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Mentally restorative areas for students: impacts of nature on psychophysiological state

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Mentally Restorative Areas for Students:

Impacts of Nature on Psychophysiological State

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<u>The Institutional Review Board of the University of Tennessee at Chattanooga (FWA00004149) has approved this research project #18-166.</u>

Table of Contents

Abstract

Situated in the top outdoor ranking city of Chattanooga, the campus of the University of Tennessee at Chattanooga (UTC) includes diverse areas available for student rest and recreation. This study aims to introduce UTC students into the collection of studies on the effects of natural environments on Attention Restoration Theory (ART) by using the Stroop cognitive test and portable electroencephalograph (EEG) headsets. Participants completed the Stroop test after ten-minute mental restoration sessions in environments of varying natural exposure included on campus. Through analysis of variance, location was found to significantly influence performance on Stroop testing and measures of relaxation ($p = 0.030$). Participants performed with highest Stroop success and measured highest relaxation after resting in environments of natural exposure. Student Stroop performance was poorest after resting in the indoor area with no outdoor exposure to natural environments. Measures of heart rate variability (HRV) and Theta Beta ratio (TBR) also showed significant impact on Stroop performance ($p = 0.015$ and $p = 0.009$, respectively). Results support that natural environments hold mentally restorative abilities specific to student cognitive performance. This experiment contributes evidence of the influence of natural environments on cognitive restoration to encourage student visitation to mentally restorative areas and educate health policy and planning.

Keywords: Attention Restoration Theory, EEG, Theta Beta, Heart Rate Variance

Introduction

ATTENTION RESTORATION THEORY

The Attention Restoration Theory (ART), presented by Steven Kaplan over two decades ago, was based upon the 1892 work of William James (Kaplan, 1995). Since then, abundant literature lends support to Kaplan's theory. James described voluntary attention to require effort and avoidance of distractions (Kaplan, 1995). James did not suggest voluntary attention to be exhaustible; however, Kaplan questioned whether voluntary attention could be exhausted by these distractions (Kaplan, 1973). Thus, ART was proposed with the concept of exhaustible, but restorative directed attention (Kaplan et al., 1989).

ART argues attention is primarily voluntary and controlled; focus is influenced by the ability to maintain concentration, distractions are dependent, and effort is manageable (Kaplan, 1995). Attention can be influenced by other outside factors such as mental and physical fatigue, or preoccupation of the mind (Felston, 2009). Furthermore, ART is claimed to be more effective in natural environments due to the presence of bottom-up attention (involuntary). Whereas urban environments mainly require top-down attention, referring to stimuli that are dramatic and demanding, *i.e.* loud noises, action, and busy movement (Berman et al., 2008). So, natural environments are more conducive for direct attention restoration.

For instance, a study using mediational analysis focused on discovering the mechanisms that underlie nature's effect on well-being (Mayer et al., 2008). Variances of administration included real urban environments, real natural environments, simulated urban environments, and simulated natural environments. Exposure to natural environments (real natural resulting in more dramatic results than simulated) produced four outcomes: increased attentional capacity, nature connectedness, ability to reflect on a life problem, and positive well-being (Mayer et al., 2008). This provides evidence that nature has greater restorative effects on attentional capacity (directed attention) than built environments.

Researchers continue to search for the ideal environment to promote ART. Felston's study specifies four subjects that determine the Restorative Ability of a study space (2009). These four factors include: 1) being away, 2) extent, 3) fascination, and 4) compatibility. *Being away* refers to the availability of physical and mental breaks (Felston, 2009). In other words, the attention can be drawn away from work and shift to inward thought or outward inspection. *Extent* refers to the presence of a rich environment with a coherent structure (Felston, 2009). Simply put, the given space includes diverse stimuli and serves almost as a world of its own. Spaces like these are more commonly found outdoors, particularly in places with a colorful natural presence and a flow of human activity. *Fascination* refers to involuntary or effortless attention stimuli. There are two main types of fascination: soft fascination and hard fascination. Soft fascination includes reflective natural environments whereas hard focus includes intense environments such as competitive situations (Felston, 2009). Finally, *compatibility* evaluates the consistency of an individual's goals with their given environment or setting (Felston, 2009). Research like this poses the question: does the individual's motivation depend on the environment? These four characteristics of restorative ability help break down how productive certain environments are in promoting focus and influencing attention. This directly links to ART, supporting that environment and outside stimuli does, in fact, have an impact on an individual's ability to focus.

BIOPHILIA

Other studies seek to quantify the effects of ART in natural environments by means of the Biophilia Hypothesis. Biophilia emphasizes the innate psychological dependence of human mental wellbeing on nature (Grinde et al., 2009; Kellert, 1995). Environments devoid of natural elements act as a “discord” on psychological well-being (Grinde et al., 2009). In support of this concept, Ulrich (1993) noted that humans are quicker to include phobic responses to evolutionary significant stimuli (found in nature) than that to potentially dangerous stimuli that are human made. The study concluded that humans show restorative responsiveness to nonthreatening natural environments (Ulrich, 1993). Biophilia has provided evidence for university campus, healthcare, and city infrastructure planning (Baur et al., 2020; Taylor et al., 2018; Totaforti, 2018).

