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The impacts of nature experience on human cognitive function and mental health

Gregory N. Bratman,[1] J. Paul Hamilton,[2] and Gretchen C. Daily[3]

[1]Emmett Interdisciplinary Program in Environment and Resources, Stanford University, Stanford, California. [2]Department of Psychology, Stanford University, Stanford, California. [3]Department of Biology, Stanford University, Stanford, California

Address for correspondence: Gregory N. Bratman, Emmett Interdisciplinary Program in Environment and Resources, 473 Via Ortega, Suite 226, Stanford University, Stanford, CA 94305. gbratman@stanford.edu

Scholars spanning a variety of disciplines have studied the ways in which contact with natural environments may impact human well-being. We review the effects of such nature experience on human cognitive function and mental health, synthesizing work from environmental psychology, urban planning, the medical literature, and landscape aesthetics. We provide an overview of the prevailing explanatory theories of these effects, the ways in which exposure to nature has been considered, and the role that individuals' preferences for nature may play in the impact of the environment on psychological functioning. Drawing from the highly productive but disparate programs of research in this area, we conclude by proposing a system of categorization for different types of nature experience. We also outline key questions for future work, including further inquiry into which elements of the natural environment may have impacts on cognitive function and mental health; what the most effective type, duration, and frequency of contact may be; and what the possible neural mechanisms are that could be responsible for the documented effects.

Keywords: ecosystem services; nature experiences; psychology; cognitive function; mental health

Introduction

For hundreds of years and across many cultures of the world, influential traditions in science, philosophy, poetry, and religion have emphasized the role that nature plays in providing feelings of well-being. In the modern era of scientific enterprise, a large body of work has demonstrated the importance of nature to human physical health, characterizing the numerous ways in which people depend on the natural environment for security in the supply of food, water, energy, climate stability, and other material ingredients of well-being. And now, in the face of intensifying human impacts on the natural environment—perhaps most visible in the form of land conversion, urban sprawl, and pollution of air and water—researchers have begun to document the importance of nature for mental functioning as well. For example, recent work has shown, though not yet explained causally, the disadvantage that individuals from urban environments have in processing stress when compared to their rural counterparts.[1]

Beliefs about the role of nature experience in mental health have played a role in the civic and political discussions surrounding conservation for a long time. In the United States, for example, writers such as John Muir and the originators of the Wilderness Act discussed nature's contributions to mental health specifically, albeit qualitatively.[2] This discourse extends well beyond "wilderness." In their work on the history of healing gardens in hospital settings, Marcus and Barnes trace the incorporation of restorative gardens and natural areas in infirmaries back to the Middle Ages, referring to the nearly thousand-year old writings of St. Bernard that support the healing effects of these natural spaces.[3] The authors follow these "courtyard traditions" in hospitals through the English, German, and French designs of the 1600s–1800s. The benefits of natural areas were

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thought to span physiological and mental aspects of well-being. Remnants of these traditions can still be found in the inclusion of *Kur* ("course of treatment" involving nature walks, herbal remedies, and mud baths) in mainstream German healthcare.[4,5]

The incorporation of nature into the estates of the rich is another example of the extent to which people have been willing to invest resources in aesthetically pleasing landscapes throughout history. The reasons for this may vary from a display of power and control over nature (as in the gardens of Versailles) to a sense of peace and enlightenment that these landscapes create in the mind of the landowner.[6] Modern environmental economics addresses the ways in which people are willing to pay for access to natural landscapes, using travel cost methods, contingent valuation, and hedonic studies of property values that embody a preference for nature in higher prices for places nearer to it.[7–13] But a central question remains: *why* are some people willing to pay more for contact with (or views of) nature?

Today, most people are experiencing significantly lower levels of daily contact with nature as compared to their parents' generation. One study estimates that the typical American now spends nearly 90% of his or her life within buildings.[14] This trend permeates most areas of the world. Many cultures with strong traditional ties to their surrounding natural environs have found themselves under the assault of modernization, development, and environmental degradation, which have been tied conclusively to an increase in feelings of isolation and depression within these communities.[15–18] As we move into cities and indoors at an unprecedented rate, we are faced with a rapid disconnection from the natural world, and this opens a suite of critical questions about repercussions for psychological well-being.

Approach to the review

Here, we review the effects of nature experience on human cognitive function and mental health, synthesizing work from environmental psychology, urban planning, medicine, and landscape aesthetics. We provide an overview of the prevailing explanatory theories of these effects, the ways in which exposure to nature itself has been considered, and the role that individuals' preferences for nature may play in its impact on psychological functioning. Specifically, we consider three possible explanations for the effects of nature experience on cognitive function and mental health. The first two, attention restoration theory and stress reduction theory, stem from effects that may remain unrecognized to the individual, while the third, an idea that has its roots in the traditions of social psychology, relates to the mediating effects of explicitly held preferences about nature.

We include studies that employ a particular set of tools and approaches (traditional psychology tests, surveys, and questionnaires) to quantify impacts of nature experience on specific aspects of cognitive function and/or mental health (attention, concentration, memory, impulse inhibition, stress, and mood). Using a "snowball" method, we began with the work of Stephen and Rachel Kaplan that played a crucial role in establishing modern environmental psychology[19] as well as the work of Roger Ulrich on the measurement of stress in individuals as they respond to different environments.[20] From these groundbreaking and foundational studies, we worked forward by compiling the literature that builds on them. Our search methods included mining the references of these subsequent studies and using computer search engines. We restrict the focus of our review to the benefits that fit under the theories developed from these two strands of thought, along with the additional exploration of the ways in which preferences for nature may or may not influence these particular benefits. Thus, our search brought us through much of the environmental psychology literature, touching occasionally on studies that fall within the bounds of urban planning, medical research, and landscape aesthetics. There is currently exciting, interdisciplinary work underway on broader aspects of "cultural ecosystem services" and relevant decision-making challenges.[21,22]

Nature

Our analysis must begin with a clear notion of nature. In their biophilia hypothesis, Wilson and Kellert claim that we, as human beings, have an innate love for the natural world, universally felt by all, and resulting at least in part from our genetic make-up and evolutionary history.[23] But what do we mean when we speak of the natural world, or nature? These are clearly subjective terms. Studies have shown that most individuals consider the term "wilderness" to consistently and generally apply to areas without discernible human influence.[19,24,25]

But "wilderness" is only one category from a broad spectrum of gradients, and the degree or amount of "nature" that a landscape contains can be culturally or personally defined. Additionally, cultures and individuals differ with respect to what are considered to be the attractive and natural components of landscapes.[26]

The definition of what makes an environment "natural" changes across time, space, and the individual engaged in the defining. Debates span the humanities and natural sciences over whether nature is a social construction or if it exists on its own in an independent and constant form.[27,28] We cannot look to science for an impartial or consistent answer to this question. "Objective" classifications from satellite data have been shown to differ from individuals' assessments of environmental qualities and descriptions of areas in the same place.[29] Philosophical debates over the human definition and representation of nature are numerous and complicated, and a summary of them is beyond the scope of this paper, but we briefly discuss some key issues below.

