Abstract

The purpose of this study was to investigate links between attention restoration theory and executive function. A series of four experiments, each using a pre- versus post-test design, studied the influence of various interventions on executive function, as assessed by a backward digit span task and Raven’s progressive matrices. Experiment 1 began by testing the influence of cognitive strategy as manipulated through task instructions. Experiment 2 tested the influence of viewing slides of nature versus urban scenes, as predicted by attention restoration theory (Berman, et al., 2008). Experiment 3 repeated these procedures, using more engaging 10-min video tours of nature versus urban environments. Experiment 4 combined the successful instructional manipulations of Experiment 1 and the video manipulation of Experiment 3 to examine interactions between strategy and environment on executive function. The results showed that the nature video intervention reduced the influence of task instructions relative to the urban intervention. This supports Berman et al. (2008), who claim that exposure to nature has a restorative influence on executive function.
Preface

The University of British Columbia Behavioural Research Ethics Board granted approval for all experiments mentioned herein. Certificate number: H14-00769.

The content of this thesis is the original and unpublished work of the author, Stefan C. Bourrier. Experimental design and data analysis was conducted by the author under the supervisory guidance of Dr. James T. Enns. Execution of this study, and data collect was conducted by Stefan C. Bourrier with the help of a research assistant: Shirley Bi.
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Acknowledgements

Sincere appreciation and thanks to my supervisor, James T. Enns, for his continuous support during my research, his intellectual contributions, and his ability to help me think outside the constraints of my pre-existing intellectual framework.

I would also like to acknowledge the peers and mentors who supported me throughout this endeavor, especially Elizabeth Blundon, Anna Maslany, Trish Varao-Sousa, Peter Lenkic, Ana Pesquita, and Catherine Rawn, whose countless hours of input were all highly valuable to me.

Lastly, I would like to thank the entire UBC Vision Lab for their support (especially my research assistant, Shirley Bi), as well as my supporting friends and family.
“We can never have enough of Nature. We must be refreshed by the sight of inexhaustible vigor, vast and titanic features, the sea-coast with its wrecks, the wilderness with its living and its decaying trees, the thunder cloud, and the rain which lasts three weeks and produces freshets.”

-Henry David Thoreau: Walden (1854)
Chapter 1: Introduction

In recent years, human behavior and natural environment interactions have become of greater interest (Kabisch, Qureshi, & Haase, 2015). This is not surprising given the current amount of discourse on environmentalism, and as findings such as climate change become issues of public concern, we turn towards a better understanding of future human and planetary existence. In doing so we hope to garner a better understanding of how we, as humans, interact with a natural world that is undergoing drastic changes. Beyond environmental concerns, there is also a subjective sense of close connection to nature, and this can be seen in how humans care for personal gardens, bring plant life indoors, and seek time in green spaces. This latter point has become of significant interest to researchers, and we are already seeing the results of studies that indicate that spending time in nature has cognitive benefits. In some of these cases it has been shown to be effective at helping in a number of areas including: depression (Berman et al., 2012), health (Arbogast, Kane, Kirwan, & Hertel, 2009), and even indoor work performance (Raanaas, Evensen, Rich, Sjøstrøm, & Patil, 2011). So why does nature have such a strong cognitive effect?

In order to gain a better understanding of the cognitive effect involved, we first need to understand a few key concepts about human behavior. The past research looking at these effects of nature have suggested that attention may be one of these key cognitive components. In Stephen Kaplan’s (1995) seminal work on attentional restoration theory (ART), he suggested that there are many reasons as to why people may seek to visit a natural environment, but that many of those reasons can be connected to a desire for cognitive restoration in nature. To better understand what restoration means in this context, we need to first look at what is proposed to be restored. Kaplan & Talbot (1983; Kaplan & Kaplan, 1989) previously proposed that attention was a critical everyday function of human life, and that in nature effortful attention was reduced, allowing attentional reserves to replenish.

This particular model of attention requires that we consider attention as something that has a finite capacity. Further to this finite capacity, there must also be a manner by which that capacity can become depleted. The concept of attentional capacity has been discussed at great length (Kahneman, 1973; Kahneman & Treisman, 1984; Moray, 1967;
Navon & Gopher, 1979; Spaulding, Plante, & Vance, 2008) and while there continues to be disagreements and improvements about this aspect of attention, it is essential that there is a clear understanding of what attention means in the context of this writing.

1.1 Attention

There are two key aspects of attention to consider within this study: (1) capacity, and (2) orientation. Theories of capacity suggest that attention is a finite resource that can become fatigued from continued use (Kaplan & Talbot, 1983). Some models suggest that there is a single pool of attentional reserves that can be accessed for a given task (Kahneman, 1973), while other models suggest there are multiple capacities or pools that do not interact with one another (Navon & Gopher, 1979; Wickens, 2002).

Attentional orientation refers to the directing of attention toward a location in space (e.g., a parking spot), or to an object (e.g., a car), or to a feature of an object (e.g., its color). There are a different theories about how orientation is accomplished (e.g., Posner & Petersen, 1990; Hurlbert & Poggio, 1985), but important to all theories is the idea that orientation can occur reflexively or automatically, meaning without effort, or voluntarily or intentionally, meaning with effort.

1.2 Attentional Fatigue

The main motivation for the empirical portion of this thesis is attentional restoration theory, as articulated by Kaplan (1995), and Berman et al. (2008). As the name given to this theory implies, a central assumption of the theory is the concept of attentional fatigue. What is implied by the notion of fatigue, is that the mental effort associated with the voluntary control of attention can lead to this resource becoming depleted over time, analogous to the way a muscle is depleted following repeated contractions (Kaplan & Berman, 2010, p. 47). In further keeping with this analogy, with sufficient rest, the mental capacity will be restored.

This specific assumption of the theory has been supported by the empirical finding performance decreases over time in a number of measures including the stroop and classification tasks (Hartig, Evans, Jamner, Davis, & Gärling, 2003), the executive attention component of the Attention Network Task (Berman, Jonides, & Kaplan, 2008),
the Sustain Attention to Response Task (Berto, 2005), and the Symbol Digit Modalities Test, (Tenessen & Cimprich, 1995).

