ATTENTION RESTORATION BENEFITS OF INTEGRATING GREEN SPACE INTO OFFICE ENVIRONMENT

BY

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THESIS

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ABSTRACT

Previous studies have demonstrated that having contact with natural environments can result in attention restoration for people who are mentally fatigued. In spite of this knowledge, we do not know the extent to which green indoor places impact attention restoration. Studies assessing the impact of green indoor spaces on attention have focus on potted plants and the findings have been mixed – often showing small or null results. In this thesis, I aim to find out if a larger scale of indoor greening, like indoor green space in the atrium, can help people recover from attention fatigue. This study explores such a possibility through an experiment in which 60 office workers were randomly assigned to simulated office environments with or without a window view of green atriums. We measured participants' attention functioning by Visual Reaction Time Test, Digit Span Backward and the Color Stroop Test. Our result shows that the window view of indoor green space has some effects on attention restoration and that the impact of such spaces may be considerably less than views to an outdoor space.

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Chapter 1: Introduction

Millions of office workers around the world spend their days paying attention to all manner of details in settings that provide them very little contact with nature. Such constant demand on attention results in increased levels of mental fatigue that often result in increased levels of inattention, impulsivity, irritability and ineffectiveness, etc. (S.Kaplan, 1995, Sullivan, 2015). Many studies have shown that spending time in a natural setting helps reduce mental fatigue and its associated symptoms (Berman, Jonides, Kaplan, 2008, Kuo & Sullivan, 2001). Even views of nature through a window have been shown to restore people's capacity to pay attention (Li & Sullivan, 2016). Evidence indicates that people's attention performance improves after watching photos of restorative photos (Berto, 2005). Moreover, even the view of photographs of roof gardens can bring attention restoration benefits (Lee, K.Williams, Sargent, N.Williams, & Johnson, 2015). Still, in dense urban settings, people who work in an office buildings often have few opportunities to go outside or view the nature from their windows.

With the increasing focus on indoor environments and human health, scholars have provided evidence of the physical benefits of indoor greening, including improving the indoor air quality (Wolverton, McDonald, & Watkins, 1984). However, when it comes to psychological benefit of indoor greenings, especially attention benefits, the research findings are inconsistent and inconclusive (Bringslimark, Hartig, & Patil, 2009). Most of the research on exposure to indoor plants has focused on potted plants in office settings. Raanaas, Evensen, Rich, Sjøstrøm, and Patil (2011), for instance, found no difference between two groups of participants' attention scores after taking a break in two types of office settings, with or without potted plants. We do not know if the volume of potted plants was too small to bring about more noticeable change, or if a larger scale of indoor greening might bring more benefits in helping people recover from attention fatigue. We also do not know if the placement of plants in indoor environment might somehow determine how often and in what way people see these plants. These gaps in our knowledge create missed opportunities to possibly promote the psychological benefits of indoor green spaces. In this study we examine a new type of indoor greening that the former studies neglected. We investigate to what extent this type of indoor green spaces in office environments benefit attention restoration.

We explored such a possibility through an experiment in which 60 office workers were randomly assigned to simulated office environments with or without a window view of green indoor atrium spaces. By examining two groups of participants' attentional performance before and after watching a treatment video to which they were randomly assigned we were able to measure the extent to which indoor green spaces can help people recover from attention fatigue. Before describing that study, I provide an overview of Attention Restoration Theory.

Chapter 2: Theoretical Background

Individuals get tired when they have to focus on tasks like finishing daily reports or reading articles for a continuous number of hours. The mechanism of focusing on those task in our daily work is called directed attention, or voluntary attention, or paying attention (James, 1892, cited in Kaplan, 1995). Paying attention requires effort and with prolonged effort, our capacity to pay attention fatigues. We call this fatigue mental fatigue. The symptoms of mental fatigue include irritability, inability to focus, impulsivity, slow reaction time and being easily distracted (Kaplan.S, 1995). Meanwhile, another type of attention, involuntary attention, takes no effort. We use involuntary attention when we observe something that is fascinating (e.g., a baby, wild animals, camp fires, waterfalls, and many forms of urban nature). Use involuntary attention provides an opportunity to rest and restore our directed attention and thus to recover from mental (Kaplan.S & Berman, 2010).

Kaplan's Attention Restoration Theory (1995), emphasizes that natural environment plays an important role in helping people recover from the mental fatigue caused by the extended use of our direct attention. Kaplan suggests that natural environment provide fascinating objects that catch people attention easily. Also the natural environment may help people temporarily get away from and forget about their working environment and help them recover from mental fatigue.

There is growing concern that the scale of urbanization in many parts of the world is separating humans from natural environments. Part of this concern is that people now have fewer and fewer opportunities to connect with nature and take advantage of the restorative powers of viewing urban green spaces – that is, they have fewer opportunities to recover from the mental fatigue that is part of our modern world.

For the past decades, scholars have found solid evidence in support of Attention Restoration Theory. Laumann, Gärling, and Stormark found that barren urban settings had an effect on delaying participant's reaction time, while the reaction time of urban nature group was the same (2003). Furthermore, taking a walk in nature reserve was associated with better performance on attention test than walking in an urban setting (Hartig, Evans, Jamner, Davis, & Gärling, 2003). Similar findings are also reported by Herzog, Black, Fountaine, and Knotts in 1997, stating that the natural setting has the most effectiveness on attention restoration comparing to urban setting and sports setting.

Studies also shows that even viewing photos of restorative environment have effect on attention restoration (Berto, 2005). After getting mental fatigued by attention tasks, participants in Berto's study were asked to view of one of the three sets of photos during a rest period, including restorative photos, non-restorative photos, and geometrical patterns. Only those who viewed the photos of restorative environment had a better performance in the post rest attention test (Berto.R, 2005). Moreover, a 40 second view of simulated green roof resulted in more accurate responses in attention test than viewing bare roof (Lee et al., 2015). These findings are consistent with those from Berman, Jonides, and Kaplan's 2008 experiment. They found that both taking a walk in nature and view the photo of natural environment enhances participants' performance in a series of attention test, including, Digit Span Backward task, and the Attention Network Task (Berman, Jonides, & Kaplan, 2008).

