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Exposure to restorative environments helps restore attentional capacity

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Abstract

Three experiments were designed to test the hypothesis that exposure to restorative environments facilitates recovery from mental fatigue. To this end, participants were first mentally fatigued by performing a sustained attention test; then they viewed photographs of restorative environments, nonrestorative environments or geometrical patterns; and finally they performed the sustained attention test again. Only participants exposed to the restorative environments improved their performance on the final attention test, and this improvement occurred whether they viewed the scenes in the standardized time condition or in the self-paced time condition. Results are in agreement with Kaplan's [(1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*, 169–182] attention restoration theory, and support the idea that restorative environments help maintain and restore the capacity to direct attention.

Keywords: Restorative environments; Directed attention

1. Introduction

An approach to understanding the restoration process and the effects of *restorative environments* on psychological well-being is provided by Kaplan's (1995) *attention restoration theory* (ART), a cognitive framework concerned with recovery from mental fatigue or *directed attention fatigue* (DAF; Kaplan S., 2001). Mental fatigue occurs when after prolonged and intense use, the capacity to direct attention is reduced and the capacity to ward off distractions diminishes (Cohen & Spacapan, 1978). In ART, Kaplan (1995) distinguishes between *directed attention* and *fascination*, following James' (1892) distinction between *voluntary* and *involuntary* attention. Voluntary attention is effortful and can be tiring, whereas involuntary attention is effortless and allows the attentional system to rest and recover.

Restorative environments should indeed facilitate recovery from DAF. A stay in an environment that does not require reliance on directed attention would allow the attentionally fatigued person to rest the inhibitory mechanism on which directed attention depends, and thus recover the capacity to direct attention. James (1892) observed that certain elements in the natural environment are effortlessly engaging and, on this basis, Kaplan also considers the natural environment experience to be a particularly effective means of recovering from mental fatigue.

There is now a large body of data demonstrating that natural environments are more restorative than urban environments (Herzog, Black, Fountaine, & Knotts, 1997; Herzog, Chen, & Primeau, 2002; Kaplan, 1995; Kaplan R., 2001; Purcell, Peron, & Berto, 2001; Tennessen & Cimprich, 1995; Ulrich, 1984; Ulrich et al., 1991). For example, Tennessen and Cimprich (1995) showed that, compared to university dormitory residents with less natural views from their windows, those

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with more natural views scored better on tests of directed attention and rated their attentional functioning as more effective. The capacity to direct attention was measured using a battery of objective (Forward and Backward Digit Span Test, the Symbol Digit Modalities Test, the Necker Cube Pattern Control test) and subjective tests (Attentional Function Index).

That study provided initial evidence of a positive relationship between natural views and the capacity to direct attention. The present experiment extends that research in several ways. First, it enhances the methodology by providing baseline information about initial attentional capacity, it uses an experimental design with random assignment to increase internal validity, and provides experimental control by conducting the experiment in a laboratory. As discussed below, it also uses a new way of exhausting and testing attentional capacity.

It is known that differential effects of natural and urban environments can quickly appear in physiology (4 min; Ulrich et al., 1991), and in emotional states (within 10–15 min; Ulrich, 1979). On the other hand, environmental effects on performance did not consistently emerge after 15–20 min (Hartig, Book, Garvill, Olsson, & Garling, 1996). Researchers may use different indices of attention. For example, Hartig, Evans, Jamner, Davis, and Garling's (2003) tracked restoration along different dimensions: the monitoring of systolic and diastolic blood pressure (SBP, DBP), the assessment of the emotional states (Zuckerman's Inventory of Personal Reactions—ZIPERS) and the measure of the performance (Necker Cuba Pattern Control Test—NCPCT, Search Memory Test—SMT) before, during and after the environmental treatments in natural and urban field settings. The environmental treatments affected NCPCT scores but not SMT scores. It is noteworthy that the NCPCT had also been a sensitive measure in previous studies on restorative environments (Tennessen & Cimprich, 1995), whereas the SMT test has already proven insensitive to natural–urban comparisons in two laboratory experiments (Hartig et al., 1996; these authors attributed the nonsignificant results to the brief period of 50 min during which subjects viewed the photographic simulations). In Hartig et al. (2003) study, neither the environments, nor the task exerted any significant influence. In sum subjects showed changes in attentiveness during the experiment, an effect not directly affected by the environment or the task condition, but more likely due to performance decrements in the urban environments than to the performance increments in the natural environments. Thus only the negative effect of the urban environments emerged.

On the contrary, many studies highlight the positive effects of natural environments on attention in particular, and on human effectiveness in general. In the present study the positive effect of the restorative environments on attentional performance will be investigated. In research on restorative environments, the only studies that directly measured the regeneration of attentional capacity were studies by Hartig, Mang, and Evans (1991), Hartig et al. (1996), Tennessen and Cimprich (1995), Hartig et al. (2003), and Laumann, Garling, and Stormark (2003). To evaluate ART, it is important to choose a task that adequately measures 'directed attention,' which is defined as 'the ability to control distractions through the use of inhibitory mechanisms' (James, 1892).

