# MEASURING COGNITION IN NATURE:

# AN EXPLORATORY STUDY USING

# ELECTROENCEPHALOGRAPHY

by

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# STATEMENT OF THESIS APPROVAL

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# ABSTRACT

Media-related technology can capture attention, leaving the user depleted of attentional resources. However, the theory of attention restoration (ART) suggests that environments with certain qualities can restore previously depleted resources. Previous research has tested ART using a variety of behavioral and perceptual tasks; however, researchers have yet to examine the predictions of ART using neurophysiological methods. I hypothesize that the default mode network, a region associated with internal thoughts, is associated with the restoration process in nature. This exploratory study evaluated the process of restoration using electroencephalography to measure potential changes in oscillatory activity after participants were exposed to a natural environment. Forty-seven (19 males) participants 18 to 37 years in age were recruited from the Salt Lake City area via flyers, advertisements, and word of mouth. In order to assess the effects of technological distraction, participants were assigned to a group that was concurrently talking on a phone during the walk or to a group that did not have any technology with them. Participants in the phone group had decreased recognition memory and increased activity at the theta frequency after the walk compared to participants who went on the walk without their phone. The data indicate that technology disrupts the process of restoration and decreases awareness of the surroundings.

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# INTRODUCTION

The presence of media-related technology has grown over the past few years (Cardoso-Leite, Green, & Bavelier, 2015). Two-thirds of Americans own a smartphone (Smith, 2015) and the average user engages with their phone for an average of 8 hours per day (Roberts & Foehr, 2008). Digital technologies, such as television and smartphones, pose as a distraction from everyday life, providing stories, entertainment media, and games to the user. These distractions compete with the real world by presenting nonessential but entertaining information. Although technology provides a break from reality, media-related technology requires attention. Technology requires focus and effort to divide attention between the environment and the screen. The persistent use of technology has potential long-term negative effects. For example, individuals who watch TV every day report decreased daily alertness and lower life satisfaction (Frey, Benesch, & Stutzer, 2007).

Decreased situational awareness due to cognitive distraction can have serious repercussions. Strayer and Drews (2007) found that drivers holding a phone conversation were less able to process the driving environment. Although participants in this experiment were not visually or manually impaired by the phone conversation, they failed to observe their surroundings due to inattentional blindness, the phenomenon that occurs when certain aspects in the environment go unnoticed because of cognitive distraction (Mack & Rock, 1999; Simons, 2000). Likewise, individuals distracted by technology do not process the surrounding environment and could miss important information. For example, texting while walking into traffic or driving through a red light while talking on the phone could result in life-threatening consequences. Media-related technology is capable of demanding attention and diminishing the individual's awareness of the surroundings.

The resources used to focus attention on cognitively demanding stimuli are limited in capacity and easily diminished with sustained mental effort (Kaplan, 1995). Although the source of attention is not yet understood, research suggests that these resources are quantified by the amount of dopamine in the neurological regions supporting attention (Nieoullon, 2002; Roiser, Müller, Clark, & Sahakain, 2006). Focusing on a task depletes the stores of dopamine and limits the ability to focus attention. Research also suggests that higher blood-glucose levels correlate with better performance on attention-demanding tasks (Benton, Owens, & Parker, 1994; Wesnes, Pincock, Richardson, Helm, & Hails, 2003). Regardless of the origin of attention, research shows that focusing on a task for an extended period decreases performance (Damos, 1991; Kahneman, 1973), and therefore, attention has limited resources.

The attentional resources that require effort and are utilized to focus on demanding tasks are defined as voluntary attention (James, 1892). Kaplan and Berman (2010) suggest that voluntary attention requires top-down control exerted from within the prefrontal cortex. Technology utilizes voluntary attention to suppress the surrounding environment and focus on the incoming stimuli (Boksem, Meijman, & Lorist, 2005). The consequences can be severe when voluntary attention is depleted due to fatigue. For example, drowsy drivers and surgeons working long hours at the hospital could commit serious, fatal errors. Therefore, understanding how to replenish the depleted cognitive resources from excess use of voluntary attention is necessary to control fatigue.

Unlike voluntary attention, involuntary attention is resistant to fatigue. Involuntary attention captures focus without requiring mental processing and interpretation of stimuli (Escera, Alho, Winkley, & Näätänen, 1998). For example, going to the beach or taking a walk in the park can be engaging without demanding cognitive resources. Involuntary attention is a bottom-up process associated with parietal lobe activity that focuses on features in the environment (Kaplan & Berman, 2010). This effortless form of attention is subcategorized into two classifications: “hard fascination,” when the mind is focused externally, and “soft fascination,” when the mind is focused internally (Herzog, Maguire, & Nebel, 2003). Cheering at a sports game or playing at a waterpark evokes hard fascination, because attention is captured by the events in the surrounding environment. Exposure to quiet, calming places evokes soft fascination, as soft fascination environments provide a time to reflect and meditate on internal thoughts (Berto, Baroni, Ainaghi, & Bettella, 2010). Involuntary attention, specifically soft fascination, is hypothesized to restore the depleted resources needed for voluntary attention (James, 1892; Kaplan, 1995).

