced. Research problems and purposes are defined, as well as the questions sought to be answered, and the reasons they are included as research questions are presented in detail. Following that, a broad explanation of the importance of this study is provided. The chapter concludes with a description of the dissertation structure.

Chapter 2, the Literature Review, provides a systematic review of existing literature and information needed to understand the background information of the research. It is divided into four sub-categories. First, it introduces green roofs, their history, types, and benefits. Secondly, the nature-human interaction is defined with the help of theoretical understanding and the possible pathways of the relationship. The next part explains work-related mental health issues in workplaces, such as mental fatigue and distress. The final section combines the previous parts and explains the impact of workplace resources and design on employee health. Green roofs are evaluated as workplace resources.

Chapter 3, Methodology, starts by describing the research design, including participant and site selection. Variables and measures follow that part. Thirdly, the study procedure and instrument development process are defined. The chapter concludes by introducing the statistical analysis used in this study.

Chapter 4, Results, present the study's results in a specific order. First, the study participants' demographic distribution is explained. Following that, work conditions and employee choice are discussed. Afterward, employee choices for green roof use are evaluated. Lastly, each research question's response is explained separately.

The last chapter, Discussion, discusses study findings together with associated design implications. Then, it continues by describing how the research contributes to the literature and practice. Possible policy implications are also defined. The chapter is concluded with the limitations and future research suggestions.

## **CHAPTER 2. LITERATURE REVIEW**

### **2.1 Introduction**

In recent years, environmental or green interventions in cities have increased due to the climate crisis. Accordingly, green infrastructure applications, such as green roofs or walls, have become integrated into these attempted interventions, and many governments have supported such attempts by creating policies and incentives that encourage green infrastructure. Meanwhile, even though nature-human relations are well-known when it comes to health, there needs to be more research done on green interventions in urban environments—especially environments that are high in stress and fatigue, like the workplace. Because stress and fatigue contribute to more significant health issues, green interventions can contribute to health promotion and disease prevention. This chapter examines the possible impacts of onsite green roofs on employee work-related stress and mental fatigue.

The review of the literature for this study is broken into four sections. The first section provides a brief overview of green roofs. It begins by providing a history of green roofs, followed by a brief description of the different types of green roofs and their benefits identified in the literature, leading to a description of the types of green roofs selected for this study. The following section examines worker health concerns, starting with a broad overview and leading to the health concerns of office workers and the different ways they can be assessed. The third section examines the relationship between humans and nature. It begins with a broad overview of the different ways to define nature, then narrows down to a discussion of the health impact of nature by analyzing theories in the literature. Lastly,

the fourth section discusses the effects of plants and natural elements on workers concerning stress, fatigue, and restoration.

## **2.2 Nature in Cities: Green Roofs**

### ***2.2.1 How the Use of Green Roofs Evolved Over Time***

While green roofs are receiving increased attention as a part of city structures because of the climate crisis, they have existed for centuries. Their form and roles have changed over time with evolving building systems and technological changes. Nonetheless, the basic idea behind the green roofs remained the same: create vegetated open space over a building while providing comfort for occupants and protecting the building structure.

According to literature, one of the earliest known examples of green roofs were ziggurats in ancient Mesopotamia, and one of the most well-known of these is the Hanging Gardens of Babylon, built sometime between 810 and 561 BC (Dunnett & Kingsbury, 2008; Farrar, 1996; Peck, 2008; Weiler & Scholz-Barth, 2009). Since then, green roofs have been used in different ways and for purposes. At first, they were installed to support irrigation systems (Farrar, 1996), and later for more aesthetic reasons in Pompeii and the Roman Empire (Jashemski, 1992; Peck, 2008). Around 1066, the Vikings took a more practical approach to green roofs, adding sod/turf layers on the roofs of their homes to insulate interiors from harsh weather (Donnelly, 1991). Throughout the 1600s and 1800s, sod roofs or earth-sheltered houses became popular again in Norway for insulation (Magill et al., 2011), then spread among Scandinavian countries due to extreme weather conditions. In modern architecture of the 1900s, green roofs were seen as a form of respect for nature. Le Corbusier's elevated buildings with potentially vegetated flat roofs served as substitutes for building sites and open spaces (Curtis, 1986).



Green roofs emerged in Germany in the 1960s (Peck, 2008) as a response to rapid urbanization and industrialization in the 1880s (Magill et al., 2011). In terms of improving the microclimate in the built environment, greening the unused impermeable surfaces was the primary purpose of the green roof concept at that time (Peck, 2008). With the influence of Scandinavian sod roofs, the first green roof system was developed for ecological and aesthetic purposes in the mid-1970s by botanist Reinhard Bornkamm at the University of Berlin (Peck, 2008). Then, with extensive research and studies, other green roof systems, layers, and whole green roof technology were further developed.

Since then, researchers have proved the benefits of green roofs for environmental challenges, especially for stormwater management and microclimatic conditions in cities. During the 1980s, when the Brundtland Report (World Commission on Environment and Development, 1987) brought the sustainable development issue to public attention, green roofs gained another role in creating more resilient and sustainable cities. In addition, the European Commission (2015) suggests a green roof as one of the 'nature-based solutions' for urban heat island prevention, stormwater management, and energy conservation. Now, almost every state or city in the United States and Europe is promoting green roofs and using policies and incentives to promote their use (Savarani, 2019; Stern et al., 2019).

Even though climate change, air pollution, and biodiversity loss are emerging topics in the public sphere, mental health problems are also increasing rapidly worldwide (World Health Organization, 2022). Despite the long history of green roofs, very little evidence has been found to indicate how they can be used for occupants' mental health and well-being. There is an underestimation of nature's ability to reduce stress regarding onsite green spaces, especially in potentially high-stress environments such as office buildings. This

study shows how workplace green roofs might impact employee mental fatigue and work-related stress.

### ***2.2.2. What Are Green Roofs?***

Green roofs are the vegetated areas/systems over building structures. Even if plants are not planted in the ground directly, a layered system mimics the ground by having all the features required for their growth while protecting the building material below.

Green roofs are engineered systems that consist of a waterproofing membrane, root barrier, drainage/water retention layer, growing medium (lightweight soil for green roofs) or soil mix, and vegetation layer on top. There are several different system variations in the industry. However, the basic principle remains the same: the system must be waterproof to protect the building material, stop plant roots before they reach the structure material, hold water for a short period for plants and to slow run-off, provide a growing environment for plants with lightweight but good soil, and finally must have a selection of plants that will complement the green roof appearance.

There are two types of green roof systems: extensive and intensive. Extensive green roof systems are mainly applied for ecological purposes such as stormwater management, thermal insulation, and urban heat island prevention by maximizing the covered area's utility with low-maintenance plants on the structure base. They are also lightweight systems and apply to almost any condition. These kinds of green roofs are also called eco-roofs, and accessibility is not always possible except for maintenance purposes. For this reason, visual rather than physical is the main form of access to these kinds of green roofs if they are at the same level as the occupants. The second type of green roof is intensive green roofs, which are more visually appealing and heavy due to plants and occupant loads.

These kinds of green roof systems and plants require greater maintenance than extensive ones. Also, plants only cover a portion of the green roof so occupants can use it as an open green space. Intensive green roofs provide visual and physical access to green roofs, depending on the location. Since intensive green roofs allow designers to create different rooms both for privacy and social engagement, there might be some differences between different kinds of green roofs in terms of health and well-being. This study only examines intensive green roofs in order to consider the social aspects of green roofs in workplaces.

### ***2.2.3 Benefits of Green Roofs***

Green roofs have ecological, economic, social, and aesthetic benefits. They are a functional part of the local ecology by providing ecosystem services such as reducing stormwater runoff by capturing rainwater. Other ecological benefits include preventing flooding by slowing the flow of runoff, decreasing water pollution through soil filtration, filtering the air through plants, reducing energy consumption by insulating the building, reducing the urban heat island effect by not reflecting solar heat into the atmosphere, and increasing biodiversity by providing habitats for native and migrating species. Incorporating green roofs into the city landscape would help create a network system of the city's ecological landscape and link parts of the local ecology.

Green roof systems protect building material by cooling the building and preventing the heat reflection into the atmosphere that causes the urban heat island effect. Cooling the buildings by providing insulation reduces electricity use and energy consumption. This can also be considered an economic benefit. Another benefit of green roofs is extending the building material's lifetime. While insulation material would be affected by the sun or other

weather-related phenomena, extra layers of green roof systems elongate the lifespan of waterproofing materials.

While intensive green roofs also create aesthetically pleasing social environments or outdoor amenity spaces over the structure, extensive green roofs still provide aesthetic enjoyment compared to bare roofs or concrete surfaces.

Additionally, green roofs bring nature to the urban environment mostly by providing essential elements of nature such as flora, fresh air, daylight, and various forms of fauna. When nature's mental health benefits are considered, green roofs' potential to provide those benefits is very underestimated. Although the mental health benefits of green roofs have started to receive attention in the literature very recently, their relationship and pathways are still not well defined.

## **2.3 Nature - Human Relationship**

### **2.3.1 *What is 'Nature'?***

Nature is a broad term, and there is no real consensus on its definition. Several sources use the term 'nature' as a norm, while others use it as a synonym for wilderness or any component of nature, including sunlight or fresh air. The Britannica Dictionary (The Britannica Dictionary, 2022) defines nature as: "the physical world and everything in it (such as plants, animals, mountains, oceans, stars, etc.) that is not made by people" (definition 1). In this study, the term nature was conceptualized as any place capable of providing a direct non-man-made experience or experience of any integral parts of nature, such as vegetation (indoor/outdoor), daylight, wildlife, and fresh air.

Nature-related studies primarily measure nature-human relationships through the wilderness. More than half of the world's population resides in cities (United Nations, 2018), and humans have become more isolated/segreated from natural environments due to rapid urbanization, which has in turn reduced daily human-nature interaction in cities (Miller, 2005). Finding access to natural environments becomes very hard for people who live in urban settings, primarily when they need to work full-time in cities during the week. As a result, green infrastructure, which brings natural components into cities, is essential in sustaining daily human-nature interaction.

As the previous section indicated, nature significantly impacts human life in terms of health and comfort. Close proximity to nature benefits human health and well-being even better (Kaplan & Kaplan, 1989; Ulrich et al., 1991). Green infrastructures such as green roofs, walls, streets, and urban parks are among the most effective ways to bring nature into cities. The nature of these green infrastructure types is still evident even though they have to be designed, constructed, maintained, and managed (Hartig et al., 2014). They also provide urban residents an opportunity to experience nature more frequently. Rather than having a big forest 20 miles from daily life that can only be occasionally visited, vegetated balconies, nearby parks, green streets, rain gardens, or green roofs provide a more frequent nature experience and consequent potential health and ecosystem benefits to the people exposed to them (Kaplan & Kaplan, 1989).

Green roofs are one of the best possible alternative natural areas in urban settings. They have the potential to provide an opportunity for direct contact with natural elements such as vegetation, fresh air, sunlight, and wildlife in city centers, especially for busy business districts. Green roofs are primarily manufactured and consist of systems but

provide onsite open spaces with natural elements in high-stress urban environments such as workplaces.

Nature can be experienced in different ways—physically or visually, through a window, photographs, films, or virtual reality (Hartig et al., 2014). In this research, physical and visual (window view) nature connections are considered as a nature experience. While the experience of visiting green roofs is physical, window views are considered visual exposure. Other exposures, such as indoor plants or natural materials used in the design, are not part of this study.

### ***2.3.2 Theoretical Understanding of the Nature-Human Relationship***

Our biology is geared toward specific needs in nature, such as survival, hiding, and surveying (Ulrich, 1993), and even though they are not usually required in the modern world to which humans have migrated relatively recently, these evolved primitive behaviors still influence our responses to nature and the built environment. An evolutionary perspective supports the idea that human visual preferences, as well as behavioral and emotional responses to nature, are based on one of our evolutionary predecessors' adaptive responses/reactions during survival (Ulrich, 1983; Wilson, 1984). The impacts of nature on stress alleviation and attention restoration are the outcomes of that adaptation (Ulrich et al., 1991).

Evolutionary theories have shaped the literature in terms of humans' relationship with nature, including the biophilia hypothesis (Fromm, 1964; Wilson, 1984), habitat theory and prospect refuge theory (Appleton, 1975), stress reduction theory (Ulrich, 1979), attention restoration theory (R. Kaplan & Kaplan, 1989), and savannah hypothesis (Orians &

Heerwagen, 1992). Since the savannah hypothesis does not apply to this study, it will not be explained in detail below.

**2.3.2.1 Biophilia (The Desire of Humans to Interact with Nature and Other Living Organisms).** Well-known biologist Edward O. Wilson (1984, p.1) described Biophilia as an "innate tendency to focus connections on life and life-like processes." Even if he popularized the biophilia hypothesis in his book in 1984, German philosopher and psychologist Erich Fromm introduced it in 1964 and 1974 (p.406) as "the passionate love of life and of all that is alive." Later, Stephen R. Kellert (1993) explained the hypothesis as human dependence on or emotional response to nature in many respects, such as aesthetic, cognitive, spiritual, and satisfaction. Appleton (1975) also expressed that maintaining human well-being is closely related to nature connection. These definitions and studies show that the Biophilia hypothesis is not just a hypothesis or theory; it is something broader and overarching. It explains the human-nature relationship as an intrinsic desire of humans to connect to nature spiritually (Joye & de Block, 2011; Kellert, 1993; Levy, 2003).

The Biophilia hypothesis considers nature-human connectedness as an evolutionary process, with savannah-type landscapes being referred to as having optimal characteristics to support that connection by natural adaptedness due to providing shelter and food to our ancestors (Cleary et al., 2017; Joye & de Block, 2011; Kellert, 1993; Wilson, 1984). In other words, the Biophilia hypothesis can be considered an evolutionary root of the human-nature relationship, examined through such theories as restorative or stress reduction theories, in a broader context. Even though Wilson and Kellert (1993) hypothesized that idea, there still needs to be more empirical evidence regarding the optimal landscape conditions in different settings to provide mental well-being to human beings through

nature connection. Also, whether that desire to be close to nature is innate or learned is not very clear according to studies in the literature (Cleary et al., 2017; Joye & de Block, 2011; Joye & van den Berg, 2011).

Kellert (1993) defined the fundamental values of the human-nature relationship under nine categories: utilitarian, naturalistic, ecologicistic-scientific, aesthetic, symbolic, humanistic, moralistic, dominionistic, and negativistic. Each dimension is part of the evolutionary process of human adaptation to the natural world. However, a naturalistic tendency also includes fascination, wonder, curiosity, and mystery (Wilson, 1984), which are also aspects of the Attention Restoration theory. Kellert (2005) also defined a model of human-nature interaction. According to that model, three different interactions are possible between humans and nature: direct, indirect, and experience of space and place.

Several theories were generated under the influence of Biophilia, including the Prospect-refuge theory, stress reduction theory, attention restoration theory, savannah hypothesis, and Place attachment theory. These theories also provide a foundation for this research.

**2.3.2.2 Prospect & Refuge.** Landscape design has an aesthetic approach and aims while providing comfortable, safe, and healthy places for users. Fromm (1964) indicated that human beings have inborn feelings to connect with nature and living things, and Appleton (1975) claimed that there are some rules to create that connection in a healthy way. He also mentioned a primitive link between living things and their habitats through aesthetic response to landscapes (Appleton, 1975). He emphasized the experience rather than the physical features of landscapes and classified the prospect-refuge theory as an



"aesthetic hypothesis" (Appleton, 1975, p. 73). The question behind the theory is: "what is it that we like about landscape, and why do we like it?" (Appleton, 1975, p. 1).

Appleton put prospect-refuge theory under evolutionary theory and habitat theory, both of which concern finding the optimal habitat for a specific creature that can meet all biological needs for survival. He hypothesized prospect-refuge theory as a sub-theory because seeing without being seen is essential to survival, a biological need. He defined the aesthetic principles of prospect-refuge theory as 1.) the relationship of the design elements and their symbolism in terms of prospect and refuge, 2.) manner and intensity of an object/design element, 3.) spatial arrangement of symbols, 4.) the balance between prospect and refuge symbols, and 5.) features and configurations of design elements to provide optimum benefit to users/viewers. According to Appleton's direct quote from Lorenz (Lorenz, 1952) in his book (Appleton, 1975, p. 69), the prospect-refuge theory is about "...to see without being seen".

While that idea will be revisited in the next section, Kaplan's (1983) point of view also supports the idea of refuge providing safety and relaxation as well as an excitement-provoking impact. Grahn and Stigsdotter's (2010) study showed that the refuge was also preferred for its spatial features among stressed individuals in terms of restoration needs.

Users' emotional responses to a place can be impacted by the intensity and configuration of place attributes as well as access to view and natural light. Even if either prospect or refuge would have stress-reducing properties, Appleton (Appleton, 1975) indicated that the well-balanced prospect-refuge is preferable among place users.

Architectural historian Grant Hildebrandt (1991) introduced the prospect-refuge theory to architecture by publishing a book on the common characteristics/patterns of

Frank Lloyd Wright's houses and an architectural analysis thereof using prospect-refuge theory. He proposed to extend the theory by adding complexity, order, exploration, excitement/mystery, and opportunity to its considerations (Dosen & Ostwald, 2013; Hildebrand, 1991). After Hildebrand's introduction in 1991, prospect-refuge theory was considered to be a design principle (Dosen & Ostwald, 2013; Lidwell et al., 2003; Lippmann, 2010) and was widely adopted in different scales, from urban scale (Loewen et al., 1993) to building scale (Jacobsen et al., 2002), and even to interior design scale (Dosen & Ostwald, 2016; Gallagher, 2006).

In 1999, Hildebrand hypothesized in 'The Aesthetics of Survival' that the aesthetic pleasure people feel when they experience architectural spaces is closely related to instinct or primitive behaviors such as shelter-seeking or investigatory behaviors. He categorized survival-advantage behavior into six categories, and prospect-refuge consists of one of them. He indicated that human beings desire a place to shelter (refuge) and a high prospect to observe the surrounding area (Hildebrand, 1991). When these results are applied to the built environment, especially green roofs, natural elements such as vegetation, daylight, and fresh air would be considered restorative with the combination of a high prospect (view) and low refuge.

**2.3.2.3 Stress Reduction Theory (SRT).** In 1972, Pert and colleagues discovered opiate receptors and proved the relationship between human beings' psychological and physiological responses (Pert, 1997). According to their discovery, our emotions, thoughts, feelings, or sensations create biochemicals, which are carried by neuropeptides and receptors throughout the body (Pert, 1997). After this groundbreaking discovery, other natural biochemicals in the human body started to be found, such as endorphin (Hughes et

al., 1975). These discoveries proved the interconnectedness of our emotions/feelings and the physiological responses of our bodies (Soderlund & Newman, 2015). Since then, aesthetic pleasure's physiological impact on the human body has been studied in the literature.

Researchers have understood other physiological responses/natural chemical events in the brain. For example, high stress can be measured through increased cortisol hormone levels, blood pressure, heart rate variability, sympathetic nervous system activity, and skin moisture conductivity (Soderlund & Newman, 2015). However, aesthetic pleasure or nature exposure decrease stress level or anxiety while improving cognitive functioning in the body (Ulrich, 1983).

According to the Stress Reduction Theory (SRT), contact with nature has positive aesthetic and effective responses to individuals' preceding affective state<sup>1</sup>, behaviors, and neurophysiological activity by preventing negative thoughts that shape feelings and minimizing physiological activation (Ulrich, 1983). This psycho-evolutionary theory-based approach mainly examines the human-nature interaction's physiological, cognitive, and behavioral effects (Ulrich, 1983). Natural view promotes positive feelings and emotions, attracts, and sustains interest/involuntary attention, and blocks negative thoughts and emotions while promoting stress restoration (Markevych et al., 2017; Ulrich et al., 1991). In other words, the SRT proposes that having a natural view causes physiological activation in the human body, such as hormonal, cardiovascular, and musculoskeletal activation, as well as increasing positive emotions and sustained involuntary attention (Markevych et al., 2017). The theory considers cognition and emotions as different but

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<sup>1</sup> Individual's affective state including cognitive history is also an important determinant of eventual behavior or feelings (Ulrich, 1983).

interrelated systems because of their occurrence in different parts of the brain (Ulrich, 1983; Ulrich et al., 1991).

In one of the earliest exploratory research projects, Ulrich (1979) measured human emotional response to nature scenes using slides and self-rating emotional state measurements. He concluded that nature exposure increases positive emotions while decreasing fear arousal among stressed individuals. The same study's findings showed that the urban environment lacking natural elements increases sadness while attracting participants' attention less effectively (Ulrich, 1979).

Ulrich and colleagues repeated the study in 1991 using nature and urban videos along with physiological measurements, including heart rate, blood pressure, muscle tension, and skin conductance. That study also showed that nature exposure positively impacts stressed individuals in terms of faster recovery from stress and the presence of a relationship with some of the components of the parasympathetic nervous system. Aside from these findings, the rest of the results supported the psycho-evolutionary theory's emotional, physiological, and attentional patterns (Ulrich et al., 1991).

Zajonc (1980) explained that the affective response emerges immediately after stimuli or environment exposure without dependence on cognition. That initial response to stimuli consists of a generalized effect through "preferences and approach-avoidance behavior" and then impacts the cognitive processes (Ulrich, 1983, p. 89). The initial positive emotional response is triggered by overall ambiance features/characteristics such as depth/spaciousness, ground surface texture, threat/tension, deflected vista, and water (Ulrich, 1983, 1993). He defined the most preferred natural properties as complexity, focal point, a moderate to high level of depth, homogeneous texture of the ground surface,

deflected vista, absence of threats, and, most important, presence of water features (Ulrich, 1983). This research is an integral part of Ulrich's psycho-evolutionary theory framework (Ulrich, 1983). This immediate approach of biophilic-avoidance (biophobic) behavior also can be explained with adaptation and survival behaviors related to evolutionary theory (Ulrich, 1983; Ulrich, 1993). Ulrich (1993) also made a connection between the restorative and stress-reducing capacity of unthreatening nature and its common characteristics that trigger restoration with the functional-evolutionary approach. These adaptive characteristics during human evolution include faster recovery from stress, an effective decrease from negative emotions such as fear and arousal, and a positive impact on the parasympathetic nervous system (Ulrich, 1993).

In accordance with this theory, Ulrich (1984) conducted an experimental study on surgical patients in a hospital setting by assigning a group of patients to a room with a natural view and another group to a room with a brick wall view. Patients with natural views from their hospital room had a faster recovery, stayed a shorter time in the hospital, reported fewer postsurgical complications, and took fewer painkillers than the other group of patients (Ulrich, 1984). After this seminal work, other studies emerged which supported this result and found that indoor plants have similar effects on patients during postoperative recovery. Those physical effects include a lower intake of pain medications, lower blood pressure and heart rate, less fatigue, reduced anxiety, and reduced pain. At the same time, they were more satisfied with the hospital room (S.-H. Park & Mattson, 2008).

Similar to hospital settings, offices are a high-stress environment for most employees. As most SRT studies measure stress through psychosocial measurements, this study measures work-related stress through a clinical scale. SRT properties were also used to

create a restorativeness scale to see how much benefit employees receive from the green roof according to their work-related stress.

**2.3.2.4 Attention Restoration Theory (ART).** The continual demand in the work environment<sup>2</sup> requires sustained directed attention but controlling thoughts or brain functions simultaneously over certain hours is challenging for most people. Employees might struggle to pay attention to work-related tasks or uninteresting stimuli after working hard over a certain amount of time. The result of such a sustained mental effort is often mental fatigue—something which employees are prone to, mainly after overworking (Hartig et al., 1991; R. Kaplan & Kaplan, 1989). According to Kaplan and Kaplan's Attention Restoration Theory (R. Kaplan & Kaplan, 1989), natural elements or settings help the human brain to rest and overcome the exhaustion that inhibits their ability to give directed attention to activities that require it. In other words, nature exposure has the potential to help people renew directed attention and concentrate on a specific task even after prolonged mental effort which causes mental fatigue (Kaplan, 1995).

While one way to recover from directed attention fatigue is sleeping or resting, it is hard to do so in the workplace (Kaplan & Kaplan, 1989). Kaplan and Kaplan's theory states that exposure to nature is another way to alleviate mental fatigue. So, natural settings or elements are alternative interventions for positively impacting work-related fatigue due to their restorative impact on humans.