Taken together, these studies demonstrate the benefits people experience, in terms of being to pay attention, which green urban settings produce. However, when it comes to indoor environment, scholars can find no such agreement. It had been observed that exposure to indoor plants caused people's performance to decrease when doing a letter identification task (Larsen, Adams, Deal, Kweon, & Tyler, 1998). In 2002, Shibara and Suzuki observed that only male participants had better responses on tests of attention in the presence of indoor plants. And yet, two years later, Shibara and Suzuki (2004) discovered that the benefits of indoor plants on task performance could only be observed in female participants. In 2011, Raanaas et al.'s research shows a slight difference in attentional functioning in participants who conducted attention test in office station with indoor plants. However, this advantage of attention capacity disappeared in the following attention task (Raanaas et al., 2011). Evensen, Raanaas, Hagerhall, Johansson, and Patil found that during a one-hour attention demanding working session, having plants in the workstation did not have a measureable effect attention restoration (2015).

None of these aforesaid studies about the researches on attention benefits of indoor greening showed continuous and distinctive positive influence of indoor plants on attention performance. Some of these result even conflicted with each other. Most of these studies discussed about potted plants in office setting when talking about indoor greenings. They neglected another possibilities of indoor greening with larger scale of vegetation, for example, the indoor greenspace in atrium scale.

Chapter 3: Methods

3.1 Overview

We recruited 60 office workers to examine the attention restoration benefits of indoor greening. After engaging in a proofreading task to induce attention fatigue, participants were randomly assigned to watch one of the two videos of office settings during a rest period. We measured their attention performance three times during the experiment with a subjective self-report scale, visual reaction time test, Digit Span Backward, and Color Stroop test.

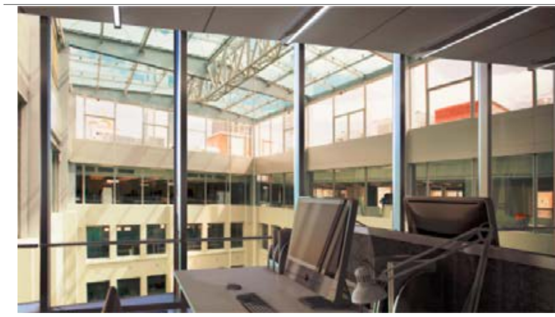
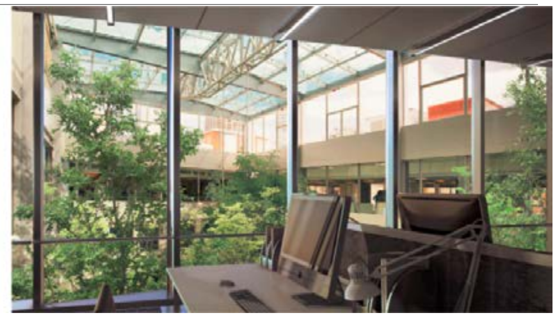
3.2 Treatments

We produced six scenarios of office setting to simulate office environments with and without greening. To create these scenarios, we combined photos of office settings with window views with photos of atriums to create six office settings with varying views to atriums. This process demands considerable skill using Photoshop and requires that one adjust the perspective, light and shadow in the images. We also erased any distracting elements, such as colorful books, indoor plants, and decorations. Then, based on these six office settings, we added indoor plants to atrium space in such a way that the plants could be seen from the office windows.

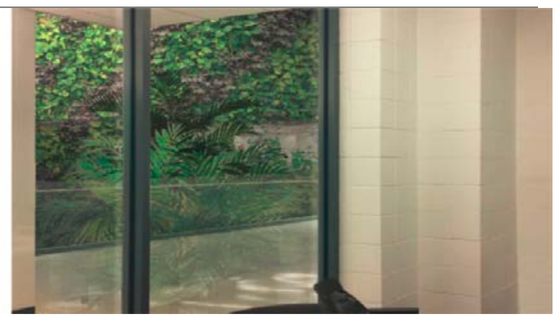
After completing the photo simulation process, we had six scenarios of the office settings. Each scenario includes a pair of simulated pictures of the same office setting with the same view of atrium space. The only difference between the two simulated photos in the pair was whether or not the atrium was full of plants.

We used these simulated images to make two 4-minutes video clips. One video included six non-green simulated pictures (one from each scenario) the other video included six simulated images with views to the green atriums. The photos in each video were displayed in an identical order that was produced by randomization (see figure 3.1 below).

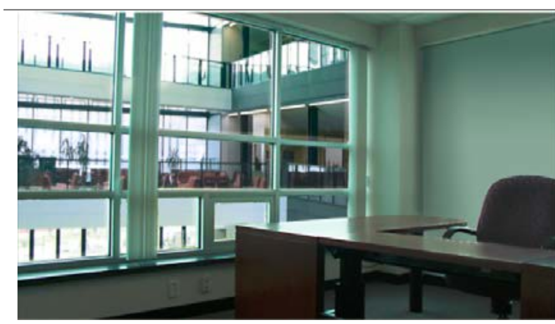
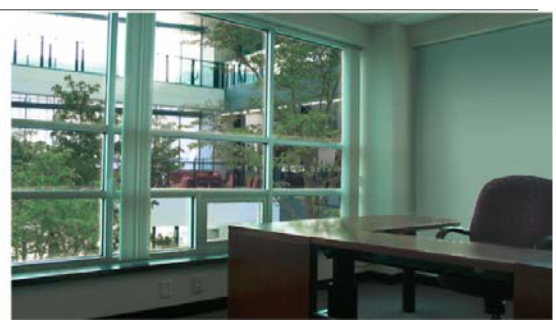

Scenario A (non-green group) | **Scenario A (green group)**

Scenario B (non-green group) | **Scenario B (green group)**

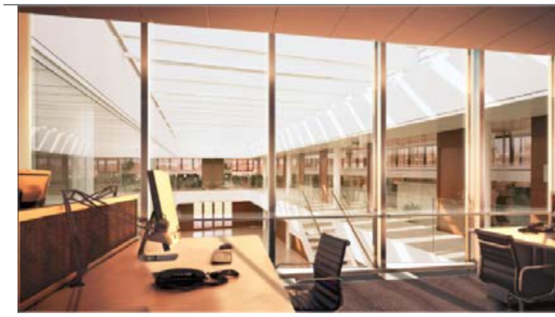



Scenario C (non-green group) | **Scenario C (green group)**

Scenario D (non-green group) | **Scenario D (green group)**

Figure 3.1 Photo simulation for treatment videos



Scenario E (non-green group) **Scenario E (green group)**

Scenario F (non-green group) **Scenario F (green group)**

Figure 3.1 (Cont.) Photo simulation for treatment videos

3.3 Participants

We recruited participants by advertising in E-week, a weekly informational email that was sent to all faculty and staff at the University of Illinois at Urbana-Champaign. In the announcement, we informed potential participants about the experiment and let them know that if they signed up, they were going to engage in an experiment about office environments. We did not mention the treatment conditions or anything about mental fatigue or attention restoration. Participants were informed that they would receive $15 after completing the entire experiment, and would receive 5$ if they decide to quit any time before the experiment ended.

