The reduction of directed attention fatigue through exposure to visual natural stimuli

Michael Varkovetski

Department of Psychology, University of Guelph, Guelph, ON Canada. Faculty supervisor: Sofie Lachapelle
For correspondence, please email: Mvarkove@gmail.com

Abstract

This study compares the restorative effects of exposure to natural landscape images on directed attention functioning, compared to exposure to scrambled/distorted landscape images. Attention restoration theory (ART) provides an analysis of the stimuli in an environment that are required for restoration of cognitive fatigue. According to ART, nature employs attention through a bottom-up process in which intrinsically fascinating stimuli from the natural environment modestly dominate attention. This allows the mechanisms responsible for top-down processing, which is necessary for directed attention, to recover and replenish. Both natural and urban environments employ attention through a bottom-up fashion. However, while natural environments employ attention in an effortless manner through intrinsic fascination, urban environments employ attention so that an individual is able to overcome or deal with a stimulus (ex. car honk) using directed attention, thus not allowing for the recovery of directed attention mechanisms. This study examines whether visual simulation of natural environments is adequate for the restoration of directed attention mechanisms as measured with the "Attention Test" application, and whether the image composition (open or closed) contributes to the restoration. The mean completion time on the Attention Test game was significantly lower in the nature image group ($M = 54.33$ s) when compared to the scrambled image group ($M = 62.04$ s), providing some support for the restorative effects of the visual aspect of ART.

Keywords: Attention Restoration Theory; Cognitive Fatigue; Voluntary Attention; Involuntary Attention; Natural Environment ; Restorative Effects

Introduction

Many therapies for combating fatigue are available on the marketplace; stimulants such as coffee, energy drinks, and/or boosters are most commonly employed. These options may provide temporary relief from fatigue, but at the cost of unwanted side effects such as insomnia or burnout after the stimulant effects weaken. Now imagine a therapy free of any side effects. Such an idea is not as impossible as it seems in today's modern urban society. Nature's effects on cognition, specifically cognitive fatigue, have recently been explored. This study approaches the idea of nature as a potential therapy for cognitive fatigue restoration from the work environment perspective. Cognitive fatigue is a significant problem in workplaces, contributing to drops in performance and making employees more prone to accidents.

What is Mental Fatigue?

Fatigue can refer to tiredness of the body following physical activity or during illness, but can also refer to a lack

of energy that is linked to cognition. In psychological literature, this type of fatigue is called *mental* or *cognitive fatigue* (Berman et al., 2007). Cognitive fatigue can be categorized into two types: chronic and acute cognitive fatigue (Craig, 1992). Chronic fatigue, as the term suggests, is characterized by a persistent and constant lack of energy. This type of fatigue does not necessarily require a previous exertion of energy, and is a core symptom in psychological conditions such as chronic fatigue syndrome or burnout syndrome.

The focus of this paper is acute cognitive fatigue, which can be linked to previous effortful activities, and is relatively easy to recover from. Acute cognitive fatigue is associated with work safety and performance, and is also the type of fatigue that researchers attempt to manipulate by having participants work on cognitively demanding tasks (such as solving a list of anagrams). Using this manipulation, researchers are able to observe the effects of fatigue on cognitive performance. The time-on-task effect, seen in

fatigued participants, refers to the progressive worsening of performance that is observed on vigilance tasks as the duration of those tasks increases (Berman et al., 2007). This effect occurs when an individual spends extended periods of wakefulness and/or extended periods of effort on a single task. Acute fatigue may be thought of as the “stop” emotion, which is employed to notify an individual to discontinue exerting further effort on a task or to reduce task engagement.

Psychobiological Mechanisms Associated with Fatigue

A rewards-costs trade-off constitutes a core component of fatigue (Boksem et al. 2005). There is a trade-off between the likely rewards and costs of every behaviour; for example, the decision to study for an exam. Getting a good grade on the exam is the rewarding aspect of the task; in contrast, the cost of studying is that one cannot engage in other, more pleasurable activities, such as going out with friends, during that time. Trade-offs such as these are fundamental to an understanding of human behaviour, as even minor decisions (such as whether one should use the backspace or delete button on the keyboard) are thought to be made on the basis of unconscious estimates of the costs versus the benefits (Dix et al., 1998).

Dopaminergic pathways in the brain are implicated in these trade-off decisions (Salamone & Correa, 2002). These pathways encompass the nucleus accumbens (NAc), the anterior cingulate cortex (ACC), the basolateral amygdala, and the orbitofrontal cortex (Salamone & Correa, 2002). These dopaminergic pathways play a role in exciting or activating an organism to promote behaviour. Activation of dopaminergic pathways has been associated with mental states of alertness, high energy and extrinsic motivation (Lorist & Tops, 2003). In contrast, if these pathways are not activated, symptoms of fatigue and a general lack of motivation manifest.