Rachel Kaplan and Stephen Kaplan (1989) hypothesize that experiencing the natural environment reduces mental fatigue. According to their theory, nature has a restorative

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<sup>2</sup> Since our study is about work environments, I evaluated the theory for the employees' perspective. This theory is not specifically for work-related fatigue. It covers all kinds of directed attention required phenomenon.

impact on the human mind, especially where it concerns mental fatigue. In recovery from directed attention (i.e., mental) fatigue, the natural environment restores people's attention, even if it is the only view. Key components of the theory are:

1. Sense of being away: The sense of being in a different place, primarily conceptually. Being distant from the existing place, situation, and/or task, along with the pressure and obligations thereof (Kaplan & Kaplan, 1989). When employees look at natural elements, they think or feel like they have escaped from where they were. They may have a sense of being away from the workplace or source of mental fatigue.

2. Extent: Kaplan and Kaplan (1989, p. 184) define this as "The sense of being in a whole other world—either physically or perceptually." This component is mostly about connectedness and scope. Suppose employees can find some connectedness with what they are experiencing in the natural space and have created a sense of connectedness with nature (Kaplan & Kaplan, 1989). Exploration is also an essential part of 'extent.' Having a lot to explore, even in a small garden, might enhance the sense of extent.

3. Fascination: This is a term for effortless (involuntary) attention. It refers to places or elements that instantly attract people's attention. In their book, Kaplan and Kaplan (1989) refer to this construct as 'soft fascination.' Instead of just fascinating people and holding their attention, natural spaces also give the feeling of pleasure.

4. Compatibility: For this element, a place's features and a person's demands should match or be compatible (Kaplan, 1993).

There are four stages of the general process of restoration underlying the theory. These are:

1. "Clearing the head" (Kaplan & Kaplan, 1989, p. 196): In this stage, cognitive leftovers, thoughts, or concerns regarding the previous tasks or attention required by stimuli goes away, and the restorative experience of nature starts to clear one's mind.

2. "Recovery from the directed attention" (Kaplan & Kaplan, 1989, p. 196): This stage is the central part of the restorative function of nature. Cognitive functions are restored and directed attention levels are back to normal.

3. "Soft fascination" (Kaplan & Kaplan, 1989, p. 197): At this stage, nature provides a distraction through a soft fascination and blocks the internal noise about cognitive residues that came from previous times. In other words, nature provides a quiet internal space by distracting the person's mind from internal noises.

4. "Restorative experience" (Kaplan & Kaplan, 1989, p. 197): This last stage is the main and deepest restorative part of the process. Achieving all the basic properties of restorative experience (being away, fascination, extent, and coherence) occurs at this stage based on the quality of the environment and the duration of the stay. While an individual's mind is restored completely, the person relaxes and is better able to think about their priorities, actions, and goals.

In summary, work-related fatigue is a common phenomenon for most employees and is related to other work-relevant outcomes. While there are different treatments for fatigue, the most practical and easy-to-reach application might be green roofs in workplaces. In the literature, most studies use digit span tests and other onsite tests to measure mental fatigue, but those studies are primarily done in controlled settings. This study follows an observational approach and measures directed attention fatigue through a concentration-related clinical scale. Additionally, a restorativeness scale based on SRT and ART domains



was developed to assess the benefits of green roofs for resolving work-related stress and mental fatigue.

### ***2.3.3 How Do Humans React to Nature?***

The interaction between humans, nature, and other living things/organisms is a part of the evolution of the human species. The study of the nature-human relationship is an inherently multidisciplinary and fundamental approach that helps people understand some of their inborn tendencies and their evolutionary history (Kellert, 1993; Wilson, 1984). Humans benefit from nature in many ways, such as psychologically, emotionally, and physically through ecosystem services. Despite ecosystem services and food production being essential benefits, this research will focus on mental health and, consequently, its effects on physical health.

There is a vast amount of research regarding the importance of nature and natural elements on human psychological and physiological health. The health benefit of nature is a well-established multidisciplinary subject studied among environmental psychologists, landscape architects, clinical psychologists, biologists, and even geographers. In this review, these socio-psychological benefits of nature will be evaluated under three categories: psychological, physiological, and social.

Attention restoration is one of the most studied psychological benefits of nature. Studies showed that nature exposure increases attention restoration (Hartig et al., 1991, 2003; R. Kaplan & Kaplan, 1989; Lee et al., 2015; Staats et al., 2003) through arousing soft fascination, as was explained earlier in this chapter. In addition, attentional functioning both reduces symptoms among children with attention deficit disorder (ADD) (Taylor et al., 2001) and enhances older children's emotional and intellectual development (Kellert,

2002). Nature exposure also improves concentration and memory restoration and provides tranquility (van den Berg et al., 2003). Furthermore, studies suggest that multi-sensory stimuli (multi-sensory experiences) simultaneously provide more effective tranquility than single-sensory stimuli (Hunter et al., 2010; Jahncke et al., 2011; Qi et al., 2022). Hearing natural sounds (called soundscape), including animal sounds such as birds or bugs, is an excellent alternative stimulus to interaction with vegetation (visual or tactile). Studies show that even a single bird's sound is associated with stress and attention restoration (Ratcliffe et al., 2013).

Fuller and colleagues (2007) state that species richness in urban greenspaces increases users' psychological well-being. In other words, in urban environments, biological complexity, or a combination of flora and fauna, provides higher benefits than only vegetated areas. More prosperous species make the nature experience richer. Other studies have hypothesized that animals play an essential role in stress recovery and restoration by having attention attraction and sustaining features (Alvarsson et al., 2010; R. Kaplan & Kaplan, 1989; Ulrich et al., 1991). However, nature-human relationships are not always positive. Certain elements or features of nature might cause fear, frustration, or other negative emotions (Bixler & Floyd, 1997; Ulrich, 1983). These elements might be some animals (the fear of which is called biophobia), darkness, or lack of surveillance (Gatersleben & Andrews, 2013) in either urban nature or wilderness, mainly depending on personal differences and gender (van den Berg & ter Heijne, 2005). Examples from the built environment include urban wildlife such as bees and birds or higher prospects for people with acrophobia (fear of heights) (Gillis & Gatersleben, 2015). In terms of green

roofs, while some people enjoy having nature views or surveillance, height might prevent other people from visiting green roofs.

### ***2.3.4 The Impact of Natural vs. Urban Environments***

The natural environment's stress reduction potential has a positive influence on user preference for those environments versus built environments (Ulrich et al., 1991; van den Berg et al., 2003). It has also been observed that a majority of stressed individuals prefer natural environments over urban ones (Staats et al., 2003), while fatigued individuals do not show the same preference trend (van den Berg et al., 2003). On the other hand, design is the most potent aspect of the urban nature that impacts user preferences (Özgüner & Kendle, 2006).

One of the most essential features of nature is being aesthetically pleasing (Parsons & Daniel, 2002). Its pleasing aesthetic is also considered the main reason for nature's psychological impact according to evolutionary theory (Ulrich, 1983), which will be explained later. Moreover, the natural environment is preferred over the urban environment because it is regarded as being more beautiful (van den Berg et al., 2003; White & Gatersleben, 2011).

Compared to urban environments, natural environments resulted in higher levels of happiness, decreased stress, faster and more significant recovery from mental fatigue, and fewer feelings of sadness and anger (Hartig et al., 1991, 2003; Ulrich, 1983; Ulrich et al., 1991). Nature exposure also improves mood (Guéguen & Stefan, 2016; Ulrich et al., 1991) and concentration more than urban environments (van den Berg et al., 2003). It is also beneficial to be exposed to natural environments before being exposed to the stressor, as they better inhibit post-exposure restoration compared to the built environment scene that

lacks any natural elements (Brown et al., 2013). Additionally, the literature shows that exercise in natural environments improves mood and self-esteem proportionally to the exercise intensity and duration based on gender, age, and current mental health status (Barton & Pretty, 2010). Walkable neighborhoods with urban greeneries such as street trees and urban parks also increase the chance of longevity among senior citizens (Takano & Nakamura, 2002).

Indoor plants have also shown a positive effect on participants' moods and task performance in different ranges of gender and the type of task (Bringslimark et al., 2009; Shibata & Suzuki, 2004). Additionally, indoor plants decrease stress levels and increase individuals' comfort by purifying the air and reducing indoor pollutants (Deng & Deng, 2018). The human body's reaction changes when the plant variation changes, and slightly fragrant, small green plants constitute the most preferred indoor environment (Qin et al., 2014).

The importance of experiencing real nature was studied by Kjellgren and Buhrkall (2010), who compared the effect of the simulation of an environment with its real counterpart. They found that both exposures have almost equally stress-reducing impact, though real nature additionally has an energy-increasing effect (Kjellgren & Buhrkall, 2010). On the other hand, Friedman and colleagues (2004) hypothesized that natural window views could be replaced by a TV screen that has a real-time natural view. Kahn et al. (2008) proved that the natural view through the TV screen is not more restorative than a blank wall view through the window. They added that the natural views through an actual window are significantly more restorative than the window with a blank wall and the TV screen with a nature view.

The absence or presence of natural elements in the environment causes physical symptoms and responses in the human body. Nature connections, visual or physical, affect the human immune system and prevent tumor development by releasing anti-cancer proteins through increasing Natural Killer (NK) activity in the body (Li, 2010). They also provide relaxation to the human body through the autonomic nervous system by reducing pulse rate, diastolic blood pressure, and stress hormones (Hartig et al., 2003; Orsega-Smith et al., 2004; Park et al., 2009; Ulrich et al., 1991). Salivary cortisol concentration is also lower among people in forest areas compared to urban settings (Park et al., 2009).

Nature contact reduces recovery time in hospital settings (Ulrich, 1984) and is also linked to fewer sick visits (Moore, 1981), improved mental health, calmness, and well-being among prisoners (Moran, 2019; Moran & Turner, 2019; Nadkarni, 2017).

Natural views and sounds reduce pain among patients during flexible bronchoscopy under conscious sedation (Diette et al., 2003). Moreover, nature sounds provide faster recovery on the sympathetic nervous system after exposure to a psychological stressor than noisy urban environments (Alvarsson et al., 2010).

In workplaces, nature-related interferences are associated with higher work performance and less distress (Kaplan, 1993). As will be explained later in this study, nature exposure's physiological impacts are established as any other emotions' physiological impact on the body. In other words, nature exposure impacts human beings' physiology through emotions (Ulrich et al., 1991). As Ryan and colleagues (2014) found, people's emotional and physiological responses to nature exposure vary depending on their health, the duration and frequency of exposure, perceptions, attitudes, expectations, and social backgrounds.

Natural environments or urban greeneries also have an impact on human social relationships in a variety of ways, such as enhancing social integration/interaction by promoting more use of outdoor spaces (Coley et al., 1997), social support (Maas et al., 2009), the desire to help others (Guéguen & Stefan, 2016), neighborhood social ties, and sense of community in urban settings (Kuo et al., 1998; Kweon et al., 1998).

Besides their health and social aspects, natural environments are also linked to safety, especially in urban settings. According to Kuo and Sullivan's (Kuo & Sullivan, 2001) findings, greener neighborhoods with high-canopy trees and grassy areas in inner cities have lower crime, aggression, and violence rates. Previous studies have noted that occupants living in densely vegetated urban settings are concerned about safety and fear of crime (Fisher & Nasar, 1992; Kuo et al., 1998; Talbot & Kaplan, 1984). Besides perception studies, some factual studies prove that more prominent and low-density vegetation in cities provides more potential hiding points for criminals (Michael et al., 2001).

Nature-human interconnection is possible in every aspect of daily life in any environment, from residential to urban scale. Every setting has stressors or restoration needs depending on the activities people do in that environment. In this study, we use workplaces as settings, consider challenges employees face during work hours, and evaluate natural solutions to impact their mental health positively.

### ***2.3.5 Possible Pathways Between Nature and Humans***

Connecting to nature may affect health via a variety of pathways, some of the most commonly studied being the promotion of stress reduction, attention restoration, physical activity, social cohesion, air quality improvement, and increased thermal comfort (Hartig et al., 2014; Markevych et al., 2017). Markevych et al. (2017, p. 303, p.304, p.305)

categorized such pathways into three main domains: “reducing harm,” “restoring capacities,” and “building capacities.” Each domain emphasizes different functions of nature in general. In this study, they are evaluated according to the green roof concept by considering work-related fatigue and distress instead of general health. Each domain of the pathway is evaluated in a separate paragraph, with a discussion of the most likely pathway of green roofs on distress and fatigue for a specific office setting at the end.

There are several environmental stressors around individuals in daily life. Green spaces, or plants particularly, may mitigate the impact of these stressors or reduce their harm by affecting ambient features such as air quality/pollution, outside noise, and air temperature (indoor and outdoor). While green spaces/tall plants can create a buffer to reduce noise annoyance from heavy traffic or other urban noises, plants might also cover unpleasant views by creating more pleasing scenery. Another example of green space benefits might be thermal comfort due to green roofs’ insulation feature. Even if eliminating thermal stress, pollution, and noise stress seem to impact only environmental stress, those stressors also impact individuals’ distress and fatigue (Holahan & Moos, 1986). In other words, natural environments/vegetation reduce the harm caused by environmental discomfort and provide healthier environments.

As mentioned earlier, green spaces have a restorative impact on human stress and fatigue by providing psychological restoration through environmental experiences (Berman et al., 2008; Hartig et al., 1997, 2014; S. Kaplan, 1995; Nordh et al., 2009; Ulrich, 1983). Two of the most well-known theories of environmental psychology, Stress Reduction Theory (SRT) (Ulrich, 1983) and Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989), explain how nature promotes psychological restoration. The SRT in

particular proposes that exposure to nature prevents negative thoughts and evokes positive emotions that eliminate acute stress responses (Ulrich, 1983). Nature contact also reduces physiological activities, including hormonal and cardiovascular. Ulrich (1983) emphasizes that nature experience leads to more positive self-reported emotions among people by increasing subjective well-being. On the other hand, the ART (Kaplan & Kaplan, 1989) explains the restorative impact of nature by using the soft-fascination feature of natural elements. Kaplan and Kaplan (1989) assume that nature attracts and holds individuals' attention involuntarily and does not require any cognitive functioning during exposure thereto. This allows people's fatigued neurocognitive mechanisms to rest and recover. Although this theory does not particularly promote workplace mental health, it is very applicable to the work environment because fatigue is a common phenomenon among employees due to excessive attentional demands of tasks. With this theory in mind, employees' cognitive functions might be recovered through exposure to natural elements. A green roof is an opportunity for employees to contact nature and have those experiences during workdays in an urban context. On the other hand, in some situations, green roofs are only accessible physically or on the top of the building, and employees might enter the green roof purposefully to escape stressful demands because of the location instead of incidental exposure to a natural view through the office window.

Another beneficial aspect of green roofs is their ability to build social space and social cohesion in the workplace or other settings. Besides social cohesion, green roofs provide an opportunity for companies to develop social ties, create social support systems, and foster a sense of community among employees (Hartig et al., 2014). Together with those opportunities, employees who experience nature through a green roof might feel more



valued by the company. Furthermore, employees would feel a sense of belonging to the company while feeling safe due to social contact (Hartig et al., 2014). These positive emotions and sense of place have the potential to influence employee engagement and work-related distress in a positive way (Loder, 2014).

Overall, there are several different pathways that exemplify nature's impact on human health, specifically work-related psychosocial measures such as distress and fatigue. Since nature and psychosocial health outcomes are multidimensional and complex factors, it is hard to explain their relationship by using a single pathway or evaluating it through a single aspect. Instead, it is highly possible to see a combination of multiple pathways while evaluating their relationships to a specific phenomenon. For example, a green roof might increase the thermal comfort of the indoor environment through its insulation feature while providing stress-reducing and attention-increasing effects for employees. At the same time, a newly installed green roof has the potential to reinforce employee engagement and sense of place by creating social cohesion. A combination of these pathways can provide a good explanation of how green roofs influence employee distress and fatigue in a workplace setting.

#### **2.4 Work-Related Mental Health**

Mental disorders are one of the most common and emerging health problems among populations all over the world (World Health Organization, 2022). Workplace mental health issues are only one part of that problem. As of 2019, 15% of working-age adults had some form of mental illness (World Health Organization, 2022). At a time when almost 60% of the world population is considered to be employed full-time (International Labor Organization, 2022), the issue's current magnitude is undeniable.

According to Chisholm et al.'s (2016) research, the yearly cost of depression and anxiety disorders is estimated to be US\$925 billion, resulting in more than 12 billion days of lost productivity. In addition to improving mental and physical health, workplaces that promote good mental health and reduced work stress have been shown to decrease absenteeism, improve work performance and productivity, boost staff motivation, and maximize social cohesion (World Health Organization, 2022). Thus, it is cost-effective to take action to protect and promote mental health in the workplace (Le et al., 2021).

Depression, anxiety, and stress-related mental illnesses are the most prevalent mental illnesses in the workforce (Chisholm et al., 2016; Harvey et al., 2017). Research also shows that depression and anxiety are significantly related to stress at different levels (Bergdahl & Bergdahl, 2002). While anxiety is more closely related to moderate stress levels, depression is more associated with high stress levels (Bergdahl & Bergdahl, 2002). Fatigue is another work-related health issue closely related to occupational stress (Rose et al., 2017). High fatigue levels may affect any occupation or industry, resulting in serious safety and health concerns. Reaction times, attention, concentration, short-term memory, and judgment can all be impaired by fatigue (Centers for Disease Control and Prevention, 2022). These common mental disorders in the workforce are mostly preventable and treatable in some cases (Harvey et al., 2017). With that in mind, fatigue and stress prevention might prevent more severe consequences in workplaces.

There is a vast amount of literature regarding environmental intervention strategies for some mental disorders. Fatigue and stress are the two most common mental health issues that can be alleviated at their early stages by nature exposure. This study also

evaluated these relationships, asking the question: Can nature exposure be used to prevent early symptoms of fatigue and distress?

#### ***2.4.1. Occupational Distress***

Stress is a physical and/or psychological response to external or internal stressors. While internal stressors might include fears and unrealistic expectations, external factors might include major life events, financial problems, and legal problems.

Stress is also a broad term that includes all the forces that make people resist. When people's cognitive responses to different types of stress sources are considered, two types of stress emerge: eustress (positive stress) and distress (negative stress) (Selye, 1976). According to Benson and Allen (Benson & Allen, 1980), stress can be beneficial until an optimum level is reached. After that level is exceeded, it becomes harmful. On the other hand, Selye (Selye, 1976) divided stress into two types, eustress and distress, according to stressor types. For example, starting a new job or receiving a promotion would be considered the reason for eustress, while illnesses or deaths of loved ones would cause distress. Even though both stress types might impact the individual similarly, increasing heart rate and blood pressure, the impact of eustress is short-term (acute), whereas distress can be either short or long-term (acute or chronic). Negative forms of stress (i.e., distress) might affect people's quality of life as well as mental and physical health, and might cause chronic diseases such as depression or cardiovascular diseases.

Causes of distress vary, but work is one of the most significant ones in many people's lives (Bloom & Farragher, 2011). There are many events that cause work-related distress, such as lack of control over work-related factors, unrealistic deadlines, long work hours, work shifts, interpersonal conflicts with supervisors and co-workers, job insecurity, and

excessive job demands (Bloom & Farragher, 2011; Wolf et al., 2016). Because of these mostly perceived problems, employees feel more distressed during workdays than on weekends (Stone et al., 2012; Wolf et al., 2016).

According to The National Institute for Occupational Safety and Health (CDC, 2009), more than 30% of employees in the US reported high levels of distress. Families and Work Institute's report (2008) shows that the stress level among employees is increasing, as well as the minor physical health conditions that might be caused by stress, such as headaches or insomnia. In Wolf et al.'s study (Wolf et al., 2016), more than half of all employees experience distress at least once a week at their workplaces.

Distress has several consequences on employees' physical and mental health, well-being, creativity, performance, job satisfaction, morale, and intention to quit (Jaramillo et al., 2005). It also impacts absenteeism, presenteeism, and turnover rates among employees (Wolf et al., 2016). Early signs of burnout, which is considered a work-related disorder, and the next level of chronic work-related distress are also worth mentioning (Rose et al., 2017).

One of the possible interventions for workplace stress prevention or reducing consequences of the workplace environment's impact is planting design in workplaces. According to previous studies, interaction with plants positively impacts human attitudes, behaviors, and health (Kamarulzaman et al., 2011). The interaction can be either active (i.e., physical) or passive (i.e., window view).

The most well-known theory regarding physical environment stress is Ulrich's Stress Reduction Theory, described earlier in this chapter.

#### **2.4.2. Work-Related Mental Fatigue**

*Fatigue* is a neuropsychological symptom defined as mental and/or physical exhaustion. It is divided into two categories: mental<sup>3</sup> (the reduced ability to concentrate or reduction of cognitive performance resulting from sustained mental effort) (Kaplan, 1993) and physiological (decrease in physical energy). Fatigue includes factors such as concentration, attention, energy, tiredness, drowsiness, and sleepiness. Due to its multidimensional nature, it might be hard to differentiate fatigue from other concepts such as stress, boredom, anxiety, and burnout (Berman et al., 2012; R. Kaplan & Kaplan, 1989, 2011; S. Kaplan & Berman, 2010).

Due to excessive cognitive demand in workplaces (mainly white-collar offices), fatigue is a part of employee life. The reasons for fatigue in occupational settings are caused mainly by overworking, overtime hours, occupational strains, shifts, work engagement problems, and insufficient leisure time (Rose et al., 2017). While fatigue is easily restored by sleeping or resting at very early stages (Kaplan & Kaplan, 1989), prolonged fatigue is considered an occupational disorder or work strain. It also can be a closely related symptom to prolonged occupational stress and might result in burnout (de Vries et al., 2015; Guan et al., 2017; Rose et al., 2017). Additionally, it affects employees' quality of life, and has several potential severe consequences for the given industry, such as poor employee performance, absenteeism, presenteeism, and poor physical and mental health (de Vries et al., 2015; Ricci et al., 2007; Rose et al., 2017). Additionally, mentally fatigued employees are more likely to make errors or mistakes during work hours due to deficits in directed

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<sup>3</sup> Since office work requires mostly cognitive functioning, only mental fatigue is included in this research.

attention, disregarding details, and poor judgment (R. Kaplan, 1993; R. Kaplan & Kaplan, 1989).

Creating natural settings or using natural elements in workplaces might be a helpful intervention strategy for reducing the number or severity of work-related fatigue cases. Kaplan and Kaplan's Attention Restoration Theory described above would be an appropriate tool to explain the mechanism of the proposed intervention.

## **2.5 Workplace Design and Occupational Health/Employee Well-Being**

World Health Organization (WHO) (Burton, 2010) emphasizes the significance of physical work environment on employee health and well-being alongside psychosocial work environment when defining healthy workplaces. Furthermore, poor physical work conditions threaten employees' mental health at workplaces (WHO, 2022).

Stokols (2011) divided workplace design in terms of employee health into categories: physical attributes of the immediate work area and ambient features, facility organization across the building, outdoor amenities, and site planning.

Physical attributes/arrangement of the immediate work area include all the physical features that are physically or visually accessible to employees from their workstations. Open-plan office layouts, workstation décor, and furniture ergonomics are included in this category; all are related to employee work performance, well-being, and job satisfaction (Colenberg et al., 2021; James et al., 2021; Stokols, 2011). Decoration colors also affect employee cognitive task performances differently, such as through motivation and creativity (Mehta & Zhu, 2009). The window is another physical attribute that impacts employee health, job satisfaction, and well-being by providing sunlight and, in some cases,

view (Leather et al., 1998). The window also contributes ambient features by providing daylight, temperature, and fresh air.

Workplace ambient features include air quality, ventilation, lighting, privacy, and noise level. All these ambient conditions and more affect employee comfort, well-being, cognitive performance, mental health, and job satisfaction (Boyce et al., 2006; Jahncke et al., 2011; Tham & Willem, 2005).

Facility organization in the building related to the layout of common areas and their physical attributes as opposed to specific workstations impacts employees overall. Onsite physical fitness facilities and well-designed dining areas can be considered workplace facilities that positively affect stress management and job satisfaction (Der-Karabetian & Gebharbp, 1986; Nguyen et al., 2021; Parker et al., 2019; Stokols, 2011).