So how does attention become fatigued? If we consider the spotlight of attention as being driven by either internal (top-down) or external (bottom-up) processes (Posner & Peterson, 1990), then it is possible to have our attention directed by either conscious volition, or by salient environmental cues that capture attention. Consider these two circumstances: (1) While walking down the street you are actively scanning for cars when you notice one from a distance and keep tracking it until it passes. (2) While deep in thought, you step out into traffic and a car honks its horn, causing you to suddenly look up and attend to the car moving towards you. The first example requires the use of top-down mechanisms, which are directing attention based on a conscious intention. The second example represents the bottom-up mechanism, which helps direct conscious attention towards the startling horn. If attention is repeatedly directed in a voluntary way, it will cause attentional capacity to diminish until depletion, as shown by Boksem, Meijman, & Lorist, (2005) when they repeatedly gave memory-set tasks to participants for three hours without a break.

In the literature on Attention Restoration Theory, several cognitively demanding tasks have been used in a deliberate attempt to fatigue attention. One of the most popular of these is a version of a flanker task (Eriksen & Eriksen, 1974), which involves having participants respond to a central visual target that is closely surrounded (i.e., flanked) by a visual distractor which bears some resemblance to the potential targets. When a distractor resembles a target other than the one shown, responses are slowed; when it resembles the target, responses are speeded. The difference between incongruent and congruent trials is a measure of the degree of distractor inhibition that is required in order to respond successfully to the target.

Empirical support for the concept of attentional fatigue has been reported by Faber, Maurits, & Lorist (2012), who showed that the congruency effect increased over time, corresponding to a decreased ability to ignore the distractor. Even when controlling for speed-accuracy trade-offs, Head & Helton, (2014) found a decrease in SART performance over time indicated by an increase in errors.
1.3 Attention Restoration Theory

If we accept that attention can become fatigued then it also stands to reason that the attentional capacity can somehow be restored. There are limited ways mentioned in the literature but the most common are sleep (Kaplan, 1995), meditation (Nyklicek & Kuijpers, 2008) and exposure to nature. The latter is a critical one within the context of the this thesis. Attention Restoration Theory (ART), as hypothesized by Stephen Kaplan (1995) posits that humans are drawn to natural environments, and that the key reason for this is that nature has an inherent restorative property.

But what about nature actually allows for restoration to occur? Many senses can be specifically activated in nature; the sight of green spaces, plant life, mountains, and water; the smells of different plants and animals; tactile response from physical contact with the environment; and also sounds of things like wind, birds or bugs. Berman, et al (2008), investigated whether the hypothesis put forth by Kaplan held true. He had participants perform two tasks in the lab before sending them on a nature walk (e.g., park) or an urban walk (e.g., residential area). They were given a backward digit span task which was followed by a forgetting task designed to fatigue participants further. After returning from their walk they were given another backward digit span task to complete. What Berman found was that individuals from the nature condition performed better during post-tests than their urban counterparts. This was a finding in favour of ART, but it did not directly indicate what aspect of nature was responsible for restoration.

Berman et al, (2008) followed up their initial experiment with a similar one that held one important difference: Participants viewed nature and urban images on a computer display instead of participating in the physical nature or urban walks. Interestingly, the results for the image experiment were comparable to the previous one. Around the same time Berto (2005; 2010) also tested the use of images for restorative properties and found similar results. If these nature images are indeed able to restore attention then it seems to suggest that the visual experience of nature is strong enough on its own to create the effect. In other words, even without the smells, the tactile feedback, or sounds of nature, the remaining visual aspects were still restorative.

This finding raised new questions about how the visual aspects of nature were responsible for restoration.
1.4 Executive Function

Given this background on attention, its potential fatigue and restoration, it is important to be explicit about the how attention and its restoration are proposed to be linked within Attention Restoration Theory (Kaplan, 1995). If we consider our earlier example of a person stepping into traffic, we can see that the direction of attention is quite different when one is actively searching for a car versus when one is directed toward it by an unexpected honk. The first mode is voluntary and therefore effortful. The second mode is automatic and therefore not effortful in itself. However, if one is to ignore the reflexive orienting of attention toward the honking car in order to maintain the larger goal of also attending to the other cars in the intersection, then the inhibition of this reflexive orienting of attention can become effortful and cognitively taxing.

This coordination between higher-order goals and lower-level reflexive activity in the direction of attention requires some kind of control system. In the attention literature, this mental capacity is often referred to as an executive controller (Royall et al., 2002) or executive function (Funahashi & Andreau, 2013). In some ways we can imagine executive function like a person sitting in a control room with the ability to perform a number of actions. Different instructions are sent to the person and they are tasked with deciding whether or not to act on the new input. So if a car honks its horn an automatic response might send a message saying, “Hey, there’s something salient. Look over there!” The EF then directs attention towards the horn and brings it into awareness. This process can also be more intentional, such as when people are given specific instructions on how to perform a memory task (Carlson, Moses, & Breton, 2002).

