THE IMPACT OF EXPOSURE TO RESTORATIVE SETTINGS AND LAPTOP USE ON COGNITIVE FUNCTIONING

BY

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THESIS

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Abstract

Many studies have shown the restorative effects of green spaces on people’s capacity to pay attention. But in these studies, participants had no distractions to direct their attention elsewhere. In many green spaces today, however, many people have a common distraction – the screen on their laptop computer or mobile device. The goal of this study was to examine the extent to which the benefits of green spaces on attention restoration are in any way compromised by laptop use. If a person is constantly looking at his or her laptop and not at the surroundings, will they gain therestorative benefits of being exposed to nature? To answer this question, we conducted a controlled randomized experiment with 81 adults at eight different outdoor locations on the University of Illinois campus: four were devoid of vegetation and four included views to vegetation. Participants were further randomly assigned to either use their laptop computers for leisure activities or to sit and relax without using their computers. Students in the green view condition who did not use their laptops scored significantly higher on tests of attentional functioning than their peers in the other three conditions. There were no significant differences in attentional functioning after the break among participants in the green view-laptop condition or the two barren conditions. The findings establish a set of causal relationships: when individuals use green outdoor environments without engaging with their laptop computers, their attentional functioning improves; however, we found no significantly restorative impact of green outdoor environments on attention functioning when laptops were used.
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Chapter 1: Introduction

We live in a changing world. Although this can be good in many ways, some of these changes negatively impact our health and well-being. Since the 1960s, Americans’ daily time spent consuming media has increased between three and five percent per year (Short, 2013). In 2012, the average American consumed 13.6 hours of media per day that was not work-related (Short, 2013). If that seems like too much, consider the fact that multiple forms of media can be viewed at once, such as a person browsing the internet while watching a TV show. One common pathway for viewing media is through the internet. With smart phones and public hotspots, people are connected almost everywhere they go. But what health risks are posed by this connectivity? Internet addiction is a growing issue around the world, and excessive internet use has also been correlated with many mental disorders such as depression, anxiety disorders, and attention deficit hyperactive disorder (Weinstein & Lejoyeux, 2010). Internet addiction is more prevalent in populations under 30, and even more common in persons under the age of 19 (Sahin, 2011), suggesting that this problem is only going to get worse for future generations.

According to Kaplan and Kaplan’s attention restoration theory, one of the greatest costs of this connectivity and technology use is derived from the way these activities demand our attention. This is a cost because our attention is a limited resource: it fatigues with use and requires a period of rest before it is fully restored. Since absorbing media requires that people pay attention, they can become mentally fatigued, meaning that their ability to focus is depleted (S. Kaplan, 1995).

The willpower we use for self-regulation is achieved using the same resource as the willpower used for executive functioning, meaning that the same part of our brain that can resist a second slice of cake is also the part that we use to focus on cognitive tasks (S. Kaplan & Berman, 2010). This has been demonstrated in studies where participants performed worse on cognitive tasks after being asked to choose something less desirable over a more desirable option, such as eating vegetables rather than sweets. Baumeister describes this as “ego-depletion,” where the act of self-control uses up the resource that allows us to engage in effective self-control (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister & Vohs, 2007; Schmeichel, Vohs, & Baumeister, 2003).

We live in an increasingly technological world, where our attention is constantly being demanded. Depleted attention causes people to make more mistakes and to have difficulties focusing, but it also predicts other behaviors. Someone who is mentally fatigued is more likely to be irritable, have
trouble with self-management, struggle to resist temptations, and miss social cues. This means that when a person is mentally fatigued, he or she will not be as effective in pursuing goals and interacting with others (S. Kaplan & Berman, 2010). Humans constantly use their brains to process information; when that ability is depleted, we are ineffective. Because of this, the condition of being mentally fatigued makes us more likely to say or do something that we might later regret, which can impact relationships, work performance, and even personal goals such as weight loss or saving money. In short, we are not at our best when we are mentally fatigued (R. Kaplan & Basu, 2015; S. Kaplan & Kaplan, 2009).