After considering a variety of options, the *Sustained Attention to Response Test* (SART) was chosen. The SART fits the definition of directed attention, and implies concepts like inhibition of stimuli, production of a response, and depletion of inhibitory capacity. The idea to use the SART arose from reading the definition of the *absent mind* (Manly, Robertson, Galloway, & Hawkins, 1999), which refers to being inattentive to ongoing activity, losing track of current aims, and becoming distracted from intended thoughts or actions by salient but irrelevant stimuli in the immediate surroundings. This definition is very similar to that of depletion of directed attention capacity, which includes the inability to focus on important goals or activities and the inability to inhibit distractions. Such 'slips' tend to happen when attention to the task, action, thought, and so on, decays through such factors as boredom and worry, or through dividing attention simultaneously among several tasks, actions, and thoughts (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997).

The sustained attention system (Posner & Petersen, 1990) is important in such errors. Sustained attention is defined as the ability to self-sustain mindful, conscious processing of stimuli whose repetitive, nonarousing qualities would otherwise lead to habituation as well as attention to other distracting stimuli. The state of mental fatigue is experienced as a subjective sense that one's mind has been absent from the activity in which one is engaged and it is most often associated with performance errors. In fact, the SART correlates with the everyday failures questionnaire (CFQ; Broadbent, Cooper, Fitzgerald, & Parker, 1982), a measure of errors in everyday life that occur because of inattentiveness.

This experiment was designed to evaluate whether restorative environments could improve attention performance. To this aim, participants were first mentally fatigued by performing the sustained attention test, then they were exposed to restorative or nonrestorative environments, and then they performed the sustained attention test for a second time. Considering that ART and the literature suggests that our capacity to direct attention can be renewed most effectively by contact with nature, the performance of participants exposed to natural restorative environments was expected to be better than the performance of the other group.

2. Experiment 1

The aim of Experiment 1 was to verify whether viewing restorative environments could improve performance on an attention task. Consistent with ART (Kaplan, 1995), it was hypothesized that restorative environments could renew depleted attentional capacity. To this end, a group of students were first mentally fatigued by performing a sustained attention task, then they viewed a series of environmental scenes preselected to be restorative or nonrestorative, and finally they performed the sustained attention task again. Participants who viewed the restorative environments were expected to perform better on the post-test than participants exposed to the nonrestorative environments, because exposure to the restorative environments should allow the attentional system to regenerate.

3. Method

3.1. Participants

Thirty-two undergraduate students (mean age = 23, S.D. = 3.22) at the University of Padova (Italy) took part in Experiment 1. Sixteen subjects (eight males and eight females) viewed the restorative environments, whereas the other sixteen (eight males and eight females) viewed the nonrestorative scenes. Participants were randomly assigned to conditions.

3.2. Development of stimulus materials

In a prescaling study done prior to Experiment 1, 40 undergraduate males and females (mean age = 26, S.D. = 5.23) at the University of Padova (Italy) assisted in developing the environmental stimuli for the experiment. A large number of photographs of different types of scenes were systematically collected from magazines and existing stimulus materials. The goal was to sample as wide a variety of settings as possible, some natural, others built, and others a mix of built and natural. No settings contained people. One hundred color pictures were eventually collected, representing lakes, rivers, seas, hills, woods, orchards, forests, city riversides, city streets, industrial zones, housing, porches, urban areas, and skyscrapers. The scenes were divided into five groups, each containing 20 randomly chosen pictures; each set of 20 pictures was rated by eight undergraduate students as described below. The pictures were transformed into slides in order to project them onto a screen.

Each participant was asked to rate the restorative value of each scene, using a short version of Korpela and Hartig's (1996) *Perceived Restorativeness Scale* (PRS). The original PRS contains 29 items and measures perceptions of five restorative qualities: *being-away, fascination*, *coherence*, *scope* and *compatibility* (for more details on the PRS factor structure see, Korpela & Hartig, 1996). The PRS short version uses a single item to measure each of the five factors, each rated on an 11-point scale (0 = not at all, 5 = rather, 10 = completely) (Berto, 2001; Peron, Berto, & Purcell, 2002).

The instructions to the PRS short version said: 'We are interested in how you experience the place in the photograph. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then ask yourself, 'How much does this statement apply to how I would experience the place?' To indicate your answer, circle only one of the numbers on the rating scale beside the statements. So, for example, if you think that the statement does not apply to your experience of the place, then you would circle '0' (not at all), if it applies rather much, then you would circle '6' (rather much), but if you think that it would apply very much, you would circle '10' (very much)'.

The statements of the PRS short version follow, with the corresponding ART factor in parentheses:

- That is a place which is away from everyday demands and where I would be able to relax and think about what interests me (*being-away*);
- That place is fascinating; it is large enough for me to discover and be curious about things (*fascination*);
- That is a place where the activities and the items are ordered and organized (*coherence*);
- That is a place which is very large, with no restrictions to movements; it is a world of its own (*scope*);
- In that place, it is easy to orient and move around so that I could do what I like (*compatibility*).

