Nature contact and psychological well-being in adults

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Abstract

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There is growing evidence that contact with natural environments is associated with a multitude of human health benefits including improved mental health and psychological well-being. However, key gaps in the literature persist. Most studies are limited to cross-sectional correlations, and few studies assess *in situ* autonomic stress responses or control for additive genetic factors. We sought to address these gaps using three separate studies. First, we used longitudinal, ecological momentary assessment methods to investigate affective well-being, and depression, anxiety and stress-related symptoms in employees at Amazon (a multinational e-commerce company), who self-reported on average visitation to a company greenspace and on the naturalness of their day-to-day indoor and outdoor environments. We found that more natural outdoor environments were associated with less anxiety, even after controlling for activity or location types.

In another study, we randomly assigned individuals to nature, urban or control sites and used mobile, continuous psychophysiology sensors to track stress responses to an induced stressor, and to the recovery period afterward. We found higher levels parasympathetic and sympathetic activation during the stressor task in the nature and control conditions (compared to urban). We also found a steeper downward slope (i.e., faster recovery) of heart rate in the nature condition. This was the first study to continuously assess *in situ* responses to both an acute stressor and the recovery afterward within experimental conditions.

In the last study, adult twin pairs self-reported on change in behavior (time spent in nature) during COVID-19 and symptoms of depression, anxiety and stress. Data from both monozygotic and dizygotic twins allowed for twin covariances to be decomposed into biometric components (additive genetic, shared environment and unshared environment). Perceived decrease (compared to no perceived change) in time spent in nature was quasi-causally associated with higher anxiety and stress symptom scores. Results also suggested perceived increase in nature contact was quasi-causally associated with higher stress scores. This was the first study to investigate associations between nature contact and mental health outcomes during COVID-19 while controlling for between-family confounds.

Collectively, these studies advanced empirical understanding of mental health benefits associated with increased nature contact, and contribute to discourse on public health implications of salutary environmental exposures.

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DEDICATION

This dissertation is dedicated to my mother, Cho Won Hee.

Chapter 1. INTRODUCTION

The field of nature contact and human health has grown exponentially over the past few decades. Today, evidence has amassed that nature contact is associated with a wide range of outcomes (across physical, mental, social domains). The literature is dominated by cross-sectional designs and limited in its consideration of individual-level psychosocial traits that could moderate the relationship between nature contact and health. The objective of my doctoral research was to quantitatively investigate the effects of time spent in nature on mental health or psychological well-being outcomes.

In chapter 2, a review of the literature sets the academic context for the research detailed in the remaining chapters. Chapters 3 through 5 report three separate research studies conducted as part of the doctoral program at the School of Environmental and Forest Sciences at the University of Washington.

In chapter 3, I report a manuscript (submitted for publication) for an original research study that explored the effects of a company greenspace and day-to-day nature contact for mental health and psychological well-being in employees at Amazon (a multinational e-commerce company with headquarters in Seattle, WA). Occupational stress and related diseases (such as burnout) are pressing public health issues[1,2]. While nature contact has been shown to reduce stress and improve psychological well-being[3,4], few studies have investigated urban workers specifically. This study sought to fill knowledge gaps on urban workers as an understudied population. In addition, the use of longitudinal, ecological momentary assessment methodology[5] complemented existing cross-sectional studies[6,7] by improving estimation of effects and providing insights based on real-world nature contact. Findings suggested more natural outdoor environments may be particularly effective at reducing state anxiety, and the implications for providing accessible nature at or near work are discussed.

In chapter 4, I present a manuscript for an experimental study that used a randomized controlled design to investigate continuous physiological stress responses of participants in natural, urban or control environments. To date, very few studies have assessed continuous physiological stress responses[8]—such as the parasympathetic ("rest and digest") and sympathetic ("fight or flight") nervous systems—and no studies have measured both *in situ* acute stress response (i.e., with an induced stressor) and stress recovery within contrasting environmental conditions (e.g., nature vs. urban). The study also investigated effect modification by individual-level characteristics such as chronic stress levels or history of early life adversity, which may result in the "wear and tear" of physiological stress response systems and therefore inform how an individual responds to stress[9–11]. These potential moderators are understudied, and this chapter contributed to that knowledge gap. Results indicated that the nature environment is associated with more parasympathetic and sympathetic activity during an acute stressor, and faster stress recovery after the stress, compared to the urban environment after controlling for demographic traits, average environmental noise, temperature, baseline psychophysiological levels, and trait nature relatedness or nature contact frequency. In addition, exploratory subgroup analyses suggested those with more chronic stress or history of early adversity may benefit *more* from nature contact, which motivates further research of the potential for natural environments to promote greater population health.

Chapter 5 is a manuscript of secondary data analysis on survey data from adult twins and self-reported mental health during the COVID-19 pandemic. This is the first study to date on the mental health benefits of nature contact during COVID-19 using familial (e.g., twin) data to account for additive genetic factors. Associations between perceived change in nature contact and psychological well-being were adjusted for between-family additive genetic confounds in order to investigate any quasi-causal effects. Finally, fully adjusted models also controlled for age, sex, income and NDVI. Results suggested perceived decrease in nature contact was quasi-causally associated with higher anxiety and stress scores, after adjusting for covariates. Perceived increase in nature contact was also quasi-causally associated with higher stress scores. Evidence suggested additive genetic factors may affect psychological well-being, thereby motivating future studies that control for additive genetic and/or shared environmental confounds.

Collectively, this dissertation presents empirical contributions to key knowledge gaps in the field. Nature contact is outlined as a relatively safe and modifiable feature of the environment that should be considered a public health strategy for improved mental health outcomes.

1.1 REFERENCES

1. World Health Organization. Burn-out an “occupational phenomenon”: International Classification of Diseases. Accessed October 10, 2020. https://www.who.int/mental_health/evidence/burn-out/en/

2. U.S. Department of Health and Human Services. *Stress...At Work.*; 1999. https://www.cdc.gov/niosh/docs/99-101/pdfs/99-101.pdf?id=10.26616/NIOSHPUB99101

3. de Vries S, van Dillen SME, Groenewegen PP, Spreeuwenberg P. Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Soc Sci Med*. 2013;94:26-33. doi:10.1016/j.socscimed.2013.06.030

4. Hartig T, Mitchell R, de Vries S, Frumkin H. Nature and Health. *Annu Rev Public Health*. 2014;35(1):207-228. doi:10.1146/annurev-publhealth-032013-182443

5. Shiffman S, Stone AA, Hufford MR. Ecological Momentary Assessment. *Annu Rev Clin Psychol*. 2008;4(1):1-32. doi:10.1146/annurev.clinpsy.3.022806.091415

6. Largo-Wight E, Chen WW, Dodd V, Weiler R. Healthy Workplaces: The Effects of Nature Contact at Work on Employee Stress and Health. *Public Health Rep*. 2011;126(1_suppl):124-130. doi:10.1177/00333549111260S116

7. Shin WS. The influence of forest view through a window on job satisfaction and job stress. *Scand J For Res*. 2007;22(3):248-253. doi:10.1080/02827580701262733

8. Kondo MC, Jacoby SF, South EC. Does spending time outdoors reduce stress? A review of real-time stress response to outdoor environments. *Health Place*. 2018;51:136-150. doi:10.1016/j.healthplace.2018.03.001

9. Sapolsky RM. Social Status and Health in Humans and Other Animals. *Annu Rev Anthropol*. 2004;33(1):393-418. doi:10.1146/annurev.anthro.33.070203.144000

10. Shields GS, Slavich GM. Lifetime stress exposure and health: A review of contemporary assessment methods and biological mechanisms. *Soc Personal Psychol Compass*. 2017;11(8):e12335. doi:10.1111/spc3.12335

11. Cohen S, Janicki-Deverts D, Miller GE. Psychological Stress and Disease. *JAMA*. 2007;298(14):1685. doi:10.1001/jama.298.14.1685

Chapter 2. NATURE CONTACT AND HUMAN HEALTH: A REVIEW OF THE LITERATURE

This chapter seeks to briefly review the central tenets in the growing field of nature contact and human health, and to lay the scholarly foundations that have informed the research studies reported in chapters 3, 4 and 5. Although a broad overview of the field is offered, the current chapter will emphasize discussions from the literature on mental health or psychological well-being outcomes using quantitative methodologies, in order to align with the foci within succeeding chapters. Additionally, unless otherwise stated, the discussions here refer to adult populations in urban (as opposed to rural) areas, which again most reflects the populations covered in remaining chapters. Finally, this chapter is modified from a previously published report[1] for the Washington State Recreation and Conservation Office.

2.1 INVESTIGATING THE ROLE OF NATURAL ENVIRONMENTS IN HUMAN HEALTH: WHY NOW?

I shall never forget the rapture of fever patients over a bunch of bright-coloured flowers. I remember (in my own case) a nosegay of wild flowers being sent me, and from that moment recovery becoming more rapid.

Florence Nightingale, 1863[2]

Nature has been identified as a source of well-being since the earliest cities including ancient Rome, whose residents wrote of nature as an antidote to the congestion and stressors of the city[3,4]. In the western world, some of early known links between nature and well-being were in the context of gardens, such as those found in medieval monasteries and hospitals[5,6], and whose surviving blueprints informed religious and secular designs thereafter[5]. For example, renowned landscape architect, Frederick Law Olmsted, prominently embraced natural features in his designs (as evidenced by his famed Central Park in New York City, for instance) for their ability to foster rest and reinvigoration from the stresses of city living[7], and whose nature-based design principles went on to influence urban park systems for subsequent generations[8].

Meanwhile, our species' millennia-long history of living in close contact with natural environments is faced with a modern, global phenomenon: urbanization. Industrialization brought people to cities in unprecedented rates and in 2008, more people were living in urban areas than rural areas for the first time in

BOX 1. DEFINITIONS

Nature While there lacks a single, objective definition, researchers in the field of nature contact and human health often operationalize it as "the physical features of non-human origin including flora, fauna and abiotic elements like sunsets across spectra of degrees of human management and scale", which overlaps significantly with *natural environment* [1,2]. Nature, and natural environments, can embody gradients of scale (e.g., plants to parks) and wildness (e.g., a home garden to remote forests). While these embodiments can include water, desert and/or vegetation features, the literature on natural environments (with regard to human health outcomes) is dominated by green, vegetative features. See related term *greenspace*.

Greenspace refers to land covered with vegetation (grass, trees, etc.). Like *nature*, this can occur across scale and wildness spectra, such as sports fields and neighborhood parks to large forests.

Nature contact There are many forms of nature contact through various sensory pathways (e.g. visual, auditory) and through a range of activities and levels of contact awareness[2]. This term is often used interchangeably with *nature experience* and *nature exposure*, although the former tends to emphasize physical contact.
For the purposes of this dissertation, the term *nature contact* is preferred.

Mental health includes the absence of psychiatric diseases (as catalogued in The Diagnostic and Statistical Manual of Mental Disorders[4] or the International Classification of Diseases[5], for example). However, the World Health Organization defines *mental* health as "a state of well-being in which [an] individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community"[3]. *Mental health* therefore includes a flourishing and well-being--overlapping with the term *psychological well-being*, in addition to the traditional disease-oriented definition. In this dissertation's chapters, levels of depression, anxiety and stress are thus considered components of mental health.

Psychological well-being consists of both eudaimonic[6] (e.g., positive emotions and happiness) and hedonic[7] (positive relationships, self-acceptance, autonomy, and other components necessary to achieve one's purpose or potential).

human history[9]. Furthermore, the percentage of urban dwellers is projected to increase to almost 70% by 2050[10]. Although urban living in general is associated with benefits like improved access to health care, nutrition, and sanitation[11], it is also associated with increased stress[11,12]. While many human physiological stress responses (e.g. increased blood pressure, heart rate and cortisol production) were well-suited for our ancestors who needed to mobilize in situations requiring fight or flight[13,14], modern urban life is also characterized by psychosocial stress that results in the chronic activation of our stress response systems, prompting a myriad of poor health outcomes such as premature death, poorer cardiovascular health, and be powerfully predictive of risk for a myriad of psychiatric disorders[14–19]. It is thus not surprising that an increasing evidence base suggests a higher prevalence or incidence of psychiatric disorder in urban populations[20–25]; for instance, an analysis of 20 research studies from multiple European and non-European countries found a 21% increased risk for anxiety disorders and 39% increased risk for mood disorders in people who were in urban areas compared to rural areas[21].

Urban life is also associated with decreased nature contact[26–28]. Limited geographical areas are divided for residential and commercial use, often leaving little of pre-existing natural areas left. Yet, the scientific study of the effects of nature or natural environments (or lack thereof) on human health laid relatively dormant until recent decades. The field has since experienced exponential growth as well as expansion into an interdisciplinary topic[29], and this remains an important time to increase our understanding of how environmental characteristics (such as the presence of nature) and behaviors (such as spending time in natural environments) may impact health for urban populations. It is a critical and timely public health discussion to inform evidence-based land use and urban planning decisions amidst ongoing urbanization.

2.2 KEY GAPS IN EXISTING LITERATURE

To date, researchers have generally found positive associations between nature contact and a long list of improved human health outcomes spanning physical, mental health, psychological, cognitive and social health domains such as birthweight, diabetes, mortality, cardiovascular disease, aggression, and physical activity (see recent reviews for more comprehensive lists of outcomes[29–33]). This chapter will outline some of the overarching findings and trends across these health domains, with special focus on outcomes covered in later chapters (i.e., depression, anxiety, and stress related outcomes). However, key knowledge and methodological gaps remain in the existing literature base.

Firstly, the dominance of correlational studies is a widely acknowledged limitation to the literature's strength of evidence[39,40,42,43]. Although the breadth of evidence generally supporting positive associations between increased nature contact and multiple health benefits is promising, more experimental studies are needed to clarify whether nature contact plays a causal role in human health. In chapters 3 and 4, I illustrate the use of longitudinal and randomized controlled experiments that build on the cross-sectional work of existing studies, to explore the associations between natural environments and psychological well-being.

Relatedly, underused methodologies such as ecological momentary assessment and *in situ* physiological monitoring can reduce recall bias, enhance ecological (i.e., real-world) validity, and illuminate more nuanced relationships between different environments and health. In chapter 3, the short, repeated surveys on current environment and self-reported state psychological well-being reduced recall bias, and also assessed contextual factors like activity and location types with environments of varying degrees of naturalness, which few studies to date have done. In chapter 4, mobile, continuous monitoring of autonomic activity collected objective assessments of stress responses in more natural vs. more urban environments and added to the relatively few studies with such high resolution (e.g., minute-by-minute) data.

Furthermore, with very few exceptions[44], existing studies do not account for the role of additive genetic factors in the association between nature contact and psychological well-being. Although the etiology of mental health disorders remain elusive and complicated, genetic factors are believed to contribute substantially to one's risk of developing a psychiatric disorder[279,280]. Therefore, studies that seek to account for variances in psychological well-being outcomes attributed to genetic factors are motivated. In chapter 5, I outline a study using the classic twin model with survey data from mono- and di-zygotic twins that provided evidence for additive genetic contributions to variations in depression, anxiety and stress-related symptoms, and was able to adjust for these factors.

In addition to the gaps addressed by the studies in following chapters, much-needed future directions in the field include the elucidation causal pathways and the disentangling of the multiple contextual factors that differentiate more natural from more urban environments. Among potential causal pathways that could explain the multitude of observed human health benefits, the most well-supported is social cohesion (for instance, time spent in natural spaces may enhance the quality of one's experiences of social support, community bonding, and positive social interactions that in turn improve health outcomes[3,114,115]). However, other potential causal mechanisms like stress reduction (which may help explain other frequently observed benefits, such as reduced anxiety) need to be explored further. Finally, existing studies often compare psychological well-being outcomes in relatively natural and/or relatively urban environmental conditions. Future research can seek to explore how specific features of such environments (e.g., noise level and noise types, air pollution, density of other people, smells, light, types of natural features present, etc.) affect and/or confound associations with well-being.

2.3 PHYSICAL HEALTH BENEFITS

Key takeaways

- *Nature contact may be associated with a wide range of physical health outcomes including mortality, cardiovascular health, cancer, respiratory illness and diabetes.*
- *Overall, the body of evidence suggests that walkable natural areas may positively impact physical activity levels for adults and children.*

Physical health is core component of overall health and is informed by a multitude of factors including sleep, exercise and diet. A seminal 1984 study found positive effects of nature contact on physical health outcomes; post-operative patients randomly assigned to recovery rooms with views of nature experienced less pain and shorter recovery times after surgery than patients with views of a brick wall[34]. Researchers have since investigated associations between nature contact and various physical health outcomes, and the number of studies contributing to this body of knowledge has surged in recent years. A review of scientific evidence through 2017 found particularly strong evidence for nature contact and decreased mortality, improved birth weight and increased physical activity, as well as intermediate strength evidence for cardiovascular health[31]. Another review also cites consistent associations between greenspace exposure and benefits for heart rate and violence, as well as some mixed support for general health, cancer, diabetes and respiratory illness outcomes[35]. Physical activity has been of especially high scientific interest due to its large role in overall physical health.

> *Box 2. Common assessment methods*
>
> *Measurement of nature contact*
>
> Researchers often quantify natural environments in a specified area (e.g., around a participant's home or within a county) using satellite image data (e.g., Normalized Difference Vegetation Index (NDVI) which measures light absorption vs. reflection to characterize vegetation presence), land cover maps which categorize land plots by cover type (forest, cropland, etc), or by calculating the distance to natural spaces. Other assessments may compare health outcomes in contrasting environmental conditions such as more urban vs. more natural environments without necessarily characterizing or quantifying the environments at length. Additionally, studies may also assess nature contact through subjective reports. For example, surveys may ask participants to self-report on the amount of time spent in, or quality of, natural environments around them.
>
> *Measurement of mental health and psychological well-being*
>
> Researchers often use survey instruments, such as validated questionnaires, to be completed by the study participant (i.e., self-report) or on behalf of the participant (e.g., by a parent, research staff member or physician). Health records data may also be used (e.g., for history of psychiatric illness diagnoses).

2.3.1 *Physical Activity*

Evidence since the 1950s has linked increased physical activity to, among many health outcomes, risk reduction for a variety of chronic diseases (e.g., cardiovascular disease[36], type 2 diabetes[37], colon and breast cancer[38], psychiatric illnesses (e.g., anxiety and depression[39–41]) and premature death[42]. Evidence is now mounting to suggest that the presence of more greenspace is associated with higher levels of physical activity and decreased likelihood of obesity[17,43,44]. Specifically, more greenspace has been tied to walking; a large sample study (n = 333,183) in the UK found that participants walked more with increasing amounts of natural areas within 600 meters around their homes[45]. Additionally, a study of 12 countries showed significant positive association between park proximity and recreational walking[46]. Evidence for increased walking is important given the associations between walking and numerous health benefits including improved cholesterol levels and protection against chronic diseases like cardiovascular disease, diabetes and obesity[47–49].

However, some reviewers have noted the mixed or negative results in some studies. Bancroft (2015) reviewed U.S.-based studies on physical activity and access to parks[50]. Of the 20 articles that met inclusion criteria, 5 found significant positive associations, while 9 found no association and 6 had mixed results. Reviewers posited that limitations in how the types and amounts of physical activity were assessed, as well as the large variability in study designs, contribute to the inconclusiveness of the literature. More research is needed using robust study designs before a causal effect can be determined[50–52]. Nonetheless, as a whole, the number of studies positively linking greenspace and physical activity exceeds the number having found mixed or insignificant results, and the overall body of evidence suggests that walkable natural areas can positively impact physical activity levels.

2.3.2 *Green exercise*

Physical activity can be achieved in many settings including indoor facilities, but compelling evidence suggests specific benefits for exercising outdoors—often referred to as *green exercise.* Researchers [53] exposed subjects to a variety of image scenes in four categories: pleasant rural, pleasant urban, unpleasant rural, and unpleasant urban, in addition to a control group of subjects that did not view any images, during walking exercise. Of these groups, only those who viewed rural pleasant scenes experienced significant reductions in all three measures of blood pressure, which provided physiological indications of decreased stress and greater restoration. Both urban scene types increased blood pressure relative to the control group, suggesting urbanicity may negate the benefits of exercise.

In a study comparing outdoor versus laboratory environments for walking, researchers found non-physical benefits for the outdoor condition including pleasant affective (i.e., mood) states, enjoyment, and intention for future participation[54]. A systematic review summarized other non-physical benefits for green exercise such as greater feelings of revitalization and positive engagement, and a decrease in anger and depression, compared to indoor exercise. Together, the research specifically supports green exercise as a distinct and valuable driver of positive health outcomes.

2.3.3 *Children's physical activity and play*

The importance of physical activity extends to children, and nature settings can boost physical activity by providing opportunities for active play. Like adults, children struggle with high rates of obesity; the Centers for Disease Control cites a tripling in youth obesity rates since the 1970s[56]. Since physical activity tendencies in childhood can persist into adulthood[57], it is important to connect children to environments that promote healthy amounts of activity. Nature-based preschools, such as Seattle's Fiddleheads Forest School, seek to provide outdoor environments and natural features (for example, fallen logs and muddy hills) that afford a variety of physical activity and play behaviors[58], and research has found that children who spent most of their time outdoors were less likely to be sedentary, and were more likely to achieve the recommended amount of daily physical activity levels[59]. Other studies found that boys' levels of physical activity were more likely to be of higher intensity in greenspace[60], and that environments that promote gross motor movements are associated with improved learning outcomes[61]. A recent systematic review summarized the findings of nearly 30 studies from nine countries to reveal that the evidence overall suggests positive effects of outdoor time on children's physical activity, sedentary behavior, and cardiorespiratory fitness[62]. They cautioned, however, that causality is yet to be determined and that more randomized controlled trials are needed.

Aside from providing environments conducive to more physical activity, nature settings can also boost children's wellbeing through the mechanism of play. A relatively large literature base links play to pivotal aspects of optimal child development including cognitive, social, physical, and emotional well-being. Play contributes to children's learning behaviors, problem-solving skills, social and emotional ties, cooperation, and creativity, among much else[63–65]. The importance of play is so well-established that the United Nations has deemed it a basic human right of every child [66]. Numerous studies have found that natural landscapes and elements are conducive to enriched play and learning[67] by increasing affordances for more engaged and varied play[68,69]. Nature settings may be of particular importance for disadvantaged children, for whom access to safe, age-appropriate play spaces can be diminished[64].

2.4 Cognitive Benefits

Key takeaways

- *Nature contact is associated with restoration of attention and improved cognitive functioning.*
- *Research evidence supports improvements in ADHD symptoms and attention and test performance in children who have more nature contact, including those who have more greenery around their schools.*
- *Nature contact has been shown to be connected to children's self-regulation and self-discipline, which are crucial predictors of academic achievement and health later in life.*

2.4.1 *Attention Restoration Theory (ART)*

Attention Restoration Theory stipulates that urban environments overly tax our finite resource of attentional control[70,71]. The barrage of stimuli (e.g., honking horns, blinking signs, the unpredictable movement of people) require us to sift through and block out irrelevant stimuli to attend to relevant stimuli, which fatigues our capacity for directed attention. By contrast, natural environments are characterized by elements of "soft fascination" (e.g., the flickering of sunlight through the trees, the trickle of a stream) that do not tax our attention capacity to the same degree, rather allowing our that fatigued attentional resource to restore and replenish.

However, specific operationalization of what constitutes "soft fascination" remains underexplored[72]. There has been interesting intersections within visual processing and cognition that recognized certain "low-level" features, such as color properties and the presence/absence of straight edges (where natural environments generally have less color saturation or hue variation, and fewer straight edges), influenced how people perceived naturalness, and also influenced the likelihood of people thinking about certain topics like spirituality[72,73]. In the auditory research, nature *sounds* have been linked to improved working memory scores and higher preference and restorativeness ratings compared to urban sounds[74,75]. However, much is left to be explored in illuminating the underlying mechanisms of nature, soft fascination, and cognitive well-being.

Nonetheless, researchers have tested ART with a range of methods, commonly utilizing concentration and working memory tasks to measure attention performance. The theory suggests that people would perform better on such cognitive tasks after experiencing restoration through nature exposure, compared to those who experience no restoration or further taxing (through urban environments). In support of the hypothesis, cognitively fatigued participants (via cognitive tasks like the backward digit span test) performed better on cognitive tasks after viewing nature images compared to those who viewed urban or geometric images[76]. Similar trends, including improved cognitive functioning and increases in positive affect and decreases in negative affect, were found in participants who walked in natural environments versus urban environments[77,78] suggesting attentional benefits can be received with varying exposures to nature (e.g., image viewing and walking).

2.4.2 *Children and cognitive benefits*

For children, the literature on nature contact and cognitive benefits largely includes attention-specific outcomes. Several studies investigated the effects of nature contact on children diagnosed with ADD/ADHD and found evidence of restoration[79–82]. In a longitudinal study, children who moved to homes with more nature than their previous homes had significantly greater improvements in attention task scores than children who moved to homes without more nature[79]. Another study found symptoms of ADD/ADHD were attenuated in children who walked in parks[80] and after participation in activities (e.g. camping, fishing, playing soccer) in greener settings[83]. In a study of non-clinical populations, Schutte (2015) saw improvements in attention and spatial working memory task performance in children who went on a nature walk, versus those who went on an urban walk[82].

Investigators have also explored connections between school settings--where children spend a significant portion of their time-- and cognitive benefits. A longitudinal study of primary school children in Spain found improvements in cognitive development (measured by working memory tasks) in children with more surrounding greenness, particularly around their schools[84]. In the United States, researchers looked at over 900 public elementary schools and their standardized test scores and found that higher levels of school greenness were associated with higher English and math scores, after adjusting for various inter-school differences such as income, race, English as a second language, and student-teacher ratio[85]. Among American high school students, those with mostly natural views in school had higher concentration scores compared to those with mostly built views[86].

Children's self-discipline has also been found to relate to levels of greenery around the home[87]. Building upon the proposition that self-discipline (assessed through measures of concentration, impulse inhibition, and delay of gratification) and directed attention have the same underlying mechanisms[87], this study explored the potential for environments to affect self-discipline in

African American children from the inner city of Chicago. These participants lived in units within high-rise buildings that were identical except for the varying degrees of nature views from their unit windows. Girls who lived in units with tree views performed better on all three measures of self-discipline than those who had views of a barren, built environment. The authors provided plausible explanation for the insignificant associations for boys, citing findings that boys typically play farther from home than girls, and may therefore net less contact with the nature directly beside their homes. The findings are still highly relevant, if even only for females, since greater degrees of self-discipline can help reduce negative tendencies such as juvenile delinquency and teen pregnancy, as well as help support the development of positive social health—all of which are particularly impactful for children of lower socioeconomic backgrounds.

Nature contact may be especially important for children from underprivileged backgrounds as they are vulnerable to diminished social-emotional functioning and development of self-regulation skills. A prospective study of young children from low-income families linked family financial strain and negative impacts on delay of gratification[88]. Delay of gratification and executive functioning (i.e. cognitive abilities like attention and working memory) are crucial predictive factors for academic achievement, social determinants of health, and emotional health[89–91]. Ample research interest in executive function and delay of gratification has revealed their connections to optimal social functioning. Interventions that support healthy social relationships and functioning, such as has been shown for nature contact, are therefore compelling.

2.5 SOCIAL CAPITAL BENEFITS

Key takeaways

- *Social connections, networks and bonds play a central role in health.*
- *Social cohesion is a causal mechanism in the physical and mental health benefits of nature contact*
- *Greenspaces can increase social activity and social cohesion, as well as decrease crime rates.*

Social capital refers to an individual's social connections, networks and the collaborative bonds therein[92,93]. Healthy People 2020, a set of national health objectives set forth by the U.S. Department of Health and Human Services, explicitly emphasizes the importance of social determinants of health (e.g. socioeconomic status, community context) as key factors in health promotion[94,95]. Strong social bonds and networks inform a broad range of health outcomes and are considered key correlates of health and wellbeing[96,97]. Existing research suggests nature contact may facilitate various components of social capital, particularly through the enhancement of social bonds. Neighborhood common spaces with more greenery increase beneficial social activity such as interpersonal interactions[98,99], sense of safety and individual-level adjustment[100], as well as a decrease in negative social aspects such as crimes[81,101]. Researchers have also found that a lack of green space has been linked to damaging outcomes such as increased feelings of loneliness and perceived shortage of social support[102].

Social cohesion, defined as the sense of community with trust, positive relationships and feelings of acceptance and belonging[103,104], appears to play an important causal role between nature contact and physical and mental health benefits[103,105,106], as well as enhancing the effect size for improved mental health; a recent study found that among European individuals with varying degrees of urban green space access, those with more social cohesion were more likely to be happy[107]. Several theories may explain why social cohesion and social capital are facilitated through nature. For example, greenspaces provide aesthetically pleasing surroundings that encourage individuals to visit, and subsequently socialize with their neighbors and enhancing community ties. A similar theory posits nature contact may create relationships between person-to-place that carry benefits, much like person-to-person relationships might. This person-to-place bond has been called *sense of place*. In other words, nature contact may provide physical places to which people can commonly connect or attach (i.e., *place attachment*), and contribute to the meaningful, emotional, and spiritual ties to places that enrich quality of life and improve health.

2.6 Mental Health and Psychological Well-being Benefits

Key takeaways

- *Nature contact is associated with a myriad of mental health or psychological well-being outcomes*
- *Stress reduction is among the most robustly supported outcomes*
- *Among children, the evidence supports benefits for overall mental wellbeing, resilience, stress reduction, quality of life, and aggressive behavior.*

The existing literature generally suggests that natural environments may be important sources of mental health and psychological well-being. The evidence to date includes a long list of outcomes outlined in several recent reviews[30–33,108]. While some of the more extensively investigated (and, aggregately, more robustly supported) outcomes include mental health or psychiatric outcomes such as depression, anxiety or stress, there appears to be a notable increase in studies on hedonic and eudaimonic outcomes within the past few years. For example, to the best of my knowledge, very few studies on nature contact and happiness or flourishing were published prior to 2015[109,110], compared to more recent publication activity[106,107,111–115]. This trend may suggest an increased investment in flourishing and thriving as important health outcomes, and reflect the World Health Organization's extended view of mental health, which exceeds the mere presence or absence of disease.

2.6.1 *Depression, Anxiety and Affect*

The disease burden of psychiatric illnesses (such as depression, anxiety and chronic stress) continues to be critical public health focus[116,117]. According to a 2011 report by the World Economic Forum, the global cost of mental health disorders was estimated at US$2.5 trillion and forecasted to more than double by 2030[118]. Depression is a serious mood disorder with symptoms such as persistent feelings of hopelessness, guilt or irritability, or decreased energy or changes to appetite[119]. Depressive disorders affect approximately 7% of all U.S. adults, and 9% of adolescents aged 12 to 17[120], and the number of people living with these disorders has increased by 18.4% globally since 2005[121]. At the same time, a growing body of work that nature contact can be beneficial for depression-related symptoms[122–129]. For example, in a survey of 3,000 adults in Tokyo, Japan, more frequent visitation to greenspaces and the presence of natural window views at home were associated with decreased levels of depression[128]. A larger sample study (N = 38,947) found that women who lived in residential areas with the highest quintile of greenness had 13% reduction in depression risk compared to those living in the lowest quintile[123]. While a recent review found a general inverse association between more nature contact and depressive symptoms, more studies were deemed needed using robust study designs and clearer reporting of methodologies (e.g., randomization procedures) to increase the quality of the evidence[130].

Anxiety disorders, such as Generalized Anxiety Disorder, include persistent symptoms that often get worse over time[131]. Symptoms may include uncontrollable feelings of worry, trouble with sleep, inability to enjoy social interactions, and shortness of breath or trembling (in the case of a panic disorder)[131]. Anxiety disorders affect 1 in 3 adults at some point in their lives, with a similarly high prevalence among adolescents[132], and the total number of people globally living with anxiety has increased 14.9% since 2005[121]. Nature contact has been shown to help symptoms of anxiety. For example, students who sat in the forest had lower state anxiety levels than those who sat with an urban view[133]. In a study using virtual reality, those randomly assigned to view biophilic environments (which included simulated plant or water features) experienced less anxiety compared to those viewing the non-biophilic environment[134].

