PSYCHOLOGICAL SCIENCE

Research Report

The Cognitive Benefits of Interacting With Nature

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ABSTRACT—*We compare the restorative effects on cognitive functioning of interactions with natural versus urban environments. Attention restoration theory (ART) provides an analysis of the kinds of environments that lead to improvements in directed-attention abilities. Nature, which is filled with intriguing stimuli,* modestly *grabs attention in a bottom-up fashion, allowing top-down directed-attention abilities a chance to replenish. Unlike natural environments, urban environments are filled with stimulation that captures attention* dramatically *and additionally requires directed attention (e.g., to avoid being hit by a car), making them less restorative. We present two experiments that show that walking in nature or viewing pictures of nature can improve directed-attention abilities as measured with a backwards digit-span task and the Attention Network Task, thus validating attention restoration theory.*

Imagine a therapy that had no known side effects, was readily available, and could improve your cognitive functioning at zero cost. Such a therapy has been known to philosophers, writers, and laypeople alike: interacting with nature. Many have suspected that nature can promote improved cognitive functioning and overall well-being, and these effects have recently been documented.

Attention restoration theory (ART; Kaplan, 1995, 2001) offers a novel approach to identifying and restoring a cognitive mechanism. ART is based on past research showing the separation of attention into two components: involuntary attention, where attention is captured by inherently intriguing or important stimuli, and voluntary or directed attention, where attention is directed by cognitive-control processes. This separation was proposed by James (1892), and subsequent research has validated James' distinction between voluntary and involuntary attention both behaviorally (Fan, McCandliss, Fossella, Flombaum, & Posner, 2002; Jonides, 1981) and neurally (Buschman & Miller, 2007; Corbetta & Shulman, 2002; Fan, McCandliss, Sommer, Raz, & Posner, 2005). In addition to top-down control, directed attention[1] involves resolving conflict, when one needs to suppress distracting stimulation. ART identifies directed attention as the cognitive mechanism that is restored by interactions with nature.

We are not the first to propose a crucial role for directed attention in effective cognitive functioning. One of the main themes of Posner and Rothbart's recent *Annual Review of Psychology* chapter (2007) is this very topic: how directed attention plays a prominent role in successful cognitive and emotional functioning. Additionally, recent research has implicated an important role for directed attention in short-term memory (see Jonides et al., 2008) and school success (Diamond, Barnett, Thomas, & Munro, 2007).

According to ART, interacting with environments rich with inherently fascinating stimuli (e.g., sunsets) invoke *involuntary* attention *modestly*, allowing *directed*-attention mechanisms a chance to replenish (Kaplan, 1995). That is, the requirement for directed attention in such environments is minimized, and attention is typically captured in a bottom-up fashion by features of the environment itself. So, the logic is that, after an interaction with natural environments, one is able to perform better on tasks that depend on directed-attention abilities. Unlike natural environments, urban environments contain bottom-up stimulation (e.g., car horns) that captures attention *dramatically* and additionally requires directed attention to overcome that stimulation (e.g., avoiding traffic, ignoring advertising, etc.), making urban environments less restorative.

Previous research has provided support for the hypothesis that interactions with nature improve attention and memory (Berto, 2005; Cimprich, 1992, 1993; Cimprich & Ronis, 2003; Faber

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[1] Fan et al. (2002, 2005) refer to this type of attention as executive attention.

Taylor, Kuo, & Sullivan, 2002; Hartig et al., 2003; Ottosson & Grahn, 2002; Tennessen & Cimprich, 1995). The present study extends these results. First, we controlled the activities that participants performed while interacting with nature. Second, we used a within-subjects design to compare cognitive functioning after interactions with nature or urban environments. Most importantly, we directly tested ART by predicting which trial-types in an attention task would benefit from interactions with nature and which would not. Such predictions test whether attention is improved in general or whether directed attention specifically is improved after interacting with nature.

EXPERIMENT 1

Experiment 1 was designed to explore how interactions with nature and urban areas would affect cognitive performance as measured with a backwards digit-span task.