Participants were tested in the Environmental Psychology laboratory individually or in small groups. The experimenter began by showing two practice slides to familiarize participants with the task. These two slides were always the same within each set; they were considered filler slides and were not analysed. Next, ten slides were projected and rated. Then a brief distraction task (counting backwards by sevens, from 100 to 0) was used to prevent participants from getting accustomed to the task. Then the remaining ten slides were projected and rated.

Cronbach's alpha (α) was calculated to check the reliability of the PRS short version. The result was .79. Though the reliability of the PRS short version was lower than the PRS original version (.94; Purcell et al., 2001), it can be considered a reliable instrument.

A mean across the 5 items was used to provide scores for selecting the stimulus pictures. Pictures with a 'restorativeness' score equal to or greater than 6.5, or

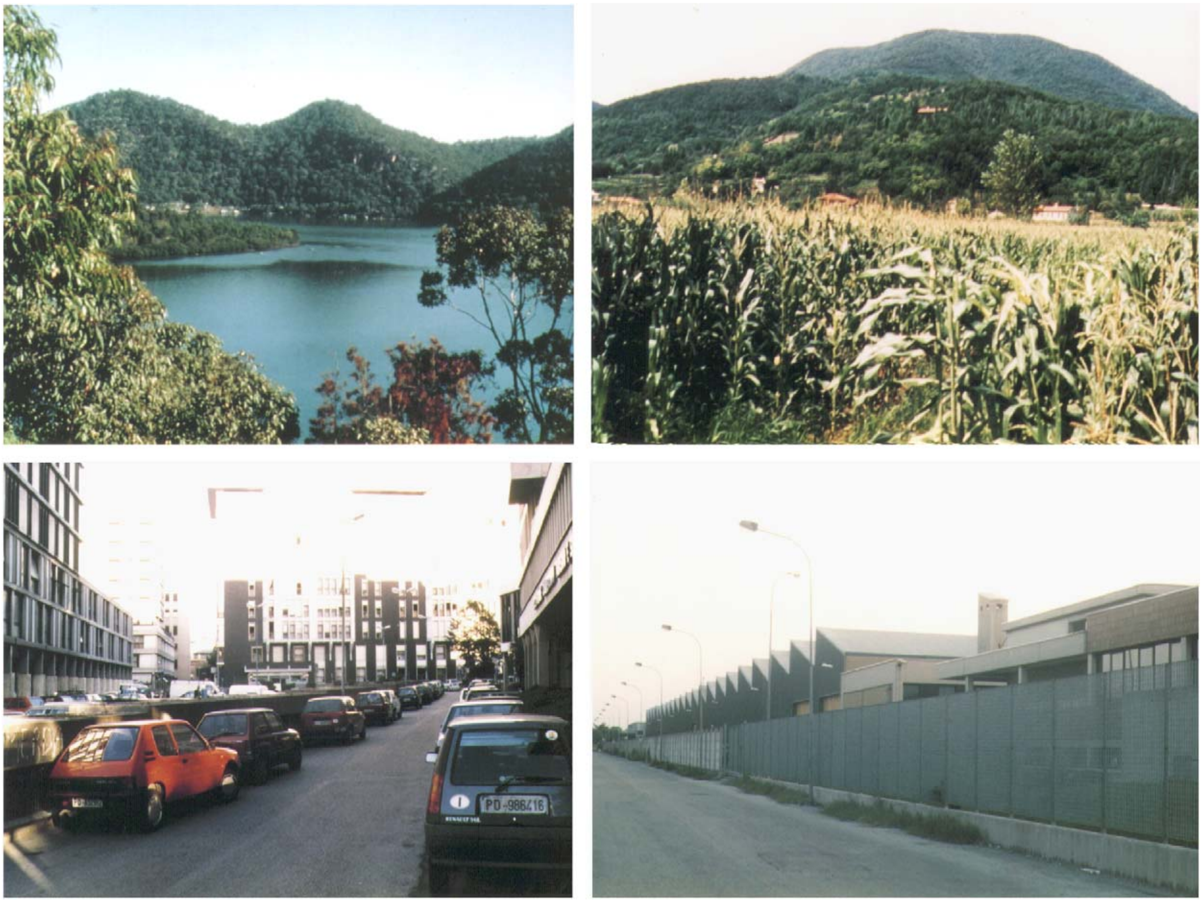

Fig. 1. The two upper pictures are examples of restorative environments, the two lower pictures are examples of nonrestorative environments.

equal to or less than 3 were chosen. Among the 100 pictures, only 50 met those requirements: 25 were high in restorativeness (all were nature scenes of lakes, rivers, sea, hills) and 25 were very low in restorativeness (none were nature scenes; they were city streets, industrial zone, housing). The two groups of pictures were labeled 'restorative' and 'nonrestorative' and used in Experiment 1. The 50 slides were digitalized to be shown on the computer screen (see Fig. 1).