Changes in emotional states, such as positive and negative affect, are central to recovery from stress[135]. In addition, a body of evidence links emotional states to wellbeing, suggesting positive psychological states may be important contributors to psychosocial resilience overall, and to risk reduction for negative physical health outcomes[136]. Nature contact has generally been associated with more positive emotions and less negative emotions (see reviews[137,138]). For example, adults who walked in nature had higher levels of positive emotions (such as positive affect) and lower levels of negative emotions (such as anger, aggressiveness or negative affect) than those who walked in the city[77,133,139].

Together, the above-mentioned literature suggests that nature contact may promote improved depression, anxiety, and affect-related health.

2.6.2 *Stress*

Stress reduction is among the most robustly supported outcomes associated with nature contact. But what is stress? The definition of "stress" has a long history of controversy and revision. Physician Hans Selye coined the term in the 1930s to describe the strain experienced by rats in his experimental laboratory[140]. He anchored the term to reflect a physiological response that included alarm and the release of emergency hormones such as epinephrine and cortisol[141]. However, scientific discovery and progress in the past fifty years has replaced this purely biological view of stress with an integrated perspective wherein an individual responds to a stressor (such as a threatening situation) through inter-related biological *and* psychological processes[142].

One of the earliest experimentalists on the effects of natural environments on stress was Roger Ulrich, who assessed stress recovery after viewing a stressful video, and observed improved physiological recovery (e.g., lower blood pressure) and improved affective states (e.g., less fear and more positive affect) in those who viewed nature videos compared to those in those who viewed urban videos[4]. Ulrich proffered a psychoevolutionary theory to explain the observed phenomenon of stress reduction in response to natural environments: Stress Reduction Theory (SRT)[143]. SRT posited that humans are evolutionarily adapted to respond to safe, natural environments with more positively toned emotional states and decreased physiological arousal. The theory maintained that, given humans' evolution in—and adaptation to—natural environments, humans are programmed to respond rapidly to restorative natural environments. Ulrich extrapolated that such recuperation from stress was an integral part of survival for our ancestors who would need to recover quickly in order to respond again to future threats[4,143].

Researchers have tested SRT using self-report assessments (including scientifically validated surveys or questionnaires) to contrast stress-related outcomes against varying levels of nature contact[144,145]. In Sweden, a survey of randomly-selected individuals correlated fewer stress-related illnesses and greater use of open green spaces[13]. An epidemiological study of a Danish nationally-representative survey also supports the positive relationship between nature contact and decreased stress[146]. Stress reduction from nature contact has also been shown to act as a protective buffer against negative life events. A representative sample of Dutch citizens found that people were less affected by stressful life events when they had high amounts of green space in a 3-km radius from their homes[147]. Evidence also suggests a buffering effect for children; vegetation near the residential environment of rural children moderated (i.e. lessened) the impact of life stress, offering a protective factor and contributing to resilience[148].

Researchers have also demonstrated that stress reduction plays a causal role in the health benefits of nature contact. A recent study[103] investigated potential causal variables such as mental health status, social support and physical activity to help explain the observed benefits of green space on general health. Importantly, they found that stress mediated (i.e., causally explained) the effects of green space on general health, adding substantial empirical support for SRT.

Despite the growing breadth of evidence in support of SRT, relatively few studies have explored the effects of natural environments on the physiological stress response systems, such as the autonomic nervous system or the neuroendocrine system. When we face stressful or threatening stimuli, our sympathetic nervous system activates and triggers adaptive physiological changes (such as pupil dilation, vasoconstriction, increased heart rate, etc.). A key goal of these changes is to optimize blood flow to critical organs and tissues, such as the large muscle groups, which can enable a survival response like quick mobilization and fleeing. This is an energy-consumptive process, however, and SRT posits that safe, natural environments activate our parasympathetic nervous system (which counteracts the sympathetic nervous system) in order to restore our physiological responses (for example, by decreasing heart rate). This quick, parasympathetically-driven restoration from stress response was thought to be adaptive, as it would allow a return to energy conservation and increase preparedness for future threats.

While SRT discusses the autonomic stress response system, the hypothalamic-pituitary-adrenal (HPA) axis is an inter-related stress response system that also exists to aid biological and behavioral responses to acute threats[149]. This hormone-based system responds to the neurotransmitters released by the sympathetic nervous system, and subsequently releases glucocorticoids (such as cortisol)[149,150]. As with the autonomic nervous system, the HPA axis plays a fundamental role in adapting to acute stress. However, when stress is sustained or there is inadequate time for recovery between incidences, these systems can become pathogenic (e.g., greater risk of infection, type 2 diabetes, obesity, cardiovascular disease, issues with memory, insulin resistance, and psychiatric morbidity[14,150–152]).

Although the relative number of studies on the effects of nature contact on physiological stress response is low, researchers have added empirical support to Ulrich's theory in multiple ways. Studies assessed physiological indicators of the two divisions of the autonomic nervous system--sympathetic (commonly referred to as the "fight or flight" response) and parasympathetic (commonly referred to as the "rest and digest" response) nervous systems--through measurements of heart rate, heart rate variability, skin conductance, and blood pressure. In general, these studies found positive associations between nature contact and parasympathetic activity, observing lower pulse rates and blood pressure, and increased heart rate variability [4,133,153,154]. Studies assessing cortisol output found that nature contact is associated with decreased salivary cortisol, suggesting decreased stress [144,145,155]. More studies are needed on the physiological outcomes of nature exposure, particularly in a continuous measurement method (such as continuous heart rate measurement) which can provide minimally invasive—yet more extensive-- data over courses of time compared to data collected at intervals (such as with salivary cortisol). Chapter 4 details an experimental study that tested SRT using psychophysiological assessments in order to contribute to this relatively limited body of evidence.

2.7 Barriers to nature contact

Key takeaways

- *Physical distance decreases greenspace use, so it is important for nature to be close to where people live (especially so for children and elderly populations).*
- *When people perceive safety concerns, the restorative and social capital enhancing properties of green space is diminished.*
- *Perceived discrimination can take on many forms; lack of park information in other languages, or lack of culturally diverse park staff, can express exclusion.*
- *Reducing barriers, particularly for children and families, and those from racial minority backgrounds, can cultivate long-lasting connectedness to nature and advocacy for the environment.*

Despite what we know about nature contact and health benefits, some people are systematically not getting outdoors. Common barriers and the populations they tend to affect most, are discussed here.

2.7.1 *Nature proximity affects access*

Children spend increasing amounts of time indoors and utilizing technology [156]. Such lifestyles are associated with sedentary behavior and decreased physical activity, which are both associated with increased obesity risk[157,158]. In addition, parenting practices for children's roaming range (i.e., the spaces children are allowed to explore without adult accompaniment) have reduced children's independence and limited their exploration of the outdoors. Reduced roaming range is attributed to increases in safety concerns[159,160] and a study has shown that children with small home ranges had low independence scores, citing parental restrictions on where they could go limiting exploration[161]. A lack of proximity to natural areas is therefore a significant barrier for children who spend free, unstructured time close to home.

The importance of close-range nature also applies to adults. A study on physical activity and green space use found that respondents who lived closest to parks were more likely to be physically active and less likely to be overweight. In addition, the frequency of green space use declined as distance to green space increased[162]. Alongside objective proximity to green spaces, perceived accessibility may be equally influential. Researchers found positive association between the number of nearby parks and moderate-to-vigorous physical activity in subjects across 14 cities in 10 countries, and also found that their perception of park proximity was the causal link between that relationship[163].

2.7.2 *Safe nature*

Safety concerns are also common to both children and adults, particularly elderly adults. The lack of safety not only acts as barrier to access, but also affects the restorative properties of green spaces[164,165]. A 2018 study among seniors in Seattle and Baltimore investigated the extent to which perception of safety (including high traffic volume and crime) may affect the relationship between green space and social capital[166]. While more natural sights were associated with greater social capital, this association only existed when safety was rated highly. Similarly, a study in New Zealand also found that the association between nature contact and life satisfaction depended heavily on perceived safety[167], suggesting (alongside the Hong et al., 2018 study) that safety may moderate the health effects of green space.

2.7.3 *Discrimination and exclusion*

Places affect health[168] yet structural racism in the US has a long history (and ongoing practice) of racialized place-based discrimination that overexposes racial minority groups to deleterious exposures while underexposing them to beneficial resources[169]. For example, poor, working-class Americans and racial minorities have disproportionately high exposure to traffic, derelict properties, pollution-generating facilities [169–171] and crime[97], while at the same facing decreased access to healthcare services, nutritious food and open greenspaces[172–175].

Concrete, place-based initiatives that emphasize health equity are important future steps in mitigating the burden of structural racism[176]. However, simply increasing the amount of greenspace located within predominantly racial minority neighborhoods, for example, is unlikely to be effective for population health when social barriers persist. For example, research indicates that even when nature is available, access is deterred by discrimination and may therefore impede any health benefits of nature contact.

In a mix of surveys and focus groups of Latino residents in Los Angeles, respondents cited a cultural rift with the majority (i.e., American Caucasians) that affected their use of the city's urban national park. They feared being ostracized by other park users due to their perceived lack of standing in the wider community, and the need to have some sort of permission in order to use the parks. One interviewee figured that the locals would "get mad" if they saw Latinos using the park (Byrne, 2012, p. 604). As predominantly Spanish language speakers, respondents also felt that the lack of basic park information (e.g., hours, directions, possible activities) in Spanish and the lack of bilingual park staff were expressions of exclusion[177]. Exclusion along cultural barriers may perpetuate a lack of cultural affinity to natural areas.

An analysis of qualitative and quantitative projects revealed that in England and Scotland, people of color and those from ethnic minorities were less likely to visit forests and woodlands[178]. Social and cultural norms emerged as influencers of non-visitation, wherein a particular group or community may not consider forest/woodland visitation as a norm. Discussions with black and ethnic minority respondents linked a general lack of confidence about visitation, and low levels of awareness of nearby woodland areas, informed the absence of cultural affinity for woodland-based recreation. This gap was further widened by relevant information being unavailable in their own languages or through their preferred media channels. The cultural accessibility of nature areas paint notions of whom parks are meant for; for example, if every signage about the park is only available in English, or if special events at parks are advertised only in media outlets predominantly serving white, English-speaking populations, then the transmitted message may be that these parks are only for white, English-speaking groups.

Data from a government-commissioned survey of over 60,000 adults in England explored reasons for infrequent nature contact[179]. Those who were not White, of higher socioeconomic status, married and with children, were more likely to be infrequent visitors. Among the cited reasons were, “This isn’t something for me/people like me”, “I don’t feel welcome/feel out of place”, and “Concerns about where allowed to go/restrictions”. These reasons illuminate how a lack of a sense of belonging can disconnect people from receiving the important health benefits documented in nature and health literature.

Thus, addressing barriers to nature contact must go hand in hand with addressing the racism and other psychosocial determinants of accessing the health benefits that are possible through nature contact. Psychosocial and environmental health pathways are interwoven, as illustrated in empirical studies that find exacerbated adverse effects of environmental stressors in those who also face psychosocial disadvantage. For example, research showed that the negative effects of air pollution exposures were worse for individuals who also experienced violence[180]. Promisingly, some government agencies have incorporated the cumulative and multifactorial (i.e., psychosocial and environmental) risk factors in assessing vulnerable population health[181]. Governing agencies and policy makers should work to address above barriers to create welcoming, empowering nature spaces for people that may contribute to improved population health, particularly for those who need it most.

2.8 References

1. Perrins SP, Bratman G. *Health Benefits of Nature*. Washington State Recreation and Conservation Office; 2020. Accessed February 1, 2021. https://rco.wa.gov/wp-content/uploads/2020/01/HealthBenefitsofNature.pdf

2. Nightingale F. *Notes on Nursing : What It Is, and What It Is Not*. Commemorative ed. Philadelphia : Lippincott; 1992.

3. Glacken C. *Traces on the Rhodian Shore: Nature and Culture in Western Thought From Ancient Times to the End of the Eighteenth Century.* University of California Press; 1967.

4. Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M. Stress recovery during exposure to natural and urban environments. *J Environ Psychol*. 1991;11(3):201-230. doi:10.1016/S0272-4944(05)80184-7

5. Higgins A. In medieval monastery gardens, an uplifting model for refuge. *The Washington Post*. https://link-gale-com.offcampus.lib.washington.edu/apps/doc/A626228550/AONE?u=wash_main&sid=AONE&xid=3f3bfb68. Published June 10, 2020. Accessed April 20, 2021.

6. Kaufman RE, Warner SB, Gerlach-Spriggs N. *Restorative Gardens : The Healing Landscape*. New Haven, CT : Yale University Press; 1998.

7. Olmstead F. *The Value and Care of Parks. Report to the Congress of the State of California*.; 1865:18-24.

8. Ulrich RS, Parsons R. Influences of passive experiences with plants on individual well-being and health. In: *The Role of Horticulture in Human Well-Being and Social Development*. ; 1992:93-105.

9. *State of World Population 2007: Unleashing the Potential of Urban Growth*. UNFPA; 2007.

10. United Nations. *2018 Revision of World Urbanization Prospects*.; 2018. Accessed May 4, 2019. https://population.un.org/wup/

11. Dye C. Health and Urban Living. *Am Assoc Adv Sci*. 2008;319(5864):766-769.

12. McDonald RI, Beatley T, Elmqvist T. The green soul of the concrete jungle: the urban century, the urban psychological penalty, and the role of nature. *Sustain Earth*. 2018;1(1):3. doi:10.1186/s42055-018-0002-5

13. Grahn P, Stigsdotter UA. Landscape planning and stress. *Urban For Urban Green*. 2003;2(1):1-18. doi:10.1078/1618-8667-00019

14. Sapolsky RM. Social Status and Health in Humans and Other Animals. *Annu Rev Anthropol*. 2004;33(1):393-418. doi:10.1146/annurev.anthro.33.070203.144000

15. Lazarus J. *Stress Relief & Relaxation Techniques*. Keats Publishing; 2000.

16. Lazarus R, Folkman S. *Stress, Appraisal, and Coping.* Springer; 1984.

17. Nielsen TS, Hansen KB. Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. *Health Place*. 2007;13(4):839-850. doi:10.1016/j.healthplace.2007.02.001

18. Siegrist J. Chronic psychosocial stress at work and risk of depression: evidence from prospective studies. *Eur Arch Psychiatry Clin Neurosci*. 2008;258(S5):115-119. doi:10.1007/s00406-008-5024-0

19. Davis MT, Holmes SE, Pietrzak RH, Esterlis I. Neurobiology of Chronic Stress-Related Psychiatric Disorders: Evidence from Molecular Imaging Studies. *Chronic Stress*. 2017;1:247054701771091. doi:10.1177/2470547017710916

20. Purtle J, Nelson KL, Yang Y, Langellier B, Stankov I, Diez Roux AV. Urban–Rural Differences in Older Adult Depression: A Systematic Review and Meta-analysis of Comparative Studies. *Am J Prev Med*. 2019;56(4):603-613. doi:10.1016/j.amepre.2018.11.008

21. Peen J, Schoevers RA, Beekman AT, Dekker J. The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatr Scand*. 2010;121(2):84-93. doi:10.1111/j.1600-0447.2009.01438.x

22. Lederbogen F, Kirsch P, Haddad L, et al. City living and urban upbringing affect neural social stress processing in humans. *Nature*. 2011;474(7352):498-501. doi:10.1038/nature10190

23. Vassos E, Agerbo E, Mors O, Pedersen CB. Urban–rural differences in incidence rates of psychiatric disorders in Denmark. *Br J Psychiatry*. 2016;208(5):435-440. doi:10.1192/bjp.bp.114.161091

24. Gruebner O, Rapp MA, Adli M, Kluge U, Galea S, Heinz A. Cities and Mental Health. *Dtsch Aerzteblatt Online*. Published online February 24, 2017. doi:10.3238/arztebl.2017.0121

25. Sampson L, Ettman CK, Galea S. Urbanization, urbanicity, and depression: a review of the recent global literature. *Curr Opin Psychiatry*. 2020;33(3):233-244. doi:10.1097/YCO.0000000000000588

26. Cox DTC, Hudson HL, Shanahan DF, Fuller RA, Gaston KJ. The rarity of direct experiences of nature in an urban population. *Landsc Urban Plan*. 2017;160:79-84. doi:10.1016/j.landurbplan.2016.12.006

27. Cox DTC, Shanahan DF, Hudson HL, Fuller RA, Gaston KJ. The impact of urbanisation on nature dose and the implications for human health. *Landsc Urban Plan*. 2018;179:72-80. doi:10.1016/j.landurbplan.2018.07.013

28. Miller JR. Biodiversity conservation and the extinction of experience. *Trends Ecol Evol*. 2005;20(8):430-434. doi:10.1016/j.tree.2005.05.013

29. Hartig T, Mitchell R, de Vries S, Frumkin H. Nature and Health. *Annu Rev Public Health*. 2014;35(1):207-228. doi:10.1146/annurev-publhealth-032013-182443

30. Frumkin H, Bratman GN, Breslow SJ, et al. Nature Contact and Human Health: A Research Agenda. *Environ Health Perspect*. 2017;125(7):075001. doi:10.1289/EHP1663

31. Fong KC, Hart JE, James P. A Review of Epidemiologic Studies on Greenness and Health: Updated Literature Through 2017. *Curr Environ Health Rep*. 2018;5(1):77-87. doi:10.1007/s40572-018-0179-y

32. Gascon M, Triguero-Mas M, Martínez D, et al. Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *Int J Environ Res Public Health*. 2015;12(4):4354-4379. doi:10.3390/ijerph120404354

33. Wendelboe-Nelson C, Kelly S, Kennedy M, Cherrie J. A Scoping Review Mapping Research on Green Space and Associated Mental Health Benefits. *Int J Environ Res Public Health*. 2019;16(12):2081. doi:10.3390/ijerph16122081

34. Ulrich R. View through a window may influence recovery from surgery. *Science*. 1984;224(4647):420-421.

35. Kondo MC, Jacoby SF, South EC. Does spending time outdoors reduce stress? A review of real-time stress response to outdoor environments. *Health Place*. 2018;51:136-150. doi:10.1016/j.healthplace.2018.03.001

36. Thompson PD. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation*. Published online 2003:3109-3116.

37. Knowler W, Barrett-Connor E, Fowler S. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346:393-403.

38. Breslow R, Ballard-Barbash R, Munoz K. Long-term recreational physical activity and breast cancer in the National Health and Nutrition Examination Survey I epidemiologic follow-up study. *Cancer Epidemiol Biomark Prev*. 2001;10:805-808.

39. Stonerock GL, Hoffman BM, Smith PJ, Blumenthal JA. Exercise as Treatment for Anxiety: Systematic Review and Analysis. *Ann Behav Med*. 2015;49(4):542-556. doi:10.1007/s12160-014-9685-9

40. Chan JSY, Liu G, Liang D, Deng K, Wu J, Yan JH. Special Issue – Therapeutic Benefits of Physical Activity for Mood: A Systematic Review on the Effects of Exercise Intensity, Duration, and Modality. *J Psychol*. 2019;153(1):102-125. doi:10.1080/00223980.2018.1470487

41. Mochcovitch MD, Deslandes AC, Freire RC, Garcia RF, Nardi AE. The effects of regular physical activity on anxiety symptoms in healthy older adults: a systematic review. *Rev Bras Psiquiatr*. 2016;38(3):255-261. doi:10.1590/1516-4446-2015-1893

42. Warburton DER. Health benefits of physical activity: the evidence. *Can Med Assoc J*. 2006;174(6):801-809. doi:10.1503/cmaj.051351

43. Astell-Burt T, Feng X, Kolt GS. Green space is associated with walking and moderate-to-vigorous physical activity (MVPA) in middle-to-older-aged adults: findings from 203 883 Australians in the 45 and Up Study. *Br J Sports Med*. 2014;48(5):404-406. doi:10.1136/bjsports-2012-092006

44. West ST. Association of Available Parkland, Physical Activity, and Overweight in America's Largest Cities. *J Public Health Manag Pract*. 2012;18:423-430.

45. Sarkar C. Residential greenness and adiposity: Findings from the UK Biobank. *Environ Int*. 2017;106:1-10. doi:10.1016/j.envint.2017.05.016

46. Sugiyama T, Cerin E, Owen N, et al. Perceived neighbourhood environmental attributes associated with adults′ recreational walking: IPEN Adult study in 12 countries. *Health Place*. 2014;28:22-30. doi:10.1016/j.healthplace.2014.03.003

47. Ball K, Bauman A, Leslie E, Owen N. Perceived Environmental Aesthetics and Convenience and Company Are Associated with Walking for Exercise among Australian Adults. *Prev Med*. 2001;33(5):434-440. doi:10.1006/pmed.2001.0912

48. Parkkari J, Natri A, Kannus P, et al. A Controlled Trial of the Health Benefits of Regular Walking on a Golf Course. Published online 2000:7.

49. Albright C, Thompson DL. The Effectiveness of Walking in Preventing Cardiovascular Disease in Women: A Review of the Current Literature. *J Womens Health*. 2006;15(3):271-280. doi:10.1089/jwh.2006.15.271

50. Bancroft C, Joshi S, Rundle A, et al. Association of proximity and density of parks and objectively measured physical activity in the United States: A systematic review. *Soc Sci Med*. 2015;138:22-30. doi:10.1016/j.socscimed.2015.05.034

51. Kondo M, Fluehr J, McKeon T, Branas C. Urban Green Space and Its Impact on Human Health. *Int J Environ Res Public Health*. 2018;15(3):445. doi:10.3390/ijerph15030445

52. Ord K, Mitchell R, Pearce J. Is level of neighbourhood green space associated with physical activity in green space? *Int J Behav Nutr Phys Act*. 2013;10(1):127. doi:10.1186/1479-5868-10-127

53. Pretty J, Peacock J, Sellens M, Griffin M. The mental and physical health outcomes of green exercise. *Int J Environ Health Res*. 2005;15(5):319-337. doi:10.1080/09603120500155963

54. Focht BC. Brief Walks in Outdoor and Laboratory Environments: Effects on Affective Responses, Enjoyment, and Intentions to Walk for Exercise. *Res Q Exerc Sport*. 2009;80(3):611-620. doi:10.5641/027013609X13088500159840

55. Thompson Coon J, Boddy K, Stein K, Whear R, Barton J, Depledge MH. Does Participating in Physical Activity in Outdoor Natural Environments Have a Greater Effect on Physical and Mental Wellbeing than Physical Activity Indoors? A Systematic Review. *Environ Sci Technol*. 2011;45(5):1761-1772. doi:10.1021/es102947t

56. Fryar C, Carroll M, Ogden C. *Prevalence of Overweight and Obesity among Children and Adolescents: United States, 1963-1965 through 2011-2012.* Center for Disease Control; 2014. Accessed May 20, 2019. https://www.cdc.gov/nchs/data/hestat/obesity_child_11_12/obesity_child_11_12.htm

57. Kjonniksen L, Torsheim T, Wold B. Tracking of leisure-time physical activity during adolescence and young adulthood: a 10-year longitudinal study. *Int J Behav Nutr Phys Act*. 2008;5(69).

58. Fiddleheads Forest School. Published 2019. Accessed July 25, 2019. https://botanicgardens.uw.edu/education/youth-family/fiddleheads-forest-school/

59. Schaefer L, Plotnikoff RC, Majumdar SR, et al. Outdoor Time Is Associated with Physical Activity, Sedentary Time, and Cardiorespiratory Fitness in Youth. *J Pediatr*. 2014;165(3):516-521. doi:10.1016/j.jpeds.2014.05.029

60. Wheeler BW, Cooper AR, Page AS, Jago R. Greenspace and children's physical activity: A GPS/GIS analysis of the PEACH project. *Prev Med*. 2010;51(2):148-152. doi:10.1016/j.ypmed.2010.06.001

61. Tandon P, Hassairi N, Soderberg J, Joseph G. The relationship of gross motor and physical activity environments in child care settings with early learning outcomes. *Early Child Dev Care*. 2020;190(4):570-579. doi:10.1080/03004430.2018.1485670

62. Gray C, Gibbons R, Larouche R, et al. What Is the Relationship between Outdoor Time and Physical Activity, Sedentary Behaviour, and Physical Fitness in Children? A Systematic Review. *Int J Environ Res Public Health*. 2015;12(6):6455-6474. doi:10.3390/ijerph120606455

63. Bodrova E, Leong DJ. Why children need play. *Early Child Today*. 2005;20(1):6.

64. Milteer RM, Ginsburg KR, Council on communications and media, Committee on psychosocial aspects of child and family health. The Importance of Play in Promoting Healthy Child Development and Maintaining Strong Parent-Child Bond: Focus on Children in Poverty. *Am Acad Pediatr*. 2012;129(1):e204-e213. doi:10.1542/peds.2011-2953

65. Zigler E, Singer DG, Bishop-Josef SJ. *Children's Play: The Roots of Reading*. Zero To Three; 2004.

66. Office of the United Nations High Commissioner for Human Rights. *Convention on the Rights of the Child: General Assembly Resolution*.; 1989.

67. Rivkin M. *The Great Outdoors. Restoring Children's Rights to Play Outside.* National Association for the Education of Young Children; 1995.

68. Fjørtoft I. The Natural Environment as a Playground for Children: The Impact of Outdoor Play Activities in Pre-Primary School Children. 2001;29(2):111-117.

69. Woolley H, Lowe A. Exploring the Relationship between Design Approach and Play Value of Outdoor Play Spaces. *Landsc Res*. 2013;38(1):53-74. doi:10.1080/01426397.2011.640432

70. Kaplan R. The role of nature in the context of the workplace. *Landsc Urban Plan*. 1993;26(1-4):193-201. doi:10.1016/0169-2046(93)90016-7

71. Kaplan R, Kaplan S. *The Experience of Nature : A Psychological Perspective*. Cambridge University Press; 1989.

72. Schertz KE, Berman MG. Understanding Nature and Its Cognitive Benefits. *Curr Dir Psychol Sci*. 2019;28(5):496-502. doi:10.1177/0963721419854100

73. Schertz KE, Sachdeva S, Kardan O, Kotabe HP, Wolf KL, Berman MG. A thought in the park: The influence of naturalness and low-level visual features on expressed thoughts. *Cognition*. 2018;174:82-93. doi:10.1016/j.cognition.2018.01.011

74. Van Hedger SC, Nusbaum H, Heald S, Huang A, Kotabe H, Berman M. *The Aesthetic Preference for Nature Sounds Depends on Sound Object Recognition*. PsyArXiv; 2018. doi:10.31234/osf.io/nsqvy

75. Krzywicka P. Restorative Qualities of and Preference for Natural and Urban Soundscapes. *Front Psychol*. 2017;8:13.

76. Berto R. Exposure to restorative environments helps restore attentional capacity. *J Environ Psychol*. 2005;25(3):249-259. doi:10.1016/j.jenvp.2005.07.001

77. Bratman GN, Daily GC, Levy BJ, Gross JJ. The benefits of nature experience: Improved affect and cognition. *Landsc Urban Plan*. 2015;138:41-50. doi:10.1016/j.landurbplan.2015.02.005

78. Hartig T, Evans GW, Jamner LD, Davis DS, Gärling T. Tracking restoration in natural and urban field settings. *J Environ Psychol*. 2003;23(2):109-123. doi:10.1016/S0272-4944(02)00109-3

79. Wells NM. At Home with Nature: Effects of "Greenness" on Children's Cognitive Functioning. *Environ Behav*. 2000;32(6):775-795. doi:10.1177/00139160021972793

80. Faber Taylor A, Kuo FE. Children With Attention Deficits Concentrate Better After Walk in the Park. *J Atten Disord*. 2009;12(5):402-409. doi:10.1177/1087054708323000

81. Kuo FE, Sullivan WC. Environment and Crime in the Inner City: Does Vegetation Reduce Crime? *Environ Behav*. 2001;33(3):343-367. doi:10.1177/0013916501333002

82. Schutte AR, Torquati JC, Beattie HL. Impact of Urban Nature on Executive Functioning in Early and Middle Childhood. *Environ Behav*. 2017;49(1):3-30. doi:10.1177/0013916515603095

83. Taylor AF, Kuo FE, Sullivan WC. Coping with add: The Surprising Connection to Green Play Settings. *Environ Behav*. 2001;33(1):54-77. doi:10.1177/00139160121972864

84. Dadvand P, Nieuwenhuijsen MJ, Esnaola M, et al. Green spaces and cognitive development in primary schoolchildren. *Proc Natl Acad Sci*. 2015;112(26):7937-7942. doi:10.1073/pnas.1503402112

85. Wu C-D, McNeely E, Cedeño-Laurent JG, et al. Linking Student Performance in Massachusetts Elementary Schools with the "Greenness" of School Surroundings Using Remote Sensing. Wicherts JM, ed. *PLoS ONE*. 2014;9(10):e108548. doi:10.1371/journal.pone.0108548

86. Matsuoka RH. Student performance and high school landscapes: Examining the links. *Landsc Urban Plan*. 2010;97(4):273-282. doi:10.1016/j.landurbplan.2010.06.011

87. Taylor AF, Kuo FE, Sullivan WC. VIEWS OF NATURE AND SELF-DISCIPLINE: EVIDENCE FROM INNER CITY CHILDREN. *J Environ Psychol*. 2002;22(1-2):49-63. doi:10.1006/jevp.2001.0241

88. Duran CAK, Cottone E, Ruzek EA, Mashburn AJ, Grissmer DW. Family Stress Processes and Children's Self-Regulation. *Child Dev*. Published online December 26, 2018. doi:10.1111/cdev.13202

89. Blair C, Razza RP. Relating Effortful Control, Executive Function, and False Belief Understanding to Emerging Math and Literacy Ability in Kindergarten. *Child Dev*. 2007;78(2):647-663. doi:10.1111/j.1467-8624.2007.01019.x

90. McClelland MM, Acock AC, Piccinin A, Rhea SA, Stallings MC. Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Child Res Q*. 2013;28(2):314-324. doi:10.1016/j.ecresq.2012.07.008

91. Razza RA, Martin A, Brooks-Gunn J. The implications of early attentional regulation for school success among low-income children. *J Appl Dev Psychol*. 2012;33(6):311-319. doi:10.1016/j.appdev.2012.07.005

92. Perkins DD, Long DA. Neighborhood Sense of Community and Social Capital. In: Fisher AT, Sonn CC, Bishop BJ, eds. *Psychological Sense of Community*. Springer US; 2002:291-318. doi:10.1007/978-1-4615-0719-2_15

93. Rocco L, Suhrcke M. *Is Social Capital Good for Health? A European Perspective.* WHO Regional Office for Europe; 2012.

94. Koh HK, Piotrowski JJ, Kumanyika S, Fielding JE. *Healthy People*: A 2020 Vision for the Social Determinants Approach. *Health Educ Behav*. 2011;38(6):551-557. doi:10.1177/1090198111428646

95. U.S. Department of Health and Human Services. Healthy People 2020: Social Cohesion. https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-health/interventions-resources/social-cohesion

96. Jennings V, Larson L, Yun J. Advancing Sustainability through Urban Green Space: Cultural Ecosystem Services, Equity, and Social Determinants of Health. *Int J Environ Res Public Health*. 2016;13(2):196. doi:10.3390/ijerph13020196

97. Kawachi I, Subramanian SV, Kim D. *Social Capital and Health*. Springer New York; 2008.

98. Kaźmierczak A. The contribution of local parks to neighbourhood social ties. *Landsc Urban Plan*. 2013;109(1):31-44. doi:10.1016/j.landurbplan.2012.05.007

99. Sullivan WC, Kuo FE, Depooter SF. The Fruit of Urban Nature: Vital Neighborhood Spaces. *Environ Behav*. 2004;36(5):678-700. doi:10.1177/0193841X04264945

100. Kuo FE, Bacaicoa M, Sullivan WC. Transforming Inner-City Landscapes: Trees, Sense of Safety, and Preference. *Environ Behav*. 1998;30(1):28-59. doi:10.1177/0013916598301002

101. Branas CC, Cheney RA, MacDonald JM, Tam VW, Jackson TD, Ten Have TR. A Difference-in-Differences Analysis of Health, Safety, and Greening Vacant Urban Space. *Am J Epidemiol*. 2011;174(11):1296-1306. doi:10.1093/aje/kwr273

102. Maas J, van Dillen SME, Verheij RA, Groenewegen PP. Social contacts as a possible mechanism behind the relation between green space and health. *Health Place*. 2009;15(2):586-595.