Method

Subjects

Thirty-eight[2] (23 females, 15 males; mean age = 22.62 years) University of Michigan students participated in this study. All participants gave informed consent as overseen by the university's institutional review board. Participants were paid $20 per session for their participation.

Measures

We used the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) to assess participants' mood. Mood-related adjectives (e.g., *enthusiastic*) were rated on a scale of 1 to 5 for how well each adjective described participants' current mood (1 = *very slightly or not at all*, 5 = *extremely*). We analyzed only the positive-affect adjectives because these might be related to improvements in cognitive functioning.

We used a backwards digit-span task as our assay of changes in directed-attention performance. Participants heard digit sequences and were required to repeat them in backwards order. Sequences were three to nine digits in length and were presented in increasing length. Correct sequences were scored the same independently of sequence length, with a maximum score of 14 (seven digit lengths times two repetitions of each length). The backwards digit-span task depends on directed-attention abilities because participants must move items in and out of their attentional focus (Cowan, 2001), which is a major component of short-term memory (Jonides et al., 2008).

Procedure

Participants first had their mood assessed with the PANAS. Afterwards, participants performed the backwards digit-span task. Then participants were given a directed-forgetting task that involved the suppression of information in short-term memory, which was used to fatigue participants further. The task consisted of 144 trials and lasted for 35 min. It was thought that taxing participants' directed-attention abilities beyond the backwards digit-span task would increase sensitivity to the effects of the nature intervention.

Participants were then randomly assigned to take a 50- to 55-min walk in the Ann Arbor Arboretum (a park near campus) or to walk in downtown Ann Arbor. The walks were predefined for the participants and were equated in total length (2.8 miles). Each participant was given a map displaying the path of each walk and wore a GPS watch to ensure compliance. The arboretum walk was tree-lined and secluded from traffic and people. The downtown walk was largely on traffic-heavy Huron Street, which is lined with university and office buildings.

After the walk, participants returned to the lab and performed the backwards digit-span task, the PANAS, and answered questions assessing their walk. A week later, participants returned to the lab and repeated the procedure, walking in the complementary location. The order of walking locations was counterbalanced across participants.

Results and Discussion

As indicated in Table 1, performance on backwards digit-span significantly improved when participants walked in nature, but not when they walked downtown. In addition, these results were not driven by changes in mood, nor were they affected by different weather conditions.

To substantiate these conclusions, we conducted a repeated measures analysis of variance (ANOVA) with two within-subjects factors: walking location (nature vs. downtown) and time of test (before walk vs. after walk). The location-by-time interaction was of most interest and was reliable, $F(1, 36) = 6.055$, $p_{\text{rep}} = .95$, showing that the improvement in backwards digit-span performance was greater when walking in nature than

TABLE 1

Behavioral Results From Experiments 1 and 2

	Natural setting		Urban setting	
Measure	Before interaction	After interaction	Before interaction	After interaction
Backward span				
Experiment 1	7.90 (0.37)	9.40 (0.41)	7.90 (0.30)	8.40 (0.33)
Experiment 2	7.92 (0.96)	9.33 (0.86)	7.83 (1.04)	8.83 (0.90)
ANT effects (ms)				
Executive	86 (11.30)	67 (8.45)	81 (15.50)	93 (17.96)
Orienting	47 (6.46)	55 (7.33)	46 (10.01)	43 (4.73)
Alerting	32 (6.86)	31 (5.23)	36 (6.52)	46 (5.63)

Note. The table presents mean scores, with standard errors in parentheses. All of the Attention Network Task (ANT) measures are contrast scores, calculated as follows: executive attention = incongruent response time (RT) – congruent RT; orienting attention = center RT – spatial RT; alerting attention = no-cue RT – center-cue RT.

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[2] One participant was removed for having an extremely low initial backwards digit-span score. Two participants had missing mood data.

when walking downtown (1.50 digits vs. 0.50 digits). With paired t tests we explored the main effects and found that the improvement when walking in nature was highly reliable, $t(36) = 4.783, p_{\text{rep}} = .99$; but it was not when walking downtown, $t(36) = 1.708$, $p_{\text{rep}} = .88$. Furthermore, there were no main effects or interactions associated with walking order (i.e., nature walk first or second). Therefore, the restorative effects of nature improved performance beyond simply repeating the backwards digit-span task a second time.