All the participants were required to have normal, or corrected to normal, eyesight, have no difficulty distinguishing colors, and have no physical impairment or discomfort that affect their operation of a computer. We require that each participant held a full-time or part-time position in an office. Participants needed to confirm that they fulfilled these requirement before scheduling a time to participate in the experiment. Those who do not meet the requirement were informed that they will not be included in the research before the experiment phase started.

Sixty people (50 female and 10 male) between the ages of 18 and 60 participated in the experiment. We gathered data regarding their age, gender, race, type of employment, office setting, level of mental fatigue and general health conditions before we began the experiment.

3.4 Experiment setting

The experiment was conducted in one study room in ACES Library. We blocked the view out the window by closing the blinds and ensured that the lighting conditions were constant for each of the 60 participants. The room temperature was in the range of 68-73F. Participants saw the window when they stepped into the study room, and sat with their backs to the window during the experiment. All participants were led to the same spot in the room facing the desk and back to the blocked window view (see Fig 3.2) at the start of the experiment.

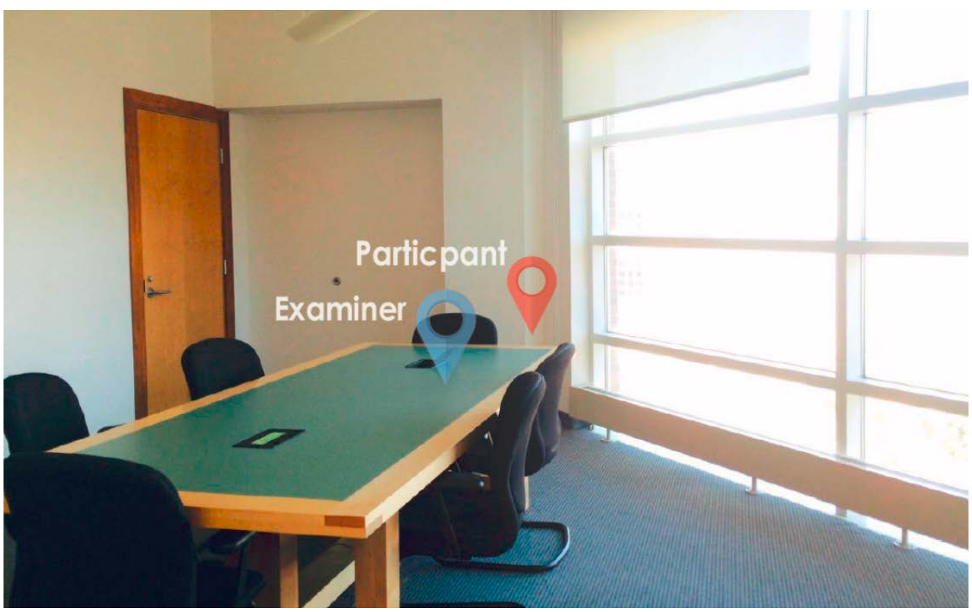


Fig 3.2 Experiment room setting

3.5 Measures

We measured participant's attentional functioning by using three objective attention tests and one subjective test. Three objective attention test includes Visual Reaction Time Test, Digit Span Backward, and Color Stroop test. The subjective test asked people to rate their current level of mental fatigue.

3.5.1 Objective attention

Visual reaction time

Reaction time had been used to detect fatigue for years (Milroy, 1909). We used the simple visual reaction time test to measure the reaction time towards a known stimulus. In our experiment, it required participants to click a mouse as soon as they saw a red cycle appeared on a computer screen. The visual reaction time (VRT) tests were conducted on the laptop computer. Each VRT test included five stimulus and responses – each response being recorded by a click of the mouse. The computer recorded the reaction time between the onset of the red cycle and the time when the mouse was clicked and the researcher took note of any impulsive mistakes that participants made. The average reaction time for each of the five clicks in each VRT test was used as the dependent variable in our data analysis.

Digit Span Backward

The Digit Span Backward Test (DSB) is often applied as a measure of short-term memory (Richardson, 2007), and was used as an objective attention measure in our research. We conducted the DSB on a laptop computer. The DSB requires participants to enter a number they saw on the screen, but to do so in reverse order. All DSB starts with three digits. The number of digits increased during the test when participants got two correct answers. And the test ended when participants made two mistakes in same digit level. The number of digits they reached during the last trail was used in data analysis.

Color Stroop

We asked participants to take the Color Stroop Test after watching the Video. This test had been used as a measure of attentional effectiveness when dealing with conflict color and text information (Macleod, 1991). Because of the noticeable learning effect of Color Stroop test (Davidson, Zacks, & Williams, 2003), participants only did this test after watching the video. Participants were given a list of words that were printed names of colors that differed from the meaning of the word. So for instance, the word green might be printed in blue ink, the word yellow might be printed in green ink, and so forth. We showed participants a page of 50 words printed in this fashion.

We first asked participants to read the text of and ignore the color of the ink. Next, we gave them a similar list of words printed in colors that differed from the meaning of the printed word and ask them to read the color of the ink. During the test, the examiner measured the time participants used in reading each list and recorded the mistakes in reading.

3.5.2 Subjective attention

Visual Analog Scale had been used to measure research subjects' attitudes in different areas including social and behavior science and clinical use (Wewers & Lowe, 1990). This measurement also had been used previously to measure subjective mental fatigue (Cook, O'Connor, Lange, & Steffener, 2007). Participants took the VAS questionnaire at the beginning of each attention test. The questionnaire contains a 10 mm long line which represented a gradient of mental fatigue from "not at all mentally fatigued" (left end) to "very much mentally fatigued"(right end). Participants indicated their mental fatigue by marking an "X" on the line. We recorded their mental fatigue by measuring the distance between the left end of the scale and the point at which they drew the "x."

3.6 Experiment Procedure

We randomly assigned participants to one of the two groups. The green group watched the video of the office settings with the view of the greening atriums while the non-green group watched the video of the same atrium spaces but without any vegetation. One person participated in the experiment at a time.

After filling out the permission forms and providing their health and demographic information, participants were given a proofreading task designed to induce mental fatigue. Then we asked them to watch a 4-minute long video clip. The video had been prepared and placed on a desktop of the computer before they came according to their randomly assigned group. We conducted three attention tests during the experiment: baseline level- at the beginning (time1), after proofreading (time2), and after watching the video (time3). The entire experiment took about 40 minutes. At the end of the experiment when all attention tests were finished we asked participants to fill in a post rest survey questionnaire about their opinion of office environments. Fig 3.3 shows the entire research procedure.

