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Toward a unified model of stress recovery and cognitive restoration in nature

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Abstract

There is abundant evidence for both cognitive and affective improvements stemming from spending time in nature; however, the mechanism underlying these effects are still under debate. Frameworks such as Attention Restoration Theory (ART; Kaplan 1995) and Stress Recovery Theory (SRT; Ulrich et al. 1991) have been helpful in understanding how restoration is achieved. Using the neurovisceral integration model (NIVM; Thayer and Lane 2000, 2002), we suggest that cognitive restoration and stress recovery co-occur and that they are bidirectional manifestations of activity in the vagus nerve, which links the peripheral nervous system (PNS) to the central nervous system (CNS). Future research should examine both PNS and CNS activity simultaneously to provide a better understanding of the changes in the body and brain associated with immersion in nature. This research program will provide the scientific evidence to help inform public policy related to human health, urban design, and environmental protection.

Although urbanization and advancements in technology have many benefits, it is important to understand how these rapid changes may affect the individual. In the modern, Western lifestyle, people are increasingly spending less time outdoors and more time interacting with technology, which can have depleting effects on levels of attention (Frey et al. 2007; Klepeis et al. 2001; Linnell et al. 2012). Sedentary indoor lifestyles can increase risk for heart disease and obesity (Lichtenstein et al. 2006). Psychologically, living in urban areas has also been linked to increased levels of stress (Lederbogen et al. 2011) and mental illness (Lambert et al. 2015; McKenzie et al. 2013; Peen et al. 2010). As over 50% of the global population is currently living in urban areas and with this proportion expected to grow (Turner et al. 2004), it is increasingly important to identify ways in which people can cope with the attentional and stressful demands of high technology urban environments. Attention Restoration Theory (ART; Kaplan 1995) and Stress Recovery Theory (SRT; Ulrich et al. 1991) aim to highlight the importance of natural environments to our cognition and physiological health, respectively. These theories can potentially be unified through the vagus nerve, a common anatomical mechanism that reflects activity from central and peripheral nervous systems (Thayer and Lane 2000, 2002). We posit that measuring vagal tone, coupled with neurophysiological measures, provides a better understanding on how changes in the brain and body co-occur with immersion in nature.

Attention Restoration Theory

ART suggests that time spent in nature restores attention (Kaplan 1995). Kaplan proposed that urban environments demand directed, or effortful attention, which can result in mental fatigue and failure to maintain goal-directed behavior (Boksem and Tops 2008; Hopstaken et al. 2014; James 1892). Specifically, Kaplan suggested that urban environments require top-down goal-directed attention to process attention-demanding stimuli, such as avoiding traffic while crossing a busy street (e.g., Berman, Jonides, and Kaplan 2008). In modern daily life, we often engage in multiple tasks at once (e.g., Sanbonmatsu et al. 2013) and draw on directed attention to inhibit distracting stimuli (e.g., phone notifications that repeatedly draw attention away from daily tasks). Over time, such demands on cognitive control systems can lead to mental fatigue and subsequent lapses in attention (Holtzer et al. 2010), causing self-regulatory failures (Heatherton and Wagner 2011; Kaplan and Berman 2010). Meanwhile, Kaplan argues, natural environments contain stimuli that can evoke "fascination," which captures attention effortlessly in a bottom-up (stimulus-driven, involuntary) fashion (Kaplan 1995). Therefore, natural environments should be an effective way to stimulate involuntary attention, allow directed attention to rest, and ultimately achieve cognitive restoration (Kaplan 1995).

