University of Utah
UNDERGRADUATE RESEARCH JOURNAL

STRESS PHYSIOLOGY IN RESPONSE TO PROLONGED PERIODS IN NATURE

Daniel Anderson (Mentor: Emily Scott)
Department of Psychology

ABSTRACT

Research suggests urban settings may induce stress and attentional fatigue. Stress Recovery Theory and Attention Restoration Theory propose exposure to natural environments reduce stress and restore attention. Exploring this, we had 26 participants complete testing before, during, and after a 5-day nature trip. Participant heart rate variability (measured by Respiratory Sinus Arrhythmia) and self-reported perceived stress were used to determine if prolonged immersion in nature promotes stress recovery. Responses to a cognitive task were used to determine if prolonged immersion in nature promotes attention restoration. We hypothesized that the exposure to nature will increase activity of the parasympathetic nervous system, reflected by an increase in heart rate variability, which would indicate recovery of stress and greater control over the stress response during attention regulation. We also expected the participants would report less perceived stress and show improved performance on the cognitive task in the nature condition relative to the urban sessions. Results for self-reported perceived stress were consistent with our hypothesis, while results for heart rate variability and cognitive tasks were inconsistent with our predictions. Notably, we found a decrease in heart rate variability during the nature condition, contradicting our hypothesis. This study provides additional data on how immersion in nature affects humans on a physiological level, which could help us better understand how nature impacts the individual at a time of increased urbanization.

INTRODUCTION

Recently, nearly every community on Earth has experienced rapid urbanization. During this period, green spaces have largely taken a back seat and our attention has drifted towards technology. This shift has warranted science to explore potential psychological drawbacks from urban exposure and benefits from exposure to natural environments.

Findings indicate that urban environments may have exhaustive impacts on individuals, leading to negative health consequences. Research suggests city living may be associated with increased amygdala activity, particularly regions responsible for stress and negative affect, which can further lead to increased prevalence of mental health disorders (Lederbogen et al., 2011). This challenges communities to question the genuine value of urban environments and seek settings that are healthier for them.

Meanwhile, natural environments contrast many characteristics of urban living. Rather than consisting of constant stimuli and distractions, nature provides individuals with a relatively tranquil environment that humans have evolved for. Grounded in this idea lies Attention Restoration Theory (ART; Kaplan, 1995) and Stress Recovery Theory (SRT; Ulrich, 1991), which each discuss a mechanism in which humans benefit from nature. In general, these theories and supporting research suggest that nature promotes individual well-being because it provides an escape from stress-inducing urban environments. This in turn allows individuals to restore attentional fatigue (ART; Kaplan, 1995), and it allows ourselves to physiologically recover faster from stress (SRT; Ulrich, 1991).

Often, research exploring ART and SRT treat these theories as distinct. However, in this study, we propose the mechanisms of ART and SRT happen simultaneously; ART and SRT act upon separate but complementary systems, where stress recovery and attentional restoration may correlate (Scott et al., 2021). As such we will look at measures for both ART and SRT, reflecting how they may act together to make natural environments restorative.

Attention Restoration Theory

Attention Restoration Theory proposes that natural environments help restore attentional fatigue. Built from philosophy on voluntary (effortful) and involuntary (automatic) attention (James, 1890), ART suggests that cognitive resources on “directed” (effortful) attention are a limited resource that may be depleted (Kaplan, 1995). Urban environments generally contain stimuli that continuously demand directed attention, such as goal-oriented behavior (avoiding traffic, monitoring technology; “top-down” processing). Certain contexts, however, may provide the ideal circumstances to restore directed attention more efficiently. Specifically, natural environments tend to provide stimuli that are relatively effortless to process, which evoke emotion in a bottom-up, or stimulus-driven fashion (awe, fascination). By being in nature and engaging this effortless attention, or “indirect” attention, it enables directed attention to be replenished (Kaplan, 1995). The negative consequences from the depletion of cognitive resources demonstrate ART’s importance. Generally, fatigued attention may lead to various forms of human error, ineffectiveness, and stress. In some cases, human error can have dire consequences, such as in a car accident, and researchers suggest many scenarios may be related to fatigued attention (Broadbent, Cooper, FitzGerald & Parkes, 1982).