The dopaminergic pathways are assumed to mediate the wanting aspect more than the liking aspect. Thus, they are able to excite an individual, and their inactivity may underlie fatigue. There is a substantial amount of literature to support this. Salamone & Correa (2002) observed that rats with lesions to the NAc were not able to motivate themselves to obtain pellets of food. The rats did not appreciate the food any less (i.e., they still liked it), but their willingness to work for it (i.e. how much they wanted the food) depreciated. Further evidence stems from the fact that pharmacological agents that promote dopamine alleviate fatigue, whereas other agents that promote acetylcholine or serotonin do not produce the same anti-fatigue effects (Stahl, 2002).

Furthermore, literature shows that the locus coeruleus-norepinephrine (LC-NE) system also plays an important role in the reward-cost trade-off calculation, with the locus coeruleus (LC) responsible for central norepinephrine (NE) levels (Aston-Jones et al. 1999). High arousal of the LC-NE system facilitates attention toward a stimulus, and the higher-

order cognitive processing of that stimulus. However, when arousal is low, the processing and excitability of a stimulus is diminished (Usher et al. 1999). The mental states associated with low arousal are symptoms of fatigue and drowsiness, proposing the idea that NE plays an important role in fatigue and its recovery. Furthermore, Stahl et al. (2002) showed that agents which raise central NE levels also reduce fatigue.

Aston-Jones & Cohen (2005) argue that the LC-NE system, like the dopaminergic system, plays an important role in directing attention to a task. However, instead of referring to the reward-cost trade-off, they refer to exploitation vs. exploration. When an individual puts effort into a task, they are doing so in order to reach a reward; in other words, they are exploiting the task for a reward. However, by exploiting one task, an individual is missing opportunities to explore other tasks and receive other rewards.

The LC-NE system is thought to direct the brain towards either supporting the exploitation of a task or the exploration of another. While exploiting, the brain concentrates attention in favour of the relevant task, and while exploring, the brain is susceptible to task-irrelevant stimuli. Aston-Jones & Cohen (2005) describe the adjustments of the LC-NE system in terms of *phasic* and *tonic* activity. Phasic activity refers to quick bursts of activity from the LC-NE system in response to stimuli, and tonic activity refers to baseline activation levels of the LC-NE system. Phasic activity in the LC-NE system prepares the brain for the exploitation of a specific task. In contrast, when tonic activation is high and phasic activation is low, the brain is prepared to explore novel stimuli in the environment.

The LC-NE system is related to cognitive fatigue through the overlap between exploration and cognitive fatigue. Exploitation of a task overlaps with directed, task-relevant attention and intrinsic motivation; however, exploration overlaps with boredom, poor task performance and distractions from the environment (Aston-Jones & Cohen, 2005). Clearly, exploration overlaps with cognitive fatigue.

Cognition also plays an important role in determining how an individual is allocating attention. For example, when an individual attends a museum, a guide’s verbal description of a painting provides cues that can help the individual to attend to certain aspects of the painting, such as its patterns or meanings. If the guide notes a small detail in the painting that the viewer has not yet noticed, the viewer can use this information to spot the detail and incorporate it into their perception of the painting. Knowledge and/or expectation of certain details or stimuli allow individuals to focus on these elements of the visual scene that otherwise may have gone unnoticed. Cognition allows an individual to maintain and change their perception of their visual field by highlighting or diverging attention to what is important in the visual scene. However, at the opposite extreme, stimuli from the visual scene or environment can dominate cognition and divert attention to these stimuli. The viewer may be intrinsically attracted to a certain aspect of the painting,

which will capture their attention before allowing them to scan the rest of the visual scene. An event or stimulus in the environment may also divert attention away from the painting, such as an alarm going off in the next room. Unexpected, novel, salient and potentially dangerous events take precedence in the brain, and divert attention from ongoing behaviours and activities.

Attention is controlled and modified by cognition, referred to as top-down processes, which are influenced by knowledge, expectations, executive processing; attention is also modulated by sensory stimulation, which is referred to as bottom-up processing. In their review of attention, Corbetta & Shulman (2002) propose that visual attention is controlled by these two partially distinct neural systems. Other factors that affect attention, like the novelty and unexpectedness of a stimulus, reflect the interaction between the two systems, which govern top-down and bottom-up processing. The dynamic relationship between these two systems controls where attention is directed. These two neural systems are often referred to in the literature as the dorsal and ventral visual streams (Corbetta & Shulman, 2002). The dorsal system, centered on the dorsal posterior and frontal cortex, is involved in the cognitive, top-down processing aspect of attention. The ventral system, centered on the temporoparietal and ventral frontal cortex, is involved in the detection of important or behaviourally relevant sensory stimuli.

