ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Current Directions in Psychological Science
2019, Vol. 28(5) 496–502

DOI: 10.1177/0963721419854100
www.psychologicalscience.org/CDPS
SAGE

Understanding Nature and Its Cognitive Benefits

Kathryn E. Schertz and Marc G. Berman
Department of Psychology, University of Chicago

Abstract

Many people have the intuition that interacting with natural environments benefits their psychological health. But what has research actually demonstrated about the benefits of nature experience and the potential mechanisms underlying those benefits? This article describes empirical research on the cognitive benefits of interacting with natural environments and several theories that have been proposed to explain these effects. We also propose future directions that may be useful in exploring the extent of nature's effects on cognitive performance and some potential mediating factors. Specifically, exposure to a variety of natural stimuli (vs. urban stimuli) consistently improves working memory performance. One potential mechanism for this is the perception of low-level features of natural environments, such as edge density in the visual domain. Although low-level features have been shown to carry semantic information and influence behavior, additional studies are needed to indicate whether perceiving these features in isolation is necessary or sufficient for obtaining the cognitive benefits of interacting with nature.

Keywords

attention, natural environments, perception, cognition

> We need the tonic of wilderness. . . . We can never have enough of nature.
>
> —Henry D. Thoreau, *Walden* (1854/1993, pp. 261–262)

> Go to the sea-shore, to the mountains, to the wilderness; go anywhere where you can forget your cares and cast aside your burdens. . . . Let the old, old nurse, Nature, . . . take you to her bosom again; and you will return to the city happier and healthier for the embrace.
>
> —William H. H. Murray, *Ministerial Vacations: Their Necessity and Value* (1873, pp. 283–284)

As the world became increasingly urbanized, writers such as Thoreau and Murray began urging people to spend more time in nature. More than ever, people are losing touch with nature, and their interactions with nature have diminished (Kahn, Ruckert, Severson, Reichert, & Fowler, 2010). In response to our diminished interaction with nature, there are no shortages of blog posts, magazine articles, and books continuing to extol the advice to get out in nature. But what has psychological experimentation actually demonstrated in terms of the benefits that nature experience can provide and the potential mechanisms underlying those benefits? This article discusses research that has been performed that enumerates nature's cognitive benefits and describes current theories, which provide frameworks to explain the benefits. We also propose future research directions to more fully understand the extent and mechanisms of nature's effects on cognition.

Cognitive Benefits of Nature

Correlational studies examining the influence of nature exposure on cognitive performance have found a positive association between green space around schools and cognitive development in children (Dadvand et al.,

Corresponding Authors:
Kathryn E. Schertz, University of Chicago, Department of Psychology, 5848 S University Ave., Chicago, IL 60637
E-mail: kschertz@uchicago.edu

Marc G. Berman, University of Chicago, Department of Psychology, 5848 S University Ave., Chicago, IL 60637
E-mail: bermanm@uchicago.edu

2015), as well as an association between green views at home and self-control behaviors in young girls (Taylor, Kuo, & Sullivan, 2002). In a study with adults, researchers also found that residents of greener public-housing buildings showed higher attentional functioning (Kuo & Sullivan, 2001). In both studies from Sullivan and colleagues, it is important to note that residents of public housing were randomly assigned to the unit they lived in, thus they did not self-select the greenness levels of the surrounding area. Experimental studies have used a wide range of stimulus types, including images (e.g., Berto, 2005), sounds (e.g., Van Hedger, Nusbaum, Clohisy, et al., 2019), and real-world exposure (e.g., Berman et al., 2012; Berman, Jonides, & Kaplan, 2008; Bratman, Daily, Levy, & Gross, 2015), to show that exposure to natural environments can improve participants' cognitive performance relative to exposure to urban environments. Several cognitive tasks, which differ in their working memory load, have been used in experimental work. The specific task showing the most consistent improvement after nature exposure is the backward digit-span task, which requires participants to repeat sequences of numbers, of varying length, in reverse order (Stevenson, Schilhab, & Bentsen, 2018). In general, cognitive tasks that require working memory and cognitive flexibility improve most reliably after nature exposure, with tasks requiring attentional control also showing some improvements. On the other hand, tasks involving impulse control, visual attention, vigilance, and processing speed have not reliably shown differences in performance following exposure to natural versus urban environments (Stevenson et al., 2018).