As there is a wide range of what “natural” environments may consist of, ART specifies it must contain four elements: being away, extent, compatibility, and soft-fascination. Being away refers to a perceived removal from urban settings, often a removal from day-to-day stressors. Extent refers to having a rich enough environment to be perceived differently than one’s typical surroundings, interesting enough to engage indirect attention (while still not engaging directed attention from distractions). Compatibility with the environment refers to the environment meeting individuals’ unique psychological needs, such as not having stressors unique to the person. Finally, soft-fascination is the ability for an environment to provoke internal reflection. Once an environment meets all of these conditions, it is said to be restorative and mitigate stress through the recovery of attentional resources (Kaplan, 1995).

Literature examining ART generally discusses cognitive task performance across varying levels of nature (imagery, virtual reality, brief walks). This is explained under the framework of ART: attentional fatigue occurs less frequently in nature-based testing conditions and therefore better cognitive performance. For instance, prolonged immersion in nature demonstrated improvements in creative problem-solving tasks (Atchley, Strayer & Atchley, 2012), and brief walks in nature have demonstrated improvements in working memory (Bratman, Daily, Levy, & Gross, 2015) and sustained attention (Berman, Jonides & Kaplan, 2008) relative to urban control groups. Even 40 second bursts of green rooftop exposure (Lee, Williams, Sargent, Williams, & Johnson, 2015) and “fascinating” pictures of nature have shown attentional improvements (Berto, Baroni, Zainaghi & Bettella, 2010) compared to their relative urban control groups.

A recent meta-analysis, however, indicates studies ART is not unilaterally supported (Ohly et al., 2016). Findings indicate that for three executive functioning tasks, participants demonstrated better attention scores following a natural exposure compared to those exposed to non-natural environments (Ohly et al., 2016). However, it was also demonstrated that 10 separate cognitive tasks designed to elicit attention did not yield significant results in nature. In fact, one cognitive task found opposite results (better performance in urban vs. nature testing conditions). Overall, Ohly et al., (2016) reveals a trend that the most reliable benefits of nature exposure are found using working memory and sustained attention tasks. Research has yet to fully determine if there is consistency with ART and how exposure to nature affects different components of attention.

Stress Recovery Theory

Similar to ART, Stress Recovery Theory provides a separate but complementary explanation for why nature is restorative. Initially proposed by Plutchik (1984), SRT suggests that due to our evolution in natural settings, humans are biologically predisposed to using non-threatening elements of nature as a mechanism to alleviate stress (Ulrich, 1991). Rapid emotional changes are historically critical for human survival and reproductive success. Just as humans have evolved to quickly and efficiently immerse ourselves in a “fight or flight” state in response to urgent danger, such as historic predators or poisonous insects, humans have an inclination to drift towards a positive emotional tone as a restorative process following a stressor (Ulrich, 1991). Here, elements of natural settings, as opposed to urban ones, provide the avenue for a faster and more comprehensive stress recovery, because humans have evolved with those environmental conditions (Ulrich, 1991). Ulrich (1991) suggests this physiological change occurs through an increase in parasympathetic nervous system activity and positive changes in affect.

Here we may see how SRT is distinct from ART: Rather than restoration from attentional fatigue being the driving force, SRT urges that benefits of nature may be attributed to its alleviation of stress grounded in psycho-evolutionary theory. Research discussing this, therefore, uses changes in positive affect and stress biomarkers as indices of nature's benefits rather than cognitive tasks. For instance, participants who were exposed to nature videotapes and recordings after watching a stressful movie recovered faster in terms of physiological stress than participants exposed to urban videos and recordings (Ulrich, 1991). Studies also consistently find lower self-reported stress after exposure to natural settings (Beil & Hanes, 2013; Roe et al., 2013). Aligning with mechanisms of stress alleviation outlined in SRT, recent literature also suggests there is an increase in parasympathetic nervous system activity, shown my measures such as heart rate variability, in response to nature walks (Lee, et al., 2014) and nature imagery (Beute & de Kort, 2014; Gladwell et al., 2012).

However, a recent meta-analysis demonstrated support for SRT in terms of positive affect, but found little to weak evidence for physiological measures (Bowler, Buyung-Ali, Knight, & Pullin, 2010). The analysis found natural vs. simulated environments (i.e., buildings) promoted positive changes in energy and emotion, but no consistent difference was found in physiological measures such as cortisol. These results suggest nature is useful for improving mood, but physiological mechanisms are unclear. SRT suggests that increases in parasympathetic nervous system activity may explain changes in mood. Given that some research has found successful indicators of this (Ulrich, 1991), more research is required to determine which physical biomarkers reliably elicit changes across various levels of nature.