The experiment followed the same procedure according to a prewritten script. Participants from each group got the same treatment except the video they watched.

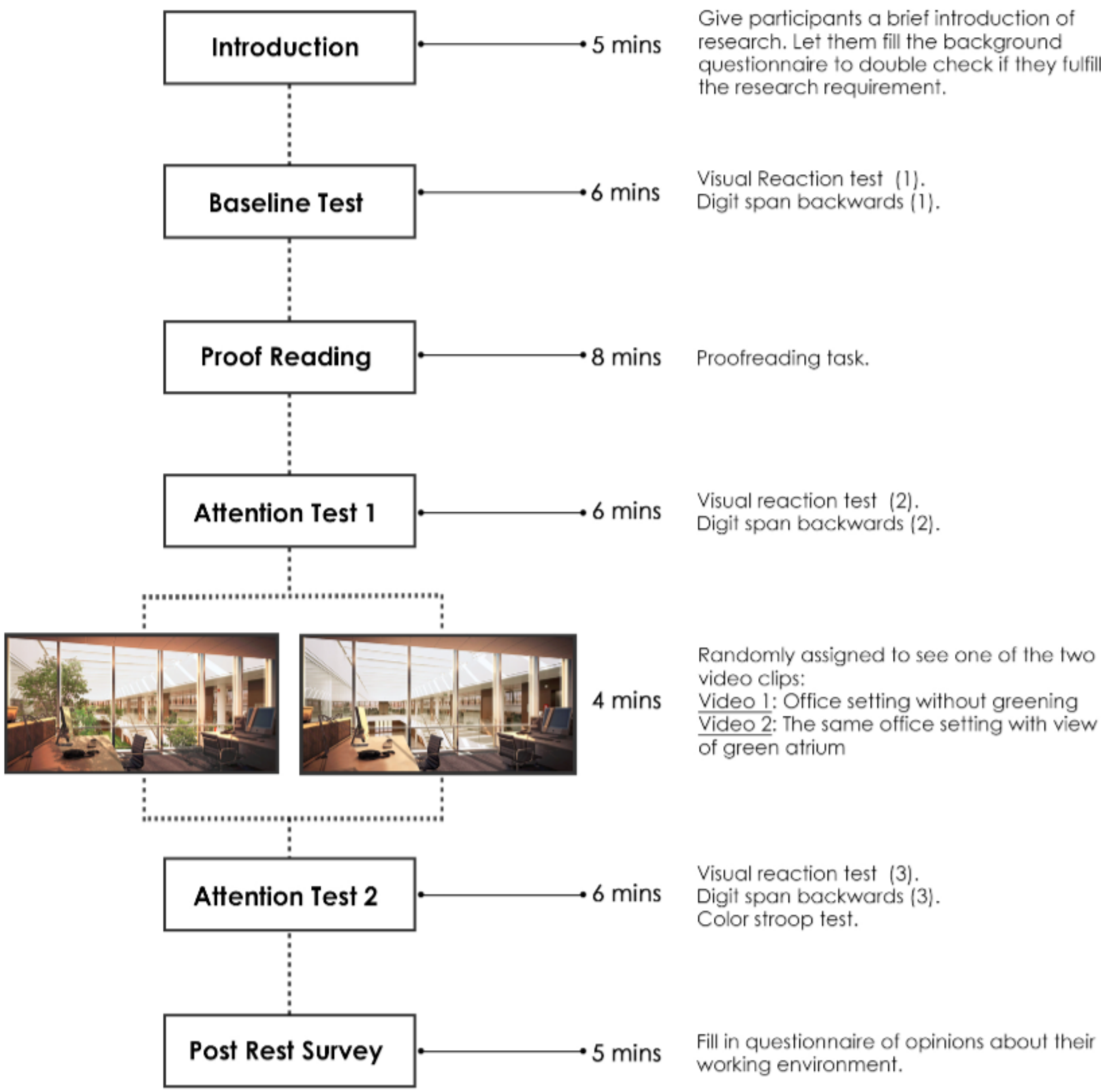


Fig 3.3 Step by step procedure

Chapter 4: Results

The results are presented in five sections. First, to assess the extent to which there were differences in the two groups of randomly assigned participants in terms of their attentional functioning, we compared the baseline objective and subjective attention levels of the two groups. Second, we examined attention functioning of the two treatment groups after the mentally fatiguing activities. Third, we examined the impact of two treatments on the participants' attention scores. Fourth, based on post rest survey questionnaire, we inferred the subjective need of people’s working environment. Finally, we examine the relationship between participants’ daily working environments and their baseline attention performance.

4.1 Baseline attention level

Were there differences in attentional functioning between the two groups of participants randomly assigned to the two treatment groups? To answer this question, we compared the result of baseline attention tests between two groups of participants. As can be seen in Table 4.1, we found no statistically significant difference between two groups of people for the Visual Analog Scale (t=-0.984, p=0.330), visual reaction time (t=0.038, p=0.97), or Digit Span Backward (t=-0.078, p=0.938) tests at the baseline.

This suggests that there is no basic differences in attentional functioning prior to beginning the experiment.

Baseline Attention Test	Mean		t	p
	Green Group	Non-Green Group		
Visual reaction time (ms)	407.0	406.5	0.037	0.97
Digit Span Backward	6.7	6.7	0.078	0.938
Visual Analog Scale	2.3	2.9	0.984	0.330

Table 4.1. Three Baseline Attention test scores for green and non-green groups

4.2 Attention level after proofreading task

To what extent did the activities designed to make the participants mentally fatigued result in measurable declines in scores on our tests of attention? To answer this question, we ran a paired samples t-test on all participants comparing their subjective attention evaluation before and after the proofreading task.

As can be seen in Table 4.2, participants report higher levels of mental fatigue using the visual analog scale ($t=-7.719$, $p<0.001$) after the tasks designed to produce mental fatigue.

Surprisingly, there were no significant changes in attentional performance after the proofreading task in the two objective attention test: visual reaction time ($t=0.061$, $p=0.951$), Digit Span Backward ($t=-1.894$, $p=0.063$). Thus, although the participants felt more mentally fatigued after the proofreading tasks, our objective measures of attention failed to detect any differences before and after.