Berto (2005), through a series of cognitive tests, demonstrated a positive connection between natural environments and direct attention. Cognitive tests were taken in both artificial and natural environments; natural environments produced more successful scores, demonstrating the environmental inclination to restore an individual's ability to control focus (Berto, 2005). Numerous studies similar in objective were produced with variances in administration: randomized investigations, natural experiments, pre and post measures, comparison of natural versus built, et cetera (Ohly at al., 2016). Through a joint evaluation of a quasi-experiment and a true experiment, evidence agreed that experiences in nature elicit greater restoration (Hartig et al., 2016). A more recent study aimed to focus on the benefits of bottom-up processing found in nature to support ART (Berman et al., 2008). Directed attention performance was significantly better following a ten-minute walk on a treadmill with a nature simulation than that without any simulation (Crossan et al., 2019). ART has also been applied to children living with Attention Deficit Disorder (ADD) and found that attention performance improves after as little as twenty minutes spent outdoors (Taylor et al., 2009).

ELECTROENCEPHALOGRAPHY

Electroencephalography (EEG) is a safe, repeatable research technique used to measure brain waves through the surface of the scalp and associate them to specific mental states (Kao et al., 2011). These mental states can include, but are not limited to, approach motivation, anxiety, arousal, inward attention, relaxation, and focus. The EEG headset is a noninvasive tool that measures electrical activity of neurons that is picked up by metal electrodes and conductive media (Teplan et al., 2014). Neurons are chemically induced to change ion permeability and produce an electrical signal. Varying stimulations produce identifiable rhythmic potential changes when passing through the synaptic clefts (Chien, 2011; Molnar et al., 2015).These rhythmic changes are picked up by the EEG headset to be processed into brainwaves ranging in frequencies (Badcock, 2015).

Emotiv portable headsets were used in this study to produce reliable EEG measurements. The headsets consist of five electrode sensors that operate at 128 Hz and have been shown to perform comparably to other EEG monitoring systems (Badcock, 2015). Brainwave frequencies range from 0.5 Hz to 100 Hz. As the frequency reading increases such as Beta (13 - 32 Hz) and Gamma (32 - 100 Hz), it indicates an increase in brain activity indicating higher excitability states such as focus or stress (Chien, 2011). Meanwhile, low frequencies such as Delta (0.5 - 3 Hz) and Theta (4 - 8 Hz) are associated with relaxation or sleep (Chien, 2011). Alpha frequencies

(8 - 13 Hz), often dominant in the parietal and occipital regions, indicate a transitionary rest state between high and low activity frequencies (Chein, 2011). The headset incorporated a filter to exclude raw data that did not fall within the range of 3 - 43 Hz, removing Delta frequencies associated with sleep. If the raw data were to exceed 43 Hz, it would likely be due to muscle contractions or other external influences and show as unrelated artifacts in brainwave data (Bailey et al., 2018).

Previous research has established formulae to compute emotional states from EEG data (Kao et al., 2011). It is important to note that exact labels for the differing mental states vary within neuroscience literature; however, the measures are consistent throughout. Relaxation can be determined by the degree of Alpha signals across all five sensors (Harmon-Jones, 2010). Focus is measured as frontal lobe high frequency waves, such as Gamma or Beta, detected by the two most anterior sensors (Coelli, 2015). Motivation can be determined by frontal asymmetry of waves. Enjoyment or interest is indicted by higher activity rooted in the left frontal lobe; meanwhile, discontentment is experienced with higher activity in the right frontal lobe. Arousal is indicated through Gamma or Beta detection in the posterior cortex (Oathes, 2008). Inward attention is measured by the posterior cortex consisting of Alpha waves while the frontal cortex primarily experiences strong Theta waves (Lagopoulos at al., 2009). Inward attention is a nondirective form of meditation that is conducive to the lack of focus on any one subject matter.

Originally, Theta Beta Ratio (TBR) was used as an indicator for sensory arousal; however, accumulating evidence in neuroimaging suggests that this measure is more complex (Clarke at al., 2019). Diagnoses such as Attention Deficit Disorder (ADD) and Attention Deficit and Hyperactivity Disorder (ADHD) have long been based on elevated TBR (Angelidis et al., 2016; Arns et al., 2012; Kiiski et al., 2020). However, emerging research suggests that TBR does not accurately serve as a diagnostic tool for poor attention control of ADD and ADHD, but as a prognostic measure of mind wandering states (Martijn et al., 2013; Son et al., 2019). Elevated frontal TBR is known to occur during mind resting states that allow the mind to withdraw from surroundings (Son et al., 2019). Researchers use this measure in studies of mental learning capacity (Swart et al., 2020) and of testing anxiety (Wei et al., 2020). This measure is used in this study to evaluate the degree of resting state of participants and indicate restorative potential of environments.