Recently there has been a great interest in studying the relationship between humans and nature. Many studies have demonstrated the restorative effects of spending time in nature. Exposure to a wide variety of natural elements and settings, even urban green settings, help people recover from mental fatigue. However, in the conditions of many of these studies, participants had no distractions that might direct their attention elsewhere. Today, many people can become absorbed in screens of portable electronic devices, even when outside in restorative settings. If a person is constantly looking at an electronic device and not attending to their restorative surroundings, do they gain the restorative effects of nature? In the high-stimuli world in which we live, this question is critical in order for us to learn how to best restore our ability to focus and act reasonably.

Nature and Attention

There is clear and copious evidence supporting attention restoration theory for people in ages across most of the human life-span. People who spend time in nature rather than urban, high-stimuli environments are better able to restore their ability to pay attention (Berman, Jonides, & Kaplan, 2008). Children with ADHD performed higher on attention tests after taking a walk in a park compared to taking a walk in a neighborhood or urban setting (Taylor & Kuo, 2009). In a study of 101 high schools in Michigan, schools with a greener views from the cafeteria and classrooms had significantly higher graduation rates, standardized tests scores, percentage of students planning to attend a four-year college, and fewer occurrences of criminal behavior (Matsuoka, 2008). In another study of high school students who were randomized to classrooms with and without views to green spaces, the students in classrooms with green views performed better on tests of attention than their peers without green views (Li & Sullivan, 2016). Nature has also been shown to have restorative benefits for adults, where photographs of green settings (Berto, 2005), window views to green settings (Tennessen & Cimprich,
1995), and being in green settings all contribute to attention restoration (Hartig, Evans, Jamner, Davis, & Gärling, 2003).

In their book *With People in Mind*, Kaplan, Kaplan, and Ryan suggest the mechanism behind attention restoration. They posit that mental fatigue can be remedied by spending time in places that provide the experience of “soft fascination” (R. Kaplan, Kaplan, & Ryan, 1998). There are two types of attention: directed and involuntary. Directed attention involves making a conscious effort to pay attention and focus: this happens while writing a paper, working out a problem, or attempting any kind of difficult mental task. The task you’re doing now, reading a journal article, requires your directed attention. Involuntary attention involves attending to something that takes little to no effort to absorb – think for instance of watching a campfire, looking into the eyes of a baby, or watching the leaves on a tree move in the breeze. Involuntary attention has a spectrum of different types of fascination. Hard fascination is engaged by something exciting that is difficult to turn away from, such as a building on fire or a fight between two people. On the other end of the spectrum, soft fascination gently captures one’s attention. Soft fascination is engaged by the wind rustling leaves in the trees or water flowing in a stream. Soft fascination allows a person’s mind to rest and recover from mental fatigue. Attention Restoration Theory proposes that we are able to restore our ability to pay attention when we engage in involuntary attention and especially soft fascination (S. Kaplan, 1995).

A growing body of evidence has demonstrated the positive effects of vegetative settings on cognitive functioning, including attention recovery and stress recovery (Berman et al., 2008; Berto, 2005; Hartig et al., 2003; Jiang, Larsen, Deal, & Sullivan, 2015; Jiang, Li, Larsen, & Sullivan, 2014; Li & Sullivan, 2016; Tennessen & Cimprich, 1995). In these studies, however, participants had no distractions during their exposure to the restorative settings. To what extend do people reap the benefits of an environment that provides soft fascination when they use an electronic device that requires their attention?