Exterior amenities and site planning include adjacent outdoor places such as balconies, green roofs, gardens, or plazas next to workplaces. The surrounding neighborhood also can be included in this category. While this part of workplace design is understudied, there is literature regarding the health benefits of visiting nearby nature (Hadavi et al., 2015; R. Kaplan & de Young, 2007) and urban parks (Hartig et al., 2014; Negrín et al., 2017; Nordh et al., 2009). These studies can be used to interpret green roofs' impact on employee mental health and well-being.

Green roofs are outdoor amenity spaces, and thus fall under the third and fourth categories of workplace design. Even if green roofs can be seen as natural places in an urban environment and are expected to promote employee health and well-being, there is not enough evidence to support that idea.

## **CHAPTER 3. METHODOLOGY**

The main objectives of this study are to 1) understand the impact of green roofs on employee mental health and well-being, 2) assess employee attitude regarding workplace facilities, and 3) identify the relationship between the restorative effects of green roofs and employees' perceived stress at work. A survey instrument was used to collect data in order to accomplish these study objectives and answer each research question.

This chapter is organized into four sections. The first section describes the research design, including participant and site selection processes and criteria. The second section evaluates each of the study variables and measures in detail. The third section discusses the research procedure and instrument development, including survey design and pilot test. Lastly, the statistical analysis used to analyze data is described.

### **3.1 Research Design**

This study evaluates whether exposure to green roofs enhances mental fatigue and alleviates work-related distress while seeking to determine the restoration value of different green roof characteristics. A cross-sectional study design was employed, with an online employee survey as the primary research tool. The reason for a cross-sectional study in this research design was to accommodate multiple variables to measure distress, fatigue, mental restoration value, employee perceptions, and attitudes. The research was primarily cross-sectional and quantitative. However, some qualitative questions were used to capture domains more holistically, as not every answer could be preconceived to create multiple-choice questions.



A thirty-two-item online survey was developed to measure the potential ways employees experience green roofs. Twenty-five of these questions were quantitative, and seven questions were qualitative.

The criteria for selecting an online survey as a research tool included adaptability to different settings and people as well as ease of administration. Online surveys also provided a means to collect information when respondents were concerned about protecting their confidentiality.

COVID-19 in the workplace resulted in many people working remotely or avoiding direct contact with others. The research did not include in-person communication to protect participant safety. This was another determining factor in using an online survey as the research tool.

The following section explains the quantitative approach used and the selection of survey participants and sites in more detail.

### ***3.1.1 Study Participants***

Since all four companies were selected based on their possession of at least one onsite green roof, all the participants had physical and/or visual access to the green roof regardless of their active use. To ensure that survey participants had ample experience in the workplace, only full-time employees were selected. Furthermore, to ensure the participants would be able to answer the survey adequately, only those employees who were full-time and over eighteen years of age were selected to participate in the study. In addition, since the survey was online, all participants were required to have access to a computer. Apart from these criteria, a conditional question was added only for the survey's last question.

That question added another inclusion criterion: only people exposed to green roofs at least twice during employment answered restoration-related questions.

For this research, 179 participants were recruited from the employees at the four selected companies:

Site 1. Architecture Company, New York City: 43 participants out of 85 total employees

Site 2. Professional Association 1, Washington D.C.: 69 participants out of 115 total employees

Site 3. Professional Association 2, Washington D.C.: 24 participants out of 46 total employees

Site 4. Biotechnology Company, Maryland: 43 participants out of 237 total employees.

### ***3.1.2 Study Site Selection***

Four different workplaces/companies were selected based on the below inclusion criteria. To identify the relationship between green roofs on employee work-related stress and mental fatigue, and to understand employee attitudes and behaviors regarding green roof use, each workplace was required to have at least one onsite alternative break area (indoor and/or outdoor). Each workplace was also required to have physical and/or visual access to the green roof to assess the level of exposure and the possible restoration. Different locations of the green roofs among the different workplaces provided different levels of green roof exposure and allowed the researcher to assess the restorative impact of different green roofs. The last criterion was having more than half of the employees use open layout office space in terms of having similar physical features and work environment

during work hours. That way, their preference to use a green roof and the impact they got from green roof exposure could be compared. Lastly, green roofs with different layouts were selected to promote different activities such as meetings (formal or informal), resting, or view to understand employee preferences in terms of how they used the green roof.

Apart from the above criteria, a conditional question added another inclusion criterion at the end of the survey. The question asked whether the participant was exposed to the green roof at least twice during employment. Upon answering yes, they were asked about the restorative properties of green roofs.

Along with inclusion criteria for site selection, the sample population represented a wide age range and occupational tasks performed within the given organization. Even if the main businesses of companies were different, the sample covered various professions in the same company, such as administrative, clerical, professional, human resources, and information technology. This resulted in a very diverse population in jobs and age groups among participants.

Each company's green roof location and green roof access also varied: two companies had the green roof on the top of the building only with physical access; another one at the same level with offices with physical and visual access; another at the same level of offices, but with only physical access and no visual access from the offices. More information for each of the study sites is provided below.

**Site 1. Architecture Company in New York City.** This company had 100 employees, and 85 had physical access to the workplace after COVID-19 closures. 43 of these active employees participated in the study.

In this company, employees worked onsite at least two days a week during the data collection. They were in alternative remote work environments, such as their home or another place they chose, for the remaining days. The company had an open floor plan and two green roofs on both the east and west sides of the office on the 17th floor in the heart of Manhattan.

The company's mission was to provide interaction between nature and human beings through architectural design in cities while prioritizing occupant wellbeing. The company believed that nature has a healing impact on human beings and provides more livable and sustainable city environments. Since they prioritized environmentally responsible and sustainable design in their practices, they also created their workplaces according to the same design principles. They used biophilic design elements such as natural materials, textures, and patterns in their interior design throughout the office.

Green roof access: The company had three green roofs/terraces on the 17th floor in a very dense urban environment. Terrace designs encouraged all the staff to use terraces equally. Besides physical access, there was also visual access to the green roofs inside the office. Even if not all desks had direct visual access during work hours, existing windows gave a green roof view in the bustling city of Manhattan.

Regarding functions and accommodation availability, two were included in the survey and analysis: green roof 1 (Arch 1) and green roof 2 (Arch 2). The third green roof did not have physical access and was barely visually accessible from inside the office. For that reason, it was excluded from the study.

Design & features: Green roofs in this company were designed to encourage employees to have casual meetings, eat their lunches, have company events, and even work

outside. While green roof 1 (Arch 1) was smaller and more natural-looking, green roof 2 (Arch 2) included more flexibility in open spaces and seating options.

The planting design included native wildflowers, sedums, and grasses throughout the terraces. Furthermore, employees planted all plants on both green roofs and were responsible for minor roof maintenance, such as watering. Plants accommodated the local ecosystem, including insects, ladybugs, grasshoppers, birds, and butterflies.

Architecture Company green roof 1 (Arch 1) had a high sense of refuge (safe and enclosed feeling) because of the narrow tall surrounding buildings. Since this green roof sat on the 17th floor and the corner of the building, it also provided a good prospect (view) of the surrounding area.

Besides building shade from the tall buildings surrounding it, this green roof had no shade structure. This may have affected employee comfort or visit trends, especially during summer or on sunny days.

In terms of seating, there were four small movable tables and four chairs for each of the tables on this green roof. While one of the four tables was located on the platform on the northeast corner at the perimeter, the other three were placed between planting beds. One of the tables offered a view of the street as well as an elevated view of the green roof, whereas the other three offered a feeling of being surrounded by vegetation/mid-sized native plants. A functional seating option allowed employees to work or rest separately or with their coworkers by combining tables and chairs.

There were two prairie-like designed planting beds on this green roof. They were placed in the middle of the green roof and included diverse plant species with native—mainly flowering—plants with different textures, shapes, and colors. The planting bed on

the south side of the green roof was divided into two, and a vegetable garden was assigned on the further side of the planting bed for herbs and vegetables to use in the company's kitchen.

This green roof also kept two beehives on the north corner, and their bees were taken care of by employees on the north side. Honey harvesting became a tradition of the company, which all employees did together at the end of the season. Other than bees, other wildlife such as insects, birds, dragonflies, ladybugs, butterflies, and other pollinators visited both green roofs from time to time.

Light-colored concrete tiles were used as decking material and created contrast with dark-colored metal edges of planting beds and lighting fixtures. Lighting fixtures were short (less than 3") and about the same height as tables. Neither lighting fixtures nor artificial light were the dominant design element on the green roof.

Architecture Company green roof 2 (Arch 2) was a more extensive green roof with an outdoor conference room as big as its indoor counterpart and which included tables. One large/communal table and eight small tables accommodated people's needs during work and break times to promote large meetings, working together, drawing outside, and casual gatherings. While a communal table could accommodate ten or more people, individual tables on the south and north sides accommodated two to four people. Since the small tables were movable, employees were able to use the green roof in different ways. It could be used as a meeting area for different sized groups as needed or as a relaxation area for individuals. There were four rooms or areas on this green roof from south to north: two individual tables on the perimeter, a communal table and arbor, three small tables with a bench on one side, and three small tables on the perimeter of the north side of the green

roof 2 (Arch 2). Each room or seating area was separated by planting beds. While some planting beds were raised to accommodate mid-sized trees, others with mid-sized native shrubs/wildflowers and grasses were not raised.

The planting design of this green roof was similar to the other green roof (Arch 1), consisting mostly of a variety of endemic wildflowers and grasses. Green roof 2 (Arch 2) had a vine just starting to climb through the arbor and some native birch trees on either side of the green roof 2 (Arch 2). Higher planting beds provided deeper soil for trees.

Green roof 2 (Arch 2) had an arbor or shade structure over the conference table. The arbor was an eye-catching design element on this green roof. While it gave a sense of enclosure and added height to the terrace, it also provided more shade as the vines grew together with birch trees. The arbor and birch trees also provided a sense of refuge (safe, enclosed), while the sense of prospect (view) was higher on this green roof compared to green roof 1 due to the further proximity of surrounding buildings.

The same decking material as green roof 1 (Arch 1) was used on the north side of green roof 2 (Arch 2) as well as on the walkway. The decking material changed under the communal table/arbor and two small tables on the south side of the green roof became wood decking. Changes in pavement material type, color, texture, and pattern provided diversity in design.

**Site 2. Professional Association 1 (ProfA 1) in Washington, D.C.:** This company had 115 employees in total, and almost 100 had physical access to the workplace after the COVID-19 closures. Sixty-nine employees answered the survey.

This company also required employees to come to the workplace at least two days a week during the data collection. Taking remote and onsite break places into consideration

was essential in understanding employee attitudes. The company had an open floor plan and some separate offices among the two floors (the 2nd and 3rd floors of a seven-story building).

Employees in this association did not work in a field related to ecology or design, and thus did not have any specific education regarding nature or greenery.

Green roof access: One physically accessible green roof was on the top of the building on the 7th floor. The green roof was intended to become a common area with other tenants eventually. However, at the time of data collection, the association was the only tenant in the building, and the green roof was occupied only by their employees. Every employee had equal access to the green roof since it is located on a separate floor and is not visible from workstations.

Design & features: The building had a glass façade and a river view with vegetation and trees alongside the river. Some parts of the building and offices had a river view, and others faced the street. However, the green roof was on the riverside, giving a beautiful view from the 7th floor.

Besides the building's shade, there was no shade structure on the roof. It also gave users a sense of refuge. Seat-height outer walls next to couches and smaller tables provided a sense of refuge. The prospect was high towards the perimeter with the elevated and distant river view. The planting design also provided openness and enclosure simultaneously due to raised planter beds, shorter shrubs, and grass-like/soft-textured plants. The planting provided prospects and refuge at the same time.

Considering the view, water seemed to be the primary inspiration for the planting design. Plants included tall and short grasses, flowering perennials, and short shrubs with



soft textures. Various plants created an airy/prairie-like atmosphere on the green roof. Tall grasses moved by the wind and made the water view visible through the leaves when moving. No big plants in the design blocked the view(s) or created an enclosed place other than raised planting beds throughout the roof. While plants attracted insects, birds, and butterflies, there was no record of other wildlife on the green roof.

There were six rooms on this green roof to accommodate a variety of users. First, there was one big communal table under the shade of the building for people to socialize or have group meetings. Secondly, there were four small tables on the perimeter toward the view, with two chairs for each. Since these tables and chairs were movable, green roof users could combine tables and chairs for bigger groups or use single tables for individual use. Third, three couches, one chair, and two coffee tables were located on the perimeter on the north side of the green roof. Individuals or smaller groups would likely find this form of seating to be more comfortable. The fourth and fifth rooms were between planting beds. While the fourth room consisted of a singular designed bench and four coffee tables, the fifth room included four chairs and two coffee tables on the other side of the planting bed. The sixth room had only one bench on the corner of the view. This secluded area was best for individual tranquil time or talking on the phone. It was possible to hold meetings with clients or colleagues in any sitting area except the sixth. While the communal table mostly oversaw tall grasses, the second, third, and fourth areas provided an unblocked view of the river.

Two decking materials, wooden and concrete, were used in five patterns on the green roof. All pavements were a light color, and patterns defined/complemented the planting bed designs. Lighting fixtures were embedded in design materials, such as the planting

beds or building wall. Neither lighting fixtures nor artificial light were the dominant design element. The company also provided employees with good Wi-Fi and several outlets to promote green roof use during work hours.

**Site 3. Professional Association 2 (ProfA 2) in Washington, D.C.:** The association was in a densely urbanized area of Washington, DC. The company was located in a three-story building, and 24 out of 46 employees participated in the study. This association's employees worked mostly remotely but were voluntarily onsite during the data collection process.

The purpose of this green roof was mainly to experiment with different plants and soil depths and demonstrate to other people the specific profession's presence in the green roof industry. This green roof project was also designed to demonstrate the effectiveness of green roofs in providing stormwater management and water quality, reducing the urban heat island effect and energy consumption, and increasing aesthetical value to the building and the neighborhood. Their employees were therefore knowledgeable about nature's positive impact on human health and wellbeing.

Green roof access: The green roof was on the top of the building, and only physical access was available to employees through the stairwell. There was no visual access from the offices. In addition to employees, visitors were able to access the facility physically. The association arranged tours to the roof for visitors and provided an online live monitoring option for anyone worldwide.

Design & features: This well-known green roof combined different green roof conditions in a small area. It had different green roof types (extensive, semi-intensive, intensive), growing media depth (from 3' to 21'), and plant types ranging from sedum to

medium sized trees. It also had two mound-shaped planting beds that mimicked waves. These mounds were located on the two sides of the seating area of the roof, and provided visitors the feeling of being surrounded by green instead of high-rise buildings without the need for taller plants and deeper soil. Mounds raised the plant material without adding extra weight to the old building structure. These plant materials included sedums, native perennials (tickseeds, chives, nodding onions, black-eyed Susans, Virginia wild rye, silver king, and butterfly milkweed), succulents (prickly pear cactus), and a sumac tree. Due to structural constraints, the only tree (sumac) was on the elevated part of the roof. Some of these plants were not usual green roof plants, and were planted for experimental purposes to identify additional plant species for urban rooftop plantings with minimal maintenance. Having diverse plant species, especially native plants, also provided a habitat for birds and insects in the area. Data about direct observation of wildlife were unavailable at the time of data collection.

In terms of seating, there was only one movable small coffee table and 13 chairs on the green roof. The roof was mainly designed for events or very casual meetings. Except for the building wall, there was no shade structure on the green roof for occupant comfort.

Since there was no additional structure or tree on the seating level, the sense of prospect was much greater than the sense of refuge. Even though some of the surrounding buildings were higher than the company building, there was not much sense of enclosure.

Wooden decking material was used for the seating area. The aluminum grating was used as a walking surface for the rest of the green roof. While this system increased the vegetated area on the roof, it also provided the feeling of walking on the greenery. The

fixtures on the building wall provided the lighting of the green roof. Since the useable area was small and compact, those fixtures provided ample light.

Even if employees could use the green roof during work hours and break time, there was no trash bin or good Wi-Fi to promote green roof use among employees. The reason for not having a trash bin on the roof was that employees were not allowed to eat or drink on the green roof due to possible rodent problems.

**Site 4. Biotechnology Company (BioT) in Maryland.** This location was considered a campus. It consisted of three adjacent buildings connected by bridges. 237 employees were working on this campus, and 43 of them participated in this study.

The company implemented several sustainability practices for buildings while considering biophilic design approaches, including fresh air circulation, daylight use, renewable energy applications, and natural and nature-inspired material use in decoration, such as green paintings and wooden materials.

Green roof access: The green roofs were accessible from some of the offices, gym, and conference rooms. Those green roofs were different in size and function. As well as having similar functions to other green roofs included in this study, two of these roofs were also larger than other green roofs on the premises, had a variety of rooms for different activities, and had easy physical access for all employees during the day. As a result, only those two green roofs were included in the study. No employees had visual access to these two green roofs from their workstation, but everyone had physical and equal access to both green roofs. The green roofs were on the second building, which sat between the first and third.

Design & features: Both 6<sup>th</sup> (BioT 1) and 7th-floor (BioT 2) green roofs were designed for different purposes using different design elements.

Biotechnology Company green roof 1 (BioT 1) The 6th-floor green roof was an intensive green roof designed as an employee break area. The planting design included lush foliage, flowering plants, tall perennial grasses, sedums, and a tree that gave height and color as well as shade, providing attraction through different colors, textures, and forms. Stainless steel planters also created a contrasting style and green color. A combination of planters and planting beds created a dynamic design even in non-flowering season. Diverse plant species attracted urban wildlife such as insects, birds, butterflies, crickets, praying mantises, bees and below soil insects including ants and bloodworms.

This green roof had four movable tables with four chairs each, along with three benches and four single chairs. While tables were placed on the perimeter, benches were surrounded by tall perennial grasses from three sides. This enclosed feeling provided users privacy (refuge) despite it being such a small place. The tree strengthened that feeling, especially in spring and summer. The 6th floor view balanced refuge by providing a sense of prospect. This green roof was suitable for both individual and group work or break time activities due to tables and chairs and their availability for flexible use. Additionally, the employer provided a good Wi-Fi connection and outlets to encourage employees to use the green roof during work hours.

Another significant design element on this terrace was an arbor. It defined the edge of the terrace, created an enclosed space feeling, created visual interest, and gave height to the space. It could also be seen as a frame to the view because of its location on the roof. It complemented the tree in terms of height, and did not provide shade because of the open

structure design. The deciduous tree was the only design element that provided shade during late spring and early summer.

The only decking material of this green roof was wood. Other than that, lighting fixtures were mounted to building walls and did not provide harsh artificial light to the place.

Biotechnology Company green roof 2 (BioT 2) There was also a multifunctional intensive green roof on the 7th floor. This green roof was smaller in size and different in terms of function.

The most notable difference was the arrangement of furniture to create a more social environment in which employees can gather. Furniture consisted of two sectional sofas facing each other and four coffee tables attached to each side of the sofas as well as two single chairs. This place was more casual, aimed more for group coffee/tea times than for lunch or individual workspace.

There was also an arbor on this green roof, but no shade structure to provide occupant comfort. The arbor was over the sitting area to define the sitting place. Its presence suited the prospect-refuge theory design criteria as it defined the space (refuge) with the glass wall behind it and an open view from the 7th floor (prospect).

There were small patches of vegetation and paving areas in which visitors could walk and stand. Plant heights were lower than the green roof 1 (BioT 1). Dwarf ornamental grasses and ferns were the only vegetation used in this place. Other than green foliage, there were no flowering plants or bushes. As a result, the planting design was monotonous. No urban wildlife observation was reported for this green roof.

Similar to green roof 1 in the same company, wooden decking material was used for the floor, and metal lighting fixtures were mounted to the building walls.

### **3.2 Variables and Measures**

Several variables based on the literature were identified in advance as potential influencers on employee perceived mental fatigue and work-related stress associated with green roof exposure. To provide a clear understanding of the relationship between variables, a list of variables is included below.

*Dependent variables:* Restorative value of the green roof, mental fatigue, work-related distress

*Independent variables:* Include weekly frequency of green roof visits, average time spent on the green roof, employees break place preference, window view, employee attitudes and perceptions towards the green roof, design, and physical attributes of green roof

*Descriptive variables:* Age, gender, education level, employment duration

The next section provides more detail about each of the variables in this study.

*Restorativeness of green roof:* According to literature, nature alleviates stress and mental fatigue. Since nature has certain components that restore attention and alleviate stress, the level of restoration capacity of each company's green roofs was examined in this study. Other additional factors that possibly impact restorativeness were assessed. While restorativeness is used as a dependent variable across the study, it is used as an independent variable for one question. In that question, the association between mental fatigue, work-related distress, and restorativeness of green roofs are assessed separately.

*Mental fatigue:* How much mental fatigue do employees believe they experience during work hours? Fatigue is a broad term, and it has several components. Since all four companies had white-collar employees who spent most of their working hours engaged in sedentary activities requiring cognitive functioning over long hours, only mental rather than physical fatigue is included in the study. This study utilized the Mental Fatigue subscale of the Multidimensional Fatigue Inventory, as will be discussed later in the Instrument Development section in detail. A four-statement subscale measures concentration as cognitive functioning.

*Work-related stress:* Occupational stress includes different components, such as job demands, job satisfaction, or lack of support, but none are directly related to nature exposure. This study uses the pressure subscale of the Stress in General scale. Participants were asked to rate this seven-item 5-point Likert subscale which measures work-related distress with more general words such as calm or pushed. This will be explained later in the Instrument Development section in detail.

*Employee green roof use choices:* Understanding employee choices/liking is essential to understand the green roof experience of employees and the mental benefit of green roof use. It would be beneficial to understand why green roofs are preferred or not over other facilities. This includes employee choice of remote and onsite breaks and the reasoning behind them, frequency of visits to green roofs on a daily and weekly basis, preferred activities on the green roof, preferred parts of the green roof, preferred time of the visit, and finally, whether improvements are necessary. These components are essential in determining whether and how employees prefer to visit the green roof, why, when, and how they engage with it. It is crucial to know the overall experience. Each component is



explained below. These are all choices that employees make and must be considered when determining employee green roof use patterns.

Weekly frequency of green roof visits: It is imperative to understand the relationship between employee visits to the green roof and its restorative properties. Determining if weekly frequency can be a mediator to impact the restorative value of green roof was the reason to include this variable.

Average time spent on the green roof on each visit: This is another green roof use pattern variable. Knowing how much time employees spent on the green roof each visit will help the researcher understand how employees used the green roof. This variable was also assessed using pre-categorized choices in the survey. If the average amount of time spent on the green roof is found to be associated with restoration, the required interventions can be more effectively decided.

Employees' break place preferences: Based on open-ended questions, categories were created for this variable. The content analysis was followed by a further categorization, resulting in two categories: green roof users and non-green roof users. 'Break time' was not defined in the survey, so employees' interpretations were assessed. Those who viewed green roof visits as break time activities were combined as 'green roof users.' That variable was also considered part of the green roof use pattern.

Type of access to nature: This research examines two nature/green roof access types: physical (green roof) and visual (window view). Employees from all four companies had physical access to all the green roofs in their place of employment through an access door. Indoor plant contact was not considered. Since none of the companies had clear visual access to green roofs from employee desks, window view context was used to assess visual

contact with nature. Employees were asked if they could access a window view from their workstations. When they answered yes, the context of the view was asked by predefined answers, including vegetation, buildings, and both (vegetation + building). This was investigated to understand whether the window view context reinforces the impact of green roof exposure on employees' mental health.

*Employee attitudes and understanding of green roofs:* Employee knowledge, attitude, and understandings were examined in this study to better understand the logic behind their attitudes. Because attitudes are a product of perceptions, they can be helpful in understanding the use of places such as green roofs.

*Green roof design and functions:* The green roof design and features have the potential to shape employees' green roof visit frequencies and usage patterns, as well as the restorative benefit they get from the green roof. This is one of the leading independent variables of the study. The researcher evaluated the green roof's design and physical attributes using observation and employee responses regarding favorite spots on the green roof.

*Demographic variables:* Include age, gender, education level, work location (onsite, remote, partial), and the length of each employee worked in the current workplace. These independent variables help to understand the background characteristics of the sample population, how the population is distributed, and how representative the general population is. They are needed to better analyze the data and describe the phenomenon.

### 3.3 Procedure

The research was conducted solely online and included an online questionnaire that took participants about 15 minutes to complete. There was no follow-up session after the questionnaire was completed. Participation was voluntary, and participants could withdraw from the survey whenever they wanted.

