Seeing Green: The Influence of Natural Environments on Restoring Visual Attention  
  
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*Abstract*—Modern life typically involves high levels of visual attention, which can consequently become depleted and fatigued. According to Attention Restoration Theory nature can have a restorative effect on some forms of directed attention.1 These studies investigates whether virtual visual exposure to nature can have a restorative effect on visual attention. The first study (n=200) used a 2x2 between-subject design, in which participants were first exposed to images of natural or urban environment. Subsequently, they were required to view a second set of images that changed over 20 seconds, and identify where a detail in the image had changed. The hypothesis was that participants in the Nature exposure condition would have restored visual attention and detect more changes. Conversely, participants in the Urban exposure condition would exhibit change blindness—an inability to detect images— hinting at depleted visual attention. No significant difference was found between the Nature and Urban exposure conditions [t(18) = -0.271, p = 0.605]. The second study (n=95) modified the Exposure intervention to be Nature or Urban videos instead of images to increase immersiveness. Again, no significant differences were found between the Nature and Urban exposure conditions [W = 41, p = 0.764]. This is in line with results from other visual attention paradigms.2 Future studies could explore whether more immersive exposure to natural environments are restorative for visual attention.

# Introduction

Modern expectations of living demand visual attention for much of our daily functioning. Driving, reading, and writing are some tasks that require focus to take in information. Directing our attention in this manner requires us to use cognitive resources­, and it takes effort to maintain this attention. Too much effort can deplete our cognitive resources, thereby reducing our ability to maintain visual attention for sustained periods of time. This constant demand on visual attention can cause fatigue. Fatigue inhibits our ability to pay attention by depleting our attention resources. The consequences of fatigue can be mild, like not seeing a person on the sidewalk and bumping into them, but also very severe, like not seeing a car as it speeds towards you. Thus, preventing or reducing attentional fatigue would be of great benefit to many people. Attention Restoration Theory (ART) suggests that nature provides a mildly fascinating environment that can reduce fatigue.1

Exposure to natural environments keeps cognitive resources engaged, but does not demand directed attention. This reduces the effort required to maintain directed attention continuously and prevents depletion of cognitive resources. Berman, Jonides and Kaplan found that taking walks through a park improved participants’ performance on a working memory tasks, while walking through an urban downtown area did not have any significant improvement.3 Stevenson et al. conducted a meta-analysis of ART studies, and found that working memory, cognitive flexibility and, to a lesser extent, attentional control are reliably improved by exposure to natural environments.2 This demonstrates that immersion in a natural environment can lead to improvement in directed attention, whereas immersion in an urban environment does not. Our study thus aims to test the restorative ability of natural environments on visual attention.

One difficulty with studying the extent of nature’s restorative effect is that it is not easy for the average person to access a fully immersive natural environment on a regular basis. However, some studies have also shown that viewing images of natural environments have a similarly effect on attention and lead to improvement in performance on directed-attention tasks.3,4 Berman et al. found that the low-level visual features of an image contribute to our perception of the ‘naturalness’ of a visual scene.5 This effect does not appear to be limited to working memory directed-attention tasks. Kardan et al. show that preference for nature might be driven by low level visual features of natural environments, and Schertz et al. show that visual features of the environment also drove and altered symbolic thoughts.6,7 Thus, it appears as though information about naturalness is being communicated through visual features, and these visual components captured in an image appear to have similar restorative effects.

Thus, the aim of this study is to investigate whether visual exposure to nature can have a restorative effect on visual attention, and what the extent of this restorative effect is, using change blindness as a measure for visual attention. The first independent variable is the type of environmental exposure condition, either a natural or urban environment. The second independent variable is the environmental condition of the images in which change must be detected, which is also either a nature or urban environment. Finally, the dependent variable is the detectability score of each image, which indicates the ease of identifying the change. By controlling the type of environment of the exposure condition, as well as of the detection images themselves, we can examine whether there is a change in performance when both types of environment are presented but to different extents.

We hypothesized that the detectability score would be greatest when the exposure condition and detection condition are both natural environments, as this would align with evidence that nature has a restorative effect on attention. We would also expect the change detection score to be lowest when both exposure and detection environments are urban, as there would be no exposure to natural environments to induce their restorative effects.

