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Modulation of P3 and the Late Positive Potential ERP Components by Standard Stimulus Restorativeness and Naturalness

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MODULATION OF P3 AND THE LATE POSITIVE POTENTIAL ERP COMPONENTS BY STANDARD STIMULUS RESTORATIVENESS AND NATURALNESS

by

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ABSTRACT

Modulation of p3 and the Late Positive Potential ERP Components by Standard Stimulus Restorativeness and Naturalness

by

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Tests of attention restoration theory (ART) consistently support that exposure to restorative environments can replenish finite cognitive resources needed to focus attention. These environments are usually natural, as opposed to human made, but dimensions of naturalness and restorativeness are not one and the same, and yet have not been empirically delineated. That stated, the restorative effect has been documented in children and adults. However, neuroscientists have barely begun to test for neural correlates of ART. In this dissertation, I employ electroencephalography (EEG) to record electrophysiological brain activity during an active visual oddball task to capture and analyze p3 elicitation and late positive potential (LPP) activation, event-related potential (ERP) components. The p3 component is a positive-going peak in brain activity occurring in the window between 200 and 600 milliseconds after the onset of a stimulus. Previous research has shown that the amplitude of the p3 potential is attenuated – and latency increased – when task difficulty is high and/or attentional resources are depleted.

Conversely, when task demands are low, p3 amplitude is greater without an accompanying increase in latency, suggesting cognitive efficiency. LPP is positive activity from 500 ms or more after stimulus onset until stimulus termination that is associated with stimulus emotional valence. I hypothesized that, in an active discrimination oddball task, using a within-subjects design, adults would show increased p3 amplitude for low-frequency target images occurring amidst standard (high-frequency) images of highly restorative environments (HR; Condition 1) versus when standard images are of lowly restorative environments (LR; Condition 2) or a solid brown tile (Br; Condition 3), and that naturalness would not interact with restorativeness such that targets amidst restorative natural environments elicit p3's that are no stronger than targets amidst restorative built environments. This is because 1) restorative scenes should increase attentional resources, resulting in greater efficiency, even though task difficulty is unchanging between conditions, and 2) naturalness is separate from restorativeness and should not affect attention when restorativeness is controlled. Results showed p3 amplitude was greater, and latency earlier, for HR standard stimuli, rather than targets, which was unusual for the oddball paradigm but is explained within the framework of ART according to standard stimulus content. Also, LPP activity was only different between one occipital channel and three frontal channels between 600 ms and 1000 ms post stimulus onset, but greater in the nature stimulus group than the built between 1000 ms and 2000 ms post stimulus onset. This finding is consistent with previous research and interpreted to mean that natural stimuli are more pleasant and arousing than built stimuli. Limitations and future directions are also discussed.

(127 pages)

PUBLIC ABSTRACT

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Salif Mahamane

Tests of attention restoration theory (ART) consistently support that exposure to restorative environments can replenish finite cognitive resources, needed to focus attention, from a depleted state. These environments are usually natural, but the dimensions of naturalness and restorativeness are not one and the same, and yet have not been empirically delineated. The restorative effect has been documented in children and adults. However, neuroscientists have barely begun to test for neural correlates of ART. In this dissertation, I employ electroencephalography (EEG) to record electrophysiological brain activity during an active visual oddball task to capture and analyze p3 elicitation and late positive potential (LPP) activation, event-related potential (ERP) components. The p3 component is a pronounced, positive-going potential in brain activity occurring in the window between 200 and 600 milliseconds after the onset of a stimulus. Previous research has shown that the amplitude of the p3 potential is attenuated – and latency increased – when task difficulty is high and/or attentional resources are depleted. Conversely, when task demands are low, p3 amplitude is greater without an accompanying increase in latency, suggesting cognitive efficiency. LPP is positive activity from 500 ms or more after stimulus onset until stimulus termination that is associated with stimulus emotional valence. I hypothesized that, in an active discrimination oddball task adults would show increased p3 amplitude for low-frequency target images occurring amidst standard (high-frequency) images of highly restorative environments versus when standard images are of lowly restorative environments or a solid brown tile, and that naturalness would not interact with restorativeness such that targets amidst restorative natural environments elicit p3's that are no stronger than targets amidst restorative built environments. Results showed p3 amplitude was greater, and latency earlier, for HR standard stimuli, rather than targets, which was unusual for the oddball paradigm but is explained within the framework of ART according to standard stimulus content. Also, LPP activity was only different between one occipital channel and three frontal channels between 600 ms and 1000 ms post stimulus onset, but greater in the nature stimulus group than the built between 1000 ms and 2000 ms post stimulus onset. This finding is consistent with previous research and interpreted to mean that natural stimuli are more pleasant and arousing than built stimuli. Limitations and future directions are also discussed.

DEDICATION

This dissertation is dedicated to…

My son, Banahari Lucca Salif. No matter how hard it may feel to do something, not doing it is so much harder. I love you.

My partner, Adriana Caputo. All I can possibly say is thank you. I could scour my eccentricities for lifetimes and still not be able to imagine something you and I can't do. I love you.

Women, femme, trans, and gender nonconforming scientists and scholars. Without you, I would not exist, both literally and professionally, and neither would the bulk of human knowledge about ourselves, the universe, and our place in it. Thank you.

Every dream, and every odd beaten, by every member of the African Diaspora, past, present, and future. I could never have done this without you. *Our Lives Matter.*

… and to afou, who never ceases to amaze.

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All of these acknowledgments are to say, it takes an entire village to raise a scientist, no exceptions.

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CHAPTER I

INTRODUCTION

An effect of natural scenery, versus built (*i.e.* urban, humanmade), as restoring and/or improving performance on tasks requiring sustained focus has been shown in neurotypical (presumed or confirmed) adults (Berman, Jonides, & Kaplan, 2008; Berto, 2005; Hartmann & Apaolaza, 2013; Lee, Williams, Sargent, Williams, & Johnson, 2015; Mayer, Frantz, Bruehlman-Senecal, Dolliver, 2009; Tennessen & Cimprich, 1995), children (Berto, Pasini, & Barbiero, 2015), and elderly people (Gamble, Howard, & Howard, 2014; Ottoson & Grahn, 2005). This effect is not only robust in that it has been well replicated, but also in that it has been shown in children with Attention-Deficit/Hyperactivity Disorder (ADHD; Kuo & Taylor, 2004; Taylor & Kuo, 2009, 2011; van den Berg & van den Berg, 2011).

Kaplan and Kaplan (1989), and Kaplan (1995), set the framework for this line of research by introducing attention restoration theory (ART). The theory explains that, as a function of several qualitative components, environments will be more or less restorative of depleted attentional resources. They postulated that natural environments would be higher in this restorativeness than built environments. Perceived restorativeness, as assessed by the Perceived Restorativeness Scale (PRS; Hartig, Korpela, Evans, & Gärling, 1997) or its short version (PRS-short; Berto, 2005), is the degree to which participants subjectively rate an environmental stimulus as likely to be restorative based on their perceptions of it possessing the aforementioned components (described below).

To date, only a few studies have used neuroscience and psychophysiology to investigate functional neural correlates of attention restoration. They used electroencephalography (EEG) to specifically identify neural correlates of affect differences in natural versus built environments, finding that green spaces lower frustration, engagement, and arousal with greater "meditation" (Aspinall, Mavros, Coyne, & Roe, 2011; Roe, Aspinall, Mavros, & Coyne, 2011). However, these studies had limitations with respect to instrumentation in that the researchers did not have access to raw data and so were confined to less rigorous data pre-processing techniques than are standard for EEG. Thus, their interpretations are restrictedly inconclusive.

Chang, Hammitt, Chen, Machnik, and Su (2008) explored alpha brainwave activity (with EEG), as well as facial electromyographic (EMG; facial muscle tension which is reflective of emotional and mental stress) and blood volume pulse (BVP) responses, during 10-second exposures to 12 environmental images which were hypothetically selected to be particularly high on one of the four restorative components (two components, 'extent' and 'coherence' were combined; component description below) compared to a "non-viewing" solid blue control image presented for 10 s between slides. Generally, they found greater alpha brainwave power in left and right hemispheres in all component-particular image conditions compared to the non-viewing image. The other physiological measures also indicated an improved state while viewing all the component-particular image categories compared to a non-viewing condition.

These findings are informative with respect to psychophysiological correlates of attention restoration. However, there are some limitations to interpretation such as a lack of any other scene category than natural, no correlations between dependent measures being reported, and blue having since been shown to induce positive emotions in a

Chinese sample (Wang, Shu, & Mo, 2014). Addressing such limitations to drawing conclusions must be a priority for future investigations.

One other study recorded EEG data while participants viewed fractals that fell into two categories, exact and statistical, which corresponded characteristically to manmade and natural scenes, respectively. Exact fractals are those in which all elements recur at exactly the same rate. Statistical fractals are patterns within which elements have certain probabilities of recurring. In nature, fractal patterns are statistical, such as the branching pattern in trees (Hägerhäll, Laike, Küller, Marcheschi, Boydston, & Taylor, 2015). They found that alpha band (8-15Hz, associated with relaxed alertness and meditative states; Aspinall et al., 2013) power increased as the fractals gradually transitioned from exact to statistical types; suggestive of an attention restoration effect (Hägerhäll et al., 2015). Schertz, Kardan, and Berman (2020) found that viewing images from which overt semantic information had been removed, but which still contained low-level visual information (i.e. scrambled edges) evoked similar thoughts as the images retaining semantic content. Fractalness is also low-level visual information. These findings are promising for further exploration of frequency band as indicative of cognitive load within different environments. But, there lacks a more technical examination of attention restoration's neural correlates that can be done using event-related potential (ERP) methodology. The study reported herein used a sample of neurotypical adults to expand on initial work our group has done with respect to such an examination.

Using fMRI, Tang and colleagues (2017) found that natural scenes, which their participants rated as most restorative compared to urban, were responded to with greatest activity in visual and attentional focus associated brain areas. Specifically, activity in the left and right cuneus different when comparing urban versus mountain and urban versus water landscapes. Further, in the urban versus water landscape comparison, the right cingulate gyrus and the left precuneus were activated. These structures are part of an area significantly involved in the focusing of attention.

Natural scenery has also been found to have a recovery effect from stress. Ulrich and colleagues (1991) conducted a study of 120 participants in which they watched a stressful film and then were exposed to a video of either natural or urban scenery. Using the dependent physiological measures of heart period, muscle tension, skin conductance, and pulse transit time, they found that, across these measures, stress recovery was faster after watching the natural scenery compared to the urban scenery. They interpreted these findings from a psycho-evolutionary perspective in that natural scenery facilitating a return to positive emotional states and positive physiological changes would be accompanied by improved sustained attention.

Attention Restoration Theory

The premise behind ART is that restorative environments engage involuntary (exogenous) attention – that which is attracted by stimuli in one's environment in a bottom-up fashion (James, 1892). This engagement affords the effortful, distraction-inhibiting mechanisms of voluntary (endogenous, directed) attention – that which is controlled in a top-down fashion according to immediate, task-relevant goals (James, 1892) – an opportunity to rest (Kaplan & Kaplan, 1989; Kaplan, 1995). This idea hinges upon the well supported hypothesis that voluntary attention relies upon finite cognitive resources that inevitably deplete, resulting in directed attention fatigue (DAF). It was foundationally tested by a paradigm in which adults' attention was taxed by the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) prior to a slideshow of either natural (collectively rated as significantly more restorative) or built scenery, or geometric patterns, before performance on the SART was measured a second time (Berto, 2005). The SART is a lengthy, mundane go/no-go task in which participants must withhold response in the case of a rare stimulus that is similar to all other task stimuli. The finding was that after a nature-scene slideshow, performance on the SART had improved at post-test from pre-test. But, after a built-scene or geometric pattern slideshow, this was not the case.

Restorative Components

High restorativeness comprises high levels across five componential psycho-environmental characteristics as outlined by Kaplan and Kaplan (1989) and Kaplan (1995). These are fascination, extent, coherence, being away, and compatibility. In some studies, extent and coherence have been assessed as one component. Herzog, Maguire, and Nebel (2003) assessed the prediction of perceived restorative potential (PRP) by ratings of each of the components (combining extent and coherence as one component). Regression analyses found significant prediction of PRP by being away and compatibility. Further, Felsten (2009) found that perceived restorativeness scores, computed by averaging ratings of campus scenes with varying views of nature across the same four components used by Herzog and colleagues (2003), were correlated strongly (r's $\geq .88$) with a single-item measure of overall perceived restorativeness.

'Fascination' refers to an environment's ability to capture involuntary attention. Fascination is further separated into 'soft' fascination and 'hard' fascination (Kaplan, 1995). Though both involve the bottom-up engagement of involuntary attention, they differ as a function of the resulting cognitive load. That is, hard fascination (*e.g.,* watching auto racing or television) occupies working memory more completely, leaving little room for reflection, while soft fascination occupies working memory partly and thus allows for the processing of lingering, unresolved thoughts without a drain on attentional resources (Basu, Duvall, & Kaplan, 2018; Kaplan, 1995). In fact, evidence has been shown that a walk in nature specifically engages soft fascination (Basu et al., 2018).

‘Extent’ refers to the environment offering sufficient perspective such that the attention it attracts is maintained for a time long enough that restoration may occur. If the environment’s engagement of exogenous attention is fleeting, restoration cannot take place sufficiently (Kaplan, 1995). That is, environments low on extent do not engage exogenous attention long enough for endogenous mechanisms to recover.

‘Coherence’ refers to the environment’s semantic holism. In the past, it has been combined with Extent with the idea that an environment making sense in an holistic, Gestalt fashion, can be continuously visually explored more naturally. Conversely, if an environment is visually or otherwise incohesive, endogenous attention is likely to become engaged in effortfully attempting to make sense of it, further taxing attentional resources (Kaplan, 1995).

Being away’ is the degree to which the environment is conceptually and/or physically distinct from the one in which fatigue was induced. That is, as long as being away from the fatiguing environment is experienced by the subject, restoration can take place (Kaplan, 1995). For example, physically, someone may leave the context of their resource-demanding task and take a break in a different place. Or, conceptually, someone may close the application on their computer they are using for work, and open one for entertainment or relaxation on the same computer, in the same environment.

And lastly, ‘compatibility’ is the degree to which a potentially restorative environment is suited for an individual’s restoration goals. Simply put, an environment must be compatible with the activities a person associates with restoration (Kaplan, 1995). For example, a person who enjoys relaxing in natural environments may not find an urban coffee shop or museum to be very restorative.

The PRS was designed to assess the restorativeness of environments (or their virtual representations) as rated by participants. The scale was originally developed with 17 items representing four components, conceptually lumping coherence and extent. Berto (2005) adapted a short version consisting of five items (one for each component, separating coherence and extent; PRS-short), to facilitate collecting ratings on a larger set of stimuli (*e.g.*, 20 environmental photos).

For instance, in selecting stimuli to test ART, Berto (2005) sourced 100 scenic color images of built and natural environments from “magazines and existing stimulus materials” (pg. 251). The images were divided into 5 subsets of 20 and rated by 8 participants per subset using the PRS-short. The images were described as “representing lakes, rivers, seas, hills, woods, orchards, forests, city riversides, city streets, industrial zones, housing, porches, urban areas, and skyscrapers” (pg. 251). Though Kaplan and Kaplan (1989) theorized that natural environments would be most likely to highly comprise the 5 restorative components, they did not explicate that all natural environments should be highly restorative or that all restorative environments should be natural; nor were such requirements, following consistently, for built and low restorative environments. However, having set cutoffs on the 0-10 scale for high perceived restorativeness (≥ 6.5) and low perceived restorativeness (≤ 3), Berto's (2005) ratings showed all of the images in the high restorative range to be natural and all of the images in the low restorative range to be built.

In further replications, significantly greater perceived restorativeness of natural over built environments has been shown via ratings, by adults (Berman et al., 2008; Berto, 2007; Lee et al., 2015) and children (Berto et al., 2015), and experimentally, showing improved attentional performance after nature-environment exposure in adults (Berman et al., 2008; Gamble et al., 2014; Hartmann & Apaolaza, 2013; Lee et al., 2015; Mayer et al., 2009; Ottoson & Grahn, 2007; Tennessen & Cimprich, 1995) and children (Berto et al., 2015). However, beyond Berto's (2005) initial assessment, the studies that used ratings only did so as a manipulation check for natural and built environmental stimuli that had already been selected. Thus, it had only been initially tested (using images subjectively selected by the researcher for their likelihood to be restorative) whether naturalness is inherently restorative, or these dimensions are separate.

However, images in a larger stimulus set (418 images), initially sourced by crowd solicitation via social media, have been categorized as nature or built and rated on the PRS-short for use in a study that tested for implicit discrimination between natural and built images using ERPs (Mahamane et al., 2020). Within this set, there was a significant positive correlation between naturalness and restorativeness ($r = .376$, $p < .001$), suggesting that while these characteristics co-vary, they also vary independently.

Recent Reviews

Berto (2014) published a review of literature addressing the effects of exposure to nature in aiding recovery from stress (Stress Reduction Theory; SRT) and mental fatigue (ART). Her synthesis of the literature highlights a clear pattern across multiple paradigms supporting both SRT and ART. She pulls from physiological (*e.g.,* electromyography, skin conductance, and cardiac response), behavioral (discipline, concentration, and delayed gratification), and neurological (EEG and fMRI) findings that consistently suggest decreased stress, improved self-regulation, greater alpha frequency power, and greater activity in the anterior cingulate and the insula – brain areas associated with empathy and altruism – for people who were exposed to real or virtual natural environments. She concludes by pointing out that several questions must still be addressed. For example, considering adaptation theory, that people grow accustomed to their environments, do people who live surrounded by nature require greater exposure to experience the benefits of stress reduction and attention restoration? Longitudinal studies should be employed to address this question.

A systematic review by Ohly and colleagues (2016) included 31 studies that met the following requirements: a) were natural experiments, randomized investigations, or pre-post measurements; b) compared natural and non-natural/other settings; and c) used objective measures of attention. The question guiding their review was, "What is the relative attention restoration potential of natural settings compared to other settings?" They pooled effect estimates across investigations and compared attention outcomes at "post" measurements between groups exposed to natural settings and groups exposed to non-natural settings. Eleven objective measures of attention were represented throughout the studies included in the meta-analysis. Of these, the only measures that showed improvement for groups exposed to nature were the digit span forward, digit span backward, and the trail-making task (B version). All three of these tasks are demanding of working memory. These results led the researchers to mixed conclusions. While the three tests showing significant group differences across studies all relied on working memory, other tests of working memory did not show differences. Also, digit span backward is more demanding than digit span forward. The researchers acknowledged that a limitation of their review was the heterogeneity of stimuli, methodology, and tasks across the studies. In fact, multiple tasks represented were only actually employed by 2 of the studies included in the meta-analysis. They call for the ART community to establish consensus regarding which measures of directed attention should measure attention restoration most appropriately, and then use these measures consistently across studies.

In response, Stevenson, Schilhab, and Bentsen (2018) published a follow-up systematic review to Ohly and colleagues' (2016) describing their attempt to find relevant cognitive measures of elements of directed attention specifically sensitive to the restoration effect. They conducted a search for peer reviewed research articles that were published since July 2013, when Ohly and colleagues (2016) conducted their search. Further, articles had to meet the following requirements: a) were experimental in nature; b) used a natural environment or natural stimuli; c) included an acceptable control or comparison environment; d) included objective outcome measures that derived from standardized cognitive tasks. The search was not limited by participant demographics, nor country, culture, or the presence of water in the environmental stimuli. This search resulted in 46 separate studies, from 42 publications, which were included in their systematic review.

The systematic review revealed that the majority of the studies were conducted in western countries (Europe, 43.5%; North America, 32.6%; Australia, 2.2%; New Zealand, 2.2%; and Asia, 19.5%). The youngest sample had a mean age of 4.53 years and the oldest 69.1 years. 54.3% of the studies used real physical exposure to the environmental conditions and 45.7% used virtual exposure, such as photographs. In the real-environment exposure category, some participants were instructed to engage more actively (*e.g.,* hiking, cycling) and some were instructed to engage more passively (*e.g.,* viewing natural environments). Virtual exposure was used 55.3% of the time in randomized-controlled trials, with the remainder of those trials being real-environmental exposure. Only three studies were included that were quasi-experimental in which environmental exposure was unable to be randomized. One of the virtual exposure studies investigated sound, rather than visual stimuli. In three virtual exposure studies, stimuli were supplemented by imagining being in the environment or mindfulness meditation. Exposure duration ranged from 40 s – 3 hrs for single exposure designs, and up to several weeks for a series of exposures. In the quasi-experimental studies, durations ranged from 6 days to several years.