Since the establishment of ART, studies have explored how varying levels of nature exposure influence attention using behavioral measures of cognitive performance. For example, one study explored longer immersion in nature via a four-day backpacking trip with no technology, finding that a hiking group performed 50% better on a creative problem-solving task after the trip compared to a control group who completed the task before the trip (Atchley et al. 2012). These results were recently replicated in a similar study (Ferraro 2015). Short walks in natural environments can also increase performance on tasks requiring sustained attention (Berman et al. 2008; Hartig et al. 2003; Johnson et al. 2019) and working memory (Berman et al. 2012; Bratman et al. 2015; Taylor and Kuo 2009) compared to walks in urban environments. Several studies have even found improved cognitive performance after participants view nature imagery compared to urban imagery (Berto 2005; Berman et al. 2008; Lee et al. 2015; Tennessen and Cimprich 1995), especially imagery that was rated as highly fascinating (Berto et al. 2010) and scenes containing forests and water (Laumann et al. 2003), although some studies have failed to replicate these effects (Neilson et al. 2020). These findings imply that even short exposures to nature, including 40-second "micro-breaks" (Lee et al. 2015), can provide a boost in attention. ART argues that these boosts in attention occur when the cognitive control networks that underlie directed attention are able to rest and recuperate during nature exposure.

Directed attention requires top-down control from the frontal and parietal lobes within the central nervous system (CNS) to actively select relevant information and suppress irrelevant information (Kaplan and Berman 2010). Such functions are supported by cognitive control networks in the brain, involving regions such as the dorsolateral prefrontal cortex (DLPFC), anterior cingulate cortex (ACC), and parietal cortices, as well as related neural networks such as the cinguloopercular (CO) and frontoparietal (FP) networks (Niendam et al. 2012). These networks increase in activation when engaging in tasks requiring directed attention, working memory, response inhibition, and sustained attention (Corbetta and Shulman 2002; Dosenbach et al. 2006, 2007, 2008; Woldorff et al. 2004).

Researchers have begun to explore the underlying neural mechanisms of such attentional effects using advanced neuroscience techniques. One functional magnetic resonance imaging (fMRI) study observed a decrease in cortical brain areas associated with visual processing in response to nature images compared to urban images, thought to indicate a downregulation of visual attention that may subsequently enable cognitive restoration in nature (Tang et al. 2017). Another fMRI study found decreased activity in the subgenual prefrontal cortex, a region of the brain associated with depression and rumination, after a 90-minute nature walk (Bratman et al. 2015). Two fMRI studies have found increased functional connectivity between the insula and the anterior cingulate cortex (ACC) in response to nature images (Kim et al. 2010) and while listening to naturalistic sounds (van Praag et al. 2017), demonstrating nature's influence on subcortical structures involved in attentional control.

While fMRI provides superior spatial resolution to depict areas of the brain that are activated or deactivated by exposure to natural stimuli, electroencephalography (EEG) can provide more direct, temporally sound measures of neural activity. Additionally, it is a more portable method, and therefore can be used to measure brain activity *while* the participant is immersed to nature, instead of after. Therefore, some researchers have utilized EEG to measure electrical activity of the brain in response to nature exposure. Compared to viewing urban images, some studies have observed an increase in spectral power in alpha frequency after viewing nature images (Ulrich 1981), potted plants (Nakamura and Fujii 1990), greenery (Nakamura and Fujii 1992), and fractal patterns associated with natural views (Hagerhall et al. 2015). This pattern of data is thought to indicate lower physiological arousal and greater relaxation after nature exposure (Ulrich 1981; though see Hopman et al. 2020). Consistent with ART, a few EEG studies have found evidence of increases in cognitive control activity. For example, brain components such as the error-related negativity (LoTemplio et al. 2020), the P300 (Scott et al., under review), and the late positive potential (Mahamane et al. 2020) increase in response to nature exposure compared to urban exposure. The reward positivity (McDonnell et al., under review), whose amplitude is inversely related to efficient allocation of attention, decreases in response to nature compared to urban environments. This small and growing body of evidence suggests that not only are there behavioral effects of exposure to nature, but there are likely underlying neurological explanations for nature's attentional benefits as well.