According to Kaplan’s theory of attention restoration (ART; 1995), spending time in a natural environment can restore depleted cognitive resources such as attention. Kaplan defines four qualifications necessary to achieve restoration from nature: soft fascination, extent, compatibility, and being away. *Soft fascination* is the ability to reflect internally without having to process an environment that presents new, attention-demanding information. Natural environments, such as parks, gardens, and forests, allow for reflection without monopolizing attention. The environment must have *extent* in order to induce a "whole other world" experience and inspire the feeling of awe. This experience must be interesting enough to capture attention but also free of distractions to allow for internal reflection. Likewise, the environment must be *compatible* with the needs of the person (Kaplan, 1995). Although an environment seems fascinating to one person, that same environment may arouse a different emotion in someone else. For example, an individual who is interested in birds will have a positive experience in an aviary compared to someone who is afraid of birds. Lastly, *being away*, either mentally or physically, from a cognitively draining environment is necessary to attain a restorative experience (Kaplan, 1995). If distractions are pulling attention away from the restorative setting, restoration cannot be achieved. Fascination, extent, compatibility, and being away are together the key principles to induce cognitive restoration (Kaplan, 1995).

Since the establishment of ART, several studies have explored the restorative effects of nature. Hartig, Evans, Lamner, Davis, and Gärling (2003) found better performance on a proofreading task for those who spent more time outdoors and who had recently been exposed to nature. Students had higher performance on an attention task when tested next to a view of nature compared to a nonnatural, urban view (Tennessen & Cimprich, 1995). Students also reported decreased mental fatigue (Herzog, Maguire, & Nebel, 2003) and increased restoration (Berto, 2005; Felsten, 2009; Laumann, Gärling, & Stormack, 2001) when exposed to scenes of nature, especially scenes containing water (Purcell, Peron, & Berto, 2001). Physiological measurements have shown decreased heart rates (Laumann, Gärling, & Stormark, 2003) and decreased skin conductance levels (de Kort, Meijnders, Sponselee, & Ijsselsteijn, 2006) when exposed to videos of nature.

Both in and out of a laboratory setting, studies have measured the restorative effects of nature using perceptual and behavioral methods. However, research has yet to examine ART using neurophysiological methods.

Although research has yet to explore the neurological process of cognitive restoration, we can hypothesize that the Default Mode Network (DMN) is activated when spending time in nature based on links from distinct areas of research. The DMN, commonly associated with mind wandering, is engaged when consciousness is focused on intrinsic thoughts (Buckner, Andrews-Hanna, & Schacter, 2008). For example, the DMN shows increased activation when meditating or resting (Jang et al., 2011). Researchers discovered a pattern of activation in the medial temporal lobe, medial prefrontal lobe, and the posterior cingulate cortex (PCC) when participants were in a resting state during functional magnetic resonance imaging studies (Buckner, Andrews-Hanna, & Schacter, 2008; Fransson & Marrelec, 2008). Activity in these regions comprises the DMN as well as aligns with the neurological anatomy associated with involuntary attention (Kaplan & Berman, 2010). Therefore, the resting state associated with the DMN is likely to be linked with involuntary attention and is necessary to achieve restoration in nature. Although previous studies have not studied ART in relation to the DMN, we expect that spending time in nature activates the DMN.

The PCC plays an important role in the activation of the DMN. Research shows that the PCC is highly correlated to the other regions of the DMN and remains active during the resting state (Fransson & Marrelec, 2008). Consequently, the PCC integrates the subsystems that comprise the DMN and acts as a control center for these frontal regions (Fransson & Marrelec, 2008). This control center operates at specific neural frequencies to coordinate activity across DMN regions. Activation of the DMN network is negatively associated with oscillatory frontal theta activity (4 to 7 Hz; Chen, Feng, Zhao, Yin, & Wang, 2008; Scheeringa, Bastiaansen, Petersson, Oostenveld, Norris, & Hagoort, 2008). Electroencephalography (EEG) studies show that midline frontal theta frequency (MFT) is more active when individuals utilize attention to perform more than one task simultaneously (Anguera et al., 2013). Likewise, attention-demanding tasks decrease the activity of the DMN (Buckner & Vincent, 2007; Mazoyer et al., 2001). The theta frequency is also positively correlated with mental fatigue (Wascher et al., 2014) and voluntary attention (Klimesch, 1999; Onton, Delorme, & Makeig, 2005). Consequently, we hypothesize that theta activity in the frontal cortex would decrease after spending time in nature. If the theta activity decreases, we predict an inverse activation of the DMN, and could then infer that restoration has occurred as measured by EEG.