In determining the cognitive domains most sensitive to environmentally driven restoration effects, studies from Ohly and colleagues' (2016) review that reported baseline measures of cognitive performance were then included by Stevenson and colleagues (2018) for their cognitive performance meta-analysis. They reported results in eight sections according to the cognitive domains assessed by the outcome measures represented in their review: working memory, attentional control, vigilance, cognitive flexibility, impulse control, processing speed, "and other emerging domains", which were the Delay of Gratification Task, Taylor's Aggression Paradigm, and the Graduate Record Exam (GRE). These last three assessments were each the only ones in the review in their respective domains. As such, meta-analyses across multiple studies of those domains were not possible. Across all levels of baseline balance, the researchers found improvement in working memory, attentional control, and cognitive flexibility following exposure to natural environments, with low to moderate effect sizes. However, the effect on attentional control was not detected when only studies with fully balanced baseline measures were used. It is of note that actual exposures showed to enhance the restoration effect compared to virtual exposures, but the studies with natural exposures typically had longer exposure durations as well, so that particular finding is inconclusive. The authors conclude by arguing that directed attention as a construct, and the restoration effect, need to be updated for future research based on these results taken in hand with Ohly and colleagues' (2016) results. Finally, the authors acknowledge that, while each domain that showed an effect by nature exposure requires directed attention to maintain focus on task-relevant stimuli and inhibit attention to task-irrelevant stimuli, we cannot know from these reviews how much is recruited for each domain compared to the others.

These recent reviews of research on ART have been valuable in illuminating a more precise direction for this area of work to pursue. In taking on the task of collecting and recruiting studies of a theory in which the relevant constructs have not been operationalized consistently well, and the paradigmatic approaches have been wide and varied, these review authors have made significant headway toward a more robust framework by revealing consistencies in which cognitive domains are sensitive to these restoration effects. For example, even in concluding their review, Stevenson and colleagues (2018) provided clearer construct tenets of directed attention.

EEG and ERP's

EEG uses electrodes (channels) placed directly on the scalp to record electrophysiological activity in cortical regions of the brain. Data collected via EEG is commonly used in two types of analyses: spectral, which assesses the power of different neuro-electric frequency bands under experimentally manipulated conditions, and time series, which analyzes mean electrophysiological characteristics (*i.e.,* amplitude and latency) of cortical activity following specific events (stimuli). These time-locked samples of activation corresponding to events are ERP's. Thus, an ERP is the activation signature seen from stimulus onset to a theoretical or precedential end time point, depending on the variables being investigated. ERP components are well-documented recurring ERP features that are empirically supported as corresponding to various cognitive and/or affective processes. The study reported herein focused solely on ERP analyses with respect to EEG data.

Components of Interest

The p3. The p3 ERP component is the highest positive-going wave peak occurring 270-500 ms after stimulus onset and has shown to be an index of stimulus discrimination and attentional resource allocation (Polich, 2007). The p3 is traditionally elicited using variations of the oddball paradigm: repetitions of an infrequent stimulus occurring randomly (or pseudo-randomly) among repetitions of a frequent stimulus. Participants can be instructed to respond, either mentally (*e.g.,* "count the number of (targets)") or behaviorally (*e.g.,* "press the button whenever you see a (target)"), so that stimulus processing is active, or to not respond (*e.g.*, "please view the images on the screen") so that stimulus processing is passive.

The p3 originates in frontal- and parietal-central locations, reaching maximum strength in parietal regions (Polich, 2007). p3 peak amplitude – the highest amplitude in the post-stimulus latency window relative to the immediately pre-stimulus baseline activation average – is greater and earlier when active task demands are low and more attentional resources are available for recruitment. Polich (2007) explains that arousal level dictates the available amount of such finite resources. When task demands are high, peak amplitude is lesser and later. But, in the case of increased cognitive efficiency, amplitude may decrease without an increase in peak latency (Pfueller et al., 2011). And, generally, amplitude is usually lower for passive than active tasks due to extraneous non-task events recruiting resources away from task stimuli (Bennington & Polich, 1999).

In sum, elicitations of the p3 ERP component under restorative stimulus conditions may reflect attention restoration. However, there is a missing link between ART and the model of p3 elicitation described by Polich (2007). The attentional resources Polich refers to are analogous to those underlying Kaplan and Kaplan's (1989) directed attention. However, ART does not account for arousal. And, Roe and colleagues (2013) found built scenes – usually found to be less restorative than nature – as associated with the "arousal" EEG component of their instrument and nature to *decrease* arousal. Again, given limited access to raw data, their results are inconclusive. Further work is needed to evaluate whether this inter-theory disconnect is simply reflective of non-communication between areas of research or an actual deficiency of one of the theories to account for conditional fluctuations in attentional resources. Expectedly, some relationship between attention restoration and arousal exists and could be revealed by incorporating restorative stimuli into a p3 oddball task could elucidate some of this ambiguity.

Late Positive Potential (LPP). The LPP is a positive-going ERP component in the window from at least 400 ms post stimulus onset until stimulus offset which is indicative of sustained attention to affective stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Foti, Hajcak, & Dien, 2009; Hajcak, MacNamara, & Olvet, 2010; Hajcak & Olvet, 2008; MacNamara, Ferri, & Hajcak, 2011; Schupp, Junghöfer, Weike, & Hamm, 2003). It is maximal over centro-parietal areas and thought to be an index of prolonged stimulus processing following the p3 peak. Specifically, greater LPP amplitude is associated with processing emotionally valent (positive or negative), versus neutral, stimuli. Based on an extensive body of converging evidence that dorsolateral prefrontal cortex (DLPFC; associated with working memory recruitment) activity attenuates limbic system activity in response to emotional stimuli, MacNamara and colleagues (2011) showed that LPP amplitude, is greater in response to aversive versus neutral stimuli, and under low versus high cognitive load.

Relationship between p3 and LPP. A recent review addressed questions about the relationship of p3 and LPP. More specifically than arousal, Hajcak and Foti (2020) argue that LPP is activation is modulated by the motivational significance of a stimulus to survival, evolutionarily speaking, or a task at hand. That is, as previously described, stimuli that we have either a negative or positive response toward show strong LPP activation compared to neutral stimuli. The authors argue that such negative or positive stimulus valence evokes avoidance or approach behavioral responses. Further, it has been found that oddball paradigms with longer stimulus presentation durations (*e.g.*, 1000 ms) elicit more drawn out p3's that remind of LPP's elicited in emotional viewing tasks. However, oddball paradigms with brief stimulus presentation durations (*e.g.*, 200 ms) elicit more typical p3's (Gable & Adams, 2013).

Previous ERP Research in Environmental Cognition

A study by Rousselet, Thorpe, and Fabre-Thorpe (2004) was conducted to push the visual system to its limits by instructing participants to note whether any of 1, 2, or 4 nature scenes, presented simultaneously for only 26ms, contained one or more animals. Following stimulus offset, participants would have 1000 ms to raise their finger from a pressure pad to indicate they had seen an animal. If after 1000 ms they did not raise their finger, their response was recorded as a no-go response. EEG data were recorded during the task and the ERPs following each stimulus presentation were analyzed.

Behaviorally, they found a main effect of the number of images to process on mean accuracy, with the greatest accuracy during 1 image compared to 2 or 4 and greater accuracy with 2 images than 4. A parallel main effect was found for response time with all pairwise comparisons being significant below the .05 level where 1-image presentations were responded to the fastest, then 2-, and then 4-. Electrophysiologically, though they did not analyze the p3 and LPP components, they found that the initial occipital amplitude was no different between target trials (animal present) and distractor trials (animal not present) for the 1- and 2-stimulus conditions. However, for the 4-stimulus presentations, there was a clear difference in amplitude between target and distractor trials. Amplitude latency, however, was longer in the 1-stimulus condition than in the 2-. But, the longest was still in the 4-stimulus condition. All of these results, taken together, indicate much greater difficulty in processing 4 scenes simultaneously than 1. The relevance of this study to the present study is its use of nature scenic photographs as stimuli for ERP research. Scenic stimuli are more complex than most conventional p3 stimuli that are often simple shapes or tones. In the present study, the scenes were not categorized so specifically for a particular constituent, such as an animal, but simply for whether it is a scenic image or a geometric pattern. Based on these findings, it was not of concern that the present study's task or stimuli difficulty would disrupt the investigation of interest.

Vogt, Herpers, Scherfgen, Strüder, and Schneider (2014) had 22 participants both moderately cycle and rest passively (on the bike while "driven" through a virtual environment; VE) in each three different city street VE conditions (none, front screen only, and surround) that each foster a different sense of presence. Condition order was randomized within participant and each condition lasted 5 minutes. To assess cognitive performance, participants were presented on the front screen of the VE with randomly ordered, equal difficulty math problems. They responded with buttons near their hands on the handlebars. Each response placed a marker in the EEG data time course corresponding to the moment it occurred during EEG recording.

Vogt and colleagues (2014) found no significant difference across conditions in cognitive performance on the math task. Electrophysiologically, they found an interaction effect of VE and regions of interest (ROI) such that amplitude of the N200 ERP component (219.50 ms post stimulus onset ± 30.27ms) increased in frontal, parietal, and occipital ROI from control to surround VE conditions. N200 amplitude at central ROI were not modulated by VE. N200 latencies at frontal and occipital ROI increased from control to surround. Regarding the p3 component (318.50 ms post stimulus onset ± 46.76ms), a VE x ROI interaction showed that amplitude increased at frontal, central, occipital, and parietal ROI from control to surround. p3 latencies decreased from front VE to surround at central ROI and from control VE to front at parietal ROI. They did not find exercise to benefit cognitive performance over rest but did contribute to the sense of presence in the VE and thus increased cognitive load. The authors concluded that the neuroelectric differences found could be adaptations to compensate with neuronal resources to avoid performance impairment in VE. Of course, the study only uses a city street VE and control without a natural scene VE as their aim was primarily the effect of exercise in a VE environment on cognitive performance. Real world natural and built environmental conditions have been tested with mild exercise (*i.e.* walking) and shown a benefit of natural compared to built environments (Berman et al., 2008).

Li, Zhou, Kong, and Guo (2020) had participants complete an active-response oddball task before and after a virtual ART program delivered via a virtual reality head-mounted display (VR-HMD). There were two types of instructions for the virtual reality experience, one was called "ST-ART" in which participants could move their limbs and torso to more easily engage with the VE. The other was "CL-ART" in which they had to remain still. By recording EEG during both types of VE tasks, the researchers could control for the negative impacts of movement on EEG. They found that participants' p3 latency to target stimuli was shorter in the post CL-ART oddball task than the pre-. Also, the RT difference from oddball Time 1 to Time 2 was positively correlated with p3 latency as well. These results suggest greater attentional capacity following a virtual attention restoration intervention. However, the authors do not report statistical analyses of p3 amplitude, or any metrics associated with LPP.

Finally, an initial study of nature/built implicit discrimination assessed by P3 elicitation used a passive, two-stimulus oddball paradigm and focused on the p3 and LPP components (Mahamane et al., 2020). The task was a within-subjects design such that sixty neurotypical participants viewed 100 one-second, randomly ordered scene presentations in each of two trial blocks that were in counterbalanced order across participants. In one block, nature images were standard ($f = 80$) and built images were rare ($f = 20$), with these roles then being reversed in the other block. Because nature stimuli had been rated as significantly more restorative compared to built ($t(387) = 7.496$, $p < .001$, $d = .79$) using the PRS-short, it was hypothesized that when nature images were standard, and built images were targets, p3 peak amplitude would be greater and earlier, suggesting improved attention via restoration in this condition, than when built images were standard with nature targets. That is, the standard photo category was expected to affect p3 signal strength and latency during target trials – which consisted of the opposite category. It was also hypothesized that average LPP amplitude for targets would be greater in the nature-standard condition versus the built-standard condition as attention restoration should be a pleasant experience.

Mahamane and colleagues (2020) operationalized p3 as the average activation, compared to pre-stimulus baseline, between 200 ms and 400 ms post stimulus onset (driven by Polich, 2008). Findings revealed that p3 amplitude for oddball stimuli was significantly higher than standard stimuli ($t(59) = 2.882$ $p = .006$, $d = .372$) within the nature-standard condition; but not within the built-standard condition ($t(59) = 1.699$, $p =$

.094, d = .219). No p3 amplitude differences emerged for targets between conditions. This finding was interpreted as implicit discrimination. However, the stimuli were permissively included based on data from a scene categorization task such that any images categorized as "nature" by 60% or more of the 51 participants were included in the experiment as nature stimuli, and images categorized as "nature" by 40% or less were included as "built" stimuli. This may have resulted in too much diversity in the stimuli with respect to naturalness, weakening p3 amplitude, and thus masking a stronger discrimination effect or between-block target differences.

Regarding the LPP, this was defined as the mean amplitude in the window from 550 ms to 930 ms post stimulus onset (driven by MacNamara et al., 2011). Mahamane and colleagues (2020) found that LPP average amplitude for oddball scenes, when nature scenes were standard, was lower than that for oddballs when built were standard with, albeit, a small effect size ($t(59) = 2.069$, $p = .043$, $d = .267$). While perceived restorativeness was assessed for the stimuli prior to the study's conceptualization, emotional valence was not. However, Roe and colleagues (2013) found that, across a large photo set, nature images were rated as significantly more positively valent than urban images, which were essentially rated as neutral. Based on this finding, it could be that Mahamane and colleagues' (2020) finding is due to greater positive valence of nature versus built images regardless of standard versus oddball status within the paradigm. Thus, there are several methodological areas of this previous investigation upon which the present study intends to improve. Nonetheless, the fact that a significant and marginally significant difference was seen between standard stimuli and oddballs within each condition, even with these limitations, suggests that the sample still implicitly differentiated these categories.

Stricter inclusion criteria for scene stimuli should be used to create more divergent stimulus sets with respect to naturalness. With the loose categorization thresholds used previously, many photos were included in each category that visibly contained elements of the other (*e.g.*, a row of resort condominiums along a beach front classified as "nature"). Stimuli should also be included to represent restorativeness extremes irrespective of naturalness, given that these dimensions are not perfectly correlated.

Another change, to investigate the effect of scene characteristics on p3 as an index of attentional resources, would be the use of neutral – that is, non-scene – visual stimuli as oddballs instead of using scenes from the opposite category (*e.g.*, a geo-pattern image, instead of a built scene, when nature scenes are standard). While Mahamane and colleagues (2020) found p3 amplitude difference between oddball and standard images in the nature condition, the effect may have been weakened by standard and oddball images both belonging to an overall "scene" category and thus oddballs less perceived as "oddballs". Conversely, because standard stimuli were each different individual images within their respective categories, they could be experienced as distinct from one another even while belonging to the same scene category; potentially increasing p3 signal strength for standard stimuli as well. Both issues, along with loose naturalness category inclusion thresholds, likely contributed to a much less dichotomous distinction between standard and target stimuli. It must be noted that this methodology represents an open question in p3 research: can multiple category exemplars serve as standard stimuli representing one standard category vs. an oddball category that also comprises multiple exemplars? Traditional p3 methods use one stimulus as the standard and another single stimulus as the target to test how paradigm characteristics (*e.g.*, inter-stimulus interval (ISI) duration).

Also, an active task, producing greater p3 amplitudes, should more visibly show modulation without hitting a floor as well as index attention (as required for task performance) rather than novelty. Bennington and Polich (1999) showed that in a visual two-stimulus oddball task, p3 amplitudes in a passive paradigm were much smaller than in the same task when participants were instructed to respond to oddballs (active paradigm).

In this study, the researchers also employed a much more controlled oddball task in which target frequency was even lower than the precedent of 20% and sequence position relative to standard stimuli was controlled (Lammers & Badia, 1989; Polich, 1989). Specifically, stimuli were distributed into twenty 10-trial sequences such that the first six images were always the standard stimulus and one of the last four was the target. Across the 20 sequences, the target would appear 5 times each in the 7^{th}, 8^{th}, 9^{th}, and 10^{th} position of the sequence, albeit in random order. This design ensures that, unlike in purely randomized order, target stimuli could not appear back-to-back or in runs. This feature offers an important control as subjective perception of greater target probability – which can be caused by consecutive targets (Sommer, Matt, & Leuthold, 1990) – attenuates the p3 signal and delays peak latency (Johnson & Donchin, 1980).

The Present Study

Given the consistent evidence supporting ART, and the lack of conclusive evidence to understand ERP correlates of scene naturalness and attention restoration, the study presented herein investigated such correlates in neurotypical adults. Specifically, this study was conducted to address the following questions: 1) Are naturalness and restorativeness inherently related constructs in attention restoration processes, or can they be effectively delineated? 2) Can attention restoration be validated neurophysiologically using rigorous ERP methodology? This general population was chosen because the study addressed open questions in both attention restoration and ERP research. The paradigm was an active, two-stimulus oddball task to elicit the p3 and LPP ERP components to investigate modulation between environmentally and restoratively defined standard stimuli.

This study investigated the effect of high and low restorative, and natural and built, standard stimuli on p3 and LPP topography in a two-stimulus, active oddball task, in a mixed-ANOVA design. The 10-trial-sequence oddball paradigm, and EEG recording, was used to investigate these components' modulation by the above factors at frontal, orbito-parietal, temporal, and occipital regions of interest (ROIs). One geometric (geo-) pattern target stimulus was presented at low frequency within a sequence of a repeating standard stimulus. That is, standard trials within each condition were the same image for one participant. However, each of six highly restorative nature (HR-N) images (with restorativeness level according to the online ratings described above) was matched on restorativeness with one of six high restorative built (HR-B) images, and each of six low restorative nature (LR-N) images was matched with one of six low restorative built (LR-B) images. These pairs were planned to rotate across participants 8 times throughout each group so that naturalness was a between-groups factor and restorativeness was a within-groups factor. This standard stimulus repetition scheme within participant was used to avoid novelty confounds of p3 amplitude as a function of within-block standard stimulus diversity. This method was chosen so that even though each participant sees one stimulus for each block to eliminate within-block standard stimulus diversity, if summary effects were observed across the sample, conclusions could be drawn for these stimuli as categories. Further, long target-to-target intervals (TTIs; produced by the controlled occurrence of targets within sequences of stimuli), as well as a very low (10%) target frequency rate, have shown to produce larger amplitudes than short TTIs because the p3 generation system has sufficient time to recover, eliminating p3 signal attenuation over time (Gonsalvez & Polich, 2002).

This paradigm was also designed to be more conducive to attention restoration as participants invariably saw one standard stimulus throughout the condition and images were presented for two seconds each. Because attention restoration works by involuntary attention being engaged (fascination) long enough (extent) for directed attention resources to replenish, extremely brief, flashy presentations of varying images would not theoretically result in restoration. Ulrich (1983) reviews some findings of a positive statistical relationship between the strength of the restoration response and viewing time. Lee and colleagues (2015) found that a single 40-second viewing of a green roof environment produced an attention restoration effect in their participants. Forty seconds is longer than typical stimulus durations in computerized experiments but likely much shorter than real world environmental exposures. In the present study, the presentation characteristics should have allowed the extent and coherence image traits of restorative environments to maintain involuntary attention long enough for restoration to occur. Further, target rarity and controlled sequencing should produce generally strong p3 potentials within which to observe effects.

The task included three blocks each comprising 24 sequences. Each block had a different standard stimulus with respect to perceived restorativeness/naturalness. Subjective preference ratings, including attractiveness, potential to visit, valence, and arousal, were collected for the selected stimuli, from the ERP participants once they completed the oddball task, to potentially explain LPP amplitude differences that may emerge between conditions to gain insight into the explanation of such differences previously observed. Also, these ratings were used to confirm that the experimental sample experienced the images as intended based on their selection from the image pool rated by an online sample.