Stress Recovery Theory

SRT draws on psycho-evolutionary theory to explain how non-threatening nature reduces stress (Ulrich et al. 1991). Proposed by Plutchik (1984), this theory suggests that changes in emotional tone and arousal served adaptive purposes to enhance our species' survival and reproductive success. These changes would occur quickly and prepare us for fight-or-flight responses to threatening stimuli, such as a rattlesnake encounter. In this example, autonomic activation of stress is adaptive and beneficial to our survival. Our modern-day environments, however, may promote chronic stress in response to psychological stressors that may be more enduring (Segerstrom and Miller 2004). Activating the stress responses system frequently and over a longer duration can have chronic effects on immune functioning and cardiovascular health (Cacioppo et al. 1998; Hawkley, and Cacioppo 2004; Uchino et al. 2007; Ulrich-Lai and Herman 2009). Thus, although our physiological stress response to a physical threat was adaptive from an evolutionary standpoint, that same response to modern-day stress, by continuing to reflect the demands of earlier environments (Cacioppo et al. 1998), is now maladaptive. In other words, events or stimuli that do not require a physical response are evoking a physiological reaction and causing us to stay in elevated states of arousal for longer, negatively affecting our homeostasis (Hobfoll 1989; Uchino et al. 2007).

Ulrich et al. (1991) argue that if humans are evolutionarily equipped to respond quickly to threatening stimuli in natural settings (e.g., predators), then humans will also be ready to quickly acquire restorative responses (e.g., recharge of physical energy) that, by the same logic, may strongly apply in natural settings. Therefore, Ulrich proposes that recovery from stress will likely occur more quickly and thoroughly in natural versus urban settings. Ulrich et al. (1991) proposes two main facets by which this recovery occurs: 1) activation of the Parasympathetic Nervous System (PSNS), our "rest and digest" system that is activated during recovery from stress, and 2) positive changes in affect, or emotional states.

A growing number of studies leveraging physiological and self-reporting methodologies have emerged in support of SRT. For example, studies have demonstrated lower self-reported stress (Beil and Hanes 2013; Roe et al. 2013), greater positive affect (Bratman et al. 2015; Beute and de Kort 2014; Lee et al. 2014), and improved immune functioning (Li et al. 2008), including a reduction in stress-related hormones such as cortisol (Beil and Hanes 2013), following exposure to natural environments. There is also evidence for decreased heart rate (Laumann et al. 2003; Lee et al. 2014) and decreased blood pressure (Hartig et al. 2003; Li 2010) after viewing nature imagery or taking walks in nature compared to viewing or walking in urban environments, although the literature is still somewhat mixed in that some studies find no changes in these measures (Brown et al. 2013; Gladwell et al. 2012). Interestingly, recent studies have found supportive evidence of greater parasympathetic nervous system activity, such as increased high-frequency heart-rate variability (HF-HRV) following exposure to nature imagery (Brown et al. 2013; Beute and de Kort 2014; Gladwell et al. 2012) and nature walks (Lee et al. 2014) compared to urban imagery or walks. These studies are consistent with Ulrich's hypothesis that activation of the PSNS is necessary to facilitate recovery from stress. Finally, correlational studies have determined greater well-being (Grinde and Patil 2009; White et al. 2013), lower levels of health inequality (Mitchell and Popham 2008), and lower incidences of morbidity, especially depression and anxiety (Maas et al. 2009), in people who live in high green space areas compared to those who do not. Taken together, this literature suggests that both access and proximity to restorative environments may have an impact on short-term stress recovery and long-term cardiovascular health.

A bidirectional relationship

Both ART and SRT expand on the biophilia hypothesis, which suggests that people have an innate connection to nature (Wilson 1984). While ART and SRT both involve a comparison of natural versus urban environments, they differ in what drives an individual to seek a restorative place: ART proposes recovery from mental fatigue, whereas SRT proposes recovery from stress. Although each theory acknowledges that each process has the potential to be involved in restoration, both lay out critiques and clear distinctions between one another. For example, Ulrich proposed that because bottom-up, involuntary attention happens in natural settings regardless of restoration (e.g., attentional intake towards a snake or other threatening stimuli), stress recovery must be necessary for restoration to occur. By contrast, Kaplan proposes that because stress can occur without a negative stimulus (e.g., physiological stress responses to a challenging but pleasant task), resource depletion can explain the increase in stress and therefore resource replenishment can better explain restoration. As a result of the debate, supporters of ART tend to focus on measurements based in the CNS while supporters of SRT tend to focus on measurements based in the Peripheral Nervous System (PNS), and thus a methodological distinction in the field has emerged.