103. de Vries S, van Dillen SME, Groenewegen PP, Spreeuwenberg P. Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Soc Sci Med*. 2013;94:26-33. doi:10.1016/j.socscimed.2013.06.030

104. Forrest R, Kearns A. Social Cohesion, Social Capital and the Neighbourhood. *Urban Stud*. 2001;38(12):2125-2143. doi:10.1080/00420980120087081

105. Sugiyama T, Leslie E, Giles-Corti B, Owen N. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *J Epidemiol Community Health*. 2008;62(5):e9-e9. doi:10.1136/jech.2007.064287

106. Kwon O-H, Hong I, Yang J, Wohn DY, Jung W-S, Cha M. Urban green space and happiness in developed countries. *ArXiv210100807 Phys*. Published online January 4, 2021. Accessed April 21, 2021. http://arxiv.org/abs/2101.00807

107. Hart EAC, Lakerveld J, McKee M, et al. Contextual correlates of happiness in European adults. Zeeb H, ed. *PLOS ONE*. 2018;13(1):e0190387. doi:10.1371/journal.pone.0190387

108. Houlden V, Weich S, Porto de Albuquerque J, Jarvis S, Rees K. The relationship between greenspace and the mental wellbeing of adults: A systematic review. Schooling CM, ed. *PLOS ONE*. 2018;13(9):e0203000. doi:10.1371/journal.pone.0203000

109. MacKerron G, Mourato S. Happiness is greater in natural environments. *Glob Environ Change*. 2013;23(5):992-1000. doi:10.1016/j.gloenvcha.2013.03.010

110. White MP, Alcock I, Wheeler BW, Depledge MH. Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data. *Psychol Sci*. 2013;24(6):920-928. doi:10.1177/0956797612464659

111. Hashemi Fesharaki SF, Behrouz A, Yang J, Wohn DY, Cha M. Green Space and Happiness of Developed Countries. In: *2020 IEEE International Conference on Big Data and Smart Computing (BigComp)*. IEEE; 2020:247-250. doi:10.1109/BigComp48618.2020.00-67

112. Houlden V, Porto de Albuquerque J, Weich S, Jarvis S. A spatial analysis of proximate greenspace and mental wellbeing in London. *Appl Geogr*. 2019;109:102036. doi:10.1016/j.apgeog.2019.102036

113. Stieger S, Aichinger I, Swami V. The impact of nature exposure on body image and happiness: an experience sampling study. *Int J Environ Health Res*. Published online August 10, 2020:1-15. doi:10.1080/09603123.2020.1803805

114. Seresinhe CI, Preis T, MacKerron G, Moat HS. Happiness is Greater in More Scenic Locations. *Sci Rep*. 2019;9(1):4498. doi:10.1038/s41598-019-40854-6

115. Souter-Brown G, Hinckson E, Duncan S. Effects of a sensory garden on workplace wellbeing: A randomised control trial. *Landsc Urban Plan*. 2021;207:103997. doi:10.1016/j.landurbplan.2020.103997

116. Marquez PV, Saxena S. Making Mental Health a Global Priority. Published online 2016:14.

117. World Health Organization. *Mental Health Action Plan 2013 - 2020*.; 2013. Accessed May 8, 2019. https://www.who.int/mental_health/publications/action_plan/en/

118. Bloom DE, Cafiero ET, Jane-Llopis E, et al. *The Global Economic Burden of Noncommunicable Diseases.* World Economic forum; 2011.

119. National Institute of Mental Health. Depression. Published 2018. https://www.nimh.nih.gov/health/topics/depression/index.shtml

120. National Institute of Mental Health. Mental health information: Major depression. Accessed May 25, 2019. https://www.nimh.nih.gov/health/statistics/major-depression.shtml#part_155031

121. Vos T, Allen C, Arora M, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *The Lancet*. 2016;388(10053):1545-1602. doi:10.1016/S0140-6736(16)31678-6

122. Berman MG, Kross E, Krpan KM, et al. Interacting with nature improves cognition and affect for individuals with depression. *J Affect Disord*. 2012;140(3):300-305. doi:10.1016/j.jad.2012.03.012

123. Banay RF, James P, Hart JE, et al. Greenness and depression incidence among older women. *Environ Health Perspect*. 2019;12(2):1-9.

124. Bezold CP, Banay RF, Coull BA, et al. The relationship between surrounding greenness in childhood and adolescence and depressive symptoms in adolescence and early adulthood. *Ann Epidemiol*. 2018;28(4):213-219. doi:10.1016/j.annepidem.2018.01.009

125. McEachan RRC, Prady SL, Smith G, et al. The association between green space and depressive symptoms in pregnant women: moderating roles of socioeconomic status and physical activity. *J Epidemiol Community Health*. 2016;70(3):253-259. doi:10.1136/jech-2015-205954

126. Beyer K, Kaltenbach A, Szabo A, Bogar S, Nieto F, Malecki K. Exposure to Neighborhood Green Space and Mental Health: Evidence from the Survey of the Health of Wisconsin. *Int J Environ Res Public Health*. 2014;11(3):3453-3472. doi:10.3390/ijerph110303453

127. Preuß M, Nieuwenhuijsen M, Marquez S, et al. Low Childhood Nature Exposure is Associated with Worse Mental Health in Adulthood. *Int J Environ Res Public Health*. 2019;16(10):1809. doi:10.3390/ijerph16101809

128. Soga M, Evans MJ, Tsuchiya K, Fukano Y. A room with a green view: the importance of nearby nature for mental health during the COVID-19 pandemic. *Ecol Appl*. 2021;31(2). doi:10.1002/eap.2248

129. Lõhmus M, Stenfors CUD, Lind T, Lauber A, Georgelis A. Mental Health, Greenness, and Nature Related Behaviors in the Adult Population of Stockholm County during COVID-19-Related Restrictions. *Int J Environ Res Public Health*. 2021;18(6):3303. doi:10.3390/ijerph18063303

130. Roberts H, van Lissa C, Hagedoorn P, Kellar I, Helbich M. The effect of short-term exposure to the natural environment on depressive mood: A systematic review and meta-analysis. *Environ Res*. 2019;177:108606. doi:10.1016/j.envres.2019.108606

131. National Institute of Mental Health. Anxiety disorders. Published 2018. https://www.nimh.nih.gov/health/topics/anxiety-disorders/index.shtml

132. National Institute of Mental Health. Mental health information: Any Anxiety Disorder. Accessed May 24, 2019. https://www.nimh.nih.gov/health/statistics/any-anxiety-disorder.shtml

133. Lee J, Park B-J, Tsunetsugu Y, Ohira T, Kagawa T, Miyazaki Y. Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. *Public Health*. 2011;125(2):93-100. doi:10.1016/j.puhe.2010.09.005

134. Yin J, Yuan J, Arfaei N, Catalano PJ, Allen JG, Spengler JD. Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environ Int*. 2020;136:105427. doi:10.1016/j.envint.2019.105427

135. Berto R. The Role of Nature in Coping with Psycho-Physiological Stress: A Literature Review on Restorativeness. *Behav Sci*. 2014;4(4):394-409. doi:10.3390/bs4040394

136. Steptoe A, Dockray S, Wardle J. Positive Affect and Psychobiological Processes Relevant to Health. *J Pers*. 2009;77(6):1747-1776. doi:10.1111/j.1467-6494.2009.00599.x

137. Meredith GR, Rakow DA, Eldermire ERB, Madsen CG, Shelley SP, Sachs NA. Minimum Time Dose in Nature to Positively Impact the Mental Health of College-Aged Students, and How to Measure It: A Scoping Review. *Front Psychol*. 2020;10:2942. doi:10.3389/fpsyg.2019.02942

138. McMahan EA, Estes D. The effect of contact with natural environments on positive and negative affect: A meta-analysis. *J Posit Psychol*. 2015;10(6):507-519. doi:10.1080/17439760.2014.994224

139. Mayer FS, Frantz CM. The connectedness to nature scale: A measure of individuals' feeling in community with nature. *J Environ Psychol*. 2004;24(4):503-515. doi:10.1016/j.jenvp.2004.10.001

140. Rothman L. Meet the doctor who changed our understanding of stress. Time.com. Published 2016. https://time.com/4243311/hans-selye-stress/

141. Selye H. A syndrome produced by diverse nocuous agents. *Nature*. 1936;138(32).

142. Baum A, Fleming R, Singer J. Understanding environmental stress: strategies for conceptual and methodological integration. In: *Advances in Environmental Psychology*. Vol 5. Lawrence Erlbaum; 1985:185-205.

143. Ulrich RS. Aesthetic and Affective Response to Natural Environment. In: *Human Behavior and Environment*. Vol 6. I. Altman & J. Wohwill; 1983:85-125.

144. Roe J, Thompson C, Aspinall P, et al. Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. *Int J Environ Res Public Health*. 2013;10(9):4086-4103. doi:10.3390/ijerph10094086

145. Ward Thompson C, Roe J, Aspinall P, Mitchell R, Clow A, Miller D. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landsc Urban Plan*. 2012;105(3):221-229. doi:10.1016/j.landurbplan.2011.12.015

146. Stigsdotter UK, Ekholm O, Schipperijn J, Toftager M, Kamper-Jørgensen F, Randrup TB. Health promoting outdoor environments - Associations between green space, and health,

health-related quality of life and stress based on a Danish national representative survey. *Scand J Public Health*. 2010;38(4):411-417. doi:10.1177/1403494810367468

147. van den Berg AE, Maas J, Verheij RA, Groenewegen PP. Green space as a buffer between stressful life events and health. *Soc Sci Med*. 2010;70(8):1203-1210. doi:10.1016/j.socscimed.2010.01.002

148. Wells NM, Evans GW. Nearby Nature: A Buffer of Life Stress among Rural Children. *Environ Behav*. 2003;35(3):311-330. doi:10.1177/0013916503035003001

149. Chrousos GP. Stress and disorders of the stress system. *Nat Rev Endocrinol*. 2009;5(7):374-381. doi:10.1038/nrendo.2009.106

150. Cohen JI. STRESS AND MENTAL HEALTH: A BIOBEHAVIORAL PERSPECTIVE. *Issues Ment Health Nurs*. 2000;21(2):185-202. doi:10.1080/016128400248185

151. Cohen S, Janicki-Deverts D, Miller GE. Psychological Stress and Disease. *JAMA*. 2007;298(14):1685. doi:10.1001/jama.298.14.1685

152. McEwen BS, Gianaros PJ. Stress- and Allostasis-Induced Brain Plasticity. *Annu Rev Med*. 2011;62(1):431-445. doi:10.1146/annurev-med-052209-100430

153. Park BJ, Tsunetsugu Y, Kasetani T, Kagawa T, Miyazaki Y. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environ Health Prev Med*. 2010;15(1):18-26. doi:10.1007/s12199-009-0086-9

154. Song C, Ikei H, Miyazaki Y. Sustained effects of a forest therapy program on the blood pressure of office workers. *Urban For Urban Green*. 2017;27:246-252. doi:10.1016/j.ufug.2017.08.015

155. Tyrväinen L, Ojala A, Korpela K, Lanki T, Tsunetsugu Y, Kagawa T. The influence of urban green environments on stress relief measures: A field experiment. *J Environ Psychol*. 2014;38:1-9. doi:10.1016/j.jenvp.2013.12.005

156. Larson LR, Green GT, Cordell HK. Children's Time Outdoors: Results and Implications of the National Kids Survey. *J Park Recreat Adm*. 2011;29(2):1-20.

157. Goran MI, Treuth MS. ENERGY EXPENDITURE, PHYSICAL ACTIVITY, AND OBESITY IN CHILDREN. *Pediatr Clin North Am*. 2001;48(1):931-953.

158. Mitchell JA, Mattocks C, Ness AR, et al. Sedentary Behavior and Obesity in a Large Cohort of Children. *Obesity*. 2009;17(8):1596-1602. doi:10.1038/oby.2009.42

159. Karsten L. It all used to be better? Different generations on continuity and change in urban children's daily use of space. *Child Geogr*. 2005;3(3):275-290.

160. Timperio A, Crawford D, Telford A, Salmon J. Perceptions about the local neighborhood and walking and cycling among children. *Prev Med*. 2004;38(1):39-47.

161. Hand KL, Freeman C, Seddon PJ, Recio MR, Stein A, van Heezik Y. Restricted home ranges reduce children's opportunities to connect to nature: Demographic, environmental and parental influences. *Landsc Urban Plan*. 2018;172:69-77. doi:10.1016/j.landurbplan.2017.12.004

162. Coombes E, Jones A, Hillsdon M. The relationship of physical activity and overweight to objectively measured green space accessibility and use. *Soc Sci Med*. 2010;60(6):816-822.

163. Cerin E, Conway TL, Adams MA, et al. Objectively-assessed neighbourhood destination accessibility and physical activity in adults from 10 countries: An analysis of moderators and perceptions as mediators. *Soc Sci Med*. 2018;211:282-293. doi:10.1016/j.socscimed.2018.06.034

164. Herzog T, Kutzli G. Preference and Perceived Danger in Field/Forest Settings. *Environ Behav*. 2002;34(6):819-835.

165. van den Berg AE, ter Heijne M. Fear versus fascination: An exploration of emotional responses to natural threats. *J Environ Psychol*. 2005;25(3):261-272. doi:10.1016/j.jenvp.2005.08.004

166. Hong A, Sallis JF, King AC, et al. Linking green space to neighborhood social capital in older adults: The role of perceived safety. *Soc Sci Med*. 2018;207:38-45. doi:10.1016/j.socscimed.2018.04.051

167. Fleming CM, Manning M, Ambrey CL. Crime, greenspace and life satisfaction: An evaluation of the New Zealand experience. *Landsc Urban Plan*. 2016;149:1-10. doi:10.1016/j.landurbplan.2015.12.014

168. Macintyre S, Ellaway A, Cummins S. Place effects on health: how can we conceptualise, operationalise and measure them? *Soc Sci*. Published online 2002:15.

169. Morello-Frosch R, Lopez R. The riskscape and the color line: Examining the role of segregation in environmental health disparities$. *Environ Res*. Published online 2006:16.

170. Shenassa ED, Stubbendick A, Brown MJ. Social Disparities in Housing and Related Pediatric Injury: A Multilevel Study. *Am J Public Health*. 2004;94(4):633-639. doi:10.2105/AJPH.94.4.633

171. Reynolds P, Behren JV, Gunier RB, Goldberg DE, Hertz A, Smith D. Traffic patterns and childhood cancer incidence rates in California, United States. :9.

172. USDA. *Access to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences*.; 2009. https://www.ers.usda.gov/webdocs/publications/42711/12716_ap036_1_.pdf

173. USDA. *Your Food Environment Atlas*. Accessed May 20, 2019. https://www.ers.usda.gov/FoodAtlas/

174. Yearby R. Racial Disparities in Health Status and Access to Healthcare: The Continuation of Inequality in the United States Due to Structural Racism. :40.

175. Dai D. Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene? *Landsc Urban Plan*. 2011;102(4):234-244. doi:10.1016/j.landurbplan.2011.05.002

176. Bailey ZD, Krieger N, Agénor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. *The Lancet*. 2017;389(10077):1453-1463. doi:10.1016/S0140-6736(17)30569-X

177. Byrne J. When green is White: The cultural politics of race, nature and social exclusion in a Los Angeles urban national park. *Geoforum*. 2012;43(3):595-611. doi:10.1016/j.geoforum.2011.10.002

178. Morris J, O'Brien E, Ambrose-Oji B, Lawrence A, Carter C, Peace A. Access for all? Barriers to accessing woodlands and forests in Britain. *Local Environ*. 2011;16(4):375-396. doi:10.1080/13549839.2011.576662

179. Boyd F, White MP, Bell SL, Burt J. Who doesn't visit natural environments for recreation and why: A population representative analysis of spatial, individual and temporal factors among adults in England. *Landsc Urban Plan*. 2018;175:102-113. doi:10.1016/j.landurbplan.2018.03.016

180. Clougherty JE, Levy JI, Kubzansky LD, et al. Synergistic Effects of Traffic-Related Air Pollution and Exposure to Violence on Urban Asthma Etiology. *Environ Health Perspect*. 2007;115(8):7.

181. deFur PL, Evans GW, Hubal EAC, Kyle AD, Morello-Frosch RA, Williams DR. Vulnerability as a Function of Individual and Group Resources in Cumulative Risk Assessment. *Environ Health Perspect*. 2007;115(5):817-824. doi:10.1289/ehp.9332

Chapter 3. NATURE AT WORK: THE EFFECTS OF DAY-TO-DAY NATURE CONTACT ON EMPLOYEE STRESS AND PSYCHOLOGICAL WELL-BEING

3.1 ABSTRACT

Chronic stress and burnout are key health issues for office workers that may contribute to a myriad of poor health outcomes. The presence of natural elements may improve psychological well-being in workers but the number of existing studies is relatively low, and more longitudinal research is specifically needed to assess how characteristics of employees' day-to-day environments may affect mental health and psychological well-being outcomes like affect, depression and stress. This report outlines a multi-study investigation of workers at Amazon, a multinational e-commerce company based in Seattle, Washington, and mental health benefits associated with exposure to nature.

In Study 1, participants (n=153) responded to a cross-sectional survey that assessed the association of self-reported visitation to an indoor company greenspace with psychological well-being including symptoms of depression, anxiety, positive and negative affect, and stress. In Study 2, a subset of participants from Study 1 (n=33) completed multiple surveys in a 2-week period that assessed the association of the naturalness of their current environments with their state levels of psychological well-being.

We found contact with outdoor environmental naturalness was significantly associated with reduced state anxiety, after adjusting for activity type, location and participants' trait levels of nature relatedness. Findings demonstrate that nature contact in everyday life is significantly associated with decreased levels of state anxiety. More research is needed to investigate the role of nature contact as a potential intervention in the workplace for improved mental health.

3.2 Introduction

The World Health Organization defines "mental health" as not only the absence of mental illness, but also the presence of psychological well-being[1]. Growing evidence suggests contact with natural environments may be a source of improved mental health such as improved affect and reduced depression and stress[2–8]. While there are many possible definitions of "nature" and "natural environments", they often refer to features of non-human origin such as flora and fauna[5,9,10].

Why might nature contact mitigate stress? One prevailing psychoevolutionary theory, Stress Reduction Theory (SRT), posits that the characteristics of natural environments elicit restorative psychophysiological responses in the human autonomic nervous system[11,12] via parasympathetic nervous system activation and reduction in arousal (e.g., increased heart rate) that accompanies stress[11,12]. Researchers have tested SRT by measuring physiological indicators of stress (e.g., heart rate, skin conductance, and biomarkers such as salivary cortisol) and self-report measures (e.g., validated surveys) in contrasting environmental exposure conditions, such as natural vs. urban conditions. The findings have generally been consistent in support of nature contact reducing stress and stress-related outcomes[13–17].

However, relatively few studies have investigated the effects of nature contact on workers' stress specifically, with a few exceptions. One study found that window views of natural elements strongly predicted increased ratings of restoration in workers compared to views of built environments[18]. Another found that a forest view for office workers was associated with decreased job-related stress, whereas views of built elements (e.g., paved areas and adjacent buildings) were associated with increased job-related stress[19]. Additionally, some emerging evidence indicates that physical contact with nature may be even more effective than viewing alone. A study found that while physical and visual access to greenery improved workplace attitude and perceived levels of stress, employees with physical access reported the lowest levels of stress[20]. Despite the benefits of physical contact with nature, studies identified barriers such as perceptions of being too busy to go outside[21] and that going outside during the workday may be ill-regarded by others[22]. Therefore, provision of nature contact that is both accessible and encouraged may be important for employees' well-being.

Amazon, an e-commerce company in Seattle, Washington, had recently completed construction on multistory nature conservatories called "the Spheres"[24] which provided employees with 2 acres of plant-filled spaces for work and relaxation (Figure 3.1). These climate-controlled buildings maintain a vast collection of more than 40,000 plants and trees from tropical, subtropical to temperate regions from across the world. These conservatories occupy half of a city block within an area of downtown in a cosmopolitan metropolis in the USA. Aside from trees on sidewalks and a park that is one third of a mile away, this urban area is generally devoid of notable greenspaces. The glass structures admit a significant amount of natural light, supplemented by indoor lighting that illuminates the overall space and featured plant displays, such as the "living wall"—a 60-foot vertical installation of plants. The interior features a system of interconnected walkways that weave through areas such as the relatively spacious seating area (often used for coffee or lunch breaks), and the narrower, more solitary seats nestled throughout. Small tables and chairs are a common feature, reflecting the conservatories' key purpose to serve as work and gathering spaces for company workers. The interior afforded work productivity by offering wifi internet, tables, chairs and power outlets; amenities such as restrooms and food/coffee services were present. When our two studies were conducted, public visitation was restricted to those who accompany company employees, or by appointment during select visiting days (usually two weekend days per month). The Spheres were notably accessible; it was nestled among the company's headquarter buildings in a pedestrian-friendly downtown area. Additionally, the climate-controlled conservatories maintained the plants year-round, providing nature contact regardless of inclement weather or season. Due to the cloud forest origin of the flora, the inside of the Spheres is maintained at relatively high humidity levels (>60%). The higher humidity level is more notable upon entry where a small check-in lobby uses badge scanning doors to admit employees; once inside the greater space of the multistory Spheres, the humidity is less noticeable. Amazon had yet to study what (if any) effects time spent in these spaces had on employees' well-being.

3.3 PURPOSE

We conducted two studies to investigate the association of increased nature contact in the workplace with improved mental health -- defined here as the absence of mental illness (e.g.., depressive symptoms) and the presence of psychological well-being (e.g., increased positive affect and decreased negative affect and stress)[1,23].

Figure 3.1. Interior shot of the Amazon Spheres conservatory

In Study 1, we conducted a cross-sectional survey in which we tested the hypothesis that more frequent visitation to the Spheres would be associated with lower anxiety and depressive symptoms, negative affect, and stress, and with higher positive affect.

3.4 MATERIALS AND METHODS

3.4.1 *Participants (N = 153)*

All employees 18 years of age or older were eligible to participate. Potential participants were recruited through posters within the company's buildings in downtown Seattle, Washington, and through notices in Amazon's internal e-newsletters. Those who were interested could use the included URL or QR code to visit the online consent form. Participation was voluntary and anonymous. Amazon did not know who participated or declined to participate. Due to company privacy policies, we did not collect information about any individual's demographic traits, such as age, sex, or race or ethnicity. Incentives were not provided for participation.

3.4.2 *Procedures*

Those who provided informed consent were emailed a link to a survey hosted on Qualtrics[25]. Survey responses were recorded from April to June 2019.

3.4.3 *Instruments*

The independent variable was amount of nature contact, assessed by asking participants, "In an average week, how often do you visit the Spheres?" with five ordinal response choices ("0 times", "1 time", "2-3 times", "4 times", "5 or more times").

Psychological well-being outcome variables included positive and negative affect using the 20-item Positive and Negative Affective Schedule (PANAS)[26] which asked participants to rate the extent to which they felt feelings such as "interested" and "ashamed" *in general* using 5-point Likert responses ranging from "Very slightly or not at all" to "Extremely". Positive and negative affect items were summed separately, with a possible score range of 10-50 (Cronbach's alpha = 0.89 for positive affect, 0.88 for negative affect).

Depression, anxiety and stress outcome variables were assessed using the subscales from the 21-item Depression, Anxiety and Stress Scale measure[27]. Participants were asked the extent to which the measure's statements (e.g., "I felt down-hearted and blue" (depression), "I was aware of dryness of my mouth" (anxiety), and "I felt that I was rather touchy" (stress)) applied to them in general, using 4-point Likert responses from "Did not apply to me at all" to "Applied to me very much or most of the time". The sums from each subscale were multiplied by 2, for a possible score range of 0-42 (Cronbach's alpha = 0.91 for depression, 0.79 for anxiety, 0.81 for stress).

Trait relatedness to nature was included as a control variable using the 6-item Nature Relatedness Scale[28], which assessed the degree to which participants in general agree to such statements as "My relationship to nature is an important part of who I am" with five Likert responses from "disagree strongly" to "agree strongly". Responses were averaged, creating a possible score range of 1-5 (Cronbach's alpha = 0.85).

Activity type within the Spheres was also included as a control variable. Participants were asked how often they partook in each of the six activities listed ("Attending work meetings", "Socializing", "Eating/ Drinking", "Working alone (e.g., on a computer)", "Taking a break from work", "Admiring nature"), with possible responses on a 5-point Likert scale from "Never" to "Very often/always".

3.5 Data analysis

Each dependent variable (positive affect, negative affect, depression, anxiety and stress) was regressed on average visitation frequency to the Spheres in separate linear models using RStudio version 1.2.5033 (RStudio Team, 2019). Depression and anxiety variables' density plots showed a positive skew, so log transformation was used to achieve normality. The independent and dependent variables were treated as continuous. Base models included nature relatedness as a control variable and adjusted models also included activity types as covariates. *A priori* statistical significance cutoff was set at a p-value of .05.

3.6 RESULTS

153 participants completed the cross-sectional survey between spring and summer of 2019. We found that more self-reported frequency of visitation to Spheres was significantly associated with more positive affect and less negative affect in the base models (Table 3.1), but these associations were no longer statistically significant when controlling for various activities.

3.1. Estimates for associations between Spheres visitation frequency and outcomes, controlling for trait nature relatedness (base) and activity (adjusted)

	Positive Affect				**Negative Affect**				**Depression**				**Anxiety**				**Stress**			
	Base		Adjusted		Base		Adjusted		Base		Adjusted		Base		Adjusted		Base		Adjusted	
Independent Variables	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value	*B* (95% CI)	p value
Spheres visitation	1.63 (0.06,3.2)	**0.043**	1.19 (-1.48,3.87)	0.38	-1.84 (-3.3,-0.37)	**0.014**	-1 (-3.54,1.54)	0.437	-0.22 (-0.45,0.01)	0.064	-0.07 (-0.47,0.33)	0.736	-0.11 (-0.34,0.11)	0.316	-0.08 (-0.47,0.31)	0.685	-1.26 (-2.97,0.46)	0.15	-0.99 (-3.97,1.99)	0.514
Nature relatedness	1.38 (0.16,2.6)	**0.027**	1.17 (-0.09,2.44)	0.068	0.36 (-0.77,1.5)	0.53	0.56 (-0.63,1.76)	0.354	-0.02 (-0.19,0.16)	0.861	0 (-0.19,0.19)	0.99	0.02 (-0.16,0.19)	0.848	0.04 (-0.15,0.22)	0.692	0.17 (-1.17,1.5)	0.807	0.18 (-1.22,1.59)	0.798
Working with others			-0.51 (-2.54,1.52)	0.62			-0.11 (-2.04,1.81)	0.908			-0.01 (-0.31,0.3)	0.969			0 (-0.3,0.29)	0.973			-0.64 (-2.91,1.62)	0.576
Socializing			1.03 (-0.33,2.38)	0.136			-0.73 (-2.01,0.55)	0.263			-0.13 (-0.33,0.07)	0.201			-0.08 (-0.28,0.11)	0.407			-0.59 (-2.09,0.92)	0.443
Eating/Drinking			0.97 (-0.48,2.43)	0.189			-0.36 (-1.74,1.02)	0.61			-0.11 (-0.32,0.11)	0.331			-0.01 (-0.22,0.21)	0.963			-0.47 (-2.09,1.15)	0.57
Working alone			-1 (-2.18,0.18)	0.097			0.43 (-0.69,1.55)	0.451			0.02 (-0.16,0.19)	0.857			0.02 (-0.15,0.19)	0.805			0.65 (-0.66,1.97)	0.329
Taking a break			-0.34 (-1.95,1.26)	0.673			0 (-1.15,1.9)	0.627			0.11 (-0.13,0.35)	0.363			0.09 (-0.14,0.33)	0.426			-0.59 (-2.38,1.2)	0.515
Admiring nature			0.07 (-1.56,1.7)	0.929			-0.24 (-1.79,1.3)	0.758			0.01 (-0.23,0.25)	0.939			-0.05 (-0.29,0.19)	0.68			0.81 (-1.01,2.62)	0.38

3.7 DISCUSSION

Results from the Study 1 cross-sectional survey suggest that one's activity within the Spheres may explain some of the associations with positive and negative affect. This potential confounding is consistent with studies that have found different activities (such as exercising and socializing) can affect psychological well-being outcomes like stress and anxiety[39–42], and motivates further investigation of the role of specific behaviors within nature with regard to well-being.

As with observational studies in general, this study forbade causal inferencing. Since the Spheres was promoted by Amazon as a place for both relaxation and work (and equipped with amenities such as wifi and tables), it is possible for example that some participants may have chosen to spend more time at the Spheres during particularly stressful times (e.g., as a coping mechanism), or during particularly less stressed times (e.g., when lighter or more flexible workloads afforded time to visit the Spheres). Additionally, this cross-sectional study inquired about self-reported average weekly visitation to the Spheres and general psychological well-being. Estimation of the effects (if any) of time spent in the Spheres on psychological well-being would be much improved by a longitudinal design. Study 2 followed a subset of participants from Study 1 over a two-week period to track how exposure to a gradient of nature in day-to-day environments, and activities within these environments, were associated with affective outcomes for this population of workers. The longitudinal design allowed us to account for how the effects of nature contact on human health may vary across situations and circumstances[5,6,30].

3.8 STUDY 2 INTRODUCTION

Study 2 used a longitudinal design to track the ways in which daily contact with a range of naturalness in environments impacts within-person, state changes in affect and stress. We hypothesized that the presence of more vs. fewer natural features indoors would be associated with psychological well-being. We also hypothesized that this association would be true in outdoor environments as well. We used brief, repeated surveys to assess *in situ* changes in affect, using ecological momentary assessment (EMA). EMA encompasses a range of methodological traditions and methods with the overall objective to gather real-time data in real-world settings that can reduce recall bias and allow for better understanding of the contexts in which data were gathered as well as their short-term impacts[31]. Recent reviews cite EMA as well-suited for studying mental health outcomes, including psychological well-being[32,33].

3.9 MATERIALS AND METHODS

3.9.1 *Participants (N = 33)*

A subset of participants from Study 1 was asked to participate; sampling was stratified based on their response to the survey item from assessing their self-reported average visitation frequency to the Spheres. Since those who visit the Spheres more or less often may also be likely to visit other natural spaces more or less frequently, respectively, we employed the stratified sampling in order to increase the likelihood of capturing variability in daily nature contact within the sample population for Study 2. Three strata were used to capture this variability: low frequency Spheres users (those who self-reported visiting the conservatories 0-1 time/week), medium frequency users (2-4 times/week), and high frequency users (5+times/week). A total of 60 participants were recruited.

3.9.2 *Procedures*

The short (~2-minute), repeated web-based survey assessed the characteristics of the participant's current environment along with their self-reported well-being. This same survey was distributed 5 times per day (every 3 hours between 8am and 8pm, Monday through Sunday, with calendar reminders sent for each survey) for a two-week period in July 2019. This study design sought to assess each individual's outcome responses across various locations (e.g., gym, work) and activities (e.g., eating, doing chores), so that each participant could act as their own control.

3.9.3 *Instruments*

The degree of naturalness in participants' environments was assessed using the question, "Which of the following most closely resembles your current environmental attributes?" with 5 categorical choices ("indoors with no/very little natural elements", "indoors with some natural elements", "outdoors with no/very little natural elements", "outdoors with some natural elements", and "outdoors, completely natural elements (e.g., park)"). Each choice was accompanied by an image to help guide categorization (Figure 3.2). The degree of naturalness was reflected in the images' density of green vegetation. The scenes were likely to reflect typical settings for the study population (i.e., office interiors, downtown settings and parks) and the vegetation (where applicable) matched the season of data collection.

Figure 3.2.Images shown alongside survey question assessing naturalness of participants' current environment (A) "Indoors with no/very little natural elements" (B) "Indoors with some natural elements" (C) "Outdoors with no/very little natural elements" (D) "Outdoors with some natural elements", and (E) "Outdoors with all natural elements"

Dependent variables included state positive affect, assessed with the 5 positive affect items from the PANAS[34,35](Cronbach's alpha = 0.88). Score calculation methods were the same as those described in Study 1. State anxiety was assessed using the 6-item State Trait Anxiety Inventory-Short Form [36] which asked participants to rate the degree to which they felt each of the listed emotions (e.g., "tense") on a 4-point Likert scale. Items 1, 4 and 5 were reverse-coded, and scores were calculated by multiplying the sum by 20/6. Possible scores ranged from 20-80 (Cronbach's alpha = 0.82). To decrease participant burden, the survey omitted assessments of negative affect or depressive symptoms (which had been included in Study 1).