Pair Baseline test -2nd attention test	Mean		t	p
	Before proofreading task	After proofreading task		
Visual Analog Scale	2.6	4.2	-7.719	0.000
Visual reaction time	406.7	406.2	0.061	0.951
Digit Span Backward	6.7	7.0	-1.894	0.063

Table 4.2. Attention scores' differences before and after proofreading

4.3 Effect of treatments on attention restoration

Is there a difference in attention scores between the two groups of participants after they watched the different videos? We answer this question by looking at each attention test. When analyzing the data of each attention test, we compared the result of the 3rd attention test between two groups by running an independent-samples t-test (one-tailed). Also, we within each group (green group, non-green group) by conducting a paired samples t-test (one-tailed) to see if the attention performance is different before and after they watch the video. Here we show the result of the four attention tests.

4.3.1 Subjective assessment of mental fatigue

Do people from the green group report that they feel less mental fatigue after watching the video than those from the non-green group? No. As can be seen in Table 4.3, after watching the video, the result of self-reported mental fatigue on the 3rd VAS questionnaire shows no significant differences between the green and non-green groups (t=-1.014, p=0.158). (Fig 4.1)

When comparing the change of attention within each group, the non-green group reports no difference after watching the video (t=0.145, p=0.443). The green group, however, reported 12.3 percent less mental fatigue on average after watching the video for a rest. The result is consistent with our hypothesis but is not statistically significant (t=1.566, p=0.064). (Table 4.4)

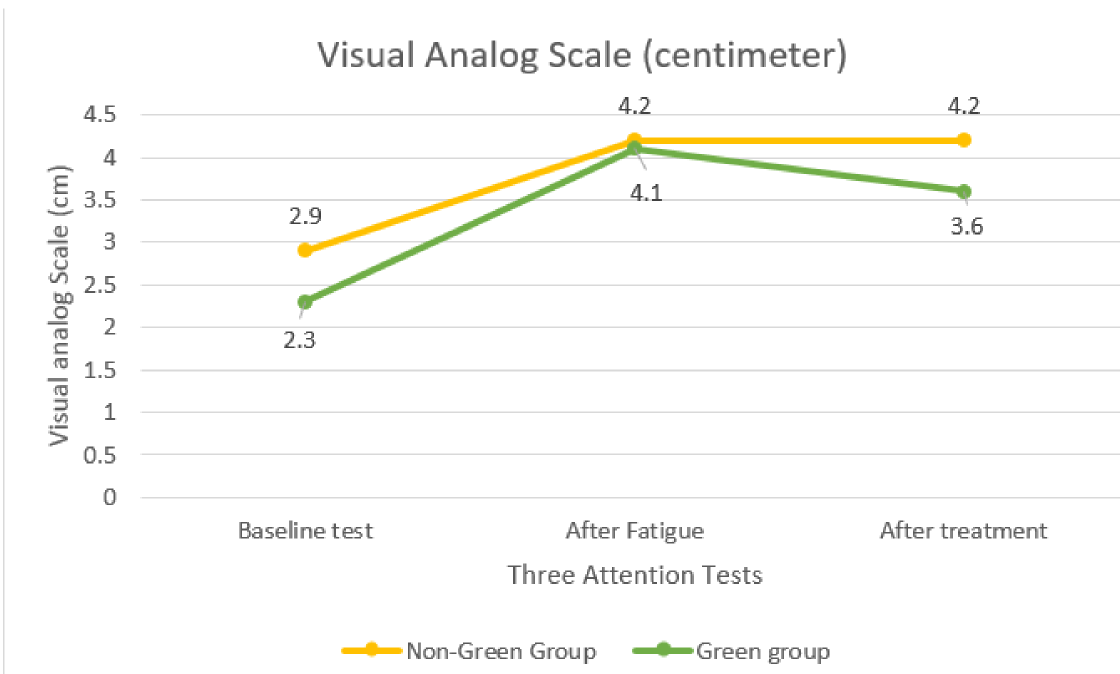


Fig 4.1 Average score on three visual reaction time tests for the green and non-green groups

Third Attention test	Mean		t	p
	Green Group	Non-Green Group		
Visual Analog Scale	3.6	4.2	-1.014	0.158

Table 4.3 Visual analog scale in 3rd attention test (one tailed)

Pair 2nd Attention test -3rd Attention test Visual Analog Scale	Mean		t	p
	Before Treatment (Video)	After Treatment (Video)		
Green Group	4.1	3.6	1.566	0.064
Non-Green Group	4.2	4.2	0.145	0.443

Table 4.4 Paired sample T-test, comparing VAS before and after treatment, by group (one-tailed)

4.3.2 Visual reaction time test

Did the people in the green group improve their reaction time from before the treatment to after the treatment? Yes, the green group's visual reaction time was shorter after watching the restorative video. As Figure 4.2 shows, after watching the video, although the average reaction time (ART3) of the green group is faster than the non-restoration group, the difference of reaction time between these two groups is not significant (t=-0.692, p=0.249)(Table 4.5). However, it is worth noticing that people in the non-green group made more impulsive actions (clicking the mouse before red circle appeared) than people in green group (t=-2.408, p=0.012). People in the green group had significantly faster reaction times after watching the video (t=1.831, p=0.039) while people in the non-group showed no improvement in visual reaction time (t=0.238, p=0.407). (Table 4.6, Table4.7)

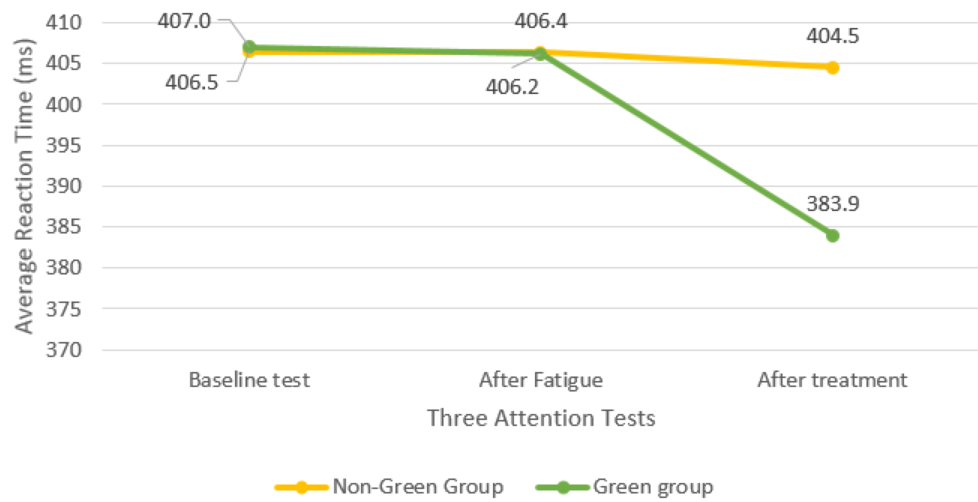


Fig 4.2 Average score on of three visual reaction time tests for the green and non-green groups.