Our Study: Prolonged Nature Exposure

The majority of research conducted on these theories has used simulated natural setting or brief exposures to nature (i.e., 30-minute nature walks) as measures. However, many real-life exposures to natural environments are more long-term, lasting hours or days. This study, therefore, seeks to explore the effects of prolonged nature exposure. In doing so, we may better establish an optimum “dose” for nature exposure (i.e., long or short) and establish the efficacy of nature’s influence in real-world contexts. In testing prolonged nature’s influence, this study will include three measures, each of which are reflective of SRT or ART: behavioral data from a cognitive task (ART), a self-reported perceived stress questionnaire (SRT), and an analysis of heart rate variability, a stress biomarker (SRT). Value may be seen in simultaneously assessing improvements in mood via self-report and stress physiology biomarkers, because being able to understand the association between these two is a foundational concept to SRT. Implications, then, may optimize human well-being benefits for attention restoration and/or recovery of stress.

For physiological stress recovery, this study will use a standard electrocardiography set-up to monitor heart rate variability before, during and after the nature trip. Respiratory Sinus Arrhythmia (RSA), which indicates parasympathetic nervous activity through the vagus nerve, is the biomarker that will be used for this study. This is a statistical measure that reflects changes in time between consecutive heart beats, which is known as heart-rate variability. Specifically, it is a measure of the process of the fluctuation of heart rate that occurs with breathing (HR increase during inhalation, decrease during exhalation; Bernston, Cacioppo & Quigley, 1993). Due to its established relationship with the vagus nerve, RSA is a well validated indicator of parasympathetic nervous system activity (Del Giudice et al., 2011; Thayer, Fredrikson, Sollers & Wager, 2012; Thayer, Hansen, Saus-Rose, & Johnsen, 2009; Smith et al., 2020). Higher levels of RSA generally reflect a greater level of parasympathetic nervous system activation, and are associated with efficient stress regulation, while lower RSA is associated with worse stress regulation. As such, RSA is used as a biomarker to determine participants' physiological stress in response to urban vs. natural environments.

Currently, there is limited research on how nature exposure alters resting heart rate variability, and there is, to our knowledge, no formal study that has examined how prolonged nature exposure affects heart rate variability. Additionally, ECG data in this study will be taken throughout a cognitive task, which may potentially affect the environments stress alleviation effect. Coinciding with this will be a self-report perceived stress scale, which will serve as a qualitative measure of affect, one of the primary mechanisms proposed to alleviate stress (Ulrich, 1991). In relation to ART, this study will include an oddball task, a standard measure of working memory performance.

We hypothesize that prolonged exposure to nature would increase activity of the parasympathetic nervous system in accordance with SRT, which will be reflected by an increase in RSA in both task-related and resting data. This would indicate recovery of stress and greater control over the stress response during attention regulation. Along with this, participants would report less perceived stress after prolonged nature exposure. We also predicted that exposure to nature would improve accuracy and reaction time on the behavioral task.

METHOD

Participants

26 participants were recruited from the broader campus and Salt Lake City community via flyers advertising a paid research trip. 46% identified as female (*N* = 12), 42% identified as male (*N* = 11), 7% identified as transgender (*N* = 2), and 4% identified as other (*N* = 1) with an age range of 18 – 38 (*M* = 26.19, *SD* = 5.54). A majority of participants (89%) identified as White, Non-Hispanic, 7% identified as Native American/Alaska Native, and 4% identified as Asian. Participants were compensated $20 per testing session for a total of $60 for all three sessions.

Design

A repeated measures design was used in this study such that each participant completed the same testing procedure three times. The independent variable, Environment Type, was manipulated for each testing period. The first testing session occurred in an urban environment 1-2 weeks prior to a five-day camping trip in nature. The second testing session took place throughout days 2-4 of the nature trip. The third testing session took place 1-2 weeks following the nature exposure in the same urban location as the first testing session. At each testing session, we measured three dependent variables: heart rate variability, self-reported perceived stress, and reaction time and accuracy on the oddball task.

Procedures

For each testing session, participants were set up with standard electrocardiography (ECG) electrodes and a respiration belt through the gel-based BIOPAC system. Participants were also connected to electroencephalogram (EEG) electrodes, data from which is referenced in alternate studies. While the research team set up the EEG and ECG electrodes, participants filled out the Perceived Stress Scale (Scott et al., 2020) to assess stress they felt in the present moment, alongside a number of other self-reported measures collected as a part of a different study.