3.3. Experimental paradigm

The SART paradigm was used to measure participants' attentional capacity. The SART is a computer-administered paradigm that measures sustained attention (Robertson et al., 1997) and/or inhibition capacity (Manly et al., 1999). The task presents repetitive and temporally predictable stimuli (digits from one to nine) to which participants are required to respond with a key press to all stimuli except the target stimulus. It is a continuous performance test because it requires participants to monitor long sequences of stimuli and change their response (i.e. not respond) on detecting infrequent targets. The SART is a brief and conceptually simple test but very demanding This laboratory task is predictive of everyday failures and action slips in brain injured patients and normal control participants (Robertson et al., 1997). The SART is a short laboratory test and though it lasts no more than 5 min and is an easy task to pick up, it is very cognitively fatiguing. There is no working memory and/or short-term memory load (there is only one target to keep in mind), and no learning effects.

The SART 10 version was used; it consisted of 240 digits from one to nine (24 different digit combinations); 10% of the 240 digits were targets (24 targets). The digit '3' was the target, the other digits were nontargets. Digits were presented on the computer screen every 1125 ms and remained on the screen for 250 ms. Participants had to press the spacebar on the keyboard any time they saw a nontarget digit and to avoid pressing the spacebar when the target appeared. A good performance required that participants remain sufficiently attentive to their responses that at the appearance of the target they could substitute the directly antagonistic response of 'not pressing'.

3.4. Procedure

Participants were individually tested in the Environmental Psychology laboratory. They sat in front of a computer and the SART instructions appeared on the screen. At the end of the SART performance, participants were seated in front of another computer at 1 m distance. To focus attention on the computer screen, the room was dimly lighted and there were no distractions adjacent to the computer or on the wall behind it. The experimenter told the participants that a series of pictures of environments would be shown; they had only to look freely at the pictures, and no other tasks would be related to the picture content. Half of the participants (16: eight males and eight females) were exposed to the 25 restorative pictures whereas the other half to the 25 nonrestorative pictures. Each picture stayed on the screen for 15 s (Henderson, Weeks, & Hollingworth, 1999; Herzog, 1985). At the end of the picture exposure, the room light was turned on and participants returned to the first computer and performed the sustained attention test again.

4. Results

Preliminary analyses indicated there were no main or interactive effects involving participant sex, and that variable is not considered further.

The following variables were considered:

- *d-prime* (D-P): participant's sensitivity in the detection of the target;
- *reaction times* in milleseconds (RT): the latency to press the spacebar;
- *number of correct responses* (CR): participant did not press the spacebar when the target (digit 3) appeared. The total number of CR is 24;
- *number of incorrect responses* (IR): the participant pressed the spacebar although the target was present.

The main aim of this experiment was to ask whether an attentional improvement or impairment occurred between the SART performance before (Session 1) and after (Session 2) exposure to the environmental scenes. The comparisons of greatest interest to this question are between Sessions 1 and 2 within each group (restorative and nonrestorative); secondarily the differences between the two groups on Session 2 will be considered as well.

Obviously, to examine the impact of treatments, Session 1 performances (i.e. before the picture exposure) of the two groups should not be significantly different. Thus, before performing any analyses, the mean number of CR, IR, the mean D-P, and the mean RT from Session 1 were calculated and compared for the two groups, using four independent samples *t*-tests (see Table 1). No significant differences emerged, thereby justifying additional comparisons.

Table 1
Experiment 1. Mean d-primes, reaction times, numbers of correct and incorrect responses in Sessions 1 (before the picture exposure) and 2 (after the picture exposure) for the restorative and nonrestorative groups

	Session	Restorative	Nonrestorative	*P*
D-prime	1	1.40 (.71)	1.97 (.96)	ns
	2	1.86 (.89)	2.00 (.95)	ns
p		$<.05$	ns	
Reaction times (in ms)	1	313.71 (38.36)	319.59 (70.98)	ns
	2	267.38 (73.78)	299.61 (41.43)	$<.05$
p		$<.05$	ns	
Correct responses	1	11.68 (5.28)	13.25 (5.09)	ns
	2	13.62 (5.37)	13.00 (5.4)	ns
p		$<.05$	ns	
Incorrect responses	1	1.81 (3.83)	3.25 (6.22)	ns
	2	2.06 (4.79)	1.62 (4.96)	ns
p		ns	$<.05$	

Standard deviations are in parentheses.

The mean SART performance scores (D-P, RT, CR and IR) were calculated for Session 2 in order to perform comparisons between Sessions 1 and 2 within each group, using dependent *t*-tests (see Table 1). As expected, for the restorative group, three of these comparisons yielded significant differences, and performance scores supported the hypothesis that nature scenes would be restorative and result in improved performance, for D-P, $t(15) = -2.87$, $p = .01$, for RT, $t(15) = 2.29$, $p = .03$, for CR, $t(15) = -2.10$, $p = .04$. For the nonrestorative group, these same comparisons yielded nonsignificant effects, for D-P, $t(15) = -.09$, $p = .92$, for RT, $t(15) = -.91$, $p = .37$, for CR, $t(15) = .25$, $p = .80$. Although this pattern was not expected, IR did not differ in the restorative scenes group, $t(15) = -.36$, $p = .72$, but they did differ in the nonrestorative scenes group, $t(15) = 3.05$, $p = .00$, and the pattern of means indicated better performance (fewer errors) in Session 2.