Third Attention test	Mean		t	p
	Green Group	Non-Green Group		
Visual reaction time	383.9	404.5	-0.692	0.249

Table 4.5 Comparison between visual reaction time tests after watching the treatment videos, for the green and non-green groups.

Pair 2nd Attention test -3rd Attention test visual reaction time	Mean		t	p
	Before Treatment (Video)	After Treatment (Video)		
Green Group	406.2	383.9	1.831	0.039
Non-Green Group	406.4	404.5	-0.238	0.407

Table 4.6 Green and non-green groups' improvement in visual reaction time after seeing treatment video (one tailed)

Third Attention test (visual reaction time)	Mean		t	p
	Green Group	Non-Green Group		
Impulsive action	0	0.17	-2.408	0.012

Table 4.7 Impulsive error after treatment in the visual reaction time test after seeing treatment video for the queen and non-green groups

4.3.3 Digit Span Backward test

Did the participants in the green group reach to more digits in Digit Span Backward test after watching the green video? No. the result of Digit Span Backward test shows no difference between two groups.

As can be seen in Figure 4.3, after the video treatment, there is no significant difference between two groups of participants (t=-0.079, p=0.469). When looking into each groups' performance on the Digit Span Backward test after treatment, the change can hardly be observe in either the green group (t=-0.953, p=0.175) or the non-green group (t=-1.342, p=0.407). (Table 4.8, Table 4.9)

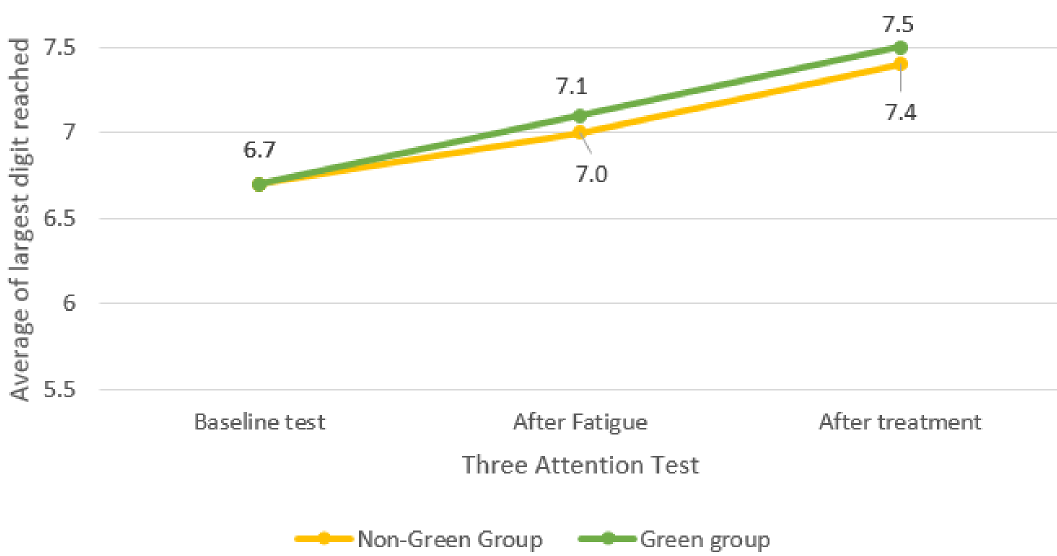


Figure 4.3 Scores on the Digit Span Backward test at baseline, after fatigue activities, and after watching the treatment video for green and non-green groups

Third Attention test	Mean		t	p
	Green Group	Non-Green Group		
Digit Span Backward test	7.5	7.4	-0.079	0.469

Table 4.8 Comparison between Digit Span Backward tests after watching the treatment videos, for the green and non-green groups.

Pair 2nd Attention test -3rd Attention test Digit Span Backward test	Mean		t	p
	Before Treatment (Video)	After Treatment (Video)		
Green Group	7.1	7.5	-0.953	0.175
Non-Green Group	7.0	7.4	-1.342	0.407

Table 4.9 Green and non-green groups' improvement in Digit Span Backward test after seeing treatment video (one tailed)

4.3.4 Color Stroop test

Did the people in the green group have a better performance in Color Stroop Test? Yes, participants who watched the video with a view to a green atrium made fewer mistakes on the Color Stroop test.

As can be seen in Figure 4.4, participants in the green group made fewer mistakes when reading the text than participants in the non-green group (t=-1.787, p=0.042). When reading the color, instead of the word in the Stroop test, they also made fewer mistakes, but the difference between two groups is not significant (t=-1.195, p=0.129). (Table 4.10)

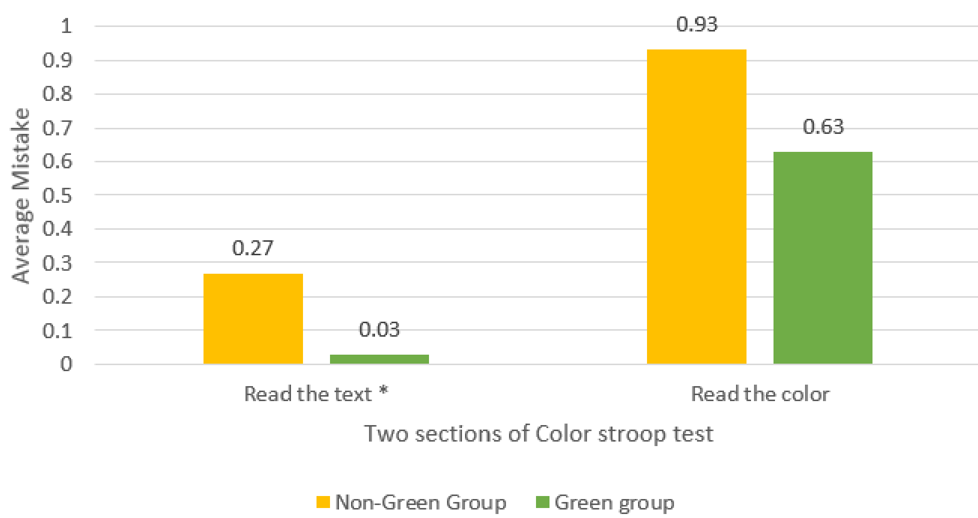


Fig 4.4 Mistakes in two sections of Color Stroop test

Third Attention Test	Mean		t	p
	Green Group	Non-Green Group		
Color Stroop test 1 (Read the text)	0.03	0.63	-1.787	0.042
Color Stroop test 2 (Read the color)	0.27	0.93	-1.195	0.129