The participant selection process consisted of sending emails to human resources managers of selected companies who then forwarded the emails to their employees. Each participant received an email regarding research instructions and a link to survey questions through the Human Resources Department of each company. Participants were asked to give consent at the beginning of the survey. After the first page about the study title, purpose, and researcher contact information, the second question was whether or not they desired to participate in this study of their own free will. Upon clicking yes, the survey started. Upon clicking no, they were taken to the end thank you page. The study procedure was approved by the Institutional Review Board of the Virginia Tech Human Research Protection Program.

Some specific survey questions were created explicitly for different companies because of site-specific aspects of each green roof design, but most other questions were the same for all locations. The survey (Appendix C) was active for four weeks after being distributed. Two follow-up email reminders were sent after the first week of the distribution and at the end of the second week. Surveys were distributed to two companies in November and the other two companies in May. There were two factors in choosing those dates. First, most employees of the two companies had been working remotely due to COVID-19 since the previous year and came back to their offices at the

beginning of October. The other two companies' employees did not return to their offices until Spring. At least four weeks after their return to office, surveys were distributed. Second, fall and spring temperatures are excellent for spending time outside in the three states wherein the companies are located (approximately 70 F during work hours). The temperatures gave employees a chance to refresh their minds and experiences with green roofs before taking the survey, which was particularly important as the questions required them to remember their experience of a previous green roof visit. The following diagram 3.1 illustrates each phase of data collection and analysis procedures.

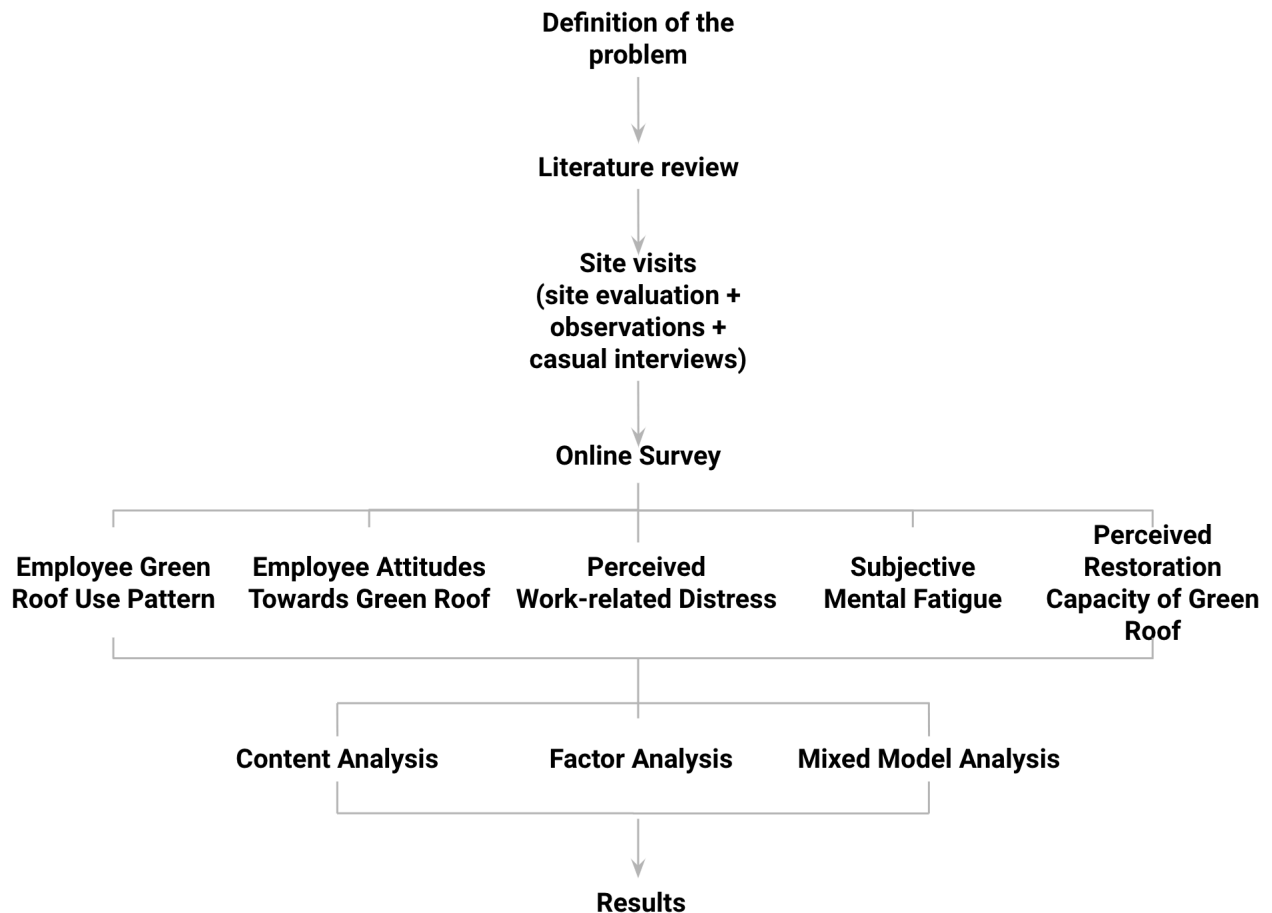


Figure 1. Research Design Diagram

### ***3.3.1 Instrument Development***

**3.3.1.1 The Survey Design.** The online 32-question survey was used to measure green roofs' impact on employees' perceived mental fatigue and work-related stress. The survey requested information about employee use of green roofs, attitudes, frequency of visits, and/or attitudes toward green roofs to identify key design elements and functions related to green roofs and their restorative effects. The survey consisted of open-ended and multiple-choice questions.

The survey opened with a picture(s) and company name for green roofs that would be in the survey. The survey had clear and precise images of green roofs. The rest of the survey was a combination of seven different sections, ensuring a more holistic approach to related research questions:

1. Current workstyle/location
2. Employee attitudes of workplace facilities (including green roofs)
3. Employee attitudes towards onsite green roofs
4. Perceived job-related stress (pressure)
5. Perceived mental fatigue
6. Perceived restorativeness of green roofs in workplaces
7. Demographic questions.

Details of each part of the survey and how participants were asked to respond to each question are discussed below.

***3.3.1.1.1 Current workstyle.*** The survey started with the question about the current workstyle/location of employees and whether employees were working onsite, remotely, or in a hybrid style at the time of data collection. When they chose hybrid, the survey

continued with an open-ended question asking, ‘On average, how many hours per week do you spend working onsite and remote (please write it separately)?’ After determining the extent of employees’ current potential experience with workplace facilities, a new set of questions started about employee attitudes.

**3.3.1.1.2 Employee choice of workplace facilities (especially green roofs).** This part of the survey started with questions about preferred work break areas. Due to the primarily hybrid workstyle, this question was asked separately for both remote and onsite workplaces: 'When working remotely, do you have any specific place to take a break from work?' or 'At your place of employment, do you have any specific place to take a break from work?' If the answer to either of these questions was yes, the survey asked for further description, with open-ended questions asking why people liked that place. These questions and gathered responses are helpful in understanding what kind of workplace facilities are preferred by employees (i.e., indoor vs outdoor) and does not limit to responses to only green roofs.

The continuing survey questions regarded weekly frequency of green roof visits to each individual green roof at a given company. In other words, this question was asked for each green roof separately, even if the same company had more than one. The answers to this multiple-choice question were a) daily, b) often (3-4 days/week), c) sometimes (1-2 days/week), d) seldom (less than one day/week), e) not at all. A follow-up question asked about the average time spent on the green roof per visit. This question was also multiple-choice and offered four options: a) less than 5 minutes, b) 5-15 minutes, c) 15-30 minutes, and d) 30+ minutes.

Two more questions were added to the survey to measure green roof-related choices. The first question was asked separately for each green roof: 'What do you usually do when you visit each green roof?' While this was an open-ended question, respondents could list as many activities as they wanted. After the open-ended question, a similar question was added which aimed to support the previous question: 'When you visit the green roof, to what extent do you engage in the following?' The question was a nine-item 5-point Likert scale question with one open-ended optional item at the end. Those nine statements were: 'sit and relax,' 'have lunch/snack on my own,' 'gather/engage with others,' 'connect to the internet,' 'work,' 'enjoy nice views,' 'observe plants and seasonal changes,' 'observe wildlife (birds, butterflies,...)', 'enjoy the overall design of the space,' 'other reasons - open-ended.' On a 5-point Likert scale, each statement was ranked as follows: 'never=1', 'sometimes=2', 'often=3', 'very often=4', and 'always=5'. At the end of the rankings, the 'do not know=0' option was included to ensure that participants read the statement. This question was also asked for each green roof rather than overall for each company. Similar questions were created with the intention of filling all the gaps and getting richer answers. The activities employees did on the green roof showed what purpose they were using the roof for, how employers could promote that use, and which design could be most useful for what purposes. User activities can direct designers to create better, more practical, and more fulfilled places.

People also tended to visit each of the green roofs at certain times of the day. These times were shaped mainly by green roofs' design features, activities the green roofs offered, and employees' needs. The purpose of asking employees about their preferred green roof visit time was to understand their green roof use pattern and whether time of day is

important for their green roof visit preference. The survey therefore included two additional questions to better understand user preferences: 'Are there any specific parts of the green roof that you enjoy the most?' and 'Is there any particular time that you like to visit any of the green roof(s) at your place of employment?' These open-ended questions asked for further explanation by asking 'What and why?' when respondents answered yes. Regardless of whether the roofs belonged to the same or different businesses, the preferred part of the green roof question was asked separately for each roof.

The last question about employees' choices was: 'Is there anything you see or experience on the green roof that you think should be improved? If so, what is that?' This question did not directly ask about likes or dislikes. However, it indicates why employees did or did not prefer to use the green roof, and also offers insight into how employers and designers can promote green roof use and whether designers should consider adding or changing when designing/updating workplace green roofs. This question was also asked separately for each company green roof.

This second portion of the questionnaire identified how employees utilized the green roof, what activities they enjoyed doing on the green roof, when they preferred to visit, what factors influenced that decision, and where on the roof they preferred to visit. This allowed the research to better understand employee attitudes regarding green roof use and how to motivate people to use green roofs to improve their mental health and well-being if applicable.

**3.3.1.1.3 Employee attitudes and understanding of onsite green roofs.** The third section of the survey consisted of one question and 12 statements related to employee attitudes, perceptions, and knowledge about green roofs in their workplaces. Participants



were asked, 'To what extent do you agree with the following statements about the green roofs at your workplace?' These statements were measured using a 5-point Likert scale, wherein not at all agree=1, a little agree=2, somewhat agree=3, agree=4, and very much agree=5. 'I do not know' (0) was added for undecided participants. These statements covered various factors regarding employees' perceptions of their companies and employers. They also included knowledge-measuring statements regarding the possible benefits of green roofs. These statements were as follows:

- Indicates a positive work environment
- Indicates that the company is environmentally conscious
- Provides opportunities to improve the relationship between employees (social interaction)
- Adds aesthetic value to the workplace
- Indicates that the company values employees
- Improve employee physical and/or mental health
- Provides environmental benefits (i.e., reducing carbon footprint)
- Builds and maintains employee morale
- Reduces heating and cooling energy consumption
- Good for air quality
- Positively impact employee productivity/performance
- Help to reduce/alleviate work-related stress

**3.3.1.1.4 Perceived job-related stress.** The survey's second portion included a self-reported scale to measure employees' perceived work-related stress. This scale differed from other existing workplace stress evaluation scales in that it measured employees'

overall stress in their workplace rather than specific issues causing stress. In this case, this scale evaluated the work-related stress, or the emotional state experienced by employees in their workplaces. Stress in General scale's pressure subscale was used to measure employees' job stress levels. The measure contained seven items or sub-scales to measure stress: demanding, pressured, hectic, calm, relaxed, many things stressful, and pushed. The survey asked employees whether they agreed or not with the words related to their job situation. Participants ranked their responses on a 5-point Likert scale ranging from 1 (not at all agree) to 5 (very much agree).

This part of the survey was intended to find out how stressful employees think their jobs are and how much pressure they have at their workplace. The researcher changed this scale's response rate from yes, no, or "?" (cannot decide) to a 5-point Likert scale to better understand the subject. The new scale was the same as the previous 5-point Likert scale statements throughout the survey: not at all agree=1, a little agree=2, somewhat agree=3, agree=4, and very much agree=5. An open-ended section was added at the end of this question in case employees wanted to add any other description regarding their job characteristics.

**3.3.1.1.5 Perceived mental fatigue.** Employee fatigue was assessed by asking: 'When you have difficulty concentrating or feel fatigued during work hours, do you have any strategy to overcome?' This binary (yes/no) question asked employees to describe that strategy. After this question, to measure employees perceived mental fatigue, participants completed a self-reporting instrument called The Multidimensional Fatigue Inventory (MFI) (Appendix x). The MFI has five types of fatigue: general fatigue, physical fatigue, mental fatigue, reduced motivation, and reduced activity (Smets et al., 1995). Due to the

study's focus on cognitive functioning, only the mental fatigue subscale was included in the survey. The subscale contains four statements regarding concentration, two of which are positive, while the other two are negative. The statements are measured using a 5-point Likert scale, wherein 1=never, 2=sometimes, 3=regularly, 4=often, and 5=always. The scoring is between 1 and 5 (mean score), with a higher score meaning a higher mental fatigue level. Statements of mental fatigue are as follows:

- When I am doing something, I can keep my thoughts on it.
- I can concentrate well.
- It takes a lot of effort to concentrate on things (reverse coding scale).
- My thoughts easily wander (reverse coding scale).

The third and fourth statements in the subscale are reverse coded. Mean score of each statement shows the fatigue level of employees.

The reasons for choosing this scale over many other well-designed clinical scales are as follows: it is brief, easily understandable, and includes positive and negative items. Due to the survey length, participants' tiredness was essential to consider in keeping the scales short. The internal consistency and reliability results have been found to be appropriate for the non-clinical assessment of self-reported mental conditions (Hewlett et al., 2011, Lin et al., 2009).

**3.3.1.1.6 Perceived restoration value of green roofs in workplaces.** Even though there are some valid and reliable scales to measure the perceived restorativeness of nature, there is yet to be a universally accepted scale for assessing the green roof experience. Since other green areas are different from green infrastructure—namely green roofs—a new scale

was adapted from several restorativeness scales by the researcher of this study. This 10-item scale measures green roofs' restorative effect on employees' cognitive abilities.

Attention Restoration had another conditional question before the restorativeness scale was asked: 'Have you visited either east or west terraces at least twice during your work time in this company, and do you remember your experience?' After participants responded to this binary question as yes, the actual question regarding the restorative capacity of green roofs appeared. This question was necessary because some people might have been hired during the COVID-19 pandemic and would either not have experienced the green roof or might not remember the experience of past visits. The people who had visited the green roof at least two times during their employment were asked to read ten statements. These statements were measured using a 5-point Likert scale, wherein 1=not at all agree, 2=a little agree, 3=somewhat agree, 4=agree, and 5=very much agree. Since this question was based on a theory and might be hard to understand, the 'do not know' option was also included to see if the person read it and did not know how to respond. Those responses were able to be included in the data. The statements were:

Being away:

- When I am on the green roof, I feel free from my daily routine.
- I forget everyday worries when I visit the green roof.

Fascination:

- There is always something to attract my attention on the green roof.
- This is a good place to let my mind wander.

Extent:

- On the green roof, everything seems and feels connected and interrelated.

Compatibility:

- The green roof is visually pleasing.
- I feel good when I am on the green roof.
- I feel connected with nature on the green roof.

Restoration outcome (ROS).

- I feel calmer after being on the green roof.
- My concentration and alertness increased after visiting the green roof.

A new scale was adapted from Hartig et al.'s (1991) 24-item Perceived Restorativeness Scale (PRS), which was updated 1997 and included 16 items; and Korpela et al.'s (2008) 6-item Restoration Outcome Scale (ROS). Both scales were developed based on the Kaplans' Attention Restoration Theory to measure the restorative capacity of places/environments regardless of whether indoor or outdoor. However, while PRS uses four factors (being away, fascination, extent, compatibility), ROS uses different factors, including a) relaxation and calmness, b) attention restoration, and c) clearing one's thoughts. Both use the same rating system, from 0 (not at all) to 6 (completely). While PRS was too long for employees' limited time, ROS was too broad and did not sufficiently cover all the ART properties.

Additionally, PRS's shorter version was written as it is for an external site/location. Consequently, these two scales were adapted with the help of the literature to develop a more suitable measurement tool for use in the research context. To capture green roof users' experiences for cognitive restoration, the researcher combined Kaplan's books, other publications about the theory, and similar scales based on the importance of everyday

nature knowledge. As explained earlier in the literature review, green roofs are smaller in size and limited in function compared to forests or urban parks; user experiences and expectations may change accordingly. For example, the statements "There is much to explore and discover here" and "I would like to spend more time looking at the surroundings" would not make sense to surveyors since not all green roofs are big enough to experience that significant fascination. Pilot study feedback also supported this idea.

Hartig's PRS and Korpela's ROS were adapted for use as major scales. Four more art-based scales were also evaluated: 1.) a shorter version of PRS, 11 items (Pasini et al., 2014); 2.) Perceived Restorative Components Scale, 15 items (Bagot, 2004); 3.) The Restorative Components Scale, 22 items (Laumann et al., 2001); and 4.) Restorative State Scale, 9 items (Van den Berg et al., 2014). The researcher checked their items and examined what aspects were changed among the scales and what kind of language was used. After evaluating existing scales and literature, a new scale was finalized. It covers the theory's four factors: escape (being away), fascination, extent, and compatibility, as well as the two of the Restoration Outcome Scale (ROS) items.

Instead of having a 7-point Likert scale like existing scales, an adapted 5-point Likert scale was used. The reasons for this included providing continuity with previous Likert scale questions that are part of the survey, reducing participants' frustration, improving ease of responding, and keeping the response time shorter for employees. Since the 'do not know' option was not a part of the rating and had 0 points, the new scale could be considered a 5-point Likert scale. According to the literature, there is not much difference between the 5-point and 7-point Likert scales regarding the reliability of results.

One of the questions on the survey asked whether employees had access to a window view from their workstation, or anywhere else they pass during their workday. When they answered yes, they were directed to a multiple-choice question about the window view's content. Answers included vegetation, buildings, and both. These two questions were used to compare the types of access to nature (visual/window view or physical/green roof visit) regarding their restorative impact.

**3.3.1.1.7 Demographic questions.** The last section of the survey included four questions regarding demographic information of participants.

The first question of this part asked, ‘How long have you worked for this company?’ This question determined if the employee had enough time to experience workplace facilities, long enough before COVID-19 closures. This was especially important considering, after COVID-19, workstyles changed, and an increased number of companies have adapted hybrid or remote workstyles since then. The other three questions were about participants’ age, gender identity, and education to understand the sample distribution among different groups.

At the end of the survey, participants were asked if they would provide their email address voluntarily in case the researcher needed to ask for any further explanation.

**3.3.1.2 Pilot Test.** After finalizing the survey questions, a pilot test was developed for the staff of the Virginia Tech Graduate School and distributed to the Virginia Tech Graduate School offices at the Blacksburg campus in July 2021. Snowball sampling was used to recruit participants and the survey link was emailed to the entire office by the office secretary. 16 office employees completed the survey and provided feedback. Two of the survey participants were observed while completing the survey for personal observation.

The pilot survey location was the Graduate Life Center Lawn. For the site-specific questions in the survey, ‘green roof’ words were replaced by ‘Graduate Life Center Lawn,’ which was the closest specific open space around the participants' workplace. For example, ‘On the days that you visit the Graduate Life Center (GLC) Lawn, how many times in a day do you visit?’ was asked instead of ‘On average, how much time do you spend on the green roof when you visit?’

At the end of the survey, there was a feedback box where participants could express their thoughts and help develop the primary survey before it was finalized. Participants were able to maintain their anonymity thanks to the anonymous box. The goal was to ensure that questions flowed well and were clear, with wording that everyone easily understood. The pilot test also assessed the survey's validity, completion time, and length. The survey was kept short and concise to avoid participant boredom.

Participant feedback led to revisions of several problematic survey items. Some participants had trouble understanding items (like “extent”) on the perceived restorativeness scale on the first try. Thus, a revision to the phrasing was necessary. Additionally, participants divided their responses to some Likert scale questions into two categories—either a little agree or agree if not neither. Therefore, the Likert scale ratings changed to comprehend the phenomenon better. The final version of the scale was still 5-point, but the rating was 1=not at all agree, 2=a little agree, 3=somewhat agree, 4=agree, and 5=very much agree. Neither “neither” was omitted. In addition, nearly half of the respondents failed to respond to two questions on the space's strengths and areas for improvement. As a result, in order to finalize the survey, the wording of the survey questions was revised,



and ten more participants completed the survey to determine whether the changes were effective or not.

### **3.4 Statistical Analysis**

This section examines the statistical techniques used to interpret this study's survey results. STATA and JMP Pro software were used to perform all analyses. All statistical analyses are tested at 0.05 and 0.10 significance levels corresponding to 95% and 90% significance levels, respectively.

The analysis began with descriptive statistics to understand the sample population, the work situation of employees, and the workplace environment overall. The open-ended questions were coded using content analysis to categorize the employees' responses. For each scale, factors were determined through factor analysis. Linear mixed models were used to appropriately analyze the relationships among the dependent and independent variables for each research question. In order to provide a practical interpretation, these analyses were followed by means tables, post-hoc testing, and characterization of slopes as indicated by the initial statistical significance in the mixed models analysis and the type of data.

#### ***3.4.1 Descriptive Statistics***

Organizing findings and understanding the demographic characteristic and distribution of the sample population and their work environment and attitudes was the reason for applying descriptive statistics to the survey results. There are separate tables in the results section for all these variables showing their percentages and frequencies.

Descriptive statistics were also used to show the psychosocial environment of the workplace. There was a separate calculation of each company's mean distress level, mental fatigue level, and perceived restoration level.

#### ***3.4.2 Content Analysis***

Since open-ended questions do not have any fixed response and participants descriptively use their own words, answers were different from one another and included similar or different contents. Content analysis helps researchers to combine responses under variables or themes and gives a fixed set of meaningful categories with higher response frequency.

Eight open-ended questions in the survey were coded manually by the researcher. Each question's responses were analyzed separately for each company, and similar responses were categorized.

#### ***3.4.3 Factor Analysis***

Factor analysis was used to determine the variance among items in the same scale. The researcher also used factor analysis to examine underlying dimensions to assess the relationship between variables. This research assessed existing and adapted scales' internal consistency and factor loadings to confirm whether they are suitable tools for measuring certain phenomena using confirmatory factor analysis.

#### ***3.4.4 Linear Mixed Model***

The linear mixed model is an extension of fixed effects linear regression and ANOVA. The linear mixed model incorporates both fixed and random effects within and between groups. Fixed effects can be used to test differences or effects between specific fixed effects levels. In contrast, random effects allow for estimating the variation between

the levels studied, indicating they are sampled from a larger population (Hinkelmann & Kempthorne, 2007).

A linear mixed model is useful when the data or assumption is hierarchical. Since the sample population of this research consisted of employees from four different organizations, a linear mixed model was specified to capture differences between employees in different organizations. The company variable was included in the model as a random effect. It is reasonable to assume that subjects within the same company would have more similar responses than subjects across different companies. Based on the researcher's hypothesis, the differences between work environments, alternative facilities, design, company culture, and the physical attributes of green roofs might influence the restorative value of green roofs. Lastly, participants' knowledge and attitudes about the green roof are expected to differ due to their occupations, which might impact the benefit of green roof use. All these differences needed to be considered to include company effect in the analysis. Note that as a random effect, the magnitude of company differences will not be assessed, but rather incorporated in the model as a source of variability that is expected as a component of the overall variability in the system. The six green roofs in four different settings were therefore tested separately as part of the second analysis phase unless the associated question was asked about the company rather than the green roof specifically. A fixed effect for each independent variable was used to determine the strength of the relationships between the dependent and independent variables in the presence of company-to-company variability and the remaining unexplained variability for each response. Categorical independent variables were interpreted through tables of descriptive statistics and Tukey's multiple comparison procedure followed the format of a

typical ANOVA analysis. The impact of continuous independent variables was characterized by interpreting the slope of the linear regression. As this is an observational study, statistical analyses represent associations and relationships only and do not imply causation.