The hypotheses are as follows: 1) p3 peak amplitude would be greater – and peak latency earlier – for targets in HR standard stimulus blocks compared to LR and the brown tile (Br) control block; particularly in frontal and parietal ROIs with parietal showing the strongest activation, as has been consistently documented for active target discrimination tasks (Polich, 2007). 2) Behavioral data would reveal faster RTs to targets in the HR blocks than those in LR and Br blocks. 3) Given that LPP amplitude has shown to be an index of affective processing, there is expected to be a significant interaction between restorativeness and naturalness with respect to LPP activation. Specifically, HR-N images were expected to produce the greatest average LPP amplitude in the parietal ROI than HR-B, LR-B, LR-N images, or Br, as informed by Roe and colleagues' (2013) finding that nature images were more positively valent than urban images. Previous findings have also shown restorativeness and preference to be highly positively correlated ($r = .82$, $p < .01$; Berto, 2007). If differential LPP amplitude is observed for presumably valence-neutral geo-pattern targets between condition, Mahamane and colleagues' (2020) original hypothesis that restoration would affect target LPP, would also be supported with greater conclusiveness. These two explanations for LPP differences for scenic and geo-pattern stimuli are not mutually exclusive. 4) Subjective preference ratings were expected to be higher for HR vs LR and N vs B images.

CHAPTER II

METHOD

Participants

Rating Sample

Four hundred and eighty-seven, self-reported neurotypical adults (305 women, 169 men, 1 intersex person, 2 transgender men, 1 transgender woman, 8, gender non-conforming, and 1 preferred not to answer; age range = 18-37, $M = 24.97$, $SD = 3.13$) were recruited via Amazon Mturk to rate the images in the stimulus pool on the PRS-short and Roe and colleagues' (2013) subjective preference items. Recruitment was restricted to English speakers residing in the United States of America. Each participant was compensated 1.50 USD. This sample size produced between 53 and 67 restorativeness scores per image as the images were divided into 8 subsets for rating collection to be feasible logistically. The survey was programmed in Qualtrics, an online survey platform, to randomly assign participants to one of the 8 photo subsets. The rating procedures is described in detail below. Past research used groups of 8 per subset (Berto, 2005) or 6-9 participants per subset (Mahamane et al., 2020).

ERP Sample

Thirty-nine neurotypical, right-handed adults (25 women; age range = 18-29, $M = 20.97$, $SD = 2.51$) were recruited at Utah State University using the online SONA research participation system. This age range was intentionally restricted to 18-30 years because studies have consistently shown significantly decreasing parietal p3 amplitude after peaking around age 21, with the first significant decrease seen between age bins 20-30 and 35-45 (van Dinteren, Arns, Jongsma, & Kessels, 2014). Participants were assigned to the nature version (*n* = 21) or built version (*n* = 18) of the experiment based on the order in which they arrived for the study.

Originally, the target sample size was *N* = 96. This sample size was chosen because, while a minimum of 28 participants is necessary to achieve conventionally sufficient statistical power ($1 - \beta \geq .80$) for the within-subjects comparison between restorativeness conditions, at least 43 per group is needed to meet the same power requirement for the between-subjects naturalness comparison. The total of 86 was increased to 96 so that the respective six of the twelve stimulus pairs can rotate completely throughout each group eight times. However, the 2020 COVID-19 pandemic disrupted the further collection of data when the USU IRB placed a hold on all in-person data collection in human research at USU. Thus, the sample size collected was 60. Of these, 39 produced enough usable data after all artifact rejection and epoch removal due to participant errors.

At the time of online sign-up, participants were informed of the required age range, that they must be right-handed, and that they must have no formally diagnosed history of neurodevelopmental disorder. When they arrived at the lab for their appointment, handedness was confirmed using a questionnaire (Edinburgh Handedness Inventory: Short Form; Veale, 2013). Then, they were asked again to confirm their age and that they had no lifetime history of any formally diagnosed neurodevelopmental disorders (*e.g.*, ADHD). Left- or mixed-handedness, indicated by a score less than 16 on the Edinburgh Handedness Inventory: Short Form, or a history of any neurological diagnoses, disqualified individuals from participation. Handedness was controlled for because previous research has found that left-handed people show greater p3 amplitude, and earlier latency overall, compared to right-handed people. Target p3 amplitude was specifically larger in frontal and central areas (Alexander & Polich, 1995). Participants were compensated with course credit and 10 USD.

Materials

Subjective Ratings

Edinburgh Handedness Inventory – Short Form. Veale (2013) validated a short form of the Edinburgh Handedness Inventory (Oldfield, 1971) that consists of four items versus the original ten (see Appendix A) which are rated on a 5-point Likert scale regarding how often the participant performs that activity with their left hand (1) or their right hand (5). Ratings were then summed across the items. Left-handedness on this scale is represented by scores less than or equal to 8. Right handedness is represented by scores greater than or equal to 16. Scores of 9-15 represent mixed-handedness. This scale was administered upon arrival to ensure that all participants were right-handed.

Subjective preference ratings. Ratings were obtained with Roe and colleagues' (2013) items for 'image attractiveness', 'potential behavior' (desire to visit that scene), 'valence', and 'arousal' of all 16 stimuli. However, an extra item was added as a fifth Likert scale with anchors, Mentally Tired (1) and Mentally Energetic (10), to differentiate arousal physically and mentally to more accurately reflect its connotation regarding cognitive resource availability as relevant to p3 elicitation (Polich, 2007; Appendix B). For ratings of control and target stimuli, the word "picture" stood in for "place" in the items. Each image's score for each preference construct was taken from the average rating across participants on the item for that construct.

PRS-short. This measure, adapted by Berto (2005) from the original PRS contains five items, each corresponding to one of the environmental components of restoration (separating extent and coherence), to be rated on an 11-point Likert scale from 0 (Not at all) to 10 (Very much) indicating the "degree to which each statement describes the current picture" (Appendix C). In her report, Berto (2005) specified that this scale showed a Cronbach's alpha of .79 and considered this to be sufficiently internally consistent.

Stimuli

Experimental scene stimuli were selected from the 418-image pool used in (Mahamane et al., 2020). As they describe, images were crowd-sourced via Facebook and, for that study, had been rated on the PRS-short by 34 adults. However, given the size of the stimulus set, when these ratings were collected, images were divided into 8 subsets (6 sets of 52, 2 sets of 53) for which 6 – 9 participants rated each subset (some rated two sets on separate days). The present study includes more ratings that were previously collected so that at least 53 participants rated each subset (and thus each image). The largest group rating a subset contained 68 participants.

These images were also previously categorized by a different adult sample (N = 51; aged 19-38 years) as being either nature or built scenes in a dichotomous, forced-choice task. Participants were shown 418 images in randomized order, one at a time, in a self-paced computer program. This categorization procedure was necessary to understand how people perceive the naturalness of the images because many of the photos are composed of natural and manmade constituents to various degrees. Images were then classed into quintiles based on the percentage of participants who called each image 'nature' with cutoffs at every multiple of 20%. In their study, Mahamane and colleagues (2020) considered any image categorized as nature by 60% or more of the sample as a "nature" scene, and any image categorized as nature by 40% or less of the sample as a "built" scene. It is likely that one contributor to the previous study not finding a p3 effect was the amount of stimulus diversity in terms of naturalness that could be present within each category given these wide ranges of inclusion. Thus, for the present study, images were defined as non-hybrid nature scenes if they were categorized as "nature" by 80% or more of the participants, and non-hybrid built scenes if they were categorized as "nature" by 20% or less.

In the present study, five one-way ANOVA's were performed to compare between-group ratings from the ratings sample for each of the 5 images that were present in every subset. There were no significant effects of group on perceived restorativeness for any of the five subset-overlapping images ($\alpha = .05$). Similarly, five one-way ANOVA's were conducted per image common across all subsets for each of the five subjective preference items. One image showed an effect of group on valence ($F(7, 478) = 2.105$, $p = .042$, $\eta^2 = .030$) such that two of the eight groups significantly differed from one another as shown by post hoc comparisons ($p = .050$). The same image showed an effect of group on self-rated desire to visit the scene in the image ($F(7, 478) = 2.247$, $p = .029$, $\eta^2 = .032$). However, there were no significant between-groups differences revealed by pairwise comparisons at the .05 alpha level. Another of the common images showed a significant effect of group on self-rated perceived attractiveness of the image ($F(7, 474) = 2.161$, $p = .036$, $\eta^2 = .031$). No pairwise comparisons revealed significant between-groups differences. Finally, one more of the common images showed a significant effect of group on self-rated physical arousal ($F(7, 478) = 2.303$, $p = .026$, $\eta^2 = .033$). Once more, pairwise comparisons did not reveal any significant between-groups differences at the .05 level. These few significant effects all bore small effect sizes and only one showed there to be only two groups different from each other pairwise. Thus, it is not expected that these rare small differences meaningfully affected ratings such that they could not be used to select stimuli.

These perceived restorativeness scores and naturalness categorization rates were used to select stimuli and organize them into 12 matched pairs. This matching was conducted using log transformed perceived restorativeness ratings as a Shapiro-Wilk test revealed that the raw ratings of the nature images were not normally distributed (W = .930, $p < .001$). Specifically, 6 nature images above the overall Log10 restorativeness mean were matched as closely as possible on with 6 built images above the overall Log10 restorativeness mean. The same was done with nature and built images below the restorativeness mean. restorative nature images, and the same for built images, specifically by restorativeness rank within extreme tails of the restorativeness distribution. See Table 2.1 for the images' naturalness categorization and perceived restorativeness scores, organized by matched pair. See Appendix D for the experimental stimuli.

A solid brown tile (RGB: 160,82,45) was the standard stimulus in the control block as studies have shown very few children (Boyatzis & Varghese, 1994) and adults (Hemphill, 1996) to have emotional associations with brown, while this was not true for most other colors. Thus, three restorativeness conditions varied between blocks: HR, LR, and Br. Three of Berto's (2005) geo-patterns were selected as targets to pseudo-randomly rotate condition assignment between participants. See Appendix E for control and target stimuli. All images in the study were kept in their original 4:3 aspect ratio and displayed on a 23" widescreen monitor with 2.5" white side borders to prevent distortion caused by stretching to the screen's 16:9 aspect ratio.

EEG Recording

Electrophysiological data were recorded directly from the scalp via gold-plated silver electrodes using the 14-channel Emotiv Epoc mobile EEG cap onto a Windows PC. The 14 electrodes were placed over brain regions across the entire scalp (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4). Samples were collected at a rate of 128 per second (2048 Hz internal). Scalp impedance was below 10kΩ at recording onset. The felt scalp contacts for each electrode were rewetted with saline solution during the rest breaks between experimental blocks.

Table 2.1

Experimental Stimuli PRS-short and Naturalness Scores

a)

High Restorativeness Matched Pairs

Nature Image ID	PRS-Short	Log10(PRS-Short)	PRS-Short z-score	Naturalness	Built Image ID	PRS-Short	Log10(PRS-Short)	PRS-Short z-score	Naturalness
P255	8.45	0.172034	-1.4978	0.98	**P211**	8.45	0.172606	-1.49443	0.14
P164	8.32	0.208721	-1.2816	0.98	**P111**	8.33	0.206985	-1.29183	0.06
P284	8.29	0.2173	-1.23104	0.98	**P106**	8.29	0.2173	-1.23104	0.12
P363	8.24	0.229622	-1.15843	0.98	**P103**	8.25	0.227062	-1.17351	0.12
P54	8.19	0.242235	-1.0841	0.94	**P102**	8.21	0.238939	-1.10352	0.1
P181	8.16	0.2508	-1.03362	1.00	**P10**	8.16	0.249224	-1.04291	0.08

Each high restorative nature image was paired with the adjacent high restorative built image on Log10 perceived restorativeness as rated on the PRS short by the subjective ratings sample.

b)

Low Restorativeness Matched Pairs

Nature Image ID	PRS-Short	Log10(PRS-Short)	PRS-Short z-score	Naturalness	Built Image ID	PRS-Short	Log10(PRS-Short)	PRS-Short z-score	Naturalness
P347	6.25	0.566792	0.82857	0.98	**P6**	6.27	0.564125	0.812852	0.08
P350	6.15	0.578781	0.899221	1.00	**P141**	6.15	0.578041	0.894862	0.02
P19	6.07	0.587922	0.953092	0.84	**P110**	6.05	0.589727	0.963731	0.04
P167	5.83	0.613383	1.103138	1.00	**P91**	5.85	0.611512	1.092111	0.02
P260	5.62	0.635511	1.23354	1.00	**P228**	5.62	0.635835	1.23545	0.04
P282	5.61	0.636806	1.241172	1.00	**P88**	5.61	0.636806	1.241172	0.12

Each low restorative nature image was paired with the adjacent low restorative built image on Log10 perceived restorativeness as rated on the PRS short by the subjective ratings sample.

Procedure

Ratings

Design. The 8 rating subsets had 5 images in common and differed by their remaining images. Participants were recruited to respond to the rating survey via Amazon Mturk. Having 8 overlapping subsets facilitated data collection and management by allowing comparisons across rating groups to check that their ratings do not significantly differ, as described above. Each participant rated one of these subsets, so that each image was rated by at least 53 participants. The survey was programmed in Qualtrics to randomly route participants to one of 8 rating surveys corresponding to the 8 subsets. This procedure resulted in roughly equal group sizes across subsets but uncontrollable factors, such as multiple participants beginning at the same time, or the participant quota being reached as some participants finish while others are mid-survey, resulted in different group sizes for each image subset. As a result, participant group sizes for the ratings obtained per image subset were 68, 62, 62, 56, 62, 53, 62, 62.

Presentation. For this rating sample, participants provided informed consent online before participating. Participants responded on a computer (the survey program prohibited participation via smartphone) at their own location. Participants were asked the dimensions of the screen on which they viewed the images (they could alternatively provide the make and model of their screen). While each image was on the screen, participants rated it on all items of the PRS-short and the five subjective preference items.

ERP's

Upon arrival to the lab, participants read and signed informed consent after any additional questions regarding the study had been answered to their satisfaction. At this point, they were seated in a chair 24” from the monitor. Then, the experimenter placed the Emotiv cap on the participant’s head and ensured that all electrode sites showed impedance of less than 10kΩ before commencing data recording.

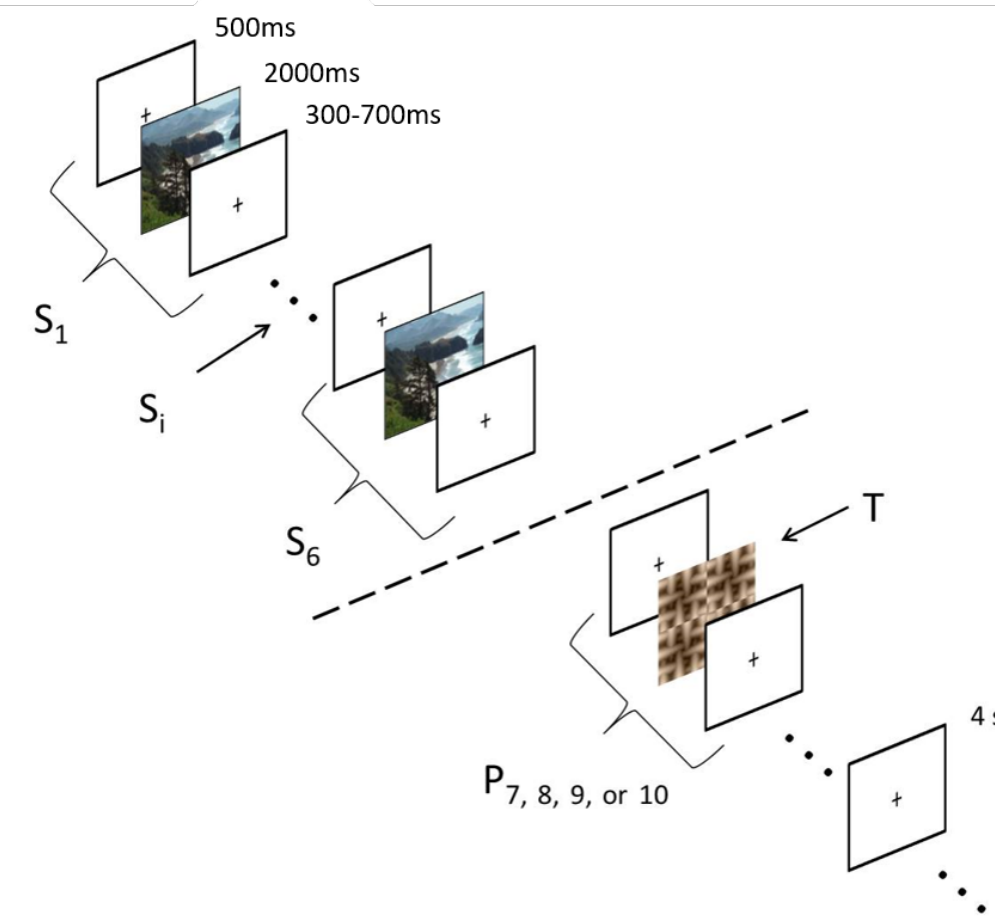
After EEG recording began, instructions were displayed on the screen as follows: “You will view various images. Please keep your fingers of your preferred hand rested on the SPACEBAR while the experiment is in progress. Press SPACEBAR ONLY ONCE as quickly as you can only when you see a geometric pattern; not a scene or a solid brown tile. Please keep your attention on the screen unless instructed otherwise. Press SPACEBAR to continue…”. Then, a very brief training phase began in which each image for that block, standard and target, were displayed with the labels “DO NOT press spacebar” and “press spacebar”, respectively. Following training was one practice sequence to ensure the participant understood the instructions. If they responded correctly to the sequence by pressing spacebar for the target, and making no responses for the standards, they advanced to the experimental phase. If not, the practice sequence was repeated until they responded correctly, with a limit of three attempts before excusal from the experiment. (All participants passed all practices for all blocks.) Then, the three-block procedure began.

Blocks corresponded to restorativeness (HR, LR, and Br; within-subjects factor). Groups corresponded to naturalness (nature and built; between-subjects factor). Block order was counterbalanced across within-group participants so that participants in each group rotated through the six distinct orders. Each stimulus block consisted of 24 ten-trial sequences. Each sequence displayed the target only once and only in either the 7th, 8th, 9th, or 10th sequential position (6 instances in each position throughout the block in random order). This design provided 72 target ERP trials per participant; 24 per condition, to exceed the targeted 20 for p3 analyses by a 4-ERP buffer in consideration of epoch (individual time window of an ERP) attrition due to artifacts (Cohen & Polich, 1997). Within each sequence, each trial began with a 500 ms fixation point (+), centered vertically and horizontally on the screen, followed by the trial image for 2000 ms, and ending with another fixation point of randomly varying duration between 300 and 700 ms, resulting in a total ISI varying between 800 – 1200 ms. This "jittering" is commonly used to ensure wash-out of inevitable ERP overlap from one epoch to the next when baseline activation averages are taken (Luck, 2014). This is more relevant for LPP analyses than p3 analyses. After the variable post-stimulus fixation, the task immediately proceeded to the next trial. Between blocks, a 2-minute rest period took place. The training phase and practice trial(s) occurred for each block (Figure 2.1).

Upon completion of the oddball task, the EEG cap was removed and participants rated all of the scenic stimulus images that were chosen for the experiment (24 images) on the five subjective preference items and the PRS-short via a separate, self-paced computer program that visually presented photos one-at-a-time in the same survey format as in the larger, online rating collection described above. Following ratings, participants were debriefed and excused. All participants in the ERP sample experienced the oddball task and rated the experimental stimuli on the same computer and monitor. All of these procedures were approved by the USU Institutional Review Board (IRB).

Figure 2.1

Trial Progression for One Sequence



In the 10-trial sequence, the first six trials were consistently standard (S_i) stimuli. The target (T) then appeared in any one of the last four sequence positions (P_i). Not depicted: the non-target trials of the last four positions were standard stimuli. Then a 2s fixation cross served as the inter-sequence interval.

CHAPTER III

RESULTS

Subjective Ratings

Rating sample

PRS-short results, and the results from the five subjective preference items are reported above in the description of stimulus selection.