Given that the purpose of this study was to better understand how nature restores attention, it seemed appropriate to select tasks that would get at this aspect of attentional orientation, as well as capacity, since the two seem closely connected (Dark, Johnston, Myles-Worsley, & Farah, 1985). In 2010, Kaplan and Berman suggested that self-regulation, such as intentionally directing attention, was the same mechanism as executive function. To make their argument they refer to the concept of ego depletion (Baumeister, Bratslavsky, Muraven, & Tice, 1998) which claims that continued acts of self-control lead to an eventual decrease in self-regulation. They also make mention of another paper (Baumeister, Vohs, & Tice, 2007) that outlines a number of different self-
control behaviours that lead to difficulty with self-regulation. While the connection between self-control and executive function appears linked conceptually, Kaplan and Berman also refer to work by Posner, Rothbart, Sheese, & Tang (2007) that points to the anterior cingulate cortex (ACC) as a location for cognitive control, but also emotional control. If the ACC is indeed the location of executive function then it opens a possible connection between executive function, by way of our cognitive strategies, and attentional restoration. In other words if self-control leads to ego depletion, and self-control occurs via the ACC then the effect from self-control on self-reliance mechanisms may function in tandem. The end result, as Kaplan and Berman point out, is that continued cognitive engagement leads to a decreased ability to do so and suggests that depletion is therefore occurring.
Chapter 2: Experiment One (Cognitive Strategies)

The purpose of experiment one was to determine whether instructions to use different cognitive strategies could influence performance on executive function tasks. Since the literature regarding cognitive strategies suggested that different instructional sets did indeed influence performance on non-EF tasks (Smilek, Enns, Eastwood, & Merikle, 2006), it seemed an appropriate place from which to gather some instructions for use in our experiment. Two critical instructional conditions were used: (1) Active instructions that were hypothesized to get the participant to actively direct their attentional focus and thereby activate executive function. (2) Passive instructions were the second, and hypothesized to diminish use of executive function by directing the participant to use intuition and a broader attentional focus to guide them in the tasks. The instructions used in experiment one were adapted from those used in Smilek, et al (2006), and were only slightly modified so that they would be clear to participants when used with our chosen set of EF tasks. It was our assumption that active cognitive strategies would be advantageous for performance on EF tasks.

2.1 Methods

Participants

Thirty participants aged 18 to 30 ($M = 21.8$, $SD = 2.88$) were recruited via the UBC Human Subject Pool. Participants were randomly assigned to either Active or Passive instructional conditions. All individuals gave informed consent in writing prior to participating in the study.

Tasks

Two separate tasks were selected for assessment. Since some different executive function tasks make use of differing aspects of EF, two tasks were selected that I felt had some overlap but were not identical. The reason for choosing two separate tasks was to attain a broader range of EF testing. The first selected was a backward digit span task adapted from the Wechsler Adult Intelligence Scale (WAIS), and requires the use of working memory, a key aspect of executive function. The second task selected was Raven’s Progressive Matrices. Designed to be a culturally unbiased intelligence task
(Raven, 1989), it uses images instead of words to test intelligence. The images are presented in an array (Appendix 1) with one of cells shown empty. Participants choose the missing cell image from a selection of options displayed alongside the matrix. As the name implies, the task is designed to become more difficult with each additional matrix. Raven’s is intended to test critical thinking and logic skills.

A Backward digit span program was written for MATLAB with the help of the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997; Kleiner et al, 2007). Participants were tested on 14 separate sequences of numbers, which started at three digits in length and increased by one digit every second trial up to our chosen maximum of nine digits. Each sequence was randomly generated and designed so that no sequence had duplicate digits. The digits were each shown in succession. They were each displayed, one at a time, and remained on the display for the length of one second. Between each digit a blank screen was displayed for 100 milliseconds. Once the entire sequence had been displayed, the participant was presented with an on-screen box where they could input the reverse order of the digits shown (Figure 1). Each entirely correct sequence returned was scored as one point, and the maximum score a participant could achieve was 14. A second, more liberal scoring was also recorded, and counted one point per correct digit per sequence (e.g., if the shown sequence was 458 and the participant responded 438 then they would receive 2 points out of 3 when liberally scored, but would have received 0 out of 1 points when using the more conservative scoring). Conservative and Liberal scoring systems were highly correlated, $r = .934, p < .001$, and as such only conservative scoring of our backward digit span task will be discussed in this document.

The Raven’s task used in this experiment was written for MATLAB and made use of the Psychophysics toolbox (Brainard, 1997; Pelli, 1997; Kleiner et al, 2007). The experiment used twenty-four 3x3 matrices, a subset of the entire available series. An example of the matrices used is seen in Appendix 2. During the experimental pilot we adjusted our subset selection of the matrices to attain a score of approximately 60% correct. The 24 selected matrices were then divided into odd and even numbered groups. Even numbered matrices were used in the pre-test and odd numbered matrices were used in the post-test. Each matrix was displayed for a total of 60 seconds and the participant had to choose the missing tile from 8 options displayed on-screen concurrently with the
corresponding matrix (Appendix 2). Each correct trial was recorded as one point for a total possible score of 12 points in each pre- and posttest trials.

**Figure 1 - Backward digit span computerized task**

e.g., If the sequence generated and displayed was 2-1-9 then the participants would respond by typing 912 for a correct score of one point.

**Instructions**

The independent variable in this study was instructional set. There were two conditions, Active and Passive, and instructions for each condition were modified versions of those used in Smilek et al. (2006). Instructional sets for both active and passive conditions had versions created for each of the EF tasks (Appendix 3). Active instructions consisted of rules that told participants to “direct their attention”, while passive instructions indicated that participants should use their “intuition” and “gut-feeling”. Active instructions were intended to make participants engage executive function, and passive instructions were intended to make participants limit executive function.

**Procedures**

All participants were tested using identical Apple computers with a 27” monitor using a display resolution of 2560x1440. Participants were instructed on how to perform the backward digit span task and then given two practice trials to confirm that they
understood the procedure. After performing the 14 backward digit span trials, the participants were shown a sample Raven’s matrix (Appendix 1) and verbally instructed on how to perform the task. Once the participant understood the instructions, they were asked to complete 12 Matrices, and to do so by answering each one within 60 seconds. Failing to do so would result in the automatic displaying of the next matrix trial and the previous trial would be scored as zero. Upon finishing the first two tasks, the participants were presented with the backward digit span instructions for their randomly assigned condition (active or passive). This was followed by a post-test backward digit span task, which was identical in design to the pre-test, with 14 new trials. After the backward digit span was completed, the condition specific instructions for the Raven’s task were shown. The participant then completed the post-test Raven’s task, which was also identical in design to its pre-test counterpart, with 12 different matrices shown.

