Of cricket chirps and car horns: The effect of nature sounds on cognitive performance

Stephen C. Van Hedger [1]
Howard C. Nusbaum [1 2]
Luke Clohisy [1]
Susanne M. Jaeggi [3 4]
Martin Buschkuehl[5]
Marc G. Berman [1 2]

[1] Department of Psychology, *University of Chicago: Chicago, IL, USA*

[2] Center for Practical Wisdom, *University of Chicago: Chicago, IL, USA*

[3] School of Education, *University of California – Irvine: Irvine, CA, USA*

[4]Department of Cognitive Sciences, *University of California – Irvine: Irvine, CA, USA*

[5]*MIND Research Institute: Irvine, CA, USA*

Corresponding Author
Stephen Van Hedger
5848 S. University Avenue
Chicago, IL 60637
svanhedger@uchicago.edu

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Abstract

The psychological benefits of interacting with nature have been discussed for well over a century[1]. More recently, research has begun to assess how interactions with nature specifically may benefit cognition and cognitive development [2]. Attention Restoration Theory (ART) posits that stimuli found in nature may restore directed attention functioning through reducing demands on the endogenous attention system [3]. In the present experiment, we assessed whether nature-related cognitive benefits extended to auditory presentations of nature. To assess directed attention, we created a composite measure consisting of a backward digit span task and a dual n-back task. Participants completed these cognitive measures and an affective questionnaire before and after listening to and aesthetically judging either nature or urban soundscapes. Relative to participants who were exposed to urban soundscapes, we observed significant improvements in cognitive performance for individuals who listened to nature soundscapes. Urban soundscapes did not systematically affect performance either adversely or beneficially. The improvement in directed attention functioning was not meaningfully related to the aesthetic ratings of the soundscapes. These results provide initial evidence that brief experiences with nature sounds can improve directed attention functioning in a single experimental session.

Keywords: *attention, cognitive and attentional control, attention restoration theory, nature*

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The view that interacting with nature may be integral to human health and well-being has been discussed by philosophers ranging from Zhuangzi, from the 4th century BCE China, to Henry David Thoreau, from the 19th century United States [4]. Recent empirical investigations have built upon this philosophical foundation, demonstrating that interactions with nature can increase positive affect and decrease negative affect [5], lower stress [6], improve physical health [7], and improve aspects of cognitive functioning and cognitive development [2]. Nature related cognitive improvements have been found across a variety of participants and study designs, often using strikingly different operationalizations of nature. For example, the extent of greenspace has been positively associated with the development of executive functions in a sample of over 2,500 children, even after controlling for factors such as socioeconomic status [8]. In experimental settings, brief interventions – ranging from several minutes to a couple of hours – in which participants take a walk through nature or view nature images on a computer screen have been shown to improve the functioning of directed attention relative to interventions in which participants are exposed to more urban environments [9].

One prominent account of how nature may improve aspects of cognition is *Attention Restoration Theory* (ART), which posits that nature environments are particularly well-suited for reducing demands on the endogenous attention system, thereby allowing subsequent restoration of attentional functioning [3]. The fact that simply viewing pictures or even artistic renderings of nature environments can improve performance on tasks requiring directed attention [10] suggests that nature, in part, may improve performance through its perceptual organization. However, the focus on visual depictions of nature in the ART literature has resulted in a relative paucity of research on other modalities, such as audition. As such, the present experiment tests whether auditory depictions of nature confer similar benefits to directed-attention functioning.

There are two broad research findings that support potential cognitive benefits from experiencing nature sounds. First, prior studies have demonstrated widespread associations between noise levels and health. Noise pollution (typically urban environments with sustained, high-amplitude sounds) has been associated with greater amounts of reported stress and distraction [11], which can lead to chronic learning and attention problems [12]. Thus, nature sounds may improve aspects of cognition relative to urban sounds because these two classes of sounds generally differ with respect to their amplitude in the real world [13]. Of course, this research does not specifically relate to the beneficial effects of nature; rather, it argues that urban or manmade auditory environments may have detrimental cognitive and general health outcomes and thus nature may not be any more beneficial than any low amplitude sound.