Although principles of ART are well established, research has yet to measure the neurological effects of restoration. In this study utilizing EEG, we explore changes in oscillatory theta activity after exposure to nature from baseline measurements. We hypothesized that exposure to nature decreases theta activity in the midline frontal regions of the brain. We also explored the effect of distraction on the process of restoration in nature. If activation of the DMN is associated with the restorative effects in nature, we hypothesized that introducing a cognitively distracting activity, such as talking on a cell phone, would negate restoration and the onset of the DMN. Technological distractions would activate voluntary attention, and ergo increase activity in the MFT regions. Likewise, we hypothesized that technology-induced cognitive distraction would impair memory of the natural environment due to inattentional blindness (Simons & Chabris, 1999).

This study used novel methods to assess changes in neurological processing after exposure to nature. We expected to find a decrease in theta activity when participants were exposed to nature without distraction and an increase in theta activity when participants were distracted by technology. Technological distractions require voluntary attention and decrease attentional resources. By contrast, exposure to nature induces involuntary attention and replenishes these depleted resources. This study furthers understanding of the effects of media use on attention and expands the field of ART using a combination of measurements.

This study measured cognitive restoration and distraction using neurological, behavioral, and subjective measurements. EEG is a commonly used as a neurological measurement to assess changes in cognitive workload (Anguera et al., 2013; Gärtner, Rohde-Liebenau, Grimm, & Bajbouj, 2014), memory (Klimesch, 1999), and distraction (Strayer & Drews, 2007) via event-related potentials (ERPs) and oscillatory activity. In this study, we compared the amount of theta oscillatory activity before and after exposure to nature. Behavioral data measured recognition of scenes along the nature walk to determine how exposure to technology influenced memory performance. In a pilot study, participants holding a phone conversation performed significantly worse on the recognition memory task compared to participants who were not engaged with technology. Thus, we hypothesized that talking on the phone in nature decreases attention to and memory of the surrounding environment. We hypothesized that talking on the phone exhausts voluntary attention resources, and therefore would decrease overall affect on subjective ratings. Likewise, walking through nature without distractions activates involuntary attention and positive affect would be increased. Generally, we expected the distracted and undistracted groups to differ significantly across all measurements postexposure to nature.

# METHODS

## Participants

Fifty-four (24 males) from the Salt Lake City area participated in the experiment. Participants ranged in age from 18 to 37, with an average age of 26 years. Seven participants were excluded due to not following directions because they were subjected to confounding distractions during the exposure period. The remaining 47 (19 males) reported normal neurological functioning, normal or corrected-to-normal visual acuity, normal color vision (Ishihara, 1993), and were fluent in English. Participants were recruited via university-approved flyers posted on campus bulletin boards, a standing board displaying information about the study in Red Butte Gardens, via an advertisement posted on Craigslist, and via word of mouth within the community. Interested individuals contacted an e-mail address to schedule an appointment. Participants received monetary compensation for their time.

## Measurements

### *Electroencephalography (EEG)*

EEG data were collected using NeuroScan 4.5 software on a 32-bit Windows 7 laptop. EEG was recorded using a NeuroScan 32-electrode NuAmp amplifier. The electrodes built in the EEG cap are configured based on the International 10-20 system (Jasper, 1958). Researchers applied 10-mm diameter Ag/AgCl biopotential mastoid and facial electrodes using adhesive electrode collars and filled with saline-based gel. Researchers assured that impedances were below 10 kOhms for each electrode. Data were filtered online using a low pass filter of 50 Hz and a high pass filter set to DC with a sample A/D rate of 250 Hz. Data collected were processed using Neuroscan's Scan 4.5 software. HEOG and VEOG artifacts were corrected using a high pass zero phase shift filter at 12 decibels per octave using linear regression derivation. Remaining artifacts were removed visually and events with artifacts were removed from analysis. The data were then filtered with a bandpass, zero phase shift filter of 1 to 30 Hz at 48 decibels per octave, and then epoched 1000ms before and after the onset of the event. Finally, artifacts above and below 50 microvolts were rejected, which included less than 10% of the data. ERPs were created using overall averages from Neuroscan in order to verify the data were accurately processed. Data were then converted to EEGlab, a free MATLAB toolbox (Delorme & Makeig, 2004). The data were labeled and electrode channels were reassigned. The data were then processed using Independent Component Analysis (ICA) in order to further filter the data. After precomputing channel measures, an average power within the 4 to 7 Hz range was calculated by session for each participant. These averages were compiled from the midline frontal region, a composite of the following electrodes: Fz, F3, F4, FCz, and Cz.

