

COGNITIVE MARKERS OF ATTENTIONAL RESTORATION WHILE VIEWING
NATURAL AND URBAN ENVIRONMENTS

by

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Abstract

Demands on directed attention can result in attentional fatigue, inhibiting our ability to voluntarily direct attention to important features of our surroundings. Inherently fascinating environments, such as nature, have been shown to promote recovery of attention. Environments that do not possess these restorative qualities, such as urban settings, by comparison do not promote recovery. Previous research has demonstrated numerous benefits associated with exposure to nature including improved physiological and mental health, and increased performance in attention tasks. Limited, if any, research has directly demonstrated the neurological correlates of recovery associated with nature. The goal of the current research was to utilise the P3 cognitive component of the event-related potential (ERP), which has been shown to be modulated by attentional demands, as a cognitive marker indicative of attentional recovery. We measured electroencephalography (EEG) data while participants simultaneously completed an auditory oddball task and viewed pictures containing nature and urban scenes. A replication was also performed using the Attention Network Task (ANT) to show that the restorative qualities of nature influence executive, voluntary attention rather than involuntary attention. Contrary to our predictions, no significant differences in the P3 component were observed and we were unable to successfully replicate previous research using the ANT. However, significant differences were found in earlier EEG components which suggest that the auditory stimuli are being processed differently depending on the scene displayed. EEG differences were also found following presentation of the scenes themselves. These differences are consistent with previous research and are likely due to differences in complexity, contrast, and other visual characteristics. Further research needs to focus on these auditory and visual EEG differences to better understand neural correlates associated with the restorative benefits of natural environments.

Preface

This thesis is an original work by Jonathan William Perry Kuziek. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, “Electrophysiological markers of Cognitive Processes”, Pro00050069, 7/12/2016.

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Chapter 1: Introduction

Our ability to direct our attention to important aspects of our environment is critical in ensuring that we can accurately and quickly respond to changes around us. Effort is required to voluntarily maintain and direct our attention to a specific aspect of our surroundings while simultaneously inhibiting other irrelevant aspects, an idea emphasised by the work of William James (1892). Tasks that place a high demand on directing and sustaining attention may result in fatigue whereby it becomes more difficult to accurately direct attention, but the early work by Kaplan and colleagues (Kaplan & Kaplan, 1989; Kaplan, 1983; Kaplan, 1995; Kaplan & Talbot, 1983) propose the Attentional Restoration Theory (ART) which suggests that this attentional fatigue may be recovered in the presence of intrinsically fascinating environments. ART suggests that environments that are intrinsically fascinating automatically attract our attention and allow mechanisms that regulate and direct attention a reprieve and a chance to recover. Natural environments contain these intrinsically fascinating qualities while more urban environments place a greater emphasis on voluntary, directed attention. Urban spaces require us to more often direct our attention to more important aspects of our surroundings, such as paying attention to moving vehicles, traffic signals, and other pedestrians, while also trying to inhibit potentially distracting and irrelevant stimuli such as flashing advertisements. Due to the greater demand placed on directing attention for urban environments, natural environments promote restoration and allow attention to recover following fatigue. The P3 component of an event related potential (ERP), derived from electroencephalogram (EEG) data, has been shown to be modulated by attentional demands and variations in task difficulty. Due to the sensitivity of the P3 to the distribution and fatigue of attentional resources, this ERP component may provide a cognitive window into the restorative effects of nature.

Directed Attention as a Resource

William James (1892) suggested that self-regulation and the ability to voluntarily direct attention both rely on attentional processes and require effort in order to be maintained. Self-regulation has been shown to become less effective and less reliable as individuals actively inhibit physical or emotional responses. Muraven, Tice, & Baumeister (1998) and Muraven & Baumeister (2000) demonstrated that participants who were instructed to inhibit emotional responses and thoughts became less effective at regulating those behaviours as time passed and even reported feelings of physical exhaustion. These results suggest that regulating responses are influenced by a limited resource and cannot be extended indefinitely. Other research supports the idea that self-regulation relies on resources (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Muraven, & Tice, 2000; Baumeister, Vohs, & Tice, 2007) and that those resources are linked with executive functioning (Rueda, Posner, & Rothbart, 2005; Kaplan & Berman, 2010; Holtzer, Shuman, Mahoney, Lipton, & Verghese, 2010). While having a limited resource that can be depleted and result in poorer regulation of actions and emotions may seem detrimental, there are likely evolutionary advantages to such a mechanism. Kaplan & Berman (2010) suggest that modulation and conservation of attentional resources would encourage individuals to maximise attention to important aspects of the environment, ignore immediately irrelevant information, and then disengage attention when it is no longer needed in order to conserve resources.

The availability of this resource has been shown to develop and change over an individual's lifespan, becoming more plentiful as one reaches adulthood and slowly waning due to age (Rueda, Posner, & Rothbart, 2005). This resource also seems to be limited to executive attention compared to other forms of attention, such as alerting and orienting, which are typically

driven by involuntary processes (Holtzer, Shuman, Mahoney, Lipton, & Verghese, 2010). While activities such as sleep promote the recovery of these attentional resources, further research has proposed other mechanisms which may promote attentional recovery and improve executive attention.

Attention Restoration Theory (ART)

Executive attention has been shown to rely on a resource whereby our ability to focus and maintain attention toward relevant stimuli and ignore potential distractions begins to weaken as this resource is depleted. While rest and limiting attentional exertion would allow for this resource to recover, thereby improving executive attention, Kaplan and colleagues (Kaplan & Kaplan, 1989; Kaplan, 1983; Kaplan, 1995; Kaplan & Talbot, 1983) suggest certain environments can facilitate this recovery. ART proposes that inherently fascinating environments, those which have elements that automatically attract attention and do not require us to attend to specific elements, promote recovery of attentional resources by easing demands on executive attention. Kaplan (1995) suggests that fascinating environments require at least four factors to promote attentional recovery; soft fascination, extent, being away, compatibility. Soft fascination refers to characteristics which automatically attract attention, in contrast to hard fascination involving aspects that require directed attention. Extent refers to the scope of the environment, which must be large enough to be consistently fascinating and cannot simply consist of a series of independent objects, for example. Being away is related to extent and allows an individual to fully escape situations that demand executive attention, and compatibility suggests that the environment should accommodate the needs of the individual. Natural environments are thought to be inherently fascinating and contain each of these four characteristics to some degree, promoting recovery from attentional fatigue. In contrast, urban,

man-made environments seem to show opposing effects and either inhibit or further fatigue attention. This lack of recovery is due to characteristics of urban environments consistently placing demands on executive attention, such as the need to attend to vehicles and pedestrians while simultaneously ignoring irrelevant stimuli. Research appears to support the assertion that natural environments are such fascinating environments, promoting attentional recovery along with other physical and emotional benefits (Berman et al., 2012; Berto, 2005; Cimprich & Ronis, 2003).

Restorative Effects of Natural Environments

Several studies have demonstrated the restorative effects of natural settings as tools in aiding patient populations. In developing a therapy to help promote attention and improve recovery times, Cimprich (1993) recruited breast cancer patients undergoing treatment and scored them on various tasks that placed a demand on directed attention, including the digit span, Necker cube, and letter cancellation tasks, among others. Patients performed these tasks before and after an intervention condition was applied whereby patients completed a series of preferred activities three times a week for 20 minutes each. All activities involved restorative experiences and nature to some extent, such as walking through natural environments, gardening, or observing natural scenes/views. Patients who received intervention involving natural environments showed an increase in overall attention scores when compared to patients who did not receive intervention. Cimprich & Ronis (2003) replicated these findings while also showing that attentional scores and recovery are greater for patients who receive intervention compared to patients not exposed to natural, restorative environments post-surgery.

Natural environments have also been shown to benefit individuals suffering from mental health issues and immersion in nature may serve as a complement to current treatment methods.

Berman et al. (2012) obtained affective and cognitive measures of individuals diagnosed with major depressive disorder (MDD) and relatively healthy controls before and after completing a 50-minute-long nature or urban walk. Both types of participants performed better in a backward digit span task and showed increased positive affect following the nature in comparison to the urban walk. Another interesting result was that MDD participants appeared to show an increased benefit to cognitive and affect measures in comparison to healthy participants. Similar results were also demonstrated by Roe & Aspinall (2011) who had participants with either good or poor mental health complete a walk in a rural and urban setting. The specific mental health situation for individuals from the poor mental health group were not divulged but the goal was to recruit individuals afflicted with either stress or depressive symptoms. Mood, reflection, and self-esteem measures were obtained pre-walk for each participant, with results showing improved mood and mindset scores following a nature walk but no change in self-esteem measures. Benefits were further enhanced for the low mental health group and interestingly this group also showed a boost to mood and reflection scores following the urban walk.

Directed Attention Fatigue and Restoration

Aside from physical and psychological benefits, many studies have also examined the restorative effects of nature with regards to executive attention. To compare the restorative effects of several environments, Herzog, Black, Fountaine, & Knotts (1997) showed participants a series of slides containing natural settings, sporting/entertainment settings, or urban settings. Participants rated each slide in perceived attention restoration and how well each slide promoted reflection on thoughts and ideas. Natural scenes were rated higher in both perceived attention restoration and reflection, followed by sporting settings and then urban settings. While direct measures of attentional recovery and fatigue were not obtained the results suggest that the

intrinsically interesting aspects of natural settings encourages attentional recovery compared to settings that place a greater demand on directed, rather than voluntary, attention.

Healthy participants directly exposed to natural environments have also shown improvements and recovery of directed attention following fatigue. Hartig, Mang, & Evans (1991) divided participants into three groups: backpacking vacation, non-nature vacation, or no vacation, and measured attention by having each group complete a proof-reading task before and after the study. Participants who completed a backpacking vacation showed improvement in the proof-reading task compared to the non-nature and no vacation groups. Under more controlled conditions Hartig, Mang, & Evans (1991) induced attentional fatigue in participants prior to completing a nature walk, urban walk, or relaxation treatment. To fatigue attention, participants completed both a Stroop task and a binary, number classification task with attentional recovery again being assessed by the proof-reading task. Similar to their first results, participants who completed the nature walk were found to perform better on the proof-reading task in comparison with the urban walk and relaxation groups after being fatigued. To better understand how attention recovers during a natural or urban walk, Hartig, Evans, Jamner, Davis, & Gärling (2003) obtained measures of attention while participants completed either a nature or urban walk. For half the participants, attention was fatigued using the Stroop task and a number classification task while the other half of participants did not have their attention fatigued. The Necker cube task and a memory search task were used to assess levels of attention and recovery pre, during, and post walk. When comparing pre-walk and post-walk scores, performance increased in the Necker cube task following the nature walk in comparison to the urban walk. Performance was also better in the nature walk condition when comparing the pre-walk and walk scores. There

was no difference in walk and post-walk scores, suggesting that the restorative effects of a nature walk likely occur early and remain consistent over the duration of the walk.

