RESTORATION OF ATTENTIONAL DEFICITS AFTER CONCUSSION

By

Katharine Earle

A Thesis Presented to

The Faculty of Humboldt State University

In Partial Fulfillment of the Requirements for the Degree

Master of Arts in Psychology: Academic Research

Committee Membership

Dr. Carrie J. Aigner, Committee Chair

Dr. Ethan Gahtan, Committee Member

Elizabeth Larson, Committee Member

Dr. Christopher L. Aberson, Program Graduate Coordinator

July 2017

Abstract

RESTORATION OF ATTENTIONAL DEFICITS AFTER CONCUSSION

Katharine Earle

Difficulties with concentration and attention are among the most prevalent symptoms experienced after concussion. Rest has been the most common form of recovery from concussion; however, new research is suggesting mild mental exertion to be an effective aid in recovery. Drawing from attention restoration theory, this study evaluated the idea that cognitive engagement with natural environments can mitigate post-concussion directed-attention deficits. A between subjects repeated measures design was used to test directed-attention after video exposure to restorative/nature and nonrestorative/city environments. Measures of mood, connectedness to environment, and symptomology scores were also collected. No meaningful difference between exposure type was found on the Victoria Stroop task. Results did not show a meaningful difference in directed-attention between the nature and city groups post-intervention, although both groups experienced improved backwards digit span scores. Those in the city condition experienced a decrease in positive affect scores post-intervention. Changes in backwards digit span scores may suggest plasticity of attentional deficits after concussion. Suggestions for future research are discussed including the evaluation of ART as an intervention for clinical populations.

Acknowledgements

A sincere thank you to all those who helped bring this project to fruition. Throughout this process I have learned invaluable skills with the guidance and advice from my advisor, Dr. Carrie Aigner and my committee members, Dr. Ethan Gahtan and Beth Larson. A special thank you to Dr. Aigner for accepting me as her advisee half way through the program and for the unbelievably quick turn-around time between drafts. Thank you Beth, for providing me with the resources to make this thesis possible and guiding me in the pursuit of concussion research. This has been an unparalleled learning experience solidifying my passion for brain injury research.

With sincere gratitude, thank you Teigan, for your grounded perspective and endless support throughout the entirety of this process. Your daily encouragement meant everything to me. Finally, to my parents, I could not have done this without you, thank you for listening, understanding, and encouraging me from start to finish. The highs were high and the lows were low; thank you for reminding me to “keep on keepin’ on!”

Table of Contents

List of Tables

Introduction

In 2010, 2.5 million hospital visits were associated with traumatic brain injuries (Frieden, Houry, & Baldwin, 2014). Reports of concussions, also known as mild traumatic brain injuries (mTBIs), are on the rise for athletes in particular with an estimated 4-5 million occurring annually in the United States (ImPACT, 2015). Much of the rise is associated with increased awareness and diagnosis; however, it is unclear how many concussions still go unreported. Much of the research on concussions is performed using athletes. This is an easily accessible population and allows assessment of varying degrees of injury. Research involving non-athletes generally recruits participants through emergency room visits and hospital records and generally includes more severe forms of concussion causing a biased sample (Kaufman et al., 2001, Seel et al., 2003). This paper will use athlete-focused research as it provides the most comprehensive model of concussions.

A concussion is the result of a direct or indirect insult to the head resulting in complex pathophysiological processes affecting the brain (McCrory et al., 2013). This injury occurs when an individual’s brain goes through rapid acceleration and deceleration, usually in a sudden back and forth motion, stretching brain tissue and causing a disruption to the normal brain activity. A concussion is classified as a functional injury rather than a structural injury due to the damage occurring at a microscopic level undetectable by standard neuroimaging equipment (McCrory et al., 2013). However, the development of Diffuse Tensor Imaging (DTI), born out of the MRI, is a promising new technique that may allow doctors to view axonal and white matter changes after concussion (Gardner et al., 2012). Concussion or mTBI refers to a trauma to the brain resulting in an injury commonly thought to recover without long-term impairment. This paper uses the terms mTBI and concussion interchangeably. Brain injury severity is rated on a spectrum, known as the Glasgow Coma Scale (GCS), with concussions falling on the mild end of the spectrum (Reith, Van den Brande, Synnot, Gruen & Maas, 2016). Severe brain injuries, although different between individuals, can result in long-term impairment, coma, or death. The GCS assists doctors in determining the level of intervention required in a hospital setting, however researchers are moving away from using the term “mild” to describe a concussion due to the misleading connotation. More accurately, a concussion is a brain injury thought to recover at a quickened rate compared to severe TBIs, although mismanaged concussions can lead to lasting damage and complications (Laker, 2015). The development of various cognitive and physical assessments allows researchers to test and measure concussion severity and track rehabilitation; however, the research is limited on treatments for those recovering from a concussion.

Review of the Literature

The current standard of care for concussion is rest and limited exertion; however, there is debate about the effectiveness of complete rest after concussion (Harmon et al., 2013). Harmon et al. (2013) concluded complete cognitive and physical rest was not as effective as rest combined with limited cognitive and physical exertion indicating positive results from low levels of exertion during the recovery period. This discrepancy paired with the lack of interventions for cognitive rehabilitation after concussion creates a large need for research on effective interventions and improved standard of care. Difficulties with concentration and attention are among the most commonly experienced symptoms of concussion. Drawing from the attention restoration theory (ART), this paper proposes the use of the natural environment as a means of mitigating the directed-attention fatigue associated with concussion. ART uses nature environments, referred to as restorative environments, to activate involuntary attention while simultaneously disengaging voluntary or directed-attention, allowing for relief from directed-attention fatigue. The present study applies ART to mTBI by examining the usefulness of this theoretical framework for understanding and potentially treating the attentional deficits associated with concussion. Applying ART to concussion rehabilitation is a novel approach not yet studied. The application of ART to clinical populations is limited, but results warrant further research into the utilization of ART as a potential means of reducing attentional deficits in clinical populations.

Concussion Symptomology

No brain injury is alike. A concussion can occur from a direct blow to the head or from biomechanical forces acting on the body causing brain tissue to stretch and/or rotate abnormally (Meaney & Smith, 2011). The damage caused by a concussion and the resulting neuropathology is known as the neurometabolic cascade of concussion (Giza & Hovda, 2014). As studied in mice, this neurometabolic cascade begins immediately after the insult, leading to nonspecific depolarization and resulting in imbalances in intracellular and extracellular ions. This imbalance causes the sodium-potassium pump to go into overdrive trying to restore homeostasis. The sodium-potassium pump requires energy from adenosine triphosphate molecules made through the metabolism of glucose. The cell then begins to hypermetabolize glucose, also requiring energy. Without enough resources to supply necessary energy, the cell enters an energy crisis. Neuronal suppression follows this state of hypermetabolism. These physiological disturbances, theorized by Giza and Hovda (2014), have symptom correlates. The symptoms experienced post-injury may be indicative of functional impairments at a physiological level; however, the causal direction of this relationship is unclear.

An athletic trainer or coach often diagnoses a concussion in sports, though recent state legislation and consensus best practice typically requires doctor approval before returning to play. The diagnosis of a concussion is frequently based on accurate answers to basic questions (e.g., “what team are we playing?”), assessment of balance, basic neuropsychological tests such as King-Devick (a visual tracking test requiring eye movement and attention), and the presence of physical symptoms such as vomiting or headache. Without pre-injury testing, it can be difficult for coaches or trained professionals to interpret the results of post-injury tests. In these cases, the average score of unimpaired and age matched individuals is used for comparison. A concussion is not characterized by loss of consciousness; rather, a loss of consciousness may indicate more severe brain trauma (McCrea et al., 2013).

When concussions are evaluated in a medical setting, the Glasgow Coma Scale (GCS), a measure of consciousness based on eye, verbal, and motor responses, is often used (Reith et al., 2016). This scale ranges from 3-14 or 15 depending on the version. A score less than 9 indicates a severe brain injury, while a 13 or higher indicates a less severe injury. A score between 9 and 13 suggests a moderate injury. Moderate to severe brain injuries may require a period of hospitalization. As mentioned previously, this scale is designed for conformity in emergency room diagnoses. This method of classification can be misleading. Despite scores on the GCS, all brain injuries have the potential for serious symptomology. A concussion is a brain injury and although it may not be as chronic as a severe brain injury or require hospitalization, it should be attended to and handled with the same caution and care as a severe TBI.

After a concussion, the presentation and duration of symptoms, influenced by previous medical and family history, are unique for each individual. There are 22 symptoms associated with concussions falling into four categories: cognitive impairment, physical impairment, emotional dysregulation, and sleep disturbance (Hunt & Asplund, 2010). One study tracked NCAA student-athletes who experienced a concussion across two years in 25 different sports across America. This study found that student-athletes experience an average of 5.29 (*SD*=2.94) symptoms post-concussion with 60.1%

experiencing symptom resolution after one week; however, 6.2% experienced symptoms for longer than four weeks (Wasserman, Kerr, Zuckerman, & Covassin, 2015). More recent research, extending the recovery window, states that the majority of adults experience symptom resolution within 14 days (McCrory et al., 2017).

Cognitive. Cognitive impairment involves disturbances in memory, attention, thought clarity, slowed processing speeds and reaction time, and general cognitive fatigue. Difficulty concentrating, or directed-attention fatigue, is one of the most common symptoms after concussion, occurring in 58.3% of athletes (Wasserman et al., 2015). Post-injury amnesia can occur as well as loss of consciousness; however, these symptoms are relatively rare (<10%; Guskiewicz, Weaver, Padua, & Garrett, 2000). Giza and Hovda (2014) believe axonal injury and impaired neurotransmission to be associated with cognitive impairment, and slowed processing and reaction times in mice; additionally, early post-injury cognitive dysfunction, amnesia, and loss of consciousness may be the result of neuronal suppression. These impairments can affect an individual's ability to perform daily tasks and may require time off work, school, practice, or other activities so as not to exacerbate symptoms.

It is well documented that post-injury, many individuals experience directed-attention (DA) deficits (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Dockree et al., 2005; Kaelin, Cifu, & Matthies, 1996). Directed-attention, a key component in executive functioning, is defined as the voluntary attention required to focus on something that does not inherently attract attention. Post-injury, individuals are prone to deficits in DA including attentional fatigue, and attentional failures, such that he/she may have increased distractibility, leave tasks unfinished, or fail to hear someone speaking to them (Dockree et al., 2005). The lack of controlled processing associated with brain injuries is argued to be the result of these transient ‘drifts’ of attention resulting in impaired executive functioning. These attentional drifts can cause an individual to react improperly to a stimulus by reacting based on previous patterned responses, rather than the present stimulus and environment, increasing the chance of attentional failures.

Individuals with concussion may experience deficits in DA similar to those seen in attention-deficit hyperactivity disorder (ADHD). After inducing a mTBI, Mychasiuk, Hehar, and Esser (2015) found ADHD-like symptoms in young rats. These symptoms included deficits in sustained attention, impulsivity, and response inhibition. Authors concluded mTBIs result in functional impairment and negatively impact executive functioning in a way similar to that of ADHD. There is concern about replicating human mTBI in animals as well as extending the results of animal studies to humans. While mTBIs in humans result from a variety of impacts, the mTBIs induced in animal studies are done so using weight drop and fluid percussion techniques among others. It is challenging for researchers to replicate human mTBIs in animals making it difficult to generalization the results of animal research.