*Detection Reaction Task (DRT)*

Detection Reaction Time (DRT) software is a device used to record reaction time and accuracy through the presentation of a stimulus in accordance with International Organization for Standardization (ISO) metric for assessing cognitive distraction (ISO, 2012). Researchers attached a tactile stimulus patch to the participants' upper left arm using medical tape. The tactile stimulus vibrated at random intervals between 3-5 seconds and participants responded to the stimuli by depressing a microswitch attached to their right thumb. The stimuli were present for 1 second or until a response was made. EEG data were collected for a 10-minute period while the participants responded to the DRT. A Windows 7 laptop recorded reaction time (RT) with millisecond accuracy, and both stimuli and response recorded event markers in the EEG data. The stimulus presentation markers were also present when the participant did not receive a stimulus to create randomized epochs in the EEG data. The event markers were also recorded when the participant received a stimulus to evaluate ERPs. The DRT responses were analyzed by average speed and accuracy in order to verify the participant was completing the task.

### *Recognition Memory Task*

The Recognition Memory Task was a slideshow including 15 pictures taken from the walk at a local garden and 15 pictures taken at a different garden area. Researchers instructed participants to respond either yes or no if they remember seeing the scene shown from their walk. Participants had a maximum of 20 minutes to complete the task, and could view each picture for any length of time, as well as flip between pictures. A lower recognition rate is an indicator of inattentional blindness during the walk.

### *Positive Affect Negative Affect Schedule (PANAS)*

The expanded form of the Positive and Negative Affect Schedule (PANAS) was used to determine perception of attention and overall affect postwalk (Watson & Clark, 1988; Watson & Clark, 1994). Participants were asked to rate on a scale of 1 (very slightly or not at all) to 5 (extremely) to what extent they agree with 28 different emotions (i.e. irritable, proud, sluggish). Analysis of the PANAS followed guidelines of Watson and Clark (1994).

## Procedure

### *EEG Preparation*

Testing was held at Red Butte Gardens on the University of Utah campus for one 3-hour session. Participants completed a University of Utah IRB-approved consent document and a general demographics survey upon arrival at the designated Red Butte Gardens preparation site. Researchers prepped the participant for the EEG cap using NuPrep surface gel to remove debris from the skin surface. A reference electrode was placed behind the left ear on the mastoid bone, and electrooculogram (EOG) electrodes were placed at the lateral canthi of both eyes (horizontal) and above and below the left eye (vertical) to record eye blinks for later data processing. Researchers measured and fastened an EEG cap to the participant in accordance to head size. Dry sponges (QuickCell cellulose-based electrodes manufactured by Compumedics) were placed in each electrode location prior to affixing the cap. Researchers inserted saline solution into each electrode in order for the sponges to expand and make contact with the scalp, with impedances below 10k Ohms. Electrode FP1 – preassigned in the cap – was used as the ground and electrode A1 was used at the reference. Participants' field of view and range of motion was not impeded when wearing the EEG cap.

*Prewalk Testing*

Once EEG preparation was complete, participants moved to the testing site for pre-exposure EEG testing. Researchers asked participants to sit without getting up, moving around, or talking to other patrons at the gardens during the two 10-minute recording periods. Researchers removed technologies from participants prior to testing to assure minimum distractions. During the first 10-minute period, EEG data were recorded while participants observed the surrounding environment. During the second 10-minute period, participants observed the surroundings while completing a Detection Reaction Task (DRT). Participants pressed a microswitch as quickly and accurately as possible every time they felt a vibrating stimulus attached to their left arm. Participants practiced responding to the DRT prior to testing.

*Exposure Walk Period*

During the exposure period, participants went on a 15- to 25-minute walk through Red Butte Gardens following chalk arrows around a designated handicap-accessible path. Participants were pre-assigned to a study condition using counterbalancing prior to arrival. In the “No Phone” condition, participants were asked to leave all technologies with the researchers for the duration of the study; therefore, no distractions were present during the exposure period. In the “Phone” condition, participants were instructed to hold a phone conversation with a friend or family member during the walk through Red Butte Gardens, thus introducing a distractor. Phone conversations were not monitored and participants could talk about any topic during the walk. For convenience, participants wore the EEG cap for the duration of the walk although it was not connected.

*Postwalk Testing*

Upon completion of the walk, researchers escorted participants to the testing site for postexposure EEG testing. Both testing and instructions were identical to prewalk testing. Once the EEG recording period was complete, participants completed a Recognition Memory Task, the PANAS, and an exit questionnaire. Upon completion, researchers removed the EEG cap and external electrodes and participants were debriefed.