Interestingly, the cognitive benefits of nature experiences do not seem to be driven by changes in mood because changes in mood do not correlate with the cognitive benefits (Stenfors et al., 2019). Other studies have tested individuals after walks in winter versus summer, and although mood significantly improved in the summer compared with the winter, the cognitive effects were not significantly different, which fails to support the notion that these cognitive effects are mood driven (Berman et al., 2008, 2012). Thus, the data support the idea that nature exposure may have separable benefits for cognition and affect.

As previously noted, in many studies, natural environments are being compared with urban environments. A reasonable question then is whether nature is improving performance or whether urban environments are worsening cognitive performance. It is difficult to have participants engage in an attention-neutral environment to the same degree that they would a real-world urban or natural environment to directly test this question. However, within-subjects studies, in which participants were tested in both types of environments, usually over two sessions, can provide some information. A review of studies from our lab showed that practice effects were seen in the first session for both natural and urban environments, with natural environments having only a slight advantage. However, in the second session, participants continued to improve their cognitive performance only if they were in the natural environment, whereas participants in urban conditions did not continue to improve (Stenfors et al., 2019), suggesting that the effect is more about interactions with nature improving performance rather than urban environments worsening performance. Studies from other labs using working memory and cognitive-flexibility tasks have also shown that participants seem to improve their performance after nature exposure but maintain performance after urban exposure (Stevenson et al., 2018). However, tasks that involve attentional control tend to show beneficial effects after nature exposure and detrimental effects after urban exposure (Stevenson et al., 2018). This suggests that multiple cognitive mechanisms may be involved in causing these environmental effects. Therefore, researchers may need to utilize multiple cognitive tasks to untangle all of the underlying processes.

Current Theories for the Benefits of Natural Environments

There have been several theories proposed to explain why interacting with natural environments confer the benefits covered above. Stress-reduction theory, proposed by Ulrich (1983), suggests that a positive emotional response to nature allows a person to return from a stressful state to an unstressed state. That is, nonthreatening natural environments reduce stress and negative affect while increasing positive affect. The change in affect and reduction of the stress response then allow a person to maintain higher levels of sustained attention, which leads to cognitive benefits (Ulrich, 1983). Although a recent meta-analysis shows evidence for improvements in mood following exposure to nature (McMahan & Estes, 2015), our analyses showed that mood effects are not correlated with cognitive benefits (Stenfors et al., 2019), thus countering the idea that mood changes drive the cognitive effects, as posited by stress-reduction theory.

Attention-restoration theory, on the other hand, claims that perceptual features of natural environments capture one's bottom-up involuntary attention while simultaneously allowing finite, top-down, directed-attention resources a chance to replenish. This feature is called *soft fascination*. Other features of restorative environments posited by attention-restoration theory are environments that provide (a) a sense of being away (i.e., mental separation), (b) a feeling of extent (i.e., large enough environments to be explored), and (c) compatibility with goals (Kaplan, 1995). The feature of compatibility is thought to be one way that the same environment could have different restorative effects for different people or even for the same person at different times. For example, if you have a walking commute through a park, you are unlikely to feel the same restorative benefits on days when you are running late for work. Thus, compatibility can be thought of as shaping how a person interacts with his or her environment at a given time.

The perceptual-fluency account relates our positive affective responses to natural stimuli to the ease of processing such stimuli and posits that attention restoration and stress reduction are by-products of this processing fluency (Joye & van den Berg, 2011). For example, fractalness is proposed to be influential in determining how fluent a scene is processed, because it increases perceptual predictability. The idea is that fluency would induce less effortful processing; this is a similar concept to soft fascination in attention-restoration theory. However, in the perceptual-fluency account, effortless processing increases positive affect, which increases attention, and in attention-restoration theory, effortless processing acts directly to increase attention. In both attention-restoration theory and the perceptual-fluency account, additional research needs to be performed to determine the features that make an environment fascinating or fluently processed.