In the workplace environment, attention is directed to specific tasks which must be accomplished to a certain degree of quality and efficiency in order for an individual to be considered a successful employee. Thus, working memory is consistently being employed to maintain and manipulate information while executing a task in the absence of important incoming sensory and motor information. Working memory is synonymous with the dorsal visual system. In macaque monkeys, the parietal and frontal regions associated with the dorsal system showed sustained activation during a memory delay of up to ten seconds (Corbetta & Shulman, 2002).

While retaining information in working memory, employees must also attend to specific locations or features to select visual information that is relevant to the task at hand. In a directed motion attention task, an arrow cues the subject on which direction a few coherently moving dots (the target) will be moving among many stationary dots (the distractors). Directional cues produce activity in the frontal and parietal regions of the brain, suggesting that the dorsal system is responsible for mediation of this task. The same regions are activated when a subject switches their attention between two objects in close proximity (Corbetta & Shulman, 2002).

Involuntary attention, which refers to attention for which no mental effort is required, is thought to be controlled by, or synonymous with, the ventral system. According to William James (1890), "In involuntary attention of the immediate sensorial sort the stimulus is either a sense-impression, very intense, voluminous, or sudden; or it is an instinctive

stimulus, a perception which, by reason of its nature rather than mere force, appeals to some of our congenital impulses."

In real life, there is no question that certain stimuli are able to grab attention, regardless of where one is focusing. According to James (1890) there are two possible reasons for this; either the stimulus is forceful (meaning it represents danger or importance), or it is inherently appealing due to some contingency that is hard-wired through development or genetics. This explains why instinctive stimuli, such as blood or wild animals, are able to divert attention to themselves so easily.

The disruption of current cognitive processes is an inevitable consequence of engaging attention to an unexpected or intrinsically important stimulus. This attention-grabbing effect of a sudden or distinctive stimulus lies outside the dorsal system; is housed in the ventral system, which includes the temporoparietal junction (TPJ) cortex and the ventral frontal cortex (VFC) (Corbetta & Shulman, 2002). Although this system is responsible for diverting attention away from the current task, it also functions to direct attention to sensory stimuli relevant to the task but outside the area of focus. Unlike the dorsal system, the ventral system is not necessary for maintaining attention; it is not engaged during working memory, or by cues that carry information about the locations or features of future stimuli. This region is activated in the presence of intriguing or infrequent stimuli in the visual field, compared to when the same stimuli are repeatedly presented (Downar et al., 2001). Furthermore, patients with lesions to the ventral prefrontal cortex had problems when adapting to novel situations, and had a decreased autonomic or involuntary response to novel stimuli (Yokoyama et al., 1987). Corbetta and Shulman (2002) suggest that the frontal cortex may have a role in evaluating the novelty of the stimuli, whereas the temporoparietal junction may be responsible for determining the behavioural valence of the stimuli.

There are a few possible explanations of the interactions between the ventral and dorsal systems. Corbetta and Shulman (2002) suggest that the ventral system works as an alerting measure, to pick out behaviourally relevant stimuli that are not in focus. Once a relevant stimulus has been detected by the ventral system, the precise localization of the stimulus is dependent on the dorsal system. The ventral system may also be acting as an attentional process breaker, for when a behaviourally relevant stimulus is detected, in order to integrate that novel stimulus into a new attentional process.

The two systems constantly moderate and maintain one another. Through focused directed attention, the dorsal system is able to lead an individual into a specific environment, thus directly modulating the ventral system by controlling the environmental stimuli to which an individual is exposed. However, the ventral system, by virtue of its role in directing attention to intrinsic and unexpected stimuli, will modulate the dorsal system by redirecting attention to stimuli in the environment.

Cognitive and Behavioural Effects of Fatigue

While executive brain control suffers from cognitive fatigue, more automatic brain control is not affected by fatigue (van der Linden et al., 2003). Executive control is a higher-order brain function which deals with conscious perceptual and motor processes for task-directed behaviour (Miller & Cohen, 2001). Examples of this would be situations in which an individual must ignore distractions in the environment, or maintain information actively in memory.