Physical. Physical impairment is another symptom of brain injury characterized by blurred or fuzzy vision, balance problems, headaches, physical fatigue, and sensitivity to light and noise. Giza and Hovda (2014) proposed that migraine headaches, photophobia, and phonophobia are associated with the ionic flux during the neurometabolic cascade after concussion in mice. The most common symptom post-concussion is headache, occurring in 92.2% of cases (Wasserman et al., 2015). Injuries resulting in vestibular impairment lead to balance problems, while oculomotor impairments result in blurred or fuzzy vision and sensitivity to light and noise, which can lead to headaches. The disorientation associated with vestibular dysregulation can significantly impair an individual's ability to function because we rely so heavily on our eyesight for balance and physical orientation. Vestibular damage can cause dizziness and balance issues and is also related to extended recovery times (Chamelian & Feinstein, 2004). Dizziness is another physical impairment common among those who have experienced a concussion, occurring in 68.9% of cases (Wasserman et al., 2015).

Emotionality. Concussion patients also exhibit higher levels of anxiety and depression than controls (McGarth, 2010). Because of this, monitoring emotional changes is especially important. Individuals recovering from a concussion may be prone to emotional changes including changes in emotional reactions, and increased feelings of irritability, anxiety, sadness, and depression. These changes may be more dramatic in cases of prolonged recovery. Cognitive performance has been associated with emotional regulation (Mueller, S.C., 2011). Although the causal relationship between symptoms of emotionality and cognition has yet to be determined in this population, some research has indicated that poor emotional regulation can negatively impact cognitive performance, thereby increasing cognitive symptoms.

Depression in particular is a large concern for people recovering from a mild or severe brain trauma. Patients with a history of brain injury are at a higher risk of developing depression and depression screening is recommended post-injury

(Schoenhuber & Gentilini, 1998). One study of 666 TBI patients determined 27% of those individuals met criteria for a major depressive episode (Seel et al., 2003). The individuals comprising the 27% did not have a depression diagnosis prior to injury and were more likely to report trouble falling asleep, restlessness, weakness and poorer concentration than their non-depressed counterparts. The authors speculate that depression may be the root cause of these symptoms rather than the injury itself, such that treating the depression may alleviate these symptoms. However, the causal direction of this relationship is unclear, and results warrant further research into symptom clusters and correlates. Seel et al. (2003) found no link between injury severity and the occurrence of depression.

Additionally, research shows that irritability increases after brain injury, but more interestingly, individuals report less irritability than friends and family members report. One study found 14.8% of patients with TBI reported irritability while families reported 29.4% occurrence of irritability (Yang, Hau, Lin, Tsai, & Huang, 2012). Despite the difference in family and self-report levels of irritability, the increase in irritability is remarkable and is described as the second most prevalent neuropsychiatric symptom, after apathy, occurring in 37% of TBI cases (Ciurli, Formisano, Bivona, Cantagallo, & Angelelli, 2011).

Sleep. Sleep disturbances after mTBI include sleeping too much, not sleeping enough, and having trouble falling and staying asleep. One study found that three years post-concussion, individuals experienced decreased sleep efficiency, increased time spent awake, and more frequent, prolonged awakening (defined as greater than 3 minutes) from sleep, as measured by a polysomnography, compared to controls without concussion (Kaufman et al., 2001). These individuals also reported trouble falling and staying asleep, and daytime sleepiness. Interestingly, another study found the biggest correlate of sleep disturbances (within three months of injury) to be the onset of anxiety post-concussion (Rao et al., 2008). This study found no relationship between injury severity and sleep disturbances. It is common for disturbed sleep to contribute to anxiety as well as anxiety to contribute to sleep disturbances. Authors speculate treating one of these symptoms could reduce or eliminate the other.

A large number of symptoms and a broad spectrum of symptom severity make treatment challenging. The research should focus on the major symptoms with common symptomology, such that treating a major symptom may resolve associated symptoms. For example, treating individuals for depression may also resolve sleep and emotional disturbances. Moreover, treating attentional deficits could potentially alleviate symptoms associated with directed-attention fatigue (DAF), such as impaired thought processing and perceptions, irritability, and distractibility, all common post-concussive symptoms.

Standard of Care

Although many individuals experience spontaneous symptom resolution within the first weeks post-injury, some individuals experience prolonged symptoms requiring treatment in the form of therapy or pharmacological intervention. Measuring the severity of brain injuries and monitoring the recovery is extremely important for the health of an individual, but also to determine when the individual can return to normal daily life.

Recovery is measured through the alleviation of symptoms largely because concussions cannot be seen through neuroimaging. The current standard of care includes a period of cognitive and physical rest (Schneider et al., 2013). If an individual too quickly returns to a high level of activity (both cognitive and physical) before symptoms have subsided, he/she is likely to experience a prolonged recovery time. The U.S. Center for Disease Control and Prevention (2015) recommends rest and limited exertion during the acute recovery period (1-7) days. Laker (2015) recommends that an individual with a concussion avoid watching T.V., using a mobile phone, reading, playing video games, or studying to prevent aggravation of symptoms. When symptoms have subsided, the individual may begin the process of reintegration into regular routine. Until the individual is able to return to a regular routine without accommodations or exacerbation of symptoms, he/she is not ready to return to physical activity.

Second Impact Syndrome and multiple concussions. Second Impact Syndrome (SIS) is the result of a second acquired brain injury before the original injury has healed, amplifying the effects of the original injury leading to death or severe and permanent disabilities (Laker, 2015). Even after the original injury has healed, additional brain traumas can lead to more severe impairment requiring an extended recovery period or, in some cases, causing permanent damage. As shown in one study, athletes with multiple concussions were six times more likely than those with a single concussion to have post-traumatic amnesia and eight times more likely to experience mental status disturbances such as disorientation or retrograde amnesia, symptoms more commonly found with severe brain injuries (Iverson, Gaetz, Lovell, & Collins, 2004). In a separate study, individuals with three or more concussions six months post-injury self-reported worse scores on memory, occurrence of headache, and processing speed than those with a single concussion (Gaetz, Goodman, & Weinberg, 2000). At six months post-injury, these individuals were not testing as well as individuals without a history of multiple concussions. These results suggest that impairments may persist long after patients stop reporting symptoms, making it increasingly important to rehabilitate concussions beyond the alleviation of noticeable symptoms. It is becoming clear that the alleviation of symptoms may not indicate full recovery.

As the danger of multiple concussions is more widely understood, it is critically important to accurately diagnose a concussion and expedite the healing process. McCrory et al. (2017) acknowledge that the majority of adults recover within 10-14 days post-injury. Individuals experiencing symptoms for longer than 14 days are said to be experiencing a prolonged recovery. It is accepted that concussive symptoms spontaneously resolve; however, through evidence of the cumulative effect of multiple concussions, it is becoming clear that while symptoms may have resolved, the underlying damage may not (Gaetz, Goodman, & Weinberg, 2000; Hunt & Asplund, 2010).

The standard of care for concussions is simple: rest (Schneider, 2013). There is research on interventions to restore cognitive functioning in those with concussions, such as Cognitive Behavioral Therapy (CBT) and pharmacological options; however, the effectiveness of such interventions is debatable and more research is needed (Snell, Surgenor, Hay-Smith, & Siegert, 2009). As research on concussions progresses, the need for effective and reliable interventions is apparent.

Treatment for Brain Injury. While the standard of care for concussions in the acute post-injury phase is rest, there are interventions designed to aid the recovery process; however, the efficacy of those interventions is debatable and the research suffers from small sample sizes, poor design, and a lack of methodological rigor. Current experimental interventions for mTBI and TBI are similar to those used on non-brain injured populations for phenotypically similar problems. For example, for those with post-concussion depressive symptoms, taking selective serotonin reuptake inhibitors (SSRIs) may improve affective lability, and anxiety (Arciniegas, Anderson, Topkoff, & McAllister, 2005).

Pharmacological Interventions. Pharmacological interventions have shown promising results for improved attention and memory after mTBI. Methylphenidate, a common drug for ADHD, improves cognitive and attentional deficits in brain-injured adults (Kaelin, Cifu, & Matthies, 1996; Plenger, 1996). These studies found lasting changes and positive effects of methylphenidate on acute TBI patients even after the discontinuation of the drug, suggesting long-term neuronal changes. This study is particularly important as it provided an intervention in the acute phase of recovery, while most research has examined the use of this medication for relief of chronic symptoms. Additionally, donepezil, often used for dementia, is demonstrated to be a useful pharmacological option for recovering short-term memory and mediating attentional deficits in adults with moderate to severe TBIs (Zhang, Plotkin, Wang, Sandel, & Lee, 2004). This study only tested short-term memory and sustained attention, thus the effects on other cognitive functions remain unclear. More research is required to determine the efficacy of donepezil on mTBI and the potential negative side effects of this drug on those with brain injury. These findings warrant further research into which practices and interventions can aid attentional rehabilitation from brain injuries. Additionally, the timeframe for implementing these interventions has yet to be established.

Non-pharmacological interventions. There have been a number of non-pharmacological experimental interventions for treatment of concussion with mixed results. Rest is the standard of care. This determination is based on the results showing regular cognitive and or physical activity post-concussion can cause prolonged recovery (Brown et al., 2014). However, it is not clear that total rest is superior to mild cognitive exertion during the recovery phase. In addition, drawing from research on the psychological symptoms associated with headaches in those with concussions, researchers attempted to alleviate post-traumatic headache with cognitive-behavioral therapy (CBT). A recent randomized controlled study comparing CBT to a control group on a waiting list found that CBT was not effective for improving headache, quality of life, or concussion symptoms among patients with concussion (Kjeldgaard, Forchhammer, Teasdale, & Jensen, 2014). However, the mean duration of time post injury in this study was approximately 27 months making it unclear whether or not the intervention would be beneficial in the acute post-injury phase. Authors did not set inclusion criteria specific to duration of time post-injury. Another study found improvement in executive functioning and processing speed following a 12-week aerobic training protocol (Chin, Keyser, Dsurney, & Chan, 2015). Unfortunately, this study suffered a small sample size of nine, lacked a control group, and the time frame post-injury ranged from 9 months to 13 years. Despite encouraging results, the efficacy of aerobic exercise post-TBI requires further study.

The limited number of studies evaluating non-pharmacological interventions creates a void in the research, as well as poses challenges for researchers and clinicians alike. There is a need for greater research on interventions and intervention implementation. Specifically, the utility of cognitive rehabilitation during the acute phase requires further study. This study aims to determine the utility of attention restoration theory on mitigating post-injury directed-attention deficits in those with concussions.

Attention Restoration Theory

ART, developed in the field of Environmental Psychology, is built on William James' idea that attention is separated into two distinct categories: voluntary or directed-attention, and involuntary attention (as cited in Kaplan, 1995). Directed attention (DA) is the effortful control of focus and thought while blocking out irrelevant and distracting stimuli. The use of DA requires executive control processes to make a decision on whether or not a stimulus warrants a reaction (Kaplan, 1995). DA is susceptible to fatigue; when it is over-used, directed-attention fatigue (DAF) may result (Kaplan, 1995). DAF can result from excessive studying, writing, working, or anything requiring superb focus on a singular topic. DAF results in attentional failures and increased distractibility, and can cause an individual to leave tasks unfinished or fail to hear someone speaking (Dockree et al., 2005). In college students, these symptoms of DAF can have adverse effects on grades and academic performance. Conversely, involuntary attention is used when stimuli are inherently interesting and do not require effortful focus or the involvement of executive processes (Kaplan, 1995). ART utilizes this idea of voluntary and involuntary attention to create a means of relieving DAF.