2.2 Results

Scores on backward digit span (Figure 2) showed an increase in performance for active instructions and a decrease in performance for passive instructions. These conclusions were supported by the following statistical analyses. Data were analyzed using a between-within, repeated measures analysis of variance (ANOVA) for the within groups factor of phase (pre, post), and the between groups factor of condition (active, passive). No significant main effect of phase was found, $F(1,28) = 1.85, p = .185$, but a significant interaction between condition and phase was found, $F(1,28) = 24.45, p < .001$. Simple main effects were found to be significant for backward digit span and active, $F(1,28) = 6.43, p = .02$, and backward digit span and passive, $F(1,28) = 19.86, p = .0001$.

Figure 3 shows the results for the Raven’s Progressive Matrices task. Between factors and within factors remained the same as those used for analysis of backward digit span data. Main effect for phase was not found to be significant $F(1,28) = 0.01, p = .937$, but a significant interaction was found for condition and phase, $F(1,28) = 4.64, p = .04$. Simple main effects were not shown to be significant for Raven’s and active, $F(1,28) = 2.15, p = .154$, nor Raven’s and passive, $F(1,28) = 2.49, p = .125$. 
Figure 2 – This chart shows pre- and post-test scores for Backward digit span (BD) per instruction conditions, active and passive. Error bars represent one standard error around the mean.

Figure 3 - This chart shows the pre- and post-test scores for Raven’s Progressive Matrices (RM) per instruction condition. Error bars represent one standard error around the mean.
2.3 Discussion

The results of experiment one confirmed our hypothesis that differing cognitive strategies would have an effect on executive function task outcomes. Importantly, these findings gave support to the idea that manipulating executive function during executive function tasks changes performance.

Smilek et al.’s (2006) findings with respect to passive and active task instructions were opposite to those we found. The central difference seems to be the kind of task that they used. Their participants were asked to perform a visual search task. When participants in their study used passive cognitive strategies their performance was better than those who used active strategies. In addition to that experiment they ran an additional one that required people perform the visual search task while also performing a concurrent working memory task. In that experiment they found that adding a cognitive load produced results similar to those of the passive instruction condition. This is interesting because the results seem to suggest that not using executive function is the same as using executive function, but if we think about this in the frame of multitasking it makes more sense.

Humans are generally considered to be poor multitaskers (Gladstone, Regan, & Lee, 1989), but as just mentioned, certain tasks performed concurrently (such as working memory and visual search tasks, have shown an improvement in performance (Olivers & Nieuwenhuis, 2005; Smilek, et al., 2006). Some explanations of this difficulty with multitasking suggest that not just capacity but also cognitive bottlenecks, play a role (Dark, et al., 1985). The existence of cognitive bottlenecks has also been postulated for different systems such as visual and motor (Salvucci & Taatgen, 2008), and declarative and procedural memory (Pashler & Johnston, 1998; Borst, Taatgen, & van Rijn, 2010).

Another example of multitasking that has shown benefit for a concurrent task comes from work done by Olivers & Nieuwenhuis (2005). In one of their experiments they used an attentional blink task but also included a secondary task for participants to perform concurrently. The attentional blink paradigm suggests that the attentional window is limited in temporal scope (Raymond, Shapiro, & Arnell, 1992), but when Olivers & Nieuwenhuis (2005) gave participants an additional task, one designed to
occupy executive function while performing the attentional blink task, the performance of the individuals improved. These cases suggest that by occupying executive function, tasks that can be performed using automatic visual processing have less of a cognitive bottleneck to contend with, and as a result, performance increases when passive instructions are combined with an automatic task. The findings of Smilek et al (2006) and of Olivers & Nieuwenhuis (2005) are thus consistent with the findings of experiment one in the present study, because taken together they suggest that task instructions are able to directly influence people’s use of their executive function. Another way to state this, is that a passive cognitive strategy can be beneficial for tasks that rely on automatic processes whereas an active cognitive strategy can be problematic for those tasks. Conversely, a passive cognitive strategy can impair tasks that rely on automatic processes whereas an active cognitive strategy can be beneficial.
Chapter 3: Experiment Two (Images)

Findings from experiment one suggested that task instructions to adopt an active or passive cognitive strategy had a direct influence on executive functioning. While this is an important first step for our goal of comparing cognitive strategies with exposure to nature, it was equally important that we test our executive function tasks within the context of an attentional restoration task. The purpose of the second experiment was to determine whether previous ART findings would also be seen when we used the executive function tasks of backward digit span and Raven’s matrices.

We drew on research from Berman (2008) who graciously provided us with copies of the nature and urban photographs used in his study. Our experiment varied from Berman’s in one important way—we switched one of their attention fatiguing tasks (i.e., attention network task) with an measure of fluid intelligence, Raven’s Progressive Matrices. Our rationale was that the backward digit span task, coupled with the Raven’s should be equally fatiguing to the ANT task during pretest, but would at the same time allow us to test a somewhat broader measure of EF than past studies. Our hypothesis was that we would see effects of attentional restoration from nature exposure similar to those that Berman found in his 2008 study.

3.1 Methods

Participants

Forty participants aged 18 to 31 ($M = 19.87$, $SD = 2.23$) were recruited via the UBC Human Subject Pool and compensated with course credit for their involvement. The participants were randomly assigned to either the Nature or Urban photo condition. All individuals gave informed consent in writing prior to participating in the study.

Images

The independent variable for this study was environment image type, which was divided into two conditions, nature and urban. The images used were acquired from Dr. Marc Berman and were identical to those used in his Attention Restoration experiment (Berman, et al., 2008). All image dimensions were resized to 900x675 pixels and 72 ppi. The sets contained 50 nature and 50 urban images in total. Nature images were a
A compilation of different scenes and featured natural environments (e.g., forests, bodies of water, mountains) while the urban images contained different types of scenes (e.g., roads, vehicles, buildings). A single image from the urban set had a visual defect and it was replaced with a similar looking image acquired from Google images, using their “visually similar images” search function.