Of secondary interest are comparisons during Session 2 between the restorative and nonrestorative groups. Only the mean RT differed significantly, $t(30) = -2.19$, $p = .03$, and the restorative group was faster, for D-P, $t(30) = -.40$, $p = .68$, for CR, $t(30) = .32$, $p = .74$, for IR, $t(30) = .25$, $p = .80$.

5. Discussion

This experiment asked whether exposure to restorative environments could actually restore one's ability to focus attention. Any prolonged mental effort leads to DAF, and although the SART was a brief test, it was very demanding, therefore it was inevitable that participants became fatigued. Only the participants exposed to the series of restorative environments regained their attentional capacity to a sufficient degree to be able to perform well on the post-test. The post-test improvement of the restorative group could not be due to learning, because the SART is insensitive to that effect (Manly et al., 1999; Robertson et al., 1997). Furthermore, if the performance improvement of the restorative group was due to learning effects, the nonrestorative group should have improved as well.

6. Experiment 2

Directed attention is very taxing because not only does one have to focus on a particular stimuli, she or he must also deliberately ignore distractions in the environment. This capacity is susceptible to fatigue, and spending time in restorative environments allows this mechanism to rest and be regenerated. Kaplan (1995) states that restorative environments are innately fascinating, and therefore do not require directed attention. Thus, a restorative environment is effortless to examine, whereas a nonrestorative environment is effortful. In a restorative environment, people do not have to focus on particular information nor do they have to avoid attending to distractions.

What would happen if participants were exposed to effortless material different from natural restorative environments? Will their attentional capacity regenerate in the same way? Experiment 2 was designed to ask whether and in which way nonenvironments can affect performance. The procedure was the same as in Experiment 1: induction of a state of mental fatigue via a sustained attention task, viewing a series of pictures, and finally, a second performance of the sustained attention task. The difference was in the stimulus materials, which in Experiment 2 consisted of geometrical patterns.

In addition to evaluating the effect of a different kind of material on performance, the data of Experiments 1 and 2 were considered together, comparing the effect of the three different materials (restorative environments, nonrestorative environments and geometrical patterns) on cognitive performance. Expectations are difficult to formulate. If geometrical patterns are viewed effortlessly, they should not overload the attentional system but instead should help in recovery from mental fatigue.

7. Method

7.1. Participants

Thirty-two undergraduate students not involved in the previous experiments (half males and half females; mean age = 23, S.D. = 3.22) at the University of Padova (Italy) took part in the experiment.

7.2. Material

Materials were 25 color stimuli representing geometrical patterns (see Fig. 2). Four cognitive psychologists selected the stimulus materials from a larger set of geometric patterns; they selected stimuli they considered to be effortless to view. The stimuli were shown for 15 s each.

7.3. Procedure

The procedure was the same as used in Experiment 1.

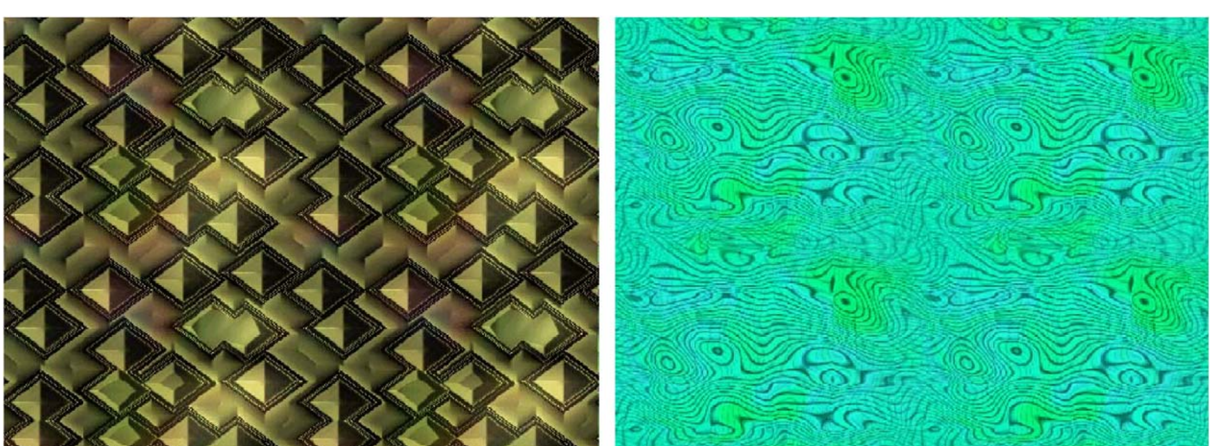

Fig. 2. Example of geometrical patterns.

8. Results

The mean D-P, the mean RT, the mean number of CR and, IR were calculated for Sessions 1 and 2 (see Table 2). Four paired samples t-tests were performed on these means. No significant differences emerged.