While it is clear the immersion in nature settings is related to restoration of attention, these benefits are not solely restricted to direct contact with nature. Berman, Jonides, & Kaplan (2008) have shown that these benefits are also apparent when simply viewing nature scenes. In one experiment, participants completed either a nature walk through a park or an urban walk through a downtown setting. Attention and recovery was assessed using the backward digit span task and, congruent with previous findings, performance on the backwards digit span improved following the nature walk in comparison to the urban walk. In a second experiment participants were shown a series of slides depicting either natural or urban settings. Attention was measured again using the digit span task but also using the Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002) which is designed to test the executive, orienting, and alerting aspects of attention, the latter two of which is believed to require less cognitive control and less influenced by directed attention. The purpose of using the ANT was to better show that nature exposure results in an increase in executive attention rather than, say, involuntary attention. Results from the second experiment complement those from the first as digit span performance increased for participants viewing the nature scenes in comparison to those who viewed the urban scenes. In regards to ART performance only executive scores showed a significant improvement for the participants viewing nature compared to urban scenes, suggesting that benefits related to nature most strongly influence voluntary, directed attention.

While previous research suggests that natural, restorative scenes promote attention recovery it is unclear how simple images, patterns, or scenes may influence attention in comparison to natural scenes. Berto (2005) examined how natural scenes influence attention in

relation to urban scenes but also studied how geometrical patterns influence attention.

Participants completed the Sustained Attention to Response Test (SART) twice, once to fatigue attention and again after the experiment to assess attentional recovery after viewing slides of either natural or urban scenes. Again consistent with ART and previous research, participants who viewed the restorative, natural scenes showed improvement in the SART when compared to those who viewed urban scenes. The procedure was repeated for a second experiment except that participants were now shown slides of geometrical patterns. These patterns were expected to place less of a demand on directed attention and should be able to be viewed with little effort, similar to the intrinsic qualities of natural settings. SART performance did not differ following exposure to geometrical patterns, suggesting that such scenes are not restorative for directed attention. However, after viewing geometrical patterns performance for the SART was less than after viewing natural scenes but still better than viewing urban scenes. This finding is consistent with the idea that urban scenes are more demanding on attentional resources since one must selectively choose aspects to pay attention to while choosing what aspects to ignore. Geometrical patterns may not have these elements that place demands on directed attention, but they are likely less intrinsically interesting and so attention performance is in the middle of both urban and natural scene viewing. The benefits of interacting with nature, both through immersion in a natural setting or viewing images of natural scenes, have been extensively showcased but little work has been done to explore how neural activity in the brain changes in response to natural scenes.

Many studies show attentional benefits, as well as mood (Barton & Pretty, 2010; Berman et al., 2012; Bodin & Hartig, 2003; Hartig et al., 2003; Roe & Aspinall, 2011) and physiological (Pretty, Peacock, Sellins, & Griffin, 2005; Hartig et al., 2003; Ulrich, 1984; Mitchell & Popham,

2008; Kardan et al., 2015) benefits associated with natural environments. Few, if any, current research has used electrophysiological measures such as the electroencephalogram (EEG) to further understand the restorative effects associated with nature. There are EEG components which may provide further insight into the restorative potential of nature.

P3 Component & Attentional Demands

The P3 response is a positive deflecting event related potential (ERP) that typically appears around 300-700 ms following the presentation of a deviant or rare stimulus (Tachibana et al., 1992). This response can be measured with an auditory or visual oddball task involving the presentation of common, standard stimuli and rare, target stimuli. Attentional demands and task difficulty have been shown to modulate the amplitude and latency of the P3 response, suggesting that the P3 reflects cognitive control and the availability of attentional resources in processing relevant stimuli (Kok, 1986; Eimer, 1993). Datta et al. (2007) had participants complete the SART and found a reduced P3 to non-target stimuli and an increased P3 when target stimuli were presented. Participants were also more likely to make errors on trials where the P3 was relatively low, supporting the idea that the P3 reflects the amount of attention devoted to a particular stimulus and the ability to inhibit incompatible responses. These results are consistent with those obtained by Polich (1986) and Nakajima & Imamura (2000) who had participants explicitly attend or ignore stimuli presented in an oddball task, showing a decreased P3 response for unattended stimuli which was independent of stimulus intensity. Nash & Fernandez (1996) and Hohnsbein, Falkenstein, & Hoormann (1995) also demonstrated attention allocation and reduced P3 responses in a dual auditory-visual oddball task whereby targets in one modality produced the typically large P3 response but if a target was presented in the other modality immediately after, a significantly lower P3 response was observed.

P3 magnitude has also been shown to decrease in response to task difficulty as well as when attentional demands become taxing and participants are fatigued. To demonstrate the influences of task difficulty on P3 magnitude, García-Larrea & Cézanne-Bert (1998) had participants complete an auditory oddball task but had participants respond to the target tones in one-of-four different ways. Participants would simply count forwards, count backwards by a set interval, count forward the week-day and month-day, or count forward the week-day, month-day, and month, each time a target tone was presented. As counting task difficulty increased, a reduction in the P3 response following target tones was observed along with an increase in response times. This would suggest that as participants devoted more attentional resources to the counting task, less resources were available to attend and process characteristics of the target tone. Sawaki & Katayama (2008) were also able to demonstrate that, using a visual oddball task, the P3 response is related to top-down demands of attention. On 80% (frequent) of trials standards were always triangles and targets were always circles, but their appearance would differ 20% of the time (deviant) in one-of-two ways; either the targets and standards would change in size and colour (change condition), or targets and standards would have distractor stimuli placed nearby (appearance condition). Participants were told to attend to the shape of the target stimuli and ignore any changes in size, colour, or the presence of distractors. As expected, a larger P3 was observed for targets than standards in all conditions but the largest P3 difference between frequent and deviant presentations occurred in the appearance condition among standards. The authors suggest these results indicate that both bottom-up and top-down modulate attention towards relevant stimuli and that the P3 response is not solely dependent on low or high-level processing.

Regarding attentional fatigue, Portin et al. (2000) were able to show reductions in P3 magnitude as participants became fatigued and cognitively impaired. Over several hours participants completed cognitive and vigilance tasks with P3 response being measured using an auditory oddball task. It was shown that participants who performed worse in the cognitive and vigilance tasks also displayed a smaller P3 response to target tones. Barkaszi, Czigler, Pató, & Balázs (2010) showed similar results by having participants complete cognitive tasks, such as the Stroop and digit span tasks, with P3 being measured using a 3-stimulus oddball paradigm. The fatigued group completed 2 hours of cognitively demanding tasks and thus showed a significantly decreased P3 response when compared to controls who simply watched videos for the same amount of time. Cognitive fatigue clearly plays a role in the P3 response, suggesting that as attentional resources become depleted individuals are less able to devote attention to relevant stimuli.

Hypothesis

The goal of the current experiment was to use P3 response as a measure of attentional fatigue when participants complete an auditory oddball task while viewing slides of either natural or urban settings. Since the P3 response has been shown to decrease as a result of attentional demand and fatigue, and urban environments have been shown to require greater directed attention when compared to natural settings, we expect to see the P3 response following the presentation of target stimuli to decrease when participants view urban scenes. As natural scenes are intrinsically fascinating and place little emphasis on directed attention, we expect the P3 response to remain stable or even increase when participants are viewing natural scenes. Viewing a blank screen, rather than natural or urban scenes, is expected to show results similar to those obtained by Berto (2005) where the P3 response to a blank screen will be between that of

natural and urban scene viewing. These expected results would allow for measurements of the P3 response to act as an online indicator of attentional fatigue. Such cognitive markers may then be used as a tool to assist in attentional recovery and may allow for the measurement and facilitation of other health benefits related to natural environments.

Chapter 2: Methods

Experiment One

For the first version of the experiment seven participants from the University of Alberta community participated in the study (mean age = 22; age range = 18-27, 5 males). Each participant completed the experiment in one sitting with the entire experiment lasting approximately 60 minutes. Participants were all right-handed, and all had normal or corrected normal vision and no history of neurological problems. All participants gave informed written consent and were either compensated at a rate of \$10/h or given research credit for their time, whichever was applicable. Course credit was given to participants who signed up for the study to fulfill the laboratory component of an introductory psychology course. The experimental procedures were approved by the internal Research Ethics Board of the University of Alberta.

Each participant completed an auditory oddball task. The task involved the presentation of two tones, a low-pitched 1000Hz tone presented on 80% of trials and a higher-pitched 1500Hz tone played on 20% of trials. These tones corresponded to the standard and target tones respectively. Each tone was presented for a total of 16 ms, with a 2 ms attack and 2 ms decay. Each tone was separated by a variable delay randomly derived from a time range of 1-1.5 seconds. A total of 750 tones were played for each oddball task and rest periods were permitted after every 250 tones, with the entire task lasting approximately 15 minutes. Participants were instructed to press the spacebar on a keyboard as soon as possible upon hearing the target tone, and withhold a button press when standard tones were played. Response times were continuously recorded following the presentation of each target tone.

To investigate the effects of viewing inherently fascinating environments on attention, participants were also shown a series of images during the auditory oddball task. These pictures

were presented in a similar study examining the effects of natural scenes on attention (Berman et al. 2008). Participants viewed 50 images of nature scenes, 50 images of urban scenes, or simply a blank, black background. A white fixation cross (1° of visual angle) was also presented when the screen was blank but not when images of visual scenes were presented, with participants being instructed to focus on the fixation cross during the entire experiment. During the presentation of visual scenes participants were encouraged to look at all aspects of the scene, but focus on the image itself. Each image was 605 pixels tall and 656 pixels wide as this was the average pixel dimensions of all images used. Since native image resolution varied, the pixel density of each image also changed. Scene images were presented for a variable amount of time, randomly between 13-17 tones, and would be presented when the next auditory tone was to be presented, essentially replacing said tone onset. Each condition was presented independently of the others whereby for an entire oddball task only nature scenes, urban scenes, or a blank screen was presented. As such participants completed three oddball tasks where the order of each task was randomised and counter-balanced.

Participants were seated 57-cm away from a 1920 x 1080 pixel ViewPixx/EEG LED monitor running at 120 Hz with simulated-backlight rastering. Visual stimuli were presented using a Windows 7 PC running Matlab R2012b with the Psychophysics toolbox (Brainard, 1997) while auditory stimuli were presented using a pair of Logitech Z130 speakers kept at a constant volume level. Video output was via an Asus Striker GTX760, and audio was output via an Asus Xonar DSX sound card. Coincident in time with sound and image onset, 8-bit TTL pulses were sent to the EEG amplifier by a parallel port cable connected to the stimulus PC computer to mark the data for ERP averaging. Figure 1 provides a diagram demonstrating the task used for experiment one.