# RESULTS

## Behavioral Data

The Recognition Memory Task data were analyzed using Signal Detection Theory (Parasurman & Davies, 1984; Swets & Green, 1963). Correct responses to pictures from the walk were coded as "hits," correct responses to pictures not along the walk as "correct rejections," incorrect responses to pictures from the walk as "misses," and incorrect responses to pictures not from the walk as "false alarms." The hit rate (HR) ("hits" / 15 total pictures from the walk) and false alarm rate (FA) ("false alarms" / 15 total pictures not from the walk) were used to calculate an APrime value: A' = 0.5 + [(HR – FA)(1 + HR - FA)][(4HR(1 - FA)]. APrime ranges from .50 for chance performance to 1.0 for perfect accuracy. A univariate ANOVA of APrime revealed the No Phone group performed significantly better than the Phone group $F(1, 45) = 8.20$, $p < 0.01$, $\eta^2 = 0.16$ (see Figure 1). Further analyses showed that this effect was due to differences in HR $F(1, 45) = 14.69$, $p < 0.01$, $\eta^2 = 0.26$ but not to FA ($p > 0.05$). Overall average HR for the No Phone condition was 61% (*SE* = 4.0) and 39% (*SE* = 4.1) for the Phone condition. Thus, the Phone group performed 36.1% worse on the recognition memory task than the No Phone group.

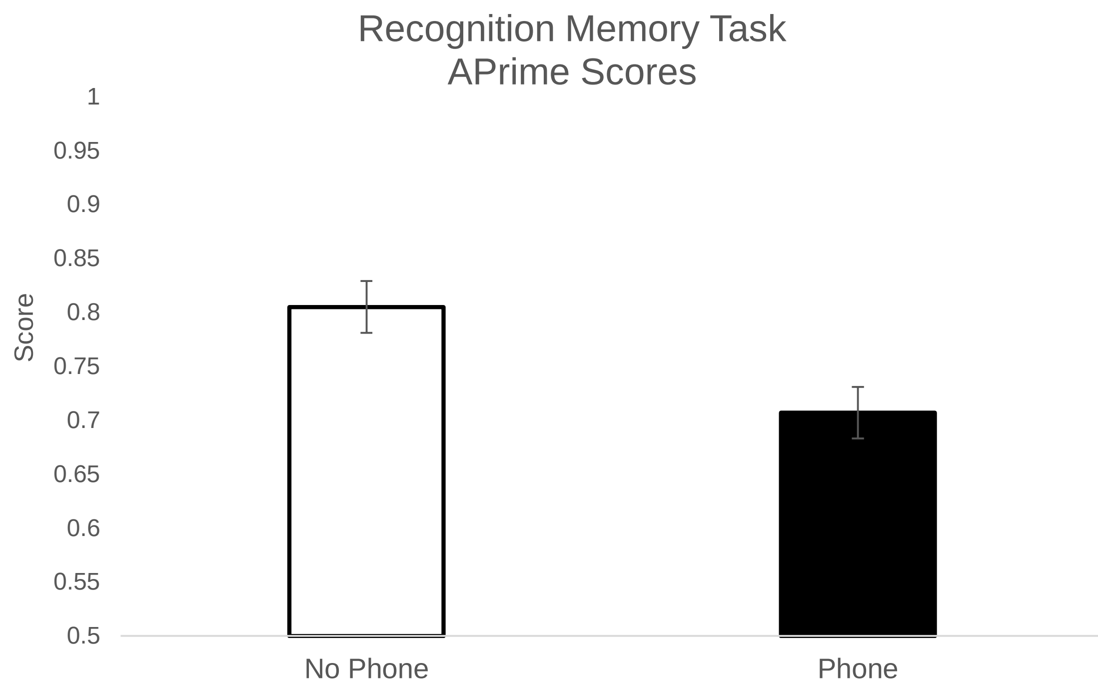


**Figure 1 –Recognition Memory Task APrime Comparison**

## Subjective Ratings

Participants rated their overall mood on the PANAS at the beginning of the study. Average mood was 6.38 ($n = 24$) on a 21-point scale of (-10) *Very Unpleasant* to (10) *Very Pleasant*. Participants scored 28 adjectives related to their current affect on a scale of 1 (very slightly or not at all) to 5 (extremely). In order to analyze the PANAS, responses were sorted by topic into one of five categories: Positive, Negative, Attentive, Fatigue, and Serenity (Watson & Clark 1994). Using a 5 (categories) X 2 (groups) MANOVA, no significant differences between groups were evident $F(1, 45) = 1.29$, $p > 0.05$, $\eta^2 = 0.142$. Mean score for Positive affect was 2.80 ($SE = 0.83$) and mean score for Negative affect was 1.20 ($SE = 0.27$). Mean score for Attentiveness was 3.00 ($SE = 0.76$), Fatigue was 2.32 ($SE = 0.85$), and Serenity was 3.90 ($SE = 0.68$) (see Figure 2).

Participants responded to the following question in an exit questionnaire: "*How much attention did you pay to your walk?*" Two participants did not respond to the question. Participants in the No Phone group reported paying significantly more attention to their walk compared to participants in the Phone group $F(1, 43) = 5.49$, $p < 0.05$, $\eta^2 = 0.11$. When asked, "*Was it more or less attention than you are used to*," participants in the Phone group also reported that the amount of attention was less than they were used to compared to the No Phone group $F(1, 43) = 4.59$, $p < 0.05$, $\eta^2 = 0.10$.