Attention restoration theory borrows the idea of restorative environments from stress reduction theory (SRT). SRT demonstrates the emotional and physiological benefits associated with natural environments (Ulrich, 1984). ART expands on SRT by proposing that one of the cognitive mechanisms through which people benefit from nature exposure is improved attentional processing. ART uses nature environments to engage involuntary attention. Because directed-attention and involuntary attention cannot be simultaneously engaged, by virtue of activating involuntary attention, directed-attention processes are relieved (Kaplan, 1995). Natural environments provide attentional restoration by engaging involuntary attention (Berman, Jonides, & Kaplan, 2008; Berto, 2005; Cimprich & Ronis, 2003; Hartig, 1991; Kaplan, Talbot, & Kaplan 1988). Through either passive (viewing the environment, such as through a window or through the use of technology) or active (interacting with the environment, such as on a nature walk) involvement, an individual can experience attentional restoration. This idea is particularly important in that SRT was developed using passive involvement in nature environments whereas ART has been tested using both passive involvement, through video and photo exposure, and active involvement, through interacting with the environment in a physical way such as walking (Berman et al., 2008; Berto, 2005; Ulrich, 1984).

It is debatable as to which method of involvement promotes the greatest level of restoration; however, both methods present as being clinically beneficial for attention restoration. Given that ART provides benefits through passive involvement with nature (e.g., video or view through a window), individuals who are unable to engage actively in the environment can also benefit. Individuals with brain injuries are strongly discouraged from engaging in physical activity immediately following the injury, making them ideal candidates for passive involvement in restorative environments.

Restorative Setting Criteria. According to ART, the difference between a restorative environment and any other environment is the effect the environment has on an individual. While studies use a variety of environments to examine ART, restorative environments, proposed by Kaplan and Talbot (1983), are thought to each have the following four key components: fascination, "being away," extent that it is coherent enough and sufficient in scope to fully engage the mind, and compatibility.

Fascination. Nature has a whole host of fascinating objects that intrigue the mind. These fascinations are considered 'soft' fascinations including, sunsets, clouds, leaves blowing in the wind, snow patterns, etc. and hold an individual's involuntary attention (Kaplan, 1995). This type of undirected-attention allows the individual to consider other things while still stimulating the mind. When something is fascinating, an individual does not have to actively direct his/her attention; rather, involuntary attention engages requiring less effort and resources. This is especially important for individuals with a brain injury. While the brain is in a state of metabolic crisis and energy deficiency, it is crucial to avoid exacerbation of symptoms and promote recovery.

Being-away. Being-away does not require the individual to physically be in a different place. It is often unfeasible for an individual to "get away" for attention restoration. Although a getaway to the mountains, the sea, or lake may be preferred, a view of natural scenery or a walk in a park adequately fulfills this criterion by allowing the individual to feel immersed in a nature environment (Kaplan, 1995).

Extent. An environment that has extent is rich and complex enough to stimulate the mind without being overly stimulating. The scope of the environment must be large enough that the individual is able to connect with the greater scene. Extent does not require a vast amount of land, but it does require the environment to have enough scope that the individual is able to connect to a larger world. This may also be established through viewing historic artifacts, which allows the individual to connect to a past time/environment or through a view of natural scenery that allows the individual a greater perspective.

Compatibility. A compatible environment is one that fulfills the individual's purpose for being there and one in which the individual fits with what the environment demands (Kaplan, 1995). An environment that requires the individual to be on guard would not be compatible for someone seeking restoration. In a compatible environment, an individual carries out activities without complication and feels that his/her natural behavior is appropriate for the environment; the environment is compatible with what the individual expects it to be.

Kaplan constructed ART using restorative environments to engage involuntary attention, and thus restore DA. In the beginning, he studied the impact of restorative environments on psychological well-being, finding improved attentional capacity after nature exposure (Kaplan & Talbot, 1983). In this study (Kaplan & Talbot, 1988), participants rated their ability to concentrate as significantly higher after a two-week nature exposure than before. Hartig (1991) expanded on this research, finding increased cognitive performance, specifically improved ability to sustain DA, after interactions with nature in both self-report and cognitive performance measures such as a proof-reading task. Using nature as a therapy tool is not a new concept and nature exposure has been examined in the literature for its psychological and physical benefits.

Psychological and physical benefits of nature exposure. There is an abundance of research measuring the psychological and physical health benefits of nature exposure. Although many of these do not follow an ART paradigm, it is useful to review this literature in understanding the wide range of beneficial effects associated with nature exposure. Studies have found improved positive affect and decreased anxiety after a nature walk in contrast to a city walk (Berman et al., 2008; Song et al., 2013), as well as decreased heart rate after nature exposure compared to a city environment (Song et al., 2013). A study measuring physiological effects of Shinrin-Yoku, “taking in the forest atmosphere,” found decreases in salivary cortisol, heart rate, and blood pressure after a 14-minute passive interaction with a forest environment as well as 15 minutes active (walking) interaction with the forest environment (Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2010). While these studies lend support to the utility of nature as a therapeutic tool, they do not test ART in its entirety. There are fewer studies presenting data on the attentional benefits of natural environments. Further research is needed in order to examine the utility of this theoretical framework for relieving DAF in both clinical and nonclinical populations.

ART research on nonclinical populations. ART has been found to be effective for restoring DA in nonclinical populations (Berman et al., 2008; Berto, 2005). Hartig (1991) measured DA using a proofreading task, a task known to cause DAF, before and after participants vacationed for one week to a wilderness environment (N = 25), non-wilderness environment (N = 25), and in those who remained in their daily routine (N = 18). This study found increases in DA after wilderness exposure only. Authors controlled for vacation duration and participant level of fitness. Research has since shown that exposure to restorative environments can improve an individual's ability to sustain DA after experimentally induced DAF (Berto, 2005). In Berto (2005), participants took a Sustained Attention to Response Test (SART), a test known to fatigue directed-attention, prior to exposure to restorative or nonrestorative environments. Berto (2005) found college students rate photos of natural environments as more restorative than built and partially built environments on the Perceived Restorativeness Scale. In this study, these nature and city photos were used as the stimuli shown after induced DAF in college students. Only students who viewed the restorative photos experienced relief from DAF, as measured by the Sustained Attention to Response Task. In a separate study, Berman et al. (2012) found that individuals were able to gain attentional restoration, as measured by the backwards digit span, through a 50-55 minute walk in the park, but a walk, equal in time and distance, in the city had no effect on DA. Participants experienced one environment (park or city) then the same individuals returned one week later to walk in the other environment. Before environment exposure, these individuals were prompted to ruminate on a personal, unresolved, negative event, a method known to impair working memory and thus negatively impact DA (Berman et al., 2011).

Lastly, non-experimental research has found that natural environments produce greater attentional benefits than non-natural or built environments. One study found that college students who had a nature view from their dormitory windows performed better on tests of DA than students with a view of an entirely built setting or partially built (containing a combination of natural and built settings; Tennessen & Cimprich, 1995). These findings are consistent with experimental studies demonstrating improved DA after nature exposure.

ART research on clinical populations. Interestingly, research has shown ART to be more effective on directed-attention in clinical populations than healthy populations (Berman, Jonides, & Kaplan, 2008; Berman et al., 2012). Both studies induced DAF prior to exposure to environments. In Berman et al. (2012), individuals with major depressive disorder found relief from DAF after a nature walk as measured by a backwards digit span test. The effect size was five times larger than the original study examining attention restorative among non-depressed individuals (Berman et al. 2008), warranting more research on ART in clinical populations and additional studies on the benefits of ART in clinical versus non-clinical populations. In another study, restorative environments improved DA in children with attention-deficit/hyperactivity disorder (Taylor & Kuo, 2009). This study found improved DA, as measured by the backwards digit span test, after a 20-minute walk in the park while no measurable improvement after the same individuals took a walk in two different urban environments. Participants were randomly assigned a treatment location then one week later returned to experience the other location. The results justify future research on ART for improving attention deficits in populations with clinically impaired attention.

Additionally, naturally occurring DAF, as in individuals undergoing cancer treatment, can be relieved through restorative environments (Cimprich & Ronis, 2003). Cimprich and Ronis (2003) implemented a six-week program involving regular exposure (120-minutes per week) to a variety of restorative environments for women beginning treatment for breast cancer. This study found increased ability to direct attention post-intervention for those in nature environments compared to a control group who self-selected relaxing activities during the intervention period. Despite there being few studies on ART in clinical populations, the studies that do exist are methodologically sound including adequate control groups and appropriate measures of attention (Berman et al., 2008; Gamble, Howard & Howard, 2014; Taylor & Kuo, 2009). While some studies had small samples, within subjects repeated measures designs were often used strengthening the results. The promising results warrant more research on the potential benefits of using ART as an intervention for clinical populations suffering from attentional deficits.

It is common for those with concussions to experience DAF (this population would not require induced DAF; Wasserman et al., 2015). Research examining the use of restorative environments for DA restoration in clinical populations experiencing impaired DA provides initial evidence that this may be an appropriate paradigm for aiding recovery among those with concussion.

Measuring directed-attention. Directed-attention is a key component of working-memory, inhibition, and/or a measured response time and is measured through these constructs. Working memory is defined as the ability to move information in and out of attentional focus while blocking out irrelevant stimuli, thus requiring the use of DA (Cowan et al., 2005). Additionally, inhibition, the ability to inhibit impulses, and reaction time, the amount of time required to produce a response, both require the use of DA to prevent distraction and both are impaired when DAF occurs (Berman, 2008). These constructs can be measured using the backwards digit-span task, a task requiring the use of working-memory (Tennessen & Cimprich, 1995; Cowan et al., 2005), and the Stroop task, a task measuring inhibition, reaction time, and DA (Stroop, 1935). These measures require DA and are sensitive to DAF.

General tests of executive functioning would not be adequate measures for this research question. While DAF negatively affects executive functioning, impaired executive functioning does not always imply impaired directed-attention. Impaired working memory, lack of inhibition, and delayed response time are common symptoms of a concussion and are all directly influenced by DAF. Using measures of working memory and inhibition, this study will attempt to alleviate DAF using restorative environments among young adults with concussion.

The Current Study

Concussions are becoming more commonly diagnosed. Increased rest and limited exertion until symptoms subside is the typical standard of care; however, long-term follow-ups of patients suffering concussion show continued impairment on neuropsychological tests in some patients. Few evidence-based interventions exist to aid in post-concussion recovery. Cognitive symptoms, including memory and attention impairment, are common symptoms of concussion, experienced by over half of patients in the acute stage of injury. A key component of brain injury-related cognitive deficits is directed-attention. Restoring directed-attention in individuals with a concussion could potentially aid the return to daily routine and decrease recovery time. Targeting one of the most common symptoms of concussion, this study aims to alleviate post-injury directed-attention fatigue in those with concussions through the application of the theoretical framework of attention restoration theory (ART).