ERP sample

Perceived Restorativeness. PRS-short ratings were averaged across the experimental stimuli within a category for each participant. That is, for each participant their PRS-short ratings for the six HR-N images used in the experiment were averaged to produce a HR-N perceived restorativeness mean. This was computed for HR-B, LR-N, and LR-B categories as well. Then, a mixed ANOVA was conducted with stimulus category as the within-subjects factor and group (nature vs. built) as the between-subjects factor. Mauchly's test of sphericity revealed a violation ($W = .696$, $p = .024$), so the results are reported with a Greenhouse-Geisser correction, a repeated-measures ANOVA adjustment that is robust to violations of sphericity, or equal variances across the times of measurement (Abdi, 2010). The results showed a main effect of stimulus category on PRS-short ratings in the ERP sample ($F(2.547, 111.992) = 61.393$, $p < .001$, $\eta_p^2 = .624$) such that HR-N stimuli ($M = 8.891$, $SD = 1.056$) were rated as most restorative, followed by HR-B ($M = 8.209$, $SD = 1.196$), LR-N ($M = 7.353$, $SD = 1.610$), and LR-B ($M = 5.978$, $SD = 1.371$). Holm pairwise comparisons showed that HR-N differed from HR-B ($p = .003$). All other pairwise comparisons showed differences below the $\alpha = .001$ level

(Figure 3.2a). There was no significant group by category interaction. Nor was there a significant effect of group on PRS-short ratings. See Table 3.1 for group means.

Table 3.1

Perceived Restorativeness Means by Group for each Scene Category

Group	HR-N Mean (SD)	HR-B Mean (SD)	LR-N Mean (SD)	LR-B Mean (SD)
Nature	8.876 (1.088)	8.457 (1.463)	7.446 (1.682)	6.276 (1.363)
Built	8.907 (1.047)	7.920 (0.719)	7.244 (1.564)	5.630 (1.333)
Combined	8.891 (1.056)	8.209 (1.196)	7.353 (1.610)	5.978 (1.371)

Subjective Preference. In the same fashion as the PRS-short ratings, averaged subjective preference ratings of the HR-N, HR-B, LR-N, and LR-B image categories, collected from the ERP participants after the experiment, were compared using mixed ANOVAs with image category as the within-subjects factor and group (nature vs. built) as the between-subjects factor, for attractiveness, desire to visit, valence, physical arousal, and mental arousal.

Scene Attractiveness. For scene attractiveness, Mauchly's test of sphericity again revealed a violation ($W = .535$, $p < .001$), so, again, the results are reported with a Greenhouse-Geisser correction. There was a main effect of stimulus category on image attractiveness in the ERP sample ($F(2.214, 106.282) = 102.112$, $p < .001$, $\eta_p{}^2 = .734$) such that HR-N stimuli ($M = 8.654$, $SD = 0.912$) were rated as most attractive, followed by HR-B ($M = 7.919$, $SD = 1.163$), LR-N ($M = 6.846$, $SD = 1.470$), and LR-B ($M = 5.009$, $SD = 1.501$). Holm-Sidak pairwise comparisons showed each category to significantly differ from each other category at the α =.001 level (Figure 3.2b). This pairwise test works in a stepwise fashion so as to avoid aggregating Type I error probability with each pairwise comparison, as is the risk in a Tukey test. However, as such, Holm-Sidak comparisons cannot predict confidence intervals (Holm, 1979). There was no significant group by category interaction. Nor was there a significant effect of group on attractiveness ratings. See Table 3.2 for group means.

Table 3.2

Scene Attractiveness Means by Group for each Scene Category

Group	HR-N Mean (SD)	HR-B Mean (SD)	LR-N Mean (SD)	LR-B Mean (SD)
Nature	8.722 (1.020)	8.238 (1.342)	7.048 (1.554)	5.278 (1.536)
Built	8.574 (0.788)	7.546 (0.796)	6.611 (1.371)	4.694 (1.439)
Combined	8.645 (0.912)	7.919 (1.163)	6.846 (1.470)	5.009 (1.501)

Desire to Visit. For ratings of participants' desire to visit the scene in the experimental images for each category, Mauchly's test of sphericity again revealed a violation ($W = .534$, $p < .001$), so, again, the results are reported with a Greenhouse-Geisser correction. There was a main effect of stimulus category on desire to visit for the ERP sample ($F(2.258, 88.557) = 80.804$, $p < .001$, $\eta_p^2 = .686$) such that HR-N stimuli ($M = 8.701$, $SD = 0.925$) were rated as most likely to be visited, followed by HR-B ($M = 8.060$, $SD = 1.307$), LR-N ($M = 6.645$, $SD = 1.625$), and LR-B ($M = 5.205$, $SD = 1.709$). Holm pairwise comparisons showed that HR-N differed from HR-B ($p = .008$). All other pairwise comparisons showed differences below the $\alpha = .001$ level (Figure 3.2c). There was no significant group by category interaction. Nor was there a significant effect of group on desire to visit. See Table 3.3 for group means.

Table 3.3

Desire to Visit Means by Group for each Scene Category

Group	HR-N Mean (SD)	HR-B Mean (SD)	LR-N Mean (SD)	LR-B Mean (SD)
Nature	8.810 (0.977)	8.373 (1.383)	6.810 (1.726)	5.468 (1.475)
Built	8.574 (0.871)	7.694 (1.142)	6.454 (1.525)	4.898 (1.945)
Combined	8.701 (0.925)	8.060 (1.307)	6.645 (1.625)	5.205 (1.709)

Valence. For ratings of image valence, Mauchly's test of sphericity again revealed a violation ($W = .660$, $p = .011$), so, again, the results are reported with a Greenhouse-Geisser correction. There was a main effect of stimulus category on valence for the ERP sample ($F(2.319, 85.808) = 78.147$, $p < .001$, $\eta_p^2 = .679$) such that HR-N stimuli ($M = 8.278$, $SD = 1.137$) were rated as the happiest, followed by HR-B ($M = 7.487$, $SD = 1.251$), LR-N ($M = 6.744$, $SD = 1.302$), and LR-B ($M = 5.389$, $SD = 1.008$). Holm pairwise comparisons showed each category to significantly differ from each other category below the $\alpha = .001$ level (Figure 3.2d). There was no significant group by category interaction. Nor was there a significant effect of group on PRS-short ratings. See Table 3.4 for group means.

Table 3.4

Valence Means by Group for each Scene Category

Group	HR-N Mean (SD)	HR-B Mean (SD)	LR-N Mean (SD)	LR-B Mean (SD)
Nature	8.444 (1.144)	7.944 (1.378)	7.000 (1.533)	5.643 (1.062)
Built	8.083 (1.129)	6.954 (0.840)	6.444 (0.922)	5.093 (0.879)
Combined	8.278 (1.137)	7.487 (1.251)	6.744 (1.302)	5.389 (1.008)

Physical Arousal. For ratings of how much scenes in each category inspired physical arousal (calm vs excited), the assumption of sphericity was not violated ($W =$

.790, p = .135), so no correction was applied to the results. There was a significant group x restorativeness category interaction effect on ratings of inspired physical arousal (F(3, 111) = 2.756, p = .046, η_p^2 = .069; Figure 4e) such that participants from the nature experimental group rated HR-N scenes higher in evoking physical arousal than participants from the built experimental group (p = .042). Further, participants in the nature experimental group rated HR-N scenes higher in evoking physical arousal than participants in the built experimental group rating HR-B scenes (p = .019), and participants in either group rating LR-B (nature group, $p < .001$; built group, p = .019) and LR-N scenes (nature group, p = .013; built group, $p < .001$). Participants in the nature experimental group rated HR-B scenes as evoking more physical arousal than participants in the built experimental group rated LR-N scenes (p = .008), and participants in the nature experimental group rating LR-B scenes (p = .044).

There was a significant effect of stimulus category on ratings of physical arousal for the ERP sample (F(3, 111) = 6.139, $p < .001$, η_p^2 = .142). Holm pairwise comparisons showed no difference between HR-N (M = 6.073, SD = 1.668) and HR-B (M = 5.778, SD = 1.663; p = .605). Significant differences were revealed between HR-N and LR-N (M = 5.038, SD = 1.600; p = .002), between HR-N and LR-B (M = 5.150, SD = 0.829; p = .010), and between HR-B and LR-N (p =.035). There was no difference between HR-B and LR-B (p = .104). There was no difference between LR-N and LR-B (p = .605; Figure 3.2e). See Table 3.5 for group means.

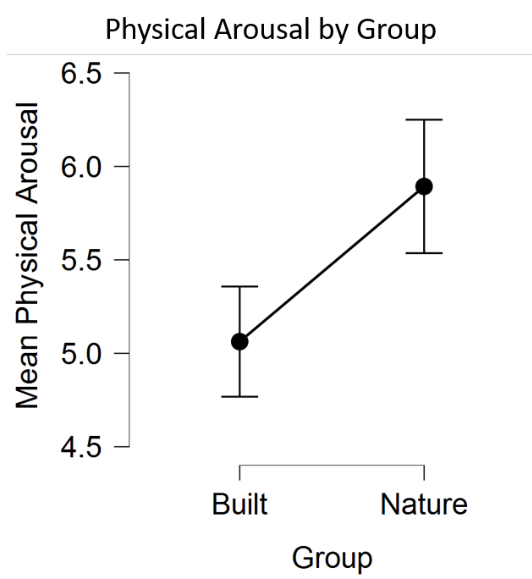
Finally, there was also a significant main effect of group (F(1, 37) = 7.299, p = .010, η_p^2 = .165) such that participants in the nature experimental group rated images, regardless of category, as being more physically arousing (*M* = 5.893, *SD* = 1.508) than participants in the built experimental group (*M* = 5.063, *SD* = 1.197; Figure 3.1).

Table 3.5

Physical Arousal Means by Group for each Scene Category

Group	HR-N Mean (SD)	HR-B Mean (SD)	LR-N Mean (SD)	LR-B Mean (SD)
Nature	6.738 (1.568)	6.294 (1.797)	5.413 (1.656)	5.127 (1.012)
Built	5.296 (1.464)	5.176 (1.294)	4.602 (1.455)	5.176 (0.573)
Combined	6.073 (1.668)	5.778 (1.663)	5.038 (1.600)	5.150 (0.829)

Figure 3.1



Mean physical arousal by experimental group, as rated by the ERP sample after the active oddball task. Note: all participants rated all scenic experimental stimuli.

Mental Arousal. For ratings of each image on mental arousal (mentally fatigued vs. mentally energetic), Mauchly's test of sphericity once more revealed a violation (*W* = .615, *p* = .004), so, again, the results are reported with a Greenhouse-Geisser correction. There was a main effect of stimulus category on image self-rated mental arousal for the

ERP sample ($F(2.308, 85.396) = 52.428$, $p < .001$, $\eta_p^2 = .586$) such that HR-N stimuli ($M = 7.551$, $SD = 1.364$) were rated as most mentally arousing, followed by HR-B ($M = 6.731$, $SD = 1.437$), LR-N ($M = 6.060$, $SD = 1.422$), and LR-B ($M = 4.838$, $SD = 1.209$). Holm pairwise comparisons showed each category to significantly differ from each other category at the α =.001 level (Figure 3.2f). There was no significant group by category interaction. Nor was there a significant effect of group on mental arousal ratings. See Table 3.6 for group means.

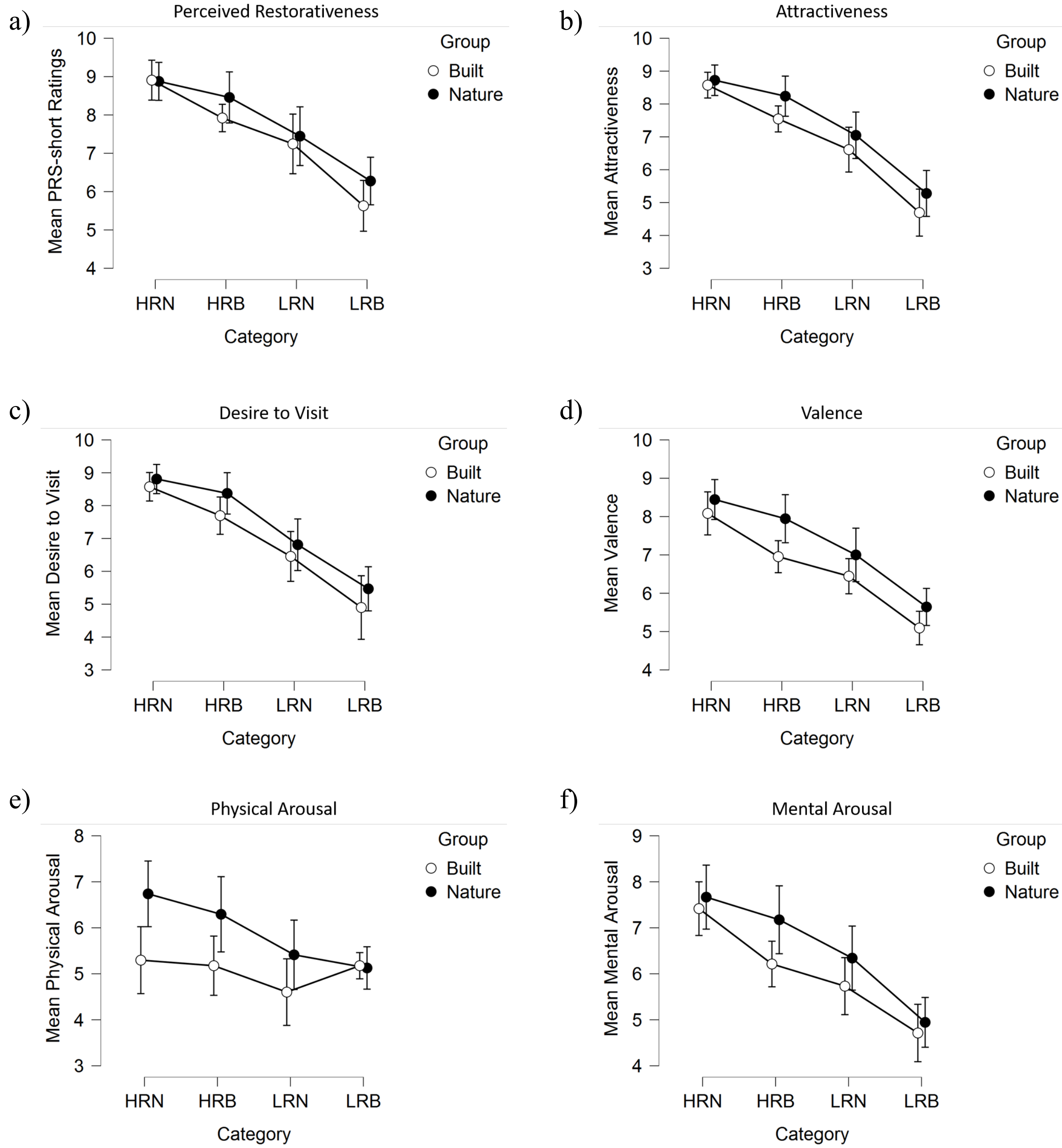
Table 3.6

Mental Arousal Means by Group for each Scene Category

Group	HR-N Mean (SD)	HR-B Mean (SD)	LR-N Mean (SD)	LR-B Mean (SD)
Nature	7.667 (1.528)	7.175 (1.621)	6.341 (1.530)	4.944 (1.188)
Built	7.417 (1.173)	6.213 (0.996)	5.731 (1.246)	4.713 (1.255)
Combined	7.551 (1.364)	6.731 (1.437)	6.060 (1.422)	4.838 (1.209)

Figure 3.2

Subjective Ratings by Group and Stimulus Category



Depicted are plots of a) perceived restorativeness, b) attractiveness, c) desire to visit, d) valence, e) physical arousal, and f) mental arousal by group and stimulus category, as rated by participants in the ERP sample. All error bars represent the 95% confidence interval.

Behavioral Data

Trials with anticipatory or delayed responses (200 ms > RT > 1200) were removed from all analyses as extremely fast responses imply anticipation and extremely slow responses imply processing interference by task-extraneous information, rather than valid stimulus processing (Ulrich & Miller, 1994). There was no significant difference between groups in number of trials removed for being outside of this valid RT window ($t(37) = 0.951$, $p = .348$). The number of trials dropped for anticipatory or delayed responses was positively skewed across the sample (*skewness* = 1.455; *Mode* = 0, *Mdn* = 2, *M* = 5.564, *SD* = 7.369).

Error data (missed targets and false alarms) were analyzed to assess accuracy and check for unexpected differences between conditions. A mixed-method ANOVA was used to compare false alarms – incorrectly responding to a non-target stimulus – between groups and between groups and stimulus categories. Results showed no interaction effect of stimulus category and naturalness group on false alarms. Nor did either factor significantly affect false alarms on its own. There was not a single recorded miss in the data. That is, all targets in epochs that were not filtered out in previous steps were correctly responded to with a spacebar press. At this point, inaccurate response trials were removed from further analyses as they do not reflect valid stimulus processing.

Mean target RTs were compared between conditions as the primary behavioral measure of performance quality using a mixed-method ANOVA with the same factors as described above. There was no significant interaction effect of stimulus category and naturalness group on RT. Nor were there effects of either factor on RT. For both false alarms and RT, counterbalancing order was included as a between-groups factor to check for any order effects. There was no significant between-groups effect of counterbalancing order on either measure.

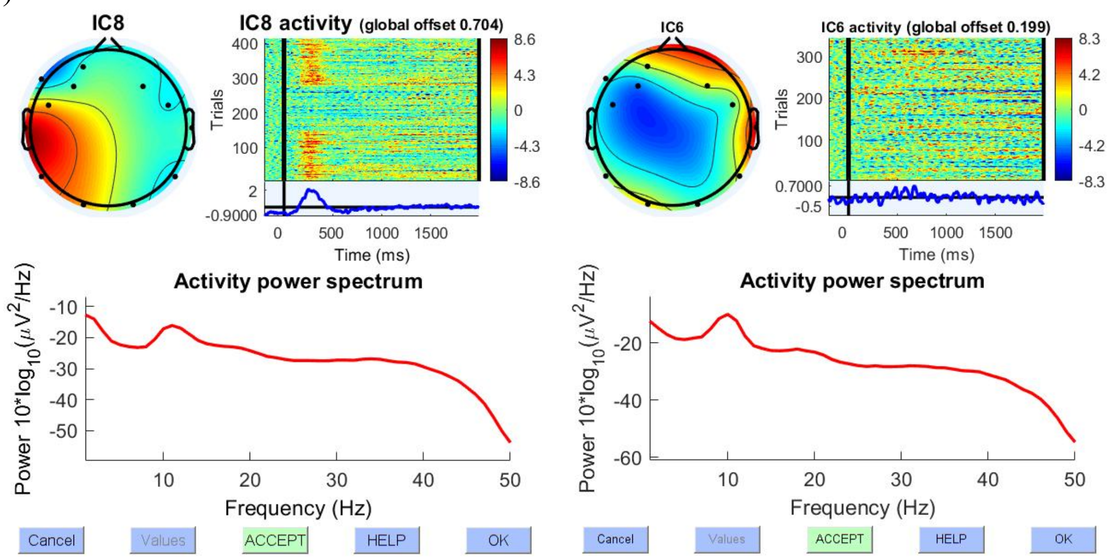
ERP's

Only target trials with correct responses occurring between 200 and 1200 ms of stimulus onset were included in target ERP analyses (Wiersema, van der Meere, Antrop, & Roeyers, 2006). Before epochs were extracted, the data were bandpass filtered at 0.01-59 Hz. Stimulus-synchronized epochs were extracted using an event-locked time window beginning 200 ms before image onset and ending 2000 ms after, well encompassing the theoretical timeframes of the target ERP components. Then, epochs with either abnormally trending (upward or downward linear drift) or improbable (extreme activity occurring beyond ±4 standard deviations of an electrode's mean) artifactual data were rejected algorithmically using independent component analysis (ICA). ICA is the most used statistical procedure for such rejection. It is a statistical method used to identify within the data a set of components, each of which has a unique scalp distribution (Luck, 2014). Components are visually inspected and those with artifactual characteristics, any signal not characteristic of cognitive activity, are manually removed. See Figure 3.3 for examples of accepted and rejected components using ICA. For both p3 and LPP analyses, block order was included as a between-subjects factor to check for potential effects of habituation, fatigue, or attention restoration carry-over.