Following the survey, participants were relocated to their testing location. For urban testing sessions, participants were guided to a secluded area on a building plaza, where they faced a large, blank cement wall. For the nature testing session, participants were guided to a location near a river, surrounded by riparian plants. Both locations were isolated and free of distractions other than weather-related conditions. The time of day each participant tested remained constant at each of the three testing sessions (for example, if a participant tested at 10am at their first testing session, then they tested at 10am for their second and third testing session) to control for naturally occurring diurnal changes in stress.

Participants remained seated in these locations for the remainder of the study, where neuropsychological data was continuously gathered. First, they completed a 10-minute resting baseline, where they were instructed to remain as still as possible. Following this, participants completed three cognitive tasks on a laptop: a 3-Stimulus Oddball Task (Luck, 2014), a Doors Task (Proudfit, 2015), and a Flanker task (Eriksen & Eriksen, 1974). The Doors Task and Flanker Task were conducted for a different study. The tasks took a cumulative of 50 minutes, with five-minute breaks between each task. Following the cognitive tasks, the EEG and ECG electrodes were then removed from the participant, ending the study.

The 3-stimulus oddball task, programmed in E-Prime 2.0, is a common task used to elicit the P3b and P3a ERP components from the EEG signal (Luck, 2014). These ERP components were analyzed for a different study not referenced in this paper. However, the behavioral data generated from this task were analyzed in the present study to assess attentional resources. Participants were instructed to respond as quickly as they could to a frequent stimulus (the letter ‘X’ on the screen) by pressing the ‘z’ key, as well as respond to an infrequent stimulus (the letter ‘O’ on the screen) with the ‘/’ key. If a novel stimulus (any other number or letter) appeared on the screen, participants were instructed to not respond. The stimuli were preceded by a fixation cross in the center of the screen for 200 milliseconds in the center of the screen, followed by a blank screen for 1s +/- 100ms. Participants completed 400 trials, culminating to around 9 minutes. 80% of the trials presented were frequent stimuli (320 trials), 10% presented were infrequent stimuli (40 trials), and 10% presented were novel stimuli consisting of randomized numbers and letters (40 trials). The frequent vs infrequent stimuli (X’s and O’s) were counterbalanced between participants to control for any perceptual differences between the two.

Measures

Perceived Stress Scale

Participants filled out a brief, four-item version of the Perceived Stress Scale (Karam et al., 2012) containing questions about their current state of stress on a scale of one through five. Questions indicating negative affect (e.g., difficulties) were coded and added together. Questions indicating positive affect (e.g., things are going my way) were reverse scored and were summed together to obtain a total score. Higher scores indicate greater perceived stress.

Physiological Stress

Heart rate data was collected through the BIOPAC Smart Center system (Biopac Systems, Goleta, CA, USA). The ECG signal was recorded through one wireless ECG transmitter. A wireless BioNomadix Smart Center amplified its signal with a 2kHz maximum sampling rate. The BioNomadix Smart Center is a data-acquisition unit that connects to a computer USB port and records physiological data onto the computer. ECG was recorded during the oddball task after 10-minutes of resting.

Once on the computer, the ECG data was observed and processed through Acq*Knowledge* (v5.0) using a standard protocol for ECG artifact identification and correction (Berntson, Quigley, Jang & Boysen, 1990). Recordings were first taken through a bandpass filter of .5-35 Hz. Then, using the QRS peak detection algorithm, interbeat interval time series were obtained (Pan & Tompkins, 1985) and QRS peaks were marked. All data was inspected visually to look for missing QRS markers and was fixed accordingly using Bernston et al.'s detection algorithm (1990). Data were divided in 60-second epochs, which were removed from analysis if there was unusable data, such as a drop in signal from an electrode falling off. We used a Fast Fourier Transform software with a hamming window in Acq*Knowledge* to convert the interbeat intervals to the approximate frequency for spectral analyses of RSA. Data from all usable epochs were averaged to create an overall RSA for each participant session. The analysis of RSA data was then conducted in R (version 3.4.3).