We propose that processes of stress recovery and cognitive restoration (and, by default, stress and cognitive fatigue) co-occur and are bidirectional, as opposed to being "separate but complementary" as suggested by both Ulrich's (1991) SRT and Kaplan's (1995) ART theories. While few studies in this field have measured both physiological *and* attentional responses to nature, results from the studies that do exist suggest a reciprocal relationship between the two. For example, one study found decreased blood pressure and increased performance on an attention task after walks in nature compared to urban walks (Hartig et al. 2003). Another study found increased HF-HRV and improved performance on an attention monitoring task during naturalistic sounds compared to artificial ones (Van Praag et al. 2017). However, in general, studies in this field tend to focus on one framework, rather than examining both theories together. We propose that changes in stress and attention happen together during nature exposure via the vagus nerve.

Vagal tone reflects central modulation of the periphery

> *When the heart is affected it reacts on the brain; and the state of the brain again reacts through the pneumo-gastric nerve on the heart; so that under any excitement there will be much mutual action and reaction between these, the two most important organs of the body*.
>
> — Darwin 1872: 69

As early as the 1800s, scientists were recognizing potential biomarkers that reflected the heart–brain connection. Drawing on Claude Bernard's (1865) work, Darwin was referring to what is now known as the *vagus nerve*. The vagus nerve, often referred to as the *X cranial nerve* or *10th cranial nerve,* links the central and peripheral nervous systems through neural regulation of the heart (Porges 1995). Resting vagus nerve activity, or vagal tone, has been used as a measure of cognitive, emotional, and self-regulation. Specifically, greater vagal tone produces rapid heart rate slowing and reflects parasympathetic activity, whereas decreased vagal tone produces an increase in heart rate and reflects parasympathetic withdrawal in concert with sympathetic excitation (Porges 1995, 2007). Because vagal tone can be used as a measure of both CNS and PNS activity, we believe it can be applied to the nature restoration literature to link ART and SRT.

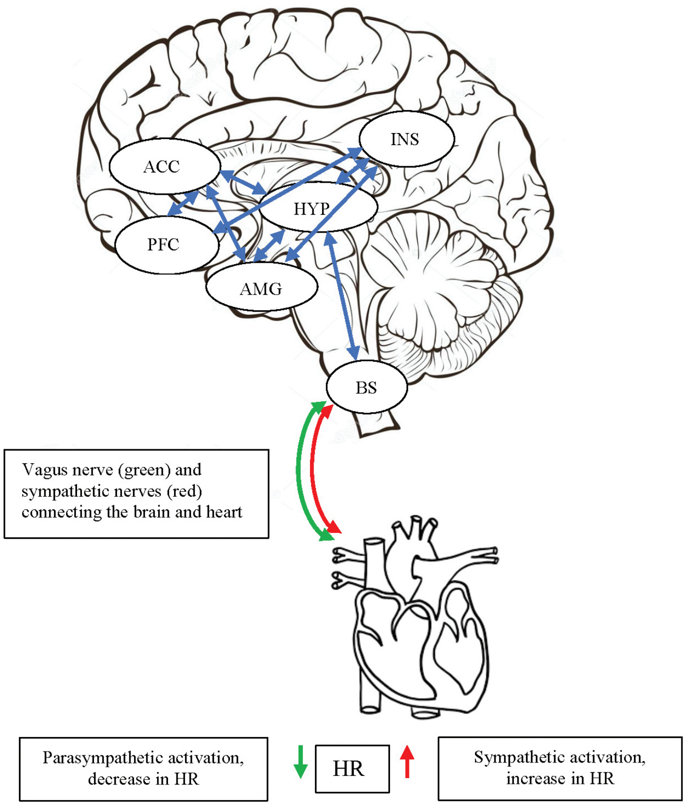
Vagal tone can be indirectly measured through indices of vagally mediated heart rate variability (vmHRV), which is thought to isolate the parasympathetic influence on the heart (Task Force of the European Society of Cardiology 1996). Indices of vmHRV, such as Respiratory Sinus Arrhythmia (RSA) or HF-HRV, are reliable measures that capture specific changes in frequency bands between successive heartbeats or beat-to-beat intervals while accounting for parasympathetic influence on respiratory cycles. Notably, these measures are best interpreted under tonic (resting) rather than phasic (reactivity) conditions, as the latter involves mechanisms that are not as well understood (Porges 1995, 2007). RSA is thought to be a direct measure of the vagal efferent outflow and thus provides a well validated index of baseline parasympathetic activity, or parasympathetic tone (Berntson et al. 2007; Del Giudice et al. 2012; Porges 1995, 1995b). HF-HRV is also thought to be a reliable measure of parasympathetic tone (Giese-Davis et al 2015; Lane et al. 2009). Higher levels of RSA/HF-HRV indicate greater vagal tone, while lower levels indicate decreased vagal tone. Low resting RSA/HF-HRV, or having too "fixed" a heart rate interval, is associated with poor regulation of the stress response and self-regulatory behaviors. In contrast, high resting RSA/HF-HRV reflects greater variability among heart rate intervals and is associated with efficient regulation of stress and behavior in response to environmental demands (Porges 1995, 2007; Thayer et al. 2009; Smith et al. 2020).