The use of the EEG is an effective way to evaluate how natural versus urban environments influence brain activity, both cognitively and emotionally. The inclusion of emotional and cognitive tests while using the EEG devices allows a connection between environmental stimuli and attention/focus ability. Bailey et al. (2018) used EEG devices to record internal response to environmental settings and testing supported that outdoor settings promoted higher cognitive test scores and higher levels of meditation and attention. This research serves as an example of how natural environments tend to be better environments for cognitive performance, allowing the allocation of directed attention, through the lack of demanding stimuli.

HEART RATE VARIABILITY

Measures of the heart performance have long been critical to diagnostic practice. Measures such as blood pressure (BP), heart rate (HR), and heart rate variability (HRV) provide insights into internal cardiologic conditions to accurately triage patient conditions (Sakamoto et al., 2018). HRV also serves as a peripheral physiological parameter for psychological mental states (Kaufmann et al., 2012; Lehrer et al., 2014). Low vagally mediated HRV (vmHRV) is associated with anxiety and heightened stress response (Williams et al., 2017). Multiple studies have employed HRV as a tool to identify conditions of acute stress susceptibility. HRV was found to increase after periods of meditation decreasing acute stress and promoting positive future emotional regulation (Kirk et al., 2020; Weiss et al., 2021). A recent study even used HRV as means to non-invasively measure the well-being and psychological health of a French population following lockdown during the COVID-19 Pandemic (Bourdillon et al., 2020). Because EEG measures of focus and arousal are higher excitability states, it is accepted that the corresponding measure of HRV would be low.

HRV can be used as a tool to assess parasympathetic activation employed during periods following mental stress (Alvarsson et al., 2010). The parasympathetic nervous system (PNS) releases acetylcholine to reverse the effects of norepinephrine released by the sympathetic nervous system during times of stress (Molnar et al., 2019). The effects can include slowed breathing, slowed HR, increased digestion, and increased HRV (Molnar et al., 2019). Thus, this form of biofeedback has been employed to measure restoration of nature environments on reduced mind wandering and focus abilities (Blum et al., 2019). Castaldo et al. (2019) suggests that HRV validity of measure is confirmed during both short term (approximately 5 minutes) and ultra-short term (<5 minutes) for ability to indicate mental stress or lack thereof.

THE STROOP TEST

Cognitive performance can be measured using the Stroop Test. The Stroop Test exposes the cognitive interference when a participant is confronted with the name of a color written in a different ink color. For example, the word red is written in green ink. This interference slows the response time down for correct identification (Hanslmayr et al., 2008). This concept is referred to as the Stroop Effect. This test has been shown to activate the right-orbito frontal and bilateral parietal structures of the brain (Bench et al., 1993). The process of the test starts with the *pure* Stroop Test portion. This involves twenty words which are printed in their respective color. For example, the word ‘red’ is printed in red ink. The next step is the *interference* Stroop Test. Another set of twenty words are printed; however, they are printed in a different colored ink than the respective color of the word. Time is recorded again as the participant identifies the set of words. To calculate the score, the time of the *pure* Stroop Test is subtracted from the time of the *interference* Stroop Test. The task of deciphering between the color meaning and the printed color takes place in the anterior cingulate cortex of the brain (Bench et al., 1993). This phenomenon can measure focus after an individual experiences a particular environment.

HYPOTHESES

Hypothesis I

If a student spends time in a natural environment, then he or she will experience a significantly higher level of focus (indicated by a low interaction score on the Stroop Test) upon returning to mental engagement than that of a student spending time in a built environment with no exposure to the outdoors.

Hypothesis II

If a student spends time in a natural environment, then he or she will experience significant differences in psychophysiological measures indicated by mobile EEG headsets compared to that of a student spending time in a built environment with no exposure to the outdoors.

Hypothesis III

If a student experiences variance in psychophysiological states, then he or she will experience a significantly higher level of focus (indicated by a low interaction score on the Stroop Test).

Methods

ETHICAL PROCEDURES

Approval from the Institutional Review Board (IRB) of the University of Tennessee at Chattanooga was obtained prior to data collection. The project was given the approval number IRB #18-166. Consent to participate prior to the study was obtained by signing an informed consent form (Appendix A). Participants were informed that they may withdraw at any point without penalty. No personal identifiers were included with data collection. Headset data, watch band data, and cognitive survey data were marked by headset number.