Behavioral data

All behavioral data was acquired from the 3-Stimulus Oddball task, programmed in E-Prime, which functions as a working memory exercise that demands attention to different stimuli. Mean reaction time (in ms) and mean accuracy (proportion accurate) were calculated from information extracted from participant responses to trials. For the novel stimuli, accuracy was coded as correct when participants made no response and incorrect if they selected any response, because they were instructed to withhold responses to novel stimuli. Due to issues with saving data in E-prime and one participant failing to participate in this task, data from 21 participants were used for pre-testing, 20 for nature testing, and 19 for post testing. In total, this sums to 60 total files across 21 participants included in the behavioral analysis.

RESULTS

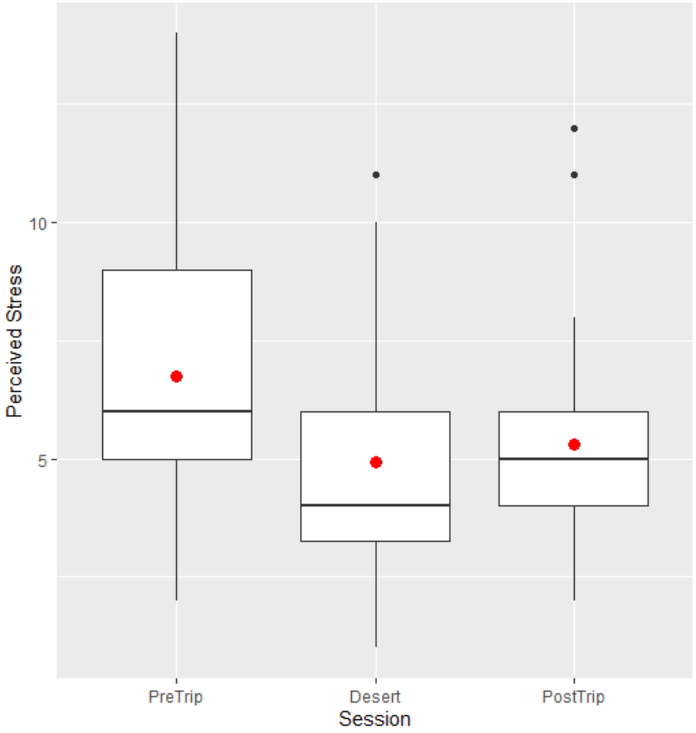
Perceived Stress

A repeated-measures ANOVA was used to test differences in responses to the Perceived Stress Scale between pre-trip urban (*M* = 6.76, *SD* = 3.14), nature (*M* = 4.92, *SD* = 2.54), and post-trip urban (*M* = 5.32, *SD* = 2.51) testing sessions. This revealed there were marginally significant differences in self-reported perceived stress between the sessions, *F*(2, 73) = 3.137, *p* = .049, at a significance level of .05, such that participants reported feeling lower levels of perceived stress while immersed in nature.

A post hoc analysis using the Tukey method was performed to compare testing sessions. This revealed a narrowly significant difference in perceived stress between the pre-trip and nature testing sessions (*p* = .050). There were no significant differences in perceived stress between nature to post-trip (*p* = .16) or pre-trip to post-trip (*p* = .86). This indicates the largest difference in participants’ perceived stress occurred between the first urban testing session and the nature trip (see figure 1).

Figure 1

Perceived stress across testing sessions



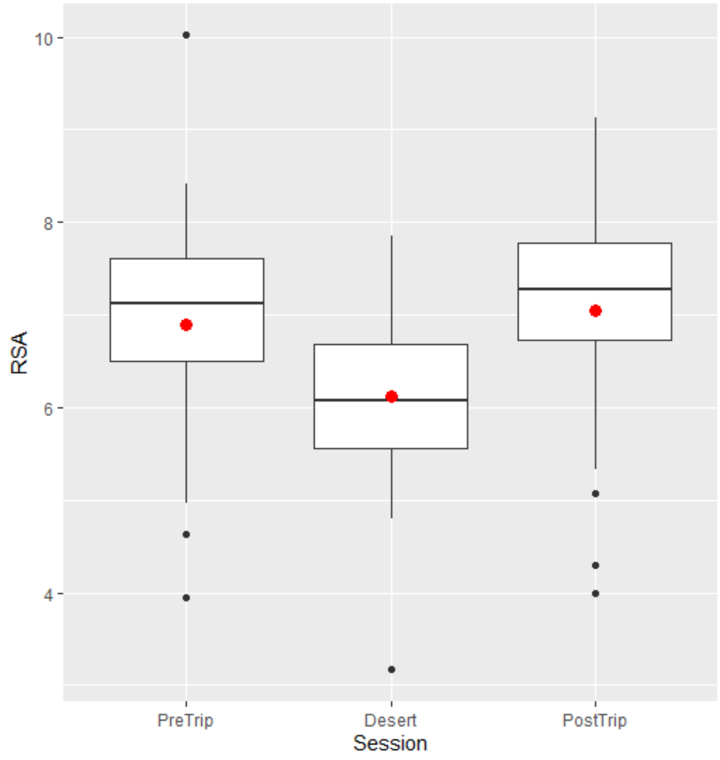
Heart Rate Variability (RSA)