Prospect-refuge theory does not focus on an urban–nature dichotomy but rather on an aesthetic judgment of landscapes. This theory suggests that people prefer landscapes that offer both prospect (a clear field of view) as well as refuge (places to hide; Appleton, 1975). Supporting this theory, research has shown that nature walks that had high prospect led to higher cognitive restoration compared with nature walks that had low prospect (Gatersleben & Andrews, 2013).

Potential Mechanisms for the Benefits of Nature

One potential mechanism that has emerged for these effects involves the perception of the low-level features of the environment. As discussed in the previous section, additional work is necessary to fully operationalize what makes an environment softly fascinating (attention-restoration theory) or fluently processed (perceptual-fluency account). In the visual modality, low-level features include color properties—such as hue, saturation, and brightness (value)—as well as spatial properties—such as the density of straight and nonstraight edges and entropy (see Fig. 1). These features allow us to quantify

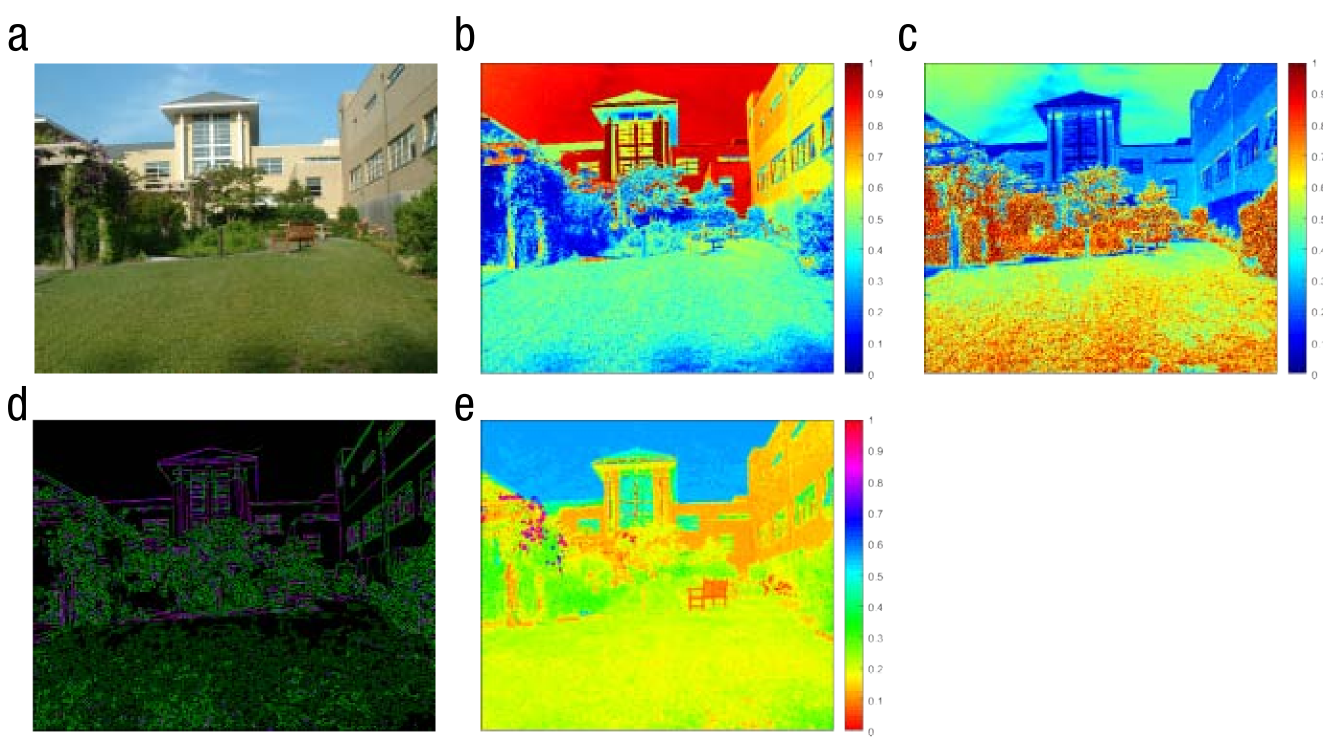

Fig. 1. Example color and spatial properties of a single visual image. Individual properties of the original image (a) are visualized separately: (b) brightness (value), (c) saturation, (d) straight (purple lines) and nonstraight (green lines) edges, and (e) circular hue. Heat maps in (b), (c), and (e) indicate areas with higher (1) to lower (0) brightness, saturation, and circular hue, respectively.