DATA COLLECTION

Participants included twelve individuals (66.6% female, Mean age = 21 with one outlier of 42) who participate in honors classes at UTC. These participants were recruited from an honors seminar with no incentive to participate and no penalties for declining participation or withdrawal. All individuals completed a waiver and a self-report questionnaire (Appendix A) to identify factors that may impact the study such as neurological or physical disabilities. The study was conducted in the afternoon to avoid conflict with student class schedules.

Participants were introduced to the test process upon arrival to the baseline location and given a brief cognitive survey to self-report any factors that may impact results. Individuals were then randomly assorted into a group (group A or group B) containing six individuals per group. Participants were then fitted with EMOTIV EEG headsets and smartwatches to be worn continuously throughout the study. To ensure accurate measurements, each access spot where the EEG electrodes contacted the scalp was dampened using water and each headset paired with the corresponding iPhone one at a time. Participants were then instructed to familiarize themselves with the Stroop testing technology. Testing was conducted using the Encephalapp cell phone application available with iOS and Android (Bajaj et al., 2014).

To introduce a baseline brainwave measurement, participants were instructed to relax in the baseline classroom location with their eyes closed for thirty seconds before opening their eyes while sitting in a relaxed position for thirty seconds. They were then instructed to complete a Positive and Negative Affect Schedule (PANAS) questionnaire and a Stroop test. The PANAS questionnaire acts as a psychometric scale to gauge either the positive or negative effects of a location on the individual's mental state. The survey asked participants to rate the degree to which they were experiencing a particular emotion (1 being not at all to 5 being extremely). The Stroop test asked participants to identify the printed color of a color word, consistent or opposing with that of the print color, by clicking a color word at the bottom of the screen. The number of incorrect responses and the time required to complete a successful attempt were recorded.

The two groups were then guided through a series of locations at random order. Group A completed the study by the order of location 1, 3, 2, 5, then 4. Meanwhile, group B completed the study in chronological order for locations one through five. At each location, the participants sat through a ten-minute restoration period before being instructed to complete a Stroop test and PANAS survey. Participants were asked to refrain from excessive conversation and phone usage during the resting periods. To account for external disturbances that may be reflected in the brainwave measurements, the testing process was video recorded and monitored for excess noise using the Decibel app. Continual records of brainwave frequencies and heart rate intervals were recorded through a custom iPhone app.

Locations were identified by the degree of natural exposure. Weather was consistent across all locations. Although the study was performed in February, it was a pleasantly warm, partially cloudy day. The baseline testing period was identified as location 1 (base) to show consistency with results. The remaining locations were identified by the following: 2) indoors without exposure to a natural environment (I-NE), 3) indoors with exposure to a natural environment (I-WE), 4) outdoors in a semi-built area (O-SB), and 5) outdoors in a green setting (O-G). Location 2 (I-NE) was set in the ground level of the library without exposure to windows. Participants were exposed to other students within this location, but it was a quiet environment. Location 3 (I-WE) was set in a quiet study room included in the library with a view of Chattanooga's cityscape and treetops. Location 4 (O-SB) included a balcony outside of Lupton Hall looking toward the main green space on campus. This environment was protected from noise interference created by the other students on campus. Location 5 (O-G) was set on a short hill next to Bretski Hall with grass and trees as cover. Here, participants were exposed to noise created by other students included on campus and was located close to outdoor sporting activities (i.e. football tossing and Pogo sticking).

Figure 1.
Location 2 (I-NE)

Figure 2.
Location 3 (I-WE)

3

Figure 3.
Location 4 (O-SB)

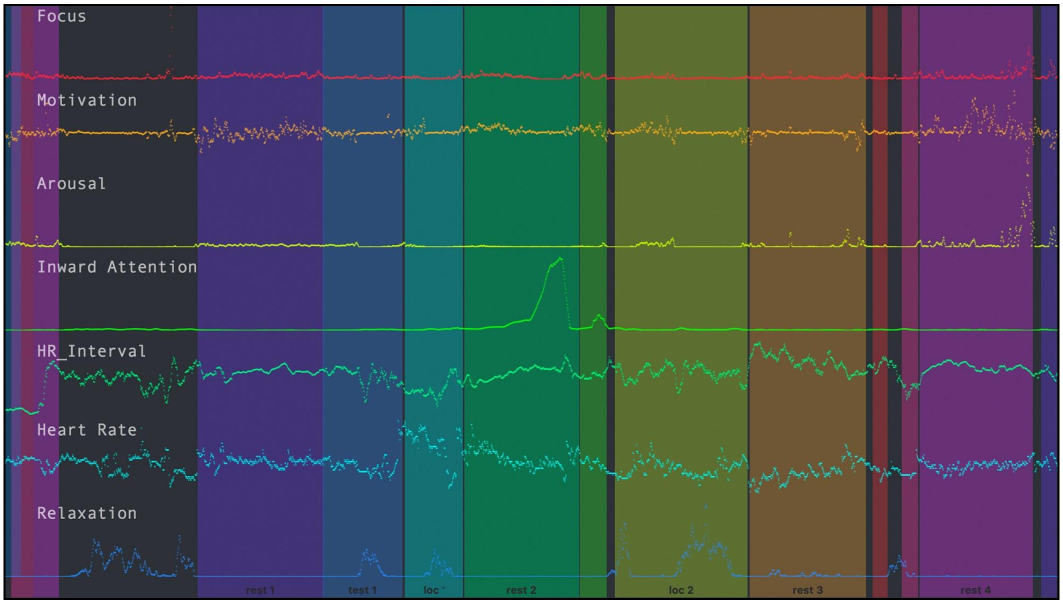
Figure 4.
Location 5 (O-G)