Most studies included in this review use comparative approaches in which the experience of individuals within one environment is contrasted with that of individuals within another, where one environment is clearly more "natural," within the context of the study (e.g., tree-lined city streets vs. trails through a nature preserve). The ranking of sites along an urban–natural gradient is therefore clear (without specific definition) within the context of each study. The impact of environments natural to different degrees is captured within these studies, though descriptions of these degrees are not categorized in a consistent way. Interestingly, all of the natural environments provided quieter atmospheres and were almost always accompanied by a comparatively larger field of view than the urban environments (e.g., there is no documented instance in which subjects were placed within a cave or another such natural but confined space).

For the purposes of this review, we developed a definition of nature that is applicable to all of the environments considered within these studies: areas containing elements of living systems that include plants and nonhuman animals across a range of scales and degrees of human management, from a small urban park through to relatively "pristine wilderness." A definition of this breadth is necessary, given the large range of landscapes included in the aggregate of these studies and the lack of pertinent ecological details.

This work addresses crucial but relatively unexplored questions about the particular elements of nature that impact the human psyche. At a minimum, it would be most informative were the research to specify the types of environments used in experiments in some detail, using modern quantitative methods at multiple scales. Ideally, further research would seek to understand and define what the "natural" components of these landscapes are that act as input for psychological mechanisms. This would lead to a more coherent and thorough set of postulates about which particular aspects of nature may have impacts on cognitive function and mental health—and ultimately, what the causal pathways are for these effects.

The nexus of nature experience and cognitive function and mental health

We examine studies that have attempted to document the psychological impacts of nature experience in a scientifically rigorous way. Many of us have experienced an emotional fulfillment from viewing—or being physically present within—natural environments. And on an instinctual level, many of us can also relate to Kellert and Wilson's hypothesis that human beings have a universal, innate connection to nature.[23,30] Theory from social psychology emphasizes the importance to the individual of belonging to a group, and Wilson argues that we have a similar need to feel connected to natural environments.[31]

Studies in environmental psychology focus particularly on the questions that follow from this connection: what happens to our cognitive abilities, emotional states, and mental health (all defined below) if we are deprived of experience in nature? Does the human psyche suffer in a measurable way—and across cultures, ages, and genders? If so, and if an increasing proportion of the global human population is experiencing the impacts of a withdrawal from nature, it may be helpful to define and investigate a new type of ecosystem service. This service would encapsulate the ways in which nature benefits our minds; thus, we might call it a *psychological ecosystem service*.

If psychological benefits from nature experience exist, they must come from the *interaction* between the individual and the environment—that is, they come as a result of our biology and cognitive

processes within the context of a place, landscape, or seascape.[32] Thus, the service takes place within the mind and body of a person as he or she experiences an environment. These types of phenomena may seem hard to define, but a growing body of research has attempted to identify the consistent benefits that experiences of nature may provide.

We examine the aspects of these benefits that are relevant to *cognitive capacities* (including attention, memory, and impulse inhibition), *emotional states* (mood), and *stress.* This is not to imply that *negative* psychological effects from nature experience are not possible as well. Fear of being attacked by wildlife or struck by certain types of disease, which are particularly possible in natural environments, can cause mental distress. Hurricanes, earthquakes, and other natural disasters bring with them high levels of emotional anguish for those affected.[33,34] Interestingly, there have been few investigations of such potential negative effects; we focus on the growing literature on positive effects.

Nature and evolution of the human psyche

In attempts to tease out consistent contributing forces across many of these studies, some authors theorize that evolutionary influences are at work in our preference for particular natural environments. A popular hypothesis explains the value of grasslands and savannas to human well-being in terms of the sightlines and room for flight that such landscapes would have provided our early ancestors, when most forms of protection or flight available today did not yet exist.[20,23,35–39]

The data supporting this hypothesis are equivocal.[40] Nonetheless, the positive feelings we may experience from viewing these spaces are in stark contrast to the immediate, impulsive, and possibly instinctive repulsive reaction we have toward snakes and spiders—animals that may not have served us well in our evolutionary past. Interestingly, the strength of these aversions has been shown to be significantly greater than that elicited by the far more damaging, modern threat of guns.[23,41]

Prevailing theories about the attraction to (and possible restorative effects of) viewing or having physical contact with natural landscapes most often stem from the supposition that human beings are not fully adapted to urban environments and that something may be missing when we are deprived of contact with nature, however we choose to define it.[19] Details of the arguments vary, but most are based upon the postulate that the overwhelming evolutionary experience of human beings as a species involves natural environments, and we are therefore predisposed to resonate with these surroundings, consciously or not. We consequently come away from them with an increase in our positive affect and decrease in our negative feelings or stress—particularly when we have interacted with those environments that were favorable for our survival as a species.[42,43]

Box 1: Terminology

Definitions used in this article and typical metrics for assessment

Directed attention: The effortful, conscious process of bringing cognitive resources to bear in order to focus on selected stimuli, while avoiding distraction from unrelated perceptual inputs. Assessment of this ability involves tests used to measure concentration, impulse inhibition and memory.

Concentration: Directed attention applied over a relatively long time interval. While a variety of tests access this construct, measures of mental vigilance (e.g., Necker Cube Pattern Control, proofreading, etc.) do so most directly and without reliance on short-term mental storage systems.

Impulse inhibition: The capacity to stop execution of an overlearned or prepotent response. Response conflict tasks such as stop signal and Stroop color-word can be used to measure this construct.

Short-term and working memory: The ability to keep information in mind over short delays has been measured in the literature with simple span tasks such as the forward digit span test. The capacity to manipulate and transform information in memory is typically measured through more complex span tasks, such as the backward digit span and operation span tests.

Mood: A sustained positive or negative affective state that can influence emotions occurring over a shorter time-span—e.g., a bad mood can increase the frequency with which one feels the emotion of anger. Mood can be measured through self-assessment surveys, such as the PANAS (Positive and Negative Affect Schedule).