Statement of the Problem

The lack of research on ART in clinical populations creates a gap in the literature with great potential for improved standard of care for a variety of populations. Specifically, individuals with concussion could greatly benefit from restored DA. Directed attention is a fragile component of cognition and is susceptible to fatigue when taxed. Humans have a limited capacity for DA, posited by Kaplan (1995) to be a result of evolutionary mechanisms; however, with a limited capacity for DA, as DA wanes, an individual can become distractible, irritable, have impaired thought processing and perception, and have decreased inhibition. Kaplan believes this limited capacity for DA resulted from our ancestral fight for survival. If an individual was too focused on a single task, he/she would not be aware of his/her surroundings increasing the risk of predation. With a limited capacity for DA individuals are likely to survey their surroundings more frequently.

The same symptoms found to be responsive to restorative environments in experimental studies are also common in individuals with mTBI. Individuals with concussions have shorter directed-attention spans (Dockree et al., 2005) making them more prone to attentional fatigue and more likely to experience symptoms of DAF. It is typical for individuals with mTBIs to complain of DAF or decreased directed-attentional capacity (Dockree et al., 2005). These attentional drifts increase the likelihood an individual will make a mistake in his/her daily life. These mistakes can include making a wrong turn, dialing the wrong number, forgetting an important meeting, etc. Unable to draw on directed-attention processes, an individual can become irritated and less effective in processing incoming information (Dockree et al., 2005). Relieving DAF among people with concussion may not only help to improve DA, but may also positively influence related symptoms in this population. Based on previous research, using ART as a novel approach to alleviating attentional deficits in those with concussions is promising. Restoring attention in those with concussions could potentially aid the individual in his/her return to daily routine and decrease recovery time.

This study does not test the mechanisms behind ART, but speculation is possible. The natural environment's positive impact on human health and well-being is well studied and the implications have taken foothold in today's society (Berman et al., 2008; Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2010; Song et al., 2013). City officials and university personnel are creating parks, promoting green living spaces, and encouraging outdoor rest periods. Humans have spent a great majority of existence in natural environments. The move to cities and industrial life is relatively recent and the body is still far more adapted to living in nature. This is one of the fundamental principles of ART. It stands to reason if an individual is placed in an environment that he/she is most adapted for, the body will function at a higher capacity and trend towards homeostasis. It is possible this is a working mechanism behind ART. As a person spends more time in a restorative environment, much like the environment humans are adapted to, he/she may move toward homeostasis, regulating attentional function and hormone levels among many other processes. After a concussion, researchers speculate the cause of many symptoms, including attentional deficits, to be a serious imbalance in cellular homeostasis (Giza & Hovda, 2014). It may be possible to promote cellular homeostasis through changing an individual's physical environment.

Additionally, humans have also adapted to a specific state of being, including exertion at varying levels, where lack of exertion is actually abnormal. This can be seen through results indicating sedentary life style as an independent risk factor for disease (Kokkinos, et al., 1995; Power, Pinto Pereira, Law, & Ki, 2014). Research on concussion recovery indicates limited exertion to be better than total rest which supports this idea

(Harmon et al., 2013). When an individual is in a nature environment he/she can be mentally stimulated using involuntary attention. By placing an individual with a concussion in this type of environment they may be more likely to move toward homeostasis than if they were in an environment that engaged voluntary attention. The low level of activation allows for a more typical state of being than total rest, and may allow a type of "backdoor" route to stimulation. By engaging lower level brain areas, a person may be stimulated without concern of exacerbating symptoms. This stimulation provides a means of recovery as it allows the physical body to move toward homeostasis promoting a healthier cellular environment for the body to heal itself. With the use of restorative environments, it may be possible for individuals to experience mild mental exertion without the concern of "over-doing it" or prolonging recovery.

Concussions are currently measured by the number of symptoms present. If an individual's symptoms are masked but the damage to the brain has yet to heal, it can cause the individual to exert themselves more than is appropriate for their stage of recovery and possibly prolong recovery. Using restorative environments to relieve DAF is not merely masking symptoms, but creating a therapeutic response. By providing low-level stimulation and disengaging voluntary attention, restorative environments may be allowing higher order thought processes to rest while still maintaining a level of cognitive activity. Rest is important for the damaged part of the brain to recovery, although it is voluntary attention not involuntary attention that the research has evaluated and suggested individuals should avoid (Laker, 2005). More and more research is showing mild exertion to be more productive than complete rest (Harmon et al., 2013), but the exact type of exertion has not been determined.

Some studies are indicating mild exertion aids in recovery (Chin, Keyser, Dsurney, & Chan, 2015; Leddy, et al., 2012), while others are reporting mild exertion impedes recovery (Brown et al., 2014). Why the discrepancy? It is possible that some studies testing exertion levels are actually engaging involuntary attention intermittently. Studies showing the benefits of exercise post-concussion argue for mild physical exertion, while studies researching the same question show exercise post-concussion to be detrimental. The same conflicting results are shown with mild mental exertion (Brown et al., 2014). It is entirely possible that the environment in which testing occurs could be engaging involuntary attention in some situations and voluntary attention in others. Walking in a park, rich in restoration, is more likely to engage involuntary attention while walking on a treadmill at a gym may fail to engage involuntary attention. On the same note, research in a lab without windows would likely cause participants to depend on voluntary attention while research labs with windows to natural environments may engage involuntary attention enough to impact results. It is in this way that these studies may be finding different results. Whether mild exertion should involve voluntary or involuntary attention networks is unknown, but the answer holds possibilities for future research on concussion rehabilitation. The mechanisms behind ART will not be tested in this study, but the theoretical use of ART is promising as a therapeutic tool for concussions.

Theoretically, ART can be applied to individuals with concussions to relieve DAF and increase directed-attention span. The use of restorative environments is a practical intervention applicable to anyone, has many low-cost applications, and has no known side effects. Restorative environments have been found to be effective in doses as short as 6 minutes in experimental studies (Berto, 2005; Cimprich, Ronis, 2003). The simplicity and practicality of this intervention would make it suitable for a wide spectrum of brain injury patients experiencing attentional deficits. With attention restoration theory as the foundation, this study predicts that individuals with mTBIs will see attentional benefits directly after exposure to restorative environments, while non-restorative environments will have no effect.

Hypotheses

Hypothesis 1: Individuals with an mTBI who view restorative environments will have greater improvement in response time on the Victoria Stroop Test post-intervention, compared to those in control condition. Lower response time on the Victoria Stroop Test is indicative of better cognitive functioning. The Stroop task is a common measure of DA. Based on ART, the restorative environments will provide directed-attention restoration and mitigate the cognitive fatigue, allowing the participant to react quicker on the post-test.

Rationale for hypothesis 1: According to attention restoration theory, restorative environments provide stimuli that do not tax an individual's directed-attention system, thus allowing it a chance to restore itself by virtue of not using it. With restored DA, an individual will be able to react quicker to stimuli. In contrast, a non-restorative environment activates DA by requiring a higher level of alertness and attentiveness to one's surroundings. A non-restorative environment does not permit a break from DA and taxes an individual's attentional capacity, likely increasing their response time on the Stroop test.

A common characteristic of mTBI is delayed reaction time. Reaction time can be associated with one's ability to maintain directed-attention long enough to react to a specific stimulus. With increased attentional capacity after exposure to restorative environments, it is predicted that participants will have a quickened reaction to stimuli in the Stroop task, resulting in an overall better performance on this task.

Hypothesis 2: Individuals with an mTBI who view restorative environments will have greater improvement on errors made during the Stroop Task pre-to-post, compared to individuals in the control condition. Participants who view restorative environments will have fewer incorrect responses on the post-test than participants exposed to the non-restorative environment. Based on ART, the restorative environments will provide DA relief and mitigate the cognitive fatigue allowing the participant to perform better on the post-test.

Rationale for hypothesis 2: According to attention restoration theory, restorative environments provide stimuli that engages involuntary attention allowing voluntary attention processes a chance to reset. An individual with impaired directed-attention is likely to make more mistakes on the Stroop test. In contrast, a non-restorative environment requires directed-attention to be alert and attentive to one's surroundings.

Non-restorative environments do not permit a break from DA requiring additional taxation on attentional processes and increasing the likelihood of an incorrect response.

It is common for an individual with mTBI to have lapses in attention resulting in “oops” moments or attentional failures (Robertson et al., 1997). Lapses in attention should manifest as greater incorrect responding on the Stroop test. It is predicted that after exposure to restorative environments, individuals with mTBIs will see a decrease in incorrect responses, relative to controls.

Hypothesis 3: Individuals with an mTBI who view restorative environments will have greater improvement on Digit Span Backward pre-to-post, compared to those in the control condition. Digit Span Backward is a measure of working memory, a construct closely linked to DA. Higher scores on Digit Span Backward indicate greater working memory capacity. Based on ART, the restorative environments will provide directed-attention relief and mitigate the cognitive fatigue associated with the backwards digit span allowing the participant to perform better on the post-test.

Rationale for hypothesis 3: According to attention restoration theory, restorative environments provide stimuli that do not tax an individual’s directed-attention system, thus allowing it a chance to restore itself. With restored directed-attention, an individual will be more attentive resulting in more responses that are correct. In contrast, a non-restorative environment activates directed-attention taxing attentional processes. A non-restorative environment does not permit a break from directed-attention and taxes an individual’s attentional capacity making it more likely that an individual will produce an incorrect response.

Digit Span Backward measures working memory and is sensitive to DAF. Working memory requires the use of directed-attention to maintain focus on specific information while blocking out other stimuli avoiding distraction; thus, if directed-attention is impaired, so will be working memory (Cowan et al., 2005).

Methods

Participants. Ten participants took part in this study, ages 18-30. The participants were recruited through the North Coast Concussion Program (NCCP). The NCCP performs baseline and post-injury testing for athletes and non-athletes at Humboldt State University and concussion education and injury evaluation for community members. Participants performed measures of directed-attention within 14 days of injury.

Measures

Participants were assessed through specific tests of directed-attention. This study used the Stroop task and the backwards digit span test to measure directed-attention.

Stroop Task. The Stroop task was used to measure DA (Stroop, 1935; Spieler, Balota, & Faust, 1996). The Stroop task requires an individual to read a list of colors printed in incongruent ink color (the word "red" printed in blue ink). The individual is asked to identify the color of the word rather than the word itself. This task presents two stimuli and the individual is required to inhibit the habitual response (reading the printed word), and respond to the other stimulus (the color of the word). The idea is that most people are proficient readers and almost automatically read the word with disregard to the color of ink. When asked to read the color of the word rather than the word itself it takes approximately 74% more time (Stroop, 1935). This phenomenon is known as the Stroop Effect.

The Stroop task is a well-known measure of attentional capacity. It requires the use of DA to voluntarily block out irrelevant and distracting stimuli (the words) and respond to the relevant stimuli (the ink color). This task is especially trying for individuals with a limited capacity for DA as they become less able to inhibit their initial inclination to read the word. Individuals with impaired DA will take more time to respond correctly, increasing the overall completion time and will make more errors during the task (Spieler, Balota, & Faust, 1996). The Stroop task has been used to measured DA after exposure to restorative environments in those with ADHD (Taylor & Kuo, 2009).