The month during which subjects were tested was added as a between-subjects factor (four levels: September, November, January, and July) to our initial ANOVA, but it was not reliable, $F(3, 33) = .998$, showing that the season in which subjects were tested had no impact. In a separate repeated measures ANOVA with mood as the dependent variable, we found that mood improved when participants walked in nature compared to downtown, $F(1, 35) = 9.639, p_{\text{rep}} = .98$, but changes in mood did not correlate with changes in backwards digit-span performance (nature: $r = .206$, $p_{\text{rep}} = .80$; downtown: $r = .029$, $p_{\text{rep}} = .54$).

Finally, participants' ratings for how refreshing the nature walk was did correlate reliably with postwalk backwards digit-span scores, $r = .41, p_{\text{rep}} = .96$, when baseline digit-span scores were partialed out. This finding indicates that participants may have had some awareness of the refreshing quality of a walk in nature. In summary, interactions with nature improved directed-attention abilities as assessed with a backwards digit-span task. This finding is consistent with ART.

EXPERIMENT 2

Our aim in Experiment 2 was to test ART by using the Attention Network Test (ANT; Fan et al., 2002, 2005; we used the ANT version from Jin Fan's Web site: http://www.sacklerinstitute.org/users/jin.fan/). This task identifies three different attentional functions: alerting, orienting, and executive attention. These different functions are dissociable both behaviorally (i.e., Fan et al., 2002) and neurally (Fan et al., 2005). We predicted that interactions with nature would improve only executive functions, but not alerting and orienting, because these latter two functions require less cognitive control compared to executive functions.

Method

Subjects

Twelve (8 females, 4 males; mean age = 24.25 years) University of Michigan students participated in this study. All participants gave informed consent as administered by the university's institutional review board. Participants were paid $20 per session for their participation.

Measures

The PANAS and backwards digit-span task were used as in Experiment 1 to replicate those results. In addition, we administered the ANT, in which participants responded to the direction of a centrally presented arrow. *Alerting* contrasts trials in which a central cue alerts participants that an upcoming trial is approaching with trials in which no cue is given (the cue facilitates performance). *Orienting* contrasts trials in which a spatial cue informs participants where the arrows will appear (top or bottom) with trials in which a center cue provides no spatial information (here, the spatial cue facilitates performance). *Executive attention* contrasts trials in which the direction of the center arrow is incongruent with the direction of flanking arrows with trials in which the direction of the flanking arrows matches the center arrow (here, incongruency worsens performance). There were 96 congruent trials, 96 incongruent trials, 72 spatial-cue trials, 72 center-cue trials, and 72 no-cue trials. In addition, there were 72 trials that had a double asterisk cue (appearing at the top and bottom of the display) and 96 trials that had no flanking stimuli surrounding the target arrow. There were 288 trials total in this task. A schematic diagram of the ANT is shown in Figure 1.

Procedure

In Experiment 2, participants viewed either pictures of nature or urban areas to further control each participant's experience. Research has shown that merely viewing pictures of nature can have restorative benefits (e.g., Berto, 2005).

Participants performed the PANAS and the backwards digit-span task as in Experiment 1. Participants then performed the ANT, after which they viewed pictures of either nature (scenery of Nova Scotia) or urban settings (pictures of Ann Arbor, Detroit, and Chicago).[3] Picture viewing lasted approximately 10 min, during which participants rated on a scale of 1 to 3 how much they liked each picture; there were 50 nature and 50 urban pictures. Pictures were displayed for 7 s, followed by a rating interval that lasted until the participant responded. After picture viewing, participants performed the backwards digit-span task, the ANT, and the PANAS a second time. Participants returned to the lab a week later and performed the same procedure, but viewed the complementary set of pictures. The order of picture type was counterbalanced across the participants.