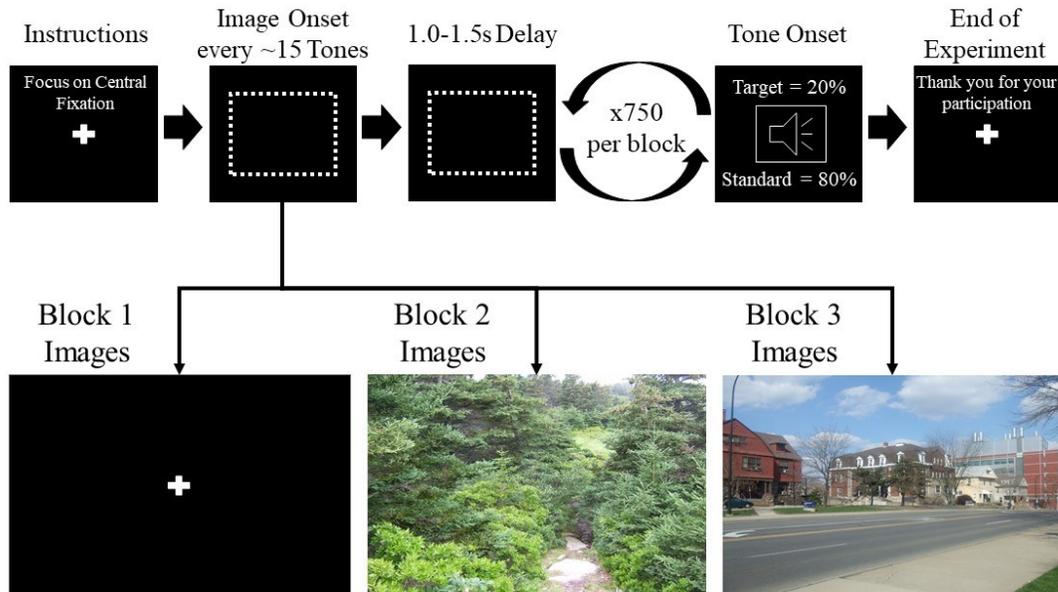


Figure 1: Example of the task used for experiment one. Participants completed three blocks of an auditory oddball task, with each block containing 750 trials. Each block contained only a specific set of images (Block 1 = Baseline, Block 2 = Nature, Block 3 = Urban).

EEG Data Recording

During each auditory oddball task EEG data was collected from each participant using passive wet low-impedance electrodes (actiCAP passive electrodes kept below 5 k Ω). Inter-electrode impedances were measured at the start of each experiment. All electrodes were arranged in the same 10-20 positions (Fp2, Fp1, F4, F3, F8, F7, FC2, FC1, FC6, FC5, C4, C3, CP2, CP1, CP6, CP5, P4, P3, P6, P5, P8, P7, PO4, PO3, O2, O1, Fz, FCz, Cz, Pz, Oz). A ground electrode was used, positioned at AFz. Ag/AgCl disk electrodes were used, with SuperVisc electrolyte gel and mild abrasion with a blunted syringe tip used to lower impedances. Gel was applied and inter-electrode impedances were lowered to less than 5 k Ω for all electrode sites. EEG was recorded online and referenced to an electrode attached to the left mastoid. Offline, the

data were re-referenced to the arithmetically derived average of the left and right mastoid electrodes.

EEG data was recorded with a Brain-Amp 32-channel amplifier (BrainVision) using identical settings across all participants. In addition to the 31 EEG sensors, two reference electrodes, and the ground electrode, the vertical and horizontal bipolar EOG was recorded from passive Ag/AgCl easycap disk electrodes affixed above and below the left eye, and 1 cm lateral from the outer canthus of each eye. Prior to placement of electrodes, the participant's skin was cleaned using Nuprep (an exfoliating cleaning gel) and electrolyte gel was used to lower the impedance of these EOG electrodes to under 5 k Ω in the same manner as previously mentioned. These bipolar channels were recorded using the AUX ports of the Brain-Amp amplifier. Data were digitized at 1000 Hz with a resolution of 24 bits. Data were filtered with an online bandpass with cutoffs of 0.1 Hz and 200 Hz. Each experiment was completed in a dimly lit, sound and radio frequency-attenuated chamber from Electromedical Instruments, with copper mesh covering the window. The only electrical devices in the chamber were an amplifier, speakers, keyboard, mouse, and monitor. The monitor ran on DC power from outside the chamber, the keyboard and mouse were plugged into USB outside the chamber, and the speakers and amplifier were both powered from outside the chamber. The fan for the chamber was turned on, and nothing was plugged into the internal power outlets. Any devices transmitting or receiving radio waves (e.g., cell phones) were either turned off or removed from the chamber for the duration of the experiment.

ERP Analysis

Analyses were computed in Matlab R2012b using EEGLAB (Delorme & Makeig, 2004) and custom scripts. The timing of the TTL pulse was marked in the recorded EEG data and used

to construct 1200 ms epochs time locked to the onset of standard and target tones, as well as to the onset of baseline, nature, and urban images, with the average voltage in the first 200 ms baseline period subtracted from the data for each electrode and trial. To remove artifacts due to amplifier blocking and other non-physiological factors, any trials with a voltage difference from baseline larger than $\pm 1000 \mu\text{V}$ on any channel (including eyes) were removed from further analysis. At this time, a regression based eye-movement correction procedure was used to estimate and remove the artefactual variance in the EEG due to blinks as well as horizontal and vertical eye movements (Gratton et al., 1984). After identifying blinks with a template based approach, this technique computes propagation factors as regression coefficients predicting the vertical and horizontal eye channel data from the signals at each electrode. The eye channel data is then subtracted from each channel, weighted by these propagation factors, removing any variance in the EEG predicted by eye movements. Artefact rejection was again performed except for this second round of artifact rejection trials containing a voltage difference of $\pm 500 \mu\text{V}$ were removed. Baseline correction was again performed following the second artifact rejection. On average artifact rejection left roughly equal number of trials per participant; baseline ($M_{\text{targ}} = 142$; $\text{range}_{\text{targ}} = 134-150$; $M_{\text{stand}} = 606$; $\text{range}_{\text{stand}} = 600-615$), nature, ($M_{\text{targ}} = 139$; $\text{range}_{\text{targ}} = 122-155$; $M_{\text{stand}} = 610$; $\text{range}_{\text{stand}} = 594-628$), and the urban ($M_{\text{targ}} = 152$; $\text{range}_{\text{targ}} = 149-155$; $M_{\text{stand}} = 598$; $\text{range}_{\text{stand}} = 595-601$) viewing conditions, from which the remaining analyses are computed. No further filtering was done on the data. Subsequent analysis of the ERPs following tone onset, unless otherwise indicated, were performed using the difference wave ERPs. These difference waves were calculated by subtracting the ERPs derived from standard tone trials from the ERPs derived from target tone trials.

Experiment Two

For the second version of the experiment 18 participants from the University of Alberta community participated in the study (mean age = 19; age range = 17-22, 12 males). Each participant completed the experiment in one sitting with the entire experiment lasting approximately 60 minutes. Participants were all right-handed, and all had normal or corrected normal vision and no history of neurological problems. All participants gave informed written consent and were either compensated at a rate of \$10/h or given research credit for their time, whichever was applicable. Course credit was given to participants who signed up for the study to fulfill the laboratory component of an introductory psychology course. The experimental procedures were approved by the internal Research Ethics Board of the University of Alberta.

Participants completed an auditory oddball task like the one described in experiment one, with some alterations. Participants were asked to focus on a white fixation cross presented in the center of the screen for the entire duration of the task. At the start of each trial the fixation cross with a 2 pixel black border would be presented by itself for approximately 300-500 ms, at which point an image would be presented behind the fixation cross. These images would consist of nature scenes, urban scenes, or blank grey images. Images were selected from a larger library of images containing 50 nature scenes and 50 urban scenes, with the order of presentation for each image being randomised for the entire task. A total of 750 images were presented during the task, resulting in 250 nature images, 250 urban images, and 250 blank grey images being randomly presented throughout the task. Auditory tones were then played after a variable delay, randomly selected between 2000-3000 ms, following image onset. Each tone was either a standard or target tone presented in the same 80%/20% ratio as described in experiment one. Each subsequent image would remain on-screen during tone onset and for 1000-1500 ms following tone onset,

after which the image would be removed from the screen and only the fixation cross would remain, indicating the start of the next trial. Participants were tasked with pressing the spacebar on a keyboard, using their right hand, as soon as a target tone was presented and to withhold a key press when a standard tone was played. All other aspects of experiment two, including stimulus presentation, setting, and EEG recording setup, were identical to those described in experiment one. Regarding EEG analysis artifact rejection left roughly equal number of trials per participant; baseline ($M_{targ} = 75$; $range_{targ} = 63-78$; $M_{stand} = 268$; $range_{stand} = 220-287$), nature, ($M_{targ} = 64$; $range_{targ} = 57-68$; $M_{stand} = 268$; $range_{stand} = 238-289$), and the urban ($M_{targ} = 59$; $range_{targ} = 47-79$; $M_{stand} = 272$; $range_{stand} = 231-281$) viewing conditions. Figure 2 provides a diagram demonstrating the time-course of experiment 2.

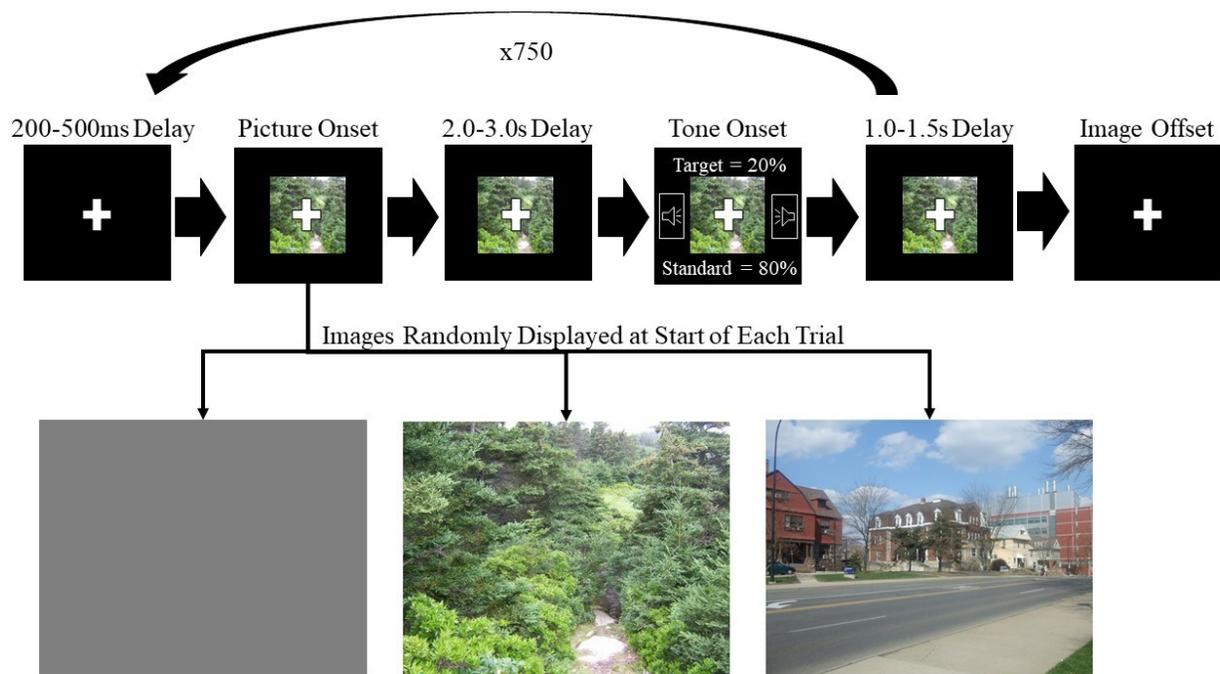


Figure 2: Design of the task used for experiment two. Participants completed a single auditory oddball task containing 750 trials. A new image, randomly chosen from the Baseline, Nature, and Urban scene conditions, was presented prior to the onset of each auditory tone.