DATA ANALYSIS

To begin data analysis, brainwave data were exported from the headset and transformed into wavelengths by applying Fast Fourier Transformation (FFT). The data were then visually filtered for unwanted artifacts that would impact the reliability of measures. The data were transformed into the five mental states (relaxation, focus, motivation, arousal, and inward attention) using established principles discussed previously. Values for heart rate and heart rate interval collected from the smartwatch were also included. The data were then sectioned into epochs for each location (Fig. 5). Separate epochs were marked for the restoration session and testing session within each location.

Figure 5.

An example of epochs in EEG wave function of a participant.



Each participant's data set was then individually processed through the Statistical Package for the Social Sciences (SPSS) 27 software to produce a mean and standard deviation value for each epoch. These data were then compiled in an Excel spreadsheet to be reanalyzed using SPSS 27 run analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), and multivariate analysis of covariance (MANCOVA) to find significance of results addressing the hypotheses ($p < 0.05$).

Results

Hypothesis I

An ANOVA tested the impact that time and location had on interaction scores. Interaction score is computed based on time spent to achieve a successful Stroop test with account of failed attempts. High interaction indicates a low level of success on Stroop testing suggesting low focus levels. Location was found to significantly impact interaction scores ($p = 0.039$); meanwhile, ongoing time did not have a significant effect ($p = 0.659$). This finding is important by showing that participants' cognitive performance scores were not impacted by the length of the study.

Table 1.

ANOVA Test of Between-Subject Effects showing significance of location

Dependent Variable: interaction

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5842.904[a]	8	730.363	1.603	.148	.204
Intercept	23380.954	1	23380.954	51.325	<.001	.507
time	382.528	2	191.264	.420	.659	.017
location	3423.483	2	1711.741	3.758	.030	.131
time * location	479.859	2	239.929	.527	.594	.021
Error	22777.288	50	455.546			
Total	51786.205	59				
Corrected Total	28620.191	58				

a. R Squared = .204 (Adjusted R Squared = .077)

Both Table 2 and Figure 6 demonstrate that cognitive performance was the worst at location 2 (I-NE). All locations were significantly different from location 2 (I-NE) as seen in Table 2 ($p < 0.05$). Interaction scores were highest at location 2 (I-NE) as indicated in figure 6.

Table 2.