Evidence suggests that vagal tone can be improved through a variety of mechanisms. For example, mindfulness meditation, yoga, and HRV biofeedback interventions focus on slow breathing to stimulate the vagus nerve and achieve a state of calm. In doing so, this calmer state allows participants to focus their attention internally, prompting improvements in attention regulation and vagal tone. Several studies have found decreased self-reported stress following yoga and HRV biofeedback interventions (Ross and Thomas 2010; van der Zwan et al. 2015). Additionally, a number of studies on mindfulness meditation found increases in HF-HRV during meditation or after mindfulness meditation training (Delgado-Pastor et al. 2013; Nijjar et al. 2014; Wu and Lo 2008). Studies examining the neural correlates of meditation have found increased activation in the DLPFC and ACC following meditation, indicating heightened prefrontal cortex functioning (Cahn and Polich 2006). EEG studies have corroborated these results, finding increased amplitude in ERPs during oddball tasks in experienced meditators compared to non-meditators (Delgado-Pastor et al. 2013; Teper and Inzlicht 2013). Research has also demonstrated improved cognitive functioning in meditators, including enhanced performance on tasks relating to sustained attention (Semple 2010), self-regulation (Tang et al. 2007), working memory (Jha et al. 2010; Mrazek et al. 2013), and cognitive flexibility (Chiesa et al. 2011; Jha et al. 2007; Moore and Malinowski 2009). Finally, mindfulness meditation has been found to improve physiological health and immune functioning (Brown et al. 2012; Davidson et al. 2003; Grossman et al. 2004). Such improvements in cognitive and physiological measurements indicate enhanced regulation of stress via vagal connections to the PFC (Williams et al. 2011). Results from these interventions support the heart–brain connection and suggest that other forms of restoration, such as nature exposure, may have similar positive effects on cardiac vagal tone.

Neurovisceral integration model

Thayer and Lane (2000, 2002) proposed in their neurovisceral integration model (NVIM) that the neural networks involved in self-regulation and cognitive control (e.g., maintaining goal-directed behavior) are also involved in autonomic control (e.g., regulating physiological responses to stress). For example, a recent meta-analysis found that greater HF-HRV is associated with better top-down self-regulation, providing support for this theory and confirming that frequency measures of vagal tone (RSA, HF-HRV) are reliable indictors of self-regulation (Holzman and Bridgett 2017). The NVIM suggests that prefrontal-subcortical inhibitory circuits involved in self-regulation and cognitive control also provide inhibitory inputs to the heart via the vagus nerve (Thayer et al. 2012; Thayer and Lane 2000, 2002).These circuits involve brain regions such as the cingulate cortex, the amygdala, insula, and hypothalamus (see Figure 1). The cingulate cortex, especially the ACC, is thought to be an integrative hub for physiological, affective, and cognitive information (Shackman et al. 2011), and functions as a source of negative feedback to the cardiovascular system (Thayer and Lane 2007; Thayer and Sternberg 2006; Thayer et al. 2009). Neuroimaging studies examining the neural correlates of HRV provide support for this model. For example, researchers have found activation in subsections of the ACC that were positively correlated with HRV during tasks that reflect high cognitive workload (Critchley et al. 2003; Gianaros et al. 2004; Nikolin et al. 2017). Behaviorally, individuals with high HF-HRV display enhanced cognitive performance such as faster reaction times, more correct responses, and fewer errors on executive functioning tasks when compared to individuals with low HF-HRV