Nature/natural: Areas containing elements of living systems that include plants and non-human animals across a range of scales and degrees of

human management—from a small urban park to "pristine wilderness."

Nature experience: Time spent being physically present within, or viewing from afar, landscapes (or images of these landscapes) that contain elements from the above category. The distinction between physical and visual contact with nature may be important.

Stress: The psychophysiological phenomenon caused when environmental demands reach or exceed an organism's capacity to address those demands.

Introduction to attention restoration and stress reduction theories (theories I and II)

There are two major explanatory theories within the environmental psychology literature that account for the restorative power of nature, and they both draw heavily on the theory of evolution. One of these frameworks, stress reduction theory (SRT), posits a healing power of nature that lies in an unconscious, autonomic response to natural elements that can occur without recognition and most noticeably in individuals who have been stressed before the experience.[44] Certain natural places (especially those along watersides and with visible horizons) may be seen as safe havens—areas in which our species tended to have greater rates of survival. The positive affective response that we feel in these spaces is due to this common evolutionary history. In other words, merely seeing or being present within nature can reduce stress through the automatic generation of physiological and psychological responses, the qualities of which will be explained more below.

The other explanatory theory, attention restoration theory (ART), centers on the power of nature to replenish certain types of attention through unconscious, cognitive processes in response to natural landscapes. Its supporters claim that directed attention is the mechanism most closely related to focus and concentration, and our urban life taxes this capability more consistently than the situations with which human beings have had to deal in our collective past.[19] The experience of interacting with natural environments allows this capability to replenish itself through a process of restoration, also to be described more below.

These theories have much in common, with the major points of departure involving a focus on cognitive versus autonomic processes. Both support the idea that changes in attention and stress load can come from interaction with natural environments, but they differ in their claims about the primary mechanisms at work. There may also be a "blurring" of effects between the two theories. Does a reduction of stress allow an individual to concentrate better, or does a replenishment of directed attention make a person feel less stressed, as an additional benefit?[45,46]

Assertions are controversial regarding the causal mechanisms of nature's impact on an individual's mental and physical state. Nevertheless, a great deal of research in environmental psychology can be seen as falling under one, or both, of these theoretical camps.[19,35,45]

The explanations of changes in measurements of mood fall somewhere between the two theories of ART and SRT and may also follow from a third theory we will discuss below: effects that are tied to conscious preferences. ART and SRT both assert that contact with nature should induce positive affect, either through the replenishment of directed attention (and the relief and relaxation that this brings) or through the benefits of reduced stress. Thus, measurements of mood appear in studies that work within either of the theories' constructs.

SRT

Ulrich suggests that landscapes with views of water and/or vegetation and that contain modest depth, complexity, and curvilinearity would have been most beneficial for survival (allowing for the spotting of food sources, predators, etc.).[42,46] These landscapes, according to SRT, help to moderate and diminish states of arousal and negative thoughts within minutes, through psychophysiological pathways.[24,35]

Ulrich appeals to work in affective psychology from the 1970s and 1980s in stating that emotions occur innately and in some state of constancy across cultures (i.e., nearly all people are born with the ability to feel "sad" or "happy").[37] Many cross-cultural regularities exist in the way these emotions are expressed facially.[47–49] Additionally, these feelings may occur before an individual is consciously aware of them.[50] Building from this work, Ulrich claims that conscious processes are not necessary or required to produce emotion. Thus, affective reactions to environments may happen at a preconscious level

and may subsequently impact cognitive processes without an individual's conscious knowledge.[42] Although urban dwellers may *think* they have habituated themselves to factors that cause stress, they may still be having stress-related reactions in their bodies and brains about which they are unaware.

Stress studies. Ulrich put his hypothesis to the test in a series of exploratory studies.[46,51] He instructed a group of mildly stressed participants to view sets of color slides: one group saw nature scenes with vegetation and trees predominating the visual field, while another group viewed city landscapes with little to no vegetation. Self-ratings of positive affect, including elation and affection, were greater in those subjects that viewed the natural, vegetative scenery. Negative feelings such as fear were lower in the nature group as well. Additionally, urban viewers experienced increases in aggravation, anxiety, and feelings of sadness.

More recent work confirms these results, showing decreases in self-reported stress and increases in positive mood after prolonged experience in wilderness areas.[2,52] Ulrich found similar results when students (stressed because of a final exam) reported higher levels of positive affect and lower levels of fear after viewing slides of natural scenes than those who viewed urban ones.[46] Further, Honeyman found the same trend when subjects were presented with urban images containing vegetation versus urban images without vegetation.[53]

To further test this theory, Ulrich *et al.* ran an experiment in which 120 subjects watched a stressful movie for 10 min and then viewed scenes (and sounds) of six different types of settings, ranging from most urban to most natural for another 10 minutes.[37] During this, subjects were monitored for levels of physiological stress through the measures of heart rate, skin conductance, muscles tension, and systolic blood pressure. Subjects were also asked to self-rate their affective states. All measures indicated significantly higher speed of recovery from stress when subjects were viewing nature scenes than when they were viewing urban scenes. In a related area, recent work using functional magnetic resonance imaging (fMRI) has shown that urbanization may tax the neural mechanisms involved in dealing with stress.[1]

Other studies add supporting evidence for SRT. The impact of forests versus urban landscapes on stress relief was explored by transporting 12 subjects between forest and city settings in Japan—and measuring salivary cortisol concentration, diastolic blood pressure, and pulse rate while the subjects were physically present within each. All of these measures indicated significantly decreased stress for the participants after being present in the forests for only 15 min—a result that was not found when they were placed in urban landscapes.[54,55] Using survey techniques, Ottosson and Grahn found that those individuals who were currently dealing with a greater crisis—and the increased level of stress that accompanies this—experienced the stress relief from nature experience to a greater degree than others.[39]

Future work in this area should explore the possibility that a change in context itself plays a role in these observed reductions in stress. Removing oneself from habitual patterns of normal experience may have a psychophysiological effect that is unrelated to the natural elements of the newer, less familiar context. The aesthetics (i.e., degree of "pleasantness") of these settings may have an effect as well. One possibility for a future study might be to examine the relative impacts of "ugly" nature scenes versus "beautiful" urban scenes. We discuss aesthetics more in a section below.