Participants were instructed to view each image carefully and told they would be prompted to rate each one after they viewed it for 10 seconds (Figure 4). The prompt to rate the image was displayed on the computer display after the image had been shown for 10 seconds. The image remained visible while participants indicated their rating.

You will now be shown a number of images.
We ask that you look at each one carefully.
After observing the image you will be prompted to rate the image indicating how much you like the image.

Figure 4 – Instructions shown to participants before starting the image viewing and rating section of experiment 2.

Tasks
Pre- and post-tests were identical to those used in experiment one. All parameters were identical except for a single difference, participants in experiment two were not given active or passive instructions to use while completing the tasks.

Procedures
All participants were tested using identical Apple computers with 27” monitors with a display resolution of 2560x1440. Participants were given pretest tasks identical to experiment one. When participants were finished with the pretests they were shown the
images of their randomly assigned condition. Before being shown the images, participants were told they would be asked to rate each of the images on a scale of 1 to 3, indicating how much they liked the image (1 = Do not like, 2 = Neutral, 3 = Like). Each image was shown for a period of 10 seconds before the participant was prompted to rate the image. The answers were recorded on the computer that displayed the images. A total of 50 images from the assigned condition were displayed to each participant. Once they were finished rating the images they were presented with the posttest backward digit span and Raven’s matrices. Posttest scoring parameters were identical to pretest ones.

3.2 Results

Figure 5 shows the mean scores for the backward digit span task and Figure 6 shows the mean scores for the Raven’s matrices task. In both of these tasks there was no evidence that the differential exposure to urban versus natural environments had any systematic influence on performance. This conclusion was supported by the following analyses.

Data were analyzed using a mixed design ANOVA involving the between groups factors phase (pre, post), and condition (urban, nature). For the backward digit span task, there was no significant interactions of phase and condition, $F(1,38) = .934, p = .340$, but the main effect of phase was significant, $F(1,38) = 4.29, p = .045$, indicating higher scores in the post-test than the pre-test.

For the Raven’s matrices task there was also no significant interactions of phase and condition, $F(1,38) = 2.55, p = .119$, and neither was the main effects of phase, $F(1,38) = 1.47, p = .232$. Figure 6 shows mean scores for Raven’s matrices using the same between and within groups factors as was used for backward digit analysis. No significant interactions were found for phase and condition, $F(1,38) = 2.55, p = .119$. Main effect of phase was also not found to be significant, $F(1,38) = 1.47, p = .232$. 
Figure 5 - Backward digit span scores. Error bars represent one standard error.

Figure 6 - Raven's matrices scores. Error bars represent one standard error.
Image Ratings

To understand the connection between images ratings and post test scores, several analyses were done. The average score for urban ($M = 1.87$, $SD = 0.28$) was less than the average score for nature ($M = 2.38$, $SD = 0.33$). Of the total 50 nature images, 41 were rated as higher than neutral score. Of the 50 urban images, only 20 were rated higher than neutral.

A univariate ANOVA was conducted with the factor of condition (nature, urban) and participant’s mean image ratings. Analysis found a significant effect of condition on mean ratings, $F(1,38) = 27.46$, $p < .001$. Additionally a Pearson correlation coefficient was computed to view the relationship between participant’s mean rating scores and their performance on post tests. Analysis of the urban condition found no significant correlations between participant’s individual mean ratings and backward digit post scores $r(16) = -.184$, $p = .466$, or Raven’s post scores, $r(16) = .095$, $p = .708$. Analysis of the nature condition found a significant correlation between participant’s individual mean ratings and backward digit post scores, $r(20) = -.486$, $p = .022$, but not for Raven’s post scores, $r(20) = -.405$, $p = .061$.

Table 1
Nature and Urban Image Ratings

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<tr>
<th></th>
<th>1 – Do not like</th>
<th>2 – Neutral</th>
<th>3 – Like</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Images</td>
<td>284 (37.9%)</td>
<td>252 (33.6%)</td>
<td>214 (28.5%)</td>
</tr>
<tr>
<td>Nature Images</td>
<td>105 (14%)</td>
<td>250 (33.3%)</td>
<td>395 (52.7%)</td>
</tr>
</tbody>
</table>

3.3 Discussion

The results of this experiment did not replicate the results of Berman et al (2008); we were unable to link a change in executive task performance to the difference between viewing urban versus nature scenes. Therefore it is important to consider what we may
have done differently to account for the difference in outcome. Note that we used a modified version of Berman et al.’s attentional restoration study. Considering the differences in method offers a few possibilities as to why the results may have differed.

A first possible difference is that our tasks were not sufficiently fatiguing in the pretest for nature scenes to have a measureable influence on restoration. It is therefore possible that the Attention Network Test is more fatiguing than the Raven’s matrices task. If so, then increasing the level of fatigue during the pretest should reinstate the Berman et al result.

A second possibility is that some of the images in the urban set were seen as outdated and unfamiliar by our participants, and therefore more intrinsically interesting than the urban images were for Berman et al’s’ participants. Consistent with this hypothesis, when images were rank by popularity, the urban images that were ranked the highest were primarily older images (estimated to be from 1970s). It is possible that those images contained another aspect, such as novelty, that somehow made them more similar to our average nature images.

A third possibility is that the slide set was not sufficiently engaging for our participants so that they became immersed in the urban and nature experiences. If that is the case, then using a more engaging video experience might help to replicate the nature advantage reported by Berman et al., (2008).
Chapter 4: Experiment Three (Videos)

Since our adaptation of Berman’s study did not produce the expected results, we decided to make changes to our design and re-run the experiment. Experiment three followed the same basic design as experiment two except with two differences: (1) Instead of participants viewing and rating images, they would be viewing a video of a nature or urban walk, and (2) the rating scale for likeability was expanded to a 7-point Likert. Our expectation was that the videos would have a stronger effect than images since motion was more likely to capture attention (Franconeri & Simons, 2003).