The second reason why nature sounds may improve cognitive functioning, which is more specifically related to the beneficial effects of nature environments (though is not mutually exclusive from the first explanation), is because nature sounds are perceived as restorative and have been associated with a number of positive health outcomes. For example, nature sounds have been shown to lower stress [6], reduce perceived pain [14], minimize self-reported distraction in open-office workspaces [15], and lead to *perceived* attention restoration [16,17].

Yet, prior research has not found convincing evidence for the benefits of nature sounds on the functioning of directed attention. Emfield and Neider [18] assessed how nature interventions improved performance on directed attention tasks. The authors found an improvement from pre- to post-intervention (i.e., a practice effect), but no nature-related performance advantage relative to urban stimuli. However, the underlying research question was not about nature sounds specifically, and as such nature (versus urban) sounds were not considered independently in any analysis. More recently, Abbott, Taff, Newman, Benfield, and Mowen [19] assessed how nature sounds influenced directed attention, ultimately finding no difference between nature and urban sound conditions. However, in this design, all participants viewed a video of Yosemite National Park concurrent with the sounds, and moreover “urban” sounds actually consisted of nature sounds (birdsong) that were periodically interrupted by manmade sound objects, making it difficult to draw strong conclusions about the effects of nature and urban sounds on cognitive performance.

The present experiment thus provides a direct test of whether randomly assigning participants to brief exposures to nature (versus urban) soundscapes improves the functioning of directed attention. We recruited 65 individuals to participate in a single session experiment, in which directed attention and mood were assessed before and after the presentation of amplitude-normalized nature sounds or urban soundscapes (between participants).

Participants first completed the Positive Affect Negative Affect Schedule (PANAS) [20], which measured the extent to which participants reported feeling 10 positive and 10 negative terms over the past few hours. We treated positive terms and negative terms separately because the mean positive and negative values moderately supported the null hypothesis (r (61) = -.15, BF_{10} = 0.30), and thus, it did not seem appropriate to create a single construct. Participants then completed two challenging cognitive tasks – the backward digit span (BDS) task and the dual n-back (DNB) task. We used the BDS in conjunction with the DNB because both place considerable demands on directed attention [21], but only modestly correlate with each other [22], suggesting that a composite measure might minimize task-specific variance while also better representing the construct of directed attention. Indeed, prior investigations of nature-related cognitive improvements have relied on composite measures [23,24].

Participants then listened to 40 soundscapes, recorded from either nature or urban soundscapes (between participants). Each soundscape was 20 seconds in duration, and participants were asked to rate how much they liked each soundscape on a 3-point scale. These ratings served two purposes. First, we wanted to employ a simple task that would keep participants engaged. Second, we were able to assess whether our nature soundscapes were more liked than our urban soundscapes, which would be conceptually supported by prior research [25] and may represent potentially informative variance in understanding how nature may influence cognitive performance. After listening to the soundscapes, participants completed the same three tasks in order (PANAS, BDS, and DNB).

Our results clearly supported the hypothesis that nature soundscapes improved the functioning of directed attention. We assessed the support for all hypotheses using Bayes factors (BFs), in addition to more standard *p*-values. The reported BFs provide the relative evidence in favor of the alternative versus the null hypothesis (BF_{10}), or the relative evidence in favor of retaining versus removing a term in a model ($BF_{Inclusion}$). Performance on the BDS and DNB was modestly but positively correlated, and this positive relationship was moderately to strongly supported by the BF (pre-intervention: r (61) = .35, p = .005; BF_{10} = 7.482; post-intervention: r (61) = .39, p = .002; BF_{10} = 18.21). This provides conceptual support for the creation of a composite measure, as the shared variance between these tasks should better reflect the use of directed attention.