Location 2 (I-NE) was found significantly different between all other locations

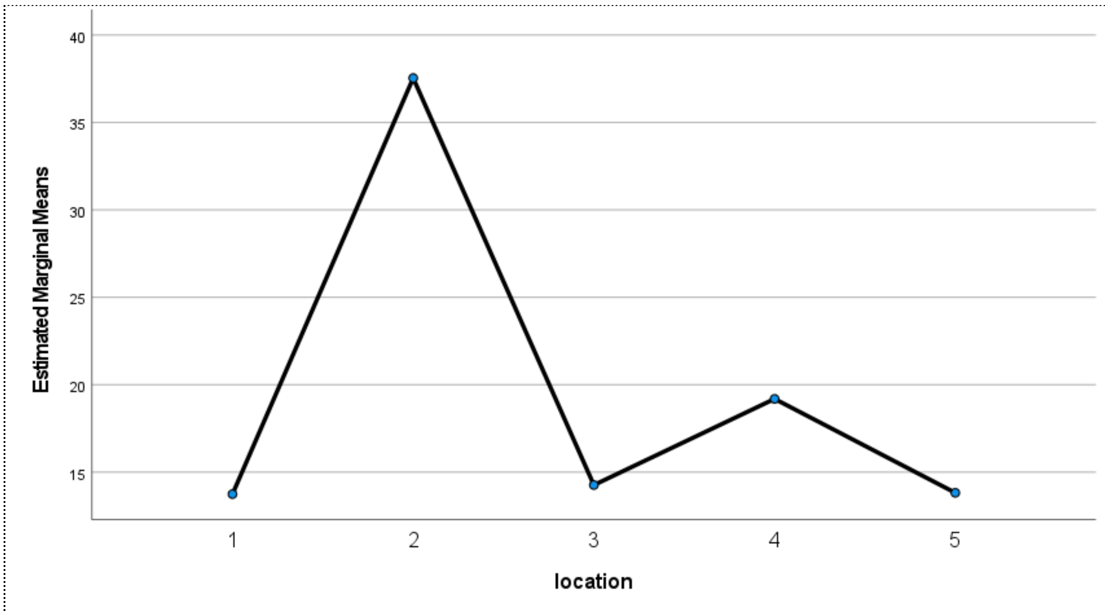
Dependent Variable: interaction
LSD

(I) location	(J) location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	-23.79*	8.909	.010	-41.69	-5.90
	3	-.52	8.909	.954	-18.41	17.38
	4	-5.45	8.909	.544	-23.34	12.45
	5	-.08	8.909	.993	-17.97	17.82
2	1	23.79*	8.909	.010	5.90	41.69
	3	23.28*	8.713	.010	5.77	40.78
	4	18.35*	8.713	.040	.85	35.85
	5	23.72*	8.713	.009	6.22	41.22
3	1	.52	8.909	.954	-17.38	18.41
	2	-23.28*	8.713	.010	-40.78	-5.77
	4	-4.93	8.713	.574	-22.43	12.57
	5	.44	8.713	.960	-17.06	17.94
4	1	5.45	8.909	.544	-12.45	23.34
	2	-18.35*	8.713	.040	-35.85	-.85
	3	4.93	8.713	.574	-12.57	22.43
	5	5.37	8.713	.540	-12.13	22.87
5	1	.08	8.909	.993	-17.82	17.97
	2	-23.72*	8.713	.009	-41.22	-6.22
	3	-.44	8.713	.960	-17.94	17.06
	4	-5.37	8.713	.540	-22.87	12.13

Based on observed means.
The error term is Mean Square(Error) = 455.546.
*. The mean difference is significant at the .05 level.

Figure 6.

Interaction as a quantitative measure of Stroop success .



Note. High levels of interaction indicate a low success on Stroop testing

Hypothesis II

Each participant's score for HRV, TBR, focus, motivation, arousal, inward attention, and relaxation were compared across locations using a MANOVA with location as the independent variable. Significance was found only for relaxation scores with all others showing that location did not have a significant impact on psychophysiological state (Table 3). Relaxation showed the highest marginal means at location 4 (O-SB) and location 5 (O-G). Relaxation was lowest at location 2 (I-NE) (Figure 7).

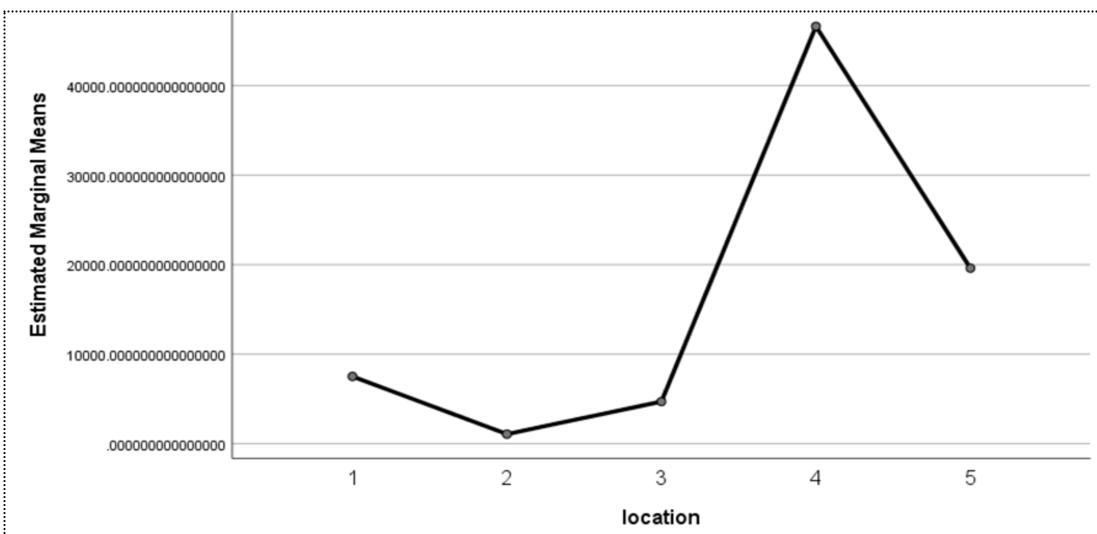
Table 3.

Psychological EEG data compared with location in Test of Between-Subject Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
location	Theta/Beta	9580.691	4	2395.173	0.618	0.652	0.048
	relax	14330784459.672	4	3582696114.918	2.935	0.030	0.193
	focus	27.447	4	6.862	1.518	0.212	0.110
	motivation	1.167	4	0.292	0.609	0.658	0.047
	arousal	37.208	4	9.302	1.543	0.205	0.112
	inward attention	15666.024	4	3916.506	0.504	0.733	0.040
	SD HR_interval	0.220	4	0.055	1.681	0.169	0.121

Figure 7.