ART

Kaplan and Kaplan formulated a theory that examines the ways in which exposure to nature can have a restorative effect on the brain's ability to focus. These researchers contend that a replenishment of our direct attentional capacities is the primary mechanism underlying effects of exposure to nature.[19] ART uses theoretical constructs dating back to William James, resting upon the proposal that attention can be separated into two distinct components voluntary (directed) and involuntary attention.[56]

The theory posits that directed attention requires the use of cognitive control—individuals must consciously use their faculties to focus on a stimulus that may or may not otherwise have attracted their attention. In order to do this, an individual must inhibit or suppress the urge to pay attention to distractions. After prolonged use, this capability can become fatigued, and this fatigue may reveal itself through difficulties in concentrating and higher rates of irritability.[57] Traditional psychological

constructs of working memory, impulse inhibition, and the less specifically defined concept of "concentration" are all capabilities that supposedly require directed attention—and we can therefore measure levels of this type of attention through established, valid psychological testing techniques.

In contrast, involuntary attention is utilized when individuals are presented with stimuli that are "inherently intriguing." ART claims that interaction with natural environments employs faculties of concentration not normally used—involuntary ones—thus allowing the neural mechanisms underlying directed attention a chance to rest and replenish. The experience that comes from viewing or being present within natural landscapes allows attentional reserves to replenish, which in turn can benefit performance on other tasks, delay of gratification, and perhaps even levels of depression and stress. Kaplan appeals to the words of a famous champion of urban parks, Frederick Law Olmsted: "[natural scenery] employs the mind without fatigue and yet exercises it; tranquilizes it and yet enlivens it; and thus, through the influence of the mind over the body, gives the effect of refreshing rest and reinvigoration to the whole system."[45,58]

Situations in which directed attention is rendered unnecessary for a period of time may allow for its restoration.[45] The Kaplans postulate that there are four essential components that a landscape must contain for it to most efficiently provide restorative effects on direct attentional capacity, and these are most often found in natural environments: *extent* (the scope of experience, including the possibility of feeling immersed within it); *being away* (an escape from the habitual activities and concerns of daily life, ranging from "micro"-experiences, such as gazing out a window, to day-long backpacking trips); *fascination* (aspects of an environment that innately capture attention, effortlessly and without directed effort); and *compatibility* (a "match" between an individual's intentions, inclinations, or purposes and the environment).[45,60–62]

Clearly, other settings may satisfy all or some of these conditions, but natural environments most consistently contain all of them simultaneously. Urban stimuli are postulated not to have these four qualities, typically, and therefore do not restore our direct attentional capacities. When removed from contact with nature, human beings are missing out on a critical type of rest. And through cognitive testing, we can measure whether replenishment has occurred after nature experience. There are a variety of behavioral studies that have been conducted in an attempt to test ART; we review these below.

Attention studies. Berman *et al.* tested subjects with a backward digit span task—a test that measures working memory and therefore serves as a proxy in environmental psychology for directed attention capacity.[63] After this test, the experimenters then induced mental fatigue in the subjects with a 35-min test that taxed memory and randomly sorted the participants into two groups: one group that walked through an urban setting, and another that walked through an arboretum—both walks were 2.8 miles and 50–55 minutes. Following this, participants performed the digit span backward task again. The "arboretum" group performed significantly better on the memory/directed attention task than did the "urban" group. The authors also showed increases in positive affect (as measured through the PANAS) in the arboretum-walk group. Significant improvements in working memory were also noted in a second study in which groups viewed pictures of natural versus urban scenery.

Tennessen and Cimprich used the digit span backward tests and the Necker Cube Pattern Test—a task in which the subjects must use their concentration to prohibit a stimulus (an ambiguously drawn cube) from "flipping orientations" as they view it—to test increased capacity for attention in students. The participants lived in dormitories with similar-sized windows that offered views ranging from "all natural" (trees and a lake) to "all built" (city streets, other buildings, or a brick wall).[64] Those students who had the most natural views showed a greater ability to direct attention. The authors consider these results to support the hypothesis that window views provide the opportunity for "micro-restorative activity." Digit span forward and backward tests were also given, but no significant differences were observed.

In a natural experiment, Taylor *et al.* compared children from the same population in a housing complex in Chicago, whose living conditions and demographic characteristics differed only by their views from home: a small pocket of urban park or a barren concrete area.[65] The authors examined the relations between near-home nature and

concentration, impulse inhibition, and delay of gratification in inner-city children who had been randomly assigned to live in one of 12 architecturally identical high-rise buildings with varying levels of nearby nature. On average, the more natural a view from home, the better the performance on digit span backward, alphabet backward, matching familiar figures, and the Stroop color-word test (assesses the ability to override the tendency to read a word when it is printed in an incongruent color—e.g., the word "white" written in blue—while the instructions require the naming of the color, instead of reading), as well as a delay of gratification test (in which subjects had to avoid the temptation to eat a bag of candy when the tester leaves the room). Interpreting their data slightly differently from previous studies, the authors consider the aggregate performance on these tests to correspond to a form of "self-discipline." This has been shown to act as a mediating factor for lower levels of aggression and violence, as well as higher levels of scholastic and career success.[66]

In testing the potential usefulness of natural images, Berto induced mental fatigue in subjects through the sustained attention to response test (SART), a five-minute response–control test that requires subjects to press a button when a rarely occurring target digit appears on a computer screen, but not when other digits appear.[67] The experimenter then exposed participants to pictures of natural scenery ("restorative environments") or urban scenery ("nonrestorative environments"). Those exposed to natural pictures performed significantly better on the second administration of the SART than did their counterparts, after exposure to the images. Additionally, these results held when the subjects were exposed to natural versus geometric figures, supporting the assertion of ART that natural scenes in particular have this type of restorative potential.

Studies that address attention and stress simultaneously

The Kaplan and Ulrich theories are related but differ in important ways. As Ulrich stresses the importance of the evolutionary aspects of response to environment, he tends to emphasize affective and stress-related components of the individual's relationship with landscapes. The Kaplans' theory is centered more on effects on cognition. Thus, Ulrich emphasizes the importance of a reduction in arousal, with physiological evidence showing decreased stress levels in subjects when viewing natural versus urban images.[37,46] This contrasts with ART, which is more concerned with a replenishment of attentional capacities.[52]

There are some studies that have attempted to address both stress- and attention-related factors at once. Hartig *et al.* used ambulatory blood pressure measurements to assess psychophysiological stress differences in groups of individuals with varying levels of attentional fatigue who viewed, or were present within, urban versus natural environments.[35] Both nature experience groups (natural views and