Using the change in the composite score as the dependent variable, we constructed a multiple regression model to assess how soundscape type, changes in mood, and aesthetic ratings of the soundscapes related to changes in our composite measure, controlling for pre-intervention composite score. We found strong evidence for the inclusion of soundscape type (B = 0.46, SE = 0.15, p = .003; $BF_{Inclusion}$ = 29.79), with nature soundscapes improving performance relative to urban soundscapes (Figure 1). The pre-intervention composite score also displayed strong evidence for inclusion, with participants' pre-intervention scores relating to the change in their composite scores (B = -0.26, SE = 0.08, p = .001; $BF_{Inclusion}$ = 21.19). We additionally found moderate evidence for the inclusion of negative PANAS change (B = 0.39, SE = 0.15, p = .013; $BF_{Inclusion}$ = 5.12), with greater reductions in negative affect corresponding to *less* of an improvement in the composite measure. Changes in positive PANAS (B = 0.09, SE = 0.11, p = .42; $BF_{Inclusion}$ = 0.46) and aesthetic ratings of the soundscapes (B = 0.02, SE = 0.19, p = .92; $BF_{Inclusion}$ = 0.36) did not show evidence for being included in the model, despite a clear aesthetic rating difference between nature ($M \pm SD$: 2.31 ± 0.37) and urban ($M \pm SD$: 1.84 ± 0.28) soundscapes (t (61) = 5.61, p < .001; BF_{10} = 2.41e4). For completeness, the means, standard deviations, effect sizes of changes from pre- to post-intervention, and BFs of changes from changes from pre- to post-intervention for each of the measures are provided in Table 1.

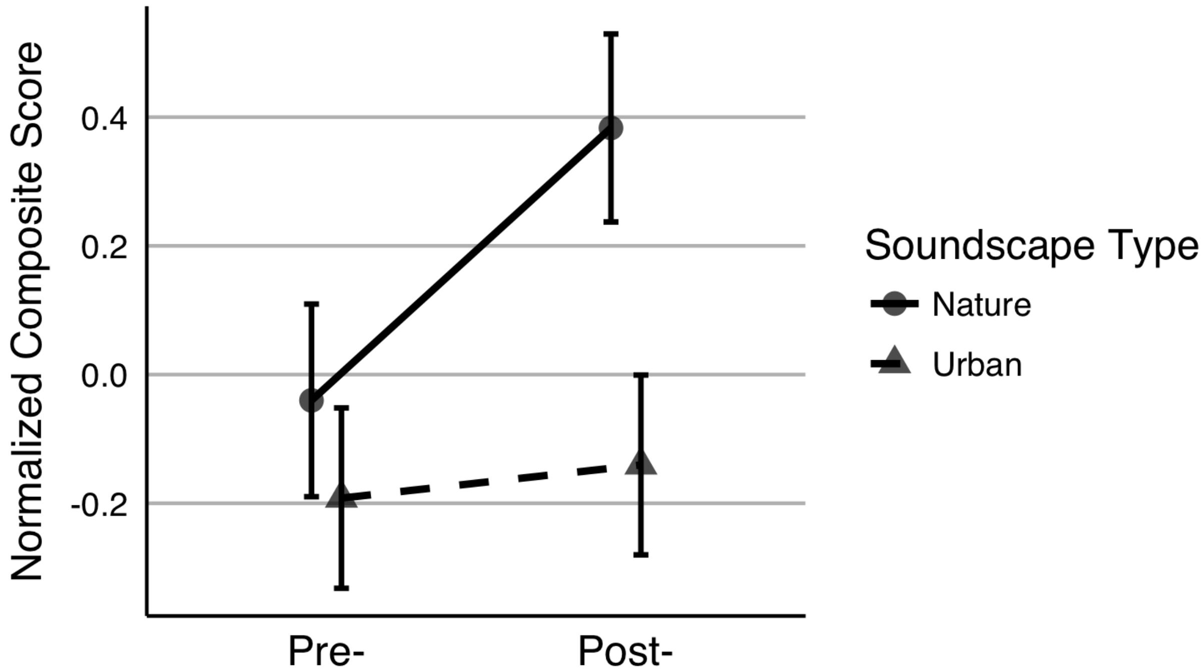

Figure 1: Normalized composite score plotted as a function of time (pre-intervention versus post-intervention) and soundscape type (nature versus urban). Error bars represent ± 1 standard error of the mean.