This study used The Victoria Stroop task (VST). VST, a shortened version of the original Stroop task, was performed using The Psychology Experiment Building Language (PEBL), a free open source software system (Mueller & Piper, 2014). The PEBL measures correct and incorrect responses, and overall task time on the Stroop task. The PEBL computerized version of the VST is an appropriate alternative to the paper version (Piper et al., 2015; Troyer, Leach, & Strauss, 2006). Research supports the use of the VST in populations with impaired cognitive function as it will not fatigue the participants as much and will reduce practice effects (Bayard et al., 2011; Troyer, Leach, & Strauss, 2006).

The VST is a popular test in studies using clinical populations due to its short administration time. Although the VST has not been examined specifically among individuals with concussion, several studies have demonstrated the reliability and validity of this test for measuring inhibition and cognitive impairment. Moraes, Rossini, & Reimão (2012) found the VST to be sensitive to attentional deficits in narcoleptic patients compared to controls. This study also found a correlation between VST score and Trail Making Test score. Both tests are a measure of executive functioning and require DA. Additionally, patients with narcolepsy can fall victim to large test batteries or long form tests that cause performance drop-offs making the short version of the Stroop, the VST, an ideal alternative for this and other clinical populations. Another study used the VST to measure cognitive aging and inhibition response in 272 healthy individuals ranging in age from 18-94 (Troyer et al., 2006). Adding support for the use of the VST, this study found inference scores to be highly correlated with age after correcting for baseline slowing. Age and error scores were positively correlated indicating a decrease in response inhibition with age. These results lend support for the use of VST as a valid measure of inhibition and cognitive vitality. In addition, D’Alcante (2012) used the VST to determine neuropsychological predictors of response to treatment in adults with Obsessive Compulsive Disorder. Authors used the VST as a measure of selective attention, mental flexibility, and inhibition control. Participants with more inhibitory control, as measured using the VST, responded better to both treatments, CBT and Fluoextine (D’Alcante et al., 2012).

Backwards digit span. The backwards digit span test was used as an additional measure of DA. The backwards digit span is a well-known measure of working memory and directed-attention capacity (Cowan et al., 2005). Working memory requires the use of DA to maintain focus on specific information while blocking out other stimuli. The test asks an individual to listen to a list of number (communicated orally by the experimenter) and then repeat the numbers in reverse order. There are several trials, with the number of digits increasing every two trials, up to seven digits. This test requires the individual to use working memory to maintain focus on relevant information (the number) long enough to manipulate that information (reverse the number). Backwards digit span is sensitive to working memory deficits and thus directed-attention deficits, as the task is dependent on the ability to hold in mind information and manipulate it to successfully complete the task. Individuals with limited DA will be unable to maintain focus long enough to complete the task successfully, receiving fewer points on the task. This task has been used to measure DA after exposure to restorative environments (Tennessen & Cimprich, 1995; Cowan et al., 2005).

PANAS. Restorative environments have been shown to increase positive affect (Berman et al., 2012). Because mood may be related to cognitive functioning, this study used the Positive and Negative Affect Schedule (PANAS) to assess mood before and after the intervention (Watson, Clark, & Tellegen, 1988). Participants rated mood-related adjectives on a 1-5 scale based on how they felt at the current moment (1= not at all or very slightly, 5=extremely). Irritability and negative affect may influence cognitive performance, also. Including this measure allowed us to explore the relationship between mood and DA during the experimental task.

Procedures

All procedures were approved by Humboldt State University's Institutional Review Board (approval #IRB 16-086). The participants were assessed 1-14 days post-injury and evaluated individually. He/she took a mood assessment (PANAS), followed by two measures of directed-attention, the Stroop task and backwards digit span. The VST and BDS are administered using PEBL software. Individuals were assigned to an intervention group through random assignment. Assessments were coded with participant number and intervention group assignment, then the order of assessments was randomized through shuffling. Participants were assigned an intervention group based on the assessment they received.

The VST is a three-part test. Each part consists of 24 required responses. Part one shows 24 dots in four different colors: green, blue, red, and yellow. The participant is instructed to press the correct key to indicate the color of each dot (1: green, 2: yellow, 3: blue, 4: red). Participants must make a correct response before advancing to the next dot. Part two instructs the participant to name the color of 24 words as quickly as possible. The words "and," "when," "over," and "hard" are presented in green, blue, red, and yellow. The participant must make a correct response before advancing to the next word. Part three instructs the participant to name the colors in which the words are printed as quickly as possible. Again, 24 words appear on the screen. The words "green," "yellow," “red,” and “blue” appear on the screen printed in non-congruent colors. The participant must make a correct response before proceeding to the next word. Results of the test are saved in a PEBL file indicated by the participant code. The participant did not see his/her results.

Following the VST, the participant read instructions on completing the BDS and proceeded with the task. The task was programed to present stimuli audibly. Every participant started with a three-digit sequence. Each participant was given two trials per sequence (two trials at three digits, two trials at four digits, etc.) and if a correct response was given the sequence was increase by one-digit up to a total of nine digits. The test ended when two incorrect responses were given for a sequence.

After the initial assessments, the participants watched a video of restorative environments or nonrestorative environments (6min.) and were reassessed on PANAS, VST, and BDS. Berto (2005) showed 6 min. to be an adequate length of exposure.

Manipulation check. A class of psychology students using the Perceived Restorativeness Scale-11 (PRS) validated the stimuli (see appendix). Berto (2005) used a similar procedure to develop her stimuli. Additionally, photos and videos stimuli have been used in previous research by Berman et al. (2008) and Van den Berg, Koole, van der Wulp (2003). This experiment used nature and urban videos from Youtube. These videos contained images similar to those images used in two experiments by Berman et al. (2008) and Berto et al. (2005). All students watched 3 minutes of a nature video and 3 minutes of an urban video. After watching the videos, participants answered 11 questions regarding how they experienced each video, rating each item on a 10-point scale. A t-test was used to determine the restorative qualities of each video.

The PRS was developed to test the restorativeness of environments (Hartig, 1996). The original version of the PRS was shortened from 26 items to 11 items and has been used in both English and Italian (Pasini, Berto, Brondino, Hall, & Ortner, 2014). This scale has been validated in several different countries. After cognitive interviews with participants (*N* = 330) from Australia, Canada, and Italy to promote question clarity, the PRS-11 was developed using items from the original version: 3 items measuring *fascination*, 3 items measuring *being away,* 3 items measuring *coherence,* 2 items measuring *scope* (Pasini, Berto, Brondino, Hall, & Ortner, 2014). Two items (1 *scope* and 1 *coherence*) were created for the shortened version. Items tapping multiple domains and those that had low factor loading were eliminated. The 'compatibility' factor was not included in the PRS-11 due to its subjective value and loose interpretation, and two items measuring "extent," "scope" and "coherence", were added to the PRS-11. This four-factor model (fascination, being-away, scope, and coherence) produced higher factor loading and better-fit indexes than when extent and compatibility were included as single factors (CFI = .95, SRMR = .04).

Statistical Analysis

A repeated-measures analysis of variance (ANOVA) was used to determine the effect of video (nature, city) and time (pre, post) on backwards digit span scores, errors on VST, time on VST, positive affect scores, and negative affect scores. T-tests were used to explore the differences in symptom severity and scores of nature connectedness between city and nature groups.

Results

Participant Characteristics

A total of 10 participants were recruited for this study, three males and seven females, ages 18-30. The sample of 10 included 9 HSU students, 3 of which were student-athletes, and 1 community member. Participants were less than two weeks post-injury and were experiencing symptoms at the time of testing.

Manipulation check results. Fifty-eight participants evaluated the restorative and non-restorative videos using the PRS-11. Berto et al. (2005) used a cut-off method where any photo with an average rating above 6.5 was considered restorative and any photo with an average rating below 3 was considered nonrestorative. However, she did not provide validation of this cutoff method, a limitation of this approach. This study used a t-test to compare the restorative qualities of each video.

A t-test was conducted to compare the level of fascination, being-away, compatibility, and scope in the nature and city videos. Fascination scores for the nature video (M = 8.96, SD = 1.70) were higher than the city video (M = 7.13, SD = 2.77). There was a significant difference in the scores for fascination in the nature and city conditions; $t(275) = 7.36$, $p < .001$, 95% CI around the difference between means [1.34, 2.36], d = 0.802. Being-away scores for the nature video (M = 8.14, SD = 2.36) were higher than the city video (M = 2.85, SD = 3.31). There was a significant difference in the scores for being-away in the nature and city conditions; $t(299) = 17.02$, $p < .001$, 95% CI around the difference between means [4.68, 5.90], d = 1.85. Coherence scores for the nature video

(*M* = 5.5, *SD* = 2.96) were the similar to the city video (*M* = 5.5, *SD* = 3.26). There was no significant difference in the scores for coherence in the nature and city conditions; *t*(333) = -0.014, *p* = .989, 95% CI around the difference between means [-0.07, 0.66], *d* = 0.001. Scope scores for the nature video (*M* = 8.66, *SD* = 2.36) were higher than those in the city video (*M* = 5.89, *SD* = 3.30). There was a significant difference in the scores for scope in the nature and city conditions; *t*(200) = 7.25, *p* <.001, 95% CI around the difference between means [2.01, 3.51], *d* = 0.966.

While the scores of the city videos were higher than the scores used by Berto et al. (2005), the scores of the nature video were much higher also. The scores on fascination, being-away, and scope in the nature video were significantly higher than the city video, suggesting that the nature video was perceived as more restorative by students than the urban video. Coherence was the only category to produce nonsignificant results. This is hypothesized to be the result of personal preference for certain environments among HSU students.

Participants characteristics. See Table 1 for descriptive statistics on participant characteristics. Baseline connectedness to environment scores did not differ between those in the city group and those in the nature group, *t*(8) = 0.991, *p* = .352, *d* = 0.625. Baseline symptom scores did not differ between those in the city group and those in the nature group, *t*(8) = 0.912, *p* = .388, *d* = 0.577.

Hypothesis 1. See Table 2 for ANOVA analyses. Data meets homogeneity of variance assumption. Time taken, in seconds, to complete Stroop task did not differ

Table 1: Participant Characteristics

Characteristic	Nature (*N* = 5)	City (*N* = 5)	Total (*N* = 10)
Gender			
Male	1	2	3
Female	4	3	7
Affiliation			
Student	3	3	6
Student-athlete	1	2	3
Community	1	0	1
Age	22.4 (3.36)	22.8 (2.39)	22.6 (2.76)
Days post injury	5 (4.53)	5.4 (2.51)	5.2 (3.46)
Symptoms score	43.0 (22.0)	54.8 (18.7)	48.9 (20.3)
Connectedness to environment score	6.60 (1.08)	7.22 (0.891)	6.91 (0.990)

Table 2: Results of repeated measures ANOVA examining the effect of experimental group (nature, city) and time (pre, post) on Stroop task time, Stroop errors, backwards digit span, PANAS positive affect, and PANAS negative affect scores.