Figure 1. Adapted model of the neurovisceral integration model (Thayer and Sternberg 2006; Nikolin et al. 2017) involving regions in the central and peripheral nervous systems. PFC, Prefrontal Cortex; ACC, Anterior Cingulate Cortex; HYP, Hypothalamus; INS, Insula; AMY, Amygdala; BS, Brainstem; HR, Heart Rate.



(Johnsen et al. 2003; Hansen et al. 2003; Thayer and Lane 2000).

The NVIM proposes that vagal tone can be considered an index of the bidirectional relationship that occurs between central-peripheral pathways (Thayer and Lane 2000, 2002). Specifically, this model indicates that vagal tone reflects central modulation of autonomic activity, or neural regulation over the stress response. This model also suggests that both top-down (e.g., cognitive processes that require directed attention, such as reappraisal and cognitive control) and bottom-up (e.g., perceptual) influences are involved in autonomic regulation. Thus, attention, emotion, and stress regulation reflected in central modulation can be measured through vagal tone. Because it models the relationship between cognitive and autonomic control, we believe the NVIM serves as a useful framework for the bidirectional relationship linking ART and SRT.

Modeling a unified framework

The NVIM framework has important applications for the nature restoration literature. Because vagal tone activity is thought to reflect both autonomic and attention regulation abilities (Berntson et al. 1994), we suggest that cardiac vagal tone could serve as an index of both attention restoration and stress recovery processes. As vagal tone can be considered a direct measure of PSNS activation (reflective of SRT) and contains pathways to the cognitive control network (reflective of ART), this biomarker provides empirical evidence that attention restoration and stress recovery are bidirectional, co-occurring processes. Vagal tone thus reflects both top-down and bottom-up influences, while ART and SRT consider these influences separately. In nature, one could expect increased PSNS activity and improved mood, as proposed by SRT, which in turn would have restorative impact on attention, as proposed by ART. These restorative influences could include better attention and emotion regulation, resulting in better regulation of the stress response. Vagal tone may not be the only neurophysiological process that connects cognitive and affective changes that occur with immersion in nature (e.g., Hopman et al. 2020), but it is a key mechanism that is relatively straightforward to examine *in situ*.

This idea is currently being evaluated by obtaining simultaneous electrophysiological measures of both heart and brain activity during exposure to nature. Measuring changes in vmHRV with electrocardiography (ECG) can be coupled with measures of event-related brain potentials (ERPs) generated from the EEG to provide insight into how increased PSNS activity is correlated with changes in neural biomarkers of attentional processing. If nature increases resting vmHRV, as previous work suggests, the NVIM suggests that there should be increased activity in brain regions associated with prefrontal cortex modulation of vagal pathways. In fact, pilot data from our lab suggest such an association, as analysis has found that increases in RSA mediated increases in P3a amplitude (a subcomponent of the P300 event-related potential) after immersion in nature. This finding suggests that changes in vagal tone may influence changes in neural biomarkers of cognitive control after nature exposure.