	Nature				Urban			
	Pre	**Post**	**ES**	**BF_{10}**	**Pre**	**Post**	**ES**	**BF_{10}**
PANAS – P	2.83 (0.57)	2.62 (0.73)	-0.45	2.86	3.18 (0.84)	2.90 (0.80)	-0.40	1.70
PANAS - N	1.91 (0.67)	1.67 (0.70)	-0.70	60.13	1.73 (0.63)	1.65 (0.63)	-0.17	0.29
BDS	9.74 (2.31)	10.61 (2.33)	0.45	2.67	9.00 (2.60)	8.94 (2.54)	-0.03	0.19
DNB	1.49 (0.60)	1.77 (0.63)	0.67	37.75	1.49 (0.52)	1.56 (0.48)	0.17	0.29
Composite	-0.04 (0.83)	0.38 (0.81)	0.82	311.12	-0.19 (0.79)	-0.14 (0.79)	0.010	0.22

Table 1: Pre- and post-intervention scores for the computerized tasks. Note: Values in parentheses represent standard deviations. Both the effect size (ES; Cohen's d) and the BF reflect the difference between pre- and post-intervention scores.

The present results demonstrate that brief experiences with nature sounds can produce benefits to performance on attentionally demanding tasks. Our results cannot be attributed to differences in mean amplitude between nature and urban sounds – which is a critical factor in real-world health outcomes of living in urban versus natural spaces [12] – given that both classes of sounds were normalized to the same amplitude and presented at a comfortable listening volume to participants. Further, it is important that these nature-related cognitive benefits can be observed in a single experimental session using a composite measure reflecting directed attention. This approach promises to more clearly elucidate the relative effect size of interacting with nature on cognitive performance, as task-related idiosyncrasies and strategies can be minimized.

How can our present results be reconciled with prior investigations of nature-related cognitive benefits, such as those by Emfield and Neider [18], which have claimed null effects of nature interventions, including nature sounds? Beyond the surface-level details in cognitive task selection, soundscape selection and the duration of the intervention, Emfield and Neider compare several nature and urban conditions (sounds, images, and images combined with sounds), along with a control condition, in an omnibus test and fail to find an interaction between time point (pre- versus post-intervention) and environment (nature versus urban). However, this kind of analysis does not address the specific question of whether nature sounds lead to cognitive improvements relative to urban sounds, which was the focus of the present experiment. Indeed, Emfield and Neider find that nature sounds result in BDS benefits of 0.81 digits, whereas urban sounds result in BDS benefits of only 0.04 digits. Despite differences in BDS task scoring, these reported improvements are remarkably similar to the changes in BDS observed in the present experiment (nature improvement: 0.87 trials; urban improvement: -0.06 trials). As such, we view our present results as consistent with prior investigations, even if our interpretation differs.

Previous research has shown that interacting with nature can increase positive affect and decrease negative affect [5]. In the present paper, we found that nature sounds lowered participants' negative PANAS scores in a manner that was very strongly supported by the BF (Table 1), conceptually supporting this prior literature. This nature-related reduction in negative affect, however, was not meaningfully different from the reduction in negative affect observed in the urban soundscape condition (t (61) = -1.58, p = .12; BF_{10} = 0.73), and moreover both nature and urban soundscape conditions nominally *reduced* positive affect. As such, our affective measures are best summarized as displaying general reductions in reported positive and negative affect, regardless of soundscape condition. With this in mind, it is perhaps not surprising that we did not find any relationship between changes in positive affect and attentional performance. Negative affect change, on the other hand, was supported in the *opposite* direction – that is, greater reductions in negative affect were related to *less* of an improvement on the composite directed attention measure. This counterintuitive relationship may be explained by participants being in a suboptimal state of arousal after listening to the soundscapes for performance on the BDS and DNB (cf. Teigen [26]).