	F	*df*	*p*	ηG^2
1. Stroop task time				
Intervention main effect	0.09	1, 8	.768	.010
Time main effect	0.21	1, 8	.662	.003
Time*Intervention	0.27	1, 8	.619	.004
2. Stroop errors				
Intervention main effect	0.18	1, 8	.684	.021
Time main effect	0.00	1, 8	1.00	.000
Time*Intervention	1.23	1, 8	.299	.005
3. Backwards digit span				
Intervention main effect	0.02	1, 8	.890	.002
Time main effect	14.4	1, 8	.005	.080
Time*Intervention	1.60	1, 8	.242	.010
4. PANAS positive				
Intervention main effect	1.97	1, 8	.198	.091
Time main effect	0.01	1, 8	.914	.000
Time*Intervention	5.44	1, 8	.048	.027
5. PANAS negative				
Intervention main effect	0.08	1, 8	.783	.010
Time main effect	3.56	1, 8	.090	.021
Time*Intervention	0.462	1, 8	.516	.003

significantly between the nature group (*M* = 43.5, *SD* = 16.5) and the City group (*M* = 40.8, *SD* = 11.7). Pre intervention (*M* = 42.9, *SD* = 14.5) and post-intervention (*M* = 41.4, *SD* = 14.2) times, in seconds, on Stroop task did not differ significantly. There was no interaction between intervention group and time.

Hypothesis 2. See Table 2 for ANOVA analyses. Data meets homogeneity of variance assumption. There was no significant difference on number of errors made during the Stroop task between the nature group (*M*= 2, *SD* = 3.71) and the city group (*M* = 1.2, *SD* = 1.69. There was no main effect of time on the number of errors made between pre intervention (*M* = 1.6, *SD* = 2.80) and post-intervention (*M* = 1.6, *SD* = 3.03). There was no interaction effect for time and intervention group.

Hypothesis 3. See Table 2 for ANOVA analyses. Data meets homogeneity of variance assumption. Backwards digit span scores did not differ significantly between the nature group (*M* = 5.4, *SD* = 2.76) and the city group (*M* = 5.6, *SD* = 1.58). There was a main effect of time on backwards digit span scores from pre intervention (*M* = 4.9, *SD* = 2.42) to post-intervention (*M* = 6.1, *SD* = 1.85). There was no interaction effect between time and intervention.

Positive PANAS results. See Table 2 for ANOVA analyses. Data meets homogeneity of variance assumption. There was no main effect for intervention group, nature (*M* = 22.7, *SD* = 7.75), or city (*M* = 16.6, *SD* = 5.48) on positive PANAS scores. There was no main effect for time on positive PANAS scores, pre intervention (*M* = 19.6, *SD* = 7.25) to post-intervention (*M* = 19.7, *SD* = 7.63). There was an interaction effect for time and intervention group.

Exploring the interaction using a paired t-test indicated a significant decrease in positive attributes for those in the city group pre-intervention (*M* = 17.6, *SD* = 5.55) to post-intervention (*M* = 15.6, *SD* = 5.86), *t*(4) = 2.83, *p* = .047, *d* = 0.351. Those in the nature group experienced an increase in positive attributes pre-intervention (*M* = 21.6, *SD* = 8.79) to post-intervention (*M* = 23.8, *SD* = 7.40) although this change was not reliable, *t*(4) = -1.33, *p* = .255, *d* = 0.271.

Negative PANAS results. See Table 2 for ANOVA analyses. Data meets homogeneity of variance assumption. There was no main effect for time, pre-intervention (*M* = 21.8, *SD* = 8.74) to post-intervention (*M* = 19.3, *SD* = 9.56) on negative PANAS scores. There was also no main effect for intervention group. Neither the nature group (*M* = 19.7, *SD* = 8.08) nor city group (*M* = 21.4, *SD* = 10.21) experienced reliable changes in negative affect scores. Additionally, there was no interaction effect between time and intervention group.

Discussion

Using restorative environments to mitigate attentional deficits associated with concussion was a novel idea and this study provides the first available data on this type of intervention for this population of 18-30 year olds with recent concussion. This study did not find the nature intervention to be more effective than the city intervention on mitigating post-injury DAF, as measured by backwards digit span and Stroop task. Both city and nature groups experienced significant improvement on backwards digit span scores post-intervention. The city group experienced a significant decrease in positive affect scores while the nature group did not experience a meaningful change. Neither group experienced significance changes in negative affect scores. No changes over time were noted on the Stroop test.

There was a main effect for time on backwards digit span, such that scores improved pre- to post-intervention. It was not hypothesized that both groups would see improvement although practice effects may explain this increase in backwards digit span scores. While care was taken to minimize the effects of practice by administering an alternative version of backwards digit span on re-test, research shows evidence of practice effects on serial administration (Sánchez-Benavides et al., 2016). Research also shows cognitively impaired populations are less susceptible to practice effects (Heaton et al., 2001) making it unclear if practice effects played a role in these results. Additionally, this population did not demonstrate a reliable increase on the Stroop task, a test also known to be affected by practice (Davison, Zacks, Williams, 2003). This population's susceptibility to practice effects warrants further study.

Main effects are often times qualified by an interaction effect. However, with a limited sample size this study may not have had the power to detect such an interaction. Using a paired *t*-test to explore the backwards digit span main effect, results indicate a reliable pre- to post increase in backwards digit span scores for the nature group, $t(4) = -3.14$, $p = .035$, 95% CI [0.184, 3.02], $d = .575$, but this reliable change was not seen in the city group, $t(4) = -2.14$, $p = .099$, 95% CI [-1.84, 0.239], $d = .496$. The group by time interaction was not significant. It is possible, with a larger sample size, this main effect will be qualified by an interaction representing an increase in DA scores post-intervention for the nature group and no such increase by the city group.

Interestingly, the city group experienced a significant decrease in positive affect scores, but did not experience an increase in negative affect scores post-intervention. These results are in contrast with previous research that shows an increase in negative affect after city exposure (McMahan & Estes, 2015), as opposed to a decrease in positive affect. Also contradicting previous research showing a decrease in negative affect scores after exposure to nature (Gamble, Howard & Howard, 2014), the nature group in the current study saw no significant change in either affect scores. It is possible that the intervention was not long enough in duration to overcome DAF or increase positive affect. Emfield and Neider (2014), upon finding decreases in positive affect scores after both nature and city exposure, speculated that the level of fatigue experienced by participants during the experiment was greater than the fatigue which could be compensated for by the environment. Participants in this experiment viewed environments for 7-10 minutes while the entire experiment lasted approximately 90 minutes. These results emphasize the importance of establishing adequate intervention exposure time.

The decrease in positive affect observed in the current study was not associated with a corresponding change in DA. While a small sample size is a limitation of this study and future research should investigate mood effects associated with this intervention, it may be that this population responds to natural environments more in line with stress reduction theory (SRT). SRT has a similar basis to ART, but posits that natural environments promote a decrease in physiological and emotional stress (Ulrich, 1984). While SRT does not touch on the effects of non-natural environments, it stands to reason that non-natural environments would have the opposite or null effect, thus explaining the decrease in positive affect experienced by the city group. Also, it may be possible that this population is more primed for negative affect (agitated, irritated, nervous) than positive affect (attentive, enthusiastic, proud) making positive affect characteristics less stable.

The hypothesized results were not substantiated; however, there were advantages to this study design that may be useful in future research. Recruiting a more narrowly defined clinical sample and standardizing the intervention helped to promote a clearer understanding of intervention effects post-injury. Often, studies on TBIs involve participants of varying ages, injury severity, and duration of time post-injury (Chin, Keyser, Dsurney, & Chan, 2015, Kjeldgaard, Forchhammer, Teasdale, & Jensen, 2014).

This study restricted the age gap to twelve years, injuries did not require hospitalization, baseline symptom scores were similar, and the post-injury time frame for intervention was maintained at no more than 14 days. Additionally, the participants in each group did not differ significantly on preference towards the natural environment, removing the potential confound of pre-existing preference for natural environments. This type of strict selection criteria allows for more informed examination of intervention effectiveness and adds to the research on concussion rehabilitation in the acute phase post-injury.

Limitations

Sample size was a limitation of this study leading to insufficient statistical power. Recruitment proved more difficult than expected, requiring the expansion of inclusion criteria. Additionally, intercollegiate athletes were involved in another study and were unavailable for participation, reducing the available population to club sport athletes and non-athletes only. Originally, this study was to include athletes, ages 18-25, within 72 hours post-injury. These inclusion criteria proved too restrictive and were expanded to include all individuals regardless of sport participation, ages 18-30, up to 14 days post-injury. Expanding the criteria aided in recruitment. Underreporting of concussions is common in the literature and may have played a role in recruitment difficulties. A within-subjects experimental design would have aided in the strength of this study; however, attrition was a major concern and the chance of spontaneous recovery made this design impractical. Additionally, some individuals did not report their concussion until symptoms persisted past two weeks, making them ineligible for participation in this study. It was important to maintain strict inclusion criteria not exceeding two weeks as this was the intervention period of interest. While a larger intervention period would have facilitated recruitment, it would also have created a mixed sample of those requiring support for persistent symptoms and those who experienced short-term symptoms and a spontaneous recovery.

Another challenge was determining the duration of intervention exposure. This study used a time frame shown to be effective on a non-clinical population (Berto, 2005). It is not clear if the six minutes of exposure to the nature video was long enough to produce a therapeutic response in this population. This population may require longer exposure to restorative environments to experience attentional benefits. Extending the time of intervention beyond 6 minutes was a concern when designing the experiment as additional exposure to a computer screen may have negatively impacted visual symptoms.

Another limitation that may have influenced the results was that most participants underwent Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) immediately before the experiment. ImPACT is a 25-minute computerized neurocognitive test used to evaluate cognitive functioning for those with concussion. The test includes a symptoms assessment and multiple tests of cognition including attention span, non-verbal problem solving, reaction time, and working memory. The increased exposure to a computer screen and the additional tax put on the attentional systems after ImPACT may have created a mental state that required a longer exposure to the intervention to see a benefit. It is not clear if this influenced the results, although it is worth noting and is something to account for in future research.

Recommendations and Directions for Future Research

This study did not mirror results seen in previous research. Unlike Berman et al. (2008; 2012) and Berto (2005) this study did not find improvement in DA after nature exposure. Intervention times in previous research ranged from 6 minutes to 55 minutes making the appropriate exposure time for this population unclear. Additionally, sample sizes in previous research were larger and many previous studies testing ART utilized a within subjects repeated measures design. These designs can increase power to detect an effect in studies with small sample sizes. The evidence of nature-based restorative experiences is plentiful on non-clinical populations and warrants continued research into the utilization of nature interventions for clinical populations.

A recommendation for future research would be to repeat this study with a larger sample size. The current study may not have been sufficiently powered to detect intervention effects. For example, the interaction effect for time X intervention on backwards digit span was non-significant in this study, but with a larger sample we may find a significant interaction effect on this outcome. Exploring this possibility is a topic for future research.

The inclusion of pre-injury data on measures of DA would allow researchers to determine the level of DA impairment prior to participation in the experiment. This study did not have pre-injury baseline data on participants, and it is possible that some participants did not experience directed-attention impairment. The literature shows that 58.3% of athletes with concussion experience DAF (Wasserman et al., 2015). Without pre-injury baseline data, it is difficult to determine how many of the participants were experiencing impaired DA at the time of testing. It is likely this sample included individuals who were not experiencing directed-attention impairment. Future research should include pre-injury DA scores. Additionally, including only those experiencing the symptom of interest would allow for the possibility of a control group including non-injured participants where DAF is induced.

