Landscape and Urban Planning 132 (2014) 26–36

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

A dose of nature: Tree cover, stress reduction, and gender differences

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HIGHLIGHTS

- We describe the dose–response curve for the impact of tree cover density on stress reduction.
- We employed 6-min, 3-D videos of community street scenes as the nature treatment.
- We measured skin conductance and salivary cortisol levels as measures of participants' stress.
- For men, the dose–response curve was an inverted-U shape.
- For women, we found no relationship between tree cover density and stress reduction.

ARTICLE INFO

Article history:
Received 22 February 2014
Received in revised form 29 July 2014
Accepted 6 August 2014
Available online 27 August 2014

Keywords:
Dose–response curve
Stress reduction
Salivary cortisol
Skin conductance
Tree cover density
3-D visual media

ABSTRACT

Although it is well established that exposure to nearby nature can help reduce stress in individuals, the shape of the dose–response curve is entirely unclear. To establish this dose–response curve, we recruited 160 individuals for a laboratory experiment. Participants engaged in the Trier Social Stress Test (TSST) to induce psychological stress, and were then randomly assigned to view one of ten, 6-min, 3-D videos of neighborhood streets. The density of tree cover in the videos varied from 1.7% to 62.0%. We measured their stress reactions by assessing salivary cortisol and skin conductance levels. Results show a clear disparity between women and men. For women, we found no relationship between varying densities of tree cover and stress recovery. For men, the dose–response curve was an inverted-U shape: as tree cover density increased from 1.7% to 24%, stress recovery increased. Tree density between 24% to 34% resulted in no change in stress recovery. Tree densities above 34% were associated with slower recovery times. A quadratic regression using tree cover density as the independent variable and a summary stress index as the dependent variable substantiated these results [$R^2 = .22$, $F(2, 68) = 9.70$, $p < .001$]. The implications for our understanding of the impacts of nearby nature, and for the practice of planning and landscape architecture are discussed.

1.. Introduction

1.1 Background

The demands and pressures of modern life are precursors to some of the most threatening medical problems we face today. Chronic stress can suppress the immune system (Cohen, Miller, & Rabin, 2001) and trigger cardiovascular disease, stroke, depression, asthma, and other critical health problems (e.g., Childs & Wit, 2009; Dimsdale, 2008; Gump et al., 2011; Russ et al., 2012; Steptoe & Brydon, 2009). There is mounting evidence, however, that exposure to nature enhances the resources necessary to manage the demands and pressures of modern life. Settings that include tress, grass, and open spaces have been shown to aid physiological stress reduction (e.g., Chang & Chen, 2005; Hartig, Mang, & Evans, 1991; Ulrich et al., 1991; van den Berg, Hartig, & Staats, 2007).

Although it is well established that exposure to nature enhances stress reduction, the shape of the dose–response curve is entirely unclear. We do not know if exposure to a small amount of green space is enough to induce calming effects, whether increase in the density of vegetation produce additional calming effects, or even if the relationship between exposure to nature and stress reduction is linear. Lack of this knowledge prevents landscape architects

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http://dx.doi.org/10.1016/j.landurbplan.2014.08.005
0169-2046/Published by Elsevier B.V.

and urban planners from making science-based design and management decisions that might improve the health and longevity of people in the communities they serve.

In this paper, we seek to describe the shape of the dose–response curve for how exposure to nearby nature impacts stress reduction. We begin by reviewing theory and evidence regarding stress and human health. Next we review recent evidence connecting exposure to nearby nature to lower levels of stress. Finally, reporting the results of an experiment involving 160 individuals, we describe a dose–response curve for each gender and discuss the implications of the findings for design and planning.

1.2 Stress and health

When we feel stress, our bodies respond via two physiological pathways: the sympathetic–adrenomedullary system (SA) and the hypothalamic–pituitary–adrenocortical axis (HPA) (Smith & Vale, 2006; Taylor, 1999). The SA activates what is often termed the fight or flight response. It causes the adrenal medulla glands to produce epinephrine and norepinephrine, which result in increased blood pressure, heart rate, sweating, and constricts peripheral blood vessels. The SA enhances our ability to physically engage with the stress or threat. The HPA axis, on the other hand, prepares our bodies for possible injury and helps bring our bodies back to normal after the threat is no longer present. In the HPA axis, the cerebral cortex sends a message to the hypothalamus, which activates the corticotrophin-releasing factor (CRF), and results in cortisol being released into the blood stream. Cortisol plays an important role in helping the body return to its normal state after the stress (Young, Abelson, & Lightman, 2004).