The present study demonstrates a relative improvement in direction attention functioning as a result of hearing nature sounds compared to urban sounds; however, it is unclear whether this relative difference reflects a nature-related enhancement of performance as opposed to an urban-related suppression of performance. Two reasons to suspect that nature may confer a benefit to directed attention (rather than simply allowing a practice effect to manifest) is that the relative amount of nature exposure relates to cognitive performance in a graded fashion [24], and nature images restore directed attention even compared to more neutral images of geometric patterns [27]. Indeed, a central component of ART is that nature stimuli contain *coherence*, *complexity*, *legibility*, and *mystery* [28], which allow for restoration not only compared to urban stimuli, but also putatively more neutral stimuli that do not contain these elements. Future research in audition should offer a more systematic investigation into how nature and urban auditory interventions influence cognitive performance relative to non-urban or neutral conditions.

One limitation of the present experiment is the fact that our experimental design offered control over stimulus presentation at the expense of ecological validity. Thus, it is unclear how attention-related improvements to nature sounds may differ in more ecologically valid situations. Nevertheless, our results suggest that even short, computerized forms of nature exposure can improve the executive control of attention, which may be easier to apply in everyday life (e.g., taking a short break in an office setting to listen to nature sounds).

To conclude, the present experiment furthers our understanding of ART through clearly demonstrating that nature sounds, which have been previously shown to be perceived as restorative, [16,17] can improve directed attention in a similar manner as nature images [9]. These results further extend single-session, experimental tests of ART to a composite measure of directed attention that is more robust against task-specific strategies and idiosyncrasies, which may ultimately provide a more accurate assessment of how nature may improve directed attention more generally.

Methods

Participants

A total of 65 individuals participated in the experiment. Two were excluded due to task non-compliance (i.e., failing to perform one of the tasks as indicated by the instructions), leaving 63 analyzable participants (*M* = 20.9 years, *SD* = 3.87 years, range: 18-44 years, 25 male, 35 female, 1 other, 2 no responses). Our sample size was determined in part from prior work [27], in which nature-related cognitive improvements were observed in a between-participant design with 16 participants per condition. Given the uncertainty of whether the effect size would be comparable when using auditory stimuli, we aimed to run twice as many participants (32 per condition). All participants provided informed consent and were treated in accordance with the NIH guidelines for interacting with human participants.

Materials

We used 80 soundscapes. Half of the sounds were representative of nature (e.g., birdsong, ocean waves), while the other half was representative of urban environments (e.g., traffic, coffee shop ambiance). Each soundscape was 20 seconds in duration with a 500ms linear onset-offset ramp. Additionally, we normalized the average loudness of the soundscapes by matching root-mean-square (RMS) amplitude and presented the files at a comfortable listening level (approximately 70 dB SPL). In prior testing, participants' naturalness ratings, taken from 5-second versions of the soundscapes, were completely non-overlapping (i.e., the "least natural" nature soundscape was rated higher than the "most natural" urban soundscape).

Procedure

After providing written consent, participants completed the Positive Affect Negative Affect Schedule (PANAS), which required participants to rate the extent to which they had felt 10 positive and 10 negative terms over the past few hours. After the PANAS, participants completed the BDS, which consisted of 14 trials (two trials per set size), similar to Berman et al. [9]. The initial set size was three, while the final set size was nine. On each trial, the digits were separately presented for 1000 ms, presented in either the auditory or visual modality (counterbalanced across participants). Participants typed their response in a designed text box and were not time-limited. Performance was operationalized as the total number of correct trials (out of 14).

After the BDS, participants completed the DNB, which consisted of both a 2-back and 3-back. On each trial, a spoken letter and blue square were simultaneously presented. The square could appear in 8 locations around a center fixation cross, and there were 8 possible letters. Participants pressed designated keys ("A" or "L") if the spoken letter or current location of the square matched the letter or square location *n* trials previously (i.e., either 2- or 3-back). If both the letter and the square matched, participants pressed both keys. No keys had to be pressed for non-matching trials. There were practice runs of 10 trials (excluding the first *n* presentations) for both the 2-back and 3-back levels, during which participants received feedback but data was not recorded. Each level (2- and 3-back) was divided into two runs of 20 trials (excluding the first *n* trials). Participants always completed the 2-back before the 3-back. There was a fixed ratio of trial types (50%: no match, 20%: auditory match, 20%: visual match, 10%: both auditory and visual match). For each participant, we calculated a single d' score [29], aggregated across the 2- and 3-back.