aspects of the visual environment. Interestingly, these "low-level" features have also been found to carry semantic information (Berman et al., 2014; Kardan et al., 2015; Kotabe, Kardan, & Berman, 2016a, 2016b). For example, some of these visual features can significantly predict people's judgments about the perceived naturalness of and their preference for a wide range of images. Natural environments in general have more nonstraight edges, less color saturation, and less variability of hues. In addition, perceiving the low-level features of the environment can influence complex cognitive and self-regulatory processes, such as thought content (Schertz et al., 2018) and the propensity to cheat (Kotabe et al., 2016b). When shown images with a greater number of nonstraight edges, people were more likely to think about topics related to spirituality and one's life journey, compared with when they were viewing images with fewer nonstraight edges, independently of the perceived naturalness of the scene (Schertz et al., 2018).

Just as in the visual domain, audio research has found that participants show increases in working memory performance after listening to nature sounds relative to urban sounds (Van Hedger, Nusbaum, Clohisy, et al., 2019). There are also low-level acoustic features that can be quantified, such as spectral entropy, a measure of noisiness of the sound, and dominant frequency. Importantly, these features often significantly differ between natural sounds and urban sounds and can be used to categorize sounds as originating from nature or urban sources (Van Hedger, Nusbaum, Heald, et al., 2019). Additionally, people tend to have a preference for natural sounds, but only when they can be identified as such. Thus, when urban and natural sounds were presented in an unidentifiable manner (i.e., thin-sliced to 100-ms duration), the low-level acoustic features remained different between nature and urban sounds, but importantly, preference levels did not differ (Van Hedger, Nusbaum, Heald, et al., 2019). This indicates that low-level acoustic features alone do not predict preferences but rather interact with semantic information. The same could also be true for the cognitive benefits seen after one interacts with nature and urban stimulation—in which cognitive benefits may or may not be seen after perceiving natural features in isolation from semantic context.

Future Directions

To begin testing the effects of perceiving low-level features in isolation, we have created scrambled versions of images (Fig. 2) that preserve certain low-level features but remove semantics and thus impair one's ability to identify the scenes. Participants may then be exposed to (a) the scrambled images (which contain only the low-level features; e.g., Figs. 2b and 2c), (b) words such as *river* or *road* (which provide only overt semantic information; e.g., Fig. 2d), or (c) intact images (which contain both; e.g., Fig. 2a) to see which type of stimulus leads to working memory and mood improvements. This would help determine whether low-level features in isolation or environmental identification in isolation is necessary or sufficient for cognitive benefits. Differential effects on affect and cognition using this paradigm may also be helpful in refining current theories such as attention-restoration theory and the perceptual-fluency account.

Different natural environments (e.g., deserts and wetlands) may also have different magnitudes of impact on cognitive functioning because these environments may differ in terms of low-level features while simultaneously offering similar perceptions of higher level features such as naturalness, compatibility, and extent. If we find evidence of different effects, we may be able to determine whether the low-level perceptual features are driving these differences. Other environments may have similar low-level features, such as a mountain scene or a forest (e.g., similar fractalness), but have very different semantic associations.

Mobile neuroimaging techniques could also be useful in determining how neural processing differs when perceiving these environments. Differences in whole-brain activation patterns, such as scale-free brain dynamics that have been linked to cognitive effort (Churchill et al., 2016; Kardan et al., 2019), could be used to elucidate neural differences in responding to different environments. In addition, eye-movement patterns that signify more effortful processing could also be used to quantify the effort exerted to process different environmental stimulation. These neuroimaging and eye-tracking data could then be used to operationalize ideas such as soft fascination and perceptual fluency.