Linear graph illustrating measure of Relaxation at varying locations



Hypothesis III

ANCOVA was used to address how TBR and HRV data collected during resting periods affected interaction scores and is reflected in the F-test below (Table 4). The measure of standard deviation of HRI readings are equivalent to HRV. Significant differences were found for both HRV ($p = 0.015$) and TBR ($p = 0.009$). TBR showed roughly five times higher marginal means at location 2 (I-NE) and location 3 (I-WE) than all other locations (Figure 8). The lowest marginal means were reported at location 5 (O-G).

Table 4.

Theta/Beta and HRV significance found on interaction scores

Dependent Variable: interaction

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
SDHR_interval	2843.706	1	2843.706	6.368	.015	.113
ThetaBeta	3330.597	1	3330.597	7.458	.009	.130
Error	22329.077	50	446.582			
Total	51122.512	54				
Corrected Total	28220.254	53				

Figure 8.

Linear representation of Theta/Beta scores at varying locations

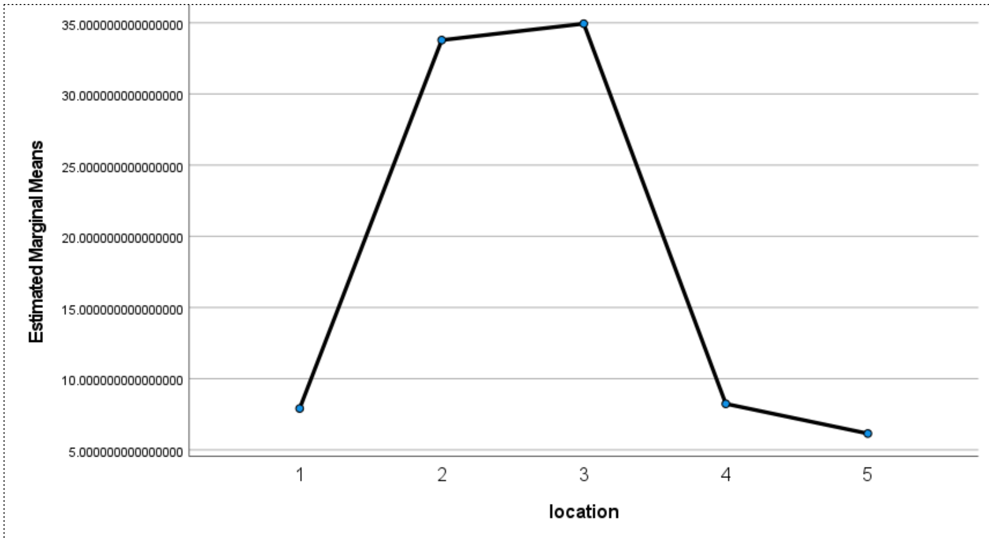
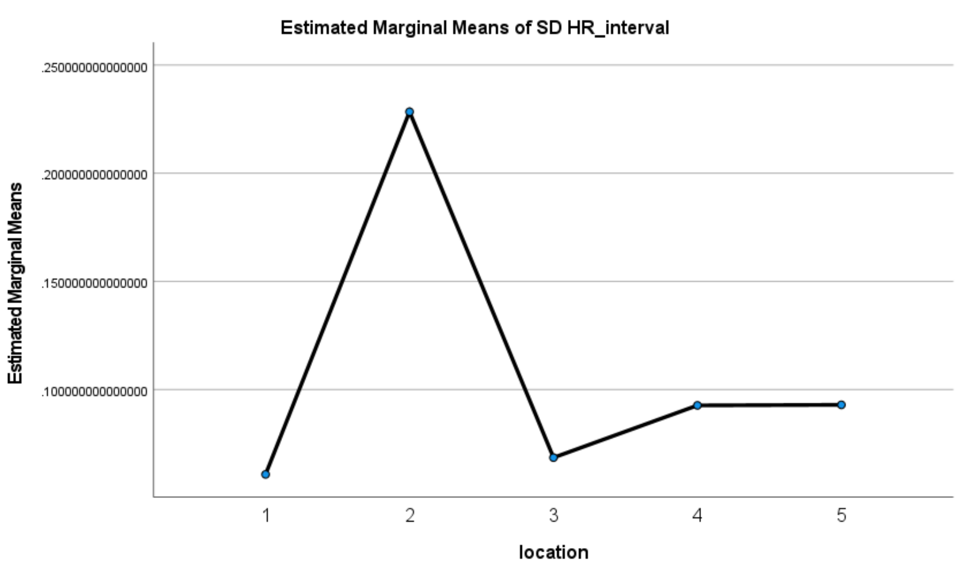


Figure 9.