# METHOD

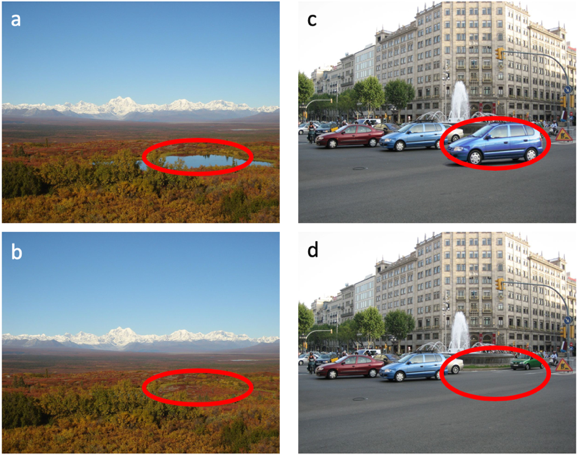
**Change Detection Task.** In order to study visual attention through change blindness, a task was designed in which participants had to detect changes. For this, we designed a novel Change Detection Task. In this task, an image was presented for a 20-second span, during which a change would first ‘fade-in’ such that something new appears in the image, and then ‘fade-out’ so the original image reappears. Some examples of these changes were the disappearance of a car or lake, the appearance of a canopy, or the color of a roof changing. After each changing image was displayed, the participant was asked if they (1) saw the change, and (2) if they saw it, where they saw it.

Fig 1. Samples of high detectability images in nature (a, b) and urban conditions (c, d). The red oval marks the areas where the change occurs.

The images for the Change Detection task were taken from the MIT SUN database.8 The Change Detection images were designed by isolating a part of the image to gradually change over 10 seconds or 65 frames, and then replayed in reverse, so that no sudden difference could cue the participant to where the change was occurring in an otherwise still image, and the first and last frames displayed were identical.

To validate our Change Detection images and select which ones to use in the study, a baseline survey was conducted. This included 39 total change detection images, of both Nature and Urban such that each participant saw all the images. The order of presentation was randomized for all. Participants who failed to complete the survey or identify even one change were excluded, for a total of 231 valid participants.

Once sorted, an average detectability score, or the ratio of successful detections to the number of participants, was obtained for each image. 10 images of each nature and urban were selected from all the Change Detection images, such that there was an even distribution of images from low to high detectability in each. The initial detectability of each Change Detection condition at baseline was compared by an un-paired two-tailed t-test, and no significant difference was found between the Nature and Urban images [t(18) = -0.071, p = 0.944]. This gave us each set of 10 images for the Nature Change Detection Task and the Urban Change Detection Tasks, which were then used in Study 1 and Study 2. An example of this is shown in Figure 1.

## Study 1

**Participants*.*** 200 US-based adults (112 male, 86 female, two other) were recruited from the online labor market Amazon Mechanical Turk via TurkPrime.9 Ages ranged from 19 to 71 (M = 35.83, SD = 11.0448). Individuals who had participated in previous studies looking at nature and urban environment effects were excluded. Participants were compensated with $2 for doing the study, with a possible additional bonus of up to $0.50 for accuracy. Informed consent was administered by the Institutional Review Board (IRB) of the University of Chicago.

**Procedure*.*** First, participants went through an environmental Exposure condition, in which a series of 50 images from the MIT SUN database of either Nature scenes or Urban scenes were displayed to the participant*.*10No image was used in both the Exposure and Change detection image sets. Participants were asked to rate their preference for each image on a 7-point Likert scale. Each image stayed on the screen for 6 seconds. Then, participants either did the Nature or Urban Change Detection Task.

**Experimental Conditions.** This was a 2x2 between-participant experiment, such that there were four possible combinations of Exposure Condition x Change Detection Task: Nature x Nature, Nature x Urban, Urban x Nature, or Urban x Urban.