Additionally, an interesting measure for future research may be to explore the duration of attentional improvement. While this study did not measure the impact of this intervention on long-term recovery, a notable question for future research is the effect of restorative environments on the occurrence of persistent symptoms related to directed-attention in concussion. Moving forward, research should also determine the adequate exposure time for this population as well as the difference between video exposure and exposure in an environment outdoors. Non-clinical individuals exposed to real environments, as opposed to simulated environments, show greater improvement in mood post-intervention (McMahan & Estes, 2014). Individuals with concussion may respond differently to outdoor exposure. Additionally, outdoor exposure oftentimes involves physical movement which may not be appropriate in the early stages of the recovery process, but may prove to be superior in later stages of recovery.

Lastly, it was not expected that the city group would experience a decrease in positive affect and this result deserves further study. Future research should measure the plasticity of positive and negative affect associated with concussion symptoms. Berman et al. (2012) showed no change in positive or negative affect scores for individuals with Major Depressive Disorder after nature and city exposure, and merely measured these constructs to be certain the changes in DA resulted from the environment and not emotional states. Affect states may be mediating factors in concussive symptoms, although additional research is required.

The main effect for backwards digit span suggests that attentional deficits brought about by concussions may be responsive to intervention during the first fourteen days post-injury. Results did not show a meaningful difference in DA between the nature and city groups post-intervention; both groups experienced improved backwards digit span scores. Future research should explore the malleability of DA after concussion to determine the utility of interventions aimed at attention restoration.

This paper offers recommendations for future interventions and suggestions for reducing limitations. These results shed light on the potential for interventions during the first two weeks post-concussion and provide the first experimental data on this type of intervention for those with concussion. This intervention is promising in that it is cost-effective, does not discriminate between social economic status, and has no known side-effects, making it practical to research as well as implement in clinical settings. Finally, these results provide the groundwork for future interventions aiming to support and aid the individual in recovery from concussion symptoms. More research is needed to determine the efficacy of ART on individuals with concussion. Providing individuals with a concussion a means of mitigating symptoms would prove beneficial to the individual as well as the research community.

References

Arciniegas, D. B., Anderson, C. A., Topkoff, J., & McAllister, T. W. (2005). Mild traumatic brain injury: a neuropsychiatric approach to diagnosis, evaluation, and treatment. *Neuropsychiatric Disease and Treatment*, *1*, 311-327. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2424119/

Bayard, S., Erkes, J., Moroni, C., & Collège des Psychologues Cliniciens spécialisés en Neuropsychologie du Languedoc Roussillon, (2011). Victoria Stroop Test: normative data in a sample group of older people and the study of their clinical applications in the assessment of inhibition in Alzheimer's disease. *Archives of Clinical Neuropsychology*, *26*, 653-661. doi: 10.1093/arclin/acr053

Berman, M., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, *19*, 1207-1212. https://doi.org/10.1111/j.1467-9280.2008.02225.x

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., ... & Jonides, (2012). Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders*, *140*, 300-305. https://doi.org/10.1016/j.jad.2012.03.012

Berman, M. G., Nee, D. E., Casement, M., Kim, H. S., Deldin, P., Kross, E., … Jonides, J. (2011). Neural and behavioral effects of interference resolution in depression and rumination. *Cognitive, Affective & Behavioral Neuroscience*, *11*, 85–96. doi: 10.3758/s13415-010-0014-x

Berto, Rita. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology*, *25*, 249-259. https://doi.org/10.1016/j.jenvp.2005.07.001

Chamelian, L., & Feinstein, A. (2004). Outcome after mild to moderate traumatic brain injury: the role of dizziness. *Archives of Physical Medicine and Rehabilitation*, *85*, 1662-1666. https://doi.org/10.1016/j.apmr.2004.02.012

Chin, L. M., Keyser, R. E., Dsurney, J., & Chan, L. (2015). Improved cognitive performance following aerobic exercise training in people with traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *96*, 754-759. https://doi.org/10.1016/j.apmr.2014.11.009

Cimprich, B., & Ronis, D. L. (2003). An environmental intervention to restore attention in women with newly diagnosed breast cancer. *Cancer Nursing*, *26*, 284-292. doi: 10.1097/00002820-200308000-00005

Ciurli, P., Formisano, R., Bivona, U., Cantagallo, A., & Angelelli, P. (2011). Neuropsychiatric disorders in persons with severe traumatic brain injury: prevalence, phenomenology, and relationship with demographic, clinical, and functional features. *The Journal of Head Trauma Rehabilitation*, *26*, 116-126. doi: 10.1097/HTR.0b013e3181dedd0e

Cowan, N., Elliott, E. M., Saults, J. S., Morey, C. C., Mattox, S., Hismjatullina, A., & Conway, A. R. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology*, *51*, 42-100. doi: 10.1016/j.cogpsych.2004.12.001

D'Alcante, C. C., Diniz, J. B., Fossaluza, V., Batistuzzo, M. C., Lopes, A. C., Shavitt, R. G., ... & Hoexter, M. Q. (2012). Neuropsychological predictors of response to randomized treatment in obsessive–compulsive disorder. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 39*, 310-317. doi: 10.1016/j.pnpbp.2012.07.002

Davidson D.J., Zacks R.T., & Williams C.C. (2003). Stroop Interference, Practice, and Aging. *Neuropsychology, Development, and Cognition Section B, Aging, Neuropsychology and Cognition*, *10*, 85-98. doi:10.1076/anec.10.2.85.14463

Dockree, P. M., Bellgrove, M. A., O'Keeffe, F. M., Moloney, P., Aimola, L., Carton, S., & Robertson, I. H. (2005). Sustained attention in traumatic brain injury (tbi) and healthy controls: enhanced sensitivity with dual-task load. *Experimental Brain Research*, *168*, 218-229. doi: 10.1007/s00221-005-0079-x

Emfield, A. G., & Neider, M. B. (2014). Evaluating visual and auditory contributions to the cognitive restoration effect. *Frontiers in Psychology, 5*, 1-11. doi: 10.3389/fpsyg.2014.00548

Frieden, T., Houry, D., & Baldwin, G. (2014). Report to Congress on Traumatic Brain Injury in the United States: Epidemiology and Rehabilitation. *National Center for Injury Prevention and Control; Division of Unintentional Injury Prevention.* Retrieved from https://www.cdc.gov/traumaticbraininjury/pdf/tbi_report_to_congress_epi_and_rehab-a.pdf

Gaetz, M., Goodman, D., & Weinberg, H. (2000). Electrophysiological evidence for the cumulative effects of concussion. *Brain Injury*, *14*, 1077-1088. http://dx.doi.org/10.1080/02699050050203577

Gamble, K. R., Howard, J. H., & Howard, D. V. (2014). Not just scenery: Viewing nature pictures improves executive attention in older adults. *Experimental Aging Research*, *40*, 513–530. http://doi.org/10.1080/0361073X.2014.956618

Gardner, A., Kay-Lambkin, F., Stanwell, P., Donnelly, J., Williams, W. H., Hiles, A., ... & Jones, D. K. (2012). A systematic review of diffusion tensor imaging findings in sports-related concussion. *Journal of Neurotrauma*, *29,* 2521-2538. doi: 10.1089/neu.2012.2628

Giza, C. C., & Hovda, D. A. (2001). The neurometabolic cascade of concussion. *Journal of Athletic Training*, *36*, 228. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC155411/?report=classic

Giza, C. C., & Hovda, D. A. (2014). The new neurometabolic cascade of concussion. *Neurosurgery*, *75*, 24-33. doi: 10.1227/NEU.0000000000000505

Guskiewicz, K. M., Weaver, N. L., Padua, D. A., & Garrett, W. E. (2000). Epidemiology of concussion in collegiate and high school football players. *The American Journal of Sports Medicine*, *28*, 643-650. doi: 10.1177/03635465000280050401

Harmon, K. G., Drezner, J. A., Gammons, M., Guskiewicz, K. M., Halstead, M., Herring, S. A., ... & Roberts, W. O. (2013). American Medical Society for Sports Medicine position statement: concussion in sport. *British Journal of Sports Medicine*, *47*, 15-26. doi:10.1136/bjsports-2012-091941

Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative effects of natural environment experiences. *Environment and Behavior*, *23*, 3-26. https://doi.org/10.1177/0013916591231001

Heaton, R. K., Temkin, N., Dikmen, S., Avitable, N., Taylor, M. J., Marcotte, T. D., & Grant, I. (2001). Detecting change: A comparison of three neuropsychological methods, using normal and clinical samples. *Archives of Clinical Neuropsychology*, *16*, 75-91. https://doi.org/10.1016/S0887-6177(99)00062-1

Hunt, T., & Asplund, C. (2010). Concussion assessment and management. *Clinics in Sports Medicine*, *29,* 5-17. https://doi.org/10.1016/j.csm.2009.09.002

Impact (2015). The imPACT test. Retrieved from https://www.impacttest.com/about/?The-ImPACT-Test-4.

Iverson, G. L., Gaetz, M., Lovell, M. R., & Collins, M. W. (2004). Cumulative effects of concussion in amateur athletes. *Brain Injury*, *18,* 433-443. http://dx.doi.org/10.1080/02699050310001617352

Kaelin, D. L., Cifu, D. X., & Matthies, B. (1996). Methylphenidate effect on attention deficit in the acutely brain-injured adult. *Archives of Physical Medicine and Rehabilitation*, *77,* 6-9. https://doi.org/10.1016/S0003-9993(96)90211-7

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*, 169-182. https://doi.org/10.1016/0272-4944(95)90001-2

Kaplan, S. (2001). Meditation, restoration, and the management of mental fatigue. *Environment and Behavior*, *33*, 480-506. https://doi.org/10.1177/00139160121973106

Kaplan, S., & Talbot, J. F. (1983). Psychological benefits of a wilderness experience. In *Behavior and the Natural Environment*, *6*, 163-203. doi: 10.1007/978-1-4613-3539-9_6

Kaplan, S., Talbot, J.F., & Kaplan, R., (1988). Coping with daily hassles: The impact of nearby nature on the work environment. Project Report. *USDA Forest Service, North Central Forest Experiment Station, Urban Forestry Unit Cooperative Agreement* 23-85.