Linear representation of HRV at varying locations



Discussion

INTERPRETATION OF FINDINGS

Location was found to have a significant effect on cognitive performance indicated by interaction scores. Lack of significance was found in time duration (Table 1) indicating participants' performance did not decline due to the duration of the study. Due to the length of the study and the slight discomfort induced by the headsets, this was an initial concern.

First, when students spent time in environments with natural exposure, it was found to significantly lower interaction scores. This indicates higher levels of cognitive performance upon returning to mental engagement in comparison to levels after having spent time in a built environment with no exposure to the outdoors (Figure 6). The greatest interaction scores were found after participants rested indoors with no exposure to a natural environment (Location 2 I-NE) meaning that participants exhibited poor cognitive performance. Location 2 (I-NE) was the only location without any exposure to the outdoors.

This finding supports the hypothesis that if a student spends time in a natural environment, then he or she will experience a significantly higher level of focus (indicated by a low interaction score on the Stroop Test) upon returning to mental engagement than that of a student spending time in a built environment with no exposure to the outdoors. This supports the process of bottom-up attention (involuntary) experienced in natural environments lending to a higher degree of mental restoration (Berman et al., 2008). This finding is also analogous with the Mayer et al. 2008 study showing that nature has greater restorative effects on attentional capacity (real or simulated).

Secondly, when students spent time in environments of natural exposure, the only psychophysiological measure that differed significantly across locations was the measure of relaxation ($p = 0.039$). Figure 7 illustrates the greatest measure of relaxation was found at location 4 (O-SB). This spike in relaxation could be attributed to the low student traffic resulting in a quiet, natural space. Relaxation at location 5 (O-G) was also significantly higher but lesser than that of location 4 (O-SB). This may be in part due to proximity to the main, crowded common area of UTC's campus.

Varying frequencies of electroencephalogy can be correlated to certain mental states (Kao et al., 2011). Relaxation was determined through Alpha signals across all five sensors included in the Emotiv headset (Harmon-Jones, 2010). Because the greatest measures of relaxation were recorded in locations with some degree of natural exposure, it is likely to account this to the "being away" and "fascination" properties included in ART (Felston, 2009).

Finally, when a student experienced variance in Theta Beta Ratio (TBR) and Heart Rate Variability (HRV), it was found that this affected interaction scores. Zero-order values show a moderate relationship of both TBR and HRV to interaction scores (Table 5) with the strongest influencer being TBR. TBR is traditionally used to measure attention control, learning capacity, and anxiety (Angelidis et al., 2016; Corantla et al., 2019; Swart et al., 2020). For this study, it was used to evaluate the degree of resting state of participants and indicate restorative potential of environments. The marginal means of TBR was reported highest at location 2 (I-NE) and location 3 (I-WE) indicating that participants were experiencing sensory arousal. This may be accounted for by hard fascination included by ART (Felston, 2009). Participants may have felt uneasy because of the closed space included in the library locations.

To conclude, this study provided EEG based data to contribute to Kaplan's Attention Restoration Theory as well as Wilson's Biophilia Hypothesis. We hope that this study can influence programming and planning of current and future academic institutions to provide the best environment for their students. This is especially important for universities located in urban settings. In short, this study could be applied to workplace, housing, long-term care resident housing, primary and secondary education, et cetera.

LIMITATIONS

While results show consistency with hypotheses, results could have been influenced by other factors. One of these would be the space itself. For example, Location 3 (I-WE) was a closed room while the outdoor locations were more open. The confined spaces could attribute to the arousal and low relaxation scores. Another example would be noise and sensory interference produced by student traffic. For example, Location 5 (O-G) was the busiest of locations and produced high arousal.

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Appendix A

Consent Agreement

Confidentiality

Your identity will be kept confidential to the extent provided by law. Your information will be assigned a code number. The list connecting your name to this number will be kept in a locked file in the faculty supervisor's office. When the study is completed and the data have been analyzed, the list will be destroyed. Your name will not be used in any report or publication. Your information, even if identifiers are removed, will not be distributed for future research.

Voluntary participation:

Your participation in this study is completely voluntary. There is no penalty or loss of benefit for choosing not to participate. You must be 18 years or older to participate in this study.

Right to withdraw from the study:

You have the right to withdraw from the study at any time without consequence or penalty. If you choose to withdraw, any data collected from your participation will be destroyed immediately.

Whom to contact if you have questions about the study:

This study has been approved by the UTC Institutional Review Board (#18-166). If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact Dr. Amy Doolittle, the Chair of the Human Subjects Committee, Institutional Review Board at 423-425-5563. Additional contact information is available at www.utc.edu/irb.

Agreement:

If you wish to participate in this study, please sign the form below. A signature will indicate agreement to participate.

Participant's Name: (Print) ____

Signature: ____(Date)______________