**Data Analysis.** Participants who failed to identify any changes correctly were excluded (final n=177). The detectability score for each image across the four conditions was obtained and analyzed in R. This included pairwise one-tailed t-tests between detectability scores within each Change Detection environmental condition (Nature x Nature vs. Urban x Nature; Nature x Urban vs. Urban x Urban) and unpaired t-tests between scores within each Exposure environmental condition (Nature x Nature vs. Nature x Urban; Urban x Nature vs. Urban x Urban).

## Study 2

Study 2 modified Study 1 by altering the exposure condition to a video intervention. Based on the hypothesis that the strength of intervention in Study 1 was not sufficient to see the predicted result, it was thought that a video would match the experience of being in natural environments more closely than still images would.

**Participants.** 95 US-based adults (67 female, 28 male) were recruited through the University of Chicago Research Participation System for the Department of Psychology. Ages ranged from 18 to 38 (M =20.55, SD = 2.85). Those who had participated in previous research studies using visual stimuli of nature scenes or other studies testing ART were excluded. Participants were compensated with either 0.5 credits to fulfill credit requirements for psychology classes, or $5, for the 30-minute study. Informed consent was administered by the Institutional Review Board (IRB) of the University of Chicago.

**Procedure.** First, participants went through an environmental Exposure condition, in which a 10-minute soundless video of either Nature scenes or Urban scenes were displayed to the participant. Then, participants either did the Nature or Urban Change Detection Task. This experiment used the same Change Detection task to measure change blindness, programmed through jsPsych.

**Exposure Stimuli.**The videos used in the Exposure condition were generated for the Environmental Neuroscience Lab. The Nature video contains scenes cut together from a documentary on Yosemite National Park (Pontecorvo, 2017) and the Urban video contains scenes cut from the travel documentary *Rick Steves’ Europe* (Steves, 2006, 2014, 2016). Videos had been rated for preference in prior studies and were matched on that dimension to ensure differences in preference were not contributing to any effects seen. The scenes were carefully chosen so that they did not contain drastic camera effects or angles that might distort them from what would normally be perceived by humans who were themselves present at those locations.

**Data Analysis.**Participants who failed to identify any changes correctly were excluded (final n = 94). The same analysis as study 1 was done using Mann-Whitney-U tests in lieu of t-tests, as data were non-parametric.

# Results & Discussion

## Study 1

The detectability of each Change Detection condition as it varied by Exposure condition was analyzed. A paired one-tailed t-test between detectability scores of Nature x Nature vs. Urban x Nature is non-significant [t(9) = -1.184, p = 0.867]. Similarly, a paired one-tailed t-test between Nature x Urban vs. Urban x Urban is non-significant[t(9) = -2.367, p = 0.979]. The detectability of both Change Detections conditions within one type of environment Exposure was also analyzed. An unpaired one-tailed t-test between Nature x Nature vs. Nature x Urban is non-significant [t(18) = -0.032, p = 0.513]. Similarly, unpaired one-tailed t-test between Urban x Nature vs. Urban x Urban is non-significant difference [t(18)= -0.082, p = 0.532]. Finally, an unpaired one-tailed t-test between Nature x Nature vs. Urban x Urban found a non-significant difference [t(18) = -0.271, p = 0.605].

| Detection  Condition | Exposure Condition | | | |
| --- | --- | --- | --- | --- |
| Nature | | Urban | |
| M | SD | M | SD |
| Nature | 0.404 | 0.363 | 0.409 | 0.402 |
| Urban | 0.483 | 0.347 | 0.504 | 0.340 |
| **Total** | **0.443** | **0.347** | **0.457** | **0.366** |

Table I shows the mean and standard deviation for the detectability scores across the four conditions, and Figure 2 displays the distribution of detectability scores across all four conditions.

## Study 2

The detectability of each Change Detection condition as it varied by Exposure condition was analyzed. Since these data were non-normally distributed, a paired one-tailed Mann

Table I. Descriptive Statistics for Detectability Scores Across Exposure and Detection Conditions in Study 1.

| Detection  Condition | Exposure Condition | | | |
| --- | --- | --- | --- | --- |
| Nature | | Urban | |
| M | SD | M | SD |
| Nature | 0.415 | 0.332 | 0.444 | 0.299 |
| Urban | 0.420 | 0.334 | 0.456 | 0.337 |
| **Total** | **0.418** | **0.324** | **0.450** | **0.310** |

Fig 2. Study 1 detection scores across exposure and detection conditions.