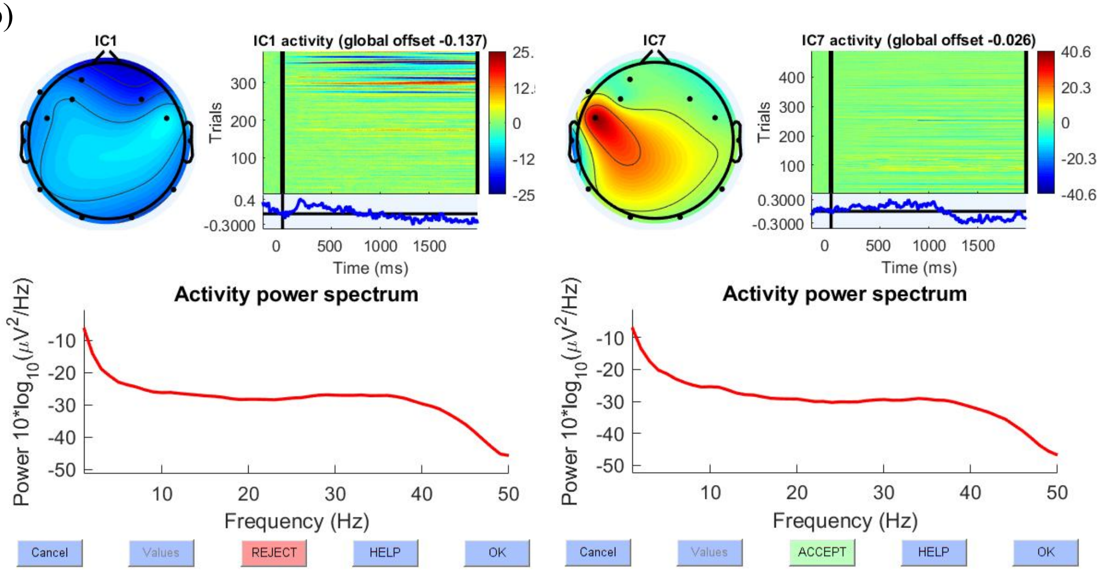
Figure 3.3

Examples of Accepted and Rejected ICA Components

a)



b)



Depicted are ICA example displays showing a heat map, activity, and power spectrum. For accepted (a) components, notice the "alpha bump" at 10hz in the activity power spectrum. This feature is indicative of data showing cognitive processing as the alpha frequency band activity is present. Power range is <30 indicated in the key in the upper right of each figure. The heat maps show evenly spread polarity across trials and the scalp. The rejected component figures (b) do not show these key features.

p3

p3 amplitude was defined as the mean amplitude between 200 ms and 600 ms post stimulus onset, relative to the mean amplitude of the 200-ms period before stimulus onset, given that stimulus duration in the present study was 2000 ms, and thus p3's could be occurring later in the epochs. This relatively large window was used because the p3 latency from stimulus onset can vary widely under different conditions (Luck, 2014; Polich, 2007). Fifty percent fractional peak latency (FPL) was used to assess p3 latency and is defined as the timepoint at which the 50% amplitude of the peak amplitude in the window occurs, between 200 ms and the peak. Amplitude and latency were assessed for frontal (AF3, AF4, F3, F4, FC5, FC6, F7, F8), parietal (P7, P8), temporal (T7, T8), and occipital (O1, O2) ROIs. Grand means were taken across target and standard trials for both p3 mean amplitude and FPL. Then, target p3 mean amplitude and latency for each ROI were compared across standard stimulus conditions using mixed-design ANOVAs with restorativeness block and ROI as within-subject factors, and naturalness condition as the between-subjects factor. Greenhouse-Geisser was applied to all results to correct for sphericity violations.

Amplitude. Results showed a significant ROI x Condition x Stimulus interaction effect on p3 mean amplitude ($F(4.837, 377.255) = 3.557$, $p = .004$, $\eta_p^2 = .044$). Specifically, p3 amplitude for HR standards was greater in the occipital ROI than in the frontal ROI ($p < .001$), as well as when comparing frontal amplitude of HR standards with occipital amplitude of LR standards ($p = .007$). p3 amplitude was also greater for HR standards in the occipital ROI than for LR standards in the frontal ROI ($p < .001$). HR and LR standards both showed greater amplitude in the occipital ROI than both HR and LR standards in the frontal ROI (*p*'s < .001). HR standards showed greater amplitude in the occipital ROI than HR targets in the temporal ROI (*p*'s < .001). LR standards showed greater amplitude in the occipital ROI than LR targets in the temporal ROI (p = .004) and HR targets in the temporal ROI (p < .003). HR standard amplitude in the occipital ROI was greater than Br standard amplitude in the parietal ROI (p = .002). HR and LR standard amplitude in the occipital ROI were both greater than Br standard amplitude in the occipital ROI (*p*'s < .001). And, HR target amplitude in the occipital ROI was lower than HR standard amplitude in the occipital ROI (p = .037). See Figure 3.4 for average amplitude across the ERP window, by condition, ROI, and stimulus type, for p3.

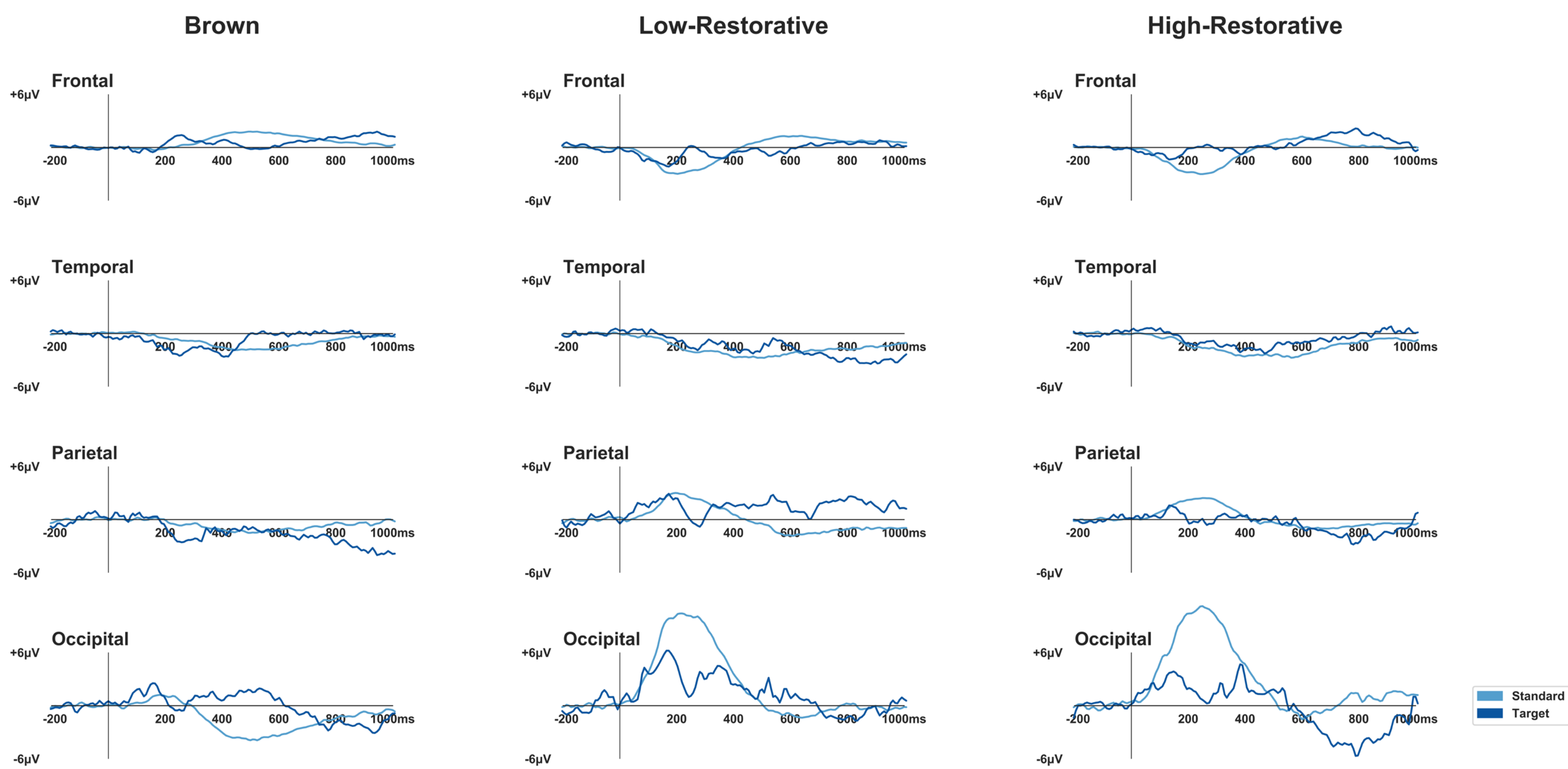
There was also a significant ROI x Condition interaction (F(4.837, 377.255) = 4.552, p < .001, η_p^2 = .055). HR p3 amplitude in the occipital ROI was greater across conditions than HR amplitude in the frontal ROI (p = .007), as was LR p3 amplitude (p < .001). HR and LR p3 occipital amplitude was also greater than LR frontal p3 amplitude (*p*'s = .001). Each of the following condition-ROI combinations showed greater p3 amplitude than Br temporal amplitude: HR-parietal (p = .039), LR-parietal (p = .019), HR-occipital (p < .001), and LR-occipital (p < .001). The following condition-ROI combinations showed greater p3 amplitude than HR-temporal: LR-parietal (p = .011), HR-occipital (p < .001), and LR-occipital (p < .001). The following condition-ROI combinations showed greater p3 amplitude than LR-temporal: HR-parietal (p = .034), LR-parietal (p = .034), HR-occipital (p < .001), and LR-occipital (p < .001). And, HR-occipital and LR-occipital showed greater p3 amplitude than both Br-parietal (*p*'s < .001) and Br-occipital (*p*'s < .001). In summary, HR conditions in posterior ROI's showed greatest amplitude compared to Br and LR conditions and in anterior ROI's.

Finally, there was a significant effect of ROI (F(2.418, 377.255) = 15.627, $p <$ .001, η_p^2 = .091). The occipital ROI was greater in p3 amplitude than the frontal ($p <=$ .001), temporal ($p < .001$), and parietal ($p = .046$) ROI's. The parietal ROI showed greater p3 amplitude than the temporal ($p < .001$). The frontal ROI showed greater p3 amplitude than the temporal ROI ($p = .006$). There was no difference between the parietal and frontal ROI's ($p = .188$).

Counterbalancing order was included as a factor in the model to check for order effects and there was a significant group x stimulus x order interaction ($F(5, 156) =$ 3.131, $p = .010$, $\eta_p^2 = .091$). Post hoc comparisons revealed only a few pairwise differences. Target trials in the nature experimental group in order 4 (LR-N, Br, HR-N) showed greater p3 mean amplitude than standard trials in the built experimental group, order 1 (HR-B, LR-B, Br; $p = .005$). Target trials in the nature experimental group in order 4 showed greater p3 amplitude than target trials in the nature experimental group in order 3 (LR-N, HR-N, Br; $p = .005$). And, target trials in the nature experimental group in order 4 showed greater p3 amplitude than target trials in the built experimental group in order 6 (Br, LR-B, HR-B; $p = .036$). Only two participants experienced order 4 in the nature experimental group after unusable data rejection and the effect of restrictions on further data collection that were imposed due to the COVID-19 pandemic. It is expected that, had a completely counterbalanced data set been obtained, this order interaction would not be present. It is likely that, due to this imbalance in the number of participants per order, the finding of an order effect is spurious and that order 4 of the experimental conditions does not uniquely impact p3 amplitude meaningfully.

Figure 3.4

ERP Grand Means by ROI, Condition, and Stimulus Type



Plots show grand means by condition (Brown, LR, and HR), stimulus (standard, target), and ROI (frontal, temporal, parietal, and occipital). p3 amplitude across the 200-600 ms window shows the condition x ROI x stimulus interaction (F(4.837, 377.255) = 3.557, p = .004, η_p^2 = .044).

Latency. There were significant ROI x condition (F(5.449, 375.959) = 5.801, $p <$ .001, η_p^2 = .078, small) and ROI x stimulus (F(2.724, 375.959) = 44.519, $p < .001$, η_p^2 = .244, medium-large) interaction effects on FLP (Figure 3.5). The ROI x condition interaction showed that occipital-HR p3 FLP was earlier than frontal-Br, temporal-Br, parietal-Br, frontal-HR, temporal-HR, frontal-LR, and temporal- LR, all below the α = .001 level. Occipital-LR p3 FLP was earlier than-Br (p = .014), temporal-Br (p = .004), parietal-Br (p = .011), frontal-HR (p < .001), temporal-HR (p = .004), frontal-LR (p < .001), and temporal-LR (p < .001). Frontal-HR p3 FLP was later than frontal-Br (p = .002), temporal-Br (p = .007), parietal-Br (p = .002), occipital-Br (p < .001), temporal-HR (p = .002), parietal-HR (p < .001), and parietal-LR (p < .001).

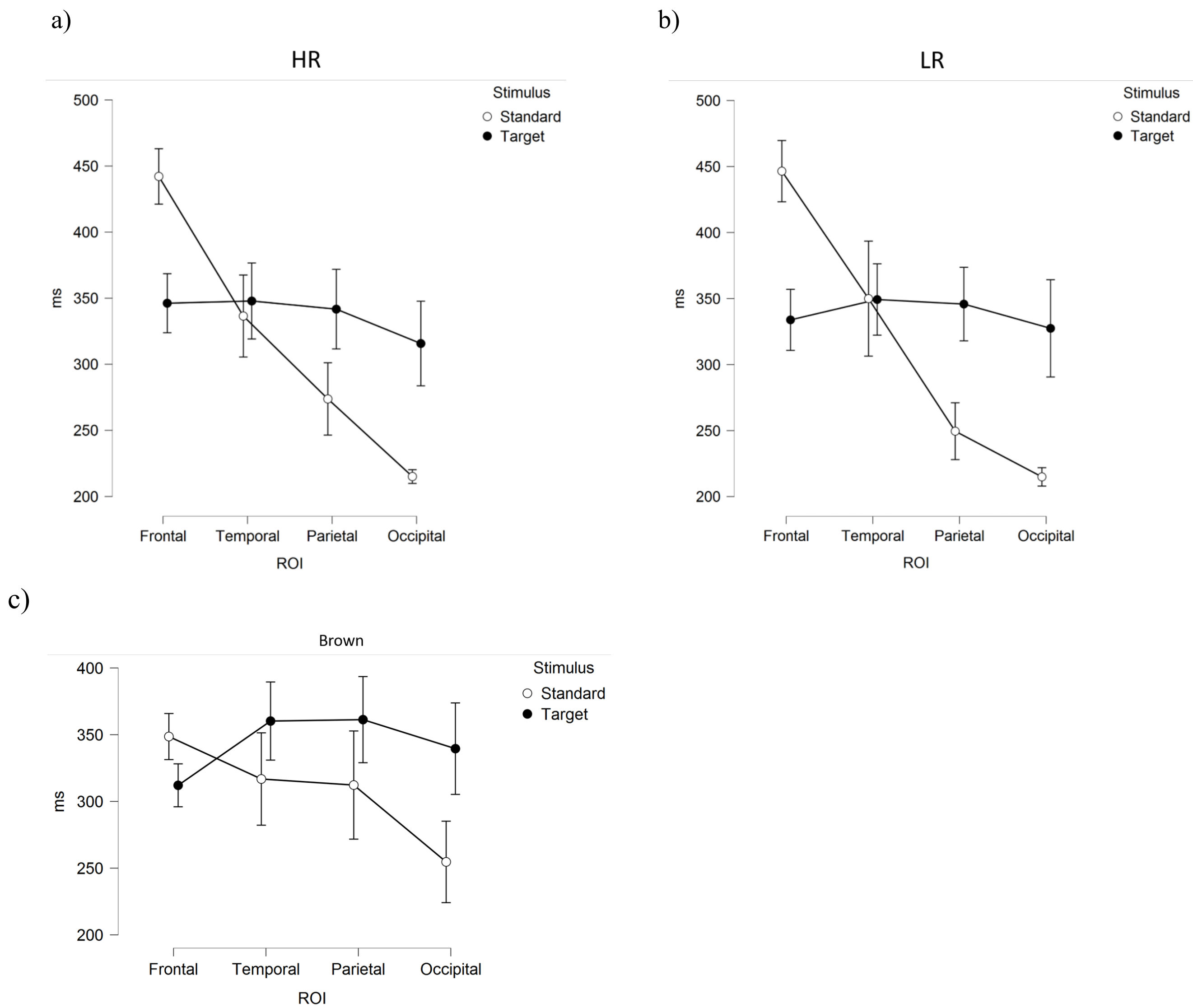
The ROI x stimulus interaction showed that frontal p3 FLP for standard stimuli was later than temporal-standard, parietal-standard, occipital-standard, frontal-target, temporal-target, parietal-target, and occipital-target, all below the α = .001 level. Temporal p3 FLP for standard stimuli was later than that of parietal-standard and occipital standard, both below the α = .001 level. Parietal p3 FLP for standard stimuli was later than occipital-standard (p = .004), and earlier than frontal-target, temporal-target, parietal-target, and occipital-target, all below the α = .001 level. Finally, occipital p3 FLP for standard stimuli was earlier than frontal-target, temporal-target, parietal-target, and occipital-target (all below the α = .001 level).

There was a medium-large main effect of ROI (F(2.724, 375.959) = 45.517, $p <$ .001, η_p^2 = .248) such that frontal p3 FLP was later than temporal, parietal, and occipital p3 FLP, all below the α = .001 level. Temporal p3 FLP was later than parietal and occipital p3 FLP, both below the $\alpha = .001$ level. Parietal p3 FLP was later than occipital p3 FLP ($p < .001$).

Finally, there was a main effect of stimulus in which target trials had later p3 FLP than standard trials ($F(1, 138) = 17.947$, $p < .001$, 115, medium). When counterbalancing order was included as a factor in the model, there was no effect of order, nor interactions between order and any other factors.

Figure 3.5

FLP in each Condition by ROI and Stimulus Role



Plots show fractional peak latency in milliseconds for a) HR, b) LR, and c) Brown as a function of stimulus type and ROI.

LPP

The average amplitude across the windows from 600-1000 ms and from 1000-2000 ms post-stimulus represented early and late LPP activation (LPP-E, LPP-L), respectively (MacNamara et al., 2011). ROIs analyzed were the same as for p3. Then, grand means taken across standard and target epochs were compared between restorativeness blocks and naturalness conditions using mixed-design ANOVAs with block and ROI as within-subject factors, and naturalness condition as a between-subjects factor. Greenhouse-Geisser corrections were applied to all results to correct for sphericity violations.