ERSP Analysis

For experiment two we also examined event-related spectral perturbations (ERSPs) following the onset of standard and target tones, along with onset of the baseline, nature, and urban images. Estimates of the ERSP for each time point and for each frequency between 1Hz and 40Hz were calculated using the “pop_newtimef()” function of EEGLAB (Delorme & Makeig, 2004). This allowed us to create 4000 ms and 3500 ms ERSP plots centered around tone onset and picture onset, respectively. ERSP estimates were obtained using a 512 ms window with a baseline correction of the ERSP data also performed by subtracting activity 1000 ms prior to tone or picture onset from each time point and frequency. Subsequent analysis for tone onset, unless otherwise indicated, was performed using the difference in ERSP between standard and target tones. This difference was calculated by subtracting ERSP activity of standard trials from the ERSP activity of target trials.

Attention Network Task (ANT)

For the third experiment 23 participants from the University of Alberta community participated in the study (mean age = 23; age range = 19-35, 7 males). The number of participants needed for this experiment was determined using power and effect size calculations, with 22 participants needed to measure an effect size similar to that obtained by Berman et al. (2008) while also maintaining a power of 0.80. Each participant completed the experiment in one sitting with the entire experiment lasting approximately 60 minutes. Participants were all right-handed, and all had normal or corrected normal vision and no history of neurological problems. All participants gave informed written consent and were either compensated at a rate of \$10/h or given research credit for their time, whichever was applicable. Course credit was given to participants who signed up for the study to fulfill the laboratory component of an introductory

psychology course. The experimental procedures were approved by the internal Research Ethics Board of the University of Alberta.

The goal of experiment three was to replicate similar findings reported by Berman et al. (2008). In previous research, it has been suggested that attention can be divided into three distinct attentional networks: orienting, alerting, and executive attention networks, and these networks can be independently assessed using the ANT. Berman et al. (2008) used the ANT to show that the viewing of natural environments influences the executive, or directed, attention network rather than the alerting or orienting networks. These results are consistent with ART which suggests that inherently fascinating environments, such as natural settings, automatically attract attention and allow directed attention to recover. The goal of experiment three was to replicate these findings and show that viewing nature scenes influences the executive attention network.

The design of the task was based on the methods described by Fan, McCandliss, Fossella, Flombaun, & Posner (2005), with Berman et al. (2008) also basing their design on said methods. A white fixation cross, corresponding to approximately 1° of visual angle, was presented centrally on a uniform grey background. A central cue, consisting of a white asterisk of 1° of visual angle, was then presented in the center of the screen for 100 ms. After this time a target was shown 400 ms following cue onset. The target consisted of a white arrow, subtending to 0.58° of visual angle, which was randomly presented either 1.06° above or below fixation, pointing randomly either left or right. Presented along with the target were four flanker arrows, two arrows to the left and the right of the central target arrow. Each of the flanker arrows subtended to 0.58° of visual angle and each arrow was separated by 0.06° . The combined length of the flanker and target arrows subtended to 3.27° of visual angle. These flanker arrows would

randomly point in the same direction (congruent) or a different direction (incongruent) to the target arrow, with 50% of trials containing congruent stimuli and the remaining 50% containing incongruent stimuli. The target and flankers were presented on screen for 1700 ms or until participants made a response. The next trial would then begin after a variable delay of 600-3200 ms. Participants were tasked with indicating the direction of the central target arrow by pressing the corresponding arrow key on the keyboard. Each ANT lasted approximately 10 minutes and 100 trials were presented.

Participants were then shown a series of either 50 nature or 50 urban images, like the images used by Berman et al. (2008). Each image was presented for 7 s and participants were then asked to rate how much they liked each picture where '1 = dislike', '2 = neutral', and '3 = like'. Participants were not rushed when making their rating response and the next trial began immediately after a response was made. Once each image was presented participants then completed the ANT a second time, identical as described above. After a 10-minute break, each participant completed each task again (ANT – Picture Rating – ANT) except they would then view the images they were not shown during the first set of tasks. The order of each image, and which set of images were presented first, were randomised and counter-balanced. EEG data was not collected for this task. All other aspects of experiment three were identical to those described in experiment one. Figure 3 provides a diagram demonstrating the design the ANT used in this experiment.

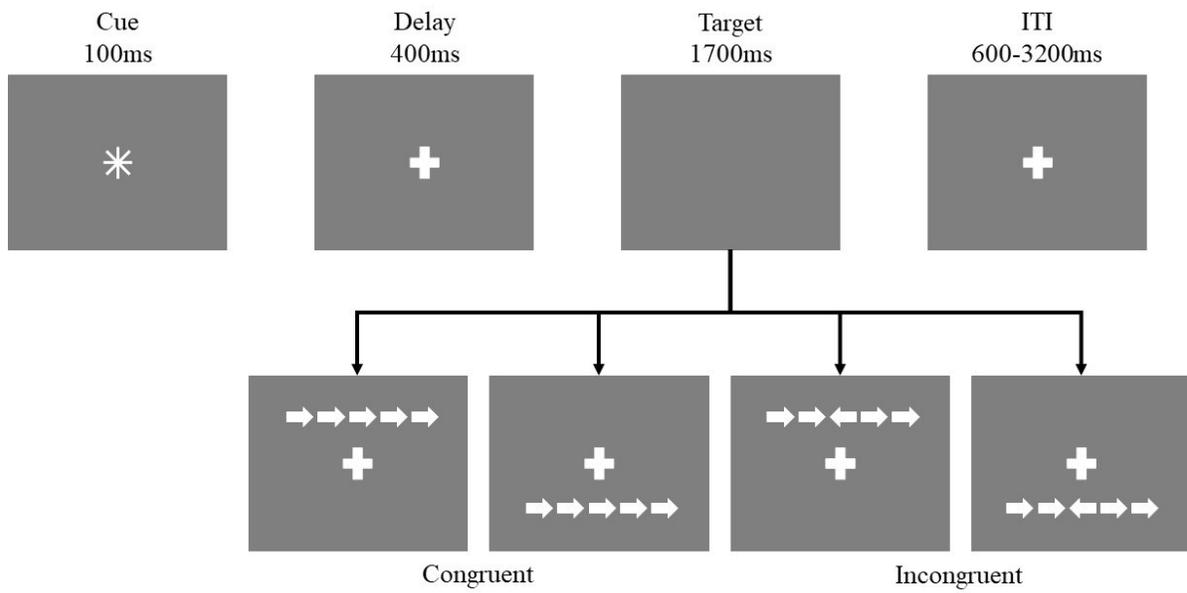


Figure 3: Example of the ANT used for experiment 3. Only a central cue was used for this task, with participants completing 100 trials.

Chapter 3: Results

Experiment One

Behavioural Analysis

Response times to high tones were calculated for each condition ($M_{baseline} = 407.7$ ms, $SD_{baseline} = 42.7$ ms; $M_{nature} = 427.8$ ms, $SD_{nature} = 44.1$ ms; $M_{urban} = 416.3$ ms, $SD_{urban} = 57.2$ ms).

Response times were collected from the onset of the most recent high tone to the onset of the subsequent tone. No responses were faster than 200 ms or slower than 2 s, although no responses were slower than 2s due to the timing between tones and how responses times were collected. A one-way ANOVA analysis reveals no significant difference in response times ($F_{2,20} = 0.3000$; $p = 0.7427$). A significance level of 0.05 was used for this analysis and all subsequent analyses.

Figure 4 shows a plot of the response times to target tones for each of the three viewing conditions.

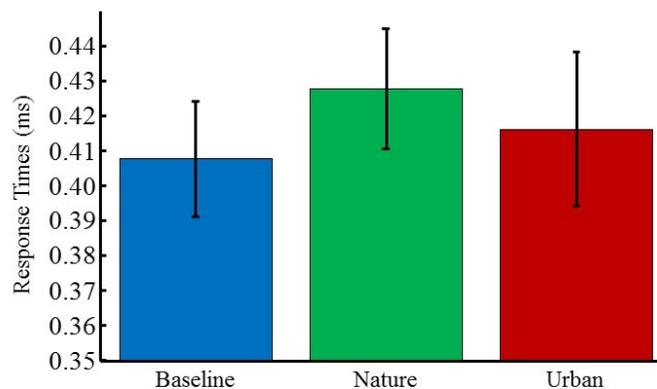


Figure 4: Response times to target tones. Average response times (ms) to target tones for each viewing condition. These response times were collected for experiment one. Error bars represent the standard error of the mean.

Tone Onset ERP Analysis

Figure 5a shows the ERPs elicited by the standard and target tones in each of the three conditions, while Figure 5b provides a comparison of the ERPs for each condition along with the difference waveforms. Initial analysis of the P3 ERP was done by averaging the voltage across a specified time window for each participant. For this and subsequent analysis the P3 time window used was approximately 350-550 ms post tone onset. P3 analysis was done using data collected from electrode Pz since the P3 component is most prominent at this electrode. One-way ANOVA analysis across our three viewing conditions reveals no difference in the P3 response magnitude ($M_{baseline} = 6.58 \mu\text{V}$; $SD_{baseline} = 3.56 \mu\text{V}$; $M_{nature} = 6.81 \mu\text{V}$; $SD_{nature} = 5.23 \mu\text{V}$; $M_{urban} = 5.88 \mu\text{V}$; $SD_{urban} = 5.11 \mu\text{V}$; $F_{2,20} = 0.0756$; $p = 0.9275$). A one-way right-tailed t-test was also performed to examine the difference in P3 response magnitude between nature and urban scene viewing, the comparison which was the main concern of the study. Similar to the ANOVA results, t-test analysis reveal no significant difference between P3 response magnitude between nature and urban scene viewing ($t(6) = 1.0853$; $p = 0.1597$).