At this point the data of Experiments 1 and 2 were considered together and a multivariate ANOVA was performed to evaluate whether the three groups differed. Though the number of the participants exposed to the geometrical patterns (32) was twice the number of the participants exposed to the restorative and nonrestorative environments (16 each) in Experiment 1, no significant differences emerged from the MANOVA used to compare the means of Session 1. Therefore, three groups were initially equivalent and their Session 2 performance scores could be compared.

A second multivariate ANOVA was performed to test whether there was a significant effect on post-test performance. Group, that is, the material shown (restorative environments, nonrestorative environments, geometrical patterns), was the between subjects factor and the dependent variables were: the mean D-P, the mean RT, and the mean number of CR and IR for Session 2. Main effects for GROUP emerged on the mean number of CR, $F(2, 61) = 4.60$, $p = .01$, $R^2 = .10$ (the restorative group produced the greater number of CRs), and on the mean RT, $F(2, 61) = 5.57$, $p = .00$, $R^2 = .01$ (the restorative group was the fastest) (see Tables 1 and 2).

No differences between the sexes emerged from these analyses.

Table 2
Experiment 2. Mean d-primes, reaction times, and numbers of correct and incorrect responses in Sessions 1 (before exposure to the geometrical patterns) and 2 (after exposure)

Patterns	Session	Geometric
D-prime	1	1.98 (.92)
	2	1.95 (1.01)
p		ns
Reaction times (in ms)	1	310.24 (43.89)
	2	289.46 (55.2)
p		ns
Correct responses	1	13.90 (5.15)
	2	13.59 (5.66)
p		ns
Incorrect responses	1	1.5 (2.59)
	2	1.71 (3.12)
p		ns

Standard deviations are in parentheses.

9. Discussion

Pictures of 'nonenvironments' were not restorative. Though the pictures were simple geometrical patterns that should take little effort to view, post-test performance did not improve, suggesting that no restoration of attentional capacity had occurred. Furthermore, in comparison to the restorative and nonrestorative groups, this group's performance was in the middle. Thus, the geometrical patterns did not appear to overload the attentional system and further undermine performance. They did not negatively affect post-test performance, but neither did they restore participants from mental fatigue. Perhaps the stimuli were not innately interesting and did not generate enough fascination to serve a restorative function, or perhaps all four of Kaplan's criteria are needed for an environment to be truly restorative. This point will be discussed further in Section 14. The results of Experiment 2 support the view that only environments high in restorativeness can relieve mental fatigue and support recovery of attentional capacity.

10. Experiment 3

Experiment 1 showed that a brief exposure to a series of restorative environments could help people recover from a state of induced mental fatigue. Participants viewed each scene for 15 s (less than 10 min total), and that turned out to be sufficient to produce significant results. If participants were exposed to the restorative pictures for a longer time, would their performance improve further? If participants could choose how long to look at each picture, would they look longer at the restorative pictures for their innate fascination?

The aim of Experiment 3 was to answer these questions. The experiment was a systematic replication of Experiment 1, but in Experiment 3 participants decided how long to look at each picture. The restorative environments were expected to be viewed for a longer time than the nonrestorative environments. Furthermore, participants exposed to the restorative environments in the self-paced condition should perform even better than those exposed to the restorative environments in the standard time condition of Experiment 1. If they looked at the restorative environments longer, their attentional system should regenerate more and the post-test performance should improve even more.

11. Method

11.1. Participants

Thirty-two undergraduate students not involved in the previous experiments (half males and half females;

mean age = 22, s.d. = 4.49) at the University of Padova (Italy) took part in this experiment. Participants were randomly assigned to conditions.

11.2. Material

The same 25 *restorative* and 25 nonrestorative pictures from Experiment 1 were used.

11.3. Procedure

The procedure was the same as Experiments 1 and 2. First participants were mentally fatigued via the SART attention task, then they viewed the pictures, and finally they performed the attention task again. This experiment differed in picture exposure times. Whereas picture exposure time was standardized in Experiments 1 and 2 (15 s per picture), in Experiment 3, it was self-determined. Each participant in each group (restorative and nonrestorative) could decide how long to look at each picture by just pressing a key on the keyboard when s/he wanted to pass to the next picture. Viewing time was recorded automatically for each picture.

12. Results

As in Experiment 1, the mean D-P, the mean RT and the mean numbers of CR and IR of Session 1 were calculated for each group. To assure the two groups were equivalent a priori, four independent samples' *t*-tests were run on Session 1 task performance means. No significant differences emerged. Thus the groups were equal initially, and any differences in performance during the second session could be attributed to the experimental treatment.

First, self-paced exposure time was considered. The mean time each picture was viewed was computed and these times were compared for the restorative and nonrestorative scenes, using an independent samples *t*-test. Restorative environments were viewed for a mean of 7038.79 ms (s.d. = 1237.24), whereas the nonrestorative pictures were viewed for a mean of 5104.35 ms (s.d. = 620.51), a significant difference, $t(48) = 6.98$, $p < .05$.