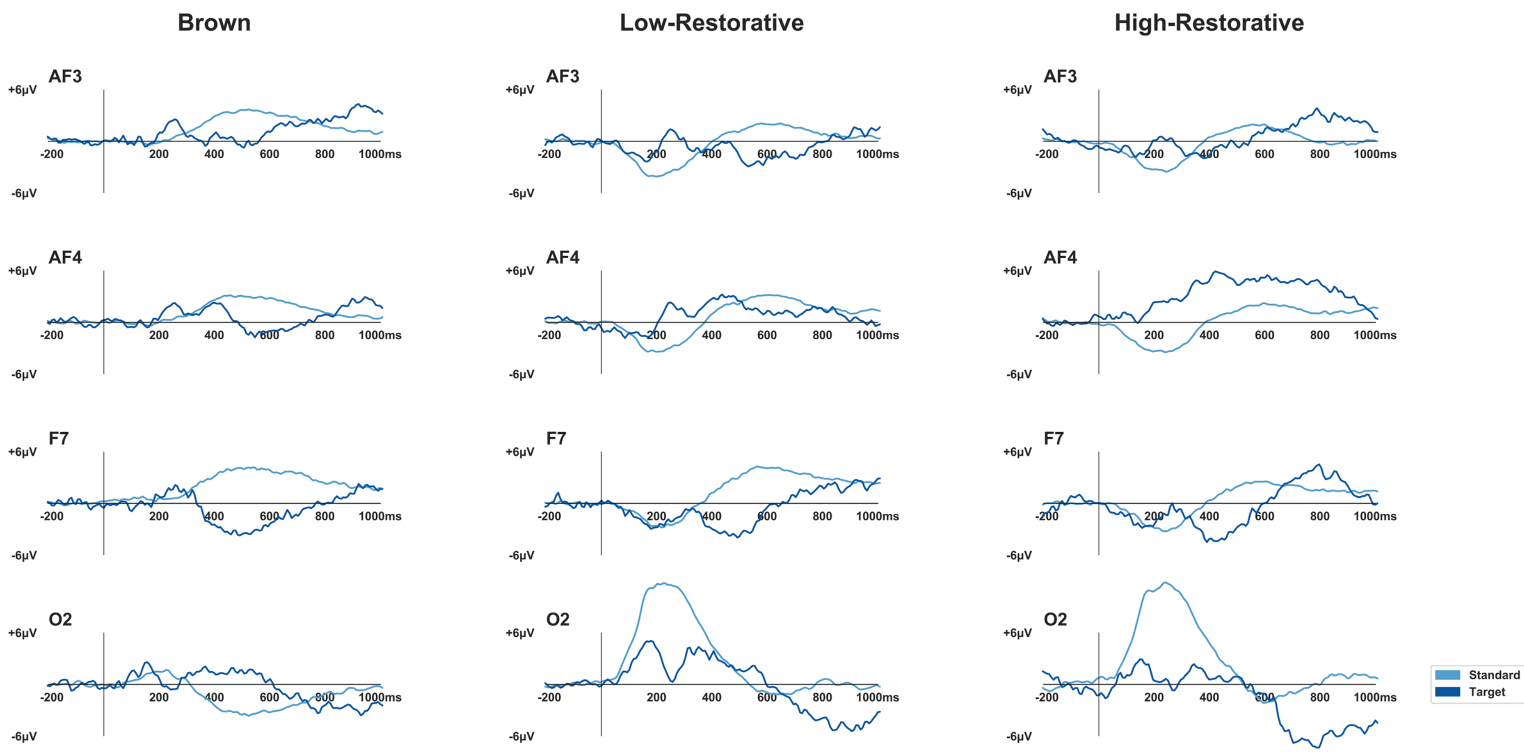
LPP-E. At the ROI level, there were no significant effects or interactions of any factors on LPP-E. The model was thus rerun with channel as a within-subjects factor, rather than ROI (which are pooled channels). This model showed a significant interaction effect of channel x group x order on LPP-E ($F(28.145, 878.130) = 2.044$, $p < .001$, $\eta_p^2 = .061$). The interaction showed consistently that LPP-E amplitude in the nature experimental group for order 4 at channel O2 was significantly lower in its pairwise comparisons with other group-order-channel combinations (p's < .05) throughout the 14,028 pairwise comparisons in the model (2 x 6 x 14). Consistent with the interaction with order for p3 amplitude, this order effect is likely due to there only being two participants in the nature experimental group who received order 4 of the experimental conditions.

After removing order from the model, there was a significant channel x stimulus interaction ($F(2, 216) = 3.325$, $p = .038$; $\eta_p^2 = .030$) and significant effects of condition ($F(2, 216) = 3.377$, $p = .036$; $\eta_p^2 = .030$) and channel ($F(6.154, 1329.180) = 2.797$, $p = .010$; $\eta_p^2 = .013$). Pairwise comparisons for the interaction between the 14 channels x two stimulus types for the interaction revealed only one difference, that target trials at O2 showed lower LPP-E amplitude than standard trials at F7 ($p = .004$).

Pairwise comparisons for the channel effect showed that O2 showed lower LPP-E amplitude than AF3 (p = .035), AF4 (p = .018), and F7 (p = .003; Figure 3.6). Pairwise comparisons for the condition effect showed that HR images evoked greater LPP-E amplitude than LR images (p < .038), though it is worth noting that the mean difference was very small (M_D = 0.0000002011, d = .167; Figure 3.6).

Figure 3.6

ERP Grand Means for Channels, AF3, AF4, F7, and O2 by Condition and Stimulus Role

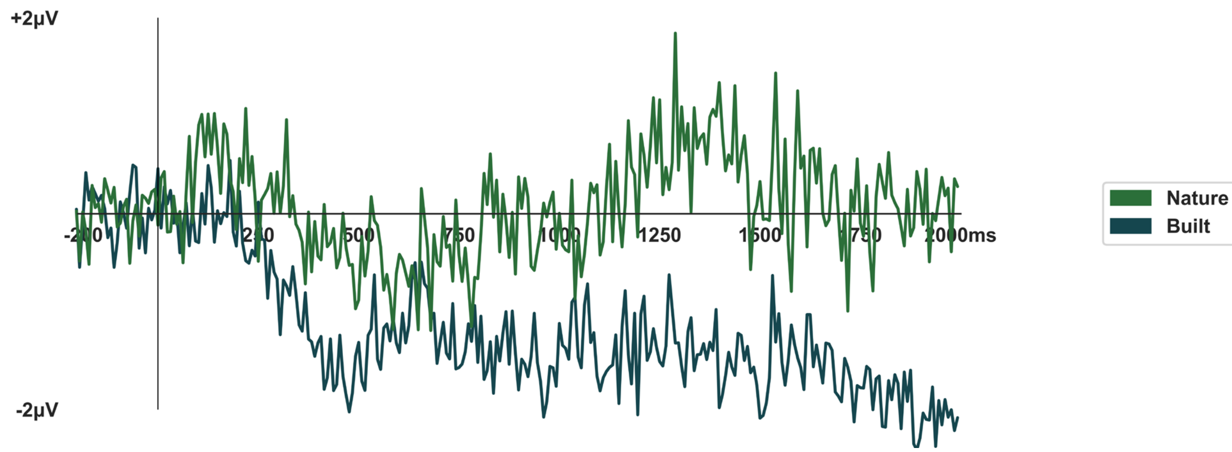


Plots show grand means by condition (Brown, LR, and HR), stimulus (standard, target), and channel (AF3, AF4, F7, and O2). LPP-E amplitude across the plots during the 600-1000 ms window shows the stimulus x channel interaction ($F(2, 216) = 3.325$, $p = .038$; $\eta_p^2 = .030$) and the significant effects of condition ($F(2, 216) = 3.377$, $p = .036$; $\eta_p^2 = .030$) and channel ($F(6.154, 1329.180) = 2.797$, $p = .010$; $\eta_p^2 = .013$).

LPP-L. There was a significant effect of group on LPP-L amplitude (F(1, 216) = 4.992; p = .026; η_p^2 = .023). Specifically, LPP-L amplitude in the nature experimental group was greater than in the built experimental group (t = 2.232, p < .027, d = .148; Figure 3.7).

Figure 3.7

ERP Grand Means by Experimental Group



This plot shows grand means for each group (nature, built). LPP-L amplitude across the 1000-2000 ms window shows the effect of group (F(1, 216) = 4.992; p = .026; η_p^2 = .023).

CHAPTER IV

DISCUSSION

The purpose of this study was to analyze ERP topography for neurophysiological evidence of attention restoration using a two-stimulus, active oddball paradigm. Further, the experimental design employed allowed the testing of naturalness and restorativeness as separate factors. The study was designed to be an improvement upon the limitations encountered by Mahamane and colleagues (2020) study, by reducing stimulus diversity for any one participant to elicit more pronounced p3's, using narrower ranges to qualify images for the nature and built categories so that hybrid images were less likely to be stimuli following the pre-established selection procedure, and by separating naturalness and restorativeness as experimental factors. Below is discussion of the findings organized by data type (*i.e.* subjective ratings, oddball task behavioral results, and oddball task ERP results).

Perceived Restorativeness and Subjective Preference

The main effect of condition on perceived restorativeness ratings in the ERP sample confirmed that the participants who completed the active oddball task subjectively found the HR-N scenes to be most restorative, followed by HR-B, LR-N, and LR-B, in that order. This difference was not moderated by experimental group. This finding serves as a subjective manipulation check of the restorativeness conditions. This finding also shows agreement between the online rating sample and the ERP sample, as the online rating sample's compiled responses were the basis for stimulus selection along the lines of restorativeness.

The other subjective preference variables showed the same pattern except for the degree to which the images evoked physical arousal. For physical arousal ratings, there was an interaction between experimental group and stimulus category of the image. In this interaction, participants in the nature experimental group rated HR-N scenes higher than the built experimental group rating any type of scenes, and any group rating LR scenes, both -N and -B. The nature experimental group did not rate HR-N scenes significantly differently than HR-B scenes. Participants in the built experimental group rating HR-N and HR-B scenes, did not rate either of those categories significantly differently from any others besides the nature experimental group HR-N ratings mentioned above. Stimulus naturalness was a between-groups variable while stimulus restorativeness was a within-groups, yet all participants rated all experimental stimuli, Thus, the differences within this interaction, taken together, suggest that both natural scenes and high restorativeness contribute significantly to an environment's evocation of physical arousal.

The main effect of stimulus category, ignoring experimental group, on physical arousal ratings showed that images in different environmental categories, but in the same restorativeness level, were not rated differently. That is, HR-N and HR-B were not significantly different, nor were LR-N and LR-B. The only cross-restorativeness comparison that was not significantly different was HR-B versus LR-N. Significant differences were seen between HR-N and LR-N, HR-N, and LR-B, and HR-B and LR-B. This finding suggests that the same visual features that cause a person to perceive an environment as natural, and those that cause them to perceive it as restorative, are most motivating of physical activity.

Also noteworthy, the main effect of experimental group on physical arousal ratings, with participants from the nature experimental group rating images as more exciting than participants in the built experimental group, suggests that having viewed nature scenes, across restorativeness levels, increases physical arousal independently of the environmental stimulus later being viewed. Recall that every participant rated all experimental scenic stimuli post experiment, including the stimuli from the other naturalness group (*e.g.*, participants in the nature experimental group also rated the built stimuli) and the stimuli in the naturalness category of their own group that they did not view during the experiment.

Behavioral Results

Analyses of RT and accuracy did not reveal significant interactions between stimulus category and experimental group, nor effects of either factor independently. High error rates were not necessarily expected to occur as the task was very easy and designed to maintain participants' sensitivity to the rare target stimulus, not induce high cognitive load. In fact, there were no misses committed throughout the dataset. False alarms did occur, however not differently on average between groups or conditions.

ERP Results

Across the analyses conducted for p3, LPP-E, and LPP-L, there were several significant interactions and single-factor effects. All of these showed small effect sizes ($\eta_p^2 < .10$), yet with many showing *p*-values below .001. Given that the sample was smaller than planned, it is expected that a complete sample of at least 48 per group would show similar results with larger effect sizes. The greater the statistical power of an analysis, the better equipped it is to detect small effects. That these small effects were detected with an incomplete sample gives reason to suspect they are deflated from what would be observed in adequately powered analyses. This limitation is also a consideration for interpreting the somewhat unusual p3 patterns between standard and target stimuli.

p3

Amplitude. The nature of the observed interaction of stimulus, condition, and ROI in affecting p3 amplitude is unusual. Where p3 amplitude in standard trials differed from target trials, standards showed greater amplitude or no difference when compared in the same condition and ROI. Standard stimuli usually show weaker p3 activation than targets given their high frequency. This reversal of the typical amplitude difference between stimulus roles could be due to the standard stimuli being scenic while the geometric pattern targets are repetitive patterns. Considering the attention restoration components, fascination and scope, scenic images should inherently be higher in these qualities than redundant geometric patterns. As such, participants could still be finding novelty and fascination within the standard stimuli after many trials despite their frequency. Olofsson, Nordin, Sequeira, and Polich (2008) explain that valence affects p3 amplitude such that pleasant images evoke greater amplitude than unpleasant images, specifically when the targets are task-relevant as in the present study. It is likely that, in the context of the experiment, the scenic standards were more pleasant to look at than the geometric targets. That said, it is still questionable whether valence alone can explain the standards' greater amplitude than targets given the extensive documentation of reliable p3 activation following rare stimuli. However, the finding that occipital p3 amplitude for HR and LR standards was greater than occipital amplitude for Br control standards serves as a better comparison supporting that the content of the experimental standards may be inherently more pleasant as scenic stimuli rather than a plain brown screen when frequency is held constant, resulting in stronger p3's despite their high frequency.

Regarding the effect of ROI on p3 amplitude, at face value it would appear unusual for parietal p3 amplitude to be lesser than occipital amplitude given that p3 is well established as showing strong generation in the dorso-medial parietal lobes (Luck, 2014). However, Cohen's *d* for that comparison was low (.151) and the distance on the scalp from O1 and O2 to Pz, where traditionally the most prominent p3 activation is detected, is shorter than the distance of P7 and P8 to Pz. So, it is likely that the channels used to represent the occipital ROI in the present study were picking up more of the p3 signal from its most prominent central parietal generators than the channels used to represent the parietal ROI. And, the Emotiv Epoc does not have channel locations along the central "z-line" which includes the Pz channel.

Latency. The ROI x condition interaction showed that p3 FLP was earlier in occipital lobes in HR conditions than most combinations of ROI and other conditions (Br and LR). The same was true for occipital p3 FLP in LR conditions compared to other combinations of ROI and condition, except for occipital HR p3 FPL. Thus, generally, anterior p3 FPL was later and posterior p3 FPL was earlier. This finding makes sense given that p3 propagates most strongly from centroparietal generators and the closest ROI measured in the present study to that region was the occipital ROI.

Within the stimulus x ROI interaction, parietal standard FLP was later than occipital standard FLP, but earlier than target FLP at all of the other ROI's. Also, occipital FLP for standard stimuli was earlier than target FLP at all ROI's, including occipital. That is, occipital standard FLP was earlier than occipital target FLP. This is an especially important difference because it shows that in the same ROI with the strongest p3 activation, target p3's were slower to propagate than standard p3's. The p3 component is representative of stimulus informational processing, including categorical information. Thus, the finding that rare target stimuli result in later propagation of the component than frequent standard stimuli, especially in controlled sequences that ensure the interval between targets is quite large, suggests that classification speed is slower when an improbable but task relevant stimulus is presented. Polich (2012) explains that latency is proportional to the time required for target detection and processing.

The main effect of ROI on p3 FLP was intuitive in that the earliest FLP was recorded in the occipital ROI, the closest to the centroparietal location of p3 generation. From there, each ROI moving forward anatomically was later than the one posterior to it as the potential moves outward from its origin. In the main effect of stimulus, standard trials showed earlier FLP than target trials.

p3 Summary. Taken together, the amplitude and FPL findings show that stimulus processing involved more resources in a shorter timeframe for standard scenic stimuli, and more time for detecting and processing target stimuli. Also, the HR condition showed greater amplitude and earlier FLP than the LR and Br conditions and in posterior ROI's, with the greatest/earliest being the occipital ROI. These results indicate that images in the HR conditions, specifically standards, recruited greater attentional resources without sacrificing processing time compared to other conditions and targets, in appropriate ROI's. Earlier latency coupled with greater amplitude in the p3 window suggests facilitated endogenous (task-driven) attention when looking at HR standards. Naturalness group did not affect p3 amplitude or latency, but restorativeness level did.

LPP

LPP-E differences were observed in the early window at the channel level, but not at the ROI level. LPP-L differences were only observed between groups in the late window.

LPP-E. The interaction effect of channel and stimulus on LPP-E amplitude revealed one specific pairwise difference between target LPP-E activation at O2 and standard LPP-E activation at F7. The effect of channel showed greater activation at AF3, AF4, and F7 compared to O2. These results are, again, unusual, and inconsistent with the vast literature on LPP that demonstrates it is centroparietal generating as LPP is essentially the measurement over time of the return to baseline of the p3 spike in activity (Hajcak & Foti, 2020; Hajcak, Weinberg, MacNamara, & Foti, 2012). Usually, LPP activation is greater in posterior ROI's, especially at Pz, than anterior ROI's. However, within the frontal ROI is where Mahamane and colleagues (2020) observed the difference in LPP between nature and built stimuli.

LPP is sometimes considered as beginning just after the p3 peak and is often averaged over a window beginning at 400 ms (Hajcak et al., 2012; Hajcak & Foti, 2020; MacNamara et al., 2011). Thus, considering an earlier window within the data may reveal that, in terms of returning to baseline activity levels following p3 activation, LPP-E could have returned more sharply, before 600 ms at channels nearest the centroparietal region. However, a concern of such a reanalysis would be an overlap between the p3 and LPP-E windows that would problematically entangle the two components in terms of drawing conclusions. Future research using scenic standard stimuli should evaluate different windows within the theoretical ranges of each of these components. Because p3 latency is affected by various conditions (*e.g.*, stimulus content, stimulus frequency, task difficulty), there is not a narrow, established window in which to evaluate p3 amplitude. Rather, it must be decided based on the design and stimuli of a given study (Luck, 2014). As such, a wide p3 window was used for the present study given the exploratory stage of the research into environmental effects on ERP components, and thus a later beginning of the LPP-E window. Mahamane and colleagues (2020) used a similar LPP window, 550-930 ms, and found significant differences between nature and built stimuli suggesting that nature was experienced more pleasantly than built. It is of note that, in their experiment, all participants were exposed to both nature and built images in a within-subjects design. Herein, the environment type defined independent groups.

LPP-L. There was a significant LPP-L difference between the nature and built experimental groups without any significant effects of ROI (or channel), condition, or stimulus, with participants in the nature experimental group showing greater LPP-L activation than in the built experimental group. This finding suggests that valence was generally higher in the nature stimuli and emotional processing was taking place throughout the stimulus presentation which ended at 2000 ms, albeit the difference was small and close to baseline measurements. Several studies have shown previously that emotional processing of stimuli, as shown by LPP, can continue to occur as long as the stimulus is present (Hajcak & Foti, 2020; Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012; MacNamara et al., 2011).

LPP Summary. LPP is an even less temporally defined component than p3. That is, as an indicator of ongoing emotional processing and arousal following the p3, it can be measured for several seconds after stimulus onset. Studies have found that as long as the stimulus is present, this processing can continue at significant amplitude difference from baseline (Hajcak & Foti, 2020). The binning of the LPP into smaller time windows, such as LPP-E and LPP-L herein, allows differences in amplitude along the overall time window to not be washed out in averaging. For example, differences were seen in the present study during LPP-E between channels, but between groups during LPP-L. At least one study has even used 90 ms bins with start times 100 ms apart to break the LPP into 11 windows from 310 ms to 1400 ms (Diedrich, Naumann, Maier, Becker, & Bartussek, 1997). Most LPP research divides the window into larger bins starting between 400-600 ms post stimulus onset and going up to 5000 ms (Hajcak & Foti, 2020; Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012; MacNamara et al., 2011; O'hare, Atchley, & Young, 2017).

The finding that LPP-E showed difference between channels, but not conditions or groups, but LPP-L showed difference between nature and built experimental groups, suggests that the emotional and arousal provoking content of nature scenes continues to be processed longer than that of built scenes. Because this difference did not emerge between HR and LR scenes, it is more difficult to interpret. Had a restorativeness level difference been found, it could be attributed to differences in the subcomponents of restorativeness that may lend to a scene's pleasantness. That said, in the present study, the scenic stimuli from both nature and built experimental groups were rated by experimental participants and averaged according to both their naturalness category and their restorativeness level (HR-N, LR-N, HR-B, and LR-B). The main effects across these four stimulus categories on subjective ratings of perceived restorativeness and dimensions of subjective preference showed that the HR-N and LR-N scenes were greater in subjectively rated valence and mental arousal than their restorativeness-respective built scenes. LPP primarily indicates stimulus valence and arousal out to 5000 ms post stimulus onset(Hajcak & Foti, 2020; Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012; MacNamara et al., 2011; O'hare, Atchley, & Young, 2017).

Support for Hypotheses

For the four stated hypotheses for the present study, support was mixed. Hypothesis 1 stated that targets in HR blocks would show greater p3 amplitude and earlier latency than targets in LR or Br blocks. However, it was found that HR standard stimuli, not targets, showed this difference from LR and Br standards, showing that stimuli rated as HR also showed neurophysiological evidence of being more attentionally restorative as well.

Hypothesis 2 stated that target RTs would be faster, and block error counts fewer, in HR blocks compared to LR and Br blocks. These behavioral measures did not show differences between conditions or between groups. The ERP results did not show clearly improved performance on targets for HR over LR or Br. Because responding was not appropriate for standard stimuli (there were false alarms, but not that significantly differed between conditions or groups), any restorative effects on standard stimulus processing were not documented behaviorally in this study.