Participants' current location was assessed with, "Where are you right now?" with possible responses: "home", "work (e.g., at the office)", "the Spheres", "restaurant/eatery", "in a form of transportation", "park/beach", "gym", "none of the above". This item was included to address potential confounding by location, e.g., whether being at home is associated with relatively improved well-being compared to being at work.

Activity was an additional control variable, assessed with a survey item, "What are you doing right now?", with the following response choices: "working with others", "working alone", "socializing", "eating/drinking", "taking a break from work", "admiring nature", "exercising", "doing chores/running errands", "none of the above".

3.10 DATA ANALYSIS

All analyses used current environment naturalness as the independent variable. This variable had 5 possible responses: indoors with no/very little natural elements, indoors with some natural elements, outdoors with no/very little natural elements, outdoors with some natural elements, or outdoors completely natural elements. We separated the data into two datasets based on responses taken indoors versus responses taken outdoors to test hypotheses that more natural elements present indoors would confer greater health benefits than indoor settings with fewer natural elements, and that more natural elements present outdoors would confer greater benefits than outdoor settings with fewer natural elements.

Due to the correlated nature of within-person repeated assessments, all analyses used multilevel random intercept and slope linear modelling[37] which clustered surveys (level 1) within individuals (level 2). Base models regressed anxiety or positive affect on environment naturalness, and controlled for trait nature relatedness. Adjusted models also included current activity and survey location as covariates.

3.11 RESULTS

Of the 60 participants recruited, 33 subjects participated and 426 state surveys were completed (mean = 13 surveys per participant).

For indoor environments (Table 3.2), the association between indoor environment naturalness and positive affect was not statistically significant (b = -0.25, p = 0.56). The base model showed a significant association between environment naturalness and state anxiety (b = -4.10, p = 0.0017).

This relationship was no longer statistically significant in the adjusted models, although the trend still suggests a negative association. Socializing (b = -5.31, p = 0.03) and being at home (b = -8.65, p < 0.001) were associated with less anxiety.

3.2. Estimates of environment naturalness and positive affect and state anxiety in indoor environments (Activity reference = no participation; Location reference = Work)

	Positive Affect		Anxiety	
	base	adjusted	base	adjusted
Independent Variables	*B*(95%CI)	*B*(95%CI)	*B*(95%CI)	*B*(95%CI)
Environment naturalness	-0.25 (-1.08, 0.59)	-1.28 (-0.36, 0.56)	-4.1** (-6.65,-1.56)	-0.86 (-3.59,1.87)
Nature relatedness	1.25 (-0.4, 2.9)	1.24 (-0.43, 2.91)	1.54 (-3.01, 6.09)	1.39 (-3.32,6.09)
Activity_Work with others		0.23 (-1.06, 1.51)		0.24 (-3.58,4.07)
Activity_Working alone		-0.51 (-1.69, 0.67)		1.52 (-1.98,5.02)
Activity_Socializing		2.18 (.57, 3.8)**		-5.31* (-10.12,-0.51)
Activity_Eating/Drinking		0.002 (-1.06, 1.06)		-3.21 (-6.37,-0.06)
Activity_Taking a break		0.09 (-1.22, 1.39)		2.91 (-0.97,6.79)
Activity_Admiring nature		-1.02 (-3.08, 1.04)		0.44 (-5.7,6.59)
Activity_Exercising		1.39 (-1.91, 4.68)		-1.15 (-10.98,8.68)
Activity_Doing chores		0.22 (-1.72, 2.16)		3.31 (-2.45,9.07)
Activity_None of the above		-1.84 (-3.54, -0.15)*		0.46 (-4.59,5.51)
Location_Home		0.12 (-1.21, 1.44)		-8.65** (-12.6, -4.7)
Location_the Spheres		2.09 (0.34, 3.83)*		-4.65 (-9.84,0.54)
Location_Restaurant		1.44 (-0.91, 3.8)		1.61 (-5.43, 8.64)
Location_Transportation		-0.6 (-3.16, 1.94)		0.15 (-7.46, 7.76)
Location_Gym		1.64 (-5.19, 8.46)		-11.03 (-31.39, 9.33)
Location_None of the above		-1.66 (-4.44, 1.13)		3.26 (-5.04, 11.56)

** $p < 0.01$
* $p < 0.05$

For outdoor environments (Table 3.3), positive affect was significantly associated with outdoor natural environment (b = 1.96, p = 0.04) in the base model, but the relationship was no longer statistically significant in the adjusted model. There was a significant inverse association between outdoor environment naturalness and anxiety (b = -7.86, p = 0.0005) in the base model, and this statistically significant trend remained after controlling for activity type, survey location and trait nature relatedness.

3.3. Associations between environment naturalness and positive affect and state anxiety in outdoor environments (Activity reference = no participation; Location reference = Work)

	Positive Affect		Anxiety	
	base	adjusted	base	adjusted
Independent Variables	*B*(95%CI)	*B*(95%CI)	*B*(95%CI)	*B*(95%CI)
Environment naturalness	1.96* (0.13, 3.79)	-0.02 (-2.36, 2.31)	-7.86** (-11.97, -3.74)	-6.71* (-11.9, -1.51)
Nature relatedness	-0.22 (-2.28, 1.85)	-0.10 (-1.8, 1.61)	4.96 (-2.23,12.15)	5.36 (-0.92,11.64)
Activity_Work with others		5.3 (0.11, 10.49)		0.08 (-10.97,11.13)
Activity_Working alone		5.75 (-1.68, 13.19)		6.37 (-9.96,22.69)
Activity_Socializing		1.35 (-3.39, 6.08)		-1.4 (-11.73,8.93)
Activity_Eating/Drinking		0.78 (-3.76, 5.33)		0.54 (-9.89,10.96)
Activity_Taking a break		0.91 (-2.67, 4.49)		4.09 (-4.04,12.22)
Activity_Admiring nature		2.1 (-1.07, 5.26)		-7.63 (-14.78,-0.48)
Activity_Exercising		3.03 (-0.6, 6.66)		7.2 (-1.24,15.64)
Activity_Doing chores		1.95 (-1.93, 5.83)		12.16* (2.36,21.95)
Activity_None of the above		3.72 (-0.4, 7.84)		0.75 (-8.49,9.99)
Location_Home		4.78 (-2.67, 12.22)		-0.27 (-16.7, 16.1)
Location_the Spheres		3.57 (-5.71, 12.86)		9.47 (-12.1, 31)
Location_Transportation		2.48 (-4.71, 9.66)		-0.92 (-16.1, 14.25)
Location_Park/beach		6.94 (-1.66, 15.54)		-3.67 (-22.3, 15)
Location_None of the above		6.15 (-1.22, 13.52)		-7.5 (-23.3, 8.32)

** $p < 0.01$

* $p < 0.05$

3.12 STUDY 2 DISCUSSION

Study 2 used repeated-measure assessments to demonstrate that time spent in more natural environments is associated with less state anxiety in outdoor settings, even after taking activity and location into account. This adds support to the research on the affective benefits of nature contact[4,15,17,38], specifically with respect to a worker population.

Within indoor environments, the significant relationship between environment naturalness and state anxiety was reduced and no longer significant when location and activity covariates were included (Table 3.2). In particular, results suggest the activity of socializing and being at home (compared to work) may confound this relationship.

Study 2 was able to differentiate indoor and outdoor environments within the same study population, which few studies have done. Outdoor natural environments were particularly associated with reductions in state anxiety, which aligns with the findings of a study by Largo-Wight et al. (2011) that found the strongest relationships between nature contact and less stress for employees who had more frequent direct, outdoor exposure to nature. In Study 2, outdoor environments had the option to be characterized with "all natural elements" (as may be the case when a participant is at a park, for example), while indoor environments could at most be characterized as having "some natural elements". The capacity for the outdoors to provide more immersive natural environments may play a role in explaining some of the study's findings.

3.13 GENERAL DISCUSSION

Taken together, the findings from this pair of studies adds to emerging research on the association between psychological well-being and nature contact for workers. However, in some cases these associations were attenuated by location or activity type. In order to increase understanding of the ways in which indoor and outdoor natural environments at or near work affect mental health, more research is needed on the contexts in which this nature contact occurs.

In Study 1, The Spheres was an accessible indoor natural environment for Amazon employees; it was located next to the company's headquarter buildings in a downtown area, with amenities such as wifi internet, power outlets and tables. This space was large in scale (nearly 2 acres), density (over 40,000 plants), and biodiversity (several hundred species from dozens of countries), relative to its setting in downtown Seattle, Washington. Furthermore, most of the plants were native to tropical cloud forests, and thus not typically seen in this geographical area. Thus, while this this environmental exposure was highly accessible for day-to-day contact, it may not be generalizable as a proxy for typical, "everyday" nature contact. Future studies can assess the role of such factors as awe—an emotion of wonder and amazement that arises in response to out-of-the-ordinary stimuli[43,44] and demonstrated in the context of nature contact[45] — in such distinct environments. In Study 2, participants' contact with natural environments was not limited to the Spheres. Rather, participants self-reported on the naturalness of their current environments—places they were visiting as part of their day-to-day lives. Outdoor natural environments had stronger associations with affective benefits compared to indoor natural environments. This finding can help employers to prioritize the provision of natural outdoor environments at or near work in order to promote psychological well-being in workers.

3.14 LIMITATIONS

There are several limitations to this pilot study. The study population was drawn from a single (albeit large) technological company in one region of the United States. In addition, rather than recruiting randomly-selected employees of Amazon to participate, participants had voluntarily responded to recruitment ads. Thus, self-selection bias limits the generalizability of the findings.

Demographic variables were not available, prohibiting inclusion of analysis of differences in the characteristics of the final study sample versus other employees who did not choose to participate. Despite the limitations of missing demographic data, the design of Study 2 allowed for each participant to act as their own control, thereby improving the estimation of effects.

Although Study 2 used a longitudinal design, the findings from these studies do not allow causal inferences; without randomization, it is not possible to eliminate alternate plausible explanations for observed associations between our independent and dependent variables. More research on workplace nature contact and mental health should seek to use robust study designs, such as randomized controlled experiments, to elucidate causal pathways. The repeated measurements (5 times per day) may have influenced participants in their choice of location or activity, in anticipation of the surveys. However, it is also worth noting that the response rate was low overall; of the 70 surveys distributed per participant over the course of two weeks, there were 13 surveys completed per participant on average (response rate = 18.6%). No incentives were given for participation, and the survey distribution (via URL available with calendar event reminders) may have contributed to the lower response rate. Future study iterations with incentives commensurate with participant burden, and survey distribution methods such as geolocation-triggered alerts (e.g., when participants enter the Spheres or other pre-specified areas of interest) may facilitate the collection of rich data.

Future versions of the study can also seek larger sample sizes and a diverse study population to reflect the heterogeneity within a large company like Amazon. With over 70,000 Amazon employees in the Seattle area, future iterations can seek to capture the variation in not only job categories (e.g., software development versus accounting versus warehouse fulfillment versus marketing, etc.) but also diversity in income, education and race/ethnicity. Such characteristics may influence preferred activities in natural settings (for example, those in more isolated offices may seek the Spheres for socialization opportunities, versus those who work in louder fulfillment centers may appreciate the Spheres for its relative quiet atmosphere), and/or psychological well-being outcomes. One of the key benefits to the cross-sectional portion of the study (Study 1) was in the consistency and characterizability of the exposure (the Spheres). In many studies in the field, the nature exposure can be diffuse, diverse and unclear. However, with the Spheres, we knew a great amount of detail about the setting, including its quality, size, temperature and humidity range, activity affordances, etc. It would be a great opportunity to use such a well-defined space as an intervention within a randomized controlled design with a large sample of diverse employee participants. This type of study would be a valuable contribution to the evidence base on the effects of nature contact on psychological well-being in workers.

3.15 CONCLUSIONS

The findings from these studies support the notion that nature contact is associated with less anxiety in employees. This is especially important given the need for greater psychological well-being at the workplace. The United States' National Institute for Occupational Safety and Health found 40% of workers described their job as being very/extremely stressful, and 25% cited their jobs as the number one stressor in their lives[46]. Additionally, the World Health Organization recently recognized "burnout" as a work-specific chronic stress phenomenon which is now included in the most recent revision of the International Classification of Diseases[47]. Although one study found stress reduction effects from exposure to natural environments in a study sample with burnout syndrome[48], more research is needed on the mental health benefits of nature contact at or near the workplace.

Given previous findings on the barriers to nature contact at the workplace---primarily perceived lack of time and perception that going outside during work hours may be frowned upon by others—companies may foster better mental health in their employees by providing opportunities for nature contact in both indoor and outdoor spaces, and by encouraging employees to utilize these opportunities.

Thus, this multistudy report (alongside existing literature on nature contact in the workplace) provide actionable priorities for companies to provide relatively low-cost, safe interventions via access to natural environments. This report may also contribute to discourses on the importance of a workplace culture surrounding time spent outside and in nature (i.e., a culture that promotes such salutary experiences versus a culture that presents barriers to such experiences), and on the consideration of activities that can be particularly promoted within such spaces.

3.16 REFERENCES

1. WHO. *The World Health Report 2001: Mental Health: New Understanding, New Hope*. World Health Organization; 2001.

2. Berman MG, Kross E, Krpan KM, et al. Interacting with nature improves cognition and affect for individuals with depression. *J Affect Disord*. 2012;140(3):300-305. doi:10.1016/j.jad.2012.03.012

3. Bratman GN, Daily GC, Levy BJ, Gross JJ. The benefits of nature experience: Improved affect and cognition. *Landsc Urban Plan*. 2015;138:41-50. doi:10.1016/j.landurbplan.2015.02.005

4. de Vries S, van Dillen SME, Groenewegen PP, Spreeuwenberg P. Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Soc Sci Med*. 2013;94:26-33. doi:10.1016/j.socscimed.2013.06.030

5. Frumkin H, Bratman GN, Breslow SJ, et al. Nature Contact and Human Health: A Research Agenda. *Environ Health Perspect*. 2017;125(7):075001. doi:10.1289/EHP1663

6. Hartig T, Mitchell R, de Vries S, Frumkin H. Nature and Health. *Annu Rev Public Health*. 2014;35(1):207-228. doi:10.1146/annurev-publhealth-032013-182443

7. Neill C, Gerard J, Arbuthnott KD. Nature contact and mood benefits: contact duration and mood type. *J Posit Psychol*. 2019;14(6):756-767. doi:10.1080/17439760.2018.1557242

8. Pouso S, Borja A, Fleming LE, Gómez-Baggethun E, White M, Uyarra MC. *Maintaining Contact with Blue-Green Spaces during the COVID-19 Pandemic Associated with Positive Mental Health*. SocArXiv; 2020. doi:10.31235/osf.io/gpt3r

9. Bratman GN, Hamilton JP, Daily GC. The impacts of nature experience on human cognitive function and mental health: Nature experience, cognitive function, and mental health. *Ann N Y Acad Sci*. 2012;1249(1):118-136. doi:10.1111/j.1749-6632.2011.06400.x

10. Perrins SP, Bratman G. *Health Benefits of Nature*. Washington State Recreation and Conservation Office; 2020. Accessed February 1, 2021. https://rco.wa.gov/wp-content/uploads/2020/01/HealthBenefitsofNature.pdf

11. Ulrich RS. Aesthetic and Affective Response to Natural Environment. In: *Human Behavior and Environment*. Vol 6. I. Altman & J. Wohwill; 1983:85-125.

12. Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M. Stress recovery during exposure to natural and urban environments. *J Environ Psychol*. 1991;11(3):201-230. doi:10.1016/S0272-4944(05)80184-7

13. Dadvand P, Bartoll X, Basagaña X, et al. Green spaces and General Health: Roles of mental health status, social support, and physical activity. *Environ Int*. 2016;91:161-167. doi:10.1016/j.envint.2016.02.029

14. Grahn P, Stigsdotter UA. Landscape planning and stress. *Urban For Urban Green*. 2003;2(1):1-18. doi:10.1078/1618-8667-00019

15. Roe J, Thompson C, Aspinall P, et al. Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. *Int J Environ Res Public Health*. 2013;10(9):4086-4103. doi:10.3390/ijerph10094086

16. Stigsdotter UK, Ekholm O, Schipperijn J, Toftager M, Kamper-Jørgensen F, Randrup TB. Health promoting outdoor environments - Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scand J Public Health*. 2010;38(4):411-417. doi:10.1177/1403494810367468

17. Ward Thompson C, Roe J, Aspinall P, Mitchell R, Clow A, Miller D. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landsc Urban Plan*. 2012;105(3):221-229. doi:10.1016/j.landurbplan.2011.12.015

18. Kaplan R. The role of nature in the context of the workplace. *Landsc Urban Plan*. 1993;26(1-4):193-201. doi:10.1016/0169-2046(93)90016-7

19. Shin WS. The influence of forest view through a window on job satisfaction and job stress. *Scand J For Res*. 2007;22(3):248-253. doi:10.1080/02827580701262733

20. Lottrup L, Grahn P, Stigsdotter UK. Workplace greenery and perceived level of stress: Benefits of access to a green outdoor environment at the workplace. *Landsc Urban Plan*. 2013;110:5-11. doi:10.1016/j.landurbplan.2012.09.002

21. Lottrup L, Stigsdotter UK, Meilby H, Corazon SS. Associations between use, activities and characteristics of the outdoor environment at workplaces. *Urban For Urban Green*. 2012;11(2):159-168. doi:10.1016/j.ufug.2011.12.006

22. Hitchings R. Urban greenspace from the inside out: An argument for the approach and a study with city workers. *Geoforum*. 2010;41(6):855-864. doi:10.1016/j.geoforum.2010.07.004

23. Bratman GN, Anderson CB, Berman MG, et al. Nature and mental health: An ecosystem service perspective. *Sci Adv*. 2019;5(7):eaax0903. doi:10.1126/sciadv.aax0903

24. The Spheres. the spheres. Accessed November 10, 2020. www.seattlespheres.com

25. Qualtrics. Qualtrics. Published 2020. Accessed November 11, 2020. www.qualtrics.com

26. Watson D, Anna L, Tellegen A. Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. Published online 1988:8.

27. Lovibond PF, Lovibond SH. The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behav Res Ther*. 1995;33(3):335-343. doi:10.1016/0005-7967(94)00075-U

28. Nisbet EK, Zelenski JM. The NR-6: a new brief measure of nature relatedness. *Front Psychol*. 2013;4. doi:10.3389/fpsyg.2013.00813

29. Largo-Wight E, Chen WW, Dodd V, Weiler R. Healthy Workplaces: The Effects of Nature Contact at Work on Employee Stress and Health. *Public Health Rep*. 2011;126(1_suppl):124-130. doi:10.1177/00333549111260S116

30. Gascon M, Triguero-Mas M, Martínez D, et al. Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *Int J Environ Res Public Health*. 2015;12(4):4354-4379. doi:10.3390/ijerph120404354

31. Shiffman S, Stone AA, Hufford MR. Ecological Momentary Assessment. *Annu Rev Clin Psychol*. 2008;4(1):1-32. doi:10.1146/annurev.clinpsy.3.022806.091415

32. de Vries LP, Baselmans BML, Bartels M. Smartphone-Based Ecological Momentary Assessment of Well-Being: A Systematic Review and Recommendations for Future Studies. *J Happiness Stud*. Published online October 23, 2020. doi:10.1007/s10902-020-00324-7

33. Wenze SJ, Miller IW. Use of ecological momentary assessment in mood disorders research. *Clin Psychol Rev*. 2010;30(6):794-804. doi:10.1016/j.cpr.2010.06.007

34. Kercher K. Assessing subjective well-being in the old-old. *Res Aging*. 1992;14:131-167.

35. Mackinnon A. A short form of the Positive and Negative A}ect Schedule] evaluation of factorial validity and invariance across demographic variables in a community sample. *Personal Individ Differ*. Published online 1999:12.

36. Marteau T, Bekker H. THE DEVELOPMENT OF A 6-ITEM SHORT-FORM OF THE STATE SCALE OF THE SPIELBERGER STATE TRAIT ANXIETY INVENTORY (STAI). *Br J Clin Psychol*. 1992;31:301-306.

37. Finch WH, Bolin JE, Kelley K. *Multilevel Modeling Using R*. CRC Press; 2014.

38. Pun VC, Manjourides J, Suh HH. Association of neighborhood greenness with self-perceived stress, depression and anxiety symptoms in older U.S adults. *Environ Health*. 2018;17(1):39. doi:10.1186/s12940-018-0381-2

39. Bekele T, Rourke SB, Tucker R, et al. Direct and indirect effects of perceived social support on health-related quality of life in persons living with HIV/AIDS. *AIDS Care*. 2013;25(3):337-346. doi:10.1080/09540121.2012.701716

40. Dour HJ, Wiley JF, Roy-Byrne P, et al. PERCEIVED SOCIAL SUPPORT MEDIATES ANXIETY AND DEPRESSIVE SYMPTOM CHANGES FOLLOWING PRIMARY CARE INTERVENTION: Research Article: Social Support Mediates Symptom Change. *Depress Anxiety*. 2014;31(5):436-442. doi:10.1002/da.22216

41. McDowell CP, Dishman RK, Gordon BR, Herring MP. Physical Activity and Anxiety: A Systematic Review and Meta-analysis of Prospective Cohort Studies. *Am J Prev Med*. 2019;57(4):545-556. doi:10.1016/j.amepre.2019.05.012

42. Stonerock GL, Hoffman BM, Smith PJ, Blumenthal JA. Exercise as Treatment for Anxiety: Systematic Review and Analysis. *Ann Behav Med*. 2015;49(4):542-556. doi:10.1007/s12160-014-9685-9

43. Keltner D, Haidt J. Social Functions of Emotions at Four Levels of Analysis. *Cogn Emot*. 1999;13(5):505-521. doi:10.1080/026999399379168

44. Piff PK, Dietze P, Feinberg M, Stancato DM, Keltner D. Awe, the small self, and prosocial behavior. *J Pers Soc Psychol*. 2015;108(6):883-899. doi:10.1037/pspi0000018

45. Ballew MT, Omoto AM. Absorption: How Nature Experiences Promote Awe and Other Positive Emotions. *Ecopsychology*. 2018;10(1):26-35. doi:10.1089/eco.2017.0044

46. U.S. Department of Health and Human Services. *Stress...At Work*.; 1999. https://www.cdc.gov/niosh/docs/99-101/pdfs/99-101.pdf?id=10.26616/NIOSHPUB99101

47. World Health Organization. Burn-out an "occupational phenomenon": International Classification of Diseases. Accessed October 10, 2020. https://www.who.int/mental_health/evidence/burn-out/en/

48. Kjellgren A. A comparison of the restorative effect of a natural environment with that of a simulated natural environment. *J Environ Psychol*. Published online 2010:9.

Chapter 4. NATURE CONTACT, PSYCHOLOGICAL WELL-BEING, AND PHYSIOLOGICAL STRESS REACTIVITY AND RECOVERY: A MULTISTUDY REPORT OF CROSS-SECTIONAL AND RANDOMIZED CONTROLLED EXPERIMENTAL FINDINGS

4.1 ABSTRACT

Stress reduction is associated with nature contact, yet relatively few studies have assessed psychophysiological correlates of autonomic nervous system responses, and no study to date continuously assessed acute stress response within randomly assigned environmental conditions (e.g., nature versus urban). In addition, no study to date has experimentally tested whether natural environments may be associated with buffering of (i.e., attenuated) acute stress response. In this multistudy report, N = 96 participants first completed a cross-sectional survey (Study 1) on self-reported average weekly nature visitation, and affective, depressive symptom, anxiety and stress-related well-being. Results showed more time spent in nature was associated with more positive affect and less depression.

Then, a subset of participants (N= 56; a smaller-than-intended sample due to COVID-19 and subsequent halt in data collection) completed a randomized controlled experimental procedure (Study 2). Participants wore discrete, mobile psychophysiology equipment and sat in the nature, urban, or control (laboratory) site during an induced stressor and for a 10-minute recovery afterward. Results suggest more parasympathetic activation (as assessed by root mean square of successive differences) and sympathetic activation (assessed by skin conductance level) in the nature and control conditions. Results also suggest faster stress recovery (assessed by heart rate) in the nature condition.

Exploratory subgroup analyses suggest preliminary trends on effect modification trends by chronic stress levels and history of early adversity, wherein those with greater psychosocial burden may benefit more from time spent in nature. More research is needed to build on the preliminary findings of these studies, including potential effect modifications by trait chronic stress or history of early adversity, and the relationship of parasympathetic vs. sympathetic dominance in natural environments during acute stress.

4.2 INTRODUCTION

The number of studies suggesting an association between nature contact and a multitude of psychological wellbeing metrics has grown exponentially in recent years, with stress reduction among the most robustly supported mental health outcomes[1–5]. A prominent psychoevolutionary theory, *Stress Reduction Theory* (SRT), lends a potential explanation for this observed effect. SRT posits that humans have evolved to respond quickly and positively to nature settings after experiencing acute stress, through activation of the parasympathetic nervous system[6,7].

Findings from existing cross-sectional studies suggest that the presence of nature around a residence may buffer (i.e., be protective) against the effects of stressors[8,9]. In these studies, participants who had more nature around their homes experienced a smaller magnitude of the negative effects of a life stressor compared to those with less nearby nature. However, these studies have been cross-sectional and unable to isolate and distinguish real-time effects of contrasting environmental conditions on physiological responses to (and recovery from) an acute stressor.

Despite the growing breadth of evidence in support of SRT[2,5,7,8,10,11], relatively few studies have explored the effects of presence in natural environments in real time on the autonomic nervous system. A review of studies investigating physical (as opposed to simulated) contact with nature and physiological stress response concluded that the mixed results and high variation in measurement strategies necessitate further research[12]. Researchers have typically assessed physiological indicators (such as heart rate, heart rate variability, and skin conductance) of the two divisions of the autonomic nervous system: the sympathetic (commonly referred to as the "fight or flight" response) and parasympathetic (the "rest and digest" response) nervous systems before and after environmental exposure. Studies also commonly compared physiological stress response in more natural versus more urban (i.e., environments with more man-made, built features) settings[13–17]. Results from these studies generally support a positive association between natural environments and parasympathetic activity, including lower pulse rates and blood pressure, and increased heart rate variability[13,14,18,19], compared to urban environments.

Through the use of mobile physiology equipment and continuous monitoring of physiological responses, *in situ* studies can now examine the effects of the environment on 1) responses to acute stressors in real time, and 2) parasympathetic-driven stress reduction immediately following a stressor. In their review, Kondo et al. (2018) identified only thirteen studies to date that have used continuous monitoring of physiological stress response, and four that induced stress prior to experimental exposure. However, no studies have measured both acute stress response and recovery within contrasting environmental conditions (e.g., nature vs. urban).

Finally, effect modification by trait psychosocial stress, such as chronic stress levels or history of early adversity, is underexplored. While it is well-documented that individuals from underserved socioeconomic backgrounds are more vulnerable to psychosocial stress, these vulnerabilities may also drive increased reactivity to social and environmental factors, perpetuating downstream health issues[20,21]. The associations between chronic stress or early adversity to a multitude of negative health outcomes have also been attributed to altered functioning of stress response systems[22–25]--the "wear and tear" resultant from chronic activation can lead to maladaptive, dysfunctioning of these systems and can thereby inform how an individual responds to stressors[25–29]. Together, this corpus of work motivates further examination of how psychophysiological responses to stressors may vary by trait levels of chronic stress or early adversity.

This current set of studies looks first at the cross-sectional associations between self-reported time spent in nature and psychological well-being (positive and negative affect, depressive symptoms, and anxiety and stress levels), as well as effect modification by chronic stress or history of early adversity in a population of undergraduate university students (Study 1). A subset of these participants then enrolled in a randomized controlled experimental procedure (Study 2) in which we induced a stressor within one of three randomly assigned conditions (nature, urban or control) and continuously monitored physiological responses to the stressor and the recovery afterwards.

4.3 GENERAL PROCEDURE

Both studies used the psychology department subject pool from a large, public university in a metropolitan city of the Pacific Northwest region of the United States. This study recruited subjects (fluent English speakers ages 18 and over) through an advertisement posted on the online participant management system used by the department. Those interested in participating used a link to access the screening questionnaire. Exclusion criteria in this questionnaire included: history of psychiatric illness or disorder, and medical conditions or medication use that may affect autonomic nervous system functioning (history of cardiovascular disease, hyperthyroidism, and/or use of asthma inhalers or allergy or cough medicines that contain decongestant).

A brief overview of the multipart study is described here (the design and methods for each study are described in detail in succeeding sections). Participants who provided informed consent completed a one-time online battery of surveys (Study 1) and were invited to choose a 1.5hr timeslot for the in-lab experiment (Study 2) using the same online management system mentioned above. The two studies were run concurrently, and procedures were approved by the University of Washington Institutional Review Board. Participants in Study 2 were randomly assigned to one of the three conditions using a web-based randomizer[30]; each participant underwent baseline physiological assessments at the lab and then walked (2 min) to their randomly assigned site where they remained seated during an induced stressor task (8 min). After the task, they continued to sit for a 10-minute "recovery" period before returning to the lab for post-intervention assessments, thereby concluding their participation in the study.

4.4 Study 1: Cross-sectional survey of nature contact and psychological well-being

In Study 1 we tested whether: H1) higher levels of self-reported average nature contact would be associated with higher levels of positive affect and lower levels of negative affect and depressive, anxiety, and stress-related symptoms; and H2) levels of chronic stress or early adversity would moderate the associations in H1, with greater stress-related benefits for those with more psychosocial burden.

4.4.1 *Method*

4.4.1.1 Participants

N = 96 participants from the University of Washington Psychology department's human subjects pool completed the online survey (referred to as the "baseline survey" from here on to reflect the assessment of general individual traits) between July and November 2019 (58% female; mean age = 19(SD = 2)). 58% of participants self-reported as being Asian, 22% as White, and 9% identified with more than one listed racial or ethnic group (race/ethnicity data were missing for N = 3 participants). Participants were compensated with course credit.

4.4.1.2 Measures

The cross-sectional baseline survey was hosted on Qualtrics software[31]. The independent variable was assessed with a single question, "On average, approximately how many hours per week do you consider yourself to interact with nature in general? For example, walking outside, biking, gardening, playing games/sports, camping, fishing, reading outside, yard work, hanging out in a park, etc…". Response choices were: "Less than 1hr/week", "1-3hrs/week", "4-6hrs/week","7-9hrs/week","10-15hrs/week" and "More than 15 hrs/week".

Psychological well-being outcome variables included positive and negative affect using the 20-item Positive and Negative Affective Schedule[32] which asked participants to rate the extent to which they felt feelings such as "enthusiastic" and "distressed" *in general* using a 5-point Likert response ranging from "Very slightly or not at all" to "Extremely". Scores were calculated by summing positive (Cronbach's alpha = 0.89) and negative (Cronbach's alpha = 0.88) affect items respectively, with a possible score range of 10-50.

Depression, anxiety and stress outcome variables were assessed using the subscales from the 21-item Depression, Anxiety and Stress Scale measure[33]. Participants were asked the extent to which the measure's statements (e.g., "I felt that I had nothing to look forward to" (depression), "I felt I was close to panic" (anxiety), and "I tended to over-react to situations" (stress)) applied to them in general, using a 4-point Likert response from "Did not apply to me at all" to "Applied to me very much or most of the time". Scores for depression (Cronbach's alpha = 0.88), anxiety (Cronbach's alpha = 0.73) and stress (Cronbach's alpha = 0.77) were calculated per measure scoring instructions with a possible range of 0-42.

Trait relatedness to nature was included as a control variable using the 6-item Nature Relatedness Scale[34], which assessed the degree to which participants in general agree to such statements as "My relationship to nature is an important part of who I am" and "I take notice of wildlife where I am" with five Likert responses from "disagree strongly" to "agree strongly". Scores were calculated by averaging all 6 items with a possible range of 1-5 (Cronbach's alpha =0.83).