## Neurophysiological Data

EEG preprocessing was conducted using Neuroscan software and then exported to EEGlab to obtain average spectral measurements. Average ERP waveforms were calculated to ensure data were preprocessed correctly (see Figure 3). Using an extension

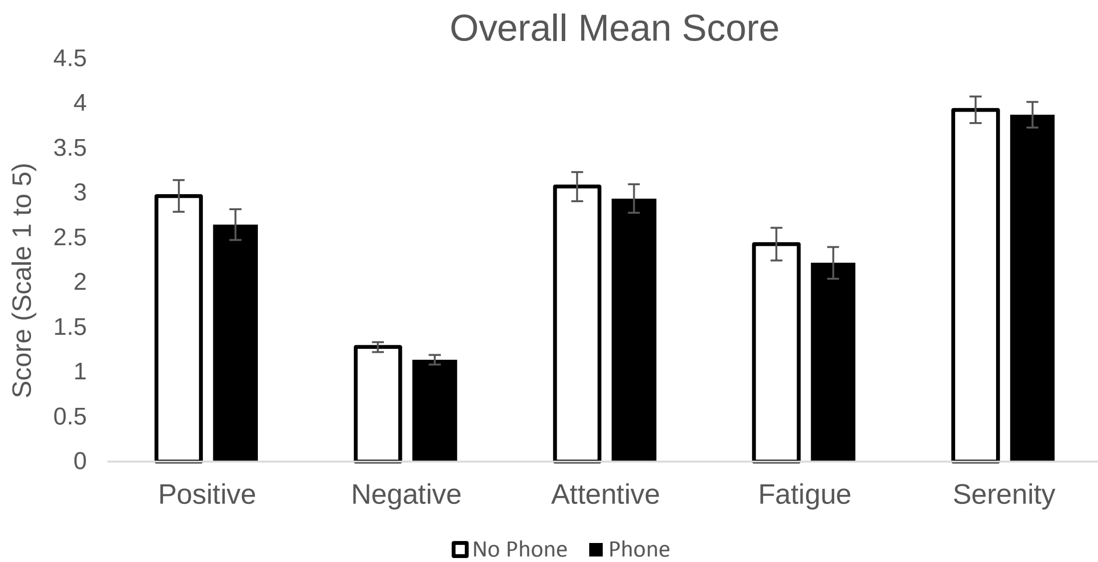


**Figure 2 – PANAS Score Comparison**

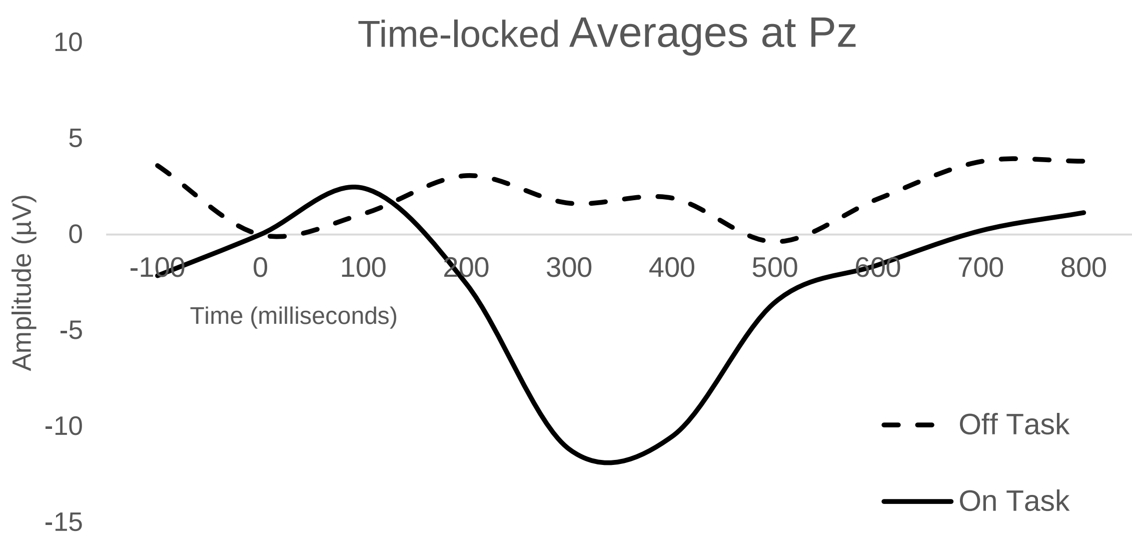


**Figure 3 – Average ERPs at Pz**

Figure 3 shows stimulus-locked grand averages of responses when on-task and mean average of waveforms when off-task.

software for EEGlab (Wyczesany, 2015), mean spectral power of theta frequency (4 to 7 Hz) for each participant was extracted from the EEG channels in the midline frontal region (Fz, FCz, Cz, F3, and F4). Average power at each channel was combined to create an overall mean score for both the pre and postwalk testing when the participant was not engaged in a task. Two participants were removed for missing partial data.