The reason fatigue affects executive control while sparing automatic control is that executive functioning is highly demanding of mental effort, while automatic control is not. As its name implies, automatic control requires very little mental effort, if any at all. While fatigued, an individual will tend to reduce effort, which negatively affects executive control. Van der Linden & Eling (2006) found that fatigue was associated with difficulties focusing on and separating the processing of current information from the distracting effects of novel incoming information. Other studies have found that fatigued individuals show reduced performance for task planning and flexibility (Boksem et al., 2006). These results suggest that executive control is impaired as a result of cognitive fatigue, as predicted.

Detachment Concept

A group of researchers introduced the detachment concept in a study on job stress and job recovery. They defined *detachment* as an “individual’s sense of being away from the work situation” (Etzion et al., 1998). However, to emphasize that detachment is both mental and spatial, Sonnentag & Bayer (2005) suggested the term *psychological detachment*. Psychological detachment from work involves not engaging in work-related task, and, even more importantly, not engaging in any work-related thoughts. Simply put, psychological detachment means to completely separate oneself from one’s work and work environment. Sonnentag & Bayer (2005) demonstrated that psychological detachment from work is significantly higher when an individual is engaging in non-work related tasks such as sports or social activities, relative to work-related activities. When an individual is not able to psychologically detach from their work and daily stressors, that individual’s strain level (fatigue) remains elevated into the next work session, which negatively impacts performance.

Nature as a Beneficial Therapy

Recently, researchers have begun to explore beliefs regarding the beneficial effects of exposure to nature. Much of the research in the area has relied on pseudoscience and poorly designed program evaluations. However, these studies have shown a significant amount of convergence in their results, with minor to significant gains and no harms observed in areas such as self-esteem and positive affect.

However, two groups of scientists have employed more rigorous research designs. Robert Kaplan (1989) conducted a longitudinal study which measured cognitive and emotional changes in participants during an outdoor challenge program over a decade. The program trained subjects in outdoor and survival skills within the context of a two-week wilderness outing. Comparisons of subjects before and after the outing showed that subjects had increased levels of confidence, self-efficacy and expected outdoor survival skills. These effects persisted for up to five months following the conclusion of the experiment.

Kaplan’s research helped to contribute to a theory of restorative environments reducing mental fatigue. Kaplan (1989) proposed a mechanism by which the capacity for directed attention may be restored. In contrast to directed attention, which requires mental effort, an involuntary form of attention called fascination requires little to no mental effort. Fascination is employed when an individual is interested, curious, and/or exploratory. Certain stimuli and processes are able to capture and hold our attention. Once involuntary attention is engaged, the systems and mechanisms necessary for voluntary attention are allowed to rest and recover; thus, their restoration becomes possible. In addition to being fascinating, restorative environments should also create a sense of extent, being away, and compatibility (Hartig et al, 1991). The concept of extent refers to the perception that the environment belongs to a larger whole, with cues that suggest that exploration is possible (such as, for example, a bend in the path, or a partially visible clearing). Although extent applies to a physical setting, it also applies in a more conceptual or mental sense. The concept of being away refers to the idea that changing locations or activities makes it more likely that one can think of other things, and temporarily escape from the fatiguing task. The benefits of being away have been documented by Driver et al. (1987) in studies of motivation in wilderness and outdoor subjects. Lastly, the environment also needs to be compatible with the individual’s inclinations. An individual’s relationship with the environment must take on an effortless quality in order to be restorative (Kaplan, 1983).

Roger Ulrich and his colleagues conducted the second major portion of research on the restorative effects of natural environments. While Ulrich’s (1983) model of restoration is similar to Kaplan’s model, it differs in three important ways. Ulrich first argues that an individual’s initial response to the environment is affective rather than cognitive. That is, the environment elicits deeply embedded and automatic responses without the need of extensive information processing (executive processing). Secondly, instead of dealing with fatigue arising from everyday activity, Ulrich focused on the emotional, mental and physiological components of responses to dangerous or threatening stimuli such as surgery. Ulrich (1984) argues that hospital patients tend to recover faster when they have views of nature from their window as opposed to views of buildings. This is based on the idea that stress reduction is one of the benefits of

natural restorative environments (Knopf, 1987). Thirdly, Ulrich's view of restoration stems from reduction of arousal, instead of replenishment of attentional capacity, which is thought to be a repercussion of arousal reduction. He argues that nature has a calming effect since it requires no mental effort while eliciting positive emotional states in individuals & inhibiting negative ones. A reduction in neurophysiological arousal is associated with these responses, while an interest in the stimulus is continued (Hartig et al. 1991). Ulrich (1983) suggests that these responses occur in nature due to the positive associations with nature through dispositions to respond positively to an environment reflecting well-being or survival.