### **3.5 Summary**

This chapter described the research design processes, how this study responded to the research questions, how each research question was answered, and which variables were used for this purpose. It also included a diagram of the research design. In addition, survey development and the questions were discussed in detail. In the final section, statistical procedures were described along with the rationale for using those procedures. The next chapter will cover the analysis results and address the responses to each research question.

## **CHAPTER 4. RESULTS**

This chapter describes the survey results and data analysis in an attempt to find the best answers to the research questions. Results have been presented in three sections. The first section includes a description of participant characteristics, demographic information, and current work conditions using descriptive statistics. The second section examines the relationship between office workers and green roofs in terms of stress and restoration. It also examines the role of employees' preferences in how they use their work environment and facilities. These include employees' break time attitudes regardless of work environment and onsite green roof use attitudes. Green roof use attitudes are preferred activities on the green roof, engagement with the green roof, preferred part or attribute of the green roof, and the preferred time to visit the green roof. This analysis is done for all workers and all green roofs combined. The findings for each of the research questions identified in the previous chapter are then provided. Differences in the restorative properties of each green roof and other potential factors that might influence the level of green roof restoration in each workplace are examined. Mixed model analyses have been run to explore the relationship between variables.

The following section presents the demographic information of the participants and descriptive attributes of the physical and psychosocial work environments by using preliminary and primary statistical analyses. As stated in Chapter 2, 95% and 90% confidence intervals have been used throughout the data analysis.

### **4.1 Description of Sample Population**

Several offices which provide physical or visual green roof access to all were selected for this study. While some offices were still working remotely after COVID-19, some

employers did not allow external surveys to be distributed to their employees. Four companies distributed the survey to their employees. Regardless of rank or position, all employees received the survey by email through the companies' Human Resources officers. 179 employees completed more than 50% of the online survey among these four companies.

Socio-demographic characteristics of the sample population are shown in Table 1 below. Most participants were female (56.4%) and between 35 and 64 years old (79.5%). None of the participants were younger than 25 years old, and only three were older than 65 (1.9%). The sample population was also well-educated, with almost half (41.8%) having a bachelor's degree, and almost the same number having an advanced degree (master's+) (41.2%).

Employment duration was measured to understand individual workplace and green roof experience. Since these measurements were done after COVID-19 openings, employees had been hired during the pandemic and have worked remotely since then. That situation might prevent employees from getting enough physical and mental experience with the green roof and other workplace amenities. For that reason, employees working less than two years and working remotely were excluded from the data. Survey results indicate that most employees have worked in the same workplace for more than two years (71.2%). Also, all newly hired employees indicated they were either hybrid or onsite. This means they had experienced the workplace environment in person enough to experience workplace facilities.

**Table 1. Demographic Characteristics of Sample Population**

<b>Gender</b>	<b>Arch n (%)</b>	<b>ProfA 1 n (%)</b>	<b>ProfA 2 n (%)</b>	<b>BioT n (%)</b>	<b>Total n (%)</b>
Female	19 (50%)	41(70.7%)	14(63.6%)	14(37.8%)	88(56.7%)
Male	18(47.4%)	16(27.6%)	8 (36.4%)	23(62.2%)	65(41.9%)
Other	1 (2.6%)	1 (1.7%)	0	0	2 (1.3%)
<b>Age</b>					
25-34	17(39.5%)	5 (7.2%)	3 (12.5%)	8 (22.2%)	33(22.3%)
35-44	19(44.2%)	8 (11.6%)	3 (12.5%)	11(30.5%)	41(27.7%)
45-54	3 (7%)	17(24.6%)	7(29.2%)	12(33.3%)	39(26.3%)
55-64	1 (2.3%)	19(27.5%)	8 (33.3%)	4 (11.1%)	32(21.6%)
65+	0	2 (3%)	0	1 (2.8%)	3 (2%)
No answer	3 (7%)	18 (26%)	3 (12.5%)	7 (16.3%)	31(17.3%)
<b>Education level</b>					
High school	0	2 (2.9%)	1 (4.2%)	1 (2.3%)	4 (2.2%)
2-year or associate	0	3 (4.3%)	0	3 (7%)	6 (3.3%)
Bachelor's	17(39.5%)	28(40.6%)	12 (50%)	18(41.8%)	75(41.9%)

Master's	22(51.2%)	15(21.7%)	8 (33.3%)	16(37.2%)	61(34%)
PhD +	0	10(14.5%)	1 (4.2%)	2 (4.6%)	13 (7.2%)
No answer	4 (9.3%)	11(15.9%)	2 (8.3%)	3 (7%)	20(11.2%)
<hr/>					
<b>Employment duration</b>					
<hr/>					
< 2 years	11(25.6%)	10(14.5%)	3 (12.5%)	9 (20.9%)	33(18.4%)
2-6 years	20(46.5%)	20 (29%)	11(45.8%)	9 (20.9%)	60(33.5%)
6-10 years	6 (13.9%)	6 (8.7%)	5 (20.9%)	9 (20.9%)	26(14.5%)
10+ years	3 (7%)	22(31.9%)	3 (12.5%)	13(30.2%)	41(22.9%)
No answer	3 (7%)	11(15.9%)	2 (8.3%)	3 (7%)	19(10.6%)
<hr/>					

Data shows a highly representative and diverse group of people among the participants in terms of age and gender. In other words, there is enough variety among the sample group to show different kinds of green roof experiences to explain the research questions. As most participants had at least a college degree, the sample also consisted of well-educated people. More than 80% of participants who worked before COVID-19 closures also showed that their experience with workplace facilities was adequate for choosing the best one for themselves for break times. Current workplace trends in terms of work conditions are examined below.

#### ***4.1.1 Description of Work Conditions/Situation of Sample Group***

Due to the COVID-19 pandemic, most offices have been working remotely or partially remotely since March 2020, which overlapped with the time frame for survey



completion. For that reason, there were some questions on the survey about whether employees were fully or partially remote and how many days they worked onsite to understand their current green roof exposure or access. As of survey distribution dates, more than half of the sample population (68%) worked hybrid (partially remote), and only a little over 20% of the population (22.5%) worked entirely onsite. Of those who worked hybrid/partially remote, most employees (66.4%) worked two days a week, and 22.7% of the population worked three days a week or more.

**Table 2.** *Work Conditions of Sample Population*

<b>Work location</b>	<b>Arch n (%)</b>	<b>ProfA 1 n (%)</b>	<b>ProfA 2 n (%)</b>	<b>BioT n (%)</b>	<b>Total n (%)</b>
Onsite	3 (7%)	20 (29.4%)	2 (8.3%)	19 (44.2%)	44 (24.7%)
Hybrid	34 (79%)	43 (63.2%)	18 (75%)	23 (53.5%)	118 (66.3%)
Remote	6 (14%)	5 (7.4%)	4 (16.7%)	1 (2.3%)	16 (9%)
<b>Onsite work hours</b>					
1-8	3 (9.4%)	1 (2.4%)	7 (41.2%)	1 (4.5%)	12 (10.6%)
9-16	20 (62.5%)	37 (88%)	8 (47.1%)	8 (36.3%)	73 (64.6%)
17-24	6 (18.7%)	3 (7.2%)	2 (11.8%)	10 (45.4%)	21 (18.6%)
25-40	3 (9.4%)	1 (2.4%)	0	3 (13.6%)	7 (6.2%)

## 4.2 Description of Work Environment

Employee attitudes were described under two categories: employee attitudes regarding break time and green roof-related attitudes. This section is essential to understand the employee preferences regarding break time places and reasons for those preferences, as well as green roof use patterns. Overall, this section examines whether employees prefer

to visit the green roof during break time, for what reason they do or do not, what activities employees prefer to do on the green roof, on what part of the green roof they do these activities, and the specific time they prefer to visit the green roof.

Six open-ended questions were included in this section. Since every person listed preferences, every response was coded. In other words, same person's response could count in multiple times. Therefore, participant numbers and respondent numbers may not be the same.

#### ***4.2.1 Employee Preferences***

This section examines employees' preference patterns by asking about their overall preferred break places onsite and in remote work environments, along with the reasons that shape those preferences. In the next section, green roof-specific questions were asked after an idea about the place and importance of green roofs in their routine had been obtained. Their green roof use pattern was analyzed by investigating preferred activities, times to visit, and parts to visit on the green roof.

According to their answers, an exploratory analysis was applied. All the open-ended questions in this section were coded by content analysis, separated by company and even green roof, as necessary. Different numbers of categories for each question were created, as listed in the tables below.

Among the 128 employees working either fully or partially remotely who answered this question, 92 of them (71.8%) indicated that they had a specific place to take a break in or around their remote workplaces (Table 3). Based on the content analysis, five places were identified: the backyard/front yard of a house, another room/kitchen,

outside/neighborhood, balcony/rooftop/porch, and exercise room. Apart from the specified places, some employees answered, 'anywhere other than my workstation.' This category is included in the table below but not categorized as a place.

Almost half of the remote or partially remote working employees who had a preferred break place preferred to go 'outside of their remote workplaces' (47.8%), mainly for a walk in the neighborhood or visit to a nearby park. 34.8% of remote/partially remote employees preferred to take a break on their 'balcony, rooftop,' while 20.6% preferred 'backyard/front yard of their homes.' In other words, most participants preferred using open spaces adjacent to their remote workplaces for their break time. Only 30.3% of the specified group preferred an indoor break area ('another room in the same place' and exercise room). In comparison, three people (3.2%) did not specify the space other than saying 'anywhere other than my workstation.'

**Table 3.** Preferred Break Places at Remote Work Locations

<b>Brake Place – Remote</b>	<b>Arch N= 29 (74.3%)</b>	<b>ProfA 1 N=35 (76%)</b>	<b>ProfA 2 N=16 (76.2%)</b>	<b>BioT N=12 (54.5%)</b>	<b>Total N=92 (71.8%)</b>
Outside/Neighborhood	18 (41.8%)	18 (26%)	6 (37.5%)	2 (16.6%)	44 (47.8%)
Balcony/Rooftop/Porch	9 (20.9%)	12 (17.4%)	5 (31.2%)	6 (50%)	32 (34.8%)
Another Room/Kitchen	6 (13.9%)	10 (14.5%)	6 (37.5%)	3 (25%)	25 (27.1%)
Back/Front yard	5 (11.6%)	3 (4.3%)	7 (43.7%)	4 (33.3%)	19 (20.6%)
Away From Desk	3 (7%)	-	-	-	3 (3.2%)
Sunroom	-	3 (4.3%)	-	-	3 (3.2%)
Exercise room	-	3 (4.3%)	-	-	3 (3.2%)

When the results were compared among companies, employees from the architecture company (Arch) (41.8%) and professional association 1 (ProfA 1) (26%) distinctly preferred to take breaks outside in the neighborhood. The employees from professional association 2 (ProfA 2) and the biotech company (BioT) also preferred to take breaks outside, but in adjacent outdoor places such as the yard of their home (43.7%) and balcony/rooftop/porch (50%), respectively.

Among four companies, 127 people (79.8% of respondents) out of 159 total respondents answered 'yes' to the question 'At your workplace, do you have any specific place to go to take a break from work?' (Table 4). While more than half of the total respondents (74%) preferred a green roof to spend their break time, participants also preferred to go outside around the neighborhood (34.6%) when they worked onsite.

**Table 4.** Preferred Break Places Onsite at Workplace

<b>Brake Place - Onsite</b>	<b>Arch N=34 (91.9%)</b>	<b>ProfA 1 N=49 (79%)</b>	<b>ProfA 2 N=16 (84.2%)</b>	<b>BioT N= 28 (68.3%)</b>	<b>Total N=127 (79.8%)</b>
Terrace / Green roof	30 (69.7%)	38 (79.1%)	9 (37.5%)	17 (62.9%)	94 (74.0%)
Outside/Neighborhood Park	18 (41.8%)	18 (26%)	6 (37.5%)	2 (16.7%)	44 (34.6%)
Kitchen	10 (23.2%)	17 (35.4%)	2 (8.3%)	13 (48.1%)	42 (33.0%)
Ground floor/Plaza	-	9 (18.7%)	5 (20.8%)	3 (11.1%)	17 (13.4%)
Away From Workspace	3 (7%)	6 (12.5%)	-	-	9 (7.0%)
Gym	-	3 (6.2%)	1 (4.17%)	2 (7.4%)	6 (4.7%)
Wellness room	-	-	4 (16.6%)	-	4 (3.1%)
Golf simulator	-	-	-	2 (7.4%)	2 (1.6%)

In total, 71.1% of responses included outdoor spaces ('terrace/green roof,' 'outside/neighborhood park,' 'ground floor/plaza'). In comparison, only 24.7% of responses included indoor space, which was 'Kitchen,' 'gym,' 'wellness room,' and 'golf simulator.' 4.1% of responses only mentioned being 'away from the workstation' and did not specify the area.

Participants' first reason for preferring a break area was 'engaging with nature' (28.8%). Nature means greenery, vegetation, and wildlife such as bees. Even if this domain is shown to be significantly popular among the three companies, the architecture company (Arch) (44.2%) has the highest value among them all. One of the reasons for this might be that they had beehives on one of their green roofs, and employees were taking care of the beehives. Participants of that company also mentioned bees many times in this part of the survey. Although most people preferred to spend their break time on a green roof or in other outdoor spaces, engaging with nature was not mentioned as a reason in place choice for the biotechnology company (BioT) employees. Since they have several green roofs onsite, and two green roofs are similar in size to those of the other three companies, this result is surprising.

**Table 5.** *Reasons of the On-site Break Place Preference*

<b>Reasons – Onsite break place</b>	<b>Arch n (%)</b>	<b>ProfA 1 n (%)</b>	<b>ProfA 2 n (%)</b>	<b>BioT n (%)</b>	<b>Total n (%)</b>
Engage with Nature	19 (44.2%)	9 (16%)	6 (31.6%)	-	34 (28.8%)
Destress / Calm / Refuge	5 (11.6%)	12 (21.4%)	6 (31.6%)	6 (24%)	29 (20.3%)
View	8 (18.6%)	12 (21.4%)	2 (10.5%)	3 (37.5%)	25 (19.8%)
Being Outside	6 (13.9%)	11 (19.6%)	2 (10.5%)	3 (12%)	22 (15.4%)

Fresh Air	6 (13.9%)	11 (19.6%)	3 (15.8%)	2 (8%)	22 (15.4%)
Daylight / Sunlight	9 (21%)	6 (10.7%)	2 (10.5%)	2 (8%)	19 (13.3%)
Change of Scenery	8 (18.6%)	4 (7.1%)	2 (10.5%)	1 (4%)	15 (10.5%)
Place/building itself	-	9 (16%)	1 (5.2%)	3 (12%)	13 (13%)
Socialization	2 (4.6%)	4 (7.1%)	3 (15.8%)	2 (8%)	11 (7.7%)
Atmosphere	-	3 (5.3%)	3 (15.8%)	4 (16%)	10 (10%)
Seating / Comfort	4 (9.3%)	4 (7.1%)	1 (5.2%)	1 (4%)	10 (7%)
Location/Access	-	5 (8.9%)	-	2 (8%)	7 (8.6%)
Cleanness	-	6 (10.7%)	-	-	6 (10.7%)
Place to Work	-	3 (5.3%)	1 (5.2%)	-	4 (5.33)

Employees among the companies also valued destressing at break times and spending them in calm places (20.3%). The view (19.8%) was also a significant part of their preference, especially for professional association 1 (ProfA 1). Even though all companies have a view, professional association 1 (ProfA 1) has a view that includes a water element and urban nature. This factor has likely affected the results.

Being outside (15.4%) and the fresh air (15.4%) were other important reasons listed for preferring a specific area to spend break time. Table 5 shows that other important factors were daylight/sunlight (13.3%) and change of scenery (10.5%). Interestingly, the opportunity for socialization (7.7%) was ranked very low for those who had a preferred break place. That could be due to employee stress, as stress keeps people away from socialization and tend to make them seek refuge or tranquility, as the results show.

### 4.3 Employee Green Roof Use Pattern

This section assesses the employee activities on the green roof by examining their preferences in terms of frequency, time, and place on the green roof. It also identifies employee engagement styles with the onsite green roof and their preferences regarding green roof use. There are four questions used to accomplish this. First, 'What activities do they like to do?' This was asked as an open-ended question. After examining the results separately for each green roof, 12 codes were identified through content analysis. The same answer was able to be included in more than one category in the content analysis. Factor analysis was then performed to identify common characteristics among responses. Second, employee engagement with the green roof through activities was analyzed based on their activities and frequency thereof. This question consisted of pre-identified categories ranked by employees with a 9-item 5-point Likert scale (1=never, 2=sometimes, 3=often, 4=very often, 5=always). After that, two more open-ended questions were asked about the preferred time to visit the green roof and the part of the green roof employees like to visit. The table for each of these questions is shown below.

The questions were asked separately for each green roof since there were six green roofs among four companies, each with distinctive characteristics. According to the question 'What do you usually do when you visit each green roof?' employees preferred to have lunch (48.2%) on the green roofs. Other than that, participants mostly visit the green roof for its tranquil features such as scenery/view (19.9%), to take fresh air and relaxation (18.9%), and to sit and relax (15.9%).

The green roofs included in this project had distinct differences, and each attracted different employee groups for different purposes. For example, green roof 2 (Arch 2)

(82.5%) was more preferred than green roof 1 (Arch 1) (38.4%) in the architecture company. Besides that, each green roof had its own best use and configuration. While green roof 2 (Arch 2) was visited for city view (32.5%), green roof 1 (Arch 1) in the architecture company was mostly preferred for observing vegetation and wildlife, particularly bees (30.7%). Almost half of the participants already mentioned beehives (45%) as their favorite part of the green roof, which is in another question below.

Since employees were not allowed to eat on the green roof because of possible rodent issues, the green roof at professional association 2 (ProfA 2) was preferred mainly for sitting and relaxation purposes (39.1%) as opposed to eating and drinking (8.7%). Unlike other companies, work (31.5%) was one of the most popular activities on the green roof for employees at professional association 1 (ProfA 1).

For the biotechnology company, eating and drinking had the highest score (33.3%), followed by sitting and relaxing with 25.9% for green roof 1 (BioT 1). On the other hand, socialization (26.6%) and taking fresh air/relaxation (26.6%) were the most popular activities for green roof 2 (BioT 2). Eating lunch and having coffee (13.3%) were not among the more-preferred activities on the green roof 2 (BioT 2). This result might be because of the site furniture (a couch) and its singular design. Design of the sitting area does not allow much privacy, mostly promote group sitting. Also, even if some vegetation exists on green roof 2 (BioT 2), none of the employees mentioned observing plants and wildlife. The 'green' part of this green roof seems invisible based on the answers.

These results are proof of the assumption that each company's green roof is suitable for different purposes, and employees prefer to use green roofs to different ends. Thus, it



is likely that the company factor would be closely associated with the other psychosocial factors, an insight that can be used to elucidate the phenomenon in greater detail.

**Table 6.** *Preferred Activities on the Green Roof*

Activities	Arch		ProfA 1	ProfA 2	BioT		Total
	G.R. 1 N=39 (90.7%)	G.R. 2 N=40 (93%)	N=57 (82.6%)	N=23 (95.8%)	G.R. 1 N=27 (62.7%)	G.R. 2 N=15 (34.8%)	N=201 (75.8%)
Lunch / Coffee	<b>15 (38.4%)</b>	<b>33(82.5%)</b>	<b>36 (63.1%)</b>	2 (8.7%)	<b>9(33.3%)</b>	2(13.3%)	97(48.2%)
Scenery / View	10 (25.6%)	<b>13(32.5%)</b>	9 (15.8%)	5 (21.7%)	1(3.7%)	2 (13.3%)	40(19.9%)
Relaxation / Taking Fresh air	5 (12.8%)	5 (12.5%)	<b>15 (26.3%)</b>	5 (21.7%)	4(14.8%)	<b>4(26.6%)</b>	38(18.9%)
Sit / Relax	6 (15.3%)	4 (10%)	4 (7%)	<b>9 (39.1%)</b>	<b>7(25.9%)</b>	2 (13.3%)	32(15.9%)
Phone calls	9 (23%)	10(25%)	3 (5.2%)	1 (4.3%)	5(18.5%)	1(6.6%)	29(14.4%)
Work	2(5.1%)	5 (12.5%)	<b>18(31.5%)</b>	1 (4.3%)	2(7.4%)	-	28(13.9%)
Socialization / Converse with coworkers	6 (15.3%)	7 (17.5%)	5 (8.7%)	1 (4.3%)	3(11.1%)	<b>4(26.6%)</b>	26(12.9%)
Observe plants and bees	<b>12 (30.7%)</b>	4 (10%)	2 (3.5%)	5 (21.7%)	2 (7.4%)	-	25(12.4%)
Events / Meetings	2 (5.1%)	4 (10%)	7 (12.2%)	6 (26%)	-	1(6.6%)	20(9.9%)
Read / Listen / Video	6 (15.3%)	3(7.5%)	6 (10.5%)	2 (8.7%)	2 (7.4%)	1(6.6%)	20(9.9%)
Wonder / Walk	2 (5.1%)	1 (2.5%)	2 (3.5%)	4 (17.3%)	3(11.1%)	2(13.3%)	14(6.9%)
Think/Focus	-	-	3 (5.2%)	1 (4.3%)	-	-	4 (1.9%)

Video / Trash	2(5.13%)	1 (2.5%)	-	-	-	1(6.6%)	4 (1.9%)
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More than half of the participants (60.2%) preferred to visit the green roof at a specific time of day (Table 7). The majority of participants among the companies chose to go out to the green roof during lunchtime (40.2%). This was followed by afternoons (30%) for a restorative break for their fatigued brain and sunset time for a view (14.1%). Some people preferred the green roof only for sun or warm weather (12.1%) while other employees preferred to use when it was quiet (2.5%), regardless of the time.

Depending on the time of day or year, as well as the design attributes of the green roof, employees preferred to use green roofs for different purposes. Due to it being the longest break, employees mostly preferred to visit green roofs during their lunch break. Even if employees were not allowed to eat their lunch on the professional association 2 green roof (ProfA 2), they still liked to spend their lunch break there. Apart from that, due to the lack of shade on both green roofs and the elimination of workday fatigue employees mentioned in their open-ended responses, people mostly preferred to visit green roofs in the late afternoon. Surprisingly, despite the flowering plants and wildlife, ‘spring and early summer’ (5.1%) was one of the least mentioned times to visit.

**Table 7.** *Specific Time to visit the Green Roof*

<b>Time to visit</b>	<b>Arch N=28 (70%)</b>	<b>ProfA 1 N=38 (60.3%)</b>	<b>ProfA 2 N=14 (58.3%)</b>	<b>BioT N= 20 (51.3%)</b>	<b>Total N=100 (60.2%)</b>
Lunchtime	<b>13 (32.5%)</b>	<b>20 (52.6%)</b>	3 (21.4%)	<b>9 (45%)</b>	45 (40.2%)
Afternoon	8 (20%)	10 (26.3%)	<b>4 (28.5%)</b>	8 (40%)	30 (26.8%)

Sunset	8 (20%)	3 (7.9%)	2 (14.3%)	-	13 (14.1%)
Morning	5 (12.5%)	7 (18.4%)	1 (7.1%)	2 (10%)	15 (13.4%)
Midday/Noon	-	6 (15.8%)	1 (7.1%)	3 (15%)	10 (13.9%)
Sunny/warm weather	5 (12.5%)	-	2 (14.3%)	2 (10%)	9 (12.1%)
Spring/Early summer	-	-	2 (14.3%)	1 (5%)	3 (5.1%)
Change of scenery	-	2 (5.2%)	-	1 (5%)	3 (5.1%)
When it is quiet	1 (2.5%)	-	-	-	1 (2.5%)

### 4.3.1 Psychosocial Environment of the Workplaces

This section describes the workplaces' mental and environmental conditions. Psychological conditions such as work-related distress and mental fatigue were measured using the Stress in General Scale's pressure subscale and the Multidimensional Fatigue Inventory's mental fatigue subscale, respectively. These both were converted to 5-point Likert scales to achieve more detailed results and cause less confusion among participants. A 10-item 5-point Likert scale was also developed within this study to assess the green roofs' perceived restorative value.