The mean D-P, the mean RT, and the mean numbers of CR and IR were calculated also for Session 2 of both groups (see Table 3).

The main aim of Experiment 3 was to ask whether an attentional improvement or impairment occurred between the SART performance before (Session 1) and after (Session 2) exposure to the environmental scenes. The comparisons of greatest interest to this question are between Sessions 1 and 2 within each group (restorative and nonrestorative); secondarily the differences between the two groups on Session 2 will be considered as well.

Table 3
Experiment 3, self-paced participants. Mean d-primes, reaction times, and numbers of correct and incorrect responses in Sessions 1 (before the picture exposure) and 2 (after the picture exposure) of the restorative and nonrestorative groups

	Session	Restorative	Nonrestorative	*p*
D-prime	1	2.12 (1.08)	1.79 (1.24)	ns
	2	2.47 (1.04)	2.03 (.93)	ns
p		< .05	ns	
Reaction times	1	311.27 (35.6)	306.21 (78.79)	ns
(in ms)	2	302.22 (32.09)	297.91 (52.98)	ns
p		ns	ns	
Correct	1	14.81 (5.55)	12.5 (6.36)	ns
Responses	2	17.12 (4.09)	14.56 (5.95)	ns
p		< .05	ns	
Incorrect	1	1.62 (2.5)	1.68 (2.62)	ns
Responses	2	.81 (1.42)	.75 (1.52)	ns
p		ns	ns	

Standard deviations are in parentheses.

The mean SART performance scores (D-P, RT, CR and IR) were calculated for Session 2 in order to perform comparisons between Sessions 1 and 2 within each group, using dependent *t*-tests (see Table 3). For the restorative group, two of these comparisons yielded significant differences, for D-P, $t(15) = -2.4$, $p = .02$, for CR, $t(15) = -2.72$, $p = .01$, for IR, $t(15) = 1.88$, $p = .09$, for RT, $t(15) = 1.72$, $p = .10$. For the nonrestorative group, these same comparisons yielded no significant effects, for D-P, $t(15) = -.52$, $p = .60$, for CR, $t(15) = -1.82$, $p = .08$, for IR, $t(15) = 1.65$, $p = .11$, for RT, $t(15) = .69$, $p = .49$.

Of secondary interest are comparisons during Sessions 2 between the restorative and nonrestorative groups. No differences emerged from the independent *t*-tests. No differences between the sexes emerged from any of these analyses.

12.1. Exposure time comparison

As stated in the introduction to this experiment, the opportunity to decide how long to look at each picture should produce an even greater improvement in participants exposed to the restorative environments. To evaluate this, data from Experiments 1 and 3 were considered together and the two different time conditions (standard and self-paced) were compared.

A 2 (Group: nonrestorative/restorative) by 2 (exposure time: standard/self-paced) by 2 (Sessions: pre/post) between and within participants MANOVA was calculated on the four SART performance scores (DVs: mean RT, mean D-P, mean number of CR and IR); sessions was the within participants factor.

No main effect of the EXPOSURE TIME, $F(4,57) = 1.09$, $p = .36$ and no EXPOSURE TIME*-GROUP interaction emerged, $F(4,57) = .84$, $p = .50$. The SART performance differed significantly within subjects, $F(4,57) = 5.65$, $p = .00$, as far as the mean RT, $F(1,60) = 5.83$, $p = .01$, the mean number of CR, $F(1,60) = 9.75$, $p = .00$, the mean number of IR, $F(1,60) = 7.55$, $p = .00$, and the mean the D-P, $F(1,60) = 5.25$, $p = .02$, was concerned.

13. Discussion

Participants in Experiment 3 were exposed to the same pictures used in Experiment 1; however, they were able to control how long they viewed each scene. Similar to Experiment 1, the post-test performance of the restorative group improved in both D-P and the mean number of CR, supporting the idea that restorative pictures help to restore attentional capacity. In contrast, performance of the nonrestorative group did not improve, nor did restorative and nonrestorative groups differ in Session 2 performance.

As expected, the restorative pictures were viewed for a longer time than the nonrestorative pictures, although they were viewed for less than 15 s, i.e. the standard exposure time in Experiment 1. It is possible that participants viewing restorative pictures chose an amount of time that was sufficient to renew their attentional capacity. In contrast, it is possible that participants viewing nonrestorative pictures 'defended' themselves from any negative effects by looking more quickly through those pictures and showing no significant worsening on their post-test performance.

Restorative pictures in Experiment 3 were viewed for less time than in Experiment 1 (i.e. 15 s). Though from the repeated measures MANOVA an exposure time effect did not emerge between subjects. It seemed that the restorative value of the environments was 'strengthened' by the possibility to 'control' the exposure time. Results concerning the nonrestorative group are interesting as well. In Experiment 3 the nonrestorative group performance was worse than the restorative group performance, as occurred in Experiment 1. The possibility to control the exposure time gave participants of experiment 3 the opportunity to 'save' the remaining attentional capacity, avoiding to fatigue further the attentional systems with the vision of the nonrestorative environments. This suggests that nonrestorative environments really have negative and disturbing effects on performance and it is better to avoid them.