Table 1. Types of environment

Urban green	Speldewinde *et al.*,[17] Mayer *et al.*[31] de Vries *et al.*,[40] Abkar *et al.*,[43] Hartig *et al.*,[52] Wells,[59] Berman *et al.*,[63] Tennessen and Cimprich,[64] Taylor *et al.*,[65] Kuo and Sullivan,[66] Nisbet and Zelenski,[76] Ulrich,[91] Kaplan,[95] Wells and Evans,[96] Pretty *et al.*,[100] Fuller,[105] Verderber,[107] Leather *et al.*,[108] Evans,[109] Grahn and Stigsdotter,[110] Groenewegen *et al.*,[111] Richardson *et al.*,[112] Coley *et al.*,[115] Kuo *et al.*,[116] Takano *et al.*,[117] Maas *et al.*,[118] Mitchell and Popham,[119] Van den Berg *et al.*[120]
Water bodies	Mayer *et al.*,[31] Ulrich,[37] de Vries *et al.*,[40] Ulrich,[51] Laumann *et al.*,[68] Chang *et al.*[113]
Forest/woodland	Hartig *et al.*,[35] Park *et al.*,[54] Lee *et al.*,[55] Chang *et al.*[113]
Countryside/farmland	Mayer *et al.*,[31] Hartig *et al.*,[35] Ulrich,[37] Ulrich[51]
Wilderness	Cole and Hall,[2] Hartig *et al.*,[52] Paxton and McAvoy[114]

Categories of natural environments in which corresponding studies were conducted. Color-coded categories represent each study by its type in Figure 1. This only includes examples in which exposure is claimed to have made a direct psychological or behavioral impact—it does not include studies in which preferences were examined based upon presentation of images, etc. (e.g., Anderson[85]).

Table 2. Duration of time in nature

Minutes to hours	Mayer *et al.*,[31] Hartig *et al.*,[35] Ulrich,[37] Abkar *et al.*,[43] Ulrich,[46] Ulrich,[51] Hartig *et al.*,[52] Park *et al.*, Lee *et al.*,[55] Berman *et al.*,[63] Berto,[67] Laumann *et al.*,[68] Nisbet and Zelenski,[76] Pretty *et al.*,[100] Fuller,[104] Chang *et al.*[113]
Days	Cole and Hall,[2] Hartig *et al.*,[52] Ulrich,[91] Verderber,[107] Paxton and McAvoy[114]
Years/longitudinal studies	Speldewinde *et al.*,[17] de Vries *et al.*,[40] Wells,[59] Tennessen and Cimprich,[64] Taylor *et al.*,[65] Kuo and Sullivan,[66] Kaplan,[95] Wells and Evans,[96] Leather *et al.*,[108] Evans,[109] Grahn and Stiggsdotter,[110] Groenewegen *et al.*,[111] Richardson *et al.*,[112] Coley *et al.*,[115] Kuo *et al.*,[116] Takano *et al.*,[117] Mitchell and Popham,[119] Maas *et al.*,[118] Mitchell and Popham,[119] Van den Berg *et al.*[120]

Studies categorized by the duration of time in which subjects were exposed to a particular natural environment. This only includes examples in which exposure is claimed to have made a direct psychological or behavioral impact—it does not include studies in which preferences were examined based upon presentation of images, etc. (e.g., Anderson[85]).

presence within natural landscapes) showed decreased stress, improved mood, and better performances on attention tests (the Necker Cube Pattern Test and proofreading task). Because the authors were able to measure both blood pressure and attentional capacities at various times throughout the walk (instead of just before and after), they were able to conclude that stress and attention impacts happened at different times and were not significantly related, providing evidence for the possibility of different causal pathways for the positive impact of both types of measures.

Both attention- and stress-related theories were studied simultaneously in another example in which subjects viewed videos of urban versus natural (waterside or forest) scenes.[68] In this example, participants had increased attentional load induced by a proofreading task. This was followed by a test of their attentional capacity with Posner's attention-orienting task, a test that allows for the experimenter to distinguish between involuntary and voluntary attention performance through examining the individual's processing of different visual stimuli (peripherally or centrally located) and the ability to shift between the two types of attention demands.[69–71] Laumann *et al.* simultaneously gathered stress reduction data by continuously recording heart rates throughout the experiment using electrocardiogram (EKG) equipment.[68] The "nature group" had significantly lower heart rates than the "urban group" while watching their respective videos, but did not show an increased ability to shift between voluntary and involuntary attention. Thus, these results support SRT, but do not provide compelling evidence for ART.

Future work

As we summarize in Table 4, these studies have used a set of valid, traditional tasks and technologies to measure attention and stress in individuals. There is room for even more finely grained analysis, however. Through the use of other tests, such as filtering tasks, complex operation span tasks, or distraction tasks, we may be able to further isolate effects of prepotent response inhibition and resistance to distractions.[72] As mentioned previously, future studies should work toward pinpointing causal effects and mechanisms, as well as determining whether the removal of subjects from the situation to which they are accustomed and placing them in a novel environment might be responsible for some of the effects that have been attributed specifically to nature in these experiments.

Box 2: Theories of restorative benefits of nature

Theory I

Stress reduction theory (Ulrich)—reduction in stress during experience of natural stimuli. Measured through physiological response.

Theory II

Attention restoration theory (Kaplan and Kaplan)—recovery from directed attention fatigue through experience of natural stimuli. Focused on cognitive processes and responses.

Theory III

Mediating effect of opinions about nature—our conscious opinions about nature relate to the impacts of nature experience on mood and other aspects of cognitive function.

Table 3. Types of exposure

Images	Mayer *et al.*,[31] Ulrich *et al.*,[37] Ulrich,[46] Ulrich,[51] Honeyman,[53] Berman *et al.*,[63] Berto,[67] Laumann *et al.*,[68] Pretty *et al.*,[100] Chang *et al.*[113]
Window views	Abkar *et al.*,[43] Tennessen and Cimprich,[64] Ulrich,[91] Moore,[93] Kaplan,[95] Verderber,[107] Leather *et al.*,[108] Takano *et al.*[117]
Physically present	Cole and Hall,[2] Speldewinde *et al.*,[17] Mayer *et al.*,[31] Hartig *et al.*,[35] de Vries *et al.*,[40] Abkar *et al.*,[43] Hartig *et al.*,[52] Park *et al.*,[54] Lee *et al.*,[55] Wells,[59] Berman *et al.*,[63] Taylor *et al.*,[65] Kuo and Sullivan,[66] Nisbet and Zelenski,[76] Wells and Evans,[96] Fuller,[104] Evans,[109] Grahn and Stigsdotter,[110] Groenewegen *et al.*,[111] Richardson *et al.*,[112] Paxton and McAvoy,[114] Coley *et al.*,[115] Kuo *et al.*,[116] Takano *et al.*,[117] Maas *et al.*,[118] Mitchell and Popham,[119] Van den Berg *et al.*[120]

Studies categorized by three different degrees of exposure: passive viewing of representations ("images"); views of natural landscapes themselves ("window views"); and presence within landscape or environment ("physically present"). This only includes examples in which exposure is claimed to have made a direct psychological or behavioral impact—it does not include studies in which preferences were examined based upon presentation of images, etc. (e.g., Anderson[85]).