Hypothesis 3 stated that an interaction effect of naturalness and restorativeness on LPP amplitude would be observed. While there was not an interaction of these factors affecting LPP, LPP-E was different between frontal channels and O2. Also, the LPP-L difference in which the nature experimental group showed greater amplitude than the built experimental group partly supports this hypothesis, suggesting that nature scenes were more pleasant and more arousing than built scenes between 1000 ms and 2000 ms after stimulus onset. This finding is consistent with stimulus ratings from the ERP sample. Of course, the ratings of the HR-N and HR-B images from the rating sample were equal because they were the basis for matching the HR stimuli in the N and B groups. This finding is also consistent with the previously found nature/built LPP difference (Mahamane et al., 2020).

Finally, Hypothesis 4 stated that the subjective preference ratings would be greater for HR versus LR scenes, and for N versus B scenes. This is exactly what was observed for restorativeness and four of the five subjective preference dimensions, with the exception of physical arousal. HR-N was the highest, followed by HR-B, LR-N, and LR-B scenes in that order with each category being different from the others.

Naturalness and Restorativeness Conclusions

One main goal of this study was to experimentally delineate the effects of scene naturalness and restorativeness on attention restoration to better understand how these aspects of an environment affect cognitive function. While there are limitations regarding the size of the final analysis sample, some inferences about these factors' effects on cognition can be made. The experimental sample rated HR-N higher on perceived restorativeness than HR-B scenes even though they had been matched for restorativeness based on ratings from the ratings sample. HR-N scenes were also rated highest in the subjective preference categories than all other scene types. There was clearly shown a preference of nature over built in our samples. This preference also bore out in the comparison of LPP-L between nature and built stimuli, as indicative of greater positive valence and mental arousal.

From the ERP results, conclusions about the effect of restorativeness on attentional processes in the present study are a bit less clear to draw. HR scenic trials, not targets, produced greater p3 amplitude and earlier latency than LR scenes and Br controls. Restorativeness seemed to directly affect processing of the standard stimuli themselves, rather than the targets immersed in blocks of standards with varying levels of restorativeness. Thus, an effect of restorativeness on attentional processing as shown by p3 characteristics was found, but not as hypothesized, nor as the paradigm would suggest based on previous research. Traditionally, in oddball tasks, both active and passive, p3 amplitude is significantly greater for target trials than standard trials (Polich, 1989; Polich, 2007; Polich, 2012; Polich et al., 1989).

CHAPTER V

LIMITATIONS, FUTURE DIRECTIONS, AND IMPLICATIONS

Sample Size

The main limitation of the findings presented herein is the ERP sample not reaching the targeted size. Only 39 of the ERP participants run were able to be used in analyses after data preprocessing. Further, the 2020 COVID-19 pandemic halted the collection of more data to achieve the 96 total participants targeted. However, several significant interactions and effects were detected using mixed ANOVA's. The sizes of these effects were mostly small, suggesting that they would likely increase in size with a larger sample as small effects are more difficult to detect with small samples. Though it must be acknowledged that with a much larger sample, as originally planned, the nature of the present results could also change.

Stimuli, Presentation, and p3 Elicitation

The paradigms in both the study reported by Mahamane and colleagues (2020) and the present study did not show a traditional p3 effect. In the former, all participants viewed both nature and built stimuli in two counterbalanced blocks that differed by which scenic category served in the standard role (80% frequency) and the target role (20% frequency). However, single images were not used repeatedly in these roles in each block. Instead, the experimental program pulled stimuli from nature and built stimulus pools at the appropriate frequencies for each block. So, stimuli within each category were also very diverse and likely why a p3 effect was not found in that study.

The present study responded to this limitation by having any one participant only see one scenic image as the standard for each block and using non-scenic geometric pattern images as targets, so that targets are not even in the “scenic” category as were all standards. Also, the standard frequency was increased to 90% and the target frequency was reduced to 10% from the previous study. Finally, the present study was an active oddball task that instructed participants to respond to target stimuli rather than passively view the stimuli as a slideshow. However, with these changes, a strong target p3 was still not elicited. Instead, standard p3 amplitude in the HR conditions was higher than target amplitude in the same conditions. The most likely explanation is that with the inherent fascination and extensiveness of the scenic standards, according to the components on ART on which the HR scenes were highly rated, stimulus processing required more attentional resources (greater p3 amplitude), but less effortfully as these components naturally engage exogenous attention (earlier latency).

Regarding the content of the stimuli, it is important to note that all of the HR-B stimuli contained many natural constituents in the researcher’s own qualitative assessment. For example, more than one image contained houses along a beachfront. One image contained a cabin surrounded by a snowy forest. Thus, while the stimuli were selected based on their categorization rates on naturalness and their ratings of perceived restorativeness, the elements that led participants to rate these scenes as highly restorative may have been the natural elements and thus whether naturalness and restorativeness were actually separated could be questioned. For example, the aforementioned cabin scene could be rated highly on the “being away” component due to the remote, forested location of the “built” cabin. This conundrum begs the question of whether naturalness and restorativeness can possibly be separate factors in any pure way.

Future ERP research using visually complex scenic stimuli in oddball paradigms to compare p3 topography between conditions should systematically test under what presentation conditions greater target p3 compared to standards are evoked. Based on the findings of the present study, a logical next step would be to reverse the roles of the geometric and scenic stimuli. The scenic standards in the present study were found to evoke greater, earlier p3 amplitude than the targets in their blocks. Switching the roles of these images in the experiment would test whether the content of a current image has more to do with the p3 characteristics in its associated ERP than the features of the standard images within which it is immersed. The present study used the immersive approach because ART research has set a precedent for long restorative stimulus presentation before testing (Berman et al., 2008; Berto, 2005, 2007; Berto et al., 2015; Gamble et al., 2014; Li et al., 2020; Taylor & Kuo, 2008, 2011). Thus, this was the logical approach to attempt replication of ART findings while incorporating ERP methodology to provide a neurophysiological assessment as well.

Future Between-Groups Investigations

It is known that habituation tends to occur after several instances of target presentation (Lammers et al, 1989; Polich, 1989). While habituation proposes minimal threat due to the controlled sequence paradigm, the present study counterbalanced block order to also control for fatigue and/or carry-over. However, carry-over effects would be interesting to examine in the future. Even though an effect of order was observed in some analyses, the largely uneven participant numbers between block orders increases the likelihood that these effects are spurious and analyzing these data for carry-over effects would not be valid. To test for carryover of attention restoration to subsequent block performance, a future replication should use a between-groups design to explore the longevity of attention restoration by having participants complete several successive blocks in the same restoration condition to compare any neurophysiologically and behaviorally evident performance declines, over time, and between conditions.

Also, as described above, the proposed study approaches attention restoration in the context of an “attention improvement during immersion” model, versus recovery from a fatigued state; and there is precedent for such an effect (Berto, et al. 2015; Tennessen & Cimprich, 1995). However, p3 and LPP modulation by attention restoration after fatigue should also be studied using a between-groups design in which participants are fatigued by an attention-demanding task prior to completing oddball task blocks with HR-N, HR-B, LR-N, LR-B, or control standard stimuli. Importantly, Boksem, Meijman, and Lorist (2006) found that P3 amplitude was not decreased, but latency did increase after they induced mental fatigue in their participants. However, Lorist, Boksem, and Ridderinkhof (2005) found in a similar task, with respect to difficulty and duration, that time-on-task did not affect p3 amplitude or latency. Thus, there is need to further explore p3 and mental fatigue, and especially how the relationship is affected by restorative and natural scene characteristics.

p3a vs. p3b

Often the p3 is thought of as having two general subcomponents: p3a (an earlier, more dramatic elicitation in response to unexpected, task-irrelevant stimuli) and p3b (analogous to the traditional p3 and a response to rare, task-relevant, target stimuli as measured herein; Polich, 2007, 2012). Given that ART functions via a mechanism defined by the switch to exogenous from endogenous attention, the p3a and p3b subcomponents should map onto those, respectively. Applying this idea to investigations of p3 within the ART framework could be illuminating and should be pursued at some point following this study. However, inclusion of that dimension herein would have been premature as the soundest method of systematically developing this line of work was to search first for modulation of p3 (p3b) via restoration, and then investigate the delineation of p3a from p3b within the ART framework. And, given that p3 elicitation in this study was not typical of an active oddball paradigm, those issues described above should be addressed first before introducing another level of complexity.

Passive tasks often show a p3 elicitation more similar to the p3a because there are not instructions giving task relevance to any of the stimuli. Three-stimulus active tasks, in which there is a rare, non-target distracter, are traditionally used to elicit both p3a and p3b for comparison. The rare, non-target distracter would involuntarily engage exogenous attention while the rare, task-relevant target would be detected when participants' endogenous attention is engaged. Thus, such a paradigm could serve future ERP investigations of ART well by representing both modes of attention. Or, a paradigm in which a two-stimulus passive task (p3a; exogenous attention engaged) displaying restorative standard stimuli precedes a two-stimulus active task (p3b; endogenous attention engaged) may show facilitation of the active task as evidenced by increased p3b amplitude and decreased latency. Such work could potentially lead to a reliable, tangible method of confirming attention restoration occurrence in future paradigms, or even applied interventions.

Other Populations

Having initiated a foundation for this work with the present study, the significant effects shown should be explored in other populations known to have differences in their capacity for directed attention from neurotypical Western adults. p3 differences are documented in a wide range of demographically and/or clinically distinct populations including neurotypical children (Pfueller et al., 2011) and children and adults with ADHD (Barry, Johnstone, & Clarke, 2003; Szuromi, Czobor, Komlósi, & Bitter, 2011). ART has been studied in children with ADHD (Taylor & Kuo, 2008, 2011). Attempts to replicate any significant effects of restorative images on p3 and LPP characteristics from neurotypical adult studies in these populations could shed light on the mechanistic nature of attention restoration in people with ADHD and other conditions characterized by attention deficits.

For example, do people with ADHD have more sensitive exogenous attention mechanisms than neurotypical controls, or are they simply unimpaired in that capacity compared to their own for endogenous attention? In a three-stimulus active oddball task as described above, but in which the distracter is very similar to an HR standard image except for one particular detail, the degree to which such distracters elicit p3a components in adults and children with ADHD, compared to controls, could be assessed. Another condition would involve a two-stimulus passive task to then compare p3a's when there is an active task (three-stimulus). It would be expected in the three-stimulus active task, versus the two-stimulus passive, that people with ADHD would elicit equally strong and timed p3a's between the two paradigms (showing their typical impaired performance and smaller p3b's versus controls on the active task). In contrast, neurotypical controls should show p3a amplitude attenuation and latency increase under suppression of the default mode network (DMN), a rest mode network of cortical and limbic structures that is active during less demanding tasks and in which activity is suppressed during more demanding tasks in neurotypical individuals (*i.e.* effective directed attention functioning; Raichle & Snyder, 2007). Alternatively, the ADHD sample would show greater p3a amplitude, and earlier latency, compared to controls in both paradigms. Significant differences between groups in such a direction would suggest that just-noticeable-difference thresholds are differently – perhaps more – fine-tuned in people with ADHD than neurotypical people, but only when detected exogenously. Finally, if these effects emerged, how might they be moderated by restorativeness and naturalness of an immersive environment or photographic experimental stimuli?

Theoretical Implications

In conclusion, this work has demonstrated neurophysiological correlates of attention restoration but, in doing so, has raised the need to bridge ART with Polich's (2007) theoretical model of p3 elicitation in which the attentional resources required to produce p3 are a direct function of arousal level. ART explains, however, that the mechanisms requiring those resources must rest during exogenous attentional engagement so that the resources may replenish, with no specific mention of arousal. Greater p3 amplitude found for restorative standard stimuli suggests that attention restoration results in greater arousal that, according to Polich (2007), underlies the attentional resources needed for directed attention during an active discrimination task. However, Roe and colleagues' (2013) findings that natural environments (restorativeness was not assessed) lowered arousal introduce some confusion to this hypothesis. It seems that "arousal" in Polich's model may be relevant to, though simply unmentioned in, ART.

The arousal ratings obtained in the present study, when combined with observed p3 characteristics, do shed some light on the relationship between arousal and attention restoration. But, future investigation is ultimately needed to experimentally inform updates of these existing theories.

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APPENDICES

Appendix A

Edinburgh Handedness Inventory – Short Form (Veale, 2013)

Please indicate your preferences in the use of hands in the following activities or objects:

Writing: Always Right Usually Right Both Equally Usually Left Always Left

Throwing: Always Right Usually Right Both Equally Usually Left Always Left

Toothbrush: Always Right Usually Right Both Equally Usually Left Always Left

Spoon: Always Right Usually Right Both Equally Usually Left Always Left

Appendix B

Image Subjective Preference (Roe et al., 2013)

Please rate on this scale your responses to the following questions.

1	2	3	4	5	6	7	8	9	10
Not at All									Extremely

1) How attractive do you find this scene?

2) How willing would you be to visit this scene?

Please rate your response to the following question on each of the two scales below.

How does this photo make you feel?

3)

1	2	3	4	5	6	7	8	9	10
Very Sad									Very Happy

4)

1	2	3	4	5	6	7	8	9	10
Calm									Excited

5)

1	2	3	4	5	6	7	8	9	10
Mentally Tired									Mentally Energetic

Appendix C

PRS-short (Berto, 2005)

Please rate on the scale below the degree to which each statement describes the current picture.

0	1	2	3	4	5	6	7	8	9	10

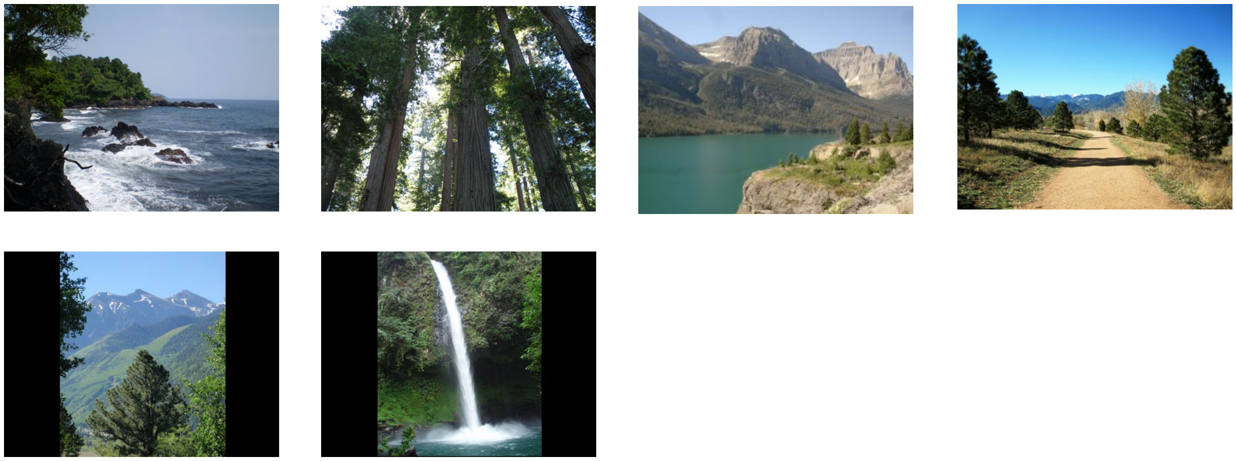
Not at all Rather much
Very Much

1. That is a place which is away from everyday demands and where I would be able to relax and think about what interests me.
2. That place is fascinating; it is large enough for me to discover and be curious about things.
3. That is a place where the activities and the items are ordered and organized.
4. That is a place which is very large, with no restrictions to movements; it is a world of its own.
5. In that place, it is easy to orient and move around so that I could do what I like.

Appendix D

Experimental Scenic Stimuli

a) HR-N



b) HR-B

c) LR-N

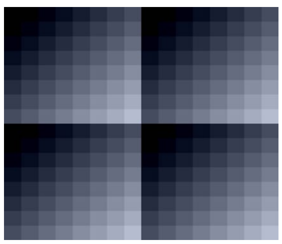
d) LR-B

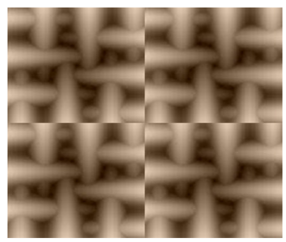
Appendix E

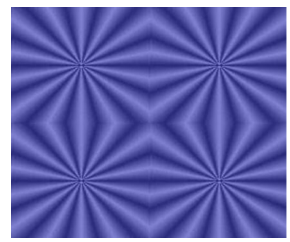
Control Standard and Target Stimuli

a) Br

b) Geometric pattern targets







CURRICULUM VITAE

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Education

2017 — *Doctoral Candidate (ABD) in Experimental and Applied Psychological Science*
Utah State University, Logan, Utah
Committee Chair: Kerry Jordan
Approved Dissertation Title: *Modulations of P3 and LPP by Standard Stimulus Dimensions of Restorativeness and Naturalness in a Two-Stimulus Oddball Paradigm: An ERP Study* (Expected completion: August 2020)

2012 — *M.S. in General Psychology*
New Mexico Highlands University, Las Vegas, New Mexico
Thesis Chair: Maura Pilotti

2008 — *B.A. in Psychology*
Minors: Environmental Studies and French
Baylor University, Waco, Texas
Thesis Chair: Wade C. Rowatt

Employment

2017-present — Assistant Professor of Psychology
Western Colorado University

2013-2017 — Graduate Instructor
Utah State University

2012-2013 — Graduate Teaching Assistant
Utah State University

Academic & Professional Awards

2019-2020 — Dean's Award for Inclusive Excellence ($1,000)
School of Graduate Studies, Western Colorado University

2016-2017 University Doctoral Student Researcher of the Year ($300)
Office of Research and Graduate Studies, Utah State University

2016-2017 College Doctoral Student Researcher of the Year
College of Education and Human Services, Utah State University
Selection by Dean-appointed committee

2015-2016 Lawson Fellow ($3,000)
Department of Psychology, Utah State University
Merit-based support for graduate students working in areas dealing with children and families

2012 Martin Luther King Fellow ($7,000)
School of Graduate Studies, Utah State University
Merit-based support for African-American graduate students

2011 Psi Chi Regional Research Award ($300)
Western Psychological Association 2011 Annual Convention
Mahamane, S., Almand, J., Pilotti, M., & Bustos, L. (2011). Invoking nature: A modest priming paradigm. Poster presented at the 91st Annual Convention of the Western Psychological Association

2010 Psi Chi Regional Research Award ($300)
Western Psychological Association 2010 Annual Convention
Simcox, T., **Mahamane, S.**, Pilotti, M., Romero, E., & Grinstein, J. (2010). Emotional and behavioral responses of bilingual individuals to taboo words. Poster presented at the 90th Annual Convention of the Western Psychological Association.

2008 Undergraduate Award for Outstanding Research in Psychology
Department of Psychology and Neuroscience, Baylor University

2008 Outstanding Honors Thesis
Baylor University
Title: The effect of photographic depictions of nature on positive/negative affect and humility

Travel Awards

2016 USU Research and Graduate Studies Travel Fund ($300)
School of Graduate Studies, Utah State University
Funds received for travel to present a poster at the annual meeting of the Society for Neuroscience in November, 2016.

2016 USU Research and Graduate Studies Travel Fund ($300)
School of Graduate Studies, Utah State University
Funds received for travel to present a poster at the annual meeting of the Cognitive Neuroscience Society in April, 2016.

2016 Psychology Student Travel Fund ($300)
Department of Psychology, Utah State University
Funds received for travel to present a poster at the annual meeting of the Society for Neuroscience in November, 2016.

2016 Psychology Student Travel Fund ($300)
Department of Psychology, Utah State University
Funds received for travel to present a poster at the annual meeting of the Cognitive Neuroscience Society in April, 2016.

2013 Dean's Travel Stipend ($250)
Emma Eccles Jones College of Education and Human Services, Utah State University
Funds received for travel to present a poster at the biennial meeting of the Cognitive Development Society in October, 2013.

2013 Psychology Student Travel Fund ($300)
Department of Psychology, Utah State University
Funds received for travel to present a poster at the biennial meeting of the Cognitive Development Society in October, 2013.