**4.3.1.1 Current Situation Regarding Work-Related Distress, Mental Fatigue, and Green Roof Restoration.** The three scales mentioned in the previous chapter were used to understand the restorative level of green roofs, work-related distress levels, and mental fatigue levels of employees. Each scale was rated with a 5-point Likert scale, and the results were calculated by summing the response rates and finding their mean value to eliminate the issue of missing responses. That way, all three results were between 0 (not at all agree/never) and 5 (very much agree/always).

When the restoration level, distress level, and mental fatigue level are divided into three categories of high, moderate, and low, the numbers are 0-1.66=low, 1.66-3.33=moderate, 3.33-5=high for each variable. According to those results (Table 8), overall, research participants had high distress levels (3.33<3.34), moderate mental fatigue levels (1.66<2.47<3.33), and high restoration levels (3.33<3.54).

According to measurements, professional association 2 (ProfA 2) had the highest degree of perceived distress level (3.44) and the lowest degree of mental fatigue (2.23). Their restoration level was also considerably high (3.76 out of 5). On the other hand, architecture company (Arch) had the highest degree of mental fatigue (2.82 out of 5) and the lowest degree of perceived distress (3.19 out of 5). Their restoration level was also the highest at 3.81 out of 5.

**Table 8.** *Work Related Distress, Mental Fatigue, and Subjective Restoration Level of Green Roof*

<b>Mental conditions (mean)</b>	<b>Arch (n)</b>	<b>ProfA 1 (n)</b>	<b>ProfA 2 (n)</b>	<b>BioT (n)</b>	<b>Combined (n)</b>
Distress level (min.-max.= .5-5)	<b><u>X=3.19</u></b> <b><u>(n=40)</u></b>	3.37 (n=59)	<b><u>3.44</u></b> <b><u>(n=24)</u></b>	3.39 (n=39)	3.34 (n=162)
Mental fatigue level (min.-max.= 1.42-5)	<b><u>2.82</u></b> <b><u>(n=39)</u></b>	2.40 (n=61)	<b><u>2.23</u></b> <b><u>(n=23)</u></b>	2.39 (n=40)	2.47 (n=163)
Restoration level (min.-max.= 1-4.5)	<b><u>3.81</u></b> <b><u>(n=38)</u></b>	3.37 (n=53)	3.76 (n=23)	<b><u>3.31</u></b> <b><u>(n=29)</u></b>	3.54 (n=143)

**4.3.1.2 What kinds of strategies employees did in terms of overcoming mental fatigue and how did the green roof visit fit into those strategies?** When employees were asked what strategy they used to overcome fatigue or concentration problems at work, 173 answered, and 131 (75.7%) stated that they had a specific strategy. 13 themes were extracted from the verbal descriptions given to open-ended questions using content analysis. While there were some overlaps between themes, each still had specific differences. While the most popular activity among employees was taking a walk (39%) either inside or outside, eating or drinking was the second most popular strategy (17%) to overcome fatigue in the workplace. Getting out (13%) and going out to the terrace (11%) were also included in overall strategies for all companies.

In their answers to this question, some respondents were not clear enough to define either the activity or the place. Therefore, the 'getting out' category would include either out of the building or on the terrace. The 'change in views' (8%) and 'take a break' (18%) categories were also vague in defining the site or activity but could not be made more specific due to how employees answered.

After establishing an understanding of the participant's background, attitudes, and work environment, the relationships between variables were examined as described below. The first step in this process was to assess the relationship between work-related distress, mental fatigue, and nature exposure including green roof use. Second, the relationship between nature exposure and the restorative impact of green roofs was explored. As a third aspect, the researcher examined how the psychosocial effects—mental fatigue and work-related stress—affect the restorative value of green roofs. After examining these relationships, several sub-questions were asked to find other factors that might contribute

to or interfere with the restorative level of green roofs. Those factors include attitude and perceptions toward green roofs, design and physical attributes of green roofs, and employee characteristics such as age, gender, and employment duration. The statistical analysis regarding the relationships mentioned above is examined below.

#### ***4.3.2 Research Question 1. What is the Impact of Green Roof Use Pattern on Employees' Mental Fatigue and Work-Related Distress?***

Linear mixed model analysis was used to answer the research question: “What is the impact of green roof use pattern on employees' mental fatigue and work-related distress?” The dependent variables in the statistical analysis for this research question were mental fatigue and work-related distress. The independent variables in the statistical analysis for this research question were preferred place for break time, weekly frequency of green roof visits, average time spent on the green roof at each visit, and window view content. Separate mixed linear models were fit which contained each independent variable as a fixed effect and company as a random effect. Recall from the methods section that company is a random effect to account for the similarity of responses within a company due to exposure to the same colleagues, company culture, policies, facilities, same green roof design, and physical attributes.

There are four independent variables related to green roof use pattern. A detailed description of the independent variables is in order. The preferred place for break time was already defined earlier in Table 4. An open-ended question was asked to employees regarding their preference for where they spent their break time. People were allowed to give more than one response. Then, their responses were analyzed and divided into eight categories through content analysis. Since this study is about green roof use, two new

variables were created using those eight categories: ‘break time users’ and ‘non-break time users.’ While employees who mentioned the green roof as a place for break time were included in ‘break time users,’ all other responses that did not mention green roof preference were combined into another group: ‘non-break time users.’ Eight categories were used for observational purposes, but the latter two categories were used in the analysis of research questions.

Continuing with the description of the independent variables, the weekly frequency of green roof visits was initially divided into five categories. After applying descriptive statistics, their numbers were not evenly distributed, so they were combined into three categories to better analyze the situation: seldom-never (less than 1/week), sometimes (1-2 days/week), and daily-often (more than 3 days/week). The average time spent on the green roof at each visit was measured pre-categorized: <5 minutes, 5-15 minutes, 15-30 minutes, and 30+ minutes. Window view content also served as a proxy for visual access to nature. This independent variable, along with the levels of building view, vegetation view, and both (building view plus vegetation view), was also included in this analysis.

- **Research Question 1.1. What is the Impact of Green Roof Use Pattern on Employees’ Work-Related Distress?** The results of the statistically significant effects from the individual linear mixed model analyses for the dependent variable of distress level are summarized in Table 9. Results are interpreted in the paragraphs and additional tables that follow in this section. Note that categorical independent variables are interpreted through tables of descriptive statistics and Tukey’s multiple comparison procedure following the format of a typical ANOVA analysis. The impact of continuous independent variables is characterized by interpreting the slope of the linear regression. As this is an

observational study, statistical analyses represent associations and relationships only and do not imply causation.

Fixed effect results show that the distress level of employees does not have a statistically significant association with spending break time on the green roof (p-value = 0.723), weekly frequency of green roof visits (p-value = 0.329), average time every employee spent on the green roof at each visit (p-value = 0.493), and window view content (p-value = 0.112). Company effect is a significant factor in variability only for the relationship between weekly frequency of green roof visits and distress level (p-value = 0.010). This means that, even if there is no significant relationship between the two variables, variance due to the company is significantly different from 0. For the remaining independent variables, there was not enough evidence to indicate that company to company variability was different from 0.

**Table 9.** Distress Level for Green Roof Use Pattern from Individual Linear Mixed Models

Distress Level	p-value	Company Random Effect p-value	Company percentage of total variance	Observation
Green roof users at break time	0.723	0.211	0.000	133
Weekly frequency of visit	0.329	0.010***	0.000	161
Average time spent on each visit	0.493	0.721	0.000	153
Window view content	0.112	0.515	0.000	151

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001



Having summarized the statistical significance, it is time to discuss the practical implications of these findings. As noted in the p-value discussion, there are no statistically significant differences in distress level as related to spending break time on the green roof. Table 10 emphasizes this point through the similarities in the values of the means relative to the variability. The difference between the two means is 0.06. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 10.** Distress Level Means by User Breaktime Category with 90% Confidence Intervals

Distress Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Non-green roof users	3.252	0.125	3.042	3.463
Green roof users	3.313	0.084	3.133	3.492

As noted in the p-value discussion, there is also no statistically significant association between distress level and weekly frequency of green roof visits. Table 11 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 11.** Distress Level Means by Weekly Frequency of Green Roof Visit Category with 90% Confidence Intervals

Distress Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Daily/Often (more than 3 days/week)	3.304	0.139	3.072	3.537

Sometimes (1-2 days/week)	3.235	0.136	2.992	3.479
Seldom/Never (less than 1/week)	3.466	0.093	3.297	3.636

As noted in the p-value discussion, there is also no statistically significant association between distress level and average time spent on each green roof visit. Table 12 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 12.** Distress Level Means by Average Time Spent on Each Green Roof Visits Category with 90% Confidence Intervals

Distress Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
<5 minutes	3.483	0.191	3.159	3.808
5-15 minutes	3.442	0.109	3.252	3.633
15-30 minutes	3.239	0.159	2.967	3.512
30+ minutes	3.179	0.173	2.884	3.473

As noted in the p-value discussion, there is also no statistically significant association between distress level and window view content. Table 13 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 13.** Distress Level Means by Window View Content Category with 90% Confidence Intervals

Distress Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Vegetation	2.891	0.234	2.502	3.280
Both (Vegetation + Buildings)	3.384	0.105	3.201	3.566
Buildings	3.422	0.114	3.187	3.656

- Research Question 1.2 What is the Impact of Green Roof Use Pattern on Employees' Mental Fatigue?** The results of the statistically significant effects from the individual linear mixed model analyses of the dependent variable of mental fatigue level are summarized in Table 14. Results are interpreted in the paragraphs and additional tables that follow in this section.

**Table 14.** Mental Fatigue Level for Green Roof Use Pattern from Individual Linear Mixed Models

Mental Fatigue Level	p-value	Company Random Effect p-value	Company percentage of total variance	Observation
Green roof users at break time	0.485	0.343	10.016	134
Weekly frequency of visit	0.552	0.401	7.109	162
Average time spent on each visit	0.586	0.370	7.690	154
Window view content	0.889	0.361	8.815	153

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Fixed effect results show that the mental fatigue level of employees does not have a statistically significant relationship with spending break time on the green roof (p-value = 0.485), weekly frequency of green roof visits (p-value = 0.552), average time each employee spent on the green roof at each visit (p-value = 0.586), and window view content (p-value = 0.889). No variability in company effect was detected from any of the above analyses.

Having summarized the statistical significance, it is time to discuss the practical implications of these findings. As noted in the p-value discussion, there are no statistically significant differences in mental fatigue level as related to spending break time on the green roof. Table 15 emphasizes this point through the similarities in the values of the means relative to the variability. The difference between the two means is 0.09. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 15.** Distress Level Means by User Breaktime Category with 90% Confidence Intervals

Distress Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Non-green roof users	2.559	0.156	2.255	2.864
Green roof users	2.465	0.139	2.159	2.771

As noted in the p-value discussion, there is also no statistically significant association between mental fatigue level and weekly frequency of green roof visits. Table 16 emphasizes this point through the similarities in the values of the means relative to the

variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 16.** Mental Fatigue Level Means by Weekly Frequency of Green Roof Visit  
Category with 90% Confidence Intervals

Mental Fatigue Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Daily/Often (more than 3 days/week)	2.589	0.170	2.279	2.899
Sometimes (1-2 days/week)	2.409	0.146	2.124	2.693
Seldom/Never (less than 1/week)	2.469	0.131	2.190	2.748

As noted in the p-value discussion, there is also no statistically significant association between mental fatigue level and average time spent on each green roof visit. Table 17 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 17.** Mental Fatigue Level Means by Average Time Spent on Each Green Roof Visits  
Category with 90% Confidence Intervals

Mental Fatigue Level	Mean	Std Error	Lower 90%	Upper 90%
<5 minutes	2.472	0.195	2.127	2.817
5-15 minutes	2.410	0.141	2.125	2.695
15-30 minutes	2.603	0.168	2.295	2.910
30+ minutes	2.585	0.174	2.271	2.899

As noted in the p-value discussion, there is also no statistically significant association between mental fatigue level and window view content. Table 18 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 18.** Mental Fatigue Level Means by Window View Content Category with 90% Confidence Intervals

Mental Fatigue Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Vegetation	2.439	0.214	2.070	2.807
Both (Vegetation + Buildings)	2.506	0.141	2.214	2.799
Buildings	2.450	0.141	2.156	2.744

In summary, both mental fatigue and work-related distress do not have any statistically significant relationship with green roof use pattern variables, including green roof use at break times, weekly green roof visit frequency, average time employees spent on the green roof at each visit, and window view content. Furthermore, no variability of company effect was detected from any of the above analyses.

***4.3.3 Research Question 2. Is there any level of nature exposure that influences the perceived restorative effect of an onsite green roof in workplaces?***

Linear mixed model analysis was used to answer the research question: “Is there any level of nature exposure that influences the perceived restorative effect of an onsite green roof in workplaces?” The dependent variable in the statistical analysis for this research question is the restorativeness level of green roofs. The independent variables in the

statistical analysis for this research question are preferred place for break time, weekly frequency of green roof visits, average time spent on green roof at each visit, and window view content. Detailed descriptions of these variables can be found in the text of the previous question. Separate mixed linear models were fit which contained each independent variable as a fixed effect and company as a random effect. Recall from the methods section that company is a random effect to account for the similarity of responses within a company due to exposure to the same colleagues, company culture, policies, facilities, green roof design, physical attributes, etc.

The results of the statistically significant effects from the individual linear mixed model analyses for the dependent variable of restorativeness level of green roofs are summarized in Table 19. Results are interpreted in the paragraphs and additional tables that follow in this section.

**Table 19.** Restorativeness Level of Green Roof Use Pattern from Individual Linear Mixed Models

Restorativeness Level	p-value	Company Random Effect p-value	Company percentage of total variance	Observation
Green roof users at break time	0.752	0.537	2.963	123
Weekly frequency of visit	0.007***	0.400	6.892	142
Average time spent on each visit	0.001****	0.521	3.060	140
Window view content	0.314	0.429	5.536	134

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Fixed effect results showed that the distress level of employees does not have a statistically significant association with spending break time on the green roof (p-value = 0.752) and window view content (p-value = 0.314). On the other hand, weekly frequency of green roof visits (p-value = 0.007) and average time each employee spent on the green roof at each visit (p-value = 0.001) have statistically significant associations with the restorative impact of green roofs. No variability in company effect was detected from any of the above analyses.

Having summarized the statistical significance, it is time to discuss the practical implications of these findings. As noted in the p-value discussion, there are no statistically significant differences in restorativeness level as related to spending break time on the green roof. Table 20 emphasizes this point through the similarities in the values of the means relative to the variability. The difference between the two means is 0.04. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 20.** Restoration Level Means by User Breaktime Category with 90% Confidence Intervals

Restoration Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Non-green roof users	3.615	0.139	3.370	3.860
Green roof users	3.664	0.107	3.443	3.884

According to fixed effect results, the weekly frequency of onsite green roof visits during workdays was significantly associated with the perceived restorative level of green roofs (P-value= 0.007). Table 21 emphasizes this point through variability or differences



in the values of the group means relative to the company and residual variability which comprise the error term for the test of this effect.

**Table 21.** Perceived Restoration Level Means by Weekly Frequency of Green Roof Visit Category with 90% Confidence Intervals

Perceived Restoration Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Daily/Often (more than 3 days/week)	3.949	0.178	3.623	4.276
Sometimes (1-2 days/week)	3.540	0.159	3.235	3.846
Seldom/Never (less than 1/week)	3.376	0.148	3.080	3.672

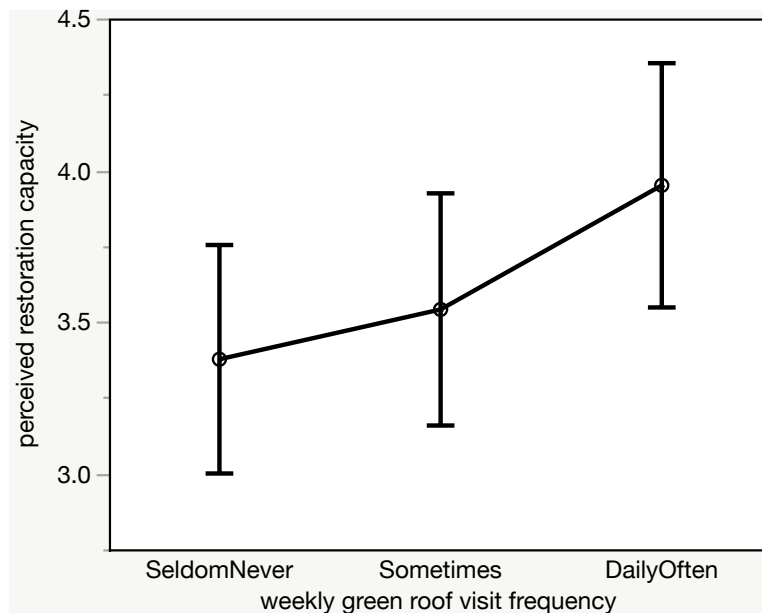


Figure 2. Perceived Restoration Levels by Weekly Frequency of Green Roof Visit

In accordance with statistical best practice, post hoc analysis was performed using Tukey’s Honestly Significant Difference Test (THSD). The results are interpreted with the estimated difference in each pair of group means accompanied by a confidence interval.

Post hoc test results indicate visiting the green roof at least three days a week was most likely to increase the perceived restoration score of the employees on average by increase (P-value = 0.006, 90% CI[0.193, 0.953]) no more than one day visiting per week. Also, three or more days of green roof visits differed significantly from visiting one to two days per week (P-value = 0.055, 90% CI[0.045, 0.773]). The statistical analysis indicates visiting the green roof at least three days in a week (Daily/Often) is positively related to a higher restoration level compared to less frequent weekly visits (Sometimes and Seldom/Never).

**Table 22.** Tukey post-hoc results for restorative value – weekly frequency of the green roof visits

Perceived Restoration Level	Mean Difference	Std Error	p-value	Lower 90% CI	Upper 90% CI
Daily/Often vs Seldom/Never	0.573	0.183	0.006***	0.193	0.953
Daily/Often vs Sometimes	0.409	0.175	0.055*	0.045	0.773
Seldom/Never vs Sometimes	-0.164	0.160	0.563	-0.496	0.168

\*p<.1, \*\*p<.05, \*\*\*p<0.01, \*\*\*\*p<.001

Fixed effect results of the linear mixed model show that the average visit duration of each green roof visit is a statistically significant predictor of perceived restorativeness level of green roofs (P-value = 0.001). Table 23 emphasizes this point through the similarities and variabilities in the values of the means relative to the variability.

**Table 23.** Perceived Restoration Level Means by Average Time Spent on Each Green Roof Visits Category with 90% Confidence Intervals

Perceived Restoration Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
<5 minutes	2.825	0.215	2.461	3.189
5-15 minutes	3.685	0.121	3.457	3.912
15-30 minutes	3.534	0.155	3.263	3.806
30+ minutes	3.794	0.167	3.506	4.083

In accordance with statistical best practice, post hoc analysis was performed using Tukey’s Honestly Significant Difference Test (THSD). The results are interpreted with the estimated difference in each pair of group means accompanied by a confidence interval.

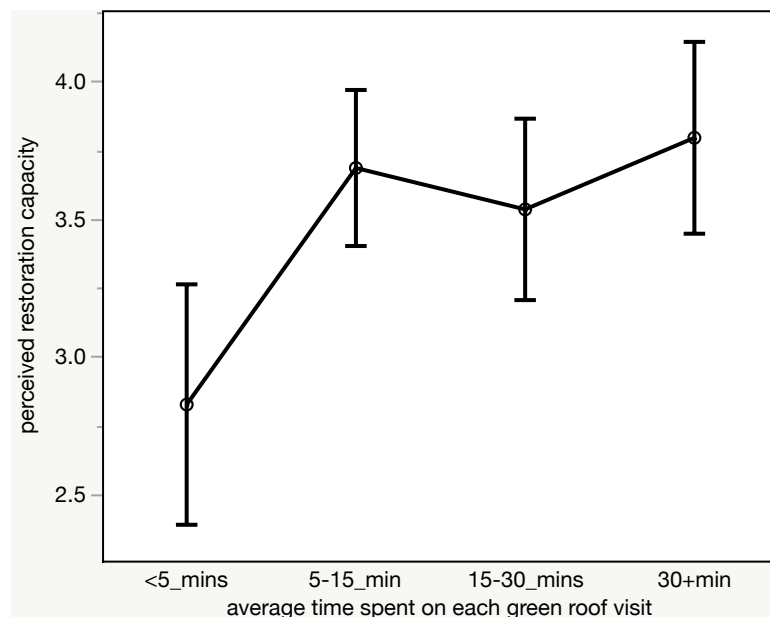


Figure 3. Perceived Restoration Level Means by Average Time Spent

The post hoc analysis shows that spending time less than 5 minutes on the green roof had a negative statistically significant relationship with 5-15 minutes (P-value = 0.001,

90% CI[-1.396, -0.322]), 15-30 minutes (P-value = 0.023, 90% CI[-1.278, -0.140]), and more than 30 minutes (P-value = 0.001, 90% CI[-1.558, -0.380]) on the green roof. In other words, spending more than 5 minutes on the green roof is highly associated with the perceived restoration.

**Table 24.** Tukey post hoc results for restorative value – weekly frequency of the green roof visits

Restoration Level	Mean Difference	Std Error	p-value	Lower 90%	Upper 90%
<5 min vs 5-15 min	-0.859	0.232	0.001****	-1.396	-0.322
<5 min vs 15-30 min	-0.709	0.245	0.023**	-1.278	-0.140
<5 min vs 30+ min	-0.969	0.254	0.001****	-1.558	-0.380
5-15 min vs 15-30 min	0.150	0.169	0.812	-0.242	0.543
5-15 min vs 30+ min	-0.109	0.181	0.930	-0.529	0.310
15-30 min vs 30+ min	-0.260	0.197	0.552	-0.716	0.196

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

As is noted in the p-value discussion, there is also no statistically significant association between perceived restoration level and window view content. Table 25 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 25.** Perceived Restoration Level Means by Window View Content Category with 90% Confidence Intervals

Perceived Restoration	Mean	Std Error	Lower 90% CI	Upper 90% CI
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Vegetation	3.794	0.258	3.359	4.228
Both (Vegetation + Buildings)	3.439	0.147	3.151	3.728
Buildings	3.605	0.148	3.313	3.897

In summary, perceived restoration level has a statistically significant relationship with weekly green roof visit frequency and average time employees spent on the green roof at each visit. On the other hand, perceived restoration level has no statistically significant association with green roof use at break times and window view content.

***4.3.4 Research Question 3. Are Employee Mental Fatigue, Perceived Work-Related Distress, and the Restorative Effects Related?***

Linear mixed model analysis will be used to answer the research question: “Are employee mental fatigue, perceived work-related distress, and the restorative effects related?”. The dependent variables in the statistical analysis for this research question are mental fatigue and work-related distress. The independent variable in the statistical analysis for this research question is perceived restoration level. Separate mixed linear models were fit which contained each dependent variable as a fixed effect and company as a random effect.

Perceived restoration level is the only independent variable in this analysis. Dependent and independent variables are continuous variables, which are the mean scores that can be anywhere between 0.5 and 5.

The results of the statistically significant effects from the linear mixed model analyses for the dependent variable of distress level are summarized in Table 26. Results are interpreted in the paragraph and additional table that follow in this section.

**Table 26.** Relationship Between Perceived Restoration Level and Distress Level of Employees from Linear Mixed Models

Distress Level	p-value	Company Random Effect p-value	Company percentage of total variance	Observation
Perceived Restoration	0.046**	0.323	0.000	140

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Fixed effect results showed that the distress level of employees has a statistically significant association with perceived restoration level of green roofs (p-value = 0.046).

No variability in company effect was detected from the above analyses.