Preferences for nature (theory III)

We now return to the issue of opinions about the environment. Conscious preferences for landscape aesthetics may relate to the restorative benefits of nature in a complicated manner. There are a number of ways to think about this issue. Do attitudes about nature directly impact the cognitive and/or mood benefits that interactions with these landscapes might provide? Or do human beings have an innate and even universal preference for the very aspects of nature that are restorative, thus eliminating the degree to which preferences themselves might influence benefits as a mediating factor?

In support of the latter view, one study has shown that the more mentally fatigued the subject, the greater the likelihood that he or she would choose a restorative walk in a natural environment over an urban one.[73] Additionally, Korpela *et al.* examined stated preferences for four of the components that Kaplan and Kaplan claim to be essential restorative qualities of natural environments—"being away, fascination, extent, and compatibility."[74] They found that these qualities correlate very closely with the aspects of an environment that *independently* make it a "favorite place" for subjects. Thus, it may be that people seek out these types of characteristics in the places to which they feel most attached, a postulate that fits well with theories of self-regulation.[75] They may make these choices without being aware of the fact that these qualifications might be most consistently fulfilled by natural settings. Indeed, a recent study demonstrated that people tend to underestimate the degree to which even short exposure to natural environments can increase positive mood.[76]

We will now explore the details of the former view—that an individual's opinions about nature may impact the way in which natural environments ultimately impact his or her mood and cognitive function. Exploration of this concept typically involves a measurement of "connection to nature"[18] and draws on theory from social psychology that the sense of belonging to something greater than oneself, and a resultant decrease in negative rumination, has an effect on feelings of well-being.[77–82]

Explicitly stated connection to nature

Much of the literature in "landscape aesthetics" involves efforts to analyze the ways in which people come to explicitly judge the scenic beauty of an environment through stated preferences and willingness to pay, typically for levels and shapes of openness, obstruction, scale, and depth of views.[83,84] Interestingly, the manner with which a landscape is described may play a crucial role in the way it is rated. Anderson showed that subjects' preconceived notions of landscape descriptions or designations impacted their perceived degree of natural beauty.[85] When shown identical photographs with varying descriptions ("commercial timber stand, leased grazing range, recreation area, national park, or wilderness area"), participants rated (the exact same) scenes higher as the degree of natural qualities increased in the descriptions. Although these studies are interesting in and of themselves, they do not explicitly address cognitive benefits, nor do they

Table 4. Psychological functions and measurements. Techniques of assessment for various functions, and examples in the literature of studies that employed these techniques

Psychological function	Techniques for assessment	Techniques developed by	Examples in the literature
Concentration/ memory	Symbol digit modalities Digit span forward and backward Alphabet backward Necker cube pattern control tests Proofreading Search and memory test Posner's attention-orienting task	Symbol digit modalities (Smith[121]) Digit and alphabet span (Wechsler[122]) Necker cube (Orbach *et al.*[123]) Search and memory test (Smith and Miles[124]) Posner's attention-orienting task (Posner[125])	Kaplan and Kaplan,[19] Mayer *et al.*,[31] Hartig *et al.*,[35] Ottosson and Grahn,[39] Kaplan,[45] Hartig *et al.*,[52] Wells,[59] Berman *et al.*,[63] Tennessen and Cimprich,[64] Taylor *et al.*,[65] Kuo and Sullivan,[66] Berto,[67] Laumann *et al.*[68]
Impulse inhibition/delay of gratification	Matching familiar figures test Stroop color-word test Bag of candy test	Matching familiar figures test (Kagan[126]) Stroop test (Stroop[127]) Bag of candy test (Rodriguez *et al.*[128])	Hartig *et al.*,[35] Taylor *et al.*[65]
Aggression	Conflicts Tactic Scale (CTS) State anger section of the Zuckerman's Inventory of Personal Reactions (ZIPERS)	CTS (Straus[129]) (Zuckerman[130])	Hartig *et al.*,[35] Hartig *et al.*,[52] Kuo and Sullivan[66]
Stress relief	Physiological measurements of heart rate (EKG), heart rate, muscle tension, systolic and diastolic blood pressure (SBP, DBP). Brain electrical activity Skin conductance Survey of Perceived Restorativeness Scale (PRS) fMRI	PRS (Hartig *et al.*[131])	Lederbogen *et al.*,[1] Ulrich,[20] Hartig *et al.*,[35] Ulrich *et al.*,[37] Korpela *et al.*,[61] Laumann *et al.*,[68] Wells and Evans,[96] Grahn and Stigsdotter,[110] Van Den Berg *et al.*[120]
Mood	Profile of Mood States (POMS). Positive and Negative Affect Schedule (PANAS) Zuckerman Inventory of Personal Reactions (ZIPERS). Overall Happiness Scale (OHS)	POMS (McNair *et al.*[132]) PANAS (Watson *et al.*[133]) ZIPERS (Zuckerman[130]) OHS (Campbell *et al.*[134])	Mayer *et al.*,[31] Hartig *et al.*,[35] Ottosson and Grahn,[39] Berman *et al.*,[63] Nisbet and Zelenski,[76] Barton and Pretty[101]
Self-esteem	Rosenberg Self-Esteem Scale (RSE). The Global Self-Worth subscale of the Harter Competency Scale	RSE (Rosenberg[135]) Self-worth subscale of Harter Competency Scale (Harter[136])	Wells and Evans,[96] Barton and Pretty[101]

Continued

Table 4. *Continued*

Psychological function	Techniques for assessment	Techniques developed by	Examples in the literature
"Child development"	Inference drawn from increased social interactions; attention capacity (using mothers' ratings of children's cognitive abilities with attention deficit disorders); Global Self-Worth subscale of the Harter Competency Scale; ADHD symptoms		Wells,[59] Taylor *et al.*,[65] Wells and Evans,[96] Coley *et al.*[117]

attempt to isolate the reasons behind willingness to pay for the aesthetic beauty of landscapes.[86,87]

Mayer and Frantz developed a survey consisting of 14 questions that identify an individual's conscious, stated level of emotional connection to nature.[18] This "connectedness to nature scale" (CNS) is closely related to its predecessors: the New Environmental Paradigm (NEP) Scale and the inclusion of Nature in the Self (INS) scale.[88,89] CNS pays special attention to the ways in which people do or do not feel that they are a part of their surrounding, natural world (based upon Leopold's assertion that this is a necessary precursor for pro-environmental behavior).[90] In Mayer and Frantz's estimation, environmental behavior can often be predicted by the degree to which a person identifies himself or herself with the natural world—the higher the sense of "belonging," the greater the likelihood of sustainable actions in "lifestyle patterns, ecological behavior, and curriculum decisions among students."