Previous research has given us many insights into how human brains use and process information and how nature impacts those processes. We know that exposure to nature improves our cognitive functioning, and we also know that cognitive functioning is linked to impulse control and effective social functioning. We do not know, however, the extent to which competitors for our attention while we are in restorative settings affect the restorative process. Are mobile devices competitors for our attention? Because we live in an increasingly technological world, we need to know if using technology interferes with our ability to recover from mental fatigue in restorative settings. By
finding out if the use of electronic devices affects attention recovery in a restorative space, we will learn more about the mechanisms behind restorative spaces. Is it necessary that people pay attention to the space and not otherwise be distracted? Is simply being in a restorative space enough, perhaps because by entering into it that a person can feel safe and relaxed? This study probes the answer to these questions through a randomized experimental design that compares attention recovery with and without the use of a laptop. Are restorative settings still restorative if a person is using a laptop?

Although soft fascination has been proposed as the mechanism through which restorative settings reduce mental fatigue this mechanism has not yet been demonstrated. We do not know if attention restoration can occur in a restorative setting if a person is engaged in another mental activity such as reading their email or surfing the Internet. By answering this question, we can better counsel people on how to restore their most critical resource – their attention – in a world that is increasingly mentally demanding and fatiguing.
Chapter 2: Methods

Experiment Setting and Participants

We chose four sites on the University of Illinois campus based on two criteria. First, each site had a nearby building with private indoor rooms of comparable size and layout. Second, the indoor rooms had to be less than a two-minute walk to both an outdoor barren setting and an outdoor green setting. We selected four green settings in which participants saw considerable vegetation, especially trees (see Figure 1a). We selected four barren settings in which participants saw no trees or other vegetation, only human-made elements such as parking lots, walls, or the side of a building (see Figure 1b). All outdoor settings had wireless internet access.

Figure 1a: The four green settings used for the rest period during the experiment
81 university students (59 undergraduate and 22 graduate) participated in this study (50 female and 31 male). We removed 5 data sets where it rained during the rest period or where the participants’ attention scores were more than two standard deviations away from the mean scores. Of all total participants, 76 of the data sets were usable.

Participants were randomly assigned to one of four conditions: a barren setting in which they used a laptop, a barren setting with no laptop, a green setting in which they used a laptop, or a green setting with no laptop (see Table 1). The experiment was conducted with one student at a time between 8:30am and 5:30pm on days in which the temperature ranged from 65-86°F. Experiments were scheduled on days with a low likelihood of rain and when temperatures were projected to be no warmer than 86 degrees Fahrenheit. Experiments were conducted regardless of sun or clouds as long as it was not raining or too warm during the rest period. Weather conditions for each day were recorded.
<table>
<thead>
<tr>
<th></th>
<th>Laptop</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barren Setting</td>
<td>20 Students</td>
<td>19 Students</td>
</tr>
<tr>
<td>Green Setting</td>
<td>18 Students</td>
<td>19 Students</td>
</tr>
</tbody>
</table>

Table 1: Participants were randomly assigned to one of four groups with nearly equal representation.

After giving consent to take part in the experiment, participants reviewed the inclusion criteria to ensure that they had not consumed any food or substances that would affect their normal cognitive performance. To account for confounding factors, all participants completed a general background questionnaire to report their age, gender, race, native language, major of study, and self-reported chronic mental fatigue.

**Procedure**

The experiment began in an indoor classroom setting in which only the facilitating research assistant and the participant were present. Before the experiments, the indoor rooms were arranged in the same configuration and room temperature, with the participant sitting at a table opposite of the research assistant. All research assistants were trained to follow the identical procedure.

After collecting the background information from participants, we assessed participants’ attention with a baseline attention test. Next, in order to simulate classroom activities and induce mental fatigue, participants engaged in 10-minutes of demanding cognitive activities. These activities included a five minute proofreading task and a five minute subtraction task. Following these activities, participants completed the attention tests for a second time. The participants then walked to the assigned outdoor setting, where they were instructed to sit on a chair or bench in the shade.