Conclusions

Overall, there is compelling evidence to support the advice of Thoreau and Murray to spend time in nature. Exposure to natural environments has been shown to improve performance on working memory, cognitive-flexibility, and attentional-control tasks. These results come from studies conducted using a variety of simulated environments (e.g., images, sounds, virtual reality) as well as real-world environmental exposure (Schertz et al., 2018; Stenfors et al., 2019; Stevenson et al., 2018). By continuing to conduct laboratory and real-world studies, researchers will maintain both experimental control and ecological validity.

This is not to say that all natural environments are universally good and all urban environments are

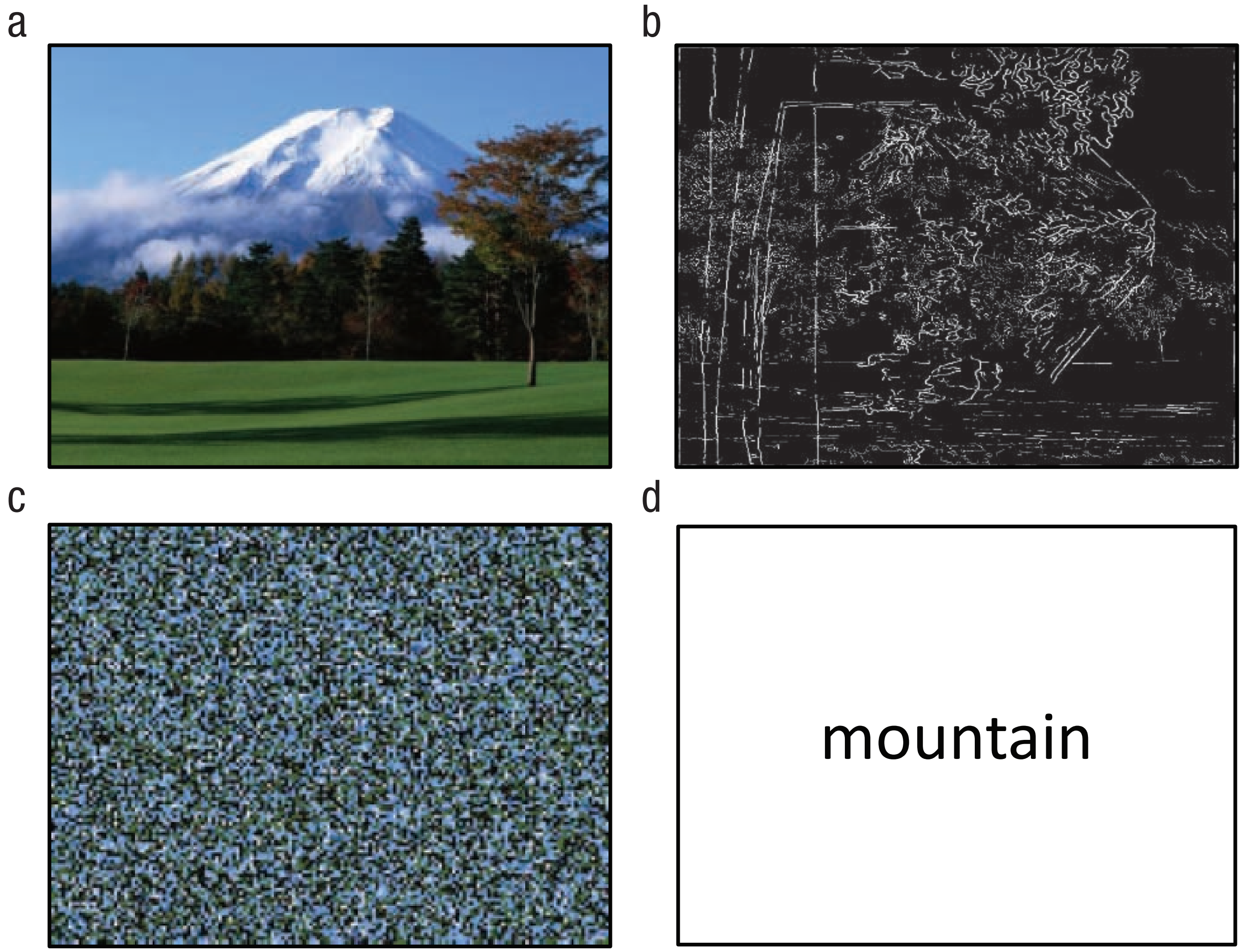

Fig. 2. Example images used to test the effects of perceiving low-level features in isolation: (a) an original image, (b) a scrambled edge version of the same image, (c) a scrambled color version of the image, and (d) a semantic-only presentation of the stimulus (i.e., without visual features).