The authors also claim that an individual's CNS score is correlated with life satisfaction, overall happiness, and perspective-taking ability.[18] In work on emotion, a decrease in self-awareness—or rumination on aspects of one's conception of self—has been shown to be associated with positive mood.[79–81] This agrees with recent work that shows increased depression can occur with increased rumination.[77,78] The tendency to engage in negative rumination might be linked to CNS scores—specifically, the notion that one is part of a force "greater than oneself" may lift an individual out of rumination on a negative sense of self. In essence, the sense of belonging to nature can provide a benefit in and of itself, in the same way that previous work in social psychology has shown that feelings of belonging to a group can provide a sense of purpose and positive impact for individuals.[31]

Thus, Mayer *et al.* argue that the positive effects of nature on mood are actually mediated by an increase in an individual's feeling of connection to nature through experience.[31] In this paradigm, connection to nature is a causal mechanism for the generation of psychological benefits because of the power of the feelings associated with belonging to a community or something "greater than oneself." A related question is whether or not there may be a relation between an individual's CNS score and the psychological benefits he or she receives from nature experience. If an individual feels more connected to nature, will there be a corresponding difference in the benefits that do or do not accrue to them with exposure to nature? Further research is needed to thoroughly investigate this question.

Urban nature

We have discussed studies that employ a variety of different types of exposure to natural environments for the subjects involved: from views of images and out of windows to being physically present within the landscape (Tables 1–3). Accessible natural areas are posited to be an important part of the mental health of urban citizens, whether viewed from inside a building or experienced while present in accessible city parks.

Windows

The power of scenic views from a window has been shown in several famous studies, including the

compelling study by Ulrich in which patients recovering from gallbladder surgery who had a view from their hospital window had shorter postoperative stays, and less potent pain medication requirements, than those who looked out onto a brick wall.[91] Although most clearly related to physical health, this study may fit within the framework of SRT, assuming that decreased stress improves physical recovery. (This provides some affirmation of the investment in gardens throughout several centuries as a critical element in European hospitals.)[3]

Studies have also shown decreased stress levels to be associated with greater job satisfaction in workers with a view through their office windows that included natural elements, as well as greater life satisfaction and attentional capacity in residents (or even prisoners) who have natural views.[93,94] Proponents of ART claim that repeated viewings of natural surroundings may have incremental effects by allowing indirect attention a chance to come to the forefront of mental mechanisms and providing brief periods of replenishment for directed attention. The aggregate of these short exposures could lead to a restoration effect—so-called "potential micro-restorative opportunities."[95]

Urban greenspace

Several observational studies have shown a strong positive correlation between urban greenspace exposure (including gardens) and physical and emotional health.[40,59] Wells showed an increase in cognitive functioning capacity in children who had recently moved to more natural surroundings versus those who had moved to more urban environments.[59] And Wells and Evans demonstrated a correlation between "nearby nature" and parent-reported stress levels and self-reported measures of self-worth in children grades 3–5, leading the authors to postulate that nature may function as a "buffer" for children against stressful life events and threats to their self-esteem.[96]

Although exercise itself has been shown in numerous studies to impact mood, some believe that natural environments benefit the individual over and above the exercise itself, leading to support for "green exercise."[97–99] Pretty *et al.* compared groups of individuals all engaged in identical exercise while viewing either green landscapes or barren urban environments.[100] The former group showed significantly greater reductions in blood pressure as well as increases in positive mood and self-esteem relative to the control group.

In a meta-analysis involving 25 studies, Bowler *et al.* examined the impacts of short-term forms of "green exercise" (nearly all were one hour or less).[60] Subjects in each of the 25 studies engaged in identical physical activities within natural (urban and university greenspace, gardens, woodlands, wilderness parks) versus "synthetic" (gyms, laboratory, or urban space) environments. Results showed that the most significant difference was an increase in positive self-reported emotion for those subjects engaged in "green exercise." The authors did not find significant differences in attention capacity or measures of stress that could be attributed to varying exposures to natural versus synthetic environments, but their analysis provided evidence for additional positive benefits of exercise, specifically in the context of natural spaces.

Duration

The majority of these studies have relied upon either longitudinal designs that examine the impacts of different living conditions' access to nature or cross-sectional designs that examine responses to natural environments for periods of between 10 min and an hour; with urban parks, terrestrial nature preserves, and arboretums being used as the predominant landscape of choice (see Fig. 1).

More recently, researchers have also asked questions about the "ideal" duration of time spent in nature for mental health benefits. Is there duration with which we may find the greatest marginal return for our time—an ideal "dose" that packs the most mental health benefit in the shortest amount of time? In a meta-analysis, Barton and Pretty analyzed previous studies in an attempt to determine the most effective dose of green exercise for mood and self-esteem benefits.[101] Their study showed both men and women improving in measurements of self-esteem after green exercise (decreasing for both sexes with age), but only men exhibited significant improvement in mood. Their dose–response charts are somewhat puzzling: with the greatest benefit (measured by total change in mood [TMD] and self-esteem) coming from only five minutes of activity, followed by an entire day, and lowest improvements coming from 10 min to half-day doses. Further research is required to arrive at satisfactory

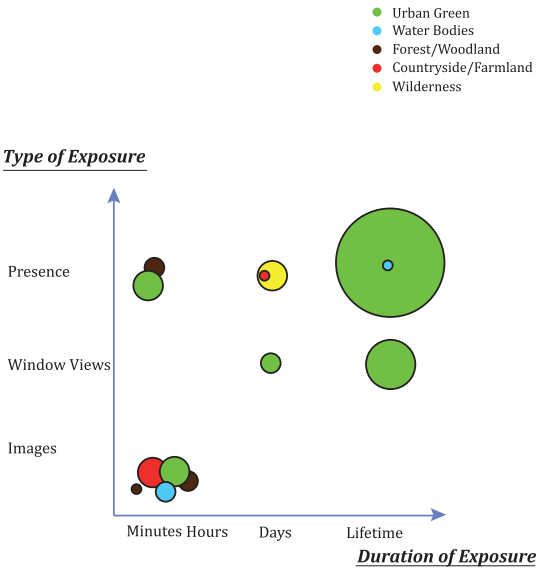

Figure 1. Distribution of studies considered in this review. Color and size of the bubble indicates the nature "type" and number of studies, respectively. Location on the *y*-axis indicates the type of nature exposure that was addressed in the work. Location on the *x*-axis illustrates the duration of exposure to which the subjects were exposed.

explanations for these differences, if they are shown to be reliable.