Demographic control variables included sex and race/ethnicity. Given the low number of respondents identifying with "Black" (N= 3), "Hispanic"(N=3) or "Other"(N=2) race/ethnicity categories, these categories were collapsed into "Other" as a strategy to preserve statistical power[35].

Chronic stress was assessed as an effect modifier, using the stress subscale score from the Depression, Anxiety and Stress Scale detailed above. Responses were coded as "Normal" when scores were 0-14 (N= 72), per suggested cut-off scores[33]. Although the suggested cut-off scores differentiate along severity (i.e., mild vs. moderate vs. severe stress), all scores greater than 14 were coded as "High" due to the relatively few above-normal responses in our study sample (N = 31).

Early life adversity was also assessed as an effect modifier, using the 10-item Adverse Childhood Events (ACE) measure[36] which asked participants to respond "yes" or "no" to different childhood experiences such as physical abuse or living with a mentally ill household member. The number of "yes" responses were tallied for a score range of 0-10. Response distributions showed a high zero count (N = 50 (52%); median = 1). Thus, responses were categorized as "0 ACEs" or "1 or more ACEs".

4.4.2 *Analyses*

All analyses were conducted in R Studio[37]. Multiple regression power calculation was completed using the *pwr* package[38] with an *a priori* significance level of 0.05, power of 0.8, and estimated effect size of 0.31 (based on a published meta-analysis of the effects of physical nature contact on affective outcomes[39]). The calculation suggested a sample size of 48 participants was needed to test the hypothesis that more self-reported average nature contact would be associated with greater psychological well-being (after controlling for trait nature relatedness, sex, and race/ethnicity), and moderated by chronic stress or early adversity.

Each dependent variable (positive affect, negative affect, depression, anxiety and stress) was regressed on average weekly nature contact in separate linear regression models with sex (reference category, “male”) and race/ethnicity (reference category, “Asian”) covariates. A separate set of models added chronic stress (reference category, “Normal”) or early adversity (reference category, “0 ACEs”) as an interaction term.

4.4.3 *Results*

N = 96 participants completed the cross-sectional baseline survey between July and November 2019. Baseline characteristics are in Table 4.1.

4.1. Baseline characteristics for N = 96 participants in Study 1 (race/ethnicity data missing for N = 3)

Mean Age years (SD)	19 (2)
Sex	
Female (%)	57 (58)
Male (%)	39 (41)
Race	
White (%)	21 (22)
Asian (%)	56 (58)
Multiracial (%)	8 (8)
Other (%)	8 (8)

Summary statistics for outcome and predictor variables are shown in Table 4.2.

4.2. Summary statistics for outcome and predictor variables (N = 96)

	mean (SD)	range
Nature relatedness	3.3(0.84)	1.7-5.0
Positive affect	3.26 (0.67)	1.0-4.9
Negative affect	2.11 (0.68)	1.0-4.2
Depression	7.44 (7.26)	0-36
Anxiety	8.56 (7.26)	0-32
Stress	10.81 (6.5)	0-30
	Categorical	**N (%)**
Average weekly nature contact	<1hr/week	7 (7%)
	1-3hrs/week	29 (30%)
	4-6hrs/week	33 (34%)
	7-9hhrs/week	17 (18%)
	10-15hrs/week	7 (7%)
	>15hrs/week	3 (3%)

More self-reported nature contact was associated with more positive affect (*B* = 0.12, p = 0.046) and less depression (*B* = -1.48, p = 0.026), after controlling for sex, race/ethnicity, and trait nature relatedness (Table 4.3). There was also a marginally statistically significant (defined *a priori* as a p-value between 0.05 and 0.10) association between more nature contact and less negative affect (*B* = -0.12, p = 0.061) and stress (*B* = -1.12, p = 0.062).

4.3. Estimates for associations between average weekly nature contact and outcomes, controlling for sex, race/ethnicity and nature relatedness (N=96)

	B	**95% CI**	**p-value**
Outcomes			
Positive Affect	0.12	(0.002, 0.24)	0.046
Negative Affect	-0.12	(-0.24, 0.01)	0.061
Depression	-1.48	(-2.78, -0.18)	0.026
Anxiety	-0.55	(-1.71, 0.6)	0.341
Stress	-1.12	(-2.31, 0.06)	0.062

Moderation models showed statistically significant interaction between chronic stress and positive affect (Table 4.4a) with the simple slope for the normal chronic stress group differing significantly from zero (Table 4.4b), and marginally statistically significant interaction between ACE and positive affect, negative affect and stress (Table 4.5). Higher chronic stress was associated with *less* positive affect with increased nature contact (*B* = -0.32, p = 0.031) (Figure 4.1).

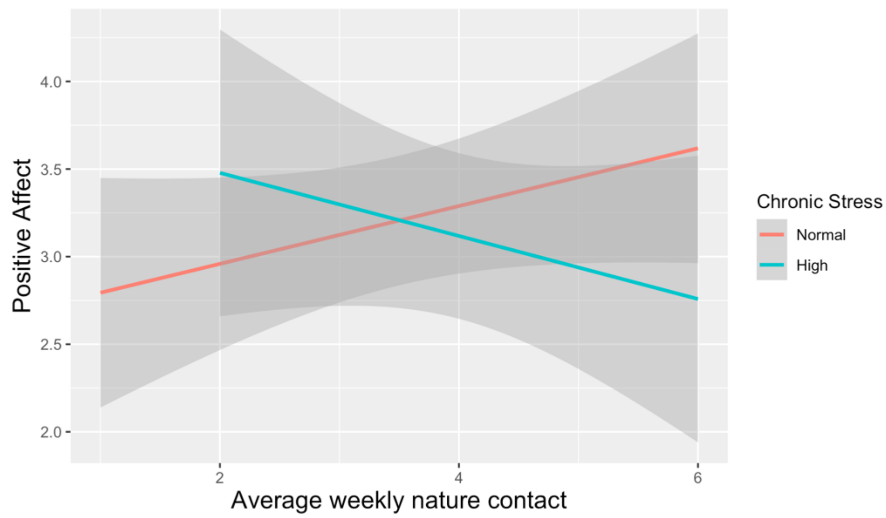

Figure 4.1. Interaction effect of chronic stress levels and average weekly nature contact frequency for positive affect.

4.4.(A; Left) Average weekly nature contact association with positive affect, with significant modification by chronic stress (B; Right) Simple slopes of chronic stress groups in association between nature contact and positive affect

Parameters	Estimate (SE)	p
Nature contact	0.183(0.066)	**0.007**
Chronic stress (ref = Normal)	0.952(0.455)	**0.039**
Sex (ref = male)	-0.101(0.138)	0.467
Nature relatedness	0.1(0.083)	0.228
Multiracial (ref = Asian)	0.093(0.222)	0.675
Other race (ref = Asian)	0.126(0.247)	0.612
White (ref = Asian)	0.189(0.175)	0.283
Nature contact * Chronic stress	-0.322(0.147)	**0.031**

Chronic Stress	Nature Contact	SE	df	lower.CL	upper.CL
Normal	0.183	0.1	87	0.0518	0.313
High	-0.14	0.1	87	-0.4071	0.127

Having 1 or more ACEs was associated (with marginal statistical significance) with more positive affect (*B* = 0.21, p = 0.086), negative affect (*B* = 0.24, p = 0.052) and stress (*B* = 2.02, p = 0.082) (Figure 4.2).

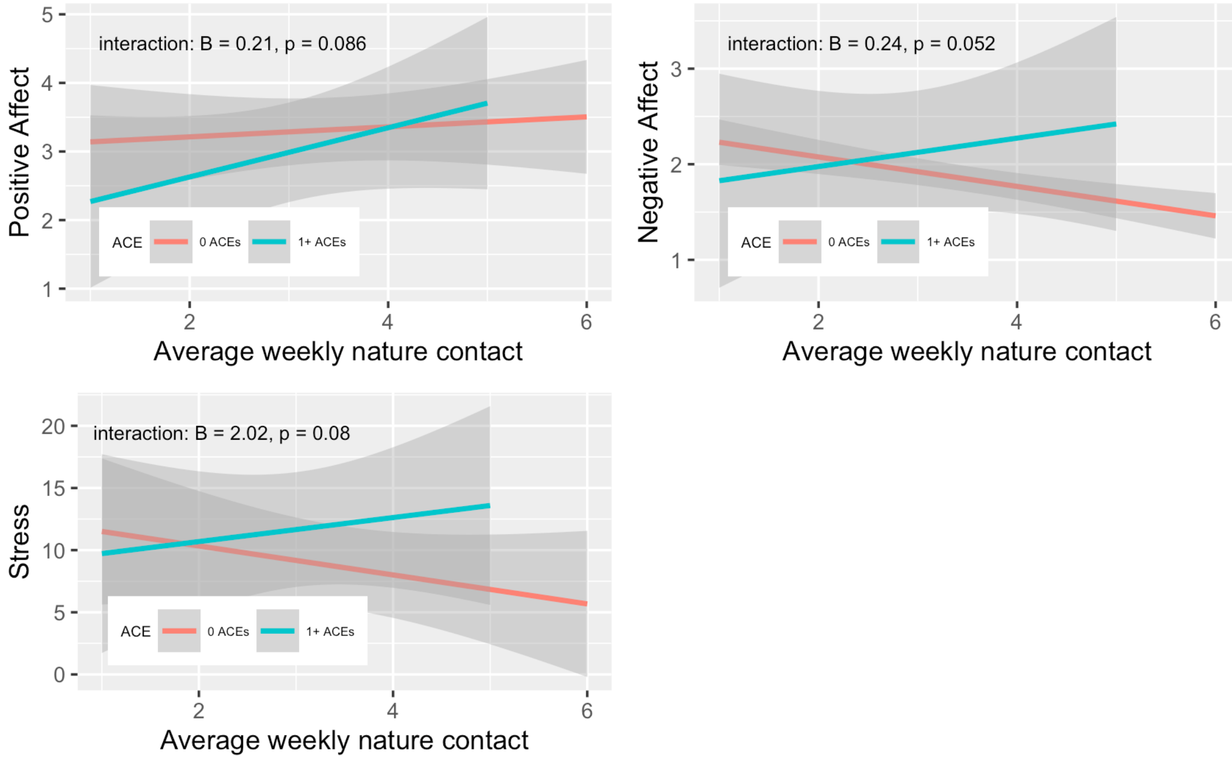

Figure 4.2. Interaction effect of ACEs and average weekly nature contact frequency for positive affect, negative affect, and stress; B coefficients and p-values for interaction terms.

4.5. Positive and negative affect and stress regressed on average weekly nature contact, with marginally significant modification by early adversity

	Positive Affect		**Negative Affect**		**Stress**	
Parameters	**Estimate (SE)**	**p**	**Estimate (SE)**	**p**	**Estimate (SE)**	**p**
Nature contact	0.035(0.077)	0.646	-0.198(0.08)	**0.013**	-1.789(0.74)	**0.017**
ACE (ref = 0)	-0.736(0.383)	0.058	-0.413(0.39)	0.288	-3.513(3.68)	0.342
Sex (ref = male)	-0.073(0.139)	0.600	0.044(0.14)	0.755	0.402(1.33)	0.764
Nature relatedness	0.11(0.083)	0.185	0.035(0.08)	0.677	0.571(0.79)	0.473
Multiracial (ref = Asian)	0.124(0.219)	0.574	0.2(0.22)	0.368	3.882(2.1)	0.068
Other race (ref = Asian)	0.211(0.256)	0.413	0.339(0.26)	0.192	0.247(2.46)	0.92
White (ref = Asian)	0.185(0.177)	0.299	0.061(0.18)	0.734	0.408(1.7)	0.811
Nature contact * ACE	0.208(0.12)	0.086	0.238(0.12)	0.052	2.022(1.15)	0.082

4.4.4 *Discussion*

Study 1 demonstrated more self-reported nature contact is associated with more positive affect and less depression, and marginally significantly associated with less negative affect and stress. These findings align with results from existing literature[5,40–44]. Our results also suggest that two individual traits—chronic stress level and history of early life adversity (ACEs)—may moderate these associations. Per the growing literature on potential effect modifiers of natural environments on health outcomes[45–48], we had hypothesized that greater psychological vulnerability would be associated with *greater* improvements in mental health outcomes with more nature contact, compared to less chronic stress or fewer ACEs. However, the trends were inconclusive; while lower chronic stress was associated with more positive affect in nature, having a history of early adversity was associated with greater responsivity in nature overall (i.e., with more positive affect as well as negative affect and stress). Limitations inherent to cross-sectional designs encourage cautious interpretation of the results. For example, a recent study found that those experiencing mental health problems such as anxiety and depression visited nature as frequently as those without these problems[49]; in the current study, it is possible that those who were not feeling well (e.g., experiencing more depressive symptoms) may have sought nature more actively as a way to cope. This self-selection bias may confound our observed associations. Study 2 therefore used a randomized controlled experiment design (with a subset of Study 1 participants) for a deeper investigation into any associations between nature contact and psychological well-being.

4.5 STUDY 2

Study 2 randomly assigned each participant to one of three conditions--nature, urban or control (i.e., stay at the lab), and tracked individuals' electrophysiological responses to their environmental condition as well as to a stressor task. By including a control condition (described further in following sections), we sought to expand on existing findings on nature versus urban comparisons to investigate whether exposure to everyday urban environments would also be as associated with worse stress-related outcomes compared to staying in the lab. The intention was to elucidate whether urban environments would be a relatively harmful exposure by capturing differences in stress response between those staying in the lab (the "control") versus those receiving the urban intervention.

In addition, trait levels of chronic stress and history early adversity (assessed in the baseline survey in Study 1) were included as hypothesized moderators to build upon the cross-sectional findings on the potential interaction effects. Study 2 sought specifically to fill key knowledge gaps on nature contact and *in situ* psychophysiological stress responses to acute stress and recovery afterward, as well as any moderation of effects by trait chronic stress or history of early adversity. Due to the COVID-19 pandemic, data collection was halted prematurely, with a resultant sample size of N = 56 (versus the targeted N = 90). As such, the methods and results outlined below are primarily useful to establish protocol development and feasibility, and reflect preliminary findings, for future study iterations.

4.5.1 *Method*

4.5.1.1 Participants

N = 56 participants from Study 1 completed the in-lab portion (i.e., Study 2) in summer and fall of 2020. Another wave of data collection was scheduled for spring 2021 for an intended final sample size of N = 90, but this was not possible due to the COVID-19 pandemic. The resumption of data collection (e.g., upon widespread vaccination and/or per public health announcements of reduced transmission rates and risks) was not deemed scientifically feasible, i.e., that the study may potentially have become meaningfully different compared to the study as executed pre-COVID-19. For instance, study procedures would be adjusted (e.g., mask-wearing by participants and study staff, moving procedures from our windowless lab space to an area with more ventilation) and other standard procedures (e.g., with study staff in close contact with the participant) may have induced more stress compared to pre-COVID. The aggregation of data with these adjustments with pre-COVID-19 data may thus have been inappropriate. Thus, analyses were begun with data from N = 56 participants (all collected pre-COVID-19).

57% of participants were female, 23% self-reported as being Caucasian, and 59% as Asian. Mean age was 19.35 (SD = 2.0). Sex, race/ethnicity and age characteristics between the Study 1 and Study 2 samples were comparable (Table 4.6).

4.6. Baseline characteristics for participants in Study 1 vs. Study 2

	Study 1	Study 2
Mean Age years (SD)	19 (2)	19(2)
Sex		
Female (%)	57 (58)	32 (57)
Male (%)	39 (41)	24 (43)
Race		
White (%)	21 (22)	14 (25)
Asian (%)	56 (58)	35 (63)
Multiracial (%)	8 (8)	3 (5)
Other (%)	8 (8)	4 (7)

4.5.1.2 Conditions

All condition sites were located at the University of Washington campus in Seattle, Washington. (Figure 4.3). The nature site was an outdoor 2-acre herb garden surrounded by trees (predominantly evergreen conifers and magnolias). Public access to the procedure area of the garden was restricted during data collection. The urban site was a brick pedestrian landing between the campus and a larger road (Montlake Boulevard), with views of the road and University of Washington medical center facilities. The nature and urban condition sites were equidistant (~450 feet, approximately 2 minutes' walk) from the control site. The control condition was a ground-level laboratory space. The interior was aesthetically muted and with minimal decorations aside from office furnishings (e.g., file cabinets, tables and chairs). The laboratory was the "control" site in that all participants began study procedures at the lab, while only those assigned to the urban or nature sites would leave the lab (and thereby receive "interventions"). Therefore, those remaining in the lab lacked an intervention. This allowed us to explore whether exposure to everyday urban environments would be associated with worse stress-related outcomes. Those assigned to the control site would stay seated at a desk with a view of the neutral-colored wall.

Figure 4.3. Nature, urban, control condition sites

4.5.2 *Measures*

The complete list of measures is detailed in the supplementary materials. Measures included in subsequent analyses sections are outlined below.

4.5.2.1 Stressor task

The paper-based stressor task used a statement provided by the participant as part of their Study 1 baseline survey. They were asked to identify and briefly describe "two UNRESOLVED major problems or issues that make you very SAD, that you are currently experiencing, and have been repeatedly dwelling on and frequently thinking about." They indicated (on a 1-10 scale) how sad each problem made them feel. If they rated a problem as less than an 8 out of 10 on the scale, they were asked to identify a different problem that was at least an 8 on the scale. During the task, participants were given a printed copy of their problem statement and then timed by a research staff member while they thought about the problem (2 min), wrote about the problem (2 min), thought about the problem again (2 min), and wrote about the problem again (2 min), for a total of 8 minutes of timed tasks. This task had been developed in-lab and in pilot work was shown to increase physiological correlates of stress (i.e., heart rate, blood pressure, and skin conductance).

4.5.2.2 Electrocardiogram (ECG)

Heart rate (HR) and heart rate variability (HRV) were assessed as physiological metrics of autonomic nervous system activity, using a portable, continuous sensor[50] worn directly on the chest. 1-minute averages of HR and root mean square successive difference (RMSSD) were used to assess parasympathetic and sympathetic nervous system activation throughout the experimental procedures[51,52]. RMSSD, has been found to be less affected by respiration than other metrics of HRV, and therefore assumed to be a relatively robust assessment of parasympathetic activity[51,52].

A baseline measurement for RMSSD was calculated by averaging 2-5 minutes' of participants' data while they sat at the laboratory before experimental procedures were begun. Baseline heart rates were assessed using an automated cuff monitor[53].

4.5.2.3 Skin conductance (EDA)

1-minute averages of skin conductance levels were obtained as a measure of sympathetic nervous system activity[54] using electrodermal sensors on the thenar and hypothenar eminences of the palms using 55mm electrodes[55]. As with heart rate variability, baseline skin conductance levels were calculated for each participant using the average of 2-5 minutes' of data while they sat in the laboratory prior to beginning experimental procedures.

4.5.2.4 Noise

Previous studies have shown that noise levels can impact well-being outcomes, including heart rate and salivary cortisol[56,57]. This study recorded ambient noise levels for each participant at their respective environmental sites using the Decibel X Pro app[58] installed on a tablet. The average decibel reading from each site was included as a continuous, numerical covariate.

4.5.2.5 Temperature

Data collection occurred across two seasons: summer and fall. Since some participants sat outdoors during the experiment, temperature data from participants' wrist-worn EDA sensor were used as a covariate to control for potential confounding of weather on psychological well-being[59].

4.5.2.6 Trait characteristics

Several trait variables from the Study 1 baseline survey were used in Study 2. Participants' sex and race/ethnicity[60–63] were included as dummy control variables (reference sex = male, reference race/ethnicity = Asian). Trait nature relatedness and average contact with nature were included as continuous covariate variables. Chronic stress ("normal" versus "high") and ACE ("0" versus "1+") was included as moderators in exploratory subgroup analyses (see separate section below).

4.5.3 *Procedure*

Prior to their in-lab appointment, participants received instructions to avoid substances that may alter heart function on the day of their participation (including caffeine, cigarettes, marijuana, decongestants, alcohol) and, for skin conductance purposes, to avoid washing hands or using hand sanitizer right before the appointment time. They were also instructed to dress appropriately for sitting comfortably outside.

Participants were randomized to one of three conditions (nature, urban or control) before they began experimental procedures. Upon arrival to the lab, participants were seated in the experiment room (see Figure 4.3 “Control”) and instructed to turn off all electronic devices. Participants were left to sit on their own for 5 minutes to allow their heart rates to recover from any physical activity leading up to the appointment. Experimental procedures were then begun (Figure 4.4); participants had baseline heart rates assessed using an automated cuff and then were fitted with the ECG and EDA sensors with the help of research staff.

In accordance with the sensors’ user manuals, participants remained seated for 10 minutes to allow adequate time for the sensors to begin collecting accurate readings. Those assigned to the nature or urban conditions were escorted to their site and then seated in a chair while control condition participants remained seated in the laboratory. All participants sat in their environmental conditions for 10 minutes without using any devices, reading books, talking to others, etc. This was considered a period for acclimating to their environmental site. During this period, research staff recorded noise decibels (i.e., for about 10 minutes).

After the acclimation period, research staff guided each participant through the stressor task. Each participant was given a printout of the stressor task instructions and the problem statement they had provided. After the stressor task, participants sat for 10 minutes to recover, again without the use of any devices, etc. Finally, research staff escorted participants back to the lab.

Additional procedures (for data not included in the results section below) are outlined in the supplementary materials.

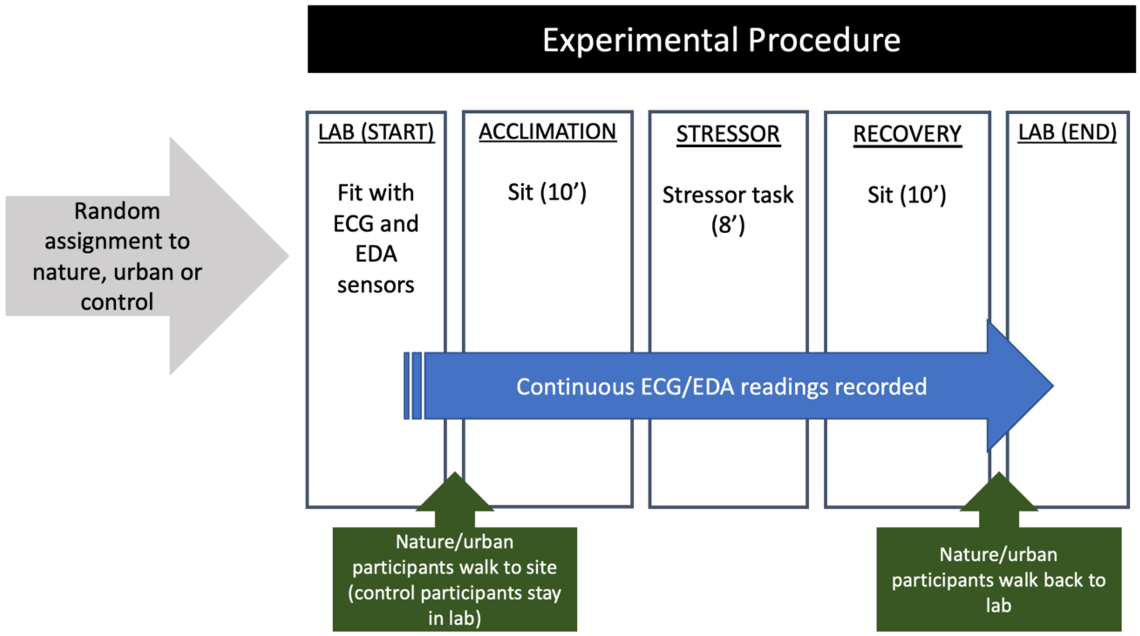

Figure 4.4. Overview of experimental procedure for Study 2

4.5.4 *Analyses overview*

In Study 2 we tested two hypotheses: H1: The natural environment would be associated with less stress (i.e., lower HR and EDA, and higher RMSSD) during the 8-minute stressor task than urban environments, thereby demonstrating the potential for natural environments to buffer individuals from the effects of a stressor, and H2: The natural environment would be associated with a greater rate of recovery from stress (i.e., steeper downward slopes for HR and EDA, and upward slopes for RMSSD) during the 10-minute "Recovery" period. Additionally, we sought to explore whether exposure to the urban environment would be associated with worse stress-related outcomes compared to staying in the lab.

To account for wide “normal” ranges for psychophysiological outcome levels[51,64] which may be due to individual differences unrelated to psychological processes (such as varying thicknesses of epidermis layers), various score correction procedures are recommended[65]. In this study, a standardized change score was calculated for each outcome; baseline levels were subtracted from each participant’s minute-by-minute average ECG and EDA data to create a change score that thereby took inter-individual baseline levels into account. Then, these change score variables were standardized within each participant[66] (i.e., a change score mean set to 0) to improve comparability of outcome inferences across individuals.

A plot of HR across the 8-minute stressor task showed a bimodal trend that appeared to coincide with the two writing portions of the task (i.e., heart rates were particularly elevated during the writing sections of the task compared to the thinking sections). Therefore, rather than use a linear model, we assessed average stress during the entire task, and used Tukey’s range test to compare condition (i.e., nature vs. urban vs. control) means. All post-hoc models controlled for condition averages of trait nature relatedness, noise, baseline outcome levels, and temperature. Assumptions were met for all post-hoc comparisons.

Linear models were used in analyzing rate (i.e., slope) across the 10-minute recovery. In order to account for correlation of within-person assessments, multilevel models[67] nested each minute’s HR, HRV, or EDA change scores (level 1) by participant (level 2). Each model controlled for potential confounding by including sex and race/ethnicity as dummy variables, and by including noise, temperature, trait nature relatedness and average trait amount of nature contact as continuous variables. In addition, we controlled for the variation across participants' baseline levels (for HR, RMSSD and EDA) by including the baseline level as a covariate.

A power analysis and sample size calculations used effect sizes from a recent meta-analysis[39] using only results from outdoor nature exposure studies (as opposed to, for example, virtual nature). The effect size was converted from a Pearson's R coefficient to a partial eta squared to reflect the repeated measures nature of this proposed study design. Using G*Power software, a sufficient sample size of 30 per condition for affect and 25 per condition for physiology were calculated. This study sought to randomize 90 subjects to one of the three conditions (i.e., 30 participants each in nature, urban and control groups). The number of repeated measures per participant (20 minute-by-minute measurements of physiology outcomes for the stressor and recovery periods) would also improve statistical power to detect effects.

4.5.5 *Results*

N = 56 participants completed the experiment (due to the COVID-19 pandemic). Thus, the results below are considered preliminary pilot findings for future studies. Faulty sensor readings resulted in N= 4 participants excluded from ECG analyses, and N = 3 participants excluded from EDA analyses, resulting in a final N = 52 for HR and RMSSD outcomes and N = 53 for EDA (see Table 4.7 for participant characteristics by condition).

4.7. Participant characteristics across nature, urban, control conditions

	Nature		Urban		Control	
	ECG	EDA	ECG	EDA	ECG	EDA
N	18	17	17	18	17	18
Mean Age years (SD)	19.7 (1.4)	19.7 (1.4)	19.4 (2.6)	19.4 (2.6)	19.6 (1.7)	19.7 (1.7)
Sex						
Female (%)	10 (56)	9 (53)	10 (59)	11 (61)	9 (53)	9 (50)
Male (%)	8 (44)	8 (47)	7 (41)	7 (39)	8 (47)	8 (44)
Race						
White (%)	3 (17)	3 (18)	6 (35)	6 (33)	4 (24)	3 (17)
Asian (%)	13 (72)	13 (76)	6 (35)	7 (39)	13 (76)	14 (78)
Multiracial (%)	2 (11)	1 (6)	1 (6)	1 (6)	-	-
Other (%)	-	-	3 (18)	4 (22)	-	-

Summary characteristics for independent and dependent variables by experimental condition and across experimental procedures are shown in Table 4.8.

4.8. Summary characteristics of heart rate (HR), root mean square successive difference (RMSSD) and electrodermal activity (EDA) outcomes across experimental sites and experimental portions

	HR (bpm)			RMSSD (ms)			EDA (us)		
Experimental portion	Nature	Urban	Control	Nature	Urban	Control	Nature	Urban	Control
Baseline	71.3(11.8)	74.4 (9.7)	74.2 (11.1)	46.1 (23.9)	42.5 (26.4)	49 (31.7)	8 (5.8)	8.4(6.2)	5.5 (3.6)
Acclimation	71.2(11.5	75.5 (10.1)	74.9 (9.5)	51 (22.8)	44.9 (27)	46.3(27.8)	6.9 (8.6)	8.8 (6.2)	4.6 (4.4)
Stressor task	72.9 (10.6)	77.6 (9.5)	76.2 (8.4)	51.6 (22.8)	40.4 (21.6)	43.7 (23.2)	11.1 (10)	12.7 (8.9)	7.4 (5.8)
Recovery	69.8 (10.1)	73.8 (9.1)	74.1 (8.1)	52.4 (22.9)	47.1 (23.7)	45.6 (21)	8.6 (9)	11.4 (8.6)	6.6 (6)

During the stressor task, pairwise comparisons among conditions (Table 4.8) showed that the control and nature conditions were associated with statistically higher mean RMSSD than the urban condition (control $B = 0.386$, p-value = 0.016; nature $B = 0.419$, p-value = .003). Both control and nature conditions also had statistically higher averages of skin conductance levels than the urban condition (control $B = 0.275$, p-value = .029; nature $B = 0.419$, p-value < .001).

4.9. Results from Tukey posthoc comparisons of heart rate (HR), root mean square successive differences (RMSSD) and electrodermal activity (EDA) during the stressor task for nature, urban and control conditions. All outcomes are scaled change scores (from baseline levels). Noise, trait nature relatedness, baseline outcome levels (before experimental procedures) and temperature included as covariates

	HR		**RMSSD**		**EDA**	
Independent Variables	B (95% CI)	p-value	B (95% CI)	p-value	B (95% CI)	p-value
Trait nature relatedness	0.008 (-0.12, 0.14)	1.000	-0.05 (-0.22, 0.12)	0.961	-0.056 (-0.17, 0.06)	0.687
Average noise	0 (-0.01, 0.01)	1.000	0.003 (0, 0.01)	0.678	0.001 (0, 0.01)	0.993
Outcome baseline	-0.008 (-0.02, 0)	0.189	0.002 (0, 0.01)	0.898	0.004 (-0.01, 0.02)	0.989
Temperature	0.017 (-0.02, 0.06)	0.838	-0.021 (-0.07, 0.03)	0.799	0.037 (0.02, 0.06)	**<.001**
Control condition (Ref = Urban)	-0.217 (-0.52, 0.08)	0.288	0.386 (0.05, 0.73)	**0.016**	0.275 (0.02, 0.53)	**0.029**
Nature condition (Ref = Urban)	-0.042 (-0.31, 0.22)	0.998	0.419 (0.1, 0.74)	**0.003**	0.419 (0.19, 0.65)	**<.001**

Results from multilevel linear models (Table 4.9; urban condition set as reference group) showed faster heart rate (HR) recovery for the nature condition (*B* = -0.075, p-value = 0.009) after controlling for sex, race/ethnicity, trait nature relatedness, noise, baseline levels for the outcome, temperature, and trait average nature contact (Figure 4.5). The control condition showed slower RMSSD (*B* = 0.151, p-value < .001) and skin conductance recovery rates (*B* = 0.057, p < .001) compared to the urban condition.

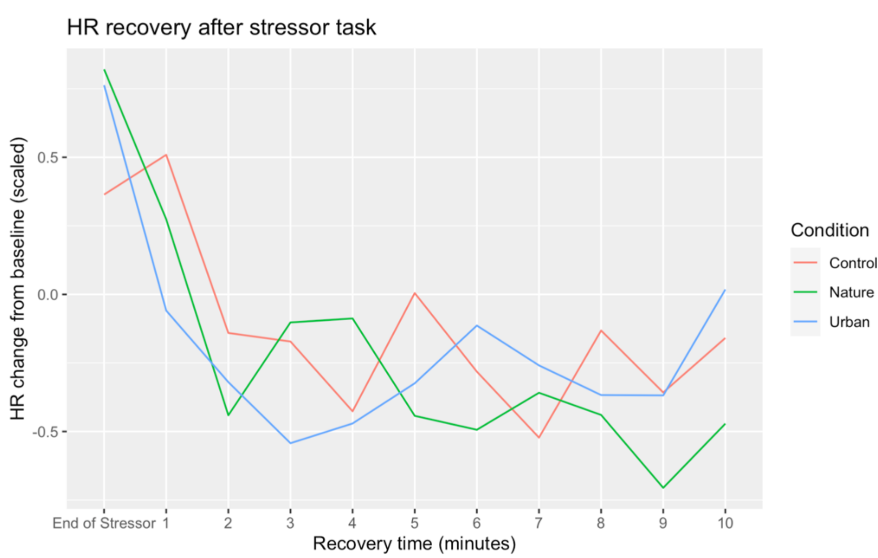

Figure 4.5. Minute-by-minute plot of heart rate (HR) during recovery across nature, urban and control conditions. HR is reported as a change score (from baseline) and scaled.