universally bad (Hartig & Kahn, 2016), because cities offer benefits at individual and societal scales (Berman, Kardan, Kotabe, Nusbaum, & London, 2019). However, there appears to be a growing consensus that exposure to elements of more natural environments leads to cognitive gains. Future work aimed at uncovering the mechanisms that elucidate these effects could help integrate natural elements into urban environments (Berman et al., 2019). This integration would allow residents to experience the benefits that nature and cities both have to offer and inform the design of all built spaces to enhance human psychological functioning.

Recommended Reading

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health*, *35*, 207–228. Review article on the health benefits of nature interactions, with recommendations on planning and public policy.

Kaplan, S., & Berman, M. G. (2010). Directed attention as a common resource for executive functioning and self-regulation. *Perspectives on Psychological Science*, *5*, 43–57. Theoretical article positing directed attention as a limited resource that can be restored with nature interactions and heavily involved in executive function and self-control.

McMahan, E. A., & Estes, D. (2015). (See References). A meta-analysis on experimental studies of affective benefits of interacting with nature.

Schertz, K. E., Sachdeva, S., Kardan, O., Kotabe, H. P., Wolf, K. L., & Berman, M. G. (2018). (See References). Example experimental article showing influence of low-level visual features on higher-level functions.

Stevenson, M. P., Schilhab, T., & Bentsen, P. (2018). (See References). A meta-analysis on the cognitive benefits of interacting with nature from the viewpoint of attention-restoration theory.

Action Editor

Randall W. Engle served as action editor for this article.

ORCID iD

Kathryn E. Schertz https://orcid.org/0000-0003-1104-0801

Acknowledgments

We dedicate this article to the memory of Stephen Kaplan (1932–2018), who inspired much of this work and was a tremendous teacher, mentor, and friend to M. G. Berman.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Funding

K. E. Schertz is supported by a National Science Foundation Graduate Research Fellowship (DGE-1746045). M. G. Berman is supported by a National Science Foundation Grant (BCS-1632445). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

Appleton, J. (1975). *The experience of landscape*. London, England: Wiley.

Berman, M. G., Hout, M. C., Kardan, O., Hunter, M. R., Yourganov, G., Henderson, J. M., . . . Jonides, J. (2014). The perception of naturalness correlates with low-level visual features of environmental scenes. *PLOS ONE*, *9*(12), Article e114572. doi:10.1371/journal.pone.0114572

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, *19*, 1207–1212.

Berman, M. G., Kardan, O., Kotabe, H. P., Nusbaum, H. C., & London, S. E. (2019). The promise of environmental neuroscience. *Nature Human Behavior*, *3*, 414–417 doi:10.1038/s41562-019-0577-7

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., . . . Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders*, *140*, 300–305.

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology*, *25*, 249–259.

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, *138*, 41–50.

Churchill, N. W., Spring, R., Grady, C., Cimprich, B., Askren, M. K., Reuter-Lorenz, P. A., . . . Berman, M. G. (2016). The suppression of scale-free fMRI brain dynamics across three different sources of effort: Aging, task novelty and task difficulty. *Scientific Reports*, *6*, Article 30895.

Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., . . . Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. *Proceedings of the National Academy of Sciences, USA*, *112*, 7937–7942. doi:10.1073/pnas.1503402112

Gatersleben, B., & Andrews, M. (2013). When walking in nature is not restorative—The role of prospect and refuge. *Health & Place*, *20*, 91–101. doi:10.1016/j.healthplace.2013.01.001

Hartig, T., & Kahn, P. H. (2016). Living in cities, naturally. *Science*, *352*, 938–940. doi:10.1126/science.aaf3759

Joye, Y., & van den Berg, A. (2011). Is love for green in our genes? A critical analysis of evolutionary assumptions in restorative environments research. *Urban Forestry & Urban Greening*, *10*, 261–268. doi:10.1016/j.ufug.2011.07.004

Kahn, P. H., Ruckert, J. H., Severson, R. L., Reichert, A. L., & Fowler, E. (2010). A nature language: An agenda to catalog, save, and recover patterns of human–nature interaction. *Ecopsychology*, *2*, 59–66. doi:10.1089/eco.2009.0047

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*, 169–182.