Another repeated-measures ANOVA was used to test the difference in heart rate variability between pre-trip urban (*M* = 6.89, *SD* = 1.32), nature (*M* = 6.12, *SD* = 1.08), and post-trip urban (*M* = 7.04, *SD* = 1.40) testing sessions. Results indicated a narrowly statistically significant difference in mean RSA, *F*(2, 61) = 3.21, *p* = .0474 at a significance level of .05.

A post hoc test using the Tukey method was performed to compare changes in mean RSA across sessions. This did not reveal any difference between testing sessions below the significance threshold of .05. However, it did reveal a marginally significant increase in RSA from the desert session to the post-trip testing session (*p* = .054). Interestingly, the nature-urban RSA marginal significance only existed from desert to post-trip; the difference in the pre-trip RSA to desert RSA was not significant (*p* = .13). The difference in means between the two urban settings, pre-trip and post-trip was not significant (*p* = .92). Overall, the data demonstrate RSA decreased in the desert testing session compared to urban settings (see figure 2). This indicates a lower heart rate variability in nature and thus less activation of the parasympathetic nervous system (less alleviation of stress in nature).

Figure 2

RSA across testing sessions



Behavioral Data

A repeated measures ANOVA was used to test reaction time to response trials (in milliseconds) and accuracy of responses to trials (proportion correct). The analysis found no significant differences in reaction time between pre-trip (*M* = 397, *SD* = 59.5), nature (*M* = 402, *SD* = 61.5), and post-trip (*M* = 379, *SD* = 50.7) testing sessions, *F*(2, 60) = .883, *p* = .42. Similarly, no significant differences were found in accuracy between pre-trip (*M* = .84, *SD* = .05), nature (*M* = .79, *SD* = .17), and post-trip (*M* = .84, *SD* = .04) testing sessions, *F*(2, 60) = 1.66, *p* = .20. Results suggest environmental settings make no difference in performance on this task. Because this this task is thought to reflect allocation of attentional resources towards working memory updating, this indicates a lack of support for nature recovering attentional fatigue.

DISCUSSION

In the present study, we hypothesized that relative to urban testing conditions, the nature testing condition would show greater heart rate variability during the task, report less perceived stress, and have faster and more accurate responses on the behavioral task. Each of these three hypotheses suggest nature enhances recovery of stress and/or attentional resources in line with SRT (Ulrich, 1991) and ART (Kaplan, 1995).

The results of this study, however, only support one of our three hypotheses: participants self-reported less perceived stress during their nature testing session relative to the urban sessions. The other two hypotheses were not supported; no significant difference in responses to the behavioral task were found across nature-urban testing sessions, and there was no significant increase in heart rate variability throughout the oddball task in the nature testing condition. In fact, a marginally significant *decrease* in heart rate variability was found in the nature testing session relative to the post-trip urban session. This is indicative of less activation of the parasympathetic nervous system in response to the nature testing condition (more stress), contradicting our hypothesis.

Our significant results indicating participants' self-reported less perceived stress in nature coincide with a lot of prior research. Notably, positive changes in affect and emotional state are a key mechanism outlined by SRT (Ulrich, 1991). Other literature also finds consistent results of participants self-reporting less stress in response to natural environments (Beil & Hanes, 2013; Roe et al., 2013).

Meanwhile, the significant decrease in heart rate variability is not supported by SRT and contradicts recent research using measures reflecting parasympathetic nervous system activity in response to nature exposure (Brown et al., 2013; Beute & de Kort, 2014; Gladwell et al., 2012). However, other literature using physiological indicators of stress find mixed results on the influence of natural environments. Some studies have found no significant findings from biomarkers such as heartrate and blood pressure (Gladwell et al., 2012), and a recent meta-analysis found little to weak evidence from stress biomarkers, such as blood pressure and cortisol after nature exposure (Bowler, Buyung-Ali, Knight, & Pullin, 2010).