After the DNB, participants were exposed to either 40 nature or urban soundscapes. After each soundscape, participants made an aesthetic judgment using a 3-point scale. Once participants listened to and rated the 40 nature or urban soundscapes, they repeated the tasks described in the previous paragraphs (PANAS, BDS, and DNB) in order. After the computerized tasks, participants filled out a brief demographic questionnaire. Prior to debriefing, we also had participants write down their thoughts as to the purpose of the study, as well as whether they had participated in any similar study. A subset of participants (17 of 63) correctly identified the general purpose of the study (Nature Condition: 10, Urban

Condition: 7). Removing these participants from all analyses did not change the pattern of our results, and as such these participants were included in all reported analyses.

Calculation of Composite Cognitive Measure

To create a composite measure from the BDS and DNB tasks, we z-normalized participants' scores separated by task and pre- versus post-intervention. We then combined pre-intervention BDS and DNB scores, as well as post-intervention BDS and DNB scores.

Statistical Analyses

For each analysis, we report a Bayes factors (BF), calculated using JASP 0.8.2 (JASP Team, 2018). We kept the default priors provided by the program, as recommended by Wagenmakers et al. [30]. The reported BF (BF_{10}) represents the relative evidence in favor of the alternative versus the null hypothesis. For example, a BF_{10} of 5 would mean that the observed data is five times more likely to occur under the alternative hypothesis than the null hypothesis given the priors of the model, whereas a BF_{10} of 0.2 would mean that the observed data is five times more likely to occur under the null hypothesis than the alternative hypothesis given the priors of the model. For our multiple regression analyses, the reported Bayes factor ($BF_{Inclusion}$) can be interpreted in a similar manner, but it represents the relative evidence in favor of including a particular term in a model (as opposed to removing the term from the model). We interpret our BF_{10} using the categories outlined by Wagenmakers et al., in which evidence for the alternative hypothesis is described as anecdotal (BF_{10} of 1-3), moderate (BF_{10} of 3-10), strong (BF_{10} of 10-30), very strong (BF_{10} of 30-100), or extreme (BF_{10} greater than 100).

Note on Materials and Data Availability

Stimuli, experimental scripts, and data from this paper can be accessed through the Open Science Framework (https://osf.io/5ub4c/)

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Declaration of Competing Interests

Martin Buschkuehl is employed at the MIND Research Institute, whose interest is related to this work and Susanne M. Jaeggi has an indirect financial interest in the MIND Research Institute. All other authors report no conflict of interest.

References

1. Olmsted, F. L. Yosemite and the Mariposa Grove: A Preliminary Report, 1865. *Landsc. Archit.* **43,** (1952).

2. Bratman, G. N., Hamilton, J. P. & Daily, G. C. The impacts of nature experience on human cognitive function and mental health. *Ann. N. Y. Acad. Sci.* **1249,** 118–136 (2012).

3. Kaplan, S. The restorative benefits of nature: Toward an integrative framework. *J. Environ. Psychol.* **15,** 169–182 (1995).

4. Dull, C. J. Zhuangzi and Thoreau: Wandering, nature, and freedom. *J. Chinese Philos.* **39,** 222–239 (2012).

5. McMahan, E. A. & Estes, D. The effect of contact with natural environments on positive and negative affect: A meta-analysis. *J. Posit. Psychol.* **9760,** 1–13 (2015).

6. Alvarsson, J. J., Wiens, S. & Nilsson, M. E. Stress recovery during exposure to nature sound and environmental noise. *Int. J. Environ. Res. Public Health* **7,** 1036–1046 (2010).

7. Kardan, O. *et al.* Neighborhood greenspace and health in a large urban center. *Sci. Rep.* **5,** 11610 (2015).

8. Dadvand, P. *et al.* Green spaces and cognitive development in primary schoolchildren. *Proc. Natl. Acad. Sci. U. S. A.* **112,** 7937–7942 (2015).