Participants assigned to use their laptop were instructed to use their laptop in a manner similar to when they were taking a break. The break lasted 15 minutes, which is a common time between university classes. We reinforced the notion of taking a break with their laptop by asking them not to use the laptop for anything related to work or school. Participants in the laptop group were given the following suggested list of activities to reinforce the instruction that they were to use their laptops for leisure activities:
Participants assigned to the no laptop conditions were instructed to simply sit and wait. All participants were instructed to remain seated and keep their eyes open for the duration of the rest period. During the rest period, the experiment administrators waited in a position where they could view the participant while remaining out of sight of the participant. Any unusual interruptions or activities were recorded. When the rest period was completed, the participant returned to the indoor setting and completed a third attention test. Finally, participants took a short follow-up survey. If they were assigned to the laptop group, the survey included questions about what activities they did, for what percentage of the break they used the laptop, and for what percentage of the break their laptop played sound.

Measures

Attention functioning was recorded using objective and subjective measures. Participants’ baseline attentional functioning was assessed using a self-report Visual Analog Scale (VAS) questionnaire and the Digit Span Forward (DSF) and Digit Span Backward (DSB) tests of attentional functioning (Wechsler, 1981).

The VAS questionnaire allowed participants to record their perceived level of mental fatigue. Mental fatigue was described to them as the inability to focus and the feeling they might get after doing cognitive work for a long period of time. Participants then marked their perceived level of mental fatigue on a line where one end read “Not at All Mentally Fatigued” and the other end read “Very Much Mentally Fatigued.”

The DSF and DSB tests required participants to repeat increasing lengths of digit sequences in normal and reverse order until two consecutive failures at the same length. These tests have been shown as a standard battery for attentional capacity, short-term memory, and working memory (Hales, 2018).
Each of these measures was employed three times throughout the experiment: before the cognitive exercises, after the cognitive exercises, and after the rest period.
Chapter 3: Results

Results are presented in two sections. First, we compare the baseline and post-activity attention levels among the four different conditions to ensure that there are no pre-treatment group differences. Second, we explore the effect of the treatment conditions on participants’ attention levels after the break.

Attention Levels before Rest

To compare attention scores across groups we created a summary attention score using two objective measures of attention, digit span forward and digit span backward, and examined the mean differences among the groups before the cognitive tasks, after the cognitive tasks, and after the rest period.

\[
\text{Digit Span Forward Average + Digit Span Backward Average} \quad 2
\]

Given that the participants had been randomly assigned to the treatment groups, we had expected that there were no differences among the groups prior to the treatments. And indeed, a repeated-measures ANOVA showed no significant differences in the participants’ attention levels among the groups before engaging in the cognitive tasks (DF= 3, F=1.868, \(p=0.144\)) or before the treatment (DF=3, F=0.345, \(p=0.793\)). Thus, none of the groups had advantages or disadvantages before the rest period.

Effect of Outdoor Condition on Attention

To what extent did the treatments affect participants’ attentional functioning after the rest period? To address this question, we first explored the extent to which the participants’ attention scores changed after the rest period. A t-test examining attention scores before and after the rest reveals that the participants’ attention scores significantly increased overall (F=4.705, \(p=0.032\)), where the mean increase was 0.4 digits longer than before the rest.

Did the treatments affect the change in attention scores? Yes, as Figure 2 shows, although participants’ attention scores were not significantly different before the rest period (F=0.024, \(p=0.995\)), they were significantly different after the rest period (F=3.105, \(p=0.032\)). We made pairwise comparisons using Tukey’s HSD and found that only one treatment had significant differences on
attention scores. The mean attention score for the green-no laptop condition was significantly higher than the three other conditions (see Tables 2 and 3).

Figure 2: Mean attention scores on the Digit Span Forward and Digit Span Backwards tests before and after the rest period by treatment group.
### Means

<table>
<thead>
<tr>
<th>Condition</th>
<th>DS2Avg</th>
<th>DS3Avg</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
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<td>7.2</td>
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<tr>
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<td>19</td>
</tr>
<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>Mean</td>
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<td>6.2</td>
</tr>
<tr>
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<td>20</td>
</tr>
<tr>
<td>Std. Deviation</td>
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<td></td>
</tr>
<tr>
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<td>6.3</td>
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<td>18</td>
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<tr>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>6.1</td>
<td>6.2</td>
</tr>
<tr>
<td>N</td>
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<td>19</td>
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<tr>
<td>Std. Deviation</td>
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<td>.8227</td>
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<tr>
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<tr>
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<td>6.5</td>
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<tr>
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<td>76</td>
</tr>
<tr>
<td>Std. Deviation</td>
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<td>1.0753</td>
</tr>
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</table>