A difference score was computed from the spectral averages for each participant (Posttesting – Pretesting). An independent-samples *T*-Test was used to compare the mean differences between groups. The average postwalk difference was significantly greater for the Phone group compared to the No Phone group $F(1,43) = 4.43$, $p < 0.05$ (Figure 4). A planned comparison revealed the prewalk to postwalk change in spectral activity was not significant for the No Phone group $F(1, 22) = 0.17$, $p = 0.69$, $\eta^2 = 0.00$; however, this change was significant for the Phone group $F(1, 21) = 7.91$, $p < 0.05$, $\eta^2 = 0.16$. Participants talking on a phone during the walk had a significant increase in activity at the theta frequency compared to baseline, whereas participants who went on the walk without digital technology showed no change from baseline (Figure 5).

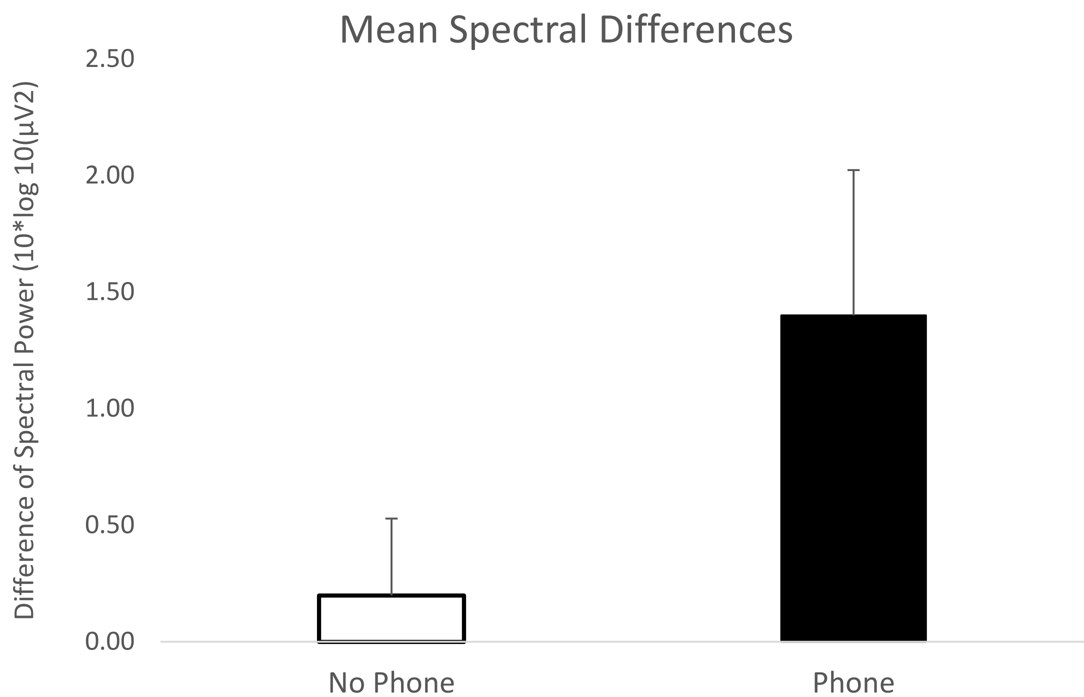


**Figure 4 – Mean Differences in Spectral Activity**

Figure 4 compares difference scores (postwalk – prewalk) for spectral activity at the theta frequency between conditions.