Ulrich (1984) later demonstrated that views of nature had positive effects on mood, attention, and self-reports of well-being, compared to views of urban or artificial landscapes. In fact, the degree of naturalness of the scene (as indicated by running water, presence of animals, etc.) correlated positively with the reported benefits.

Ulrich also examined restoration from naturally-induced stress (via college examination; Ulrich, 1979) and laboratory-induced stress (via industrial accident film; Ulrich & Simons, 1986). In the examination experiment (1979), subjects who viewed scenes of nature reported greater positive affect, compared to subject who viewed scenes of urban environments. Similar results were found by the laboratory study (1986); subjects who viewed natural slides showed faster physiological recovery than those who viewed urban slides. Pulse, skin conductance, and muscle tension were used as physiological measures of subjects' stress. Furthermore, Hartig et al. (1991) demonstrated numerous cognitive and physiological benefits associated with exposure to nature, compared to urban environments. The researchers were primarily interested in participants' self-reports of decreased mental fatigue. The reduction in fatigue was observed in the group exposed to nature, but not in a group exposed to urban environmentst.

Attention Restoration Therapy

Attention restoration theory (ART), proposed by Kaplan (1995), offered a new approach for identifying and restoring cognitive mechanisms. The theory is based on past literature showing that attention is separated into two components: voluntary attention, directed by cognitive controlled processes, and involuntary attention, which is captured by important or intrinsically fascinating stimuli in the environment. The separation of attention into two distinct streams both behaviourally and physiologically was proposed by James (1892), and has been discussed earlier in this paper. In addition to top-down processes, cognitive control (voluntary attention) also works to suppress distracting stimuli, making voluntary attention extremely effortful. ART identifies voluntary attention as the mechanism which benefits from exposure to nature.

According to ART, interacting with natural environments which are rich with stimuli considered

fascinating (such as, for example, waterfalls) invokes automatic attention, allowing executive control mechanisms to recover (Kaplan, 1995). In the correct context, the requirement for directed attention in natural environments is minimal, allowing for recovery while attention is employed in a bottom-up manner by stimuli from the environment itself. Therefore, following exposure to a natural environment, an individual would perform better on tasks that require directed attention. Unlike natural environments, which capture attention effortlessly in a bottom-up manner, urban environments require mental effort through executive control when capturing attention in the same fashion. A stimulus such as a car honk employs an individual's voluntary attention in order to overcome or react to that stimulus (e.g. avoid being hit by the car), making urban environments much less restorative than natural environments.

Berman et al. (2007) designed two experiments to test ART. The first experiment explored how submersion in either a natural or urban environment affected subject's performance on a measure of cognition (a backwards digit-span task). Subjects who walked in nature showed significant improvements in performance on the digit-span task, compared to their performance following a walk downtown. The aim for experiment two was to test ART with the attention network test, which identifies three different components of attention: alerting, orienting, and executive attention (Berman et al., 2007). The three components of attention are separate both in a behavioural and neurological sense (Fan et al., 2005). Subjects who viewed pictures of natural landscapes improved on the executive control portion of the attention network test (ANT), compared to those who viewed urban areas. Furthermore, the results of experiment one were replicated, with subjects' performance on the backwards digit-span task improving only after viewing pictures of natural landscapes (Berman et al., 2007). The alerting and orienting components of attention did not show improvements, likely because these functions rely less on cognitive control than the executive function component. Furthermore, if an effect was seen in all three components of attention, then alternative explanations may have been considered, such as increases in motivation or effort induced by nature.

To relate the detachment concept to ART, nature stimuli, by virtue of employing attention in a bottom-up process, should be adequate in providing detachment from the work environment. The detachment concept describes an individual's sense of being away from the work environment, with researchers finding that psychological detachment from work is significantly higher when engaging in non-work related activities (Sonnentag & Bayer, 2005). Furthermore, and related to the present study, detachment from work should be equally mental and spatial, meaning that voluntary attention or thoughts related to work must be reduced to achieve optimal mental restoration. Thus, a natural environment is an excellent outlet that one is able to connect to in an effortless fashion, allowing for the dissociation of

any voluntary attention, and indirectly causing detachment from any directed attention task attended to previously.