Although in Experiment 1, the restorative group's RT were higher in Session 2 than Session 1, and higher than those of the nonrestorative group, that improvement did not occur in Experiment 3, when viewing times were self-paced. It might be that repeatedly pressing the space bar was tiring, and participants slowed down because of that physical fatigue. However, this did not happen in the nonrestorative group, where performance was as fast as it had been in Experiment 1. Nor is this pattern consistent with Easterbrook's (1959) and Eysenck's (1982) hypothesis, that reduced physiological arousal would be followed by reduced attentional selectivity. In Experiment 3, participants' performance was slower but still very good.

An alternative explanation could be that the 'restoration process' had begun to lower participants' arousal levels, thereby slowing down their RT. It is possible that participants were more relaxed and possibly less concerned about responding to what they might have perceived as trivial pressures to increase their speed. This interpretation is consistent with recent research by Laumann et al.(2003). The authors expected that subjects would be less mentally fatigue after watching a nature video and would be able to make faster attentional shifts in Posner's attention-orienting task, compared to subjects exposed to an urban video. No differences emerged between the two groups, and the nature group was actually slower than the urban group. The results did not support the ART hypothesis and the authors concluded that nature stimuli are experienced as restorative because they reduce physiological arousal and lower attentional selectivity (for more details see Laumann et al., 2003).

Kaplan and Kaplan (1989) suggest that during a lengthy restorative experience, a person may pass through successive experiences and levels of restoration: clearing the head, recovering of attention capacity, facing accumulated matters on one's mind and reflecting on one's priorities, prospects, actions and goals in life. In fact restoration can happen at many different levels and in vastly different amounts of time (Kaplan, Kaplan, & Ryan, 1998). Participants in this research did not have time enough to pass through all these phases, but the regeneration process may have involved some of them. In future research we may be able to identify where participants are in this total restorative process.

14. General discussion

Olmsted (1865) understood the possibility that the capacity to focus might be fatigued and he also recognized the need for urban dwellers to recover this capacity in the context of nature. Experiments 1 and 3 examined recovery from induced attentional fatigue and showed that a short laboratory exposure of slightly more than 6 min to a series of restorative environments improved performance on a sustained attention test. This restoration of attentional capacity was reflected in improved target detection (D-P values), and the related index, increases in CR. Furthermore, in Experiment 1, the restorative group also responded more quickly, as shown in decreased RT. In contrast, participants exposed to nonrestorative environments (urban scenes) showed no significant improvements in target detection or reaction time in these experiments (although in Experiment 1, the mean number of IR decreased significantly).

In Experiment 2, participants exposed to geometric figures did not recover their attentional abilities. These figures required no effort to view, yet they did not result in improved performance during Session 2. As Kaplan and Kaplan (1989) discussed, environmental stimuli contain different amounts of *coherence*, *complexity, legibility* and *mystery*. Although the geometric figures required no effort, they did not contain these attractions. The results of this study support this idea that it is the total configuration of a setting that contributes to its restorativeness. This configuration makes a substantial difference in how 'comfortable' (from a cognitive point of view) people feel in a setting.

The results were in agreement with ART (Kaplan, 1995) which states that any prolonged mental effort leads to DAF; attentional capacity can be renewed in natural environments because natural environments are innately fascinating: they evoke a type of effortless attention or fascination, that allows directed attention to rest and restore. ART considers attention particularly important because it allows us to select appropriately from the available percepts and appropriate actions. The capacity to select is essential in thinking and problem-solving as well as in choosing correct actions. Selective attention allows us to *control* emotions and impulses and to ignore potentially distracting materials. Attention is the key ingredient in human effectiveness, both independently as well as in relation to other cognitive functions, and that is why its restoration is of vital important.

The present experiments underscore ART's premise that natural environments are more restorative than urban environments: attentional capacity can be regenerated only in environments high in restorativeness, and this regeneration occurs even if the amount of exposure is brief. In this research, restoration was achieved in less than 10 min, whereas other researchers have used more or less time. ART states that some levels and amount of time are necessary to completely restore attentional capacity (Kaplan, 1995). Experiment 3 suggested that the length of exposure and the possibility to control exposure time are important and deserve further investigation. The time it takes to become fully restored probably depends on task difficulty and length (how fatigued one becomes during the task), how inherently restorative the environment is, and how long one experiences the restorative environment. Future research could examine the boundary conditions—what combinations of task difficulty and exposure to restorative experiences are optimum.

Research suggests that the antecedent condition of attentional fatigue increases preference for natural over urban environments (Staats & Hartig, 2004). Therefore finding ways to recover from mental fatigue is greatly helped by the availability of restorative environments and experiences. It is possible to design urban and indoor environments (schools, hospitals, environments for old people, etc.) to be more 'comfortable' from a cognitive point of view and to manage natural environments in ways to encourage recovery from mental fatigue, taking that mental fatigue is a fact of life in a world overflowing with information.

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