2013 Cognitive Development Society Student Travel Award ($450)
Cognitive Development Society Biennial Conference

Grants Submitted as PI

2017 PI, Graduate Research & Creative Opportunities ($1,000; *awarded*)
Utah State University
Title: Modulations of P3 and LPP by Standard Stimulus Dimensions of Restorativeness and Naturalness in a Two-Stimulus Oddball Paradigm: An ERP Study
Goal: Use ERP methodology to observe modifications in P3 and LPP as a function of restorativeness and naturalness of task stimuli, to better understand these dimensions' effect on attention and affect.

2013 Co-PI, Project funded by Blue Goes Green Student Grant Program ($2,000; *awarded*)
Utah State University
Title: Psychological Mechanisms of 'Green' Behavior. (2013-2014).
Goal: Investigate attitudes towards, and perceptions of, local environments with respect to their categorization as natural versus manmade and polluted versus clean.

2010 PI, Project funded by Sigma Xi Student Research Grant ($500; *awarded*)
Title: Are components of fascinating stimuli more likely to be visually processed in parallel than serially?
Goal: Investigate how fascinating scenes affect visual scanning during a search task to better understand the 'fascination' component of attention restoration theory.

2010 PI, Girard Fund Research Grant ($150; *awarded*)
Behavioral Sciences Department, New Mexico Highlands University
Title: Priming the nature schema: A modest paradigm
Goal: Does an active priming task affect responses on a lexical decision task?

Publications

Peer Reviewed Journal Articles

Mahamane, S., Wan, N., Porter, A., Hancock, A. S., Campbell, J., Lyon, T. E., & Jordan, K. E. (2020). Natural categorization: Electrophysiological responses to viewing natural versus built environments. *Frontiers in Psychology, 11.* https://doi.org/10.3389/fpsyg.2020.00990.

Borden, D. S., **Mahamane, S.,** (2020). Borden, D. S., & Mahamane, S. (2020). Social marketing and outdoor recreational advocacy groups: Lessons from a rock-climbing campaign. *Journal of Outdoor Recreation and Tourism, 29*, 100262.

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The value of clean air: Comparing discounting of delayed air quality and money across magnitudes. *Psychological Record, 67(2),* 137-148.

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Watts, C. M., Moyer-Packenham, P. S., Tucker, S. I., Bullock, E. P., Shumway, J. F., Westenskow, A., Boyer-Thurgood, J., Anderson-Pence, K., **Mahamane, S.,** Jordan, K. (2016). An examination of children's learning progression shifts while using touch screen virtual manipulative mathematics apps. *Computers in Human Behavior, 64,* 814-828.

Moyer-Packenham, P. S., Shumway, J. F., Bullock, E., Tucker, S. I., Anderson-Pence, K. L., Westenskow, A., Boyer-Thurgood, J., Maahs-Fladung, C., Symanzik, J., **Mahamane, S.**, MacDonald, B., & Jordan, K., The Virtual Manipulatives Research Group at Utah State University. (2015). Young children's learning performance and efficiency when using virtual manipulative mathematics iPad apps. *Journal of Computers in Mathematics and Science Teaching*, *34(1),* 41-69.

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Pilotti, M., Gutierrez, A., Klein, E., & **Mahamane, S**. (2014). Young adults' perceptions and use of bilingualism as a function of an early immersion program. *International Journal of Bilingual Education and Bilingualism,* 1-12. doi: 10.1080/13670050.2014.904841

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Gutierrez, A., Pilotti, M., Romero, E., **Mahamane, S.,** & Broderick, T. (2012). Proactive interference between languages: Do task demands matter? *International Journal of Bilingualism*, *16(4).*

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Simcox, T., Pilotti, M., **Mahamane, S.,** & Romero, E. (2012). Does the language in which aversive stimuli are presented affect their processing? *International Journal of Bilingualism, 16(4),* 419-427.

Pilotti, M., Chodorow, M., Agpawa, I., Krajniak, M., and **Mahamane, S.** (2012). Proofreading for word errors. *Perceptual and Motor Skills, 114,* 641-664.

In Preparation

Mahamane, S., Haynes, J., Young, J., & Jordan, K. E. (in preparation). Spatial discounting in *Canis latrans* as affected by human threat, sex, and the breeding cycle.

Other Publications

Mahamane, S. (2009). The global water crisis and what you can do about it. *Hunger News and Hope, 10(3).*

Press Coverage

2017 Interviewee for *ADHD: Horizon*. London: BBC. Released May, 2017.

2015 *The Utah Statesman,* "TEDxUSU takes off during fourth year" http://usustatesman.com/tedxusu-takes-off-during-fourth-year/

2015 *The Utah Statesman,* "Undergraduate research provides opportunities, growth for students" http://usustatesman.com/undergraduate-research-provides-opportunities-growth-for-students-2/

Professional Membership/Offices

2010-present Member, Rocky Mountain Psychological Association

2016-2017 Member, Society for Neuroscience

2015-2017 Member, Cognitive Neuroscience Society

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2010-2012 Member, Western Psychological Association

2010-2012 Associate Member, Sigma Xi
New Mexico Highlands University

2010-2011 Graduate Student Representative, Department of Behavioral Sciences
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Responsibilities: represent the interests and concerns of students in graduate psychology programs at psychology faculty meetings

2010-2011 Vice President/Campus Liaison, Psi Chi
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New Mexico Highlands University
Responsibilities included: evaluation of research proposals submitted by undergraduate and graduate students currently pursuing degrees in STEM disciplines

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New Mexico Highlands University
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2005-present Member, Psi Chi
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Psi Chi National Psychology Honors Society

Invited Presentations

2019 Mahamane, S. (2019). *Spatial discounting in Canis latrans as affected by human threat, sex, and the breeding cycle*. Gardner Memorial Lecture. 89th Annual Convention of the Rocky Mountain Psychological Association, Denver, Colorado.

2018 Mahamane, S. (2018). *Belief and Behavior in an Alternative Facts Environment*. Talk given at the annual Water Workshop, Western Colorado University, June 2018.

2017 Uncomfortable Conversations panelist
Western Colorado University

2016 Keynote address & panelist at "Mental Health is No Joke: Stand up to Stigma Student Mental Health Panel"
Mental Health Week, Utah State University
Title: *Living with ADHD in Grad School*

2010, 2011 Invited Speaker to Dr. Camea Gagliardi's class, Professional Ethics and Issues
New Mexico Highlands University
Topic: Ethical mental health practice in rural areas

Conference Presentations

Oral Presentations

Mahamane, S., Bingham, M. (2016). *The power of "learning disabilities".* Workshop conducted at the Utah Art Education Association's annual conference.

Gutierrez, A., **Mahamane, S.,** Pilotti, M., & Trujillo, L. (2011). *Interference and order of access to languages in bilingual speakers.* Oral presentation at the 91st Annual Convention of the Western Psychological Association.

Mahamane, S., Almand, J., & Pilotti, M. (2010). *An investigation of the relationship between activation of the nature schema and cooperation.* Oral presentation at the 80th Annual Convention of the Rocky Mountain Psychological Association.

Posters

Mahamane, S., Mortensen, S., Lyon, T., & Jordan, K. E. (2017). *Age and sex differences in environmental perception and response time during a nature versus built scenery categorization task*. Poster presented at the Annual Meeting of the Rocky Mountain Psychological Association, Salt Lake City, Utah.

Mahamane, S., Wan, N., Hancock, A., Porter, A., & Jordan, K. E. (2017). *Greater theta and delta synchrony when viewing natural versus built environments in a passive oddball task.* Poster presented at the Annual Meeting of the Cognitive Neuroscience Society, San Francisco, California.

Mahamane, S., Porter, A., Hancock, A., Wan, N., & Jordan, K. E. (2016). *Implicit discrimination of natural versus built environments as evidenced by p3 elicitation*. Poster presented at the Annual Meeting of the Society of Neuroscience, San Diego, California.

Mahamane, S., Porter, A., Hancock, A., Campbell, J., Wan, N. J. A., Jordan, K. E. (2016). *The effect of natural versus built environments on child reverse digit span performance: A spectral analysis.* Poster presented at the Annual Meeting of the Cognitive Neuroscience Society, New York, New York.

Porter, A., **Mahamane, S.**, Hancock, A., Wan, N. J. A., Jordan, K. (2016). *An ERP investigation into attention restoration theory*. Poster presented at the Annual Meeting of the Cognitive Neuroscience Society, New York, New York.

DeHart, W. B**., Mahamane, S.**, Friedel, J. E., Odum, A. L., & Jordan, K. (2015). *Blue Goes Green II: Implicit preference for natural vs. man-made environments.* Poster presented at the Intermountain Sustainability Summit 6th Annual Meeting, Ogden, Utah.

Friedel, J. E., DeHart, W. B., **Mahamane, S.**, Odum, A. L., & Jordan, K. (2015). *Blue Goes Green I: increased delay discounting for better air quality*. Poster presented at the Intermountain Sustainability Summit 6th Annual Meeting, Ogden, Utah.

Mahamane, S., DeHart, W. B., Friedel, J. E., Odum, A. L., & Jordan, K. (2015). *Blue Goes Green III: Does visual pollution affect nature/built categorization?* Poster presented at the Intermountain Sustainability Summit 6th Annual Meeting, Ogden, Utah.

Moyer-Packenham, P. S., Westenskow, A., Shumway, J. F., Bullock, E., Tucker, S. I., Anderson-Pence, K. L., Boyer-Thurgood, J., Maahs-Fladung, C., Symanzik, J., **Mahamane, S.**, MacDonald, B., & Jordan, K., The Virtual Manipulatives Research Group at Utah State University. (2014). The effects of different virtual manipulatives for second graders' mathematics learning in the touch-screen environment. *Proceedings of the 12th International Conference of the Mathematics Education into the 21st Century Project*, (Vol. 1, p. 1-6). Herceg Novi, Montenegro.

Moyer-Packenham, P. S., Shumway, J. F., Bullock, E., Tucker, S. I., Anderson-Pence, K., Westenskow, A., Boyer-Thurgood, J., Maahs-Fladung, C., Symanzik, J., **Mahamane, S.**, MacDonald, B., & Jordan, K., The Virtual Manipulatives Research Group at Utah State University. (2014, April). *Young children's learning performance and efficiency when using virtual manipulative mathematics iPad apps.* Paper presented at the annual National Council of Teachers of Mathematics Research Conference (NCTM), New Orleans, Louisiana.

Moyer-Packenham, P. S., Anderson, K. L., Shumway, J. F., Tucker, S., Westenskow, A., Boyer-Thurgood, J., Bullock, E., **Mahamane, S.**, Baker, J., Gulkilik, H., Maahs-Fladung, C., Symanzik, J., & Jordan, K., The Virtual Manipulatives Research Group at Utah State University. (2014, January). Developing research tools for young children's interactions with mathematics apps on the iPad. *Proceedings of the 12th Annual Hawaii International Conference on Education* (HICE), (pp. 1685-1694), Honolulu, Hawaii, ISSN# 1541-5880.

Mahamane, S., Morath, J., Grunig, K., & Jordan, K. E. (2013). *Early preference for natural vs. built environment types.* Poster presented at the biennial meeting of the Cognitive Development Society, Memphis, Tennessee.

Almand, J., **Mahamane, S.,** Pilotti, M., Sena, S., & Wilson, A. (2011). *Top-down processing and memory of aversive events.* Poster presented at the 23rd Annual Convention of the Association for Psychological Science.

Mahamane, S., Almand, J., Pilotti, M., & Bustos, L. (2011). *Invoking Nature: A modest priming paradigm.* Poster presented at the 91st annual Convention of the Western Psychological Association.

Almand, J., **Mahamane, S.,** Pilotti, M., & Swift, J. (2011). *Taboo word expressions as a function of gender and bilingualism.* Poster presented at the 81st Annual Convention of the Rocky Mountain Psychological Association.

Simcox, T., **Mahamane, S.,** Pilotti, M., Romero, E., & Grinstein, J. (2010). *Emotional and behavioral responses of bilingual individuals to taboo words.* Poster presented at the 90th Annual Convention of the Western Psychological Association.

Mahamane, S., & Rowatt, W. (2008). *The effect of photographic depictions of nature on positive/negative affect and humility.* Poster presented at Baylor University's Undergraduate Research and Scholarly Achievement Presents: Scholar's Day.

Mentee Presentations

Nyman, L., **Mahamane, S.**, Young, J., & Jordan, K. E. (2016). *Spatial discounting in coyotes across the breeding cycle in risky and normal conditions.* Poster accepted to the 86th Annual Convention of the Rocky Mountain Psychological Association, Denver, Colorado.

Grunig, K. L., **Mahamane, S.**, Baker, J., Young, J., & Jordan, K. E. (2014). Coyote numerical discrimination based on memory. Poster presented at the 84th Annual Convention of the Rocky Mountain Psychological Association, Salt Lake City, Utah.

Lyon, T. E., **Mahamane, S.**, & Jordan, K. E. (2014). Categorization of mixed-environment photos by adults and children. Poster presented at the 84th Annual Convention of the Rocky Mountain Psychological Association, Salt Lake City, Utah.

Research Experience

2015-2016 Project Manager, Project funded by Research Catalyst Seed Funding
Utah State University
PI: Dr. Kerry Jordan
Title: The Nature of Self-Control Throughout the Lifespan
Goal: Does exposure to natural environments increase self-control in young children?

2013-present Manager, Multisensory Cognition Lab
Utah State University
Responsibilities: training and supervision of research assistants, lab scheduling, research design, data collection, data analysis, manuscript writing

2013 Doctoral Student Researcher, Project funded by Vice President for Research RC Funding
Utah State University
PI: Dr. Patricia Moyer-Packenham, Co-PI: Cathy Maahs-Fladung
Title: Captivated! Young Children's Learning Interactions with iPad Mathematics Apps. Goal: Investigate young children's ways of thinking and interacting with virtual manipulatives using touch-screen mathematics apps on the iPad.
Responsibilities: live coding, video coding, study design, data analysis

2012 Graduate Research Assistant, Multisensory Cognition Lab
Utah State University
Responsibilities: assist in training and supervision of research assistants, research design, data collection, data analysis, manuscript writing

2011 Graduate Research Assistant, PREM Grant, funded by the National Science Foundation
PI: Dr. Tatiana Timofeeva
New Mexico Highlands University
Goal: Using cell culture techniques to test newly synthesized photodynamic therapy compounds' effect on cancer cell proliferation
Responsibilities: data collection and analysis

2010-2011 Research and Teaching Assistant Supervisor, Project funded by the Spencer Foundation
PI: Dr. Maura Pilotti
New Mexico Highlands University
Project: Enhancing Learning and Retention by Means of Conceptual
Integration
Responsibilities: development of test materials, supervision of introductory psychology teaching assistants, study design, data collection and analysis, manuscript writing

2010-2011 Cognitive Psychology Lab Manager
New Mexico Highlands University
Responsibilities: training and supervision of research assistants, lab scheduling, research design, data collection and analysis, research dissemination

2009-2011 Graduate Research Assistant
Cognitive Psychology Lab, New Mexico Highlands University
Responsibilities: research design, data collection and analysis

2006-2008 Research Assistant
Dr. Wade Rowatt's Social/Personality Psychology Lab
Baylor University
Responsibilities included: study design, data collection and analysis

Teaching Experience

Fall 2018-present Instructor of Record, Multicultural Psychology
Western Colorado University

Summer 2018-present Instructor of Record, Environmental Psychology
Western Colorado University

Spring 2018-present Instructor of Record, Quantitative Skills in Environmental Management
Western Colorado University

Spring 2018-present Instructor of Record, Research Methods
Western Colorado University

Fall 2017-present Instructor of Record, Data and Statistics
Western Colorado University

Fall 2017-present Instructor of Record, Cognitive Psychology
Western Colorado University

Fall 2017-present Instructor of Record, General Psychology
Western Colorado University

Fall 2019 Instructor of Record, Social Psychology
Western Colorado University

Fall 2013-2016 Instructor of Record, Psychological Statistics (four semesters)
Distance Education (broadcast), Utah State University

Summer 2016, Spring 2017 Instructor of Record, Psychometrics (two semesters, **Online**)
Utah State University

Summer 2015 Instructor of Record, Psychological Statistics
Utah State University

Spring 2014-2015 Instructor of Record, Cognitive Psychology (two semesters)
Utah State University

Summer 2014 Instructor of Record, Scientific Thinking and Methods in Psychology
Utah State University

Summer 2013 Graduate Teaching Assistant, Introductory Psychology (**Online**)
Utah State University

Summer 2013 Graduate Teaching Assistant, Scientific Thinking and Methods in Psychology
Utah State University

Spring 2013 Graduate Teaching Assistant, Cognitive Psychology
Utah State University

Spring 2013 Guest lecturer in Cognitive Psychology
Utah State University
Topic: Environment and Cognition

Fall 2012 Graduate Teaching Assistant, Introductory Psychology
Utah State University

Fall 2012 Guest lecturer in Introductory Psychology
Utah State University
Topic: Treatment of Psychological Disorders

Spring 2012 Graduate Teaching Assistant, Statistics for Behavioral Science
New Mexico Highlands University

Fall 2011 Graduate Teaching Assistant, Research Methods in Psychology
New Mexico Highlands University

Spring 2011 Instructor of Record, Introductory Psychology Dual Credit Course
New Mexico Highland's University/Mora High School
Responsibilities: Conduct an introductory psychology dual credit course for high school juniors and seniors

Fall 2010 Graduate Teaching Assistant, Graduate Level Memory and Cognition
New Mexico Highlands University
Responsibilities: lead class discussions on relevant research articles and grade essay homework and tests

Service

WSCU Member, Information Technology Committee
Member, Diversity, Equity, Inclusivity, and Internationalization Committee
Member, ENVS Council
Advisor for Black Student Alliance

2016 Co-Presenter, "What is Civility?"
Hillcrest Elementary School, Logan, Utah
Role plays conducted to teach inclusion and acceptance to 4th- and 5th-graders.

2016 Founder/Co-Facilitator of USU Neurodiversity Group (biweekly meetings)
Mission: Establish a community support group for USU students, faculty, staff, and administration with LD, ADHD, and other cognitive and psychological conditions

2014 Founder/Coordinator of MCL Summer Statistics Workshop
Workshop conducted to bolster statistics knowledge and application for undergraduate research assistants in the Multisensory Cognition Lab.

2010, 2011 Served as Sigma Xi judge for New Mexico Regional Science and Engineering Fair

Outreach

2016 **Podcast Interview**
See In ADHD
Title: The Double Side of The ADHD Coin

2015 **Speaker**
TEDxUSU
Title: ADHD sucks, but not really (Click to Watch)

2015 **Speaker**
USU Ignite! Utah State University Research Week
Title: Serendipity in Science (Click to Watch)

2013-2014 **Co-Founder**
Logan Nerd Night (Local monthly science outreach event)

Other Skills

Software Proficiency

Microsoft Office (Excel, statistical analysis)
SPSS
JASP
Eprime
Superlab
Emotiv Testbench
Matlab*
(*training)

Languages

French* – good reading proficiency, good/fair speaking proficiency
Spanish* – good/fair reading proficiency, good/fair speaking proficiency
(*suffers slightly from lack of use)

References

Dr. Greg Haase (Department Chair, Behavioral and Social Sciences)
Professor, Western Colorado University
Kelley Hall
Gunnison, CO 81232
ghaase@western.edu

Dr. Kerry Jordan (Ph.D. Advisor; research, teaching and mentorship reference)
Associate Professor, Utah State University Department of Psychology
Emma Eccles Jones Education Building, 473
Logan, UT 84322
Tel: (435)-797-2797
Email: Kerry.Jordan@usu.edu

Dr. Scott C. Bates (Committee Member; teaching and mentorship reference)
Department Head, Utah State University Department of Psychology
Emma Eccles Jones Education Building, 487E
Logan, UT 84322
Tel: (435)-797-2975
Email: Scott.Bates@usu.edu

Dr. Melanie Domenech-Rodriguez (ethics and diversity mentor/reference)
Professor, Utah State University Department of Psychology
Emma Eccles Jones Education Building, 425
Logan, UT 84322
Tel: (435)-797-3059
Email: Melanie.Domenech@usu.edu