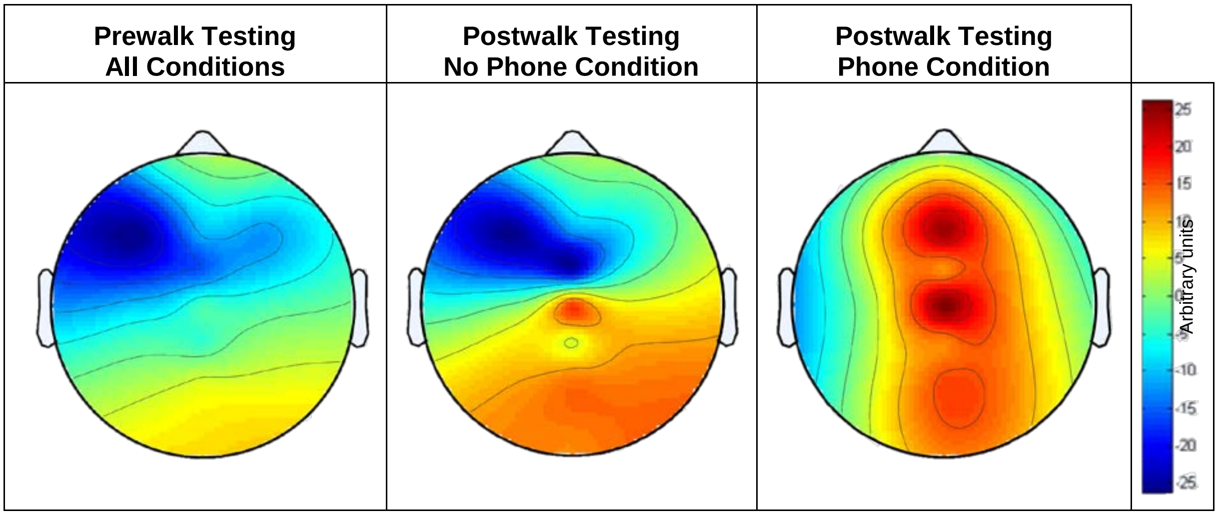


**Figure 5 – Spectral Maps**

Figure 5 shows average spectral activity across the scalp for the No Phone and Phone conditions postwalk compared to the spectral activity prewalk.

# DISCUSSION

The primary purpose of this study was to test ART using neurophysiological methods, specifically by using EEG recordings to measure theta frequency activity in the midline frontal regions. We measured spectral frequencies before and after exposure to nature to determine if the phenomenon of ART is supported by neurophysiological evidence. Previous literature suggests that the DMN is correlated with restoration due to activation in the frontal lobe during a resting state (Buckner, Andrews-Hanna, & Schacter, 2008; Jang et al., 2011). Activation of the DMN is negatively correlated with the MFT activity (Chen et al., 2008; Scheeringa et al., 2008). Therefore, we hypothesized that theta frequency would decrease after exposure to nature when an individual is undistracted by technology. We also hypothesized that the theta frequency would increase when exposed to nature while talking on a cell phone due to increased voluntary attention. Likewise, we hypothesized participants talking on a phone would have decreased situational awareness and therefore remember less of the walk compared to participants who were not distracted by technology.

Participants talking on a phone performed significantly worse on the Recognition Memory task compared to participants who were not distracted. Distracted participants performed similarly to those guessing, as compared to data collected in a pilot study. Although participants were not visually impaired, the phone conversation induced inattentional blindness – the lack of attentiveness due to cognitive distraction (Mack &

Rock, 1998; Simons & Chabris, 1999). Therefore, holding a phone conversation in a restorative place has a depleting effect on brain activity as well as impairing recognition memory performance. Although many individuals believe they are aware of their environment when holding a phone conversation or interacting with technology, the results of this study suggests technological interactions may have negative effects that influence perception of the environment.

As hypothesized, the Phone condition showed significant increases in activity at the theta frequency after walking in the garden. This increase in activity at the midline frontal regions corresponds well with previous research measuring multitasking and cognitive distraction (Anguera et al., 2013; Klimesch, 1999). Overall MFT activity increased after talking on the phone in nature. Holding a phone conversation has lasting residual effects to neurophysiological processing after hanging up the phone that is comparable to multitasking. Interacting with technology is cognitively demanding; thus, restoration in nature can occur only without technological distractions.

After a 20-minute exposure to nature, the theta frequency did not significantly change from baseline for the No Phone condition. This finding suggests that the exposure period in the current study was not long enough to result in significant neurophysiological changes from restoration. However, baseline spectral activity shows that participants already had low levels of theta frequency activation at the beginning of the study. Participants may have already been restored before the 10 minutes of pre-walk testing while the EEG system was prepped, and therefore did not significantly change during the postwalk testing. Future studies could measure participants in a lab environment before testing in nature, or deplete participants prior to the experiment to control the baseline activity.

In addition, it is possible participants were not restored during the walk. According to Kaplan (1995), the four qualifications of ART (soft fascination, extent, compatibility, and being away) must be met to be restored. Although the walk provided extent and allowed for soft fascination, participants could hear construction noises and see buildings in the distance. The feeling of being away from a cognitively demanding environment was not achieved during the short walk through the garden. In order to further understand the period needed for cognitive restoration, future studies could measure the neurophysiological changes after spending an extended period in nature undistracted by technology. With further investigation exploring potential restorative neurophysiological differences from exposure to nature, we can better understand the process of ART.

Previous research has measured ART using subjective, behavioral, and physiological measurements. This study proposed a novel methodology to measure ART using neurophysiological methods. Future studies can further this research by measuring changes in spectral frequencies when individuals experience nature. This study also shows the importance of disconnecting with technology in order to obtain cognitive benefits from the outdoors. Being away from cognitive demands is a key element of ART (Kaplan, 1995); however, technology plays an important role in many individual's daily lives (Roberts & Foehr, 2008; Smith, 2015). Putting down the phone and stepping away from the computer are key elements to restoring cognitive functioning. Although research has yet to understand the aspects of nature that benefit our brains and well-being, this study begins the neurological investigation of restoration through nature.

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