Table 4.10 Mistakes made in two sections of the Color Stroop test by green and non-green groups (one-tailed)

4.4 Which kind of work-break activity do office workers prefer?

Beside the attention restoration benefits of indoor green space, we want to know what kind of work- break activities and environments the office workers preferred. We asked participants the question "After what work-break activities do you feel most refreshed and ready to work again?" This was an open-ended question and participants answered without any guidance or prompts. Of the 60 participants, we got 57 valid answers. The keywords of their answers were extracted and sorted into following categorizes：

1. Outside
2. Drink/ eat
3. Stretch
4. Rest eyes
5. Communicate
6. Other entertainment
7. Look out of window

As Figure 4.5 shows, among those 57 people with valid answers, more than half (36/57) mentioned that they will take a walk inside or outside of their office building for a rest. Also, nearly half of them (24/57), specified in their answers that they need contact with outdoor environments, either by being in those spaces or by looking at them through a window. Twenty-three people mention that a drink or lunch break will be helpful. One dozen of the participants said that they will talk with other colleagues for a rest.

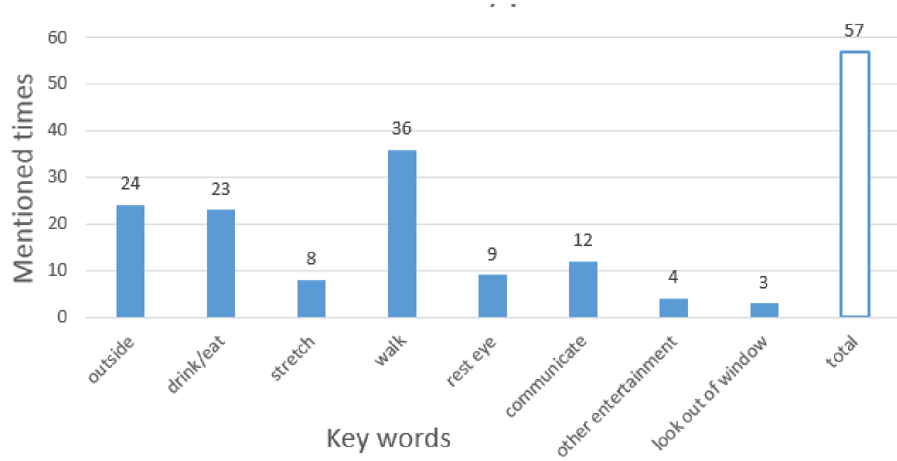


Fig 4.5 Number of times participants mentioned various types of break activities that they preferred

4.5 Baseline attention performance and original working environment

To what extent do participants' daily working environments predict to their baseline attention scores? To answer this question, we divided participants into two groups based on their self-reported daily working environment. They reported whether or not they had a window in their office. We ran an independent-samples t-test to compare the results of baseline attention tests between these two groups of participants.

The result shows (Table 4.11) that people who work in an office setting without a window had a significantly better performance in two baseline objective attention test. The no-window group had shorter reaction times (t=-3.350, p=0.001) than the window group. Moreover, they also scored significantly higher in the DSB test (t=0.688, p=0.014) than the group who had windows.

Baseline Attention test	Mean		t	p
	Office with window view	Office without window view		
Visual reaction time (ms)	426.2	381.2	-3.350	0.001
Digit Span Backward	6.2	7.3	0.688	0.014

Table 4.11 Baseline Attention Test scores of participants who reported they have or do not have a window view in their office.

Chapter 5: Discussion

This study explored the impact of a short exposure to green atrium spaces within a building on recovery from mental fatigue in office workers. We randomly assigned 60 office workers to two treatment groups – a green group and non-green group – and tested their attentional functioning before and after they watched videos of atriums with or without vegetation. Our findings showed some indications that green atriums produced faster recovery from mental fatigue: participants in the green group showed significant improvement in their reaction time tests after watching the video and made fewer impulsive mistakes than the non-green group. They also made fewer mistakes than the non-green group in the Color Stroop test after watching the video. In the sections below, I discuss the contributions of this work, the implications of the findings, and some ideas for future research.

5.1 Contributions

We already know that natural environments play an important role in helping people recover from the mental fatigue caused by the use of directed attention (Kaplan, 1995). Kaplan mentioned that many natural environments provide fascinating objects that catch people attention easily and in doing so, allow people to rest and restore their directed attention. Moreover, natural environments help people temporarily get away and forget about their work, and thus help them recover from direct attention fatigue.

Previous studies that examined the psychological benefits of indoor greening report mixed results (Bringslimark et al., 2009). Shibara and Suzuki (2001) evaluate the influence of indoor plants on attention by conduction task-performing tests. They found that on the one hand, indoor plants helps people recover from attention fatigue during a rest period. On the other hand, they also report that the same plants might somehow distract people during their work time. Other research found that indoor plants somehow make people's performance decrease when doing a letter identification task (Larsen et al., 1998).

Our research is the first study that we know to focus on a larger scale of indoor greening. Pervious work examined house plants in an office (Larsen et al., 1998); or a combination of house plants and views to green landscapes (Chang & Chen, 2005). By examining a new office building type with green interior core, we proposed a new perspective of integrating greening with atrium space to maximize office workers' opportunities to connect with vegetative views.

The results of our research are similar to the findings of previous research of indoor plants. Views of green atrium spaces helped people recover from attention fatigue as measured by some of the attention test, such as visual reaction time test and Color Stroop test. Still, the benefits of green atriums are not as consistent or as powerful as videos to outdoor green spaces (Jiang, Li, Larsen, & Sullivan, 2016), views out windows to green spaces (Li & Sullivan, 2016),or being in urban spaces that contain a good deal of vegetation (Berto, 2005; Berman, Jonides, & Kaplan, 2008). The benefits from viewing green atriums are not nearly as strong as the benefits found for people who view outdoor landscapes with vegetation. Still, green atrium spaces have some attention restoration benefits, but these benefits are not as powerful as the outdoor spaces have been shown to be.

Our research complements the category of attention benefit of indoor plants. Green atrium spaces likely provide the maximum volume of plants that are reasonable for indoor settings based on existing patterns of office design. By demonstrating that green atrium spaces have some measureable impacts on attention restoration, we hope this study will inspire future research to challenge tradition office design when looking into the attention benefits of indoor greening.