9. Berman, M. G., Jonides, J. & Kaplan, S. The Cognitive Benefits of Interacting With Nature. *Psychol. Sci.* **19,** 1207–1212 (2008).

10. Felsten, G. Where to take a study break on the college campus: An attention restoration theory perspective. *J. Environ. Psychol.* **29,** 160–167 (2009).

11. de Paiva Vianna, K. M., Cardoso, M. R. A. & Rodrigues, R. M. C. Noise pollution and annoyance: An urban soundscapes study. *Noise Health* **17,** 125–133 (2015).

12. Hammer, M. S., Swinburn, T. K. & Neitzel, R. L. Environmental noise pollution in the United States: Developing an effective public health response. *Environ. Health Perspect.* **122,** 115–119 (2014).

13. Lynch, E., Joyce, D. & Fristrup, K. An assessment of noise audibility and sound levels in U.S. National Parks. *Landsc. Ecol.* **26,** 1297–1309 (2011).

14. Kline, G. A. Does a view of nature promote relief from acute pain? *J. Holist. Nurs.* **27,** 159–66 (2009).

15. DeLoach, A. G., Carter, J. P. & Braasch, J. Tuning the cognitive environment: Sound masking with ‘natural’ sounds in open-plan offices. *J. Acoust. Soc. Am.* **137,** 2291 (2015).

16. Ratcliffe, E., Gatersleben, B. & Sowden, P. T. Bird sounds and their contributions to perceived attention restoration and stress recovery. *J. Environ. Psychol.* **36,** 221–228 (2013).

17. Jahncke, H., Eriksson, K. & Naula, S. The effects of auditive and visual settings on perceived restoration likelihood. *Noise Heal.* **17,** 1 (2015).

18. Emfield, A. G. & Neider, M. B. Evaluating visual and auditory contributions to the cognitive restoration effect. *Front. Psychol.* **5 VN-re,** 548 (2014).

19. Abbott, L. C., Taff, D., Newman, P., Benfield, J. A. & Mowen, A. J. The influence of natural sounds on attention restoration. *J. Park Recreat. Admi.* **34,** 5–15 (2016).

20. Watson, D., Clark, L. A. & Tellegen, A. Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. *J. Pers. Soc. Psychol.* **54,** 1063–1070 (1988).

21. Jaeggi, S. M. *et al.* The relationship between n-back performance and matrix reasoning - implications for training and transfer. *Intelligence* **38,** 625–635 (2010).

22. Redick, T. S. & Lindsey, D. R. B. Complex span and n-back measures of working memory: a meta-analysis. *Psychon. Bull. Rev.* **20,** 1102–13 (2013).

23. Cimprich, B. & Ronis, D. L. An environmental intervention to restore attention in women with newly diagnosed breast cancer. *Cancer Nurs.* **26,** 284-292-294 (2003).

24. Tennessen, C. M. & Cimprich, B. Views To Nature: Effects on Attention. *J. Environ. Psychol.* **15,** 77–85 (1995).

25. Kaplan, S., Kaplan, R. & Wendt, J. S. Rated preference and complexity for natural and urban visual material. *Percept. Psychophys.* **12,** 354–356 (1972).

26. Teigen, K. H. Yerkes-Dodson: A Law for All Seasons. *Theory Psychol.* **4,** 525–547 (1994).

27. Berto, R. Exposure to restorative environments helps restore attentional capacity. *J. Environ. Psychol.* **25,** 249–259 (2005).

28. Kaplan, S. & Kaplan, R. *The experience of nature: A psychological perspective*. (Cambridge University Press, 1989).

29. Macmillan, N. A. & Creelman, C. D. *Detection theory: A user's guide*. (Lawrence Erlbaum Associates, 2005).

30. Wagenmakers, E. J. *et al.* Bayesian inference for psychology. Part II: Example applications with JASP. *Psychon. Bull. Rev.* 1–19 (2017). doi:10.3758/s13423-017-1323-7