4.10. Results of recovery rate after stressor across Nature and Control conditions (reference = Urban) for heart rate, root mean square successive difference and electrodermal activity. All outcomes reported as scaled change scores (from baseline levels). Sex, race, nature relatedness, noise, baseline outcome levels, temperature, and trait average nature contact as covariates

	HR		**RMSSD**		**EDA**	
Independent Variables	*B* (95% CI)	p-value	*B* (95% CI)	p-value	*B* (95% CI)	p-value
Time	0.005 (-0.03, 0.05)	0.792	-0.096 (-0.14, -0.05)	**<.001**	-0.098 (-0.13, -0.07)	**<.001**
Control condition	1.487 (-0.1, 3.07)	0.069	-4.357 (-6.16, -2.55)	**<.001**	-17.297 (-32.06, -2.53)	**0.025**
Nature condition	2.021 (0.48, 3.56)	**0.013**	-0.926 (-2.8, 0.95)	0.329	2.05 (-12.52, 16.62)	0.781
Sex (reference = male)	0.03 (-0.18, 0.24)	0.781	0.005 (-0.32, 0.33)	0.975	0.083 (-0.2, 0.37)	0.566
Race_Mixed (reference = Asian)	-0.105 (-0.58, 0.37)	0.664	-	-	-0.742 (-1.46, -0.03)	**0.045**
Race_Other (reference = Asian)	0.434 (-0.02, 0.89)	0.066	-0.034 (-0.72, 0.66)	0.922	-0.227 (-0.84, 0.39)	0.466
Race_White (reference = Asian)	0.028 (-0.23, 0.29)	0.83	0.002 (-0.39, 0.39)	0.99	0.307 (-0.08, 0.7)	0.125
Trait nature relatedness	0.015 (-0.12, 0.15)	0.832	0.166 (-0.1, 0.44)	0.229	-0.054 (-0.24, 0.13)	0.557
Average noise during recovery	-0.001 (-0.01, 0.01)	0.759	0 (-0.01, 0.01)	0.962	0.004 (0, 0.01)	0.353
HR/RMSSD/EDA baseline	-0.011 (-0.02, 0)	**0.034**	-0.01 (-0.02, 0)	**0.004**	-0.017 (-0.05, 0.01)	0.275
Temperature during recovery	0.018 (-0.02, 0.05)	0.346	-0.001 (-0.06, 0.05)	0.968	0.034 (-0.01, 0.08)	0.133
Trait average nature contact	0.036 (-0.06, 0.14)	0.477	-0.017 (-0.16, 0.13)	0.814	-0.027 (-0.16, 0.1)	0.677
Time:Control condition	-0.048 (-0.11, 0.01)	0.1	0.161 (0.1, 0.22)	**<.001**	0.057 (0.01, 0.1)	**0.02**
Time:Nature condition	-0.075 (-0.13, -0.02)	**0.009**	0.028 (-0.04, 0.09)	0.416	-0.008 (-0.05, 0.04)	0.754

4.5.6 *Discussion*

Study 2 sought to investigate experimentally the psychophysiological effects of nature vs. urban vs. control environmental exposures on acute stress reactivity and recovery. The results showed that the nature condition was associated with higher average RMSSD levels during the stressor task—suggesting relatively more parasympathetic (i.e., restorative) activation--compared to the urban condition. This finding contributes to the very limited existing literature on the potential for natural environments to be protective against stressors; two cross-sectional studies found more nature contact attenuated the effects of stressful life events for psychological wellbeing[9] and physical health[8], and one experimental study found null results on the buffering effects of nature walks on mental health outcomes from stressful life events[68]. The potential of natural environments to foster wellbeing, and whether the activation of the parasympathetic nervous system specifically underlies this wellbeing, remains understudied and should be explored further.

The control (laboratory) condition also had a significantly higher mean RMSSD level during the stressor compared to the urban condition, with an effect size similar to the nature condition. This suggests that the control and nature sites were relatively more restorative and protective than the urban condition. It is worth noting that the urban condition was used as the reference level in analyses because it represented participants' usual, day-to-day exposure; the urban site resembled a typical campus location with roads, walkways, bus stops and campus buildings. The physiological responses that occurred at this site were therefore assumed to most closely mirror participants' usual response tendencies in their daily lives.

Conversely, the nature and control conditions also associated with more sympathetic activation (per higher skin conductance results) during the stressor period. Distraction has been shown to have beneficial effects on affect after negative mood induction[69,70] and the current study's urban environment may proffer more distraction (e.g., pedestrians passing by, changes to traffic patterns, various auditory stimuli) and therefore be associated with less stress compared to the nature or control conditions. Similarly, this theory may also explain why the control site was associated with slower skin conductance and RMSSD recovery after the stressor compared to the urban condition. However, the lack of distraction is only one possible mechanism underlying these differences, and more research is needed.

During the recovery period, the nature condition was associated with significantly faster heart rate recovery compared to the urban condition. This finding aligns with Ulrich's stress reduction theory and experimental findings[6,18]. This finding also aligns with more recent experimental studies that found reduced heart rate after time in natural environments compared to control or urban environments[16,17,71].

To build upon Study 1 findings on effect modification by chronic stress and childhood adversity, Study 2 tested whether this moderation would also be found experimentally for psychophysiological correlates of stress in a randomly assigned sample. As stated above, data collection was prematurely ceased due to the COVID-19 pandemic and the resultant sample size was insufficient for this moderation analysis as originally intended. However, exploratory analyses were used to investigate whether interaction trends were present in the nature condition.

4.6 Exploratory subgroup analyses

The exploratory plots for the nature condition show interaction trends for chronic stress (Figure 4.6) and ACE (Figure 4.7) in which those with higher levels of psychological disadvantage (i.e., greater levels of chronic stress and ACE) exhibited faster psychophysiological stress recovery. Furthermore, heart rate and RMSSD levels were improved from baseline levels, indicated by the Y-axis mean of 0, by the end of the experimental procedures, suggesting particularly restorative effects for these psychologically vulnerable subpopulations. Future experimental studies with larger sample sizes can further elucidate how trait chronic stress and ACE may influence the stress-related effect of nature contact.

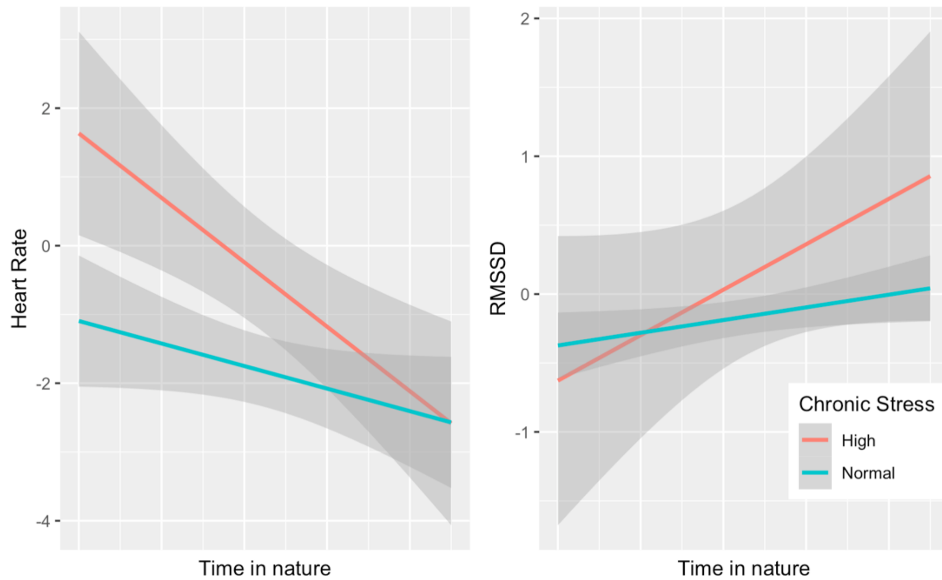

Figure 4.6. Interaction plots showing those with higher chronic stress experiencing faster heart rate and parasympathetic recovery after a stressor task compared to those with lower chronic stress

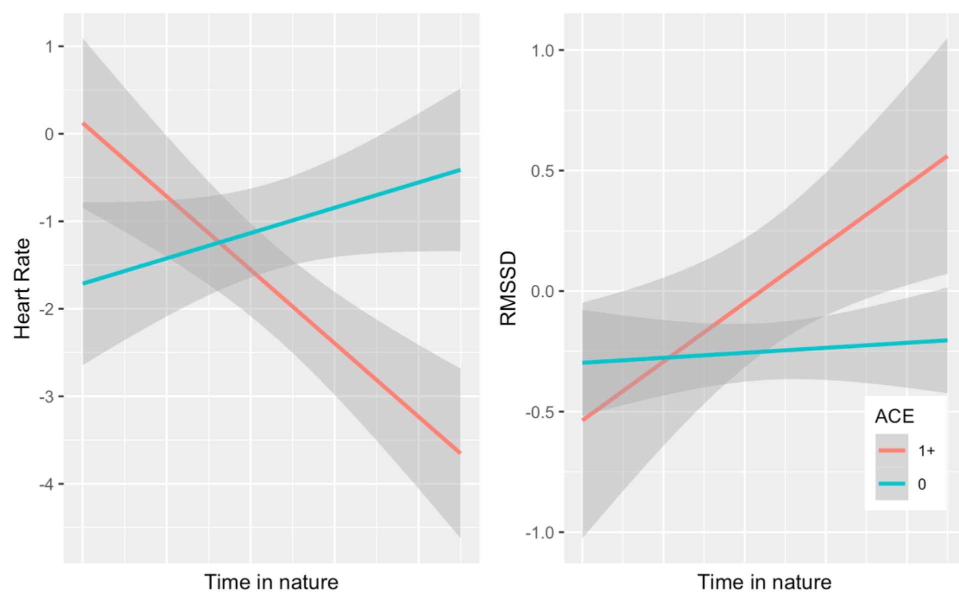

Figure 4.7.Interaction plot showing those with at least 1 ACE experiencing faster heart rate and parasympathetic recovery after a stressor task compared to those without history of early adversity

4.7 General discussion

This multistudy report contributed to the relatively limited experimental literature on the effects of nature contact on psychophysiological correlates of stress. Study 1 found cross-sectional evidence in a sample of 96 university students that more self-reported time spent in nature was associated with more self-reported positive affect and less negative affect, depressive symptoms and chronic stress levels after controlling for sex, race/ethnicity and nature relatedness.

In Study 2, a subset of Study 1 participants completed an experimental procedure with random assignment to a nature, urban or control condition. In alignment with prominent existing theory on stress reduction and the activation of parasympathetic activity in natural environments[6,18], results suggested the nature condition was significantly associated with faster heart rate recovery after a stressor task. *During* the stressor task, however, the nature and control conditions were both associated with significantly higher root mean square successive difference (RMSSD) and electrodermal activity (EDA) levels--reflecting greater parasympathetic and sympathetic nervous system activity, respectively--compared to the urban condition. This contradicts what we expected to find (i.e., that either the parasympathetic *or* sympathetic division would be dominant in any particular group). The comparison of means across the entire stressor period forbade a more granular look at how each division may have responded to the other. For example, it may have been possible that the elevated parasympathetic activity was in response to an elevated sympathetic activation in the nature and control conditions. Thus, *a priori* analysis plans that seek to disentangle temporality (i.e., whether elevated sympathetic activity is followed by a counteracting elevation of parasympathetic activity, and whether this counteraction is more effective in more natural environments compared to urban environments) may clarify environmental effects on autonomic activity during acute stress. Owing to the complexity of autonomic nervous system functioning in general, more studies using a variety of indices (e.g., time- and frequency- domain analyses of heart rate variability), may also be helpful in inferring branch functioning.

Only 9.4% of the current study's cross-sectional population had an ACE score of 4 or higher (compared to a 12.5% prevalence in the 17,000 individuals of the original ACE study[72]). While the current study population's low median ACE score and large number of 0 ACE scores mirror characteristics in other undergraduate student populations[20,73], the extensive literature on the negative health outcomes associated with adverse childhood experiences has traditionally used a cutoff score of 4 or higher to delineate those at particularly increased risk for negative health outcomes[36,74,75]. However, the interaction trends from this study (albeit at marginal statistical significance and exploratory) nonetheless suggest that a history of even a single adverse childhood experience may be a meaningful distinction for this current population and set of research questions. Cross-sectionally, those with 1 or more ACEs were generally more reactive to more nature contact, feeling higher levels of positive affect, negative affect and stress. A recent review found childhood trauma was associated with emotional hyperreactivity[76], and may therefore suggest that those with a history of ACEs display greater emotional lability in general.

Physiologically, preliminary trends among participants randomly assigned to the nature condition showed that an ACE of 1 or more may be associated with enhanced post-stress recovery. This is in line with our theory that those who are most in need of psychological restoration benefit more from nature[77]. However, more randomized controlled studies with larger sample sizes are needed to bolster these preliminary findings. Furthermore, while this study used a healthy (i.e., no history of psychiatric illness) student population, subgroups such as those with greater levels of depressive or anxiety symptoms, for example, may experience nature differently. Future studies should investigate these potential differences.

There are important limitations to this current set of studies to consider. The study sample was drawn from the student body of a single public national university in the Pacific Northwest of the United States. Therefore, the generalizability of baseline or observed effects may not apply outside the region or to other age groups. Additionally, the final sample had an overrepresentation of those who identified as Asian (58% in Study 1) compared to the university overall (23%)[78] or the city of Seattle (15.4%)[79] in 2019. The participants had self-selected based on recruitment materials available online; since the study did not seek to recruit randomly selected members of the university student body, the findings of the study are therefore not generalizable to this population. Finally, due to COVID-19 and the resultant limitations of human subjects research, the Study 2 sample size was likely underpowered to detect effects. Despite these limitations, the present studies offer important contributions to the literature on the objective psychophysiological benefits of nature contact, and on effect moderation by psychological disadvantage.

Future versions of this study could improve generalizability by sampling from the entire university. The current study participants were recruited from a human subjects pool, which allows students enrolled in a Psychology department course to receive course credit for participating in research studies. Students in other departments and majors may experience environmental exposures and psychological well-being differently. Thus, future iterations should seek to use a more diverse body of participants. In addition, larger sample sizes would be critical to building upon current findings. Additional assessments may illuminate sources of variance across environmental conditions in Study 2; for example, the urban site was closer to the road than the other sites. Therefore, unmeasured factors like air pollution levels may play a role in impacting autonomic activity. Furthermore, noise was addressed in the current study as a continuous, numerical, control variable by decibels. However, the effects (if any) of noise types within and across sites were not explored. For example, future studies can assess whether natural environment exposures with sounds of passing airplanes or passersby have different effects on stress-related outcomes compared to natural environment exposures with the sounds of birds and squirrels.

4.8 Conclusion

Mental health and psychological well-being are pressing public health issues. In addition to well-known health disparities across socioeconomic demographics, a robust body of literature also documents the far-reaching and long-lasting negative health outcomes associated with chronic stress and early adversity. Therefore, identifying sources of well-being for those who have higher levels of trait chronic stress or history of early adversity is worthy of research and policy prioritization. In light of burgeoning evidence on the potential for natural environments to reduce health gaps, future research should continue to investigate how nature contact may provide these vulnerable populations with much-needed restoration.

The nature setting in the Study 2 experiment was an urban greenspace located on the university campus. As such, it was a proxy for accessible, day-to-day natural environments. More research is needed on whether such environments are protective against new or ongoing stressors in daily life, and whether such buffering can promote improved downstream health outcomes. Additionally, experimental investigation of stress reactivity is an important method to understand inter-individual differences in stress reactivity, and to elucidate why some individuals suffer worse health outcomes than others[26]. An essential component of this elucidation is to build a rich characterization of an individual's stress profile, for example by examining both an individual's shorter term (i.e., acute or minute-by-minute) stress reactivity as well as longer term stress levels[26]. Continuous psychophysiological assessments have become portable and discrete to facilitate a diverse assessment of stress at different timescales, and future research can take advantage of this technological development to further our understanding of individual traits, stress reactivity, and health outcomes and whether natural environments can be salutary exposures to improve well-being.

4.9 SUPPLEMENTARY MATERIAL

4.9.1 *Study 2 measures*

4.9.1.1 Heart rate variability (LF/HF)

1-minute averages of low-frequency to high-frequency power (LF/HF) were assessed (with the electrocardiogram sensor described in the methods section) to capture relative sympathetic activation. In this study, however, the testing conditions obfuscated the contributions of sympathetic versus parasympathetic nervous systems on the low-frequency power; literature suggests that when subjects are seated upright, low-frequency power may be driven by parasympathetic and baroreflex activity as opposed to sympathetic activation[51]. Thus, this measure was not used in final analyses.

4.9.1.2 Blood pressure (BP)

Systolic and diastolic blood pressure were measured with an automated cuff monitor[53].

4.9.1.3 State affect

Positive and negative affect were assessed using the 10-item International Positive and Negative Affect Schedule Short Form[80] which asked participants to rate the extent to which they felt feelings such as “enthusiastic” and “distressed” *right now* using a 5-point Likert response ranging from “Very slightly or not at all” to “Extremely”. Scores were calculated by summing positive (Cronbach’s alpha = 0.8) and negative (Cronbach’s alpha = 0.81) affect items respectively, with a possible score range of 5-25.

4.9.1.4 State anxiety

State anxiety levels were measured using the 6-item State Trait Anxiety Inventory-Short Form[81] which asked participants to rate the degree to which they felt each of the listed emotions (e.g., “worried”, “calm”) at the time of the survey on a 4-point Likert scale. Items 1, 4 and 5 were reverse-coded, and scores were calculated by multiplying the sum by 20/6. Possible scores ranged from 20-80 (Cronbach’s alpha = 0.82).

4.9.1.5 State rumination

State rumination levels were assessed using the 8-item Brief State Rumination Inventory[82], which asked participants to rate the degree to which they agreed with statements such as “Right now, I am reflecting about my mood” using a visual analog scale from 0-100. Scores were calculated by summing all items, with a possible range of 0-800.

4.9.2 *Study 2 additional procedures and assessments*

Upon arrival to the lab for experimental procedures, each participant was asked to sit in the experimental room for 10 minutes. This was to allow ample time for recovery from any physical activity in traveling to the appointment, and for staff members to prepare supplies for the experimental procedures. Then, a staff member took blood pressure measurements ("pre") and again at the end of the experimental procedure upon return from the experimental site ("post").

Participants were also asked to self-report on state psychological well-being (using the validated affective, anxiety and rumination instruments outlined above). This short battery of surveys was distributed four times per participant; the first survey was upon arrival at the lab as an assessment of participants' individual baseline levels for each outcome. The second survey was just before the stressor task, the third survey was after the stressor task, and the last survey was at the end of the recovery period. The surveys were thereby used to capture changes to state psychological well-being as a result of the stressor (change score between the second and third surveys) and recovery (change score between the third and fourth surveys) procedures.

4.9.3 *Study 2 blood pressure and self-report survey analyses*

An automated cuff monitor was used at the beginning and end of laboratory procedures to capture "pre" and "post" heart rate and blood pressure assessments. However, upon preliminary plotting of heart rate data across the entire experiment, the "post" assessment of heart rate appeared much lower across all conditions compared to "pre" assessments. Research staff also observed during data collection that participants generally seemed tense during the “pre” assessments. The initiation of experimental procedures--with gloved research staff applying the blood pressure arm cuff with the formality one may experience during a hospital visit—may have induced unintended stress. During the “post” assessments, participants overall seemed relieved when notified by the research staff that this last assessment would mark the end of their study participation. Together, these observations raised concerns that the “pre” and “post” measurements (for both heart rate and blood pressure) may have assessed stress and relief related to participation beginning and ending, respectively, as opposed to assessing environmental exposure as hypothesized. Thus, “pre-post” analyses were not conducted for heart rate or blood pressure.

No between-group differences were found at baseline for all state measures.
Change scores for each outcome were calculated. Tukey adjusted comparisons of means were conducted to assess whether there were significant group effects during the stressor or recovery periods. In other words, we tested hypotheses that those in the nature condition would report significantly smaller reductions in positive affect following the stressor period (indicating a greater preservation of positive mood), and significantly smaller increases in negative affect, rumination and anxiety. We also hypothesized that, after the 10-minute recovery period, the nature condition would be associated with significantly larger increase in positive affect and larger decreases in negative affect, rumination, and anxiety (suggesting greater psychological well-being recovery after the stressor compared to the other conditions).

4.9.4 *Study 2 self-report survey results*

There were no significant differences in post-stressor or post-recovery scores across groups for the self-report state surveys. Results are outlined in Table 4.11.

4.11. Results from Tukey comparisons of means for self-reported state anxiety, positive and negative affect, and rumination after the stressor and recovery periods

		Anxiety		Positive Affect		Negative Affect		Rumination	
group 1	group 2	Estimate (95% CI)	p-value	Estimate (95% CI)	p-value	Estimate (95% CI)	p-value	Estimate (95% CI)	p-value
post-Stressor (change from pre-Stressor)									
Lab	Nature	-7.9 (-18.1, 2.4)	0.16	0.5 (-1.8, 2.9)	0.85	-0.0(-2.7, 2.6)	1	-15.2 (-102, 72)	0.9
Lab	Urban	-8.3 (-18.8, 2.1)	0.14	0.4 (-2, 2.8)	0.92	-1.2 (-3.9, 1.6)	0.56	-73.1 (-162.7, 16.6)	0.13
Nature	Urban	-0.5 (-10.7, 9.7)	0.99	-0.1 (-2.5, 2.2)	0.99	-1.1 (-3.8, 1.5)	0.56	-57.8 (-145.2, 29.5)	0.26
post-Recovery (change from post-Stressor)									
Lab	Nature	4.4 (-6.4, 15)	0.59	-0.7 (-3.2, 1.7)	0.74	0 (-3.4, 2.3)	0.9	-39.2 (-148, 69.5)	0.66
Lab	Urban	-0.2 (-11.1, 10.7)	0.99	1.1 (-1.3, 3.6)	0.52	0 (-2.9, 2.9)	1	2 (-109.6, 113.6)	1
Nature	Urban	-4.5 (-15.2, 6.1)	0.56	1.9 (-0.6, 5.3)	0.17	0 (-2.3, 3.4)	0.9	41.2 (-67.5, 150)	0.63

4.10 REFERENCE

1. Dadvand D, Dadvand P. Green spaces and General Health: Roles of mental health status, social support, and physical activity. *Environ Int*. 201605;91:161-167.

2. Grahn P, Stigsdotter UA. Landscape planning and stress. *Urban For Urban Green*. 2003;2(1):1-18. doi:10.1078/1618-8667-00019

3. Roe J, Thompson C, Aspinall P, et al. Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. *Int J Environ Res Public Health*. 2013;10(9):4086-4103. doi:10.3390/ijerph10094086

4. Stigsdotter UK, Ekholm O, Schipperijn J, Toftager M, Kamper-Jørgensen F, Randrup TB. Health promoting outdoor environments - Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scand J Public Health*. 2010;38(4):411-417. doi:10.1177/1403494810367468

5. Ward Thompson C, Roe J, Aspinall P, Mitchell R, Clow A, Miller D. More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landsc Urban Plan*. 2012;105(3):221-229. doi:10.1016/j.landurbplan.2011.12.015

6. Ulrich RS. Aesthetic and Affective Response to Natural Environment. In: *Human Behavior and Environment*. Vol 6. I. Altman & J. Wohwill; 1983:85-125.

7. Hartig T, Mitchell R, de Vries S, Frumkin H. Nature and Health. *Annu Rev Public Health*. 2014;35(1):207-228. doi:10.1146/annurev-publhealth-032013-182443

8. van den Berg AE, Maas J, Verheij RA, Groenewegen PP. Green space as a buffer between stressful life events and health. *Soc Sci Med*. 2010;70(8):1203-1210. doi:10.1016/j.socscimed.2010.01.002

9. Wells NM, Evans GW. Nearby Nature: A Buffer of Life Stress among Rural Children. *Environ Behav*. 2003;35(3):311-330. doi:10.1177/0013916503035003001

10. de Vries S, van Dillen SME, Groenewegen PP, Spreeuwenberg P. Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Soc Sci Med*. 2013;94:26-33. doi:10.1016/j.socscimed.2013.06.030

11. Gascon M, Triguero-Mas M, Martínez D, et al. Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *Int J Environ Res Public Health*. 2015;12(4):4354-4379. doi:10.3390/ijerph120404354

12. Kondo MC, Jacoby SF, South EC. Does spending time outdoors reduce stress? A review of real-time stress response to outdoor environments. *Health Place*. 2018;51:136-150. doi:10.1016/j.healthplace.2018.03.001

13. Gidlow CJ, Jones MV, Hurst G, et al. Where to put your best foot forward: Psycho-physiological responses to walking in natural and urban environments. *J Environ Psychol*. 2016;45:22-29. doi:10.1016/j.jenvp.2015.11.003

14. Grazuleviciene R, Vencloviene J, Kubilius R, et al. Tracking Restoration of Park and Urban Street Settings in Coronary Artery Disease Patients. *Int J Environ Res Public Health*. 2016;13(6):550. doi:10.3390/ijerph13060550

15. Lee J, Park B-J, Tsunetsugu Y, Ohira T, Kagawa T, Miyazaki Y. Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. *Public Health*. 2011;125(2):93-100. doi:10.1016/j.puhe.2010.09.005

16. Park B-J, Tsunetsugu Y, Ishii H, et al. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in a mixed forest in Shinano Town, Japan. *Scand J For Res*. 2008;23(3):278-283. doi:10.1080/02827580802055978

17. Song C, Ikei H, Igarashi M, Takagaki M, Miyazaki Y. Physiological and Psychological Effects of a Walk in Urban Parks in Fall. *Int J Environ Res Public Health*. 2015;12(11):14216-14228.

18. Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M. Stress recovery during exposure to natural and urban environments. *J Environ Psychol*. 1991;11(3):201-230. doi:10.1016/S0272-4944(05)80184-7

19. Park BJ, Tsunetsugu Y, Kasetani T, Kagawa T, Miyazaki Y. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environ Health Prev Med*. 2010;15(1):18-26. doi:10.1007/s12199-009-0086-9

20. Olvera Alvarez HA, Provencio-Vasquez E, Slavich GM, et al. Stress and Health in Nursing Students: The Nurse Engagement and Wellness Study. *Nurs Res*. 2019;68(6):453-463. doi:10.1097/NNR.0000000000000383

21. Olvera Alvarez HA, Kubzansky LD, Campen MJ, Slavich GM. Early life stress, air pollution, inflammation, and disease: An integrative review and immunologic model of social-environmental adversity and lifespan health. *Neurosci Biobehav Rev*. 2018;92:226-242. doi:10.1016/j.neubiorev.2018.06.002

22. Heim C, Nemeroff CB. The role of childhood trauma in the neurobiology of mood and anxiety disorders: preclinical and clinical studies. *Biol Psychiatry*. 2001;49(12):1023-1039. doi:10.1016/S0006-3223(01)01157-X

23. Heim C, Newport DJ, Mletzko T, Miller AH, Nemeroff CB. The link between childhood trauma and depression: Insights from HPA axis studies in humans. *Psychoneuroendocrinology*. 2008;33(6):693-710. doi:10.1016/j.psyneuen.2008.03.008

24. Cohen JI. STRESS AND MENTAL HEALTH: A BIOBEHAVIORAL PERSPECTIVE. *Issues Ment Health Nurs*. 2000;21(2):185-202. doi:10.1080/016128400248185

25. Sapolsky RM. Social Status and Health in Humans and Other Animals. *Annu Rev Anthropol*. 2004;33(1):393-418. doi:10.1146/annurev.anthro.33.070203.144000

26. Shields GS, Slavich GM. Lifetime stress exposure and health: A review of contemporary assessment methods and biological mechanisms. *Soc Personal Psychol Compass*. 2017;11(8):e12335. doi:10.1111/spc3.12335

27. Slavich GM, Irwin MR. From stress to inflammation and major depressive disorder: A social signal transduction theory of depression. *Psychol Bull*. 2014;140(3):774-815. doi:10.1037/a0035302

28. Cohen S, Janicki-Deverts D, Miller GE. Psychological Stress and Disease. *JAMA*. 2007;298(14):1685. doi:10.1001/jama.298.14.1685

29. Carpenter LL, Carvalho JP, Tyrka AR, et al. Decreased ACTH and Cortisol Responses to Stress in Healthy Adults Reporting Significant Childhood Maltreatment. Published online 2007:17.

30. Research Randomizer. www.randomizer.org

31. Qualtrics. Qualtrics. Published 2020. Accessed November 11, 2020. www.qualtrics.com

32. Watson D, Anna L, Tellegen A. Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. Published online 1988:8.

33. Lovibond PF, Lovibond SH. The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behav Res Ther*. 1995;33(3):335-343. doi:10.1016/0005-7967(94)00075-U

34. Nisbet EK, Zelenski JM. The NR-6: a new brief measure of nature relatedness. *Front Psychol*. 2013;4. doi:10.3389/fpsyg.2013.00813

35. Ross PT, Hart-Johnson T, Santen SA, Zaidi NLB. Considerations for using race and ethnicity as quantitative variables in medical education research. *Perspect Med Educ*. 2020;9(5):318-323. doi:10.1007/s40037-020-00602-3

36. Felitti VJ, Anda RF, Nordenberg D, et al. Relationship of Childhood Abuse and Household Dysfunction to Many of the Leading Causes of Death in Adults. *Am J Prev Med*. Published online 1998:14.

37. RStudio Team. *RStudio: Integrated Development Environment for R*. RStudio, Inc.; 2019. http://www.rstudio.com/

38. Champely S. *Pwr: Basic Functions for Power Analysis*.; 2021. https://CRAN.R-project.org/package=pwr

39. McMahan EA, Estes D. The effect of contact with natural environments on positive and negative affect: A meta-analysis. *J Posit Psychol*. 2015;10(6):507-519. doi:10.1080/17439760.2014.994224

40. Bratman GN, Daily GC, Levy BJ, Gross JJ. The benefits of nature experience: Improved affect and cognition. *Landsc Urban Plan*. 2015;138:41-50. doi:10.1016/j.landurbplan.2015.02.005

41. Neill C, Gerard J, Arbuthnott KD. Nature contact and mood benefits: contact duration and mood type. *J Posit Psychol*. 2019;14(6):756-767. doi:10.1080/17439760.2018.1557242

42. Berman MG, Kross E, Krpan KM, et al. Interacting with nature improves cognition and affect for individuals with depression. *J Affect Disord*. 2012;140(3):300-305. doi:10.1016/j.jad.2012.03.012

43. Banay RF, James P, Hart JE, et al. Greenness and depression incidence among older women. *Environ Health Perspect*. 2019;12(2):1-9.