We also performed further analysis using a different time window, since it is possible that other ERP components common to auditory oddball tasks could be influenced by the different viewing conditions. For this analysis, we utilised a 150-250 ms time window which corresponds to the P2 ERP component at parietal electrodes, such as Pz, and the mismatched negativity component typically found at frontal electrodes, such as Fz. A one-way ANOVA analysis performed at the early time window for electrode Pz (corresponding to the P2 time window) reveals no significant difference between our conditions ($M_{baseline} = -0.81 \mu\text{V}$; $SD_{baseline} = 2.03 \mu\text{V}$; $M_{nature} = -0.39 \mu\text{V}$; $SD_{nature} = 1.99 \mu\text{V}$; $M_{urban} = -1.40 \mu\text{V}$; $SD_{urban} = 1.19 \mu\text{V}$; $F_{2,20} = 0.5645$; $p = 0.5784$). A two-tailed t-test comparing our nature and urban viewing conditions approaches

significance ($t(6) = 2.3264$; $p = 0.0589$). A one-way ANOVA analysis performed at the early time window for electrode Fz (corresponding to the MMN time window) reveals no significant difference between our conditions ($M_{baseline} = -2.26 \mu\text{V}$; $SD_{baseline} = 1.05 \mu\text{V}$; $M_{nature} = -1.94 \mu\text{V}$; $SD_{nature} = 2.34 \mu\text{V}$; $M_{urban} = -2.50 \mu\text{V}$; $SD_{urban} = 1.63 \mu\text{V}$; $F_{2,20} = 0.1833$; $p = 0.8340$). A two-tailed t-test comparing our nature and urban viewing conditions also reveals no significant differences ($t(6) = 1.0332$; $p = 0.3413$).

Exploratory t-tests were also performed across the entirety of the auditory ERP for electrode Pz to identify differences between the auditory ERPs elicited in the nature and urban scene viewing conditions. This was performed using a two-tailed t-test for each time point across the entire auditory ERP. The results of the t-test across the entire auditory ERP can be seen in the plot of the difference waves for the nature and urban conditions in Figure 5b.

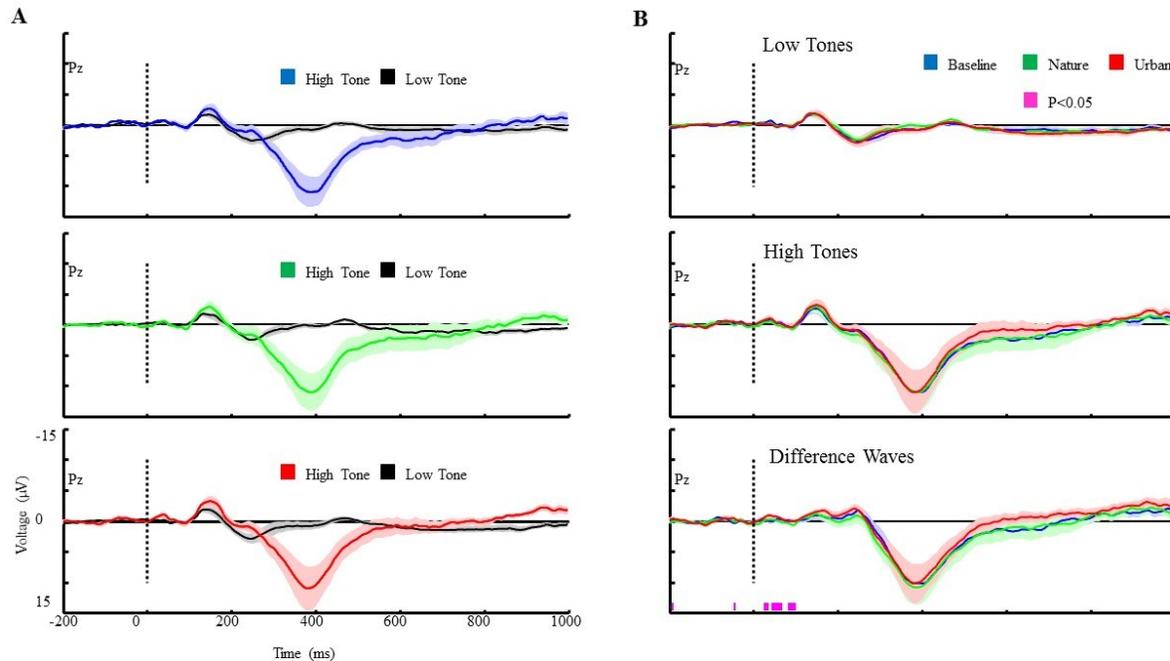


Figure 5: Auditory ERPs to all tones. A) Auditory ERPs to all standard and target tones for each viewing condition. B) These plots show a more direct comparison of standard and target tone ERPs for each condition, along with the difference waveform (target tone ERP minus standard tone ERP). Pink markers near the bottom of the difference waveform plot indicate time points where a pointwise t-test suggests significant differences between nature and urban conditions. Error bars represent the standard error of the mean.

Following these analyses, it was thought that the initial design of the experiment may be interfering with any potential influences of our viewing conditions on P3 responses. Since each condition was presented in blocks, and each image was presented for approximately 15 tones, it was thought that participants may become accustomed to the images being presented. As such, any influence the different scenes have on P3 response magnitude may be more prominent for tones occurring immediately following picture onset and these influences will be diminished for later trials further from picture onset. To work around this possible limitation, we analysed ERPs elicited by the first high and low tones following picture onset. Figure 6a shows the ERPs for the

first standard and target tones for each condition. Figure 6b provides a more direct comparison of the ERPs along with the difference waveforms.

One-way ANOVA analysis of the P3 time window at electrode Pz reveals no difference in P3 magnitude between our three viewing conditions ($M_{baseline} = 6.32 \mu\text{V}$; $SD_{baseline} = 3.44 \mu\text{V}$; $M_{nature} = 7.02 \mu\text{V}$; $SD_{nature} = 6.81 \mu\text{V}$; $M_{urban} = 6.45 \mu\text{V}$; $SD_{urban} = 5.54 \mu\text{V}$; $F_{2,20} = 0.0331$; $p = 0.9678$). One-way right-tailed t-test analysis between our nature and urban viewing conditions reveals no difference between these two conditions ($t(6) = 0.3472$; $p = 0.3702$). A one-way ANOVA analysis at the early time window at electrode Pz (P2 time window) reveals no difference in P2 magnitude between the three viewing conditions ($M_{baseline} = -0.77 \mu\text{V}$; $SD_{baseline} = 2.05 \mu\text{V}$; $M_{nature} = -0.36 \mu\text{V}$; $SD_{nature} = 1.48 \mu\text{V}$; $M_{urban} = -1.79 \mu\text{V}$; $SD_{urban} = 1.73 \mu\text{V}$; $F_{2,20} = 1.2088$; $p = 0.3217$). A two-tailed t-test analysis between our nature and urban viewing conditions reveals no difference between these two conditions ($t(6) = 1.2883$; $p = 0.2451$). A one-way ANOVA analysis at the early time window at electrode Fz (MMN time window) reveals no difference in MMN magnitude between the three viewing conditions ($M_{baseline} = -2.24 \mu\text{V}$; $SD_{baseline} = 1.06 \mu\text{V}$; $M_{nature} = -1.67 \mu\text{V}$; $SD_{nature} = 2.32 \mu\text{V}$; $M_{urban} = -2.97 \mu\text{V}$; $SD_{urban} = 2.93 \mu\text{V}$; $F_{2,20} = 0.5858$; $p = 0.5669$). A two-tailed t-test analysis between our nature and urban viewing conditions reveals no difference between these two conditions ($t(6) = 1.1745$; $p = 0.2847$). Results from a t-test across the entire auditory ERP for the first standard and target tones can be seen in the difference waveform depicted in Figure 6b.

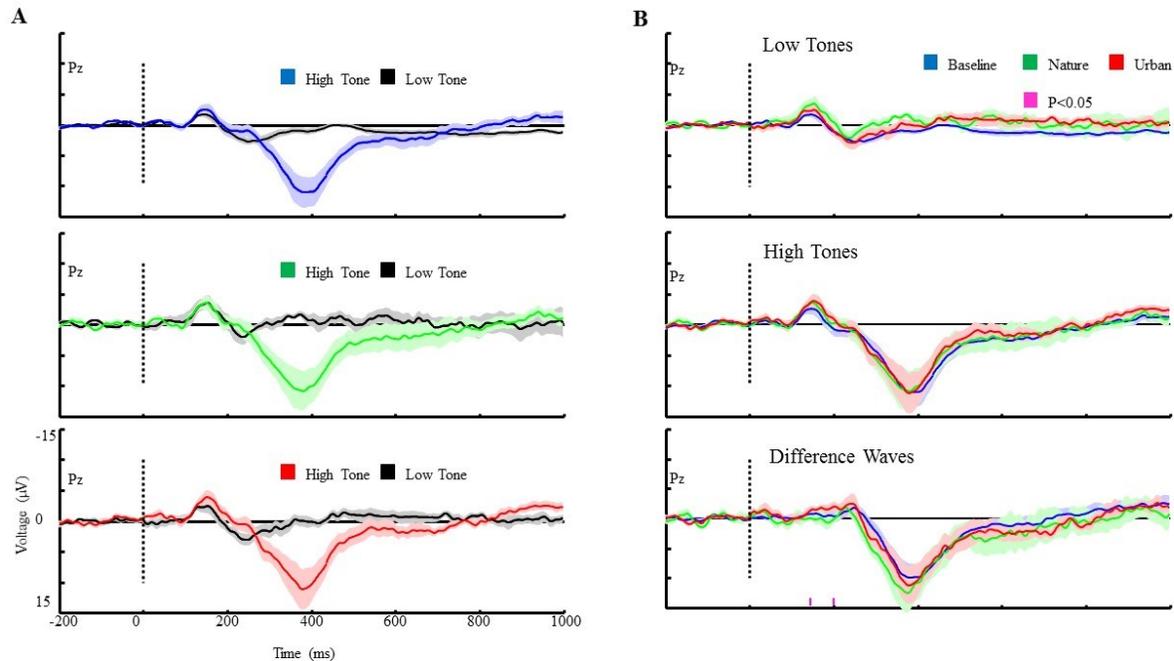


Figure 6: Auditory ERPs to first tones after picture onset. A) Auditory ERPs to the first standard and target tones after picture onset, for each viewing condition. B) These plots show a more direct comparison of standard and target tone ERPs for each condition, along with the difference waveform (target tone ERP minus standard tone ERP). Pink markers near the bottom of the difference waveform plot indicate time points where a pointwise t-test suggests significant differences between nature and urban conditions. Error bars represent the standard error of the mean.

Picture Onset ERP Analysis

We also decided to analyse the ERPs elicited following the onset of each image. Based on the timing of picture onset for experiment one, where a new image would be randomly displayed in place of a tone, we suspected the onset of each image would be treated like a visual oddball stimulus. As such, a P3 response would be expected to occur following image onset at similar time windows. For the P2 and MMN components we used a time window of 175-250 ms and for the P3 component we used a 300-450 ms time window. For experiment one we were only

able to generate ERPs for nature and urban image onset since the baseline condition only consisted of a blank screen that was always present throughout the task. Figure 7 shows the visual ERPs elicited by the onset of the nature and urban scenes at electrodes Fz and Pz.