The literature abounds with studies demonstrating the restorative and beneficial effects of being submerged in nature on attention and other cognitive functions, and much has been written on the psychobiological mechanisms responsible for this effect. However, little effort has been made towards elucidating which specific stimuli, factors or perceptions in natural environments are actually contributing to the reported benefits. The question remains open regarding what aspects of viewing nature stimuli compared to urban stimuli are responsible for the restoration of directed attention. According to Oliva & Torralba (2001), one significant difference between natural and urban images is that images of nature tend to be considered open composition, and images of urban environments tend to be considered closed composition. Landscapes are considered open composition images, as an individual can easily imagine the environment continuing beyond the boundaries of the image. However, an urban environment is considered a closed image since the elements of the image direct the viewer's eye towards the subject of the image, and do not draw the viewer's eye away or make it jump from one object to another. Since Berman et al. (2007) found that viewing natural landscapes improved subjects' executive control performance compared to that of subjects viewing urban landscapes, it would be interesting to determine whether the heightened performance is due to the open composition of the natural landscapes. This study will focus on the visual aspect of nature, and examine whether nature's beneficial effects on attention restoration is due to the open composition of natural environments and scenes.

I predict that subjects with fatigued directed attention who view pictures of nature landscapes will show improved performance on a directed attention task, compared to subjects who view pictures of scrambled nature landscapes. I hypothesize that viewing nature stimuli will allow the mechanisms necessary for directed attention to recover, while employing attention in a bottom-up process through intrinsically fascinating stimuli.

Methods

Subjects

Sixteen University of Guelph students participated in this study (7 females, 9 males; mean age = 22.75 years). All participants gave informed consent as required and overseen by the University of Guelph's Research Ethics Board. Participants were given their choice of candy or chocolate as an incentive for their participation.

Environmental Stimuli

Two sets of images were used in this study, both considered of open composition. The first set of images, labeled as the nature group, consisted of twenty high-

resolution images of natural landscapes. The landscapes ranged from scenes of forests and fields to rivers and waterfalls. Water stimuli were included in most scenes, since past literature has shown that nature scenes containing water are perceived to be more restorative than nature scenes that do not contain water (Purcell et al., 2001). The second set of images, labeled as the scrambled group, were the same high-resolution nature landscapes; however, the scrambled group images were distorted beyond recognition using Adobe Photoshop software. Figure 1 shows an example image from each group.

Figure 1. Examples of both the (top) nature group images and the (bottom) scrambled group images. Participants viewed a slideshow of 20 images, at an interval of 15 seconds an image, specific to their assigned group.

Measures

The "Attention Test" application was used as an assay of directed attention performance. This is the first time this application has been used in the study of attention. This application was chosen because it could provide simple, conclusive results. Furthermore, this application closely resembles the map search subset of the Test of Everyday Attention (TEA), which requires subjects to scan a large map to locate a specific symbol, employing goal-directed selective attention (Ward et al., 1994). The application was downloaded for free from the Google Play Store (link provided under **Figure 2.**), and presented to subjects on a Samsung Galaxy Tab 2 tablet. The variable font size and font

12	26	27	15	10	21
19	7	3	30	29	34
13	1	4	28	5	34
33	22	20	11	6	5
16	2	18	35	9	32
14	31	17	36	25	23

Figure 2. Examples of both the (A) nature group images and the (B) scrambled group images. Participants viewed a slideshow of 20 images, at an interval of 15 seconds an image, specific to their assigned group.

colour settings were used, with the largest grid (6x6). Participants were presented with a grid of numbers, one number per cell, each varying in font size and font colour. **Figure 2** contains a screenshot of the Attention Test, showing an example of the test stimulus presented to the participants. The object of the game is to correctly count upwards starting from the number 1 and ending on the number 36; the placement of the numbers, font colours, and font sizes are all randomized. The participant's time of completion was used as a measure of their attentional engagement. The Attention Test depends on directed-attention abilities, as participants must use working memory while scanning the grid to find the next correct number.

Procedures

Participants were tested individually in a classroom, and were randomly assigned to either the nature picture group or scrambled nature picture group. Participants were first asked to complete a series of eleven anagrams for five minutes to the best of their ability; the anagram task was intended to induce fatigue. An example of an anagram used is "Elvis", which can be rearranged to spell "Lives". The anagrams ranged from being five to ten letters in length, ascending in length and difficulty. The seventh anagram ("Punkids") was impossible, and was included in the series to ensure directed attention fatigue in participants who were not challenged by the other anagrams.

Following the anagram task, participants viewed a slideshow of twenty pictures specific to the group to which they were assigned at the beginning of the experiment. The nature group pictures consisted of twenty high-resolution images of natural scenery, as described previously. The scrambled group pictures consisted of the same twenty high resolution images, distorted and scrambled beyond recognition, as described previously. The participants

viewed the images on a laptop screen, with the lights in the classroom dimmed to ensure focus on the screen.