4.1 Methods

Participants

Ninety participants aged 17 to 45 ($M = 21.1$, $SD = 3.54$) were recruited via the UBC Human Subject Pool (HSP), the Reservax subject pool, and poster advertising. HSP participants received course credit as compensation for their time and all other participants were paid $5 per 30 minutes of their time. The participants were randomly assigned to a control group, or a video viewing condition which was either urban or nature. All individuals gave informed consent in writing prior to participating in the study.

Tasks

The third experiment used the same two tasks as those used in experiments one and two. The order was also identical to the previous two experiments with the backward digit span given first and then followed up by the Raven’s Progressive Matrices. All task parameters remained the same as the past posttests.

Videos

Two videos were selected for this experiment. For the nature condition, a 10-minute segment from a YouTube video of a Banff National Park walking tour was shown (Figure 7). For our urban condition, a 10-minute segment of a Barcelona walking tour video was also selected from YouTube (Figure 8). Both videos were shown in full screen mode, with the sound disabled. The control condition did not have a video component.
Figure 7 - Nature video stills source: www.youtube.com/watch?v=1Go2b40YsOw

Figure 8 - Urban video stills source: www.youtube.com/watch?v=clW7aV0vVAY
Procedures

Participants from experiment three were tested on identical Apple computers with 27” monitors with display resolutions of 2560x1440. All participants were given pretests identical to experiments one and two. After participants completed the pretest they were either shown an urban or nature walking tour video for 10 minutes. Participants in the control group were simply asked to sit for a two minute break in lieu of watching a video. Participants were asked to rate the video on a 7-point scale with 1 indicating the lowest possible liking score and 7 indicating the highest possible liking score. Video ratings were recorded by a research assistant. After the video viewing (or rest period) was complete, participants were given the posttest tasks, which again were identical in design to the pretest tasks.

4.2 Results

Mean scores for backward digit span and Raven’s matrices are shown in Table 2 and Figure 9 shows three conditions (urban, nature, and control) with the combined backward digit span and Raven’s matrices scores. The results of this experiment indicate that exposure to nature improved post-test scores when compared to exposure to an urban video or no video at all. This conclusion was supported by the following analyses.

Backward digit span and Raven’s scores were combined for analysis because preliminary inspection of the data indicated that both tasks were influenced in a similar way in each condition.

Data were analyzed using a between-within, repeated measures ANOVA with the between factor of condition (nature, urban, control) and the repeated factor of phase (pre, post). A main effect of phase was found to be significant, $F(1,87) = 20.60, p < .001$. Interaction between phase and condition were not found to be significant, $F(1,87) = 1.91, p = .155$. 
Table 2
Pre-/Post-test scores for backward digit span and Raven’s matrices

<table>
<thead>
<tr>
<th></th>
<th>Backward Digit</th>
<th>Raven's Matrices</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>n</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Nature</td>
<td>30</td>
<td>7.53 (2.776)</td>
</tr>
<tr>
<td>Urban</td>
<td>30</td>
<td>7.73 (3.172)</td>
</tr>
</tbody>
</table>

Since urban and control groups (seen in Figure 9) were near identical they were collapsed together to form an other/non-nature condition. Nature and other (urban & control) were compared (Figure 10) and a main effect of phase was found to be significant, $F(1,88) = 24.56, p < .001$. A significant interaction was also found between phase and condition, $F(1,88) = 3.84, p = .05$. No significant interaction was found for phase and condition, $F(1,87) = 1.91, p = .155$. Main effect of phase was found to be significant, $F(1,87) = 20.60, p < .001$.

Video ratings

Videos were rated for likeability on a 7-point Likert scale with a 7 indicating the most positive likeability. Ratings were split into two bins, 2 to 4 (low), and 5 to 7 (high). Figure 9 shows backward digit span scores for pre-/posttests divided by high and low liking scores, and suggests that individuals who liked the nature videos more showed a stronger effect compared to all other groups which showed no difference.
Figure 9 - Combined backward digit span and Raven’s scores for pre- and post-tests shown by nature, urban and control conditions. Error bars represent one standard error around the mean.

Figure 10 – Combined backward digit span and Raven’s scores for pre- and post-tests shown by nature condition and other (urban and control). Error bars represent one standard error around the mean.
4.3 Discussion

The results of experiment three support attentional restoration theory (Kaplan, 1995). Our inclusion of a no-video control condition allowed us to conclude, in addition, that the tasks we selected to index executive functioning were appropriate for measuring restoration following exposure to nature. This is because we observed that participants who viewed urban videos acted much like the controls did. There are two possible interpretations: (1) our urban videos were not fatiguing, or (2) maximum fatigue occurred prior to watching the urban videos, and so the results seen were closer to the fatigue experienced by the control conditions pretests.

The second interesting finding was that individuals who liked nature experienced a stronger benefit in the post-test from the nature videos. During the experimental trials many individuals remarked that they enjoyed the Barcelona video, and a few even expressed a desire to travel there. It was a concern that benefits may be seen because
individuals simply enjoyed the videos they watched, but the results did not confirm this to be the case.
Chapter 5: Experiment Four (Videos & Cognitive Strategies)

Experiment 4 tested a combination of cognitive strategies and nature/urban video exposure. The goal was to determine whether the effects seen in Experiments 1 and 3 involved the same cognitive mechanisms, using additive factors logic (Sternberg, 1998). We hypothesized that if both factors involve the same mental components then these two factors should interact in their effects. Conversely if the underlying mechanisms were separate, then additive results would be predicted. The specific interactions predicted by Attention Restoration Theory (Berman et al, 2008; Kaplan, 1995) were that the nature videos, in comparison to the urban video, should either increase the pre-post improvement seen in Experiment 1 for the active strategy, or reduce the pre-post impairment for the passive task strategy, or perhaps even do both.

The alternative hypothesis, that the influence of instructions and videos were on separate mental components, would be supported if the results showed an additive influence, such that the pre-post differences in active and passive strategies were the same following the two types of videos.

5.1 Methods

Participants

Eighty participants aged 18-63 ($M = 23.2$, $SD = 8.05$) were acquired using UBC’s Human Subject Pool, who received course credit, as well as through advertisement, who received a $5 compensation per 30 minutes of their time.