Kardan, O., Adam, K. C. S., Mance, I., Churchill, N. W., Vogel, E. K., & Berman, M. G. (2019). Distinguishing cognitive effort and working memory load using scale-invariance and alpha suppression in EEG. *PsyArXiv*. doi:10.31234/osf.io/7q4m8

Kardan, O., Demiralp, E., Hout, M. C., Hunter, M. R., Karimi, H., Hanayik, T., . . . Berman, M. G. (2015). Is the preference of natural versus man-made scenes driven by bottom–up processing of the visual features of nature? *Frontiers in Psychology*, *6*, Article 471. doi:10.3389/fpsyg.2015.00471

Kotabe, H. P., Kardan, O., & Berman, M. G. (2016a). Can the high-level semantics of a scene be preserved in the low-level visual features of that scene? A study of disorder and naturalness. In A. Papafragou, D. J. Grodner, D. Mirman, & J. Trueswell (Eds.), *Proceedings of the 38th Annual Conference of the Cognitive Science Society* (Vol. 38, pp. 1721–1726). Seattle, WA: Cognitive Science Society.

Kotabe, H. P., Kardan, O., & Berman, M. G. (2016b). The order of disorder: Deconstructing visual disorder and its effect on rule-breaking. *Journal of Experimental Psychology: General*, *145*, 1713–1727. doi:10.1037/xge0000240

Kuo, F. E., & Sullivan, W. C. (2001). Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment & Behavior*, *33*, 543–571.

McMahan, E. A., & Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. *The Journal of Positive Psychology*, *10*, 507–519. doi:10.1080/17439760.2014.994224

Murray, W. H. H. (1873). Ministerial vacations: Their necessity and value. In *Park-street pulpit: Sermons*. Boston, MA: James R. Osgood.

Schertz, K. E., Sachdeva, S., Kardan, O., Kotabe, H. P., Wolf, K. L., & Berman, M. G. (2018). A thought in the park: The influence of naturalness and low-level visual features on expressed thoughts. *Cognition*, *174*, 82–93. doi:10.1016/j.cognition.2018.01.011

Stenfors, C. U. D., Van Hedger, S. C., Schertz, K. E., Meyer, F. A. C., Smith, K. E. L., Norman, G. J., . . . Berman, M. G. (2019). Positive effects of nature on cognitive performance across multiple experiments: Test order but not affect modulates the cognitive effects. *Frontiers in Psychology*, *10*, Article 1413. doi:10.3389/fpsyg.2019.01413

Stevenson, M. P., Schilhab, T., & Bentsen, P. (2018). Attention restoration theory II: A systematic review to clarify attention processes affected by exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, *21*, 227–268. doi:10.1080/10937404.2018.1505571

Taylor, A. F., Kuo, F. E., & Sullivan, W. C. (2002). Views of nature and self-discipline: Evidence from inner city children. *Journal of Environmental Psychology*, *22*, 49–63. doi:10.1006/jevp.2001.0241

Thoreau, H. D. (1993). *Walden or life in the woods*. New York, NY: Barnes & Noble. (Original work published 1854)

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the natural environment* (pp. 85–125). New York, NY: Springer.

Van Hedger, S. C., Nusbaum, H. C., Clohisy, L., Jaeggi, S. M., Buschkuehl, M., & Berman, M. G. (2019). Of cricket chirps and car horns: The effect of nature sounds on cognitive performance. *Psychonomic Bulletin & Review*, *26*, 522–530. doi:10.3758/s13423-018-1539-1

Van Hedger, S. C., Nusbaum, H. C., Heald, S. L. M., Huang, A., Kotabe, H. P., & Berman, M. G. (2019). The aesthetic preference for nature sounds depends on sound object recognition. *Cognitive Science*, *43*(5), Article e12734. doi:10.1111/cogs.12734