Kaufman, Y., Tzischinsky, O., Epstein, R., Etzioni, A., Lavie, P., & Pillar, G. (2001). Long-term sleep disturbances in adolescents after minor head injury. *Pediatric Neurology*, *24*, 129-134. https://doi.org/10.1016/S0887-8994(00)00254-X

Kjeldgaard, D., Forchhammer, H. B., Teasdale, T. W., & Jensen, R. H. (2014). Cognitive behavioural treatment for the chronic post-traumatic headache patient: a randomized controlled trial. *The Journal of Headache and Pain*, *15*, 81. http://doi.org/10.1186/1129-2377-15-81

Kokkinos, P., Holland, J., Pittaras, A. , Narayan, P. , Dotson, C., & Papademetriou, V. (1995). Cardiorespiratory fitness and coronary heart disease risk factor association in women. *Journal of the American College of Cardiology*, *26*, 358-364. https://doi.org/10.1016/0735-1097(95)80007-4

Laker, S. R., (2015). Sports-related concussion. *Current Pain and Headache Reports*, 19, 1-8. doi: 10.1007/s11916-015-0510-3

Leddy, J. J., Sandhu, H., Sodhi, V., Baker, J. G., & Willer, B. (2012). Rehabilitation of concussion and post-concussion syndrome. *Sports Health*, *4*, 147-154. https://doi.org/10.1177/1941738111433673

Lim, J., Wu, W., Wang, J., Detre, J., Dinges, D., & Rao, H., (2010). Imaging brain fatigue from sustained mental workload: An ASL perfusion study of the time-on-task effect. *NeuroImage*, *49*, 3426-3435. doi: 10.1016/j.neuroimage.2009.11.020

Malek, A., & Amiri, S. (2013). The standardization of Victoria Stroop color-word test among Iranian bilingual adolescents. *Archives of Iranian Medicine*, *16*, 380. doi: 013167/aim.004

McCrea, M., Guskiewicz, K., Randolph, C., Barr, W. B., Hammeke, T. A., Marshall, S. W., ... & Kelly, J. P. (2013). Incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes. *Journal of the International Neuropsychological Society*, *19*, 22-33. doi: 10.1017/S1355617712000872

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, R. C., Dvorák, J., Echemendia, R. J., ... & Turner, M. (2013). Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport. *Journal of Athletic Training*, *48*, 554-575. doi: 10.1136/bjsports-2013-092313

McCrory, P., Meeuwisse, W., Dvorak, J., Aubry, M., Bailes, J., Broglio, S., ... & Davis, G. A. (2017). Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *British Journal of Sports Medicine*, *0*, 1-10. doi: 10.1136/bjsports-2017-097699

McGrath, N. (2010). Supporting the Student-Athlete's Return to the Classroom After a Sport-Related Concussion. *Journal of Athletic Training*, *45*, 492–498. doi: 10.4085/1062-6050-45.5.492

McMahan, E., & Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. *The Journal of Positive Psychology*, *10*, 507-519. http://dx.doi.org/10.1080/17439760.2014.994224

Meaney, D. F., & Smith, D. H. (2011). Biomechanics of Concussion. *Clinics in Sports Medicine*, *30*, 19–vii. http://doi.org/10.1016/j.csm.2010.08.009

Morales, M., Rossini, S., & Reimão, R. (2012). Executive attention and working memory in narcoleptic outpatients. *Arquivos de Neuro-Psiquiatria*, *70*, 335-340. http://dx.doi.org/10.1590/S0004-282X2012005000007

Mueller, S. C. (2011). The Influence of Emotion on Cognitive Control: Relevance for Development and Adolescent Psychopathology. *Frontiers in Psychology*, *2*, 327. doi: 10.3389/fpsyg.2011.00327

Mueller, S. T., & Piper, B. J. (2014). The psychology experiment building language (pebl) and pebl test battery. *Journal of Neuroscience Methods*, *222*, 250-259. doi: 10.1016/j.jneumeth.2013.10.024

Mychasiuk, R., Hehar, H., & Esser, M. J. (2015). A mild traumatic brain injury (mTBI) induces secondary attention-deficit hyperactivity disorder-like symptomology in young rats. *Behavioural Brain Research, 286*, 285-292. doi: 10.1016/j.bbr.2015.03.010

Pals, R., Steg, L., Siero, F. W., & Van der Zee, K. I. (2009). Development of the PRCQ: A measure of perceived restorative characteristics of zoo attractions. *Journal of Environmental Psychology*, *29,* 441-449. https://doi.org/10.1016/j.jenvp.2009.08.005

Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine*, *15,* 18-26. doi: 10.1007/s12199-009-0086-9

Pasini, M., Berto, R., Brondino, M., Hall, R., & Ortner, C. (2014). How to measure the restorative quality of environments: The PRS-11. *Procedia-Social and Behavioral Sciences, 159*, 293-297. https://doi.org/10.1016/j.sbspro.2014.12.375

Piper, B. J., Mueller, S. T., Geerken, A. R., Dixon, K. L., Kroliczak, G., Olsen, R. H., & Miller, J. K. (2015). Reliability and validity of neurobehavioral function on the Psychology Experimental Building Language test battery in young adults. *PeerJ*, *3*, e1460. doi: 10.7717/peerj.1460

Plenger, P. M., Dixon, C. E., Castillo, R. M., Frankowski, R. F., Yablon, S. A., & Levin, H. S. (1996). Subacute methylphenidate treatment for moderate to moderately severe traumatic brain injury: a preliminary double-blind placebo-controlled study. *Archives of Physical Medicine and Rehabilitation*, *77*, 536-540. https://doi.org/10.1016/S0003-9993(96)90291-9

Power, C., Pinto Pereira, S., Law, C., & Ki, M. (2014). Obesity and risk factors for cardiovascular disease and type 2 diabetes: Investigating the role of physical activity and sedentary behaviour in mid-life in the 1958 British cohort. *Atherosclerosis*, *233*, 363-369. doi: 10.1016/j.atherosclerosis.2014.01.032

Rao, V., Spiro, J., Vaishnavi, S., Rastogi, P., Mielke, M., Noll, K., & ... Makley, M. (2008). Prevalence and types of sleep disturbances acutely after traumatic brain injury. *Brain Injury*, *22*, 381-386. doi:10.1080/02699050801935260

Reith, F. C., Van den Brande, R., Synnot, A., Gruen, R., & Maas, A. I. (2016). The reliability of the Glasgow Coma Scale: a systematic review. *Intensive Care Medicine*, *42*, 3-15. doi: 10.1007/s00134-015-4124-3

Robertson, I.H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). ‘Oops!’: performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*, 747-758. https://doi.org/10.1016/S0028-3932(97)00015-8

Sánchez-Benavides, G., Gispert, J. D., Fauria, K., Molinuevo, J. L., & Gramunt, N. (2016). Modeling practice effects in healthy middle-aged participants of the Alzheimer and Families parent cohort. *Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring*, *4*, 149-158. https://doi.org/10.1016/j.dadm.2016.07.001

Schneider, K. J., Iverson, G. L., Emery, C. A., McCrory, P., Herring, S. A., & Meeuwisse, W. H. (2013). The effects of rest and treatment following sport-related concussion: a systematic review of the literature. *British Journal of Sports Medicine*, *47*, 304-307. doi: 10.1136/bjsports-2013-092190

Schreiber, S., Lin, R., Haim, L., Baratz-Goldstien, R., Rubovitch, V., Vaisman, N., & Pick, C. G. (2014). Enriched environment improves the cognitive effects from traumatic brain injury in mice. *Behavioural Brain Research*, *271*, 59-64. doi: 10.1016/j.bbr.2014.05.060

Seel, R. T., Kreutzer, J. S., Rosenthal, M., Hammond, F. M., Corrigan, J. D., & Black, K. (2003). Depression after traumatic brain injury: a National Institute on Disability and Rehabilitation Research Model Systems multicenter investigation. *Archives of Physical Medicine and Rehabilitation*, *84*, 177-184. https://doi.org/10.1053/apmr.2003.50106

Snell, D. L., Surgenor, L. J., Hay-Smith, E. J. C., & Siegert, R. J. (2009). A systematic review of psychological treatments for mild traumatic brain injury: an update on the evidence. *Journal of Clinical and Experimental Neuropsychology*, *31*, 20-38. doi: 10.1080/13803390801978849

Song, C., Joung, D., Ikei, H., Igarashi, M., Aga, M., Park, B. J., ... & Miyazaki, Y. (2013). Physiological and psychological effects of walking on young males in urban parks in winter. *Journal of Physiological Anthropology*, *32*, 1. doi: 10.1186/1880-6805-32-18

Spieler, D. H., Balota, D. A., & Faust, M. E. (1996). Stroop performance in healthy younger and older adults and in individuals with dementia of the Alzheimer's type. *Journal of Experimental Psychology: Human Perception and Performance*, *22*, 461-479. doi: 10.1037/0096-1523.22.2.461

Stark, M. (2003). Restoring attention in pregnancy: The natural environment. *Clinical Nursing Research*, *12*, 246-265. doi: 10.1177/1054773803252995

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643-662. doi: 10.1037/h0054651

Taylor, A. F., & Kuo, F. E. (2009). Children with attention deficits concentrate better after walk in the park. *Journal of Attention Disorders, 12*, 402-409. doi: 10.1177/1087054708323000

Troyer, A. K., Leach, L., & Strauss, E. (2006). Aging and response inhibition: Normative data for the Victoria Stroop Test. *Aging, Neuropsychology, and Cognition*, *13*, 20-35. doi: 10.1080/138255890968187

Tennessen, C. M., & Cimprich, B. (1995). Views to nature: Effects on attention. *Journal of Environmental Psychology*, *15*, 77-85. https://doi.org/10.1016/0272-4944(95)90016-0

Ulrich, R. (1984). View through a window may influence recovery. *Science*, *224*, 224-225. Retrieved from http://www.jstor.org/stable/1692984

U.S. Center for Disease Control and Prevention (2015). Returning to school. Retrieved from http://www.cdc.gov/headsup/basics/return_to_school.html.

Van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration:(How) are they related? *Journal of Environmental Psychology*, *23*, 135-146. doi: 10.1016/S0272-4944(02)00111-1

Wasserman, E., Kerr, Z., Zuckerman, S., & Covassin, T. (2015). Epidemiology of sports-related concussion in national collegiate athletic association athletes from 2009-2010 to 2013-2014: Symptom prevalence, symptom resolution time, and return-to-play time. *The American Journal of Sports Medicine, 44,* 226-233. doi: 10.1177/0363546515610537

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063. http://dx.doi.org/10.1037/0022-3514.54.6.1063

Weber, A. F., Mihalik, J. P., Register-Mihalik, J. K., Mays, S., Prentice, W. E., & Guskiewicz, K. M. (2013). Dehydration and performance on clinical concussion measures in collegiate wrestlers. *Journal of Athletic Training, 48*, 153-160. doi: 10.4085/1062-6050-48.1.07

Yang, C. C., Hua, M. S., Lin, W. C., Tsai, Y. H., & Huang, S. J. (2012). Irritability following traumatic brain injury: divergent manifestations of annoyance and verbal aggression. *Brain Injury*, *26*, 1185-1191. http://dx.doi.org/10.3109/02699052.2012.666374

Zhang, L., Plotkin, R. C., Wang, G., Sandel, M. E., & Lee, S. (2004). Cholinergic augmentation with donepezil enhances recovery in short-term memory and sustained attention after traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *85*, 1050-1055. http://dx.doi.org/10.1016/j.apmr.2003.10.014

Appendix

PRS-11

We are interested in your experience of this place. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, then ask yourself, 'How much does this statement apply to my experience here?'
To indicate your answer, circle one of the numbers on the scale beside it. A sample of the scale with verbal descriptions for the values is given below.

Verbal descriptions for the scale values are as follows: 1 = Very little; 2 = Rather little; 3 = Neither little nor much; 4 = Rather much; 5 = Very much; 6 = Completely.

1	2	3	4	5	6	Places like that are fascinating
1	2	3	4	5	6	In places like this my attention is drawn to many interesting things
1	2	3	4	5	6	In places like this it is hard to be bored
1	2	3	4	5	6	Places like that are a refuge from nuisances
1	2	3	4	5	6	To get away from things that usually demand my attention I like to go to places like this
1	2	3	4	5	6	To stop thinking about the things that I must get done I like to go to places like this

1	2	3	4	5	6	There is a clear order in the physical arrangement of places like this
1	2	3	4	5	6	In places like this it is easy to see how things are organized
1	2	3	4	5	6	In places like this everything seems to have its proper place
1	2	3	4	5	6	That place is large enough to allow exploration in many directions
1	2	3	4	5	6	In places like that there are few boundaries to limit my possibility for moving about