Similarly, our insignificant findings on responses to the behavioral task are not supported by ART and other research. In general, most recent literature suggests nature has restorative effects on attentional capacity, using various cognitive tasks designed to test working memory (Bratman, Daily, Levy, & Gross, 2015) and sustained attention (Berman, Jonides, & Kaplan, 2008). Additionally, there is a trend that cognitive tasks oriented towards working memory demonstrate the restorative effects of nature (Ohly, 2016). However, consistent restorative benefits of nature still have only been found in select cognitive tasks (Ohly, 2016). This indicates that some element of our chosen cognitive task may be ineffective at operationalizing the restorative effects of nature, thereby receiving insignificant findings. Finally, recent research has demonstrated failures in replicating restorative effects of nature using cognitive tasks (Neilson, Craig, Curiel & Klein, 2021).

This study held important limitations. Notably, a limiting factor of this study was our limited sample size. With fewer than 30 participants used for each experiment, it is difficult to draw significant conclusions from results; post hoc conclusions for RSA and behavioral data yielded marginally significant results and a priori conclusions from behavioral data were only narrowly significant. A larger sample size would make these results more precise and potentially show clearer differences between testing sessions. Next, this study took a sample of volunteers from the community who were able to attend a 5-day trip. Typically, those who would volunteer for this study would be people who orient themselves towards natural environments already. While none of the hypotheses were shared with the participants, it is reasonable to conclude participants guessed the present study was related to some beneficial effects of nature and may have attempted to respond to the behavioral tasks or self-report questions accordingly. Additionally, the participants did not know each other and were not necessarily comfortable in a new social environment. This, coinciding with a new environment, may have introduced a consistent stressor for some participants, causing them to be more physiologically dysregulated while still reporting to be less stressed. Finally, RSA does not account for all of the variance in stress, as it is a measure of only parasympathetic nervous system activity. Some of the differences in stress may be due to the sympathetic nervous system as well, which could be caused by many elements of the trip (cognitive stimulation, brighter lights, weather conditions, novelty of the experiment to the participant, etc.).

Despite these limitations, the present study demonstrates that the relationship between attention, stress, and nature exposure is not clear cut. While this study did not yield significant results with heart rate variability or behavioral data from the oddball task, there may be other measures that prove to be more sensitive to nature's effects. For instance, clearer differences may be found through different tasks, such as a creative problem-solving task, or different biomarkers, such as blood pressure, each of which have yielded significant results in alternate studies (Atchley, Strayer, & Atchley, 2012; Li, 2010). Additional research is needed to determine how prolonged nature exposure may influence such measures.

Similarly, benefits derived from nature exposure may be more context-dependent. Perhaps prolonged exposure or our nature testing location did not provide the appropriate context in some way or another. Many alternate studies describe the benefits of nature following some form of initial experimental attentional fatigue or stress condition, which this study did not include in its procedure. This would serve to prime participants to experience depletion or stress from which they can subsequently be “restored” from. Further research is needed to determine what elements of nature are most helpful in the process of stress alleviation and the mechanisms in which it may be measured. Implications of these findings may then be used for community well-being, such as natural design in urban environments, and management of natural spaces.

REFERENCES

Atchley, R. A., Strayer, D. L., & Atchley, P. (2012). Creativity in the wild: Improving creative reasoning through immersion in natural settings. *PLoS ONE*, *7*(12), e51474. https://doi.org/10.1371/journal.pone.0051474

Beil, K., & Hanes, D. (2013). The influence of urban natural and built environments on physiological and psychological measures of stress—A pilot study. *International Journal of Environmental Research and Public Health*, *10*(4), 1250–1267. https://doi.org/10.3390/ijerph10041250

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, *19*(12), 1207–1212. https://doi.org/10.1111/j.1467-9280.2008.02225.x

Berntson, G. G., Quigley, K. S., Jang, J. F., & Boysen, S. T. (1990). An approach to artifact identification: Application to heart period data. *Psychophysiology*, *27*(5), 586–598. https://doi.org/10.1111/j.1469-8986.1990.tb01982.x

Berto, R., Baroni, M. R., Zainaghi, A., & Bettella, S. (2010). An exploratory study of the effect of high and low fascination environments on attentional fatigue. *Journal of Environmental Psychology*, *30*(4), 494–500. https://doi.org/10.1016/j.jenvp.2009.12.002