Following the slideshow, each participant immediately engaged in the Attention Test game, which was ready for each participant adjacent to the computer displaying the images. Once the participant completed the Attention Test, their time of completion was recorded. The participant was thanked for participating, and then left the classroom. Then, the next participant was invited inside

Results

As indicated in **Figure 3**, the mean completion time of the Attention Test game for the natural environment picture group was lower than that of the scrambled nature picture group.

Figure 3. Group means and standard error for completion time on the "Attention Test" game

Thus, performance on the Attention Test game was significantly quicker in participants who viewed pictures of natural environments, when compared to participants who viewed pictures of scrambled natural environments. Using an independent-samples t-test, it was determined that the nature group ($M = 54.33$, $SD = 7.66$) performed significantly better on the Attention Test game than the scrambled group ($M = 62.04$, $SD = 9.11$), $t(14) = -1.83$, $p = .044$ (one-tailed). Therefore, the restorative effects of viewing pictures of natural environments improved directed-attention abilities as assessed with the Attention Test game. This finding is consistent with ART.

Discussion

This experiment demonstrated the restorative benefits of viewing natural stimuli on attention-directed fatigue. More importantly, this experiment demonstrated that the image composition (open or closed) is not critical, as both sets of images were open in composition. This data is of particular interest when one considers its potential applications in the work environment, and the difficulty and cost of discovering

and developing regimens that are intended to reduce cognitive fatigue and improve performance on directed attention tasks.

Directed attention mechanisms were restored more efficiently for participants who viewed images of natural scenes than for participants who viewed scrambled images. The Attention Test game relies heavily on directed attention mechanisms, since it employs goal-directed selective attention while participants scan the grid for the next correct number. Thus, a lower completion time indicates decreased cognitive fatigue. This finding is supportive of Kaplan's (1989) longitudinal outdoor study, and Ulrich's (1983) hospital studies in which participants expressed lower levels of mental fatigue and an improved sense of overall well-being when exposed to nature stimuli. As ART suggests, the nature images were intrinsically fascinating and able to engage involuntary attention, allowing the systems and mechanisms necessary for voluntary attention to rest and recover.

This study was completed as preliminary research, with minimal resources and time allocated towards it. This being said, the results are considered significant, but require a replication with a larger sample size. Furthermore, in future replications, a within-subjects design should be used. This way, participants' scores for both conditions could be compared, allowing for an assessment of individual improvement. Administering a pre-test measure of the Attention Test to get a baseline score for each participant could allow for a point of comparison for the score they achieved after viewing the slideshow. Administering a pre-test would help to address individual differences in performance.

Future directions for this area of study would be to consider the other sensory modalities and their relationship to nature. As this study explored only the visual influence of nature on directed attention restoration, it would be interesting to incorporate the other senses to see if nature has continued restorative effects on fatigue. Future studies must first test each sense alone, to see if that individual sense is able to facilitate restoration of directed attention mechanisms. The next step would be to test multiple senses simultaneously (visual and auditory nature stimuli, visual and olfactory nature stimuli) to see which multisensory combination has the greatest restorative effects on directed attention fatigue.

Furthermore, exploring the psychobiological mechanisms responsible for attention and, more importantly, for recovering directed attention fatigue would allow for a more complete understanding of the phenomenon. The ventral and dorsal system could be manipulated via transcranial magnetic stimulation while the subject engages in a directed attention task. The same method can be employed when the subject is submerged in nature following a directed attention task, and compared to when the subject is submerged in an urban environment. Transcranial magnetic stimulation can also be used to manipulate the LC-NE system. The dopaminergic pathway can be manipulated in a

laboratory through dopamine agonists and antagonist injections in rats. Zhang et al. (2003) ran a study in which they evaluated whether incentive motivation for palatable food is altered after manipulations to neurotransmitter systems, including the dopaminergic system. Manipulating the dopaminergic system in human subjects would not be feasible, and thus rodent models are required for future research.

When researching mental fatigue, examining only the mean participant errors or reaction times may not adequately represent individual variability. A more sophisticated approach would be to identify subgroups of participants who use different attentional strategies, and examine these groups separately. For example, certain individuals prefer slower reaction times with higher response accuracy, while others prefer quick reaction times with lower response accuracy. Another approach is to examine costs as well as performance. For example, some individuals may not show a decrease in performance while fatigued, but will experience greater subjective fatigue following the task, while other individuals will show a decrease in performance during the task due to fatigue. The reason the former group of individuals experience strong subjective fatigue following the task is because of their strong exertion of mental effort to stay focused on the task at hand. These compensatory strategies against fatigue are important to take into consideration when researching attention, as they influence how an individual is affected by fatigue.