Table 2: Mean scores on the Digit Span Forwards and Digit Span Backwards tests before and after the rest period by treatment group
Multiple Comparisons ANOVA

Dependent Variable: Attention Score 3
Tukey HSD

<table>
<thead>
<tr>
<th>(I) Condition</th>
<th>(J) Condition</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
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<td>.3203</td>
<td>.006</td>
<td>.244</td>
<td>1.929</td>
</tr>
<tr>
<td></td>
<td>Barren without Laptop</td>
<td>.9313 *</td>
<td>.3289</td>
<td>.030</td>
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<td>-.0687</td>
<td>.3289</td>
<td>.997</td>
<td>-.934</td>
<td>.796</td>
</tr>
</tbody>
</table>

Table 3: ANOVA table comparing means of four groups on average attention scores after the rest period

Another way to look at this is to assess the magnitude of the effect of attention restoration after the break. In addition to being significantly different between groups after the rest, we found that the green*no laptop group had significantly higher attention scores after the rest (F=5.2, p=0.029). The green*laptop, barren*no laptop, and barren*laptop groups were statistically equivalent before and after the rest (F=0.178, p=0.675; F=0.681, p=0.415; F=0.367, p=0.549; respectively).

To further explore the change before and after the rest, we compared change in attentional scores (pre-break scores subtracted from post-break scores) between the different break conditions. As...
shown in Figure 3, change in attention level in the green*no laptop group was significantly greater than the other three conditions (F=5.693, p=0.001).

![Increase in Attention After Rest](image)

**Figure 3:** Average increase in attention scores from immediately after the cognitively demanding tasks to immediately after the rest.

Are green settings still restorative for people using laptops? Our data are clear: the answer is no. We compared the mean attention scores of laptop users before and after the rest and found no significant differences. Thus, using a laptop in a restorative setting negates the restoration effects of the setting.

We collected demographic information from each participant in order to detect possible confounds. We were concerned that factors such as race, gender, or age of the participants might impact their attention scores. We examined this possibility by examining the correlation between these variables and attention scores and found there were no significant correlations between age, race, or gender with the final attention scores. Additionally, there were no significant correlations between the final attention scores and the recorded weather conditions of temperature and cloud cover.
Chapter 4: Discussion

In this study, 81 adults were randomly assigned to outdoor spaces that had views to built spaces devoid of vegetation and to spaces that included views to vegetation. Participants were further randomly assigned to either use their laptop computers for leisure activities or to sit and relax without using their computers. Students in the green view condition who did not use their laptops scored significantly higher on tests of attentional functioning than their peers in the other three conditions. There were no significant differences in attentional functioning after the break among participants in the green view-laptop condition or the two barren conditions. The findings establish a set of causal relationships: when individuals use green outdoor environments without engaging with their laptop computers, their attentional functioning improves; however, we found no significantly restorative impact of green outdoor environments on attention functioning when laptops were used.

Contributions

To our best knowledge, this is the first study to use a randomized controlled experimental design to compare the combined effect of green landscapes and the use of laptop computers on attentional functioning. The findings demonstrate that the restorative effects of green settings are mitigated by laptop use: taking a break in a restorative setting while using a laptop has the same impact on attentional functioning as not taking a break at all.

Why did the green-laptop setting not result in higher attentional functioning than the barren settings? The settings, after all, were very green and these same settings produced significant improvements in attention scores for those individuals who did not use their laptop computers. The explanation is likely found in Kaplan’s article on Attention Restoration Theory, which describes two ways of paying attention: voluntary and involuntary. Involuntary attention is then divided into two categories: soft fascination and hard fascination. The proposed mechanism behind attention restoration is the soft fascination found in nature, where leaves blowing in a breeze or a running stream gently capture a person’s attention while allowing their mind to wander (S. Kaplan, 1995).