Beute, F., & de Kort, Y. A. W. (2014). Natural resistance: Exposure to nature and self-regulation, mood, and physiology after ego-depletion. *Journal of Environmental Psychology*, *40*, 167–178. https://doi.org/10.1016/j.jenvp.2014.06.004

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, *138*, 41–50. https://doi.org/10.1016/j.landurbplan.2015.02.005

Broadbent, D. E., Cooper, P. F., FitzGerald, P., & Parkes, K. R. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology*, *21*(1), 1–16. https://doi.org/10.1111/j.2044-8260.1982.tb01421.x

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, *10*(1). https://doi.org/10.1186/1471-2458-10-456

Gladwell, V. F., Brown, D. K., Barton, J. L., Tarvainen, M. P., Kuoppa, P., Pretty, J., Suddaby, J. M., & Sandercock, G. R. H. (2012). The effects of views of nature on autonomic control. *European Journal of Applied Physiology*, *112*(9), 3379–3386. https://doi.org/10.1007/s00421-012-2318-8

James, W. (2013). The principles of psychology, 1890. Read Books Ltd.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., … Meyer-Lindenberg, A. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature*, *474*(7352), 498–501. https://doi.org/10.1038/nature10190

Lee, J., Tsunetsugu, Y., Takayama, N., Park, B.-J., Li, Q., Song, C., Komatsu, M., Ikei, H., Tyrväinen, L., Kagawa, T., & Miyazaki, Y. (2014). Influence of forest therapy on cardiovascular relaxation in young adults. *Evidence-Based Complementary and Alternative Medicine*, *2014*, 1–7. https://doi.org/10.1155/2014/834360

Lee, K. E., Williams, K. J. H., Sargent, L. D., Williams, N. S. G., & Johnson, K. A. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *Journal of Environmental Psychology*, *42*, 182–189. https://doi.org/10.1016/j.jenvp.2015.04.003

Li, Q. (2010). Effect of forest bathing trips on human immune function. *Environmental Health and Preventive Medicine*, *15*(1), 9–17. https://doi.org/10.1007/s12199-008-0068-3

Neilson, B. N., Craig, C. M., Curiel, R. Y., & Klein, M. I. (2021). Restoring attentional resources with nature: A replication study of Berto's (2005) paradigm including commentary from Dr. Rita Berto. *Human Factors, 63*(6), 1046-1060.

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B, 19*(7), 305–343. https://doi.org/10.1080/10937404.2016.1196155

Pan, J., & Tompkins, W. J. (1985). A real-time QRS detection algorithm. *IEEE Transactions on Biomedical Engineering*, *BME-32*(3), 230–236. https://doi.org/10.1109/TBME.1985.325532

Plutchik, R. (1984). Emotions: A general psychoevolutionary theory. *Approaches to emotion, 1984*, 197-219.

Roe, J., Thompson, C., Aspinall, P., Brewer, M., Duff, E., Miller, D., Mitchell, R., & Clow, A. (2013). Green space and stress: Evidence from cortisol measures in deprived urban communities. *International Journal of Environmental Research and Public Health*, *10*(9), 4086–4103. https://doi.org/10.3390/ijerph10094086

Scott, E., LoTemplio, S., McDonnell, A., McNay, D. Greenberg, K., McKinney, T. Uchino, B., & Strayer, D. (2020). The autonomic nervous system in its natural environment: immersion in nature is associated with changes in heart rate and heart rate variability. *Journal of Psychophysiology* e13698.

Scott, E. E., McDonnell, A. S., LoTemplio, S. B., Uchino, B. N., & Strayer, D.L. (2021). Towards a unified model of stress recovery and cognitive restoration in nature. *Parks Stewardship Forum, 37*, 46-60

Smith, T. W., Deits-Lebehn, C., Williams, P. G., Baucom, B. R. W., & Uchino, B. N. (2020). Toward a social psychophysiology of vagally mediated heart rate variability: Concepts and methods in self-regulation, emotion, and interpersonal processes. *Social and Personality Psychology Compass*, *14*(3). https://doi.org/10.1111/spc3.12516

Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, *36*(2), 747–756. https://doi.org/10.1016/j.neubiorev.2011.11.009

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201–230. https://doi.org/10.1016/s0272-4944(05)80184-7

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(6), 1063.