Results and Discussion

Our results verified our predictions based on ART; improvements were found only on the executive portions of the ANT and only after viewing pictures of nature compared to urban areas. Furthermore, we replicated the results of Experiment 1 as participants reliably improved their backwards digit-span only when viewing pictures of nature.

We were led to these conclusions by a multivariate (executive, orienting, and alerting) repeated measures ANOVA on ANT response time for correct trials with two within-subjects factors:

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[3] Our stimuli can be downloaded at http://www-personal.umich.edu/~bermanm/RestorationPictures/.

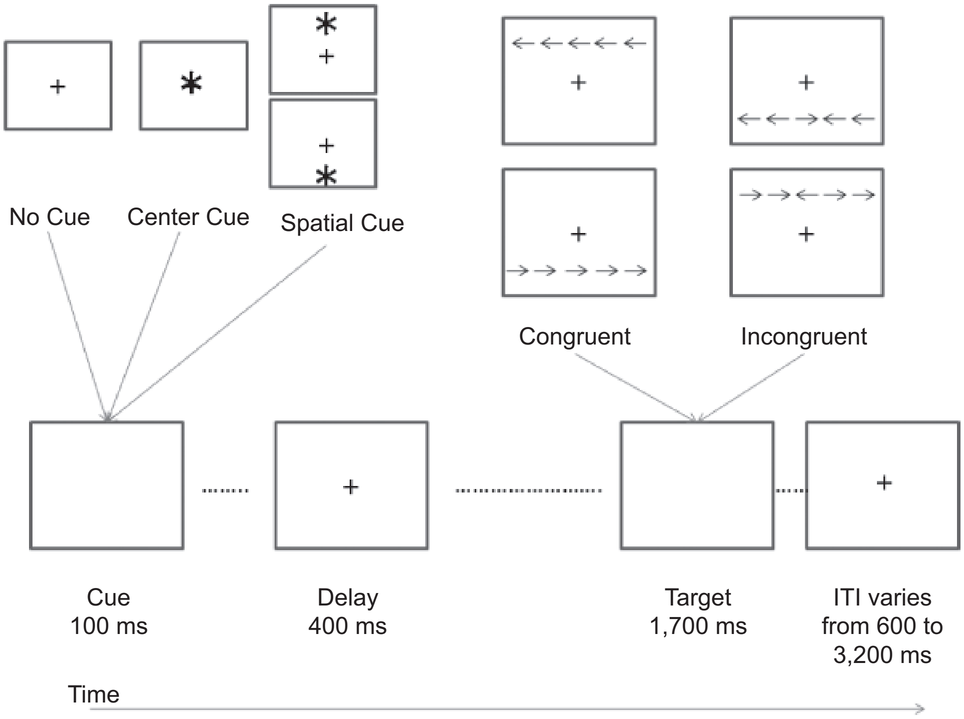

Fig. 1. Schematic diagram of the Attention Network Task (adapted from Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Initially, participants encountered one of the three cue types that are shown in the upper left of the figure: a centrally presented cue, warning that a target was approaching; a spatial cue, indicating where the target would appear; or no cue to provide spatial or anticipatory information. After a delay interval, participants saw a set of arrows either at the top or at the bottom of the display and were required to respond to the direction of the center arrow. The different target types are shown in the upper right of the figure. In congruent targets, all arrows pointed in the same direction, and in incongruent targets, the center arrow pointed in a different direction from the flanking arrows. Executive attention is represented as the difference in accuracy (ACC) and response time (RT) between congruent and incongruent targets, averaging over all preceding cue types (i.e., no cue, central cue, spatial cue). Orienting attention is represented as the difference in performance (ACC and RT) between spatial-cue trials and center-cue trials, averaging over all target types (i.e., congruent and incongruent targets). Alerting attention is represented as the difference in performance (ACC and RT) between center-cue trials and no-cue trials, averaging over all target types (i.e., congruent and incongruent targets). The intertrial interval (ITI) varied between 600 and 3,200 ms (averaging 2,400 ms) and depended in part on the participant's response. See Fan et al. (2005) for more details.

the picture type viewed (nature vs. urban) and the time of test (before picture viewing vs. after picture viewing). The picture-type-by-time interaction was of most interest and was found reliable only for the executive portions of the ANT, indicating that exposure to pictures of nature led to more improved executive attention performance than did exposure to urban pictures, $F(1, 10) = 17.089$, $p_{\text{rep}} = .99$. In all analyses, there were no main effects or interactions associated with picture-viewing order (i.e., viewing the nature pictures first or second). As predicted, no reliable differences were found on alerting or orienting contrasts when participants viewed pictures of nature compared to urban pictures. Overall, performance was quite accurate (i.e., $\geq 91\%$), and no reliable changes were associated with accuracy.