Tasks

Tasks used in experiment four included the backward digit span as well as the same subset of Raven’s progressive matrices used in the previous experiments. Both tasks were administered in an identical manner to the previous three experiments.

Videos
Experiment four used the same two video segments as used in experiment three, with the same 10 minute segments selected from either the Banff National Park walking tour for the nature condition, or from the Barcelona walking tour for the urban condition.

**Instructions**

Active and passive instructions were identical to those used in experiment one. Again, active instructions were intended to direct the participant to use EF while the passive instructions were intended to direct the participant to reduce EF usage during the task.

**Procedures**

Participants from experiment four were tested on identical Apple computers with 27” monitors with display resolutions of 2560x1440. All participants were given pretests identical to the previous three experiments. After participants completed the pretest they were either shown an urban or nature walking tour video for 10 minutes. Participants were asked to rate the video on a 7-point scale with 1 indicating the lowest possible liking score and 7 indicating the highest possible liking score and video ratings were recorded by a research assistant. After the video viewing was complete, participants were given either active or passive instructional sets on how to perform the posttest tasks, similar to experiment one. After viewing instructions the participants performed the backward digit span and raven’s matrices tasks.

**5.2 Results**

Table 3 shows the mean scores in Experiment 4, and Figures 12 and 13 show the mean pre-post change scores for the Backward Digit Span and Raven’s Matrices tasks respectively. The main finding of this experiment was that the pre-post change scores were greater for the urban video condition than they were for the nature video condition. This was especially true for the Backward Digit Span task; it was much weaker and not statistically significant for the Raven’s Matrices task. These conclusions were supported by the following statistics.
The data from this experiment were first analyzed using a mixed-design ANOVA, involving the between groups factors of instruction (active, passive) and video (nature, urban) and the repeated measures factors of phase (pre-, post-test) and measure (backward digit, Raven’s).

Table 3
Pre-/Post-test scores for backward digit span and Raven’s matrices

<table>
<thead>
<tr>
<th></th>
<th>Backward Digit</th>
<th>Raven’s Matrices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>n</td>
<td>M (SD)</td>
<td></td>
</tr>
<tr>
<td><strong>Active/Nature</strong></td>
<td>20</td>
<td>6.25 (3.432)</td>
</tr>
<tr>
<td><strong>Active/Urban</strong></td>
<td>20</td>
<td>7.50 (2.875)</td>
</tr>
<tr>
<td><strong>Passive/Nature</strong></td>
<td>20</td>
<td>6.55 (2.964)</td>
</tr>
<tr>
<td><strong>Passive/Urban</strong></td>
<td>20</td>
<td>8.00 (3.354)</td>
</tr>
</tbody>
</table>

The results for backward digit span (Figure 12) showed significant interaction between phase and instruction, $F(1,76) = 19.92, p = .025$, as well as between phase, video, and instruction, $F(1,76) = 5.24, p = .024$. Interaction between phase and video was not significant, $F(1,76) = 1.93, p = .169$, and interaction between instructions and video were also not significant, $F(1,76) = 0.68, p = .412$. Main effects were not found to be significant for instructions, $F(1,76) = 2.19, p = .144$, video, $F(1,76) = 2.42, p = .124$, and phase, $F(1,76) = 1.03, p = .412$.

Results for Raven’s matrices (Figure 13) showed significant interaction for phase and instructions, $F(1,76) = 7.09, p = .009$. No significant interaction was seen for phase and video, $F(1,76) = 0.02, p = .1893$, video and instruction, $F(1,76) = 2.65, p = .108$, or phase, instruction and video, $F(1,76) = 0.736, p = .394$. Significant main effect was seen for video, $F(1,76) = 4.75, p = .032$. No significant main effects were found for instruction, $F(1,76) = 3.721, p = .058$, or phase $F(1,76) = 0.10, p = .753$. 

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Figure 12 – Pre/Post mean scores for backward digit span. Error bars represent one standard error.

Figure 13 - Pre/Post mean scores for Raven's matrices
This overall analysis was followed by an analysis focusing on the change scores (post- minus pre-test) as the dependent variable. Here the factors tested were the between-groups factors of instruction (active, passive) and video (nature, urban) and the repeated measures factors of measure (backward digit, Raven). Change scores (post minus pre) were also computed for backward digit span (Figure 14) which found significant main effect of instructions, \( F(1,76) = 19.92, p < .001 \), and interaction between instruction and video, \( F(1,76) = 5.23, p = .025 \). No significant main effect of video was found, \( F(1,76) = 1.93, p = .169 \). Change scores (post minus pre) were also computed for Raven’s (Figure 15) which found significant main effect of instruction, \( F(1,76) = 7.09, p = .009 \). No significant main effect of video was seen, \( F(1,76) = 0.02, p = .893 \). No significant effect of interaction between instruction and video was found, \( F(1,76) = 0.74, p = .394 \).

![Bar chart showing change scores for backward digit span and Raven's measures.](image)

*Figure 14 – Backward digit span change scores (post minus pre). Error bars represent one standard error.*
5.3 Discussion

The results of Experiment 4 showed that the nature video reduced the effects of instruction, when compared to urban video. In the urban video condition, the change in pre- versus post scores resembled the results reported in Experiment 1, where there was both a significant increase in scores with the active instructions and a significant decrease in scores with the passive instructions. However, in the nature video condition these pre-post change scores were markedly diminished, showing no significant differences between pre- and post-testing. Importantly, this pattern of findings was stronger for the backward digit span than it was for the Raven’s matrices task.