Ecosystem services

We have examined numerous ways in which nature experience has been shown to impact cognitive and emotional capacities for individuals. If these benefits do exist, discussions about an "ideal" length of exposure to specific types of environment might be framed in a way that has become increasingly familiar to conservation scientists and environmental economists. We may attempt to determine the benefit that comes from a particular type of interaction (e.g., images, window views, physical presence), for a particular amount of time (for example, minutes, days, years), with a particular form of nature (for example, urban parks, forests, water bodies). With further research, we may eventually be able to quantify the marginal benefit that comes with the addition of something as "small" as a single tree. This type of thinking has a role for policy makers, urban planners, and even architects as they ponder the value of spending tax dollars on urban parks, putting gardens in hospitals, or providing outdoor learning experiences for children.

With this in mind, we can begin to envision a way in which environmental psychology fits into the ecosystem services paradigm. Organizations such as the Natural Capital Project have developed tools that present easy ways to visualize the value of particular parcels of land (or pixels in GIS) as a means for carbon sequestration, water purification, flood mitigation, pollination, and other ecosystem services (including a suite for seascapes).[102] Policy makers can then be presented with an analysis of explicit tradeoffs that would result under alternative choices or scenarios. Until now, most of this work has been tied to biophysical processes. If further research is able to attribute "psychological benefit values" reliably to these areas (the impact that comes from specific elements contained within the area), similar results might be presentable. As stated in the Introduction, however, these benefits exist only through the interaction of an individual with the landscape, raising the importance of duration of exposure in a different way than it has been incorporated within previous ecosystem service studies.

The time is ripe for such development within the scientific community that is advancing ecosystem service tools. Policy makers are becoming increasingly engaged in the issue of the health benefits of nature, with a national study commission by the Dutch government in 2004[103] and China investing in a new reserve system to span 25% of the nation for the provision of vital ecosystem services (Personal Communication, Professor Zhiyun Ouyang, Chinese Academy of Sciences, 1 September 2011). Many of these efforts focus on the benefits from urban and suburban greenspace, as well as more extensive natural areas.

Conclusion and future directions

We have reviewed many studies that demonstrate impacts of nature experience on human cognitive function and mental health. These effects have been shown to occur in measures of memory, attention, concentration, impulse inhibition, and mood. The studies considered here span many of the major areas of examination within contemporary psychology and, taken together, constitute a strong foundation for an emerging field of inquiry. We now point to ways of building upon this foundation, both to make different lines of existing work more intercomparable, so that individual experiments add maximum value in the context of advancing the broader

field, and also to open promising new directions for exploration.

First, formal, quantifiable, and consistent metrics could be used to compare "urban" and "natural" environments. In existing literature, they are often loosely and vaguely described. Second, a large percentage of these studies has been conducted within a small range of landscape types, and many involve similar durations and frequencies of time spent in nature (see Fig. 1). More extensive work remains to be done to cover the full range of variety, duration, frequency, and spatial scale. Third, there is need to incorporate systematically the possible repercussions of opinions about nature on the individual psychological benefits that a landscape may provide. Fourth, there remains great scope for considering more detail in measured behavioral effects. For example, filtering tasks, complex operation span tasks, distraction tests, and other modern psychology tests may allow for examination of more detailed capabilities in the broad category of "attention." And last, following the precedent of countless intervention studies within psychology, there is need to assess the degree to which the measured impacts persist once subjects have returned to their normal environments.

Explicitly categorizing and quantifying the elements of nature considered within a study will do much to encourage the development of consistency across the field. To challenge or replicate a claim about particular effects, scholars must ensure that the variables of manipulation are duplicated accurately. It may be helpful to develop a common language of "geographical features" that allows for a mutual understanding and shared terminology with respect to the description of various landscapes. This may lead to an agreement upon what aspects of an environment combine to result in its classification as, for example, "forest," "field," or "urban greenspace." Furthermore, when placing a landscape into one of a variety of categories, it would likely prove most fruitful to incorporate basic principles of ecology and integrate considerations of scale, diversity (biological and geographical), topography, and vegetation density. Remotely sensed landscape imagery, coupled with on-site verification, can help formulate rigorous classifications within and across studies. Additionally, the landscape aesthetics literature provides a precedent for a systematic consideration of the "visually appealing" aspects of an environment (consistent to various degrees across individuals).

With the exception of one study, biodiversity has not been shown to correspond independently to psychological benefits.[104] As with all preferences, however, this can change. With increased appreciation for biodiversity might come an increased tendency to appreciate landscapes containing qualities of native habitats and species, thereby eliciting more positive responses from the viewer.[105]

Finally, as we have mentioned throughout, much more research is needed to determine possible causal mechanisms for the observed effects that have been demonstrated in the studies contained within this review. Functional magnetic resonance imaging (fMRI) and other tools in cognitive neuroscience offer exciting possibilities for examinations of brain activity before and after nature experience—and may offer insights into the neural activity changes that are responsible for the compelling observations we have found in the literature.

Interdisciplinary efforts have much to offer in this exploration. For example, combining mapping, tracking, and testing approaches from ecology, psychology, epidemiology, and computer science may allow researchers to study the real-time effects on mood and cognitive function within individuals as they move through a variety of landscape types.[106] There are many other exciting possibilities for synthesis across disciplines in pursuit of this subject matter. Isolating effects that are attributable to environmental change has been of utmost importance in recent decades for the study of population biology, climate change, and other high-profile areas in the sciences. Similar demands for rigor and specificity on the ways in which natural landscapes impact the mind may lead to exciting, compelling, and even completely unanticipated results. These are essential considerations for humanity as we move away from the surroundings with which we have dealt for millennia.

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Conflicts of interest

The authors are not aware of any biases that might be perceived as affecting the objectivity of this review.

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