Whitney U-test between detectability scores of Nature x Nature vs. Urban x Nature is non-significant [V = 21, p =

0.754]. Similarly, a paired one-tailed Mann Whitney U-test between Nature x Urban vs. Urban x Urban is non-significant [V= 10.5, p = 0.751].

The detectability of both Change Detections conditions within one type of environment Exposure was also analyzed. An un-paired Mann Whitney U-test between detectability scores of Nature Exposure condition for both Change Detection conditions (Nature x Nature vs. Nature x Urban) reveals a non-significant difference [W = 44, p = 0.688]. Similarly, an un-paired Mann Whitney U-test between detectability scores of Urban Exposure condition for both Change Detection conditions (Urban x Nature vs. Urban x Urban) reveals a non-significant difference [W = 43.5, p= 0.650]. Finally, a one-tailed Mann-Whitney-U test between the condition of maximal Nature exposure and that of the minimal Nature exposure (Nature x Nature vs. Urban x Urban) found a non-significant difference [W = 41, p = 0.764]. Table II shows the mean and standard deviation for the detectability scores across the four conditions, and Figure 3 displays the distribution of detectability scores across all four conditions.

Table II. Descriptive Statistics for Detectability Scores Across Exposure and Detection Conditions in Study 2*.*

Fig 2. Study 2 detection scores across exposure and detection conditions.

**Discussion.** In both studies, we failed to reject the null hypothesis that the nature exposure does not improve detectability scores of images on the detection task. Our hypothesis was that visual attention would be restored by visual exposure to natural environments. This hypothesis was based on the theory that natural environments are restorative for some forms of directed attention, evidence that environmental restoration can be induced by virtual exposure, and evidence that visual feature processing might be one of the mechanisms for the restoration effect. This was an experimental hypothesis, which has not been explored in much depth. While we cannot find evidence in support of the null hypothesis, there are several possible reasons for the null effects that our results show.

First, it may be the case that change detection tasks are not a type of task that show restorative effects from nature. Stevenson et al.’s meta-analysis, published after this study was initiated, found that similar studies on other visual attention tasks did not show a restorative effect of natural environments.2 However, each of the studies included on visual attention used a virtual visual stimulus to simulate exposure to nature. Thus, secondly, it may be the case that the restorative effects on visual attention are not as strong as effects on other types of tasks and, thus it is possible that the increased immersiveness of an actual environment would induce restorative effects for visual attention that the virtual environments do not. They also note, importantly, that virtual exposures are systematically shorter in duration then actual exposure.2 Thus, longer environmental exposure may also be necessary to observe these effects.

An assumption made in this design is that participants, in both the online and in-person paradigms, are operating at a baseline state of some fatigue. The meta-analysis also found that fatigue led to increased restoration effect for working memory, though not for cognitive flexibility or attentional control.2 Measuring fatigue would provide useful insight into how the restorative effect of natural environment might work. However, fatigue or depletion of visual attention was not measured in these studies. A more rigorous design would include a baseline, then fatigue intervention and measurement of fatigue, followed by the environmental exposure and post-test detection task.

# Conclusion

Taken together, these studies suggest that visual attention could be a form of directed attention that is not restored by natural environments in the way we currently understand attention restoration and how it works. This adds nuance to the restorative ability of natural environments. Future research could explore the restorative effect of natural environments on visual attention, or the lack thereof, by exploring visual attention restoration concurrently with working memory and cognitive flexibility restoration in actual natural and urban environments. This could allow us to measure the effectiveness of the exposure with a form of directed attention that is known to be restored, and provide insight into how nature restoration might act on multiple modalities at once. This would take us a step further to exploring nature’s potential therapeutic applications as well, which could be beneficial for populations with attentional difficulties. Further, if visual exposure to nature is ineffective in restoring some forms of directed attention, it could incentivize the development of ‘green spaces’ in urban environments. The need for physical nature for human productivity could thus encourage natural development that is sorely needed, especially as urban development and natural resource exhaustion threaten natural environments, and climate change becomes an increasing threat.

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