Methods and measurement of stress recovery and cognitive restoration

Although beyond the scope of the current paper, it is noteworthy that there is considerable heterogeneity in the research examining the impact of nature on cognitive restoration and stress recovery. On the one hand, this variability may have the benefit of increasing the generalizability of the research. On the other hand, the different approaches are a likely source for the discrepant findings in the literature. Some of the variability likely stems from what is considered to be nature (e.g., forests, deserts, rivers, beaches, etc.) or urban (e.g., crowds, digital technology, cities, traffic, etc.). Other sources of variability arise from the type and duration of nature exposure (e.g., photos, videos, short walks in a garden, longer hikes in a nature park or arboretum, or multi-day immersion in natural settings). Research also varies on the methodologies used to measure the effects of nature exposure (e.g., subjective reports, behavioral measures, and physiological measures). Subjective reports ask people to rate their cognitive or affective state after nature exposure. Behavioral measures range from assessing proofreading performance, Necker cube reversals, measures of working memory digit span, measures of creativity, performance on the Attention Network Task (Fan et al. 2002) or components thereof, etc. Physiological measures include assessing blood glucose, salivary cortisol, blood pressure, heart rate and its variability, time and frequency-based measures of EEG, ERPs, and fMRI. With physiological measures, there is also variability in how the measures are conceptualized, quantified, and analyzed. Additionally, studies often differ in the comparison group utilized. Some use a between-subjects comparison between a nature exposure group and an urban exposure group. Others use a within-subjects design comparing the same person in both nature and urban settings. Few of the studies have yet to employ the "gold-standard" randomized control trials that are designed to control for participants' expectations from the assessment. This variability in research methods and design sets the stage for future research to prioritize replication of past studies, as well as pursue a research agenda that standardizes the approach taken for a more comprehensive understanding of the restorative effects of nature.

Translating environmental neuroscience into public policy

The empirical research seeking to identify biomarkers of stress recovery and cognitive restoration is important in understanding the underlying biological mechanisms of restoration and recovery (i.e., what is happening in the brain and body). This research also serves to augment the subjective, behavioral, and anecdotal reports that often suffer from demand characteristics. When reliable methods and measurements are identified, they will provide the framework for answering questions such as what kinds of nature are restorative, what length of exposure is necessary, how long the benefits persist, and whether or not there are individual differences in the response to nature. Once we have empirically identified the specific aspects of nature that reduce stress and improve cognition, these characteristics can be integrated into urban environments to optimize human functioning. Perhaps offices, hospitals, and prisons could prioritize exposure to nature, as viewing images of nature may contribute to improved well-being, cognitive functioning, affect, and physiological functioning. Reducing stress in these settings may promote positive outcomes, such as increased productivity in the workplace. In particular, utilizing electrophysiological methods to further understand potential changes in both the brain and the body in response to exposure to nature can help move the needle for public policy and environmental protection. To extend the generalizability of this program of research, future studies should explicitly document participant demographic variables such as race, gender, socioeconomic status, and prior exposure to nature, as these factors are not consistently reported in the literature.

Good public policy should be guided by reliable scientific evidence. Research has established that connectedness to nature has been found to be the strongest predictor of pro-environmental behavior such as recycling and use of public transportation (Mayer and Frantz 2004; Otto and Pensini 2017). The greater access an individual has to natural spaces such as neighborhood parks or national forests, the more likely they are to feel connected to the natural world, and thus more likely to care for it (Otto and Pensini 2017). Scientific evidence for the restorative aspects of nature may offer reason to increase access to, and presence of, both public parks and protected wilderness areas. It is thought that research employing physiological measures may carry more weight than behavioral measures in political decisionmaking and will therefore be more effective in the implementation of environmental policy (Ulrich 1981). Ultimately, the scientific evidence stemming from programmatic research, such as that proposed in this paper, can be used to craft policies that harness the restoration potential of nature.

Conclusion

There is an abundance of evidence for both cognitive and affective improvements in nature, though the mechanism underlying these effects remains debated. Frameworks such as ART and SRT have been helpful in understanding how restoration is achieved, yet few researchers have examined both attention restoration and stress recovery together. We suggest that these two processes are manifestations of activity in the vagus nerve, which links the peripheral nervous system (PNS) to the central nervous system (CNS). Future research examining both PNS and CNS activity simultaneously will help to further characterize the mechanisms behind the nature effect, which in turn should be used to inform public policy related to urban design and environmental protection.

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