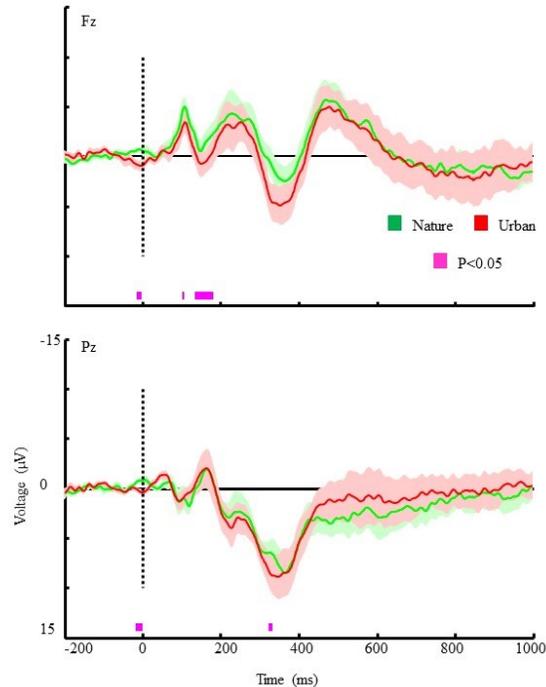


Figure 7: Visual ERPs following picture onset. Visual ERPs elicited by nature and urban picture onset, at electrode Fz and Pz. There is no baseline visual ERP since a blank screen was consistently present during this condition. Pink markers near the bottom of the difference waveform plot indicate time points where a pointwise t-test suggests significant differences between nature and urban conditions. Error bars represent the standard error of the mean.

A two-tailed t-test at the P3 time window for electrode Pz reveals no differences ($M_{nature} = 6.00 \mu\text{V}$; $SD_{nature} = 3.93 \mu\text{V}$; $M_{urban} = 6.49 \mu\text{V}$; $SD_{urban} = 4.55 \mu\text{V}$; $t(6) = -0.9667$; $p = 0.3710$), a t-test at the early time window for electrode Pz also reveals no significant differences ($M_{nature} = 1.82 \mu\text{V}$; $SD_{nature} = 3.26 \mu\text{V}$; $M_{urban} = 2.37 \mu\text{V}$; $SD_{urban} = 4.19 \mu\text{V}$; $t(6) = -0.8081$; $p = 0.4499$), along with a t-test at the early time window for electrode Fz ($M_{nature} = -3.52 \mu\text{V}$; $SD_{nature} = 4.81 \mu\text{V}$; $M_{urban} = -2.39 \mu\text{V}$; $SD_{urban} = 5.27 \mu\text{V}$; $t(6) = -1.3771$; $p = 0.2177$).

Experiment Two

Behavioural Analysis

Response times were collected following the presentation of the high tones ($M_{baseline} = 581.6$ ms, $SD_{baseline} = 135.4$ ms; $M_{nature} = 569.9$ ms, $SD_{nature} = 131.6$ ms; $M_{urban} = 572.3$ ms, $SD_{urban} = 135.6$ ms). Response times were collected from the onset of the most recent high tone until approximately 1s following the onset of the next subsequent image. Trials with response times faster than 200 ms or slower than 2 s were removed from further analysis. This resulted in approximately the same number of trials being removed from each condition (Baseline = 58 trials; Nature = 42 trials; Urban = 46 trials). We also determined how many of the total removed trials were composed of response times faster than 200 ms (Baseline = 58 trials; Nature = 41 trials; Urban = 45 trials) and which were slower than 2 s (Baseline = 0 trials; Nature = 1 trial; Urban = 1 trial). A one-way ANOVA analysis reveals no significant difference in response times ($F_{2,20} = 0.0400$; $p = 0.9628$). Figure 8 shows the average response times following the presentation of target tones for each viewing condition. Also shown are plots showing average number of trials where response times were either faster than 200 ms or slower than 2 s.

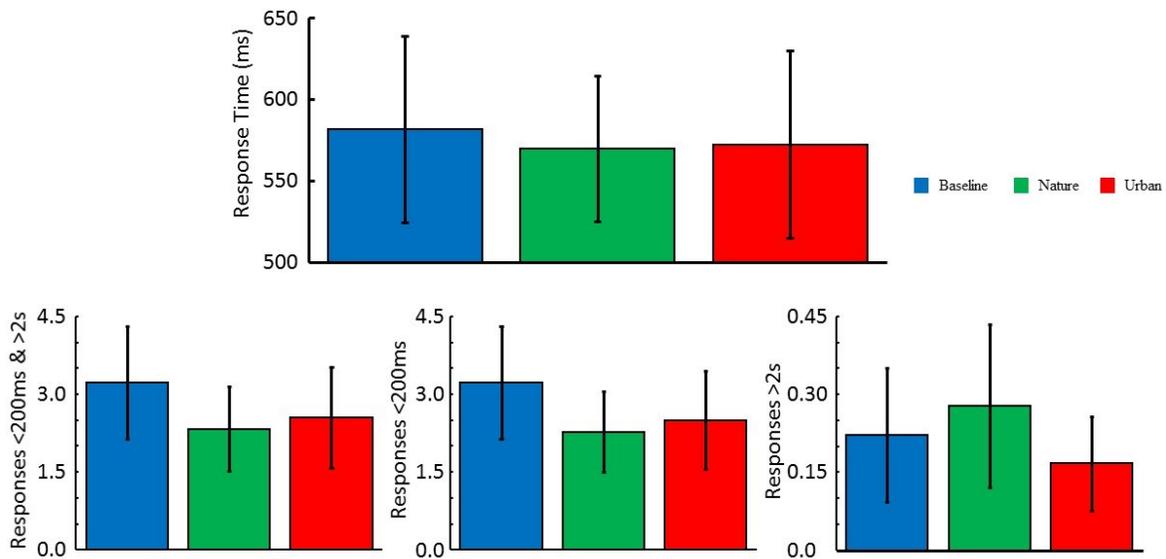


Figure 8: Response times to target tones. Average response times (ms) to target tones for each viewing condition. Bottom plots also show the average number of trials where response times were either faster than 200 ms or slower than 2 s. Error bars represent the standard error of the mean.

Tone Onset ERP Analysis

A one-way ANOVA analysis at electrode Pz for the P3 time window shows no difference in P3 amplitude for each of the three viewing conditions ($M_{baseline} = 7.32\mu\text{V}$; $SD_{baseline} = 7.30\mu\text{V}$; $M_{nature} = 6.92\mu\text{V}$; $SD_{nature} = 6.75\mu\text{V}$; $M_{urban} = 6.34\mu\text{V}$; $SD_{urban} = 6.50\mu\text{V}$; $F_{2,53} = 0.0923$; $p = 0.9120$), with similar results obtained from a right-tailed t-test comparing nature and urban conditions ($t(17) = 0.7809$; $p = 0.2228$). Figure 9a shows the ERPs elicited by both the auditory standard and target tones for each viewing condition. Figure 9b provides a more direct comparison of these auditory ERPs across the three conditions, and shows the difference waveform for each condition.

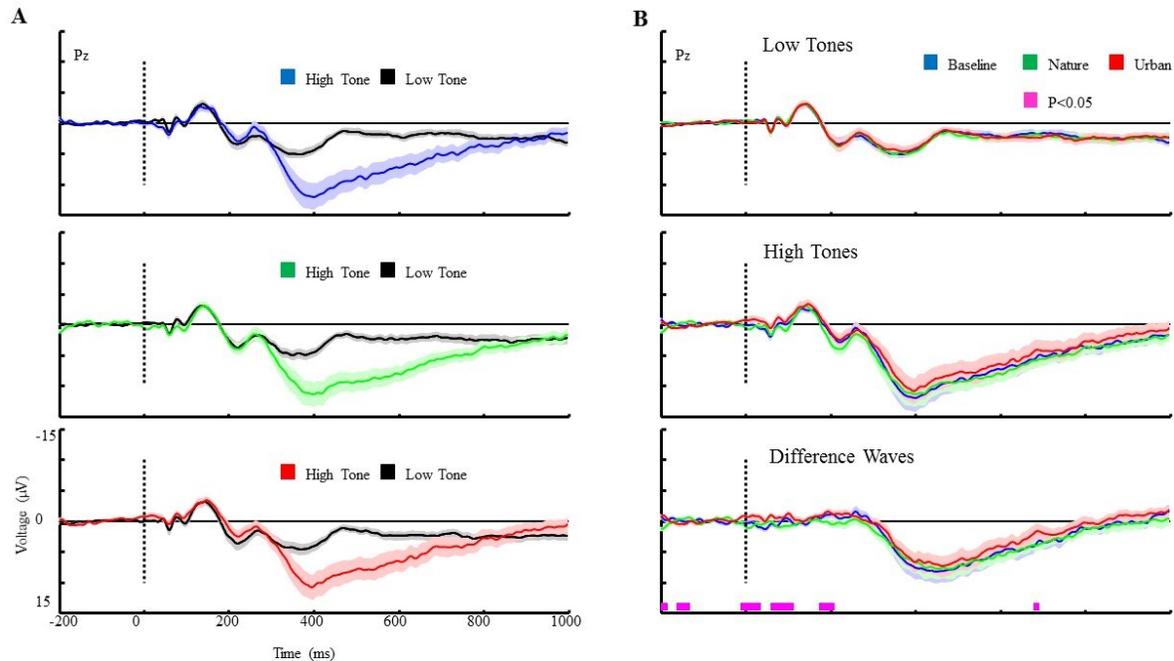


Figure 9: Auditory ERPs. A) Auditory ERPs elicited by the standard and target tones at electrode Pz. B) These plots provide a more direct comparison of the standard and target tone ERPs for each viewing condition, along with the difference waveform (target tone ERP minus standard tone ERP). Pink markers near the bottom of the difference waveform plot indicate time points where a pointwise t-test suggests significant differences between nature and urban conditions. Error bars represent the standard error of the mean.

A one-way ANOVA analysis at this same electrode, but for the P2 time window also reveals no significant difference ($M_{baseline} = -0.66 \mu\text{V}$; $SD_{baseline} = 2.26 \mu\text{V}$; $M_{nature} = 0.12 \mu\text{V}$; $SD_{nature} = 1.97 \mu\text{V}$; $M_{urban} = -1.07 \mu\text{V}$; $SD_{urban} = 1.93 \mu\text{V}$; $F_{2,53} = 0.0900$; $p = 0.9120$), however a two-tailed t-test reveals a significant difference in P2 amplitude between our nature and urban viewing conditions ($t(17) = 2.4871$; $p = 0.0236$).

A one-way ANOVA analysis at electrode Fz for the MMN time window shows no difference between the three viewing conditions ($M_{baseline} = -1.31 \mu\text{V}$; $SD_{baseline} = 2.10 \mu\text{V}$;

$M_{nature} = -1.05 \mu\text{V}$; $SD_{nature} = 2.07 \mu\text{V}$; $M_{urban} = 1.98 \mu\text{V}$; $SD_{urban} = 2.49 \mu\text{V}$; $F_{2,53} = 0.8197$; $p = 0.4463$), with similar results obtained from a two-tailed t-test comparing nature and urban conditions ($t(17) = 1.7826$; $p = 0.0925$).