5.2 Implications

Our research suggests that view of green atrium spaces can helped office worker recover from attention fatigue. The effects, however, are relatively small compared to taking a break in an outdoor green space.

Facing considerable pressure and long work days, office workers often experience high levels of mental fatigue. Roelen, van Rhenen, Groothoff, van der Klink and Bültmann (2012) asserted that prolonged mental fatigue can lead to serious physical and psychological health issues.

The result in our post rest survey questionnaire supports the need of attention restoration during work. In the post rest survey, half of the participants mentioned that they need a walk during working break, and 40% of participants indicates they need to go outside or at least view the outdoors multiple times per day. Clearly, office workers' need breaks from their work activity. Finding ways to connect workers to nature is a challenge and an opportunity for designers and for people who work in offices.

Office buildings not only become the places in which people suffered from mental fatigue but they also too often isolated workers from the natural environment. As the recognition that we can all benefit from having lower levels of mental fatigue grows, people will likely try to improve their office environments by adding potted plants and indoor green walls. Based on the findings of our research and a review of previous studies, such actions are likely to have only minor benefits on worker's attention restoration. In our research, the attention restoration benefit of indoor green spaces' window view also deviated in different attention tests. The effective way of integrating greening into the office building to reduce mental fatigue is still needed to be found. Thus, for mentally fatigued office workers, this research and previous research suggest that a reliable way to restore their attention during the workday is likely to be taking a walk in a green setting for a few minutes.

Traditional office buildings are designed with function and effectiveness as the primary concerns. Ensuring green views from each office has most often not been a concern for developers or for architects. But architects and researchers should seek new ways of integrating contact with nature in office environments. And this new way might include a breakthrough in the traditional concept of how office buildings take advantage of and use indoor greening.

5.3 Limitations and future research

As with all research, this study as its limitations, and it also opens the door to future research. I discuss both of these below.

We designed the experimental procedure used in this experiment to be concise. The treatment itself – a 4-minute video – was a relatively short intervention compared to the three attention task (each around 6-minutes). In spite of this short intervention, we found some evidence that views to green atrium spaces help people recover from attention fatigue faster than people of viewed atriums with no vegetation. Would a longer treatment lead to more significant results? That is, would a 6, 8, or 10-minute view of a green atrium produce greater results than the 4-minute video used in this study? There is reason to think so, and these seems to be an issue ripe for future research.

We expected to see a slower reaction time and fewer digits in Digit Span Backward task after participants engaged in the proofreading task. The results, however, showed that, on average, participants' scores on both the visual reaction time test and the DSB test after the proofreading task were not different from the scores at baseline. Why did we not see a decrease in performance in these measures after the proof reading tasks?

Two possibilities are worth consideration. The first is that our 8-minutes long proof reading task, which was designed to induce mental fatigue, was too short produce significant changes in mental fatigue. In other recent work with students, the research protocol used a 30-minute period to induce mental fatigue (Li & Sullivan, 2016). We suggest that future researchers use a set of tasks lasting at least 15 minutes to induce mental fatigue rather than the 8 minutes employed in this study.

Second, it is possible that the procedure we used for the Digit Span Backward test helped participants remember the numbers better than the traditional method of administering this test. Traditionally, in the DSB test, a researcher reads the digits out loud and the study participants recites the numbers back to the researcher. In our study, the digits were displayed on the computer screen and the participants typed the numbers into the computer. It is possible that this slight change in perceiving the digits visually instead of aurally was enough to change the typical pattern of results. Indeed, there is research to suggest as much (Drewnowski, A., & Murdock, B. B, 1980). In the future, we recommend that researchers use the traditional procedures – that is, they should read the digits our loud and ask that participants recite the digits out loud too.

We recruited 60 office workers in Champaign-Urbana to represent the research target group. We recruited our participants via a campus email notification called E-Week – a message that goes to all faculty and staff on the campus. Therefore, most of the participants in this study were employed by the University of Illinois. Our final sample included 50 female and 10 male participants. The gender composition of our sample is in line with the demographic characteristics of people who work in offices on our campus. We separated participants randomly into two experiment groups with 25 females and 5 males in each group, to minimize the variation between two groups. However, this female to male rate (16.7%) can still hardly represent the demographic gender ratio of office workers in the US. Thus, in future research, scholars should seek a better balance between the genders that we were able to achieve here.

We also observed that participants' daily working environment correlate to their attention performance in the experiment. Participants who reported having no window view in their daily work environment perform better on the baseline objective attention tests than their peers who reported they did have a window. Office setting also correlated other factors such as position, profession and work type, which could cause the difference of individual's attention performance. We cannot draw a conclusion regarding the cause-effect relationship between participants' window views in their daily work environments and their attention performance in our experiment. Future research can look into the impact of office environment on attention restoration by investigating larger group of sample and comparing the difference of attention performance of people who work in different office settings.

Chapter 6: Conclusions

Driven by our contemporary economy, millions of office workers spend their days focusing their attention on details and tasks and little opportunity to seek relief from the mental fatigue they experience by seeing natural elements like trees or water. These office workers are at risk of prolonged mental fatigue and their working environment does little to provide relief.

This problem will not be addressed until we take actions to improve the ways in which, and the places in which, we live and work. Attention Restoration Theory suggests that if office workers had more and better opportunities to connect with nature from their offices, they might be able to recover from mental fatigue. Unfortunately, previous research shows that a few indoor plants are not enough to significantly reduce mental fatigue.

This study observed the attention restoration benefit of a larger scale of indoor greening effort – green atrium spaces. Our results are consistent with previous studies about the impact of indoor plants on human cognition. We found that turning atriums into indoor green spaces have some effects on attention restoration but that these influences are not as large as one would expect from seeing green outdoor spaces. In this study, we found that simply viewing larger green indoor office settings did not dramatically reduce in mental fatigue.

Our study's limitations offer opportunities for future research. Such research should create more mental fatigue in study participants. Participant's attentional functioning should be measured using standard procedures for measuring attention.

Although we did not produce concrete evidence that exposure to green atriums can reliably restore attentional functioning in people who are experiencing mental fatigue, our findings suggest there may be an impact here and that additional careful research may uncover the conditions under which such spaces help people recover from the mental fatigue that is consistent with office work for millions of people around the world.

Moreover, we hope these findings inspire designers to seek innovative office building designs that create recurring opportunities for office workers to connect with nature during working hours.

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