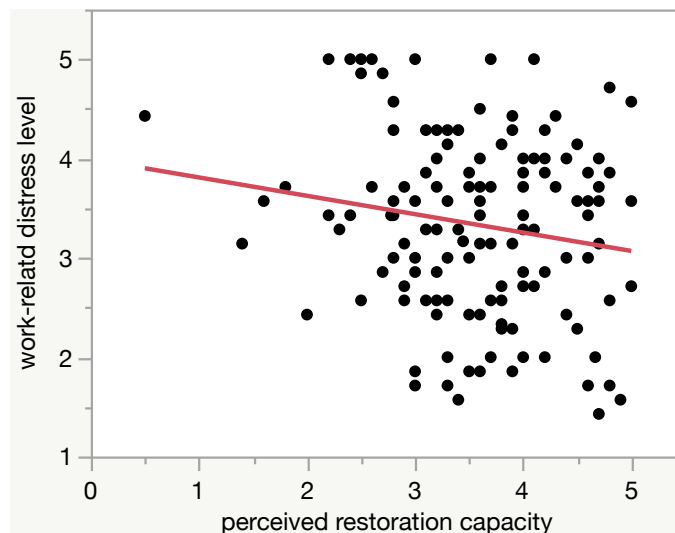


Figure 4. Relationship Between Perceived Restoration Level and Distress Level

Having summarized the statistical significance, it is time to discuss the practical implications of the findings. As noted in the p-value discussion, there is a statistically

significant difference in distress level as it relates to perceived restoration value of green roofs. Both variables are continuous, so their impact is characterized by interpreting the slope of the linear regression.

**Table 27.** Parameter Estimates of Perceived Restoration Level and Distress Level Relationship

	Estimate	Std Error	p-value	Lower 90% CI	Upper 90% CI
Intercept	3.994	0.336	<.0001****	3.437	4.551
Perceived Restoration	-0.185	0.092	0.046**	-0.337	-0.032

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Based on the estimated slope parameter, a 1 unit increase in perceived restoration results in an associated -0.185 decrease in distress level. In other words, there is sufficient evidence to support a negative association between distress level and perceived restoration level. Employees who reported higher perceived restoration had a lower distress level.

The results of the statistically significant effects from the linear mixed model analyses for the dependent variable of mental fatigue level are summarized in Table 28. Results are interpreted in the paragraph and additional table that follow in this section.

**Table 28.** Relationship Between Perceived Restoration Level and Mental Fatigue Level of Employees from Linear Mixed Models

Mental Fatigue Level	p-value	Company Random Effect p-value	Company percentage of total variance	Observation
Perceived Restoration	0.409	0.352	8.708	140

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Fixed effect results show that employee mental fatigue does not have a statistically significant association with perceived restoration level of green roofs (p-value = 0.409). Also, no variability in company effect was detected from the above analyses. Since there is no significant difference between variables, no interpretation of the slope was made as the slope is not significantly different from 0.

**4.3.5 Research Question 4. What Other Factors Possibly Contribute to or Interfere with the Restorative Value of Green Roofs?**

**4.3.5.1 Research Question 4.1. Does attitude and perception toward the green roof contribute to the restorative impact thereof?** Linear mixed model analysis was used to answer the research question: “Does attitude and perception toward green roofs contribute to their restorative impact?” The dependent variable in the statistical analysis for this research question is the restorativeness level of green roofs. The independent variable in the statistical analysis for this research question is employee attitude and perception of green roofs. Attitude and perception were fit into the respective models as fixed effects, whereas company was added as a random effect.



The result of the statistically significant effects from the linear mixed model analyses for the dependent variable of perceived restoration is summarized in Table 29. The result is interpreted in the paragraphs and additional tables that follow in this section.

**Table 29.** Perceived Restoration Level of Employee Attitude and Perception from Individual Linear Mixed Models

Restorativeness Level	p-value	Company Random Effect p-value	Company percentage of total variance	Observation
Attitude and Perception	0.000****	0.451	5.515	142

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Fixed effect results showed that the perceived restoration level of employees has a statistically significant association with employee attitude and perception about green roofs (p-value = 0.000). In other words, employees who had higher attitude-perception scores reported higher perceived restoration value for the green roof they visited. No variability in company effect was detected from any of the above analyses.

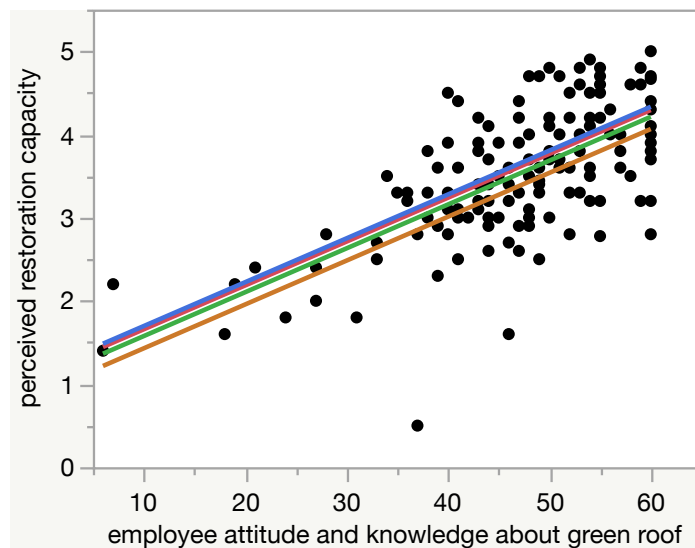


Figure 5. Perceived Restoration Levels of Employee Attitude and Perception

Having summarized the statistical significance, it is time to discuss the practical implications of this finding. As noted in the p-value discussion, there is a statistically significant difference in perceived restoration level as it relates to employee attitude and perception toward green roofs. Since both variables are continuous, their impact is characterized by interpreting the slope of the linear regression.

**Table 30.** Parameter Estimates of Perceived Restoration Level and Employee Attitude and Perception

	Estimate	Std Error	p-value	Lower 90% CI	Upper 90% CI
Intercept	1.061	0.260	0.000****	0.627	1.495
Attitude and Perception	0.052	0.005	<.000****	0.044	0.061

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Based on the estimated slope parameter, for every unit increase in attitude and perception, there is a 0.052 increase in perceived restoration. In other words, there is sufficient evidence to support a positive significant association between attitude and perception and perceived restoration level.

**4.3.5.2 Research Question 4.2. Do the design and the physical attributes influence the restorative effect of the green roof?** Participants indicated their preferred part of each green roof in response to the open-ended question: 'Is there any specific place or part of the green roof that you like the most?' Since every green roof varied in design,

features, and physical attributes, the content analysis needed to be site-specific and separate for each company and green roof.

Because the sample size for this question was small (below 40% of participants per company), a relationship could not be detected. For that reason, descriptive statistics of employee responses are provided below. In addition, the researcher's observations from site visits and expert reviews of each green roof were used to examine the physical attributes of the green roofs. The restorativeness value of each green roof attribute was also defined through employee restoration scores. The restorativeness score's mean value was calculated based on whoever mentioned a specific attribute.

The architecture company had two green roofs, and their content analysis was conducted separately. Among the 39 employees, 20 (51.3%) preferred to spend their time on green roof 1 (Arch 1). Half of the respondents mentioned raised platform on the northeast corner (50%) as their favorite part of the green roof. Beehives (45%) and view/scenery areas (35%) were other preferred areas. Other physical and design attributes of this green roof that employees mentioned were vegetation and the lower seating area.

Researcher's observation: The green roof was characterized by an abundance of prairie-like endemic vegetation in the center. Moreover, it was surrounded by tall buildings, creating a powerful sense of refuge. A raised platform and an edge of the planting bed were furnished with small tables and chairs. This way, individuals or small groups of two to three people seemed to be encouraged to make use of the space. Furthermore, the green roof had a serene atmosphere. A great deal of fascination was associated with the beehives on the green roof. This statement is also supported by its restoration value, which is the highest among the items in the below table 31.

**Table 31.** *Specifically Preferred Part of the Green Roof 1 (Arch 1)*

<b>Areas</b>	<b>Frequency</b>	<b>%</b>	<b>Restoration means</b>
Raised platform on the NE corner	10	50%	3.81
Beehives	9	45%	4.20
View / Scenery	7	35%	3.78
Wildflower / Vegetation	3	15%	3.63
Lower seating <sup>4</sup>	1	5%	4.70

The architecture company's other green roof (Arch 2) had six attributes. Those attributes included a large table/trellis, small tables at the southwest corner, a sunset view, a raised deck, vegetation, and a north walkway. From these attributes, the majority of employees preferred the communal tables under the trellis (45%). They also chose to visit this green roof for the availability of the view (40%) and small tables on the corner (35%).

Researcher's observation: This green roof was more spacious than the first. Additionally, it was divided into different areas that served different purposes. While it had a substantial conference table for socializing or outdoor meetings, some small tables and chairs were on the same green roof, separated by vegetation. As a result of the different furniture configurations, this green roof promoted spending time outside in big or small groups or even individually. Vegetation was varied on this green roof, from low-growing perennials to a couple of mid-size trees. The variations in plants and the wildlife they attract, such as praying mantises, added extra fascination and excitement to the green roof. Besides vegetation, this green roof offered a sunset view due to its location on a high

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<sup>4</sup> Since only one person mentioned lower seating, its restoration value was ignored.

building. That also promoted tranquility. Since it was facing the street, taller buildings were not adjacent to the green roof, and its prospect was much more apparent than that of the first green roof (Arch 2).

**Table 32.** *Specifically Preferred Part of the Green Roof 2 (Arch 2)*

<b>Areas</b>	<b>Frequency</b>	<b>%</b>	<b>Restoration means</b>
Large table/Trellis	11	45%	4.00
Sunset/View	8	40%	4.04
Small table/SW corner	7	35%	3.95
Vegetation	4	15%	4.12
Raised deck	3	10%	4.06
North walkway	1	5%	4.40

The 41 participants (68%) from the Professional association 1 (ProfA 1) did not prefer any specific part of the green roof, whereas 19 (32%) participants had. There were seven designs and/or physical attributes that participants preferred to visit on the green roof, primarily: the big communal table, sofa/couches at the edge, views at the railing overlooks, chairs at the perimeter, round tables, vegetation, and the shaded bar area. Almost half of the employees who responded mentioned a big table as their preferred part of the green roof (42%). Smaller round tables (26%) and sofas/couches on the roof edge (21%) that provided good views were the second and third most popular parts of the green roof among employees, respectively.

**Table 33.** *Specifically Preferred Part of the Green Roof (Professional Association 1)*

<b>Areas</b>	<b>Frequency</b>	<b>%</b>	<b>Restoration means</b>
Big table	8	42%	3.62
Round tables	6	26%	3.84
Sofa / Couches on the edge	5	21%	3.32
View / Railing overlooks	5	21%	3.16
Plants / Vegetation	5	21%	4.03
Chairs on the perimeter	3	15%	3.20
Openness / Shaded area	3	15%	3.00

Researcher's observation: This green roof offered different sitting options and other activities. The spacious table, preferred by most people, was adjacent to the building wall and provided a sense of refuge. Planters blocked the river view at the time of observation. However, the table promoted socialization by accommodating at least ten people at once. Round tables on the perimeter allowed visitors to sit individually or in small groups while enjoying the view. The other seating option was the couch. The far side of the green roof had two groups of couches, with the couches in each pair facing one other. While these couches provided comfortable group seating, they also offered prospect (view, even if not directly to the river) and balanced refuge (green roof perimeter wall).

Professional association 2 (ProfA 2) employees' attribute list included five categories: vine-shaded canopy, chairs on the patio, vegetated waves, roof view/scenery, and vegetation (variety). While 33.3% of the participating employees had a specific area on the green roof they preferred, 66.6% did not have any preference. 50% of participants who did

have a favored attribute mentioned vegetation as their preference, and 37.5% enjoyed being on the patio, specifically where the chairs were (Table 34).

**Table 34.** Specifically Preferred Part of the Green Roof (ProfA 2)

<b>Areas</b>	<b>Frequency</b>	<b>%</b>	<b>Restoration means</b>
Greenery / Variety of plants	4	50%	3.70
Chairs / Patio	3	37%	4.20
Vine shaded canopy	2	25%	3.25
Elevated planters	2	25%	4.40
View	1	12%	2.70

Researcher's observation: This green roof did not have tall plants except for one sumac tree on the high and back sides of the green roof. Elevated mound planters gave the green roof depth and an enclosed feeling when sitting. In terms of plants, some native plants—mostly sedum—were planted in the planters. Food was not allowed on the green roof, Wi-Fi was spotty, trash was not placed, and there was no good-sized table; the green roof therefore did not promote lunchtime socialization or work. There were only individual chairs for seating. The most practical use for employees was a tranquil space or a space to have phone calls.

The biotechnology company had two green roofs that were included in this project. Only 12 participants out of 34 had a preferred area on green roof 1 (BioT 1), and 8 had a specific preferred area on green roof 2 (BioT 2). The green roof 1 (BioT 1) had four places/parts that were preferred the most: shade/arbor, vegetation/tree, seating/bench, and

city view. Both green roofs' preferred areas were seating areas at 50%. The view was the second most popular part of green roof 2 (BioT 2) (37.5%).

**Table 35.** Specifically Preferred Part of the Green Roof 1 (BioT 1)

<b>Areas</b>	<b>Frequency</b>	<b>%</b>	<b>Restoration means</b>
Seating area / Bench	6	50%	3.46
View	2	16.7%	3.25
Shade / Arbor	2	16.7%	2.77
Vegetation / Tree	2	16.7%	2.50

Researcher's observation: This company's two green roofs differed in several aspects. First, while the first one (BioT 1) had several tables and chairs, as well as a couple of benches, the second green roof (BioT 2) had only two couches that faced each other as a seating element with a coffee table in the middle. So, while the first green roof (BioT 1) promoted individual or small group use of green roofs, the second one (BioT 2) mainly promoted group gatherings. The second most visible difference was in the planting design. While the first green roof (BioT 1) had flowering plants and a tree, the second green roof (BioT 2) only had short, dark green, narrow-leaf perennial plants. The first green roof (BioT 1) consequently had a greater potential to attract wildlife and arouse the fascination feeling among visitors. Both green roofs had arbor over seating elements but in different shapes. Both arbors were open structures and provided no shade to visitors. On the other hand, they created an enclosed feeling and, together with an open view from both green roofs, balanced prospect-refuge.



**Table 36.** Specifically Preferred Part of the Green Roof 2 (BioT 2)

<b>Areas</b>	<b>Frequency</b>	<b>%</b>	<b>Restoration means</b>
Seating/Couch	4	50%	3.64
View	3	37.5%	3.20
Covered space/Arbor	2	25%	3.90
Vegetation	2	25%	3.30

**4.3.5.3 Research Question 4.3. Is there any relationship between employee characteristics (i.e., demographic information, work type/work classification) and the perceived restorative effect of green roofs?** Linear mixed model analysis was used to answer the research question: “Is there any relationship between employee characteristics (i.e., demographic information, work type/work classification) and the perceived restorative effect of green roofs?” The dependent variable in the statistical analysis for this research question is perceived restoration. The independent variables in the statistical analysis for this research question are age, gender, education level, and employment duration. Separate mixed linear models were fit which contained each independent variable as a fixed effect and company as a random effect. Recall from the methods section that company is a random effect to account for the similarity of responses within a company due to exposure to the same conditions.

There are four independent variables related to the demographic character of participants. Each independent variable measured was pre-categorized. While age, education level, and employment duration are divided into four categories, gender difference is assessed with two categories.

The results of the statistically significant effects from the individual linear mixed model analyses for the dependent variable of perceived restoration are summarized in Table 37. Results are interpreted in the paragraphs and additional tables that follow in this section.

**Table 37.** Perceived Restoration Level for Employee Characteristics from Individual Linear Mixed Models

Perceived Restoration Level	p-value	Company Random Effect p-value	Company percentage of total variance	Observation
Age	0.649	0.384	8.182	128
Gender	0.628	0.388	7.827	130
Education Level	0.797	0.360	9.117	136
Employment Duration	0.204	0.446	5.516	138

\*p<.1, \*\*p<.05., \*\*\*p<0.01, \*\*\*\*p<.001

Fixed effect results showed that the perceived restoration level of employees does not have a statistically significant association with age (p-value = 0.649), gender (p-value = 0.628), education level (p-value = 0.797), or employment duration (p-value = 0.204). No variability in company effect was detected from the association between any independent variables and perceived restoration level.

Having summarized the statistical significance, it is time to discuss the practical implications of these findings. As noted in the p-value discussion, there are no statistically significant differences in perceived restoration level as it relates to age. Table 38 emphasizes this point through the similarities in the values of the means relative to the

variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 38.** Perceived Restoration Level Means by Age Category with 90% Confidence Intervals

Perceived Restoration	Mean	Std Error	Lower 90% CI	Upper 90% CI
25–34-year-old	3.633	0.193	3.284	3.982
35–44-year-old	3.493	0.175	3.163	3.822
45–54-year-old	3.623	0.179	3.295	3.951
55–64-year-old	3.749	0.184	3.410	4.088

As noted in the p-value discussion, there are also no statistically significant associations between perceived restoration level and gender of participants. Table 39 emphasizes this point through the similarities in the values of the means relative to the variability. The difference between the two means is 0.06. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 39.** Perceived Restoration Level Means by Gender Category with 90% Confidence Intervals

Perceived Restoration Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
Female	3.592	0.144	3.286	3.898
Male	3.659	0.151	3.355	3.963

As noted in the p-value discussion, there is also no statistically significant association between perceived restoration level and education level. Table 40 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 40.** Perceived Restoration Level Means by Education Level Category with 90% Confidence Intervals

Perceived Restoration Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
<2-year associate	3.783	0.403	3.112	4.453
Bachelors	3.633	0.154	3.311	3.955
Masters	3.558	0.162	3.234	3.883
PhD+	3.805	0.274	3.340	4.270

As noted in the p-value discussion, there is also no statistically significant association between perceived restoration level and employment duration. Table 41 emphasizes this point through the similarities in the values of the means relative to the variability. In accordance with statistical best practice, no post hoc testing was performed since there was no overall difference with this independent variable.

**Table 41.** Distress Level Means by Employment Duration Category with 90% Confidence Intervals

Perceived Restoration Level	Mean	Std Error	Lower 90% CI	Upper 90% CI
<2 year	3.841	0.181	3.522	4.160

2-6 year	3.597	0.146	3.315	3.880
6-10 year	3.431	0.189	3.103	3.760
10+ year	3.448	0.171	3.136	3.760

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In summary, perceived restoration level does not have any statistically significant relationship with employee characteristic variables including age, gender, education level, and employment duration. Furthermore, no company effect variability was detected from any of the above analyses.

## CHAPTER 5. DISCUSSION

The primary purpose of this study was to examine the association between the restorative value of the onsite green roof in the workplace and the employees' mental health, including work-related stress and mental fatigue. Other possible factors that might affect restorativeness, such as green roof use-related factors, employee attitude, employee demographic information, and physical attributes of green roofs, were also examined. These relationships were studied using a quantitative approach. The researcher collected data among four office settings through an online survey which included validated clinical scales. The study answered six research questions:

1. What is the impact of green roof use patterns on employee mental fatigue and work-related distress?
2. Does the level of exposure to nature influence the restorative effect of a green roof?
3. Are employee mental fatigue, perceived work-related distress, and the restorative effects related?
4. What factors are related to the restorative effect of the green roof?
  - a. Do employee attitudes and perceptions of green roofs influence the perceived restorative effect?
  - b. Do the design and physical attributes influence the perceived restorative effect of a green roof?
  - c. Do differences in employee characteristics (i.e., demographic information, work type/work classification) influence the perceived restorative effect of green roofs?

This chapter discusses the study's significant findings and examines how these findings can be adapted to the real world through possible design and policy implications. This chapter is organized into four sections. The first section summarizes the study findings on research questions and general observations on employee choices. The second section discusses the study's contributions to the field and the practical implications of the policy and design of the study. The third section describes the limitations of the study. The final section discusses ideas for future studies.

## **5.1 Main Findings and Implications**

### ***5.1.1 Office Employees and Indoor and Outdoor Places***

When employee break place preferences were compared between remote (Table 3) and onsite (Table 4), the similarity in the pattern was significant. While remote employees' first preference was to go out of the neighborhood for a walk, employees working onsite reported the same preference as the second most popular choice. The most popular onsite break place was the terrace/green roof, which was also the second most popular break place choice for remote locations. Indoor places such as the kitchen or another room in the same place were third choices at both locations. The fourth choice in both workplaces was the backyard/front yard, which was substituted with a ground floor garden/plaza in the onsite workplace. That is the adjacent ground-level open space.

Employees tend to go to open spaces for break time. While being in an adjacent place to the workplace during break time is important when they work onsite, it is less necessary for remote conditions. Most probably, employees intend to add some physical extent to break time activities besides being outside when possible.

It is surprising, however, that ground-level adjacent spaces are less popular to take breaks in than another room or kitchen in remote or onsite workplaces, while green roofs or balconies are among the most popular places for onsite employees. The reason for this might be the place design, the feeling that a private area provides, or the view aspect of the green roofs/balconies.

Self-report responses regarding reasons behind employees' preferred onsite break places (Table 5) partially explain the above-mentioned choices. The first six reasons participants listed define green roof choice very well: engaging with nature, destressing/refuge, view, being outside, fresh air, and daylight. The results were consistent with Korpela's (2003) research, as people prefer to be alone during the restoration process when they experience stress. As indicated by the data, employees are experiencing high stress, so it is not surprising that socialization was not as popular a reason as more tranquil choices. This suggests that green roofs should accommodate people who need tranquility/refuge, nature connection, view, outdoor features such as fresh air and daylight, and social engagement. For that purpose, creating different rooms<sup>5</sup> for different needs on the green roof is critical. Giving people an opportunity to find something suitable to their needs would be helpful in making them feel compatible, as the ART suggested.

### **5.1.2 Employee Attitudes Towards the Green Roof Design**

As there are six green roofs among the four companies in this study, each green roof is preferable for different purposes. All preferences point to a particular attribute of a specific green roof. While many employees at the architecture company had their lunch on both green roofs, the most popular reported activity was watching bees and plants on the

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<sup>5</sup> Distinct areas for specific functions such as socialization, lounging, mediating, or working.



green roof (Arch 1) that had a prairie-like native vegetation garden and beehives. Employees mostly preferred to use the second green roof (Arch 2) for its city and sunset views because this green roof offered a high viewpoint for visitors.

At the second company, professional association 1 (ProfA 1), employees preferred to have lunch on the green roof. This may be because this green roof offered different furniture arrangements and eating areas, such as large tables for large gatherings and small tables for smaller gatherings. Employees also used this green roof for work because of the smaller tables, outlets, and good Wi-Fi that employers provided on the roof. Relaxation was the third reason to visit the green roof, but almost as important as the previous reason among employees of this company. These three unconnected activities show how green roof attributes can be separated for different uses by dividing one big area into different rooms.

Professional association 2 (ProfA 2) did not allow employees to eat on the green roof, so employees' first reason for visiting the green roof was relaxation. Elevated mound shape planters on either side of the seating area created a comfortable enclosed feeling with vegetation when visitors were sitting.

The biotechnology company had two green roofs with different designs. Since the first green roof (BioT 1) had several small tables and chairs, eating lunch was the most popular activity there. The second most popular activity was sitting and relaxation due to the several different seating options different kinds of plants, including tall grasses, flowering plants, and a tree. While benches were surrounded from three sides by tall grasses and provided more privacy, chairs allowed users to sit individually or in small groups. Design-wise, the second green roof (BioT 2) was utterly different, and employee

preferences were shaped accordingly. Employees preferred to visit that green roof (BioT 2) for relaxation, fresh air, and socialization. Because that green roof had two couches that faced each other with a coffee table on either side of the couches, the furniture configuration did not allow for privacy. So, the design promoted group gatherings for coffee, because if multiple people were on the roof at the same time, there would be no other place for them to sit than the two couches. It was not comfortable to eat lunch on the second green roof (BioT 2) because there was no suitable table on which to lay food out. This green roof (BioT 2) was also distinctively different from others because of vegetation selection. Only two types of short compact non-flowering plants were planted repeatedly; the employees did not mention vegetation for this green roof (BioT 2). As a finding of how design contributes to green roof use, employee expectations and needs should be well-analyzed, and green roofs should be designed according to employee needs.

### ***5.1.3 Organizational Attitudes Toward Nature and Effects on Employee Choices***

The psychosocial environment of each office was different, as Table 6 shows. The company effect was also significant in mixed model analysis for some research questions. That being said, what are the company differences in this research? First, the companies belong to different industries, some of which are nature related or their approach is close enough to educate employees. For example, the architecture company (Arch) is working on sustainable and biophilic designs. Professional association 2 (ProfA 2) also works with environment-related fields. Employees at both companies are expected to be knowledgeable enough about nature and its benefits to be successful in their work. The other two companies work in fields not related to nature or the environment. It is also worth

noting the biotechnology (BioT) and architecture (Arch) companies also adapted biophilic design<sup>6</sup> and sustainability<sup>7</sup> attributes to interior design in their workplaces.