We also constructed topographies at both earlier and late time windows to understand which electrodes showed a significant difference between the nature and urban conditions, where $p < 0.05$. According to the topographies only a single electrode (O2) showed a difference at the P3 time window. Electrodes O1, Oz, O2, PO3, PO4, P7, P5, P3, Pz, P4, P6, CP5, CP1, CP2, C3, and Cz showed a significant difference between nature and urban viewing conditions at the P2 time window. These differences were calculated by performing a two-tailed t-test at each time window for each electrode. Figure 10 shows the difference waveforms for each of the midline electrodes (Oz, Pz, Cz, FCz, Fz) along with the topographies at both the early and late time windows. Figure 11 shows the difference waveform at electrode O2.

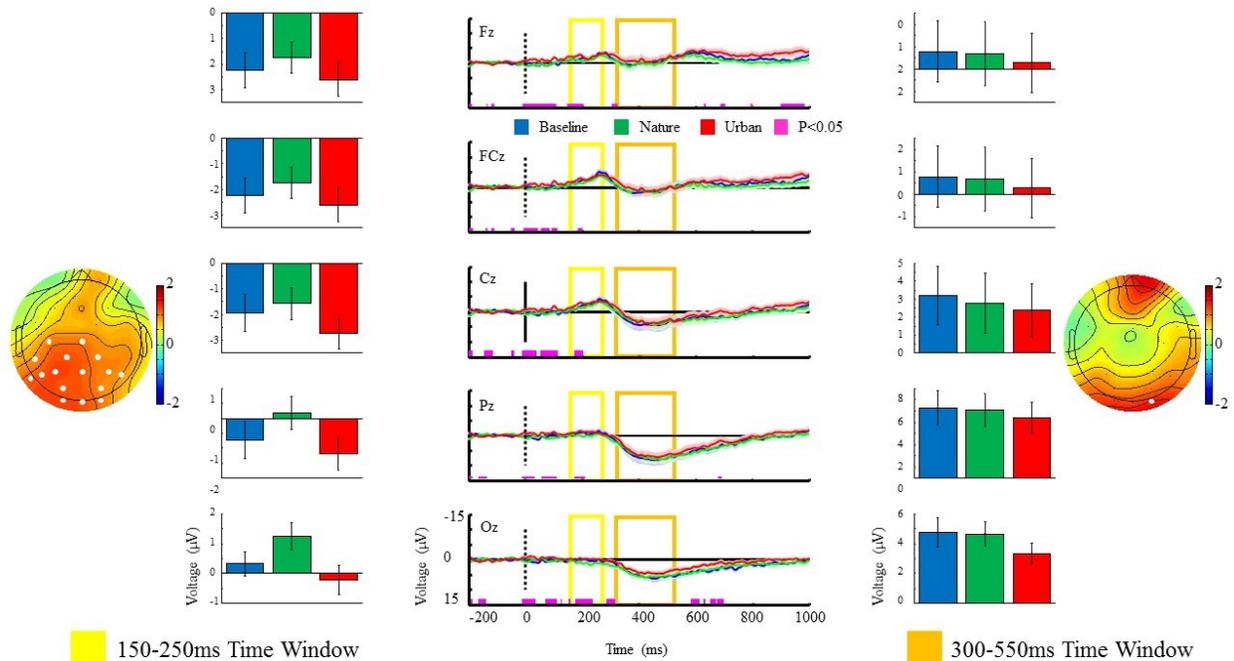


Figure 10: Auditory difference waveforms and topographies. Plots of difference waveforms (target tone ERP minus standard tone ERP) for each of the midline electrodes (Oz, Pz, Cz, FCz, Fz). Early time window (150-250 ms) and late time window (300-550 ms) are highlighted in yellow and orange, respectively. The average voltage across these time windows, for each viewing condition, are shown in the bar plots. Pink markers near the bottom of the difference waveform plots indicate time points where a pointwise t-test suggests significant differences between nature and urban conditions. Topographies show the averaged activity across the entire scalp at both time windows, with electrodes showing a significant difference between the nature and urban difference waveforms signified by white dots. Error bars represent the standard error of the mean.

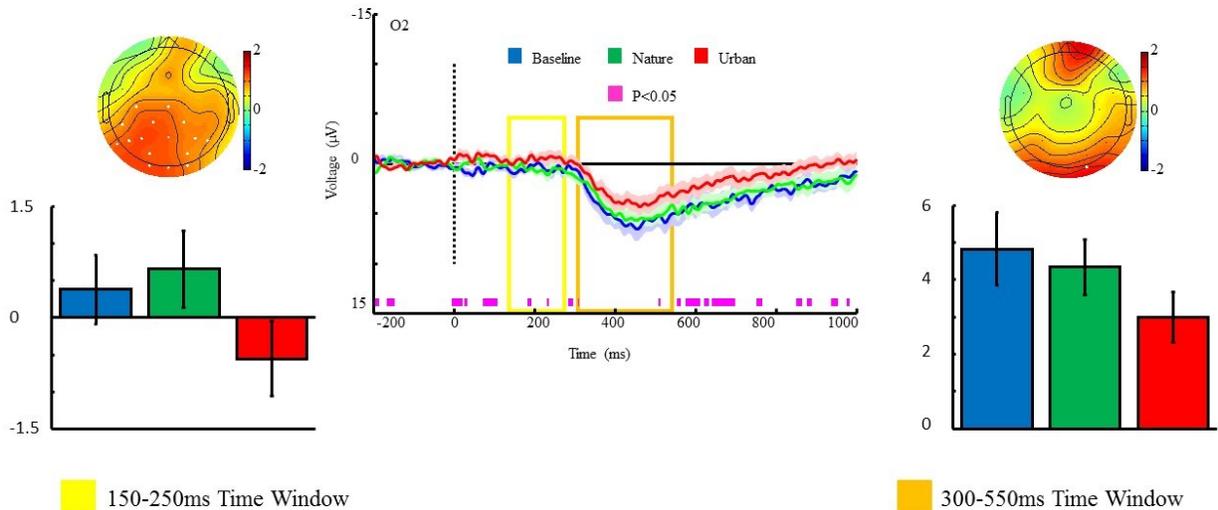


Figure 11: Auditory difference waveform at electrode O2. Difference waveforms (target tone ERP minus standard tone ERP) for electrode O2. Pink markers near the bottom of the difference waveforms indicate time points where a pointwise t-test suggests significant differences between nature and urban conditions. Topographies at the early (150-250 ms; yellow) and late (300-550 ms; orange) suggest significant differences between nature and urban difference waveforms for electrode O2, with this being the only electrode showing a significant difference across the late time window. Bar plots indicate the average voltage at each time window. Error bars represent the standard error of the mean.

As a final test to identify significant differences between our nature and urban viewing conditions we performed a t-test to compare the difference of our difference waves. That is to say, we calculated our auditory ERP difference waves for both nature and urban scene viewing conditions (determined by subtracting standard tone ERPs from target tone ERPs) and then subtracting the auditory ERP difference wave in the urban condition from the difference wave in the nature condition. We performed a two-tailed t-test across the entire auditory ERP comparing this difference wave to $0\mu\text{V}$. Time points and electrodes showing a significant difference are

shown in Figure 12a, with significant time points highlighted by bright blue (negative t statistic) or red (positive t statistic).

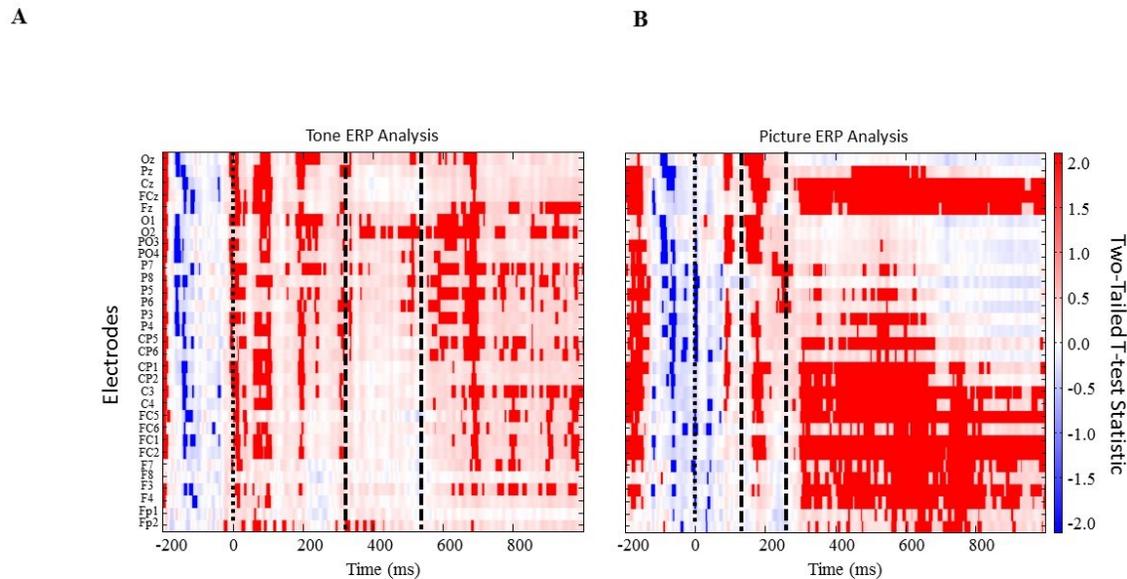


Figure 12: T-test comparison of auditory and visual ERPs for nature and urban Scenes. A) Plot showing the t-test statistics for each time point of the auditory ERP, and at each electrode. This was done by determining the difference between the nature and urban difference waveforms, and then using a point-wise two-tailed t-test to compare this difference to zero. Bright red or bright blue markers indicate time points and electrodes where there is a significant difference. The dotted line indicates tone onset while the two dashed lines indicate the late/P3 time window. B) Same procedure as mentioned above but concerning the visual ERPs. The dotted line indicates picture onset and the two dashed lines indicate the early (100-250 ms) visual ERP time window.

Picture Onset ERP Analysis

As with experiment one, we also analysed ERPs elicited by images. Since each trial began with the onset of a new image it is unlikely that the images themselves would be treated as an oddball stimulus, and because of this we decided to use two different time windows for analyses. For the picture ERPs we used both a 100-250 ms and a 300-600 ms time window to capture early and late ERP differences. A one-way ANOVA analysis at the early time window at electrode Pz shows no significant differences ($M_{baseline} = -1.04 \mu\text{V}$; $SD_{baseline} = 1.60 \mu\text{V}$; $M_{nature} =$

-1.57 μV ; $SD_{nature} = 2.94 \mu\text{V}$; $M_{urban} = -2.29 \mu\text{V}$; $SD_{urban} = 3.06 \mu\text{V}$; $F_{2,53} = 1.0267$; $p = 0.3655$), while a one-way ANOVA at the later time window for electrode Pz does reveal significant differences ($M_{baseline} = -0.53 \mu\text{V}$; $SD_{baseline} = 1.58 \mu\text{V}$; $M_{nature} = -2.06 \mu\text{V}$; $SD_{nature} = 2.80 \mu\text{V}$; $M_{urban} = -2.84 \mu\text{V}$; $SD_{urban} = 2.86 \mu\text{V}$; $F_{2,53} = 4.0255$; $p = 0.0238$). A two-tailed t-test comparing nature and urban pictures shows a significant difference at both the early time window ($t(17) = 2.7514$; $p = 0.0136$) and the late time window ($t(17) = 2.7003$; $p = 0.0152$).