The participants in the green-no laptop group experienced soft fascination, but the participants in the green-laptop group did not. Although the participants used their laptops for leisure activities, these activities required voluntary – or focused – attention. Prior to the break, participants’ ability to pay attention was fatigued when they engaged in a variety of demanding cognitive tasks. For those in the laptop conditions, because the activities still required voluntary attention, the mechanism used to
focus on mentally demanding tasks did not get a chance to recover (S. Kaplan & Berman, 2010). During the break, participants’ in the green-no laptop group experienced involuntary attention and soft fascination, which gave their focusing mechanism a chance to rest, thus restoring their ability to pay attention.

Implications

The evidence presented here indicates that human behavior in a restorative setting affects attention restoration. Planners, designers, and policy-makers can intervene to provide green spaces for different users, but if those users choose to use their laptops in those spaces, they will not reap the benefits of taking a break in a restorative setting. These findings suggest that it is not enough to advise designers about how to make green settings accessible to people, but that everyday persons must be advised on how to recover from mental fatigue. Since laptop use in a restorative setting mitigates the benefits of attention restoration, mentally fatigued adults should be advised to put away their laptops in restorative settings in order to restore their ability to pay attention.

Future Directions

To assess the impact of green settings and laptop use on students’ cognitive functioning, we carefully controlled many factors such as indoor and outdoor settings, cognitive tasks, and break activities. The limitation of this approach is that it does not take into account various different situations that might be associated with laptop use. Participants in this study were instructed to use their laptop for the entire duration of the break, while in reality, students using a laptop in a green setting might stop periodically to gaze at their surroundings. Thus, in future research, an additional condition might be added to the conditions we tested here: one in which the laptop users are told to use their computers as much as they’d like or to look around as much as they would like.

This is the first study to demonstrate that laptop use mitigates the restorative effect of taking a break in a green setting. Certainly, these findings must be replicated in a variety of conditions before we are convinced of their veracity. Given that digital devices are nearly ubiquitous and that many people have easy access to smart phones and tablets, this study should be replicated with participants using a variety of mobile electronic devices because screen size and content used may be confounding factors.

This study examined the effect of laptop use on attention restoration in green settings. Based on the existing literature, our findings suggest that the relationship between laptop use and attention
restoration may be similar for individuals of different ages (Matsuoka, 2008; Taylor & Kuo, 2009; Zhang, 2015). The findings of this study also suggest that the use of portable electronic devices and taking breaks in restorative settings may impact workers as well. Many future studies may be conducted concerning the impact of electronic devices and various activities on attention restoration.

Although the results of this study are best applied to individual behavior, there are some implications for planners and designers. These results suggest that it may not be beneficial for people to have wireless internet access readily available in all outdoor settings. These findings also pose questions for future research about the design of restorative settings. Is there a way to design outdoor spaces in such a way that draws people’s attention to their surroundings rather than to their laptops? How can settings be designed to promote walking or sitting without electronic devices?

**Conclusion**

We conclude by emphasizing that taking a break in a restorative setting while using a laptop was equivalent to not taking a break at all. While you may feel that surfing the web is taking a break, it is not a break for your attentional functioning. In order to reap the benefits of being in a restorative green space, it appears that one needs to allow themselves to take in the softly fascinating objects in the landscape.

Using a controlled, randomized experimental design, this study demonstrated that taking a break in a green setting while relaxing resulted in significantly higher attentional functioning than taking a break in a green setting while using a laptop, taking a break in a barren setting without a laptop, or taking a break in a barren setting with a laptop. These findings widen our understanding of the mechanism behind attention restoration, demonstrating that the benefits of a restorative setting may be mitigated by different activities engaged in those spaces. This allows us to make recommendations to adults who are suffering from mental fatigue.
Bibliography


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