44. Pun VC, Manjourides J, Suh HH. Association of neighborhood greenness with self-perceived stress, depression and anxiety symptoms in older U.S adults. *Environ Health*. 2018;17(1):39. doi:10.1186/s12940-018-0381-2

45. Wheeler BW, Lovell R, Higgins SL, et al. Beyond greenspace: an ecological study of population general health and indicators of natural environment type and quality. *Int J Health Geogr*. 2015;14(1):17. doi:10.1186/s12942-015-0009-5

46. Mitchell R, Popham F. Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet*. 2008;372(9650):1655-1660. doi:10.1016/S0140-6736(08)61689-X

47. Rigolon A, Browning MHEM, McAnirlin O, Yoon H (Violet). Green Space and Health Equity: A Systematic Review on the Potential of Green Space to Reduce Health Disparities. *Int J Environ Res Public Health*. 2021;18(5):2563. doi:10.3390/ijerph18052563

48. Mitchell R. What is equigenesis and how might it help narrow health inequalities? CRESH. Published November 8, 2013. Accessed April 3, 2021. https://cresh.org.uk/2013/11/08/what-is-equigenesis-and-how-might-it-help-narrow-health-inequalities/

49. Tester-Jones M, White MP, Elliott LR, et al. Results from an 18 country cross-sectional study examining experiences of nature for people with common mental health disorders. *Sci Rep*. 2020;10(1):19408. doi:10.1038/s41598-020-75825-9

50. movisens GmbH. *ECG Move 4*. movisens GmbH

51. Shaffer F, Ginsberg JP. An Overview of Heart Rate Variability Metrics and Norms. *Front Public Health*. 2017;5:258. doi:10.3389/fpubh.2017.00258

52. Shaffer F, McCraty R, Zerr CL. A healthy heart is not a metronome: an integrative review of the heart's anatomy and heart rate variability. *Front Psychol*. 2014;5. doi:10.3389/fpsyg.2014.01040

53. GE. *Carescape V100 Vital Signs Monitor*. GE

54. Boucsein W. *Electrodermal Activity*. 2nd ed. Springer; 2012.

55. movisens GmbH. *EDA Move 4*. movisens GmbH

56. Lusk SL, Gillespie B, Hagerty BM, Ziemba RA. Acute Effects of Noise on Blood Pressure and Heart Rate. *Arch Environ Health Int J*. 2004;59(8):392-399. doi:10.3200/AEOH.59.8.392-399

57. Lusk SL, Hagerty BM, Gillespie B, Caruso CC. Chronic Effects of Workplace Noise on Blood Pressure and Heart Rate. *Arch Environ Health Int J*. 2002;57(4):273-281. doi:10.1080/00039890209601410

58. Skypaw Co. *Decibel X Pro*. Skypaw Co.

59. Denissen JJA, Butalid L, Penke L, van Aken MAG. The effects of weather on daily mood: A multilevel approach. *Emotion*. 2008;8(5):662-667. doi:10.1037/a0013497

60. Rosenfield S, Mouzon D. Gender and Mental Health. In: Aneshensel CS, Phelan JC, Bierman A, eds. *Handbook of the Sociology of Mental Health*. Springer Netherlands; 2013:277-296. doi:10.1007/978-94-007-4276-5_14

61. Fernando S. *Mental Health, Race and Culture*. 3rd ed. Basingstoke, Hampshire; 2010.

62. Altemus M, Sarvaiya N, Neill Epperson C. Sex differences in anxiety and depression clinical perspectives. *Front Neuroendocrinol*. 2014;35(3):320-330. doi:10.1016/j.yfrne.2014.05.004

63. McCarthy MM, Arnold AP, Ball GF, Blaustein JD, De Vries GJ. Sex Differences in the Brain: The Not So Inconvenient Truth. *J Neurosci*. 2012;32(7):2241-2247. doi:10.1523/JNEUROSCI.5372-11.2012

64. Mayo Clinic. What's a normal resting heart rate? Accessed March 11, 2021. https://www.mayoclinic.org/healthy-lifestyle/fitness/expert-answers/heart-rate/faq-20057979

65. Cacioppo JT. *Handbook of Psychophysiology*. Cambridge University Press; 2017.

66. Ben-Shakhar G. Standardization Within Individuals: A Simple Method to Neutralize Individual Differences in Skin Conductance. *Psychophysiology*. 1985;22(3):292-299.

67. Finch WH, Bolin JE, Kelley K. *Multilevel Modeling Using R*. CRC Press; 2014.

68. Marselle M, Warber S, Irvine K. Growing Resilience through Interaction with Nature: Can Group Walks in Nature Buffer the Effects of Stressful Life Events on Mental Health? *Int J Environ Res Public Health*. 2019;16(6):986. doi:10.3390/ijerph16060986

69. Sheppes G, Catran E, Meiran N. Reappraisal (but not distraction) is going to make you sweat: Physiological evidence for self-control effort. *Int J Psychophysiol*. 2009;71(2):91-96. doi:10.1016/j.ijpsycho.2008.06.006

70. Kuehner C, Huffziger S, Liebsch K. Rumination, distraction and mindful self-focus: effects on mood, dysfunctional attitudes and cortisol stress response. *Psychol Med*. 2009;39(2):219-228. doi:10.1017/S0033291708003553

71. South EC, Kondo MC, Cheney RA, Branas CC. Neighborhood Blight, Stress, and Health: A Walking Trial of Urban Greening and Ambulatory Heart Rate. *Am J Public Health*. 2015;105(5):909-913. doi:10.2105/AJPH.2014.302526

72. CDC-Kaiser Permanente. ACE score prevalence for CDC-Kaiser ACE study participants by sex, waves 1 and 2. Published 2016. Accessed April 15, 2021. https://www.cdc.gov/violenceprevention/aces/about.html

73. Vartanian LR, Froreich FV, Smyth JM. A serial mediation model testing early adversity, self-concept clarity, and thin-ideal internalization as predictors of body dissatisfaction. *Body Image*. 2016;19:98-103. doi:10.1016/j.bodyim.2016.08.013

74. Anda RF, Whitfield CL, Felitti VJ, et al. Adverse Childhood Experiences, Alcoholic Parents, and Later Risk of Alcoholism and Depression. *Psychiatr Serv*. 2002;53(8):1001-1009. doi:10.1176/appi.ps.53.8.1001

75. Dube SR, Anda RF, Felitti VJ, Edwards VJ, Croft JB. Adverse childhood experiences and personal alcohol abuse as an adult. *Addict Behav*. 2002;27(5):713-725. doi:10.1016/S0306-4603(01)00204-0

76. Janiri D, Kotzalidis GD, De Chiara L, Koukopoulos AE, Aas M, Sani G. The Ring of Fire. *Psychiatr Clin North Am*. 2020;43(1):69-82. doi:10.1016/j.psc.2019.10.007

77. Mitchell RJ, Richardson EA, Shortt NK, Pearce JR. Neighborhood Environments and Socioeconomic Inequalities in Mental Well-Being. *Am J Prev Med*. 2015;49(1):80-84. doi:10.1016/j.amepre.2015.01.017

78. University of Washington. Quick Stats of Student Enrollment. Published 2019. https://studentdata.washington.edu/quick-stats/

79. United States Census Bureau. QuickFacts Seattle city, Washington. Published July 1, 2019. Accessed April 10, 2021. https://www.census.gov/quickfacts/seattlecitywashington

80. Thompson ER. Development and Validation of an Internationally Reliable Short-Form of the Positive and Negative Affect Schedule (PANAS). *J Cross-Cult Psychol*. 2007;38(2):227-242. doi:10.1177/0022022106297301

81. Marteau T, Bekker H. THE DEVELOPMENT OF A 6-ITEM SHORT-FORM OF THE STATE SCALE OF THE SPIELBERGER STATE TRAIT ANXIETY INVENTORY (STAI). *Br J Clin Psychol*. 1992;31:301-306.

82. Marchetti I, Mor N, Chiorri C, Koster EHW. The Brief State Rumination Inventory (BSRI): Validation and Psychometric Evaluation. *Cogn Ther Res*. 2018;42(4):447-460. doi:10.1007/s10608-018-9901-1

Chapter 5. CHANGE IN TIME SPENT IN NATURE DURING COVID-19 AND DEPRESSION, ANXIETY, AND STRESS SYMPTOMS: FINDINGS AMONG ADULT SAME-SEX TWIN PAIRS

5.1 ABSTRACT

This present study investigated the associations between perceived change in amount of nature contact (compared to one month prior, i.e., before the widespread issuance of stay-at-home orders due to the COVID-19 pandemic) and symptoms of depression, anxiety and stress in March 2020 survey data from adult twin pairs. Results show perceived decrease in nature contact during COVID-19 was quasi-causally associated with higher anxiety and stress symptoms compared to no perceived change in nature contact, even after adjusting for age, sex, income and NDVI. However, results also suggest perceived increase in nature contact is quasi-causally associated with more stress. This is the first study to date on the mental health benefits of nature contact during COVID-19 using familial (e.g., twin) data to account for additive genetic factors. However, more research is needed to disentangle the causal direction of psychological well-being and coping behaviors, such as spending time in nature.

5.2 INTRODUCTION

Studies on the mental health impacts of the COVID-19 pandemic have found, unsurprisingly, that psychological well-being has diminished since the emergence of the SARS-CoV-2 coronavirus. Two studies using nationally representative samples in the United States reported a significant increase in the symptoms of serious psychological distress[1] and decreased flourishing particularly in regard to self-reported health and happiness[2] compared to pre-COVID assessments.

State level mitigation strategies, known as “lockdown” or “stay-at-home” mandates, became widespread beginning in March 2020[3]. With businesses closed, more people reported going out into nature compared to pre-pandemic times[4]. A relatively robust literature base supports a long list of improved mental health and psychological well-being outcomes associated with increased nature contact such as more positive affect and happiness, and less symptoms of depression, anxiety and stress[5–9]. Some of these effects have been found during the COVID-19 pandemic; a survey in Japan found greenspace use and the existence of green views from home were positively associated with life satisfaction and happiness, and inversely associated with symptoms of depression, anxiety and loneliness[10]. Another study used satellite imagery to quantify nearby nature and concluded more greenness around the home was associated with improved mental health and wellbeing, and decreased symptoms of depression, anxiety and stress[4]. Conversely, those who perceived nature deprivation during stay-at-home mandates felt less flourishing[11]. Thus, nature contact may have been an important source of psychological well-being during these trying times.

The literature on the mental health benefits of nature contact is dominated by cross-sectional studies that are limited in causal inferencing and in accounting for genetic heritability confounds. Although the etiology of mental health disorders remain elusive and complicated, genetic factors are believed to contribute substantially to one's risk of developing a disorder[12,13]. However, very few studies have accounted for additive genetic confounding in investigating the effects of nature contact on health; of these, outcomes have included blood pressure[14], aggression[15], and one study included depression, anxiety and stress outcomes[16]. The lattermost study found that more nearby greenspace (as measured by satellite imagery-derived Normalized Differential Vegetation Index) was associated with less depressive symptoms within identical twin pairs. More research is needed that use genetically informed data (e.g., data from identical and/or fraternal twins, adopted siblings, half-siblings, etc.) to disentangle the roles of heritability, shared environment, and unshared environment (e.g., the behavior of spending time in nature) factors on mental health and psychological well-being.

5.3 THE PRESENT STUDY

This study investigated nature contact during the first month of the COVID-19 stay-at-home mandates and depression, anxiety and stress-related outcomes using data from adult same-sex twin pairs (see Duncan et al., 2020 for more information on the parent study). Structural equation modeling was used to parameterize additive genetic, shared environment and unshared environment factors, and to estimate a quasi-causal association between self-reported changes in time spent in nature, and self-reported psychological well-being.

5.4 MATERIALS

5.4.1 *Participants*

This study used data collected by the Washington State Twin Registry (WSTR). More information on this registry are reported elsewhere[17–19]. As part of a Washington State University IRB-approved study[20], a survey was administered to the registry participants in the last week of March 2020. 2,580 pairs completed the survey (21.2% pair-wise response rate), among which 909 pairs were same-sex pairs (i.e., male-male or female-female twins). 77% of these 909 pairs were monozygotic (MZ) twins, and 23% dizygotic (DZ). Only data from same-sex pairs were used to reduce confounding introduced by sex differences within twin pairs. 90% of participants lived in urban (as opposed to rural) areas.

5.4.2 *Measures*

The independent variable, perceived change in time spent in nature, was assessed with "Compared to one month ago (i.e., prior to the spread of COVID-19), how much as your daily life changed in the following areas?" Among the behaviors listed, "Amount of time spent in nature or parks" was a single questionnaire item with five possible ordinal responses ("Increased a lot", "Increased some", "No change", "Decreased some", and "Decreased a lot").

Frequency of depressive symptoms was assessed with the 2-item Patient Health Questionnaire (PHQ-2), a validated screening tool for diagnosing unipolar depression[21]. Participants were asked how frequently in the past 2 weeks they experienced “little interest or pleasure in doing things”, or felt “down, depressed, or hopeless”. Both questions had four possible Likert responses “Not at all”, “Several days”, More than half the days”, or “Nearly every day”, corresponding to a score range of 0-4 for each item. The two items were summed (range: 0-6; Cronbach’s alpha: 0.81).

Anxiety symptoms were assessed with the 6-item Brief Symptom Inventory anxiety subscale[22]. Participants were asked the degree to which each listed symptom caused discomfort in the past 2 weeks (for example, “Nervousness or shakiness inside”) with a 5-point Likert response (“Not at all”, “A little bit”, “Moderately”, “Quite a bit” and “Extremely”). Each item ranged 1-5, all items were summed (range: 0-24; Cronbach’s alpha: 0.88).

Stress was assessed using the 10-item Perceived Stress Scale[23]. Participants reported the frequency with which they experienced the listed symptoms (for example, “found that you could not cope with all the things that you had to do”) in the past 2 weeks. 5-point Likert responses (“Never”, “Almost never”, “Sometimes”, “Fairly often”, and “Very often”) were scored 0-4 each. All items were summed (range 0-37; Cronbach’s alpha: 0.89).

Covariates included pair sex (male or female dummy variable with male as reference), age (divided by 10 to mirror the scale of other variables), household income (categorized in $10,000 increments between “Less than $20,000” and “$90,000-$99,999”, and then “$100,000-

$149,999", "$150,000 or more"), and Normalized Difference Vegetation Index (NDVI) as a value between 0 and 1. NDVI (a quantification of the amount of vegetation in an area based on satellite imagery) is a commonly used to assess available nearby greenspace and has been show to be associated with mental health and psychological well-being outcomes[24–26].

5.5 STATISTICAL ANALYSIS

An exploratory plot showed a non-linear relationship between the independent and dependent variables (Figure 5.1).

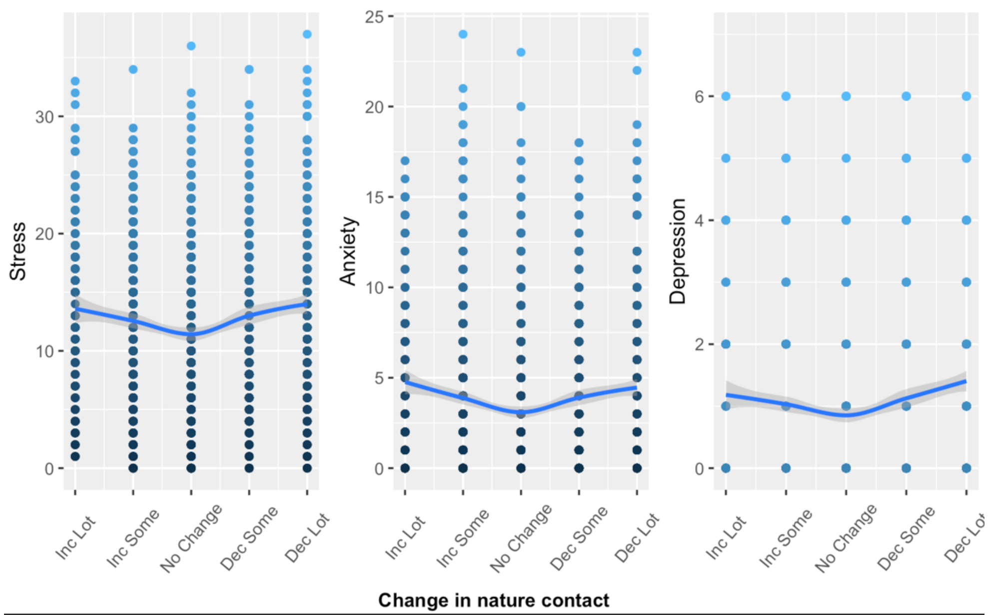

Figure 5.1. Scatterplot demonstrating non-linear relationship between change in nature contact and outcomes (Stress, Anxiety and Depression).

Thus, the "increased a lot" and "increased some" responses were combined into an aggregate "increased" response, and the two decrease responses were similarly aggregated into a "decreased" response. Analyses then used two logistic models for each outcome: increased vs.

no change, and decreased vs. no change. Another study using the same dataset had also combined responses and compared increase vs. no change and decrease vs. no change[20].

Per twin structural equation modeling methods outlined in chapter on behavior genetic research methods by Turkheimer and Harden[27] and used in a recent study[20], the independent variable and dependent variables were first decomposed into the ACE variance components, which correspond to additive genetic (A), shared environmental (C), and unshared environmental (E) variances using the *OpenMX* package in R[28]. The univariate model for the independent variable (change in time spent outside in nature) showed 81.3% of the variance within this sample were explained by E, and 18.7% by A, and near-zero (3.77^{-14})% by E. Thus, the C paths were not estimated[20] in order to achieve parsimonious models, and confirmed by AIC model fit statistics.

Then, three logistic regression models were fitted for each outcome: the base model examined the association between change in nature contact and the outcome of interest (the "phenotypic model", Model 1), then the genetic (b_A) confound was added as covariates ("quasi-causal model", Model 2), and finally, age, sex, household income, and NDVI were included as additional covariates in the fully adjusted model ("quasi-causal model", Model 3). All outcome variables were square root transformed to achieve normality.

The study's hypothesis was that perceived increase in nature contact would be quasi-causally associated with lower depressive, anxiety, and stress symptoms, and that perceived decrease in nature contact would be quasi-causally associated with greater depressive, anxiety, and stress symptoms. All latent variable path analyses were run using Mplus v8.6 software[29]. Statistical significance was set *a priori* to an alpha level of 0.05.

5.6 Results

Participant demographic characteristics are reported in Table 5.1.

5.1. Demographic characteristics for study sample and descriptive statistics for perceived change in nature contact (IV) and depression, anxiety and stress symptoms (DVs). DV statistics on raw data before square root transformation

		N = 1808 individuals (n = 909 pairs)
Age (sd)		49.9 (16)
Sex		
	Men	444 (24.4%)
	Women	1374 (75.6%)
Race/Ethinicity		
	White	1738 (95.6%)
	Other	140 (7.7%)
Zygosity		
	MZ	700 pairs (77%)
	DZ	209(23%)
Change in time spent in nature		
	Increased a lot	133 (7.3%)
	Increased some	482 (26.5%)
	No change	593 (32.6%)
	Decreased some	337 (18.5%)
	Decreased a lot	268 (14.7%)
Depressive symptoms (sd)		1.06 (1.39)
Anxiety (sd)		3.78 (3.97)
Stress (sd)		12.55 (7.15)

5.6.1 *Decrease in nature contact*

Depression symptoms. We found no association between perceived decrease in nature contact (compared to no perceived change in nature contact) and depression symptoms. However, three of the covariates—age (B = -0.12, p <0.001), sex (B = 0.214, p <0.001), and income (B = -0.029, p = 0.008)—were significantly associated with our outcome (Table 5.2).

5.2. Unstandardized regression estimates for phenotypic and quasi-causal models on the association between perceived decrease in nature contact (compared to no perceived change in nature contact) and depression symptoms

	Model 1 Phenotypic model *B* (SE)	 *p*	Model 2 Quasi-causal model *B* (SE)	 *p*	Model 3 Quasi-causal model *B* (SE)	 *p*
Decrease vs. no change						
b_{phen}	0.073	0.562	0.081	0.479	0.029 (0.22)	0.896
b_A			0.111	0.698	0 (0.06)	0.99
Age					-0.12 (0.01)	**<0.001**
Sex					0.214 (0.05)	**<0.001**
Income					-0.029 (0.01)	**0.008**
NDVI					-0.106 (0.22)	0.623
RMSEA [90%CI]	0 (0, 0.041)		0 (0, 0.043)		0.01 (0, 0.029)	

Outcome is square root transformed and age is divided by 10. The b_{phen} is the phenotypic association between IV and DV. b_A is the amount of variance in outcome attributed to additive genetic factors. RMSEA is the root mean square error of approximation to assess model fit.

Anxiety symptoms. There was a statistically significant association between decrease in nature contact and anxiety (Model 1: *B*= 0.245, p = 0.011), with those who reported less time in nature displaying more anxiety symptoms (Table 5.3). This association remained significant after controlling for between-family confounds (Model 2: *B* = 0.24, p = 0.01), which suggested decreased time in nature was quasi-causally associated with more anxiety. Furthermore, this association remained significant after the addition of age, sex, income and NDVI covariates (Model 3: *B* = 0.232, p = 0.009).

5.3.Unstandardized regression estimates for phenotypic and quasi-causal models on the association between perceived decrease in nature contact (compared to no perceived change in nature contact) and anxiety symptoms

Decrease vs. no change	Model 1 Phenotypic model *B* (SE)	*p*	Model 2 Quasi-causal model *B* (SE)	*p*	Model 3 Quasi-causal model *B* (SE)	*p*
b_{phen}	0.245 (0.1)	**0.011**	0.24 (0.09)	**0.01**	0.232 (0.09)	**0.009**
b_A			0.824 (1.24)	0.506	0.32(0.87)	0.712
Age					-0.21 (0.02)	**<0.001**
Sex					0.495 (0.07)	**<0.001**
Income					-0.035 (0.02)	**0.032**
NDVI					-0.013 (0.34)	0.97
RMSEA [90%CI]	0.015 (0, 0.047)		0.014 (0, 0.047)		0.02 (0, 0.035)	

Outcome is square root transformed and age is divided by 10. The b_{phen} is the phenotypic association between IV and DV. b_A is the amount of variance in outcome attributed to additive genetic factors. RMSEA is the root mean square error of approximation to assess model fit.

Stress. We found evidence for a significant association between decreased nature contact and stress (Model 1: *B* = 0.325, p <0.001), with members of twin pairs who perceived a decrease in nature contact experiencing more stress symptoms (Table 5.4). The association remained statistically significant after controlling for between-family confounds (Model 2: *B* = 0.322, p <0.001), suggesting a quasi-causal relationship between decreased nature contact and stress symptoms. This relationship remained statistically significant after adjusting for age, sex, income, and NDVI.

5.4.Unstandardized regression estimates for phenotypic and quasi-causal models on the association between perceived decrease in nature contact (compared to no perceived change in nature contact) and stress symptoms

	Model 1 Phenotypic model		Model 2 Quasi-causal model		Model 3 Quasi-causal model	
Decrease vs. no change	*B* (SE)	*p*	*B* (SE)	*p*	*B* (SE)	*p*
b_{phen}	0.325 (0.09)	**<0.001**	0.322 (0.09)	**<0.001**	0.33 (0.09)	**<0.001**
b_A			.0578 (1.16)	0.62	0.115(1.03)	0.91
Age					-0.272 (0.02)	**<0.001**
Sex					0.296 (0.07)	**<0.001**
Income					-0.042 (0.02)	**0.009**
NDVI					0.33 (0.09)	**<0.001**
RMSEA [90%CI]	0.01 (0, 0.044)		0.014 (0, 0.047)		0.024 (0, 0.038)	

Outcome is square root transformed and age is divided by 10. The b_{phen} is the phenotypic association between IV and DV. b_A is the amount of variance in outcome attributed to additive genetic factors. RMSEA is the root mean square error of approximation to assess model fit.

5.6.2 *Increase in nature contact*

Results below discuss phenotypic (Model 1) and quasi-causal (Model 2) associations between perceived increase in nature contact and the three outcomes. The addition of age, sex, income, and NDVI covariates caused models to fail in convergence, thus single covariate models (i.e., the quasi-causal model adjusting for between-family confounds plus one covariate—age, sex, income or NDVI—one at a time) are reported.

Depression symptoms. Perceived increase in nature contact was phenotypically associated with depression symptoms (Model 1: *B* = 0.128, p = 0.043). However, this association was attenuated when taking additive genetic factor into account (Model 2: *B* = 0.118, p = 0.069)(Table 5.5).

5.5.Unstandardized regression estimates for phenotypic and quasi-causal model on the association between perceived increase in nature contact (compared to no perceived change in nature contact) and depression symptoms

	Model 1 Phenotypic model		Model 2 Quasi-causal model	
	B (SE)	*p*	*B* (SE)	*p*
Increase vs. no change				
b_{phen}	0.128 (0.07)	**0.043**	0.118 (0.07)	0.069
b_A			0.118 (0.29)	0.685
Age				
Sex				
Income				
NDVI				
RMSEA [90%CI]	0.012 (0, 0.045)		0.016 (0, 0.048)	

Outcome is square root transformed and age is divided by 10. The b_{phen} is the phenotypic association between IV and DV. b_A is the amount of variance in outcome attributed to additive genetic factors. RMSEA is the root mean square error of approximation to assess model fit.

The single covariate quasi-causal models are summarized in Table 5.6. Increased nature contact is quasi-causally associated with higher stress, even after controlling for age (Age only: *B* = 0.151, p = 0.019). The quasi-causal association is no longer significant, however, when sex, income or NDVI are added as covariates. The variances are within normal range for each single covariate model, but the combination of covariates into a single model fails to converge.

5.6.Unstandardized regression estimates for quasi-causal models on the association between perceived increase in nature contact (compared to no perceived change in nature contact) and depression symptoms with single covariates

	Age only		Sex only		Income only		NDVI only	
	B (SE)	*p*	*B (SE)*	*p*	*B (SE)*	*p*	*B (SE)*	*p*
Increase vs. no change								
b_{phen}	0.151 (0.06)	**0.019**	0.121 (0.07)	0.091	0.114 (0.07)	0.119	0.129 (0.07)	0.071
b_A	1.32 (1.47)	0.369	0.136 (0.41)	0.739	0.1 (0.34)	0.766	0.196 (0.58)	0.734
Age	-0.125 (0.01)	**<0.001**	-	-	-	-	-	-
Sex			0.297 (0.05)	**<0.001**	-	-	-	-
Income					-0.026 (0.01)	**0.015**	-	-
NDVI							-0.249 (0.23)	0.276

Outcome is square root transformed and age is divided by 10. The b_{phen} is the phenotypic association between IV and DV. b_A is the amount of variance in outcome attributed to additive genetic factors.

Anxiety symptoms. There was no evidence to suggest an association between perceived increase in nature contact and anxiety in the phenotypic (Model 1: *B* = 0.144, p = 0.227) or quasi-causal (Model 2: *B* = 0.164, p = 0.093) models. As such, single covariate models are not reported.

Stress symptoms. Increase in nature contact was significantly associated with stress symptoms (Model 1: *B* = 0.233, p = 0.008), and this remained statistically significant even after controlling for between-family additive genetic confounds (Model 2: *B* = 0.211, p = 0.013) (Table 5.7).

5.7.Unstandardized regression estimates for phenotypic and quasi-causal model on the association between perceived increase in nature contact (compared to no perceived change in nature contact) and stress symptoms

	Model 1 Phenotypic model		Model 2 Quasi-causal model	
Increase vs. no change	*B* (SE)	*p*	*B* (SE)	*p*
b_{phen}	0.233 (0.09)	**0.008**	0.211(0.09)	**0.013**
b_A			0.408 (0.58)	0.484
Age			-	-
Sex				
Income				
NDVI				
RMSEA [90%CI]	0.015 (0, 0.046)		0.016 (0, 0.048)	

Outcome is square root transformed and age is divided by 10. The b_{phen} is the phenotypic association between IV and DV. b_A is the amount of variance in outcome attributed to additive genetic factors. RMSEA is the root mean square error of approximation to assess model fit.

Single covariate models (Table 5.8) suggest this relationship remains significant after adjusting for age, sex, income or NDVI.

5.8. Unstandardized regression estimates for quasi-causal models on the association between perceived increase in nature contact (compared to no perceived change in nature contact) and stress symptoms with single covariates

	Age only		Sex only		Income only		NDVI only	
	B (SE)	*p*	*B* (SE)	*p*	*B* (SE)	*p*	*B* (SE)	*p*
Increase vs. no change								
b_{phen}	0.248 (0.08)	**0.002**	0.229 (0.09)	**0.01**	0.218 (0.09)	**0.018**	0.236 (0.09)	**0.008**
b_A	3.07 (2.54)	0.228	0.674 (1.26)	0.592	0.487 (1)	0.626	0.83 (1.7)	0.619
Age	-0.272 (0.02)	**<0.001**	-	-	-	-	-	-
Sex			0.449 (0.07)	**<0.001**	-	-	-	-
Income					-0.4 (0.02)	**0.017**	-	-
NDVI							-0.383 (0.33)	0.244

Outcome is square root transformed and age is divided by 10. The b_{phen} is the phenotypic association between IV and DV. b_A is the amount of variance in outcome attributed to additive genetic factors.

5.7 Discussion

5.7.1 *Decrease in nature contact*

We found that perceived decrease in nature contact was significantly associated with more symptoms of anxiety and stress, even after adjusting for additive genetic confounding, and controlling for age, sex, income, and NDVI. This aligns with existing literature that generally support improved mental health outcomes from more nature contact[6,9,30], and with findings that those who reported feeling deprived of nature during the COVID-19 pandemic had lower psychological well-being[11]. The quasi-causal models with covariates showed those who were younger, female, and/or with higher incomes experienced less stress and anxiety symptoms, which aligns with existing studies on psychological well-being during COVID-19[1,20,31].

5.7.2 *Increase in nature contact*

The present study also showed that perceived increase in nature contact was phenotypically associated with higher depressive symptom scores. Because this association was no longer significant when adjusting for between-family confounds, additive genetic factors likely contributed to observed depressive symptom levels more than any perceived changes to nature contact. Increase in nature contact was, however, quasi-causally associated (i.e., after taking additive genetic confounds into account) with higher stress levels. It was not possible to adjust for multiple covariates in the same model due to failed convergence. One reason for this failure may be the small effect sizes (<1 unit) noted in all outcome models; this may suggest that precise estimations are difficult in these models, and that the addition of multiple covariates exceeds convergence capacity.

However, perceived increase in nature contact remained quasi-causally associated with higher stress scores in each of the separate models with age, sex, income or NDVI as a covariate. This finding aligns with another study using the same study population that found those who reported increasing physical activity during COVID-19 had a higher mean stress level compared to those who did not perceive a change in physical activity[20]. Since--in the absence of randomization--this study forbids causal interpretation, it is possible that those who were experiencing high stress during COVID-19 may have increased time spent in nature as a coping behavior. A survey of healthcare workers during the pandemic reported a high prevalence of depressive, anxiety and stress symptoms, as well as prevalent use of coping behaviors (such as increased physical activity) among respondents[32]. Thus, it is possible that in our study sample, those who were more adversely affected by events related to COVID-19 (and reported higher levels of stress symptoms) may have employed behavior changes (i.e., increasing or decreasing time spent outside in nature), while those who were able to go about daily life relatively unaltered may not have perceived any change in behavior.

5.7.3 *Role of heritability in nature contact and psychological well-being*

A key strength of this study was in its ability to account for the effects of additive genetic factors on psychological well-being outcomes, made possible by the twin dataset comprised of survey responses from both mono- and dizygotic twins. The decomposed standardized biometric variances showed that additive genetic factors indeed contributed to the variance in psychological well-being in the study sample, thus providing evidence that heritability may play a role in depression, anxiety and stress-related symptoms. However, studies in the field (with the exception of one[16], to the best of authors' knowledge) do not account for this role, and thereby are vulnerable to confounded estimations of effects. Motivation for future study directions and alternate designs to investigate confounding by heritability are discussed below.

5.7.4 *Limitations*

The present study sample characteristics may limit generalizability of findings; the Washington State Twin Registry participants are predominantly White and highly educated (over 42% with bachelor's or more advanced degrees)[17]. In addition, self-selection may bias our results. Particularly considering the time of the survey (within the first weeks of the stay-at-home mandates of a global pandemic), registry participants who were comparatively less adversely affected by the pandemic may have had the capacity to participate in the present survey than those more affected. Figure 5.2. shows the density and summary plot of survey responses; there was a high density of lower scores for depressive, anxiety and stress symptoms, and more investigation is needed to assess whether this study sample is significantly different from those who did not self-select to participate.

Additionally, the current survey was distributed at the end of March 2020. Depending on participants' residential city, place of work, etc, pandemic-related policies (e.g., shutting down of business or initiation of working from home) may have differed. Therefore, the degree to which participants began to engage in altered behavior (such as spending time in nature) may have differed depending on these policies. Also, the current survey did not assess sources of stress that may have occurred due to the pandemic, for example the loss of employment or childcare help, social isolation, or illness. These such pandemic-prompted stressors were likely to vary from participant-to-participant, and were unmeasured potential sources of confounding.