Cortisol responses differ within and among individuals. Cortisol levels change within healthy individuals each day, generally peaking shortly after waking in the morning and reaching a low shortly after falling asleep at night (Edwards, Clow, Evans, & Hucklebridge, 2001; Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004; Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004). Men typically have stronger physiological responses to stress than do women, as indicated by greater increases in cortisol levels to stressful events (Bratman, Hamilton, & Daily, 2012; Dedovic, Wadiwalla, Engert, & Pruessner, 2009; Jackson, 2003). An individual's health status also can impact the levels of cortisol in their blood (De Rooij & Roseboom, 2010). Given this amount of variation within and among individuals, research that examines levels of cortisol must take gender and other confounding factors, such as measurement time, physical and mental health status, and intake of drugs, tobacco, or acohol, into consideration.

Together, these physiological responses to stress can be lifesaving. But if they are activated too often, if we spend significant parts of our daily lives feeling stress, these same physiological systems can be life threatening. People who experience chronic stress are at risk for immune dysfunction, cardiovascular disease including ventricular arrhythmias and stroke, depression, obesity, memory and concentration problems, and early death (Curtis & O'Keeffe, 2002; Lee, Park, Tsunetsugu, Kagawa, & Miyazaki, 2009; Taylor, 1999).

1.3 Contact with nature and stress recovery

For centuries, philosophers, poets, and artists have suggested that people can reduce the stress they feel by escaping to nature. Emerson, Whitman, and Thoreau all wrote about the sense of peace and tranquility that comes with being in a wood, meadow, or other natural place. During the past two decades, scientists have shown that exposure to urban nature is related to a greater capacity to deal with difficult life problems (Kuo, 2001); increasing "peacefulness," "tranquility," and "relaxation" (Ulrich, 1993); and decreasing physiological indicators of stress (Chang & Chen, 2005; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998).

Ulrich's Stress Reduction Theory (SRT) is an important framework explaining why contact with nature might foster stress reduction (Bratman et al., 2012; Ulrich et al., 1991). Ulrich et al. (1991) postulated that landscapes containing water, vegetation, richness (or complexity), some visual depth, and a degree of curvilinearity would have aided human survival for hundreds of thousands of human generations. The idea is that in such settings, our ancestors could have spotted food or other resources, predators, and other humans that would have aided their survival. Ulrich argued that, given the impact such settings had on shaping our survival as a species, such settings should help moderate and reduce the physiological signs of stress in modern day humans.

SRT proposes that contact with such natural places will produce a relatively fast (within minutes) affective reaction at a subconscious level that can be measured through physiological pathways. In the last decade, scholars have measured physiological responses associated with various kinds of landscapes and have generally found that, in urban areas, the higher the level of vegetation, the greater the stress reduction (e.g., Alvarsson, Wiens, & Nilsson, 2010; Beil & Hanes, 2013; Lee et al., 2009; Roe et al., 2013; Ward Thompson et al., 2012).

None of these previous studies have reported gender differences in physiological responses after individuals have been exposed to various forms of nature. But a host of other studies that examine physiological responses to stressful conditions do report varying rates of recovery between males and females (e.g., Kudielka, Buske-Kirschbaum, et al., 2004; Kudielka, Schommer, et al., 2004; Wang et al., 2007; Weekes et al., 2008). Both biological and social difference between men and women might explain gender difference in stress responses (e.g., Carrillo et al., 2001; Dedovic et al., 2009; Wang et al., 2007). Thus, in this study, we examine the extent to which gender differences exist in response to varying densities of nature.

Although previous studies demonstrate that exposure to nature, even urban nature, has calming effects, they do not help us understand the shape of the dose–response curve for the impact of nature on stress reduction. That is because none of the previous studies was able to examine the impacts of small, incremental increase in the density of nature have on stress outcomes. Previous findings show that exposure to natural environments is generally more beneficial to human well-being than exposure to predominantly built environments (Hartig, Evans, Jamner, Davis, & Garling, 2003; Laumann, Garling, & Stormark, 2003; Lee et al., 2009; Ulrich et al., 1991), but they do not help us understand the dose–response relationship between exposure to nature and stress reduction.

Thus, there is a critical gap in our knowledge regarding the shape of the dose–response curve for the effect of nearby nature on stress reduction. Is a little exposure to nearby trees and other forms of vegetation enough to produce calming effects from a stressful event? Do higher densities of vegetation produce more calming? Is the relationship linear, or does the effect lessen with greater and greater amounts of vegetation? Are there gender differences in these responses? This study begins to address these questions for one particular setting: the residential street in a single-family neighborhood.

2.. Methods

2.1 Overview

To establish this dose–response curve, we recruited 160 individuals for a laboratory experiment. Participants engaged in the Trier Social Stress Test (TSST), which was designed to induce mental