In what follows, I address three questions that arise from this pattern of results. First, why did exposure to a nature video help to buffer the otherwise harmful effects of adopting a passive cognitive strategy? Our finding hints at capacity being a larger factor than active or passive strategies. In both nature conditions what we saw was that strategies seemed to matter less after nature exposure, suggesting that by restoring attentional capacity you limit the effect of cognitive strategies. Second, why did exposure
to an urban video help to amplify the benefits of adopting an active cognitive strategy? One of the more interesting finding was that urban exposure benefited most from active strategies. There are several reasons this may be possible. The first is that urban environments may be cognitively fatiguing but the active strategies are more helpful when individuals are cognitively fatigued. The second is that the urban environment exposure is not just fatiguing but potentially activating some mechanism that is in turn beneficial for individuals using active strategies. Third, why was the data pattern stronger for the Digit Span task than the Raven’s Matrices task? Since the backward digit span relies more on directed attention compared to Raven’s (Berman, et al. 2008), the result may come from the way this particular task relies more on working memory, compared to the Raven’s task which requires more critical thinking and logic skills, cognitive aspects that require experience and learning (Gelder, 2007; Halpern, 1998).
Chapter 6: General Discussion

During the process of conducting the four experiments in this study it became clear that there were several factors involved in the connection between executive function and attentional restoration. Experiment one supports cognitive strategies as a method for manipulating executive function. Experiments two, three and four, lend support to existing ART literature and indicate that restoration of attentional capacity is possible, especially with exposure to nature.

Cognitive strategies effect how people perform on both EF and non-EF tasks. Active strategies were shown to be beneficial for performance on executive function tasks such as backward digit span and Raven’s matrices, while passive strategies were detrimental to performance. In an interesting contrast, passive strategies were previously shown to be beneficial for some non-EF tasks such as visual search or attentional blink, tasks that benefit from automatic visual processing, but active strategies decreased performance on these same tasks. This interesting cross-over suggests that cognitive strategies have control over more than one area of cognitive processing, or at least the area it can control has the ability to be redirected. If we consider a model where capacity and orientation both exist, but share a common output stream, the active condition may increase capacity usage, but that may be required for EF tasks. When active EF is outputting at the same time as automatic processing (such as in attentional blink) then there may be a cognitive bottleneck that slows down performance. In the case of EF tasks like the backward digit span, cognitive load is high and therefore must make use of the attentional reserves but also lead to output. If no automatic process is attempting to output at the same time then there is no competition and performance is superior to a situation where there was competition.

The overall findings of this study may also be relevant to overinvestment theory (Olivers & Nieuwenhuis, 2005). It has been shown that when people become cognitively overinvested in an automatic action they are performing, it leads to decreases in performance, but also depends on ability to perform the task in the first place (Gray, 2004). This is akin to a skilled tennis player who suddenly notices something off about their swing and then begins to think about how they are moving their arm every time they
swing for the ball. Performance suffers, and the suggestion is that a cognitive bottleneck or competition occurs leading the automatic response to become inhibited.

If we consider the Smilek, et al. (2006) research on cognitive strategies, we see that those individuals performed better when they used a passive strategy. The comparison here is that the visual search task is the automatic process, like the professional tennis player’s swing. When you direct people using the active cognitive strategies they become more cognitively invested in the task. The automatic processing attempts to output responses (or perform actions), but has to contend with the EF also attempting to output information.

This differs from our findings in experiment one because the backward digit span and Raven’s matrices tasks require active engagement of the EF to perform the task. There is no known automatic number memory or manipulator, and so it stands to reason that EF must manage those actions. The reason it is likely able to do this well in the backward digit span task, is because it is not contending with some other automatic processing. It would be beneficial to run a task where an individual performs the backward digit span task using active strategies but also has to perform some kind of automatic action. If the automatic action interferes with the EF task and vice versa then it would support the hypothesis that a cognitive bottleneck was reducing performance. If the automatic action task had no interference effect on the EF task, then it may indicate that EF tasks take priority over automatic tasks and that is why using active strategies in visual search are so detrimental.

In conclusion, the findings of this study support the notion that nature has a restorative effect, and that cognitive strategies can alter executive function task performance. The combination of findings points to a connection between executive function and the restorative effects of exposure to nature. Finally, the findings show that people prefer nature stimuli over the urban counterpart, and that those that like nature benefit the most. Future research would be best focused on determining the connection between liking nature and the related beneficial outcomes.
References


Appendix 1

2x2 matrix example
Appendix 2

Sample of 3x3 matrix used in this study (Difficulty: Easy)
Appendix 3

Active Instructions

For backward digit span:

_The best strategy for this task, and the one that we want you to use in this study, is to be as active as possible in remembering and recalling of the numbers._

_The idea is to deliberately direct your attention to determine your response. Sometimes people find it difficult or strange to “direct their attention” but we would like you to try your best. Try to respond as quickly and accurately as you can while using this strategy. Remember, it is very critical for this experiment that you actively search for the unique item._

For Raven’s progressive matrices:

_The best strategy for this task, and the one that we want you to use in this study, is to be as active as possible in remembering and recalling of the numbers._

_The idea is to deliberately direct your attention to determine your response. Sometimes people find it difficult or strange to “direct their attention” but we would like you to try your best. Try to respond as quickly and accurately as you can while using this strategy. Remember, it is very critical for this experiment that you actively search for the unique item._
Passive Instructions

For backward digit span:

The best strategy for this task, and the one that we want you to use in this study, is to be as receptive as possible and let the answers ‘‘pop’’ into your mind as you look at the screen.

The idea is to let your intuition determine your response. Sometimes people find it difficult or strange to tune into their ‘‘gut feelings’’ but we would like you to try your best. Try to respond as quickly and accurately as you can while using this strategy. Remember, it is very critical for this experiment that you let the unique item just ‘‘pop’’ into your mind.

For Raven’s progressive matrices:

The best strategy for this task, and the one that we want you to use in this study, is to be as receptive as possible and let the answers ‘‘pop’’ into your mind as you look at the screen.

The idea is to let your intuition determine your response. Sometimes people find it difficult or strange to tune into their ‘‘gut feelings’’ but we would like you to try your best. Try to respond as quickly and accurately as you can while using this strategy. Remember, it is very critical for this experiment that you let the unique item just ‘‘pop’’ into your mind.