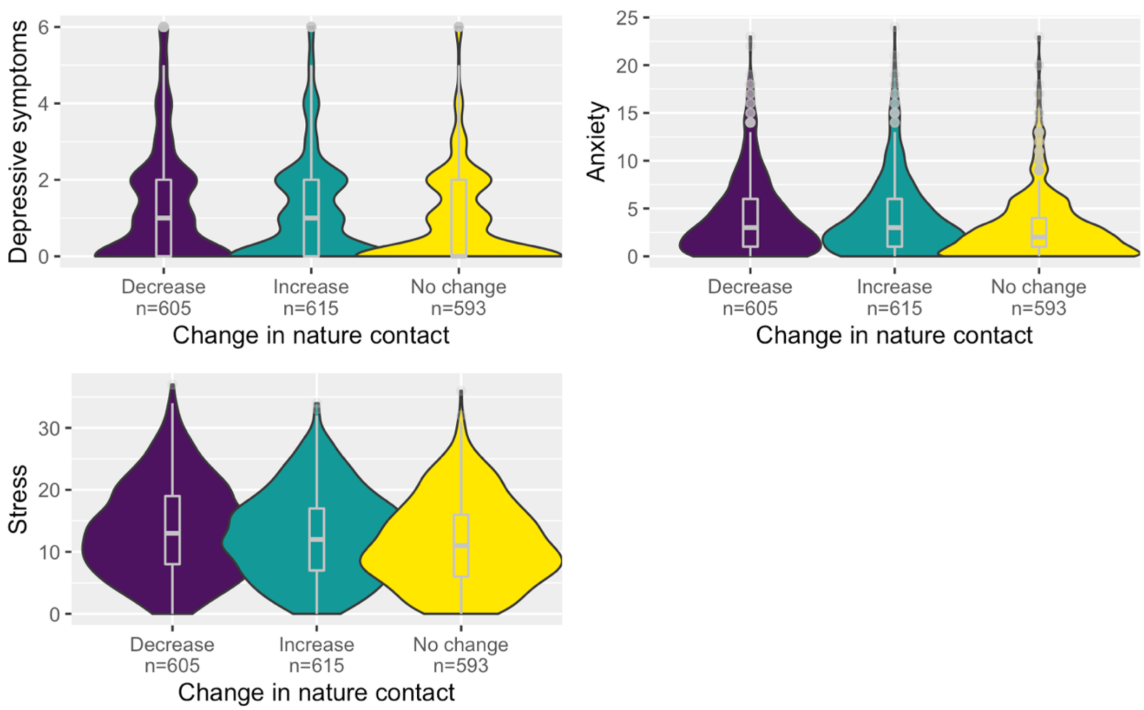

Figure 5.2.Boxplot and violin plots of depressive, anxiety and stress symptom scores

Future directions

Future studies should seek to elucidate causal direction (i.e., those experiencing mental health issues choosing to spend time in nature as a coping mechanism versus time in nature conferring mental health benefits). Additionally, while the analyses in the current study controlled for NDVI to account for variability in overall nearby nature, more research is needed to disentangle whether specific types of natural areas may have been more accessible or health-promoting during the pandemic. A study reported that, compared to before COVID-19, the proportion of individuals visiting a "park" and "green play park" decreased during COVID-19, while the proportion of respondents visiting a "private garden" or "nature reserve" increased[4]. Changes to visitation patterns based on types of natural areas may suggest a shift in priorities during the pandemic shifted. For example, natural areas conducive to social distancing (e.g., private garden or nature reserve) may have been most desirable during the pandemic compared to more crowded greenspaces (e.g., green play park).

The small effect sizes (less than 1 unit change in stress or anxiety symptoms) observed in the present study motivate future studies that assess actual nature contact (such as duration or frequency of time spent in nature, as opposed to a perceived change), which may improve our understanding of the effects of nature contact on psychological well-being. Studies should also seek representative study samples in order to increase generalizability.

Finally, the role of heritability is worthy of consideration when assessing nature contact and psychological well-being. More studies that account for heritability are needed to further clarify the degree to which nature contact may specifically be responsible for changes to psychological well-being. While the current study used survey responses to assess perceived change to nature contact behavior, twin registries also tend to record data on registrants' home or work addresses. One potential future direction is to use such location data for analysis on nearby nature and psychological well-being outcomes (e.g., regularly updated assessments of psychiatric illness diagnosis prevalence); such data may be available for a large proportion of the registrants, providing adequate sample size for analyses. However, the generalizability of twin-specific studies may be limited when seeking broader public health implications for nature contact. Studies with non-familial data may benefit from ascertaining family history of both nature contact and psychological well-being characteristics (e.g., family tendencies for spending time in nature, perceptions of nature contact, family history of psychiatric illness) as an alternate way to partially assess the role of heritability.

Conclusion

The results of this study indicate perceived change in time spent outside in nature were associated with increased depressive, anxiety or stress symptoms. The strongest evidence (using quasi-causal modeling adjusted for age, sex, income and NDVI in a single model) suggests perceived decrease in time spent in nature was associated with higher anxiety and stress scores. Preserving one's usual nature contact habits during COVID-19 may promote more psychological well-being. However, increasing nature contact during COVID-19 was quasi-causally associated with higher stress. More research is needed to illuminate the role of nature contact during COVID-19.

5.8 References

1. McGinty EE, Presskreischer R, Han H, Barry CL. Psychological Distress and Loneliness Reported by US Adults in 2018 and April 2020. *JAMA*. 2020;324(1):93. doi:10.1001/jama.2020.9740

2. VanderWeele TJ, Fulks J, Plake JF, Lee MT. National Well-Being Measures Before and During the COVID-19 Pandemic in Online Samples. *J Gen Intern Med*. 2021;36(1):248-250. doi:10.1007/s11606-020-06274-3

3. Moreland A, Herlihy C, Tynan MA, et al. Timing of State and Territorial COVID-19 Stay-at-Home Orders and Changes in Population Movement — United States, March 1–May 31, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(35):1198-1203. doi:10.15585/mmwr.mm6935a2

4. Lõhmus M, Stenfors CUD, Lind T, Lauber A, Georgelis A. Mental Health, Greenness, and Nature Related Behaviors in the Adult Population of Stockholm County during COVID-19-Related Restrictions. *Int J Environ Res Public Health*. 2021;18(6):3303. doi:10.3390/ijerph18063303

5. Bratman GN, Anderson CB, Berman MG, et al. Nature and mental health: An ecosystem service perspective. *Sci Adv*. 2019;5(7):eaax0903. doi:10.1126/sciadv.aax0903

6. Gascon M, Triguero-Mas M, Martínez D, et al. Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *Int J Environ Res Public Health*. 2015;12(4):4354-4379. doi:10.3390/ijerph120404354

7. Barton J, Rogerson M. The importance of greenspace for mental health. *BJPsych Int*. 14(4):3.

8. Meredith GR, Rakow DA, Eldermire ERB, Madsen CG, Shelley SP, Sachs NA. Minimum Time Dose in Nature to Positively Impact the Mental Health of College-Aged

Students, and How to Measure It: A Scoping Review. *Front Psychol*. 2020;10:2942. doi:10.3389/fpsyg.2019.02942

9. Wendelboe-Nelson C, Kelly S, Kennedy M, Cherrie J. A Scoping Review Mapping Research on Green Space and Associated Mental Health Benefits. *Int J Environ Res Public Health*. 2019;16(12):2081. doi:10.3390/ijerph16122081

10. Soga M, Evans MJ, Tsuchiya K, Fukano Y. A room with a green view: the importance of nearby nature for mental health during the COVID-19 pandemic. *Ecol Appl*. 2021;31(2). doi:10.1002/eap.2248

11. Tomasso LP, Yin J, Cedeno Laurent JGC, Chen JT, Catalano PJ, Spengler JD. The relationship between nature deprivation and individual wellbeing across urban gradients under COVID-19. *Int J Environ Res Public Health*. 2021;18(1511). doi:10.3390/ijerph2004010001

12. Polderman TJC, Benyamin B, de Leeuw CA, et al. Meta-analysis of the heritability of human traits based on fifty years of twin studies. *Nat Genet*. 2015;47(7):702-709. doi:10.1038/ng.3285

13. Sullivan PF, Daly MJ, O'Donovan M. Genetic architectures of psychiatric disorders: the emerging picture and its implications. *Nat Rev Genet*. 2012;13(8):537-551. doi:10.1038/nrg3240

14. Bijnens EM, Nawrot TS, Loos RJ, et al. Blood pressure in young adulthood and residential greenness in the early-life environment of twins. *Environ Health*. 2017;16(1):53. doi:10.1186/s12940-017-0266-9

15. Younan D, Tuvblad C, Li L, et al. Environmental Determinants of Aggression in Adolescents: Role of Urban Neighborhood Greenspace. *J Am Acad Child Adolesc Psychiatry*. 2016;55(7):591-601. doi:10.1016/j.jaac.2016.05.002

16. Cohen-Cline H, Turkheimer E, Duncan GE. Access to green space, physical activity and mental health: a twin study. *J Epidemiol Community Health*. 2015;69(6):523-529. doi:10.1136/jech-2014-204667

17. Duncan GE, Avery AR, Strachan E, Turkheimer E, Tsang S. The Washington State Twin Registry: 2019 Update. *Twin Res Hum Genet*. 2019;22(6):788-793. doi:10.1017/thg.2019.36

18. Strachan E, Hunt C, Afari N, et al. University of Washington Twin Registry: Poised for the Next Generation of Twin Research. *Twin Res Hum Genet*. 2013;16(1):455-462. doi:10.1017/thg.2012.124

19. Afari N, Noonan C, Goldberg J, et al. University of Washington Twin Registry: Construction and Characteristics of a Community-Based Twin Registry. *Twin Res Hum Genet*. 2006;9(6):1023-1029. doi:10.1375/183242706779462543

20. Duncan GE, Avery AR, Seto E, Tsang S. Perceived change in physical activity levels and mental health during COVID-19: Findings among adult twin pairs. Murakami M, ed. *PLOS ONE*. 2020;15(8):e0237695. doi:10.1371/journal.pone.0237695

21. Arroll B, Goodyear-Smith F, Crengle S, et al. Validation of PHQ-2 and PHQ-9 to Screen for Major Depression in the Primary Care Population. *Ann Fam Med*. 2010;8(4):348-353. doi:10.1370/afm.1139

22. Derogatis L, Melisaratos N. The Brief Symptom Inventory: an introductory report. *Psychol Med*. 1983;13(3):595-605.

23. Cohen S, Kamarck T, Mermelstein R. A Global Measure of Perceived Stress. *J Health Soc Behav*. 1983;24(4):385. doi:10.2307/2136404

24. Houlden V, Porto de Albuquerque J, Weich S, Jarvis S. A spatial analysis of proximate greenspace and mental wellbeing in London. *Appl Geogr*. 2019;109:102036. doi:10.1016/j.apgeog.2019.102036

25. Rigolon A, Browning MHEM, McAnirlin O, Yoon H (Violet). Green Space and Health Equity: A Systematic Review on the Potential of Green Space to Reduce Health Disparities. *Int J Environ Res Public Health*. 2021;18(5):2563. doi:10.3390/ijerph18052563

26. Balseviciene B, Sinkariova L, Grazuleviciene R, et al. Impact of Residential Greenness on Preschool Children's Emotional and Behavioral Problems. *Int J Environ Res Public Health*. 2014;11(7):6757-6770. doi:10.3390/ijerph110706757

27. Turkheimer E, Harden KP. Behavior Genetic Research Methods. In: Reis HT, Judd CM, eds. *Handbook of Research Methods in Social and Personality Psychology*. 2nd ed. Cambridge University Press; 2013:159-187. doi:10.1017/CBO9780511996481.012

28. Neale MC, Hunter MD, Pritikin JN, et al. OpenMx 2.0: Extended structural equation and statistical modeling. *Psychometrika*. 2016;81(2):535-549.

29. Muthen L, Muthen B. *Mplus User's Guide. Eighth Edition.* Muthen & Muthen; 1998.

30. Hartig T, Mitchell R, de Vries S, Frumkin H. Nature and Health. *Annu Rev Public Health*. 2014;35(1):207-228. doi:10.1146/annurev-publhealth-032013-182443

31. Gamonal Limcaoco RS, Mateos EM, Fernández JM, Roncero C. *Anxiety, Worry and Perceived Stress in the World Due to the COVID-19 Pandemic, March 2020. Preliminary Results*. Psychiatry and Clinical Psychology; 2020. doi:10.1101/2020.04.03.20043992

32. Shechter A, Diaz F, Moise N, et al. Psychological distress, coping behaviors, and preferences for support among New York healthcare workers during the COVID-19 pandemic. *Gen Hosp Psychiatry*. 2020;66:1-8. doi:10.1016/j.genhosppsych.2020.06.007

Chapter 6. CONCLUSION

The overarching research questions explored in my doctoral work were rooted in Stress Reduction Theory (SRT), and the corpus of studies that has investigated its tenets. This theory was based on a psychoevolutionary perspective that highlighted our species as a historically nature-borne and nature-raised species; thus, the theory drew a very deep commonality across all humans by supposing a *species-wide* tendency to express a positive response to natural environments. Unsurprisingly, evidence suggests that a kaleidoscope of factors can color (and sometimes even negate) this species-level assumption: gender[1], life stage[2], social and cultural norms[3], and earlier experiences[4] and many other factors inform the associations between nature contact and well-being. There is still much to be done empirically towards identifying important moderators and confounders that can inform the translation of the existing literature to public health and land use policies. The research presented in this dissertation contributed to this growing knowledge base, and quantified some of these nuances.

The objective of my doctoral research was to quantify the effects of nature contact on depression, anxiety, stress, and affect-related outcomes. In chapter 1, a review of literature portrayed the wide and growing list of human health benefits associated with nature contact. However, the dominance of correlational investigations and relative dearth of robust study designs (such as longitudinal methods or analyses that account for important confounders or moderators) are persistent limitations in the literature. In addition, recent advances in technology such as portable electrocardiogram sensors or smartphone-accessible survey software, enable new study methods that have important advantages, such as *in situ* data collection.

Chapter 2 outlined a study with Amazon employees who were repeatedly surveyed across a two-week period using ecological momentary assessment methodology[5,6] in order to investigate the effects of nature contact in day-to-day settings and various metrics of psychological well-being. Findings suggested that time spent in more natural outdoor environments was associated with decreased anxiety. This aligned with findings from a study of employee stress and nature contact[7] and contributed to the knowledge gap on an understudied population (urban employees).

Chapter 3 presented an experimental study that tracked *in situ* physiological responses during and after a stressor, across nature, urban and control conditions. The results indicated nature and control conditions were associated with more electrodermal as well as parasympathetic-driven heart rate variability activation compared to the urban condition. The nature condition was also associated with faster heart rate recovery after the stressor. Additionally, trait chronic stress levels and history of early adversity may moderate these effects. This study augmented the small, but growing, literature base on the physiological stress responses in natural environments. However, the study's sample size was smaller than intended due to the COVID-19 pandemic, and future studies with larger samples should continue to investigate these findings.

In Chapter 4, secondary data analysis of surveys from adult twins during the first month of COVID-19 revealed perceived decrease in nature contact during the first month of the pandemic was quasi-causally associated with higher anxiety and stress symptom scores, after adjusting for age, sex, income and NDVI. However, results also suggested perceived increase in nature contact was quasi-causally associated with more stress, which aligned with findings using the same dataset wherein perceived increase in physical activity during COVID-19 was associated with higher stress[8]. It is possible that those who changed behavior (i.e., increase or decrease spending time in nature or exercising) may reflect coping behaviors related to the adverse effects of the COVID-19 pandemic. This study contributed to the few studies that control for additive genetic and/or shared environmental confounds, and was the first study to date to investigate quasi-causal associations between nature contact and psychological well-being during the COVID-19 pandemic. However, more research is needed for strict causal inference, including randomized controlled studies, and assessments of actual time spent in nature (as opposed perceived change) may elucidate the effects of nature contact on mental health.

Together, the research studies presented in chapters 3, 4, and 5 add to the growing investigation on whether modifiable environmental characteristics, such as the presence of natural features, can improve health in important ways for urban, adult populations.

6.1 How nature contact affects overburdened subpopulations and decreases health gaps

The research on nature contact and health exists within the context of two important broader health trends. First, the prevalence and incidence rates of mental health issues are major global public health crises[9–12]. Second, the disease burden is disproportionately felt by those who are underserved; health inequity is pervasive across America, following income, educational attainment or geographical patterns across populations[13] that stem from structural racism[14]. As a result, subgroups of the population are consistently at greater risk for poor health[15,16], largely due to differences in the physical, social, and economic living conditions that accompany residential segregation along racial or economic boundaries[17–19], and the health behaviors that co-occur with these divisions of resources[20]. For example, American low-income neighborhoods often lack access to fresh foods and supermarkets[21] which leads to increased consumption of unhealthy food. This behavior in turn contributes to higher prevalence of obesity in these underserved communities compared to more affluent communities[22,23]. Another cause of health inequity may be the distribution of greenspaces in favor of wealthier, whiter neighborhoods[24,25]. With less nature contact and/or discrimination from using available natural spaces[26,27], people from underserved backgrounds are often limited in, or excluded from, receiving the multitude of health benefits conferred through nature contact.

This unbalanced, discriminatory distribution of accessible greenspace is a missed opportunity for decreasing health gaps. A growing number of studies find that the effect of nature contact on human health is moderated by factors such as socioeconomic status such that those who are from more disadvantaged backgrounds (e.g., lower income) appear to benefit more from nature contact[28–31]. While these effects cannot fully address the far-reaching, complex and systematic drivers of health inequities, continued investigation of social determinants of health equity[32]--and the potential role of natural environments specifically—can inform public health priorities for providing access to salutary environments.

The study populations in chapters 3, 4, and 5 were not particularly racially or ethnically diverse. Demographic characteristics were unknown for participants from Amazon (chapter 3) but those in the experimental study (chapter 4) predominantly self-reported as being Asian, and the twin participants (chapter 5) were over 90% White. Thus, an important future direction would be to replicate these studies with more diverse samples, and to assess how equity (for example accessibility, perceptions, and use of natural spaces) may inform the conferment of psychological well-being related benefits from nature contact.

6.2 Towards a One Health model of symbiosis

Achieving improved population health through nature contact can be part of a larger well-being objective: the optimal health of *all* species on Earth. The ecosystem we inhabit provides life-sustaining services such as water, cooling and sources of food[33]. More recently, health services such as physical and psychological benefits were added to that list[34,35]. Some have warned against viewing nature as a mere "service provider"[36]—a perspective that may perpetuate abusive and overuse practices such as clear-cutting, waterway damming and littering. Such practices affect wildlife by obliterating refuges and decreasing wildlife survival rates[37,38] and impeding migration and spawning habitats[39] (to name just a few consequences among many). These practices also negatively affect humans; as one example, deforestation can increase insect-born and other infectious diseases, and reduce protection from natural disasters[40–42].

Biodiversity is the variety of life within ecosystems[43] and is an important facet of overall ecosystem health[44]. A small but growing set of research directly links biodiversity to human health. In one study from the UK, greater diversity of plant and/or bird species was associated with enhanced psychological well-being[45]. Importantly, this study also found participants' ratings of biodiversity levels correlated with objective assessments, suggesting people may be sensitive to ambient species richness. Other studies found improved health outcomes were positively correlated with objective assessments of biodiversity; an experimental study found that those who viewed aquatic tanks with greater fish diversity experienced more improved mood and greater reduction in heart rate compared to those who viewed tanks with fewer biota[46]. Another study found self-reported satisfaction with one's neighborhood was positively correlated with objective data on surrounding bird diversity[47]. Finally, analysis from a 2011 census across Great Britain revealed greater prevalence of good health in areas with more bird species diversity[29]. Albeit small, this collection of studies motivates further research on the effects of biodiversity on human health and motivates the incorporation of biodiversity into conceptualizations of human health.

These early empirical foundations may be pivotal in sparking a new generation of "One Health"[48] policies. Public health and land use policies can seek to prioritize potential sources of symbiosis where human health, wildlife, and urban ecology are improved. For example, studies tend to find that urban street tree density is positively associated with improved mental health-related outcomes, such as decreased antidepressant prescription rates[49], mitigation and adaptation to climate change[50], and increased bird species richness and abundance[51]. Policies can thus look at street tree density as a public health priority. Future studies can seek to specify whether certain shared characteristics (e.g., older, native trees with low allergenicity) may be particularly informative for such policies. Research and policies that emphasize a "One Health" approach can thereby build towards a future in which cities are planned and maintained in ways that champion the well-being of all life on Earth.

6.3 References

1. Richardson EA, Mitchell R. Gender differences in relationships between urban green space and health in the United Kingdom. *Soc Sci Med*. 2010;71(3):568-575. doi:10.1016/j.socscimed.2010.04.015

2. Astell-Burt T, Mitchell R, Hartig T. The association between green space and mental health varies across the lifecourse. A longitudinal study. *J Epidemiol Community Health*. 2014;68(6):578-583. doi:10.1136/jech-2013-203767

3. Kessel A, Green J, Pinder R, Wilkinson P, Grundy C, Lachowycz K. Multidisciplinary research in public health: A case study of research on access to green space. *Public Health Lond*. 2008;123(1):32-38. doi:10.1016/j.puhe.2008.08.005

4. Thompson CW, Aspinall P, Montarzino A. The Childhood Factor: Adult Visits to Green Places and the Significance of Childhood Experience. *Environ Behav*. 2008;40(1):111-143. doi:10.1177/0013916507300119

5. de Vries LP, Baselmans BML, Bartels M. Smartphone-Based Ecological Momentary Assessment of Well-Being: A Systematic Review and Recommendations for Future Studies. *J Happiness Stud*. Published online October 23, 2020. doi:10.1007/s10902-020-00324-7

6. Shiffman S, Stone AA, Hufford MR. Ecological Momentary Assessment. *Annu Rev Clin Psychol*. 2008;4(1):1-32. doi:10.1146/annurev.clinpsy.3.022806.091415

7. Largo-Wight E, Chen WW, Dodd V, Weiler R. Healthy Workplaces: The Effects of Nature Contact at Work on Employee Stress and Health. *Public Health Rep*. 2011;126(1_suppl):124-130. doi:10.1177/00333549111260S116

8. Duncan GE, Avery AR, Seto E, Tsang S. Perceived change in physical activity levels and mental health during COVID-19: Findings among adult twin pairs. Murakami M, ed. *PLOS ONE*. 2020;15(8):e0237695. doi:10.1371/journal.pone.0237695

9. Gallagher RP. *National Survey of Counseling Center Directors 2011*. University of Pittsburgh; 2011. http://www.iacsinc.org/ 2011%20NSCCD.pdf

10. National Institute of Mental Health. Anxiety disorders. Published 2018. https://www.nimh.nih.gov/health/topics/anxiety-disorders/index.shtml

11. National Institute of Mental Health. Mental health information: Major depression. Accessed May 25, 2019. https://www.nimh.nih.gov/health/statistics/major-depression.shtml#part_155031

12. Department of Health and Ageing. *National Mental Health Report 2013: Tracking Progress of Mental Health Reform in Australia 1993-2011.*; 2013.

13. World Health Organization, UN-Habitat. *Hidden Cities: Unmasking and Overcoming Health Inequities in Urban Settings.* WHO; 2010. http://www.wholint/iris/handle/10665/44439

14. Phelan JC, Link BG. Is Racism a Fundamental Cause of Inequalities in Health? Published online 2015:22.

15. OECD. *Health for Everyone?: Social Inequalities in Health and Health Systems*. OECD; 2019. doi:10.1787/3c8385d0-en

16. National Center for Health Statistics. *Health, United States, 2015 with Special Feature on Racial and Ethnic Health Disparities*.; 2016:461. https://www.cdc.gov/nchs/data/hus/hus15.pdf

17. Williams DR, Collins C. Racial Residential Segregation: A Fundamental Cause of Racial Disparities in Health. *Public Health Rep*. 2001;116:13.

18. Massey DS, Rothwell J, Domina T. The Changing Bases of Segregation in the United States. :17.

19. Logan JR. The Persistence of Segregation in the Metropolis: New Findings from the 2010 Census. :25.

20. World Health Organization. *Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health: Commission on Social Determinants of Health Final Report*. WHO; 2008.

21. USDA. *Access to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences*.; 2009. https://www.ers.usda.gov/webdocs/publications/42711/12716_ap036_1_.pdf

22. Cannuscio C, Glanz K. Food environments. In: *Making Healthy Places: Designing and Building for Health, Well-Being, and Sustainability*. Island Press; 2011:50-63.

23. Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built Environments and Obesity in Disadvantaged Populations. *Epidemiol Rev*. 2009;31(1):7-20. doi:10.1093/epirev/mxp005

24. Dai D. Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene? *Landsc Urban Plan*. 2011;102(4):234-244. doi:10.1016/j.landurbplan.2011.05.002

25. Gobster PH. Managing Urban Parks for a Racially and Ethnically Diverse Clientele. *Leis Sci*. 2002;24(2):143-159. doi:10.1080/01490400252900121

26. Byrne J. When green is White: The cultural politics of race, nature and social exclusion in a Los Angeles urban national park. *Geoforum*. 2012;43(3):595-611. doi:10.1016/j.geoforum.2011.10.002

27. Morris J, O'Brien E, Ambrose-Oji B, Lawrence A, Carter C, Peace A. Access for all? Barriers to accessing woodlands and forests in Britain. *Local Environ*. 2011;16(4):375-396. doi:10.1080/13549839.2011.576662

28. Maas J. Green space, urbanity, and health: how strong is the relation? *J Epidemiol Community Health*. 2006;60(7):587-592. doi:10.1136/jech.2005.043125

29. Wheeler BW, Lovell R, Higgins SL, et al. Beyond greenspace: an ecological study of population general health and indicators of natural environment type and quality. *Int J Health Geogr*. 2015;14(1):17. doi:10.1186/s12942-015-0009-5

30. Mitchell R, Popham F. Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet*. 2008;372(9650):1655-1660. doi:10.1016/S0140-6736(08)61689-X

31. Rigolon A, Browning MHEM, McAnirlin O, Yoon H (Violet). Green Space and Health Equity: A Systematic Review on the Potential of Green Space to Reduce Health Disparities. *Int J Environ Res Public Health*. 2021;18(5):2563. doi:10.3390/ijerph18052563

32. Marmot M, Friel S, Bell R, Houweling TA, Taylor S. Closing the gap in a generation: health equity through action on the social determinants of health. *Public Health*. 2008;372:9.

33. Millenium Ecosystem Assessment. *Ecosystems and HumanWell-Being: Synthesis.*; 2005.

34. Bratman GN, Hamilton JP, Daily GC. The impacts of nature experience on human cognitive function and mental health: Nature experience, cognitive function, and mental health. *Ann N Y Acad Sci*. 2012;1249(1):118-136. doi:10.1111/j.1749-6632.2011.06400.x

35. Bratman GN, Anderson CB, Berman MG, et al. Nature and mental health: An ecosystem service perspective. *Sci Adv*. 2019;5(7):eaax0903. doi:10.1126/sciadv.aax0903

36. Varanasi U. Focusing Attention on Reciprocity Between Nature and Humans Can Be the Key to Reinvigorating Planetary Health. *Ecopsychology*. 2020;12(3):188-194.

37. Sigman MJ. Impacts of clearcut logging on the fish and wildlife resources of southeast Alaska. Published online 1985.

38. Escobar MAH, Uribe SV, Chiappe R, Estades CF. Effect of Clearcutting Operations on the Survival Rate of a Small Mammal. Russo D, ed. *PLOS ONE*. 2015;10(3):e0118883. doi:10.1371/journal.pone.0118883

39. Northwest Power and Conservation Council. Dams: impacts on salmon and steelhead. https://www.nwcouncil.org/reports/columbia-river-history/damsimpacts

40. Robbins J. How Forest Loss Is Leading To a Rise in Human Disease. Yale Environment 360.

41. Díaz S, Fargione J, Chapin FS, Tilman D. Biodiversity Loss Threatens Human Well-Being. *PLoS Biol*. 2006;4(8):e277. doi:10.1371/journal.pbio.0040277

42. World Health Organization. *Biodiversity and Human Health: A State of Knowledge Review.* World Health Organization and Scretariat of the Convention on Biological Diversity; 2015. https://www.cbd.int/health/SOK-biodiversity-en.pdf

43. United Nations. *Convention on Biological Diversity*.; 1992.

44. Mace GM, Norris K, Fitter AH. Biodiversity and ecosystem services: a multilayered relationship. *Trends Ecol Evol*. 2012;27(1):19-26.

45. Fuller RA, Irvine KN, Devine-Wright P, Warren PH, Gaston KJ. Psychological benefits of greenspace increase with biodiversity. *Biol Lett*. 2007;3(4):390-394. doi:10.1098/rsbl.2007.0149

46. Cracknell D, White MP, Pahl S, Nichols WJ, Depledge MH. Marine Biota and Psychological Well-Being: A Preliminary Examination of Dose–Response Effects in an Aquarium Setting. *Environ Behav*. 2016;48(10):1242-1269. doi:10.1177/0013916515597512

47. Hepburn L, Smith AC, Zelenski J, Fahrig L. Bird Diversity Unconsciously Increases People's Satisfaction with Where They Live. *Land*. 2021;10(2):153. doi:10.3390/land10020153

48. Centers for Disease Control and Prevention. One Health. Published 2019. https://www.cdc.gov/onehealth/index.html

49. Taylor MS, Wheeler BW, White MP, Economou T, Osborne NJ. Research note: Urban street tree density and antidepressant prescription rates—A cross-sectional study in London, UK. *Landsc Urban Plan*. 2015;136:174-179. doi:10.1016/j.landurbplan.2014.12.005

50. Salmond JA, Tadaki M, Vardoulakis S, et al. Health and climate related ecosystem services provided by street trees in the urban environment. *Environ Health*. 2016;15(S1):S36. doi:10.1186/s12940-016-0103-6

51. Pena JC de C, Martello F, Ribeiro MC, Armitage RA, Young RJ, Rodrigues M. Street trees reduce the negative effects of urbanization on birds. Chapman M (Gee) G, ed. *PLOS ONE*. 2017;12(3):e0174484. doi:10.1371/journal.pone.0174484

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McHugh, R.K., **Park, S.,** & Weiss, R.D. (2014). *Cue-induced craving in dependence upon prescription opioids and heroin.* The American Journal on Addictions, 23, 453-458.

McHugh, R.K., Sugarman, D.E., Kaufman, J.S., **Park, S.,** Weiss, R.D., & Greenfield, S. (2014). *Readability of self-report alcohol misuse measures.* Journal of Studies on Alcohol and Drugs, 74,328-334.

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- Distill research projects related to a 5-year, $40mil USDA-funded project on biofuels into written products (reports, public statement sheets, policy briefs, stakeholder newsletters)
- Prepare grant materials including letters of intent, data management plan, statement of project objectives

Research Collaborator, Harvard University, 2014-2016

- Supervise 8 undergraduate and graduate research assistants
- Conduct cross-sectional, natural experimental and experimental studies on psychology of eating behavior (Psychology of Eating and Consumer Health Lab)
- Use mTurk, diet diary software and image coding
- Design, run, analyze pilot studies

Clinical Research Assistant, McLean Hospital, 2012-2014

- Independently collect data with Substance Use Disorders division with outpatient psychiatric populations
- Administer Structured Clinical Interview for DSM Disorders (SCID)
- Use computer-based cue presentation software

Research Assistant, McLean Hospital, 2010-2012

- Run immunohistochemistry assays at the Molecular Neurobiology lab

SERVICE

Journal article peer reviewer, *Ecopsychology*, 2019

Senator, Graduate and Professional Student Senate, University of Washington, 2016-2017

Poster Abstract Reviewer, The Society for a Science of Clinical Psychology (SSCP), 2013-2015

SPEAKING ENGAGEMENTS

Invited speaker, Washington State Capital House of Representatives Budget Committee Meeting, January 2020

Invited speaker, Nature and Health Lunchtime Talks, University of Washington EarthLab, February 2020