We conducted a separate repeated measures ANOVA for backward span. The location-by-time interaction was not reliable, $F(1, 10) = 0.486$, $p_{\text{rep}} = .68$. However, when we explored the main effects with paired t tests, we found that performance on the backwards digit-span task only improved reliably when viewing pictures of nature, $t(11) = 2.972$, $p_{\text{rep}} = .96$, but not when viewing pictures of urban areas, $t(11) = 1.436$, $p_{\text{rep}} = .83$. The ANT and backwards digit-span results can be seen in Table 1.

No reliable changes in mood were found when participants viewed pictures of nature versus pictures of urban areas, $t(11) = .03$, $p_{\text{rep}} = .51$. However, participants rated viewing pictures of nature as significantly more refreshing, $t(11) = 4.45$, $p_{\text{rep}} = .99$, and more enjoyable, $t(11) = 3.35$, $p_{\text{rep}} = .97$, than pictures of urban areas. In addition, liking ratings of the nature pictures were greater than those of the urban pictures, $t(11) = 3.70$, $p_{\text{rep}} = .98$. These ratings did not correlate reliably with changes in performance on the backwards digit-span task or the ANT, but were positive.

In sum, Experiment 2 extended the results of Experiment 1, confirming that improvements achieved through interacting with nature were selective to directing attention. If interactions with nature had improved all portions of the ANT, alternative explanations, such as increases in motivation or effort induced by interactions with nature, may have been tenable. Additionally, we replicated the findings of Experiment 1 with the backwards digit-span task.

GENERAL DISCUSSION

Taken together, these experiments demonstrate the restorative value of nature as a vehicle to improve cognitive functioning. These data are of particular interest especially when one considers the difficulty of discovering training regimens that are intended to improve cognitive performance in any way (Posner & Rothbart, 2007, but see Jaeggi, Buschkuehl, Jonides, & Perrig, 2008).

We can be confident that directed-attention mechanisms were restored in these studies because only portions of the ANT that involved directed attention were improved by interactions with nature. Moreover, the backwards digit-span task relies heavily on directed-attention mechanisms because such working memory measures have a large attentional component (Jonides et al., 2008) as items are moved in and out of the focus of attention. Each of our experiments showed consistent improvement on the backwards digit-span task as a function of interactions with nature. There were also indications that participants' perceptions of the restorative value of nature were valid, as these perceptions correlated with improvements on the backwards digit-span task.

Nature may also be more peaceful than other environments, thereby restoring directed-attention abilities. However, in Experiment 2, the environments were equally peaceful (i.e., both were in a quiet experimental room), yet only viewing pictures of nature produced cognitive improvements. We concur that there is an important peaceful element to nature, but believe that this peacefulness is driven by natural environments capturing attention modestly and limiting directed attention—not to sheer quiescence alone.

Other interventions have been found that alter cognitive performance, such as glucose consumption, which can improve performance on cognitive and self-regulatory tasks and worsen performance when glucose is depleted (Gailliot et al., 2007). Chervin et al. (2006) have shown similar effects with sleep. Meditation may be another intervention able to restore directed-attention abilities (Kaplan, 2001; Slagter et al., 2007; Tang et al., 2007). Therefore, it is important to compare the effects of these interventions with that of nature and to see whether these interventions affect similar cognitive mechanisms.

In sum, we have shown that simple and brief interactions with nature can produce marked increases in cognitive control. To consider the availability of nature as merely an amenity fails to recognize the vital importance of nature in effective cognitive functioning.

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