Green roof locations are another significant difference between companies. While two of the companies (ProfA 1 and ProfA 2) had green roofs on the top of their buildings, another company's green roof was at the same level as the office (Arch). Also, the fourth company's green roofs (BioT 1 and BioT 2) were in one building, on the same floor as some of the offices in the company. The location of the green roof is closely related to access. It is another criterion compared in this study.

According to the criteria mentioned above, only the architecture company (Arch) had moderate work-related stress, and others all had high-level stress. Moreover, all four companies had moderate perceived mental fatigue. On the other hand, differences are apparent in the restoration scores. Employees at the architecture company (Arch) and professional association 2 (ProfA 2) experienced above-average, high perceived restoration levels on these roofs. In contrast, professional association 1 (ProfA 1) had a high but below average level, and the pharmaceutical company (BioT) had a below average and moderate level of restoration. Based on these results, it is reasonable to assume people might be more aware of the benefits they get from nature when they work in a related field. Familiarity with nature might be another reason for these results.

This finding suggests something more profound than a need to educate employees, such as through behavior change interventions. Providing nature-based interventions to

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<sup>6</sup> Including interior walls were painted in natural tones such as green or earth tones, some nature pictures were on the walls, natural materials used as design materials such as wood as, indoor plants were placed in offices and hallways, and nature mimicking materials in decoration.

<sup>7</sup> Attention to use as much daylight as possible in interior design strategies (this is also one of biophilic design elements), fresh air circulation inside the building, solar panels to generate enough electric for the buildings and educational boards for employees to understand how effective the system is.

employees can increase their engagement with nature and enable them to incorporate nature into their everyday lives. Some of these intervention activities might include daily or weekly outdoor yoga or department-wide happy hour (versus company-wide) to increase the chance of equal participation and provide department-wide social engagement. Another alternative intervention might be a designated planting area (like a planting box, depending on the size of the green roof) for each department, such as a department-wide small-scale community garden. The planter's design and use can be the department's choice. Employees can create a kitchen or flower garden with annuals or perennials. Additionally, they can be responsible for maintaining the garden and take advantage of the benefits.

#### ***5.1.4 Physical and Visual Access Effects on Mental Fatigue***

In the survey, nature use and exposure patterns (whether employees visited the green roof at break time, the weekly frequency of those visits, the average time they spent on the green roof at each visit, and whether they had a vegetation view from the window they were most frequently exposed to during work hours) were examined. Nature use patterns and visual nature exposure were not found to be significantly associated with mental fatigue. In other words, neither of the above factors significantly impacts employees' mental fatigue.

Due to the location of green roofs and offices in busy areas of city centers, the 'only vegetation view' sample size was not big enough to compare a building view or a combined view. For that reason, window view measurements may not provide successful results. Since the survey measures the cumulative/overall impact of nature exposure on concentration and attention, the result may not accurately detect the actual impact. While the survey assesses mental fatigue subjectively and cross-sectionally, more investigation is

needed using longitudinal research with objective measurements to understand the phenomenon better. Objective measurements might include mental exercises such as the digit span test immediately before and after the exposure.

#### ***5.1.5 Physical and Visual Access Effects on Work-related Distress***

According to the findings, whether or not employees visit green roofs during break times, how much time employees spend on the green roof on each visit, or the frequency of visits in a week do not predict employees' work-related distress levels. However, no relationship was found between window view content and distress level. On the other hand, vegetation view content was close to being significantly related to perceived restoration. Due to the unbalanced sample size, that result may not be accurate. In order to conclude this finding, further investigation with more balanced data is needed since the sample size for window view content was not balanced with other categories.

#### ***5.1.6 Relationship Between Work-Related Distress and Restorativeness of Green Roofs***

The results were consistent with the Stress Reduction Theory (Ulrich, 1983), suggesting that onsite green roof exposure has a significant negative relationship with work-related stress. In conjunction with the theory, employees with lower distress levels reported higher restorativeness through green roof exposure. Company-wide results also support this finding. While the architecture company (Arch) had the highest restorativeness of green roofs, the same company also had the lowest level of employee distress.

Since work-related distress is an important issue among employees, employers might encourage employees to visit green roofs for recovery. Just as they can encourage small green roof breaks, they also can provide a couple of work nooks (physical individual spaces for work) on the green roof for employees.

However, no significant association was observed between mental fatigue and restoration through green roof exposure. In this study, the overall impact of green roofs on concentration was measured as mental fatigue. Since the results did not complement the well-established body of work, there might be some other factors contributing to the results. For this reason, further study is needed to understand the phenomenon better.

#### ***5.1.7 Exposure Duration and Perceived Restoration of Green Roof***

The data shows a significant positive association between the weekly frequency of green roof visits and the restoration score of green roofs. In other words, more frequent green roof visits are highly associated with higher restoration levels. In particular, three or more days of green roof visits in a week show a better relationship with restoration.

Moreover, the results were consistent with Korpela's (2008) and Kaplan and Kaplan's (1989) findings, as the increased time in the restorative environment provides higher restorative benefits. In this study, spending more than five minutes on the green roof was associated with higher restorative benefits. Employees who visited green roofs more than three days a week and spent more than five minutes at a time reported higher restoration than employees who spent less time or visited less frequently.

Even if further study is needed to determine time more precisely, this data supports encouragement of employees to visit green roofs more frequently per week for longer than five minutes at a time. Some beverage areas or dining tables can be placed on the green roof for that purpose. If there is enough space, work or casual outdoor meetings can be encouraged to be held on the green roof. These options can also be diversified according to analysis of employees' characters and interests. Study of whether or not work-related

visits to the green roof have a similar impact on restoration as a recreational visit is needed to conclude this implication.

### ***5.1.8 The Effect of Attitude and Knowledge about Green Roofs on Perceived***

#### ***Restoration***

Psychological restoration depends on several aspects such as aesthetic features and proximity of the restorative place, according to the two theories used in this research (Attention Restoration Theory and Stress Reduction Theory). In addition to these aspects, this research also found that the employees' attitudes toward green roofs and knowledge thereof are significantly associated with the restorative benefits of green roofs. In other words, whether employees think the green roof positively impacts the company and benefits the environment and themselves strongly contributes to their perceived restoration.

In light of the study results, educational programs to increase employee awareness of nature's benefits, including its impact on health, may effectively promote nature exposure and mental health in workplaces. Additionally, educating employees on the benefits and importance of green roofs for the urban environment would help them receive more mental health benefits. The education can be provided through brochures, educational boards on the walls of common areas, informative workshops, or gatherings with nature experts.

### ***5.1.9 Nature Observation and Restorative Value***

The most notable of all the physical attributes of green roofs is a diversity of nature. Even if only one company has an onsite specific species (bees) besides vegetation, the importance of bees for employees is visible not just in one question, but from overall survey responses. Having beehives onsite obviously added extra fascination/excitement to the

green roof, and employees seemed to be close to them. The approach of the company may have also had an impact on this result. Employers turned bee harvesting into an event, and that ritual became a part of company culture. That could be a factor that also affected employees' perceptions. The employees who mentioned bees also had a very significant restoration level. This finding is consistent with research by Fuller et al. (2007) regarding multiple species providing higher benefits to place visitors. This result may be different in different places. People are sometimes afraid of or allergic to living organisms, such as bees, birds, and bugs, but those species also attract place users' attention. This data is not a conclusive observation, but it is worth conducting further studies on diversity of nature on green roofs.

A further observation was derived from onsite visits to four companies, wherein the people who gave green roof tours noted that they had frequently seen birds, butterflies, bugs, and even praying mantises on the roofs. The survey results, however, did not reflect that. Most likely, this is because the employees did not see them regularly and did not feel they belong there. Even so, bees were accepted as a part of the green roof ecosystem by employees.

Aside from nature diversity, communal tables, views, and comfortable seating are employees' most valued design attributes. Employees did not mention much about the vegetation. Even though their first reason for going out to the green roof was engaging with nature, with socializing not being as popular, when employees were asked what their favorite part of the green roof was, they stated a big table and not much vegetation. Since their idea of 'nature' is unknown, they might have been referring to fresh air and daylight as nature. In terms of seating, not every company had a big table or couch. However,



employees mentioned the most preferred seating in this order based on availability: communal table, couch, small table and chairs, and single chairs. Research suggests several different seating options can be introduced to the green roof when possible: big tables for socialization, small tables for flexible use<sup>8</sup>, couches for comfortable seating.

Only one company's employees mentioned vegetation as the most liked and view as the least liked part of the green roof. They still mentioned seating as the second most important attribute. The reason for this might be their occupation being nature related or the design difference of the green roof (elevated mound shape planters).

Nevertheless, no restorative impact pattern was detected regarding design attributes and employee restoration. Seating elements were found to be most restorative in some companies, while vegetation was most restorative in others. Also, since each company's sample size is very small, it is hard to interpret each design attribute's restorative impact. This data is inconclusive and requires further research with a more significant sample size.

People seem to enjoy seeing other species/wildlife around their living environments. For that purpose, specific green roof designs can be studied and implemented to attract more diverse species. The design might include a small, separated area with vegetation to attract designated species so employees can observe wildlife but not disturb it except for maintenance. In this way, people can observe wildlife without disturbing it. Plants with berries, bird feeders, and some plants that attract butterflies can also be included in designs. In addition, plants with attractive foliage that are suitable for green roof environments can be planted to attract the attention of people and wildlife.

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<sup>8</sup> Flexible use as an individual or a small group, or can be combined for bigger groups, and good for lunch.

### ***5.1.10 Employee Demographics and Perceived Restoration***

The data showed no significant association between individual characteristics and the restorative impact of green roofs. None of the demographic groups benefit from green roofs in terms of restoration more than the others. This finding suggests that the perceived restorativeness level of green roofs is consistent across different ages, genders, and educational backgrounds among employees. Furthermore, employment duration does not have any significant association with the restorative value of green roofs.

## **5.2. Contributions and Policy Implications**

The most important contribution of this study is in assessing green roof exposure as a preventative approach to more severe results of work-related distress and mental fatigue. Rather than mail surveys and control environments, this study created online surveys separately for each workplace to capture site-specific features. This method allowed the researcher to visit work settings and combine survey results with the site observations. By doing so, it was possible to compare designs and psychosocial measurements across workplaces.

The study can contribute to the literature on green infrastructure, environmental psychology, and landscape architecture. Green roof designers, the green roof industry, and business owners especially can benefit from the design implications to create more restorative green roofs.

The study contributes to understanding the relationship between employees' green roof use patterns, preferences, and their relationship with mental restoration and work-related distress. Employee values regarding places where they prefer to spend time during break or work hours, whether in onsite or remote locations, contribute to understanding the

basic needs and choices employees have and make during workdays. This information would benefit designers in providing more appropriate workplace green roof designs and employees in applying more suitable interventions.

Nature alleviates stress, according to the findings of previous research. Since green roofs are one of the easiest and the most immediate nature options to access from workplaces for most offices in city centers, employers should consider installing and promoting green roofs among employees.

The frequent and more prolonged visit times of green roofs were associated with mental restoration. Since distress might eventually cause more severe health problems, research suggests additional policies and interventions need to address green roofs as a preventive health intervention. Related agencies and policymakers such as NIOSH should recommend green roof installation for employees to prevent work-related stress and promote mental restoration, as well as publish possible interventions to integrate green roof use into employees' everyday activities. After the green roof is shown to prevent health issues, insurance companies should incentivize companies to green roof installation.

Employee attitude and knowledge regarding green roof benefits were significantly related to the restorativeness of green roofs. Employers who install green roofs should therefore inform their employees of the benefits of green roofs in the workplace. They can include environmental education in their strategic plan to increase the restorative benefit of their green interventions.

Green roof design attributes affect green roof use and employee choices. Each attribute might also impact restorativeness differently, even if one of the findings suggests that the sample size was small. For that purpose, additional investigation is needed.

However, the pattern mentioned in this study can still be beneficial for designers and employers during the design process. Related associations, such as the American Society of Landscape Architects, might advocate promoting specific green roof designs or design elements for occupant health. They can also add additional chapters on green roofs to their educational sessions.

### **5.3. Limitations of the Study**

There were a few limitations of the study. The first and most significant limitation was the COVID-19 pandemic. Around the time of data collection, all offices were closed, including this study's sites—a situation that remained for almost two years. Data collection had to start during partial opening times, and most employees were still hybrid. As a result, full performance could not be measured. Because of partial closures, it was hard to find participants who would benefit from workplace green roofs, so the participation rate was very low in some offices. Another reason for the low participation rate could be not having an incentive for participation. Incentive could help to increase the participation rate.

Due to the controlled opening, the researcher could not interact with the participants. It took a lot of work to communicate with companies because most employees were remote or hybrid. Because of the lack of physical access to workplaces, the researcher could not obtain physical measurements such as heart rate as per the original research plan.

Since the measurements were subjective and the study was observational, no cause-and-effect relationship could be detected. Only possible relationships were found, but no casualties.

#### **5.4. Future Research Suggestions**

As a result of some of the research findings and limitations, several possibilities for further research were identified.

The sample population was mostly hybrid, and some of the responses were interpreted by participants, such as the weekly frequency of green roof visits. After work life returns to pre-COVID conditions, more observational studies can be done to measure green roof exposure's impact on work-related distress, mental fatigue, and mental restoration. If employees are in their workplaces more than four days and if they complete distress and fatigue scales at least twice a day (maybe before and after green roof exposure), results would be more robust. Questions about weekly frequency might also be more straightforward to ask in that situation.

While study findings suggest wildlife adds more excitement for green roof visitors, there was only one site that had a diverse ecosystem. The study sites were also all in city centers, and the wildlife aspect of the green roof could not be captured appropriately except for the bees that the architecture company had onsite. More investigation is needed to evaluate ecosystem impact on green roof use patterns and visitors' restoration levels. Additional research is needed to understand how biodiversity can be implemented in the green roof. What kinds of species can handle high altitudes? From those species, which ones can live in an urban environment? What kinds of plants would be more suitable to those species' needs?

In both remote and onsite workplaces, employees preferred outdoor areas for taking breaks. However, they added walking as a light physical exercise into that choice in remote locations, even though there was no green roof to promote physical activity in this study.

A further possible study could integrate physical activities into green roof design to promote higher mental restoration.

This study examined design attributes across six green roofs in terms of restoration and employee preferences. A more detailed study is needed to evaluate each design attribute in different green roofs at different locations to provide a more detailed understanding of the role of specific design attributes on mental fatigue, stress, and restoration. The frequency of use of each spatial room or area would contribute to the literature on green roof design.

This study suggests that workplace cultures, such as communication between management and workers and communication between workers regarding the green roof, have a potentially positive impact on mental restoration. A more detailed study is needed to verify this. It is essential to understand 1) if employers encourage employees to visit the green roof during breaks or work hours and encourage workers to engage in green roof activities, and 2) if this encouragement will influence mental restoration.

Lastly, the perceived restorativeness scale created for this study may be investigated further for validation purposes. That way, the best tool to measure green roof restorativeness can be found.

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## APPENDIX A. Key Terms

Several terms might be considered jargon throughout this study. In terms of having a basis for understanding and ruling out any interpretation, the following definitions pulled from existing literature:

**Green infrastructure:** “Section 502 of the Clean Water Act defines green infrastructure as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspire stormwater and reduce flows to sewer systems or to surface waters." (EPA, 2021)

**Green roofs:** “Green roofs are covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water. They are particularly cost-effective in dense urban areas where land values are high and on large industrial or office buildings where stormwater management costs are likely to be high.” (EPA, 2021)

**Fatigue:** “Fatigue is extreme tiredness and an inability to perform everyday tasks with your usual amount of energy.” (WebMD, 2021)

**Work-related distress:** “Work-related stress is the response people may have when presented with work demands and pressures that are not matched to their knowledge and abilities and which challenge their ability to cope.” (WHO, 2020)

## APPENDIX B. IRB Approval Letter



Division of Scholarly Integrity and  
Research Compliance  
Institutional Review Board  
North Hall Center, Suite 4120 (MC 0497)  
300 Turner Street NW  
Blacksburg, Virginia 24061  
540/231-3732  
ib@ut.edu  
<http://www.research.ut.edu/irb/app>

### MEMORANDUM

**DATE:** July 22, 2021  
**TO:** Patrick Miller, Sevda Ozturk Sari, Cermetrius Lynell Bohannon  
**FROM:** Virginia Tech Institutional Review Board (FWA00000572)  
**PROTOCOL TITLE:** THE INFLUENCE OF GREEN ROOFS ON EMPLOYEE WELLBEING IN WORKPLACES  
**IRB NUMBER:** 21-344

Effective July 22, 2021, the Virginia Tech Human Research Protection Program (HRPP) determined that this protocol meets the criteria for exemption from IRB review under 45 CFR 46.104(d) category (ies) 2(i),2(ii).

Ongoing IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities impact the exempt determination, please submit an amendment to the HRPP for a determination.

This exempt determination does not apply to any collaborating institution(s). The Virginia Tech HRPP and IRB cannot provide an exemption that overrides the jurisdiction of a local IRB or other institutional mechanism for determining exemptions.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

<https://secure.research.vt.edu/external/irb/responsibilities.htm>

(Please review responsibilities before beginning your research.)

### PROTOCOL INFORMATION:

Determined As: **Exempt, under 45 CFR 46.104(d) category(ies) 2(i),2(ii)**  
Protocol Determination Date: **July 22, 2021**

### ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

*Invent the Future*

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY  
*An equal opportunity, affirmative action institution*

## APPENDIX C. Continuous Variables List

<b>Descriptive Statistics</b>					
Variable	Observation	Mean	Std. Dev.	Min	Max
<b>attitude perception</b>	164	3.867	.932	0	5
Indicates a positive work environment	164	4.28	1.149	0	5
Indicates that the company is environmentally conscious	164	4.268	1.046	0	5
Provides opportunities for social interaction	164	3.756	1.297	0	5
Adds aesthetic value to the workplace	163	4.595	.851	0	5
Indicates that the company values employees	162	3.87	1.31	0	5
Improve employee physical and/or mental health	164	4.049	1.228	0	5
Provides environmental benefits	164	4.012	1.296	0	5
Builds and maintains employee morale	164	3.646	1.291	0	5
Reduces heating and cooling energy consumption	164	2.909	1.826	0	5
Good for air quality	164	3.677	1.51	0	5
Positively impact employee productivity / performance	164	3.561	1.487	0	5
Help to reduce/alleviate work-related stress	164	3.799	1.357	0	5
<b>Perceived restoration (mean)</b>	143	3.543	.822	.5	5
When I am on the green roof, I feel free from my daily routine	143	3.224	1.241	0	5
I feel calmer after being on the green roof	142	3.838	1.096	0	5
My concentration and alertness are increased after visiting the green roof	143	3.392	1.284	0	5
I forget everyday worries when I visit the green roof	143	2.469	1.192	0	5
On the green roof, everything seems and feels connected and interrelated	143	2.608	1.487	0	5
There is always something to attract my attention on the green roof	143	3.685	1.177	0	5
This is a good place to let my mind wander	143	3.615	1.144	0	5
The green roof is visually pleasing	143	4.608	.639	2	5
I feel good when I am on the green roof	143	4.266	1	0	5
I feel connected with nature on the green roof.	141	3.723	1.19	0	5
<b>mental fatigue mean</b>	163	2.479	.74	1	4.5
When I am doing something, I can keep my thoughts on it	163	2.663	.911	1	5
I can concentrate well	163	2.742	.96	1	4
It takes a lot of effort to concentrate on things	163	2.27	.875	1	5
My thoughts easily wander	163	2.239	.845	1	5
<b>distress level mean</b>	162	3.344	.896	1.429	5
Demanding	162	3.599	1.198	1	5



Pressured	161	3.292	1.248	1	5
Hectic	162	3.222	1.164	1	5
Pushed	158	2.475	1.27	1	5
Many things stressful	162	3.019	1.248	1	5
Calm	160	3.825	.975	1	5
Relaxed	160	3.956	1.012	1	5

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## APPENDIX D. Sample Survey Questions

Q5

▼  Display this question

If Which one below best describes your present work location? On-site (place of employment) Is Selected

Or Which one below best describes your present work location? Partially - on site and remote Is Selected

At your workplace, do you have any specific place to go to take a break from work?

Yes (please describe that place)

No

Q6

▼  Display this question

If When working remotely do you have any specific place to go to take a break from work? Yes (please describe that place) Is Selected

Or At your workplace, do you have any specific place to go to take a break from work? Yes (please describe that place) Is Selected

What do you like most about this place?

Q7

When you have difficulty concentrating or feel fatigued during work hours, do you have any strategy to overcome?

Yes (please specify)

No

Q8


Can you see out of the window while you are at your workstation at your place of employment?

Yes

No

No, but I pass by the window(s) during the workday

Q9

 [Display this question](#)

If Can you see out of the window while you are at your workstation at your place of employment? Yes Is Selected

Or Can you see out of the window while you are at your workstation at your place of employment? No, but I pass by the window(s) during the workday Is Selected

What do you see through the window from your workstation or the window you pass by most frequently at your place of employment?

- Vegetation (including green roof)
- Buildings
- Both
- Other

Q10

On average how many days a week do you visit 7thfloor green roof?

In a week...	Daily	Often (3-4 days/week)	Sometimes (1-2 days/week)	Seldom (less than 1 day/week)
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q11

On average how much time do you spend at the 7thfloor green roof when you visit?

- Less than 5 minutes
- 5 – 15 minutes
- 15 – 30 minutes
- 30+ minutes

Q12

When was the last time you visited 7th floor green roof at your place of employment? (approximately)

- Today
- Not today, but sometime this week
- Last week
- Last month
- Before COVID
- Never

Q13

What do you usually do when you visit 7th floor green roof? (list as many as you can below)

Usually...

Q14

When you visit the green roof to what extent do you engage in the following?

	never	sometimes	often	very often	always	don't know
Sit and relax	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Have lunch/snack by myself	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gather/engage with others	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Connect to the Internet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Enjoy nice views	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Observe plants and seasonal changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Observe wildlife (birds, butterflies,...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Enjoy the overall design of the space	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other reason(s) (please write specifically)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input type="text"/>						

Q15

Is there any specific place or part at the green roof that you like the most?

	yes	no
(If yes, please indicate what and why?) <input type="text"/>	<input type="radio"/>	<input type="radio"/>

Q19

To what extent do you agree with the following statements about the green roofs at your workplace?

	not at all agree	a little agree	somewhat agree	agree	very much agree	don't know
Indicates a positive work environment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indicates that the company is environmentally conscious	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provides opportunities to improve the relationship between employees (social interaction)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adds aesthetic value to the workplace	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indicates that the company values employees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improve employee physical and/or mental health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provides environmental benefits (i.e. reducing carbon footprint)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Builds and maintains employee morale	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reduces heating and cooling energy consumption	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Good for air quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Positively impact employee productivity/performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Help to reduce/alleviate work-related stress	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other reason(s) (please write below) <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q20

Please indicate whether you agree or disagree with the following characteristics as they relate to your job:

(Again, your response will remain confidential, and will not be reported or shared in a way that will reveal your individual identity.)

	not at all agree	a little agree	somewhat agree	agree	very much agree
Demanding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pressured	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hectic	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Calm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relaxed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Many things stressful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pushed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other word(s) to describe (please write specifically) <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q21

To what extent do the statements below describe how you have been feeling lately during or after work hours? (Again, your response will remain confidential, and will not be reported or shared in a way that identifies you.)

	never	sometimes	regularly	often
When I am doing something, I can keep my thoughts on it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can concentrate well	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It takes a lot of effort to concentrate on things	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My thoughts easily wander	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q22

Have you visited 7th floor green roof at your place of employment at least twice during your work time in this company and do you remember your experience?

- Yes
- No

Q25

What is your age?

- a) 18 – 24 years old
- b) 25-34 years old
- c) 35-44 years old
- d) 45-54 years old
- e) 55-64 years old
- f) 65 and over
- g) Prefer not to answer

Q26

What is your gender identity? (optional)

- Female
- Male
- Other

Q27

What is the highest degree or level of education you have completed?

- a) High school
- c) Two-year or associate of arts degree
- b) Bachelor's degree
- d) Master's degree
- e) PhD or higher
- f) Prefer not to answer