The results of this study raise the possibility that visual stimuli of natural landscapes may provide a restorative effect on fatigued directed attention mechanisms. This intervention is applicable in working environments, where cognitively fatigued employees are an everyday occurrence. Through further research into the relationships between cognitive fatigue restoration and different sensory modalities, a protocol exploiting the natural therapy of nature stimuli could be developed for the workplace. This research supports the belief that natural environments help foster, to paraphrase John Muir (1898), peace of the body and restoration of the mind.

Acknowledgements

I am grateful to Sofie Lachapelle and the University of Guelph for providing me with this opportunity and for supporting my research

References

- Aston-Jones, G. & Cohen, J. D. (2005). An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annual Review of Neuroscience*, 28, 403-450.

The reduction of directed attention fatigue through exposure to visual natural stimuli (Varkovetski)

- Aston-Jones, G., Rajkowski, J. & Cohen, J. (1999). Role of locus coeruleus in attention and behavioral flexibility. *Biological Psychiatry*, 46(9), 1309-1320.
- Berman, M. G., Jonides, J. & Kaplan, S. (2007). The cognitive benefits of interacting with nature. *Psychological Science*, 19(12), 1207-1212.
- Boksem, M. A., Meijman, T. F. & Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research*, 25(1), 107-116.
- Boksem, M. A., Meijman, T. F. & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biological Psychology*, 72(2), 123-132.
- Corbetta, M. & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews*, 3 (3), 201-215.
- Correa, M., Carlson, B. B., Wisniecki, A. & Salamone, J. D. (2002). Nucleus accumbens dopamine and work requirements on interval schedules. *Behavioural Brain Research*, 137(1), 179-187.
- Craig, A. (1992). Symptoms of acute and chronic fatigue. *Academic Press*.
- Dix, A., Finley, J., Abowd, G., & Beale, R. (1998). *Human-computer interaction*. Prentice Hall.
- Downar, J., Crawley, A. P., Mikulis, D. J. & Davis, K. D. (2001). The effect of task relevance on the cortical response to changes in visual and auditory stimuli: An event-related fMRI study. *Neuroimage*, 14(6), 1256-1267.
- Driver, B. L., Nash, R., Haas, G. & Others (1987). Wilderness benefits: A state-of-knowledge review. *General Technical Report, Intermountain Research Station, USDA Forest Service*, (INT-220), 294-319.
- Etzion, D., Eden, D. & Lapidot, Y. (1998). Relief from job stressors and burnout: Reserve service as a respite. *Journal of Applied Psychology*, 83(4), 577.
- Fan, J., Mcc, Liss, B. D., Fossella, J., Flombaum, J. I. & Posner, M. I. (2005). The activation of attentional networks. *Neuroimage*, 26(2), 471-479.
- Hartig, T., Mang, M. & Evans, G. W. (1991). Restorative effects of natural environment experiences. *Environment and Behavior*, 23(1), 3-26.
- James, W. (1892). *Psychology: The briefer course*. New York: Holt.
- James, W. (1890). *The Principles of Psychology*. New York: Holt.
- John, M. (1898) *The Atlantic Monthly, Volume 81*. Washington: DC
- Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal Of Environmental Psychology*, 15(3), 169-182.
- Kaplan, S. (1983). A model of person-environment compatibility. *Environment and Behavior*, 15(3), 311-332.
- Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge: Cambridge University Press.
- Knopf, R. C. (1987). Human behavior, cognition, and affect in the natural environment. *Handbook of Environmental Psychology: Vol 1* (p. 783-825). New York: Wiley.
- Lorist, M. M. & Tops, M. (2003). Caffeine, fatigue, and cognition. *Brain And Cognition*, 53(1), 82-94.
- Miller, E. K. & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review Of Neuroscience*, 24(1), 167-202.
- Oliva, A., & Torralba, A. (2001). Modeling the shape of the scene: A holistic representation of the spatial envelope. *International Journal of Computer Vision*, 42(3), 145-175.
- Purcell, T., Peron, E. & Berto, R. (2001). Why do preferences differ between scene types? *Environment and Behavior*, 33(1), 93-106.
- Salamone, J. D. & Correa, M. (2002). Motivational views of reinforcement: Implications for understanding the behavioral functions of nucleus accumbens dopamine. *Behavioural Brain Research*, 137(1), 3-25.
- Sonnentag, S. & Bayer, U. (2005). Switching off mentally: Predictors and consequences of psychological detachment from work during off-job time. *Journal Of Occupational Health Psychology*, 10(4), 393.
- Stahl, S. M. & Others (2002). The psychopharmacology of energy and fatigue. *The Journal Of Clinical Psychiatry*, 63(1), 7.