A one-way ANOVA analysis at the early time window at electrode Fz shows a significant difference between our viewing conditions ($M_{baseline} = -2.33 \mu\text{V}$; $SD_{baseline} = 1.75 \mu\text{V}$; $M_{nature} = -5.94 \mu\text{V}$; $SD_{nature} = 2.49 \mu\text{V}$; $M_{urban} = -6.17 \mu\text{V}$; $SD_{urban} = 2.63 \mu\text{V}$; $F_{2,53} = 15.5311$; $p < 0.0001$), as does a one-way ANOVA at the later time window for electrode Fz ($M_{baseline} = -0.85 \mu\text{V}$; $SD_{baseline} = 1.77 \mu\text{V}$; $M_{nature} = -6.78 \mu\text{V}$; $SD_{nature} = 2.31 \mu\text{V}$; $M_{urban} = -7.91 \mu\text{V}$; $SD_{urban} = 2.81 \mu\text{V}$; $F_{2,53} = 47.2840$; $p < 0.0001$). However, a two-tailed t-test comparing nature and urban pictures shows no significant difference at the early time window ($t(17) = 0.9401$; $p = 0.3603$) but there is a significant difference at the late time window ($t(17) = 3.6105$; $p = 0.0022$).

We again generated topographies to identify which electrodes showed differences between our nature and urban viewing conditions, at each of the specified time windows. A two-tailed t-test was performed at both the early and late time windows with α set to 0.05. At the early time window electrodes Oz, Pz, Cz, O1, O2, PO3, and CP1 show significant differences between nature and urban pictures, while electrodes Pz, Cz, FCz, Fz, P5, P3, CP5, CP1, CP2, C3, C4, FC5, FC1, FC2, F7, F8, F3, and F4 show significant differences at the later time window. Figure 13 shows the difference waveforms derived from the visual ERPs elicited by image onset. Waveforms are shown for the midline electrodes (Oz, Pz, Cz, FCz, Fz) and topographies are shown for activity in both the early and late time windows.

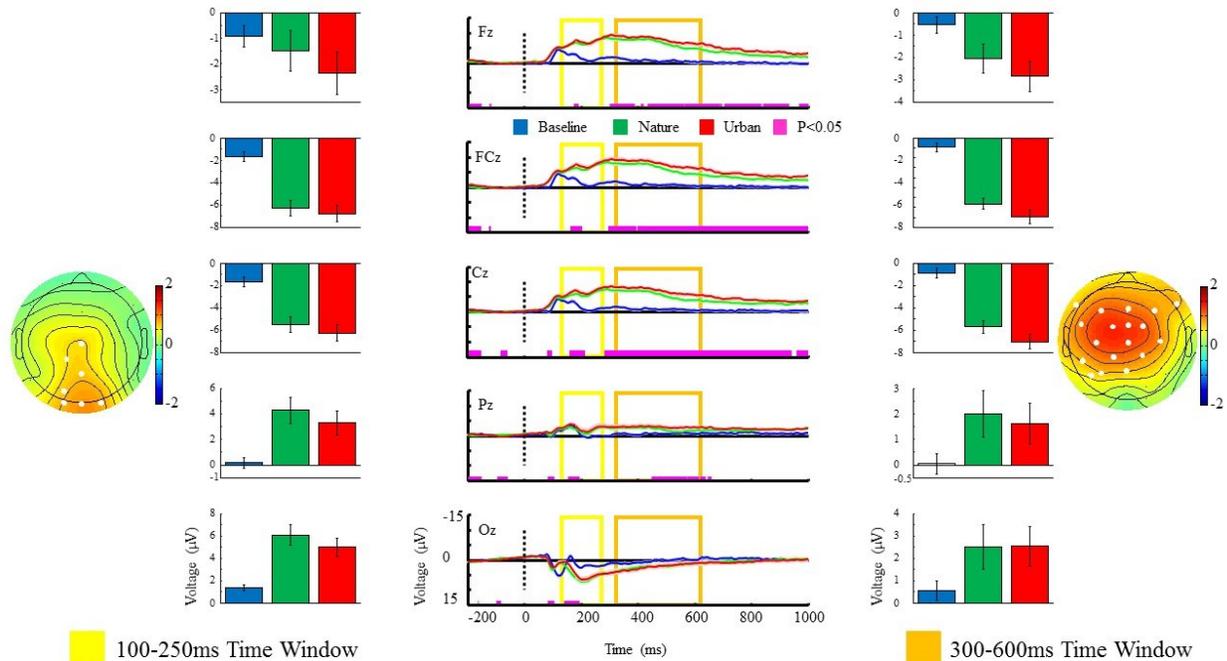


Figure 13: Visual ERPs and topographies. Visual ERPs elicited by picture onset for each viewing condition, along each midline electrode (Oz, P, Cz, FCz, Fz). Early time window (100-250 ms) and late time window (300-600 ms) are highlighted in yellow and orange, respectively. The average voltage across these time windows, for each viewing condition, are shown in the bar plots. Pink markers near the bottom of the difference waveform plots indicate time points where a pointwise t-test suggests significant differences between nature and urban conditions. Topographies show the averaged activity across the entire scalp at both time windows, with electrodes showing a significant difference between the nature and urban difference waveforms signified by white dots. Error bars represent the standard error of the mean.

Relationship Between Picture ERP and P3 Component

We also wished to understand if the early and late time windows for the picture ERPs would influence either the P2 or P3 time windows for the tone ERPs. To test this, a simple linear regression was calculated for each condition, predicting either the P2 or P3 component based on activity occurring in the late picture ERP time window. However, no significant linear regression equations were found for the P2 time window under the baseline ($F_{2,15} = 0.0780$; $p = 0.92525$; R^2

= 0.0103; $R^2_{adj} = -0.122$), nature ($F_{2,15} = 1.8489$; $p = 0.19154$; $R^2 = 0.198$; $R^2_{adj} = 0.0908$), or urban ($F_{2,15} = 2.1888$; $p = 0.14653$; $R^2 = 0.226$; $R^2_{adj} = 0.123$) conditions. Similar results were also found for linear regression equations at the P3 time window for the baseline ($F_{2,15} = 0.031342$; $p = 0.96921$; $R^2 = 0.00416$; $R^2_{adj} = -0.129$), nature ($F_{2,15} = 2.5716$; $p = 0.10958$; $R^2 = 0.255$; $R^2_{adj} = 0.156$), and urban ($F_{2,15} = 0.95126$; $p = 0.40837$; $R^2 = 0.113$; $R^2_{adj} = -0.00577$) conditions. Figure 14 plots the relationship between the magnitude of the visual ERP at the late time window in relation to the magnitude of the auditory ERP during the late (P3) time window.

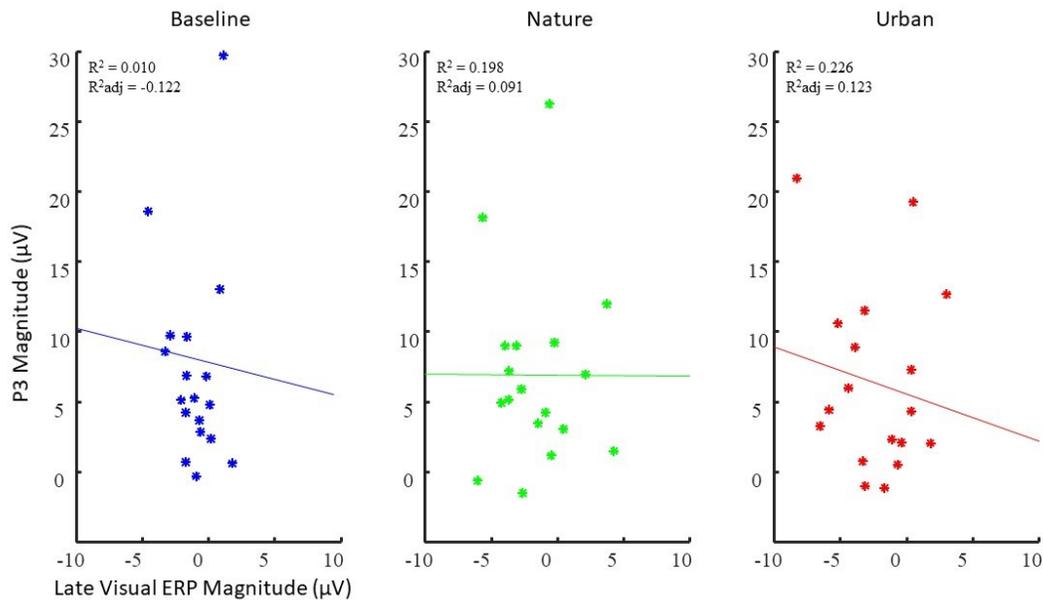


Figure 14: Late visual ERP component in relation to auditory P3 magnitude. Average late (300-600 ms) visual ERP voltage in relation to the average late/P3 (300-550 ms) auditory ERP voltage. Each marker signifies a single participant, while the coloured lines indicating the least-squares line for each plot.

Tone Onset ERSP Analysis

While we did not find significant differences in tone ERPs for our conditions, we decided to further explore other possible areas where we may find a difference between our viewing conditions. We decided to examine potential difference in the ERSPs in our three conditions, allowing us to understand if there are changes in neural activity across various frequency bands. We focused our ERSP analysis on the alpha frequency band (8-12Hz) as these frequencies have been shown to modulate visual attention (Adrian & Mathews, 1934; Busch, Dubois, & VanRullen, 2009; Ergenoglu et al., 2013; Lindsley, 1952; Mathewson, Beck, Fabiani, & Ro, 2009). We again analysed two time windows for the tone ERSPs, an early time window at 200-500 ms and a later time window at 700-1000 ms. This later time window was used since it corresponds to 300 ms prior to the earliest possible start of the next trial. Analysis is done by first averaging our ERSP values across our specified time windows across activity at the 8-12 Hz frequency ranges only. This is done separately for each participant and for each condition. The means for each participant are then compared across conditions.

A one-way ANOVA at electrode Pz for the early time window shows no difference across our conditions ($M_{baseline} = -0.3314$; $SD_{baseline} = 1.3508$; $M_{nature} = -0.8885$; $SD_{nature} = 1.5466$; $M_{urban} = -0.5294$; $SD_{urban} = 1.3192$; $F_{2,53} = 0.7229$; $p = 0.4902$) and there are no significant differences at the later time window as well ($M_{baseline} = -2.8437$; $SD_{baseline} = 1.7501$; $M_{nature} = -2.4511$; $SD_{nature} = 1.9115$; $M_{urban} = -2.4508$; $SD_{urban} = 1.7831$; $F_{2,53} = 0.2806$; $p = 0.7565$). Two-tailed t-tests comparing nature and urban conditions for the early time window ($t(17) = -0.9895$; $p = 0.3363$) and the late time window ($t(17) < -0.0006$; $p = 0.9995$) also reveal no differences. Figure 15 shows the ERSP activity elicited by both the standard and target tones at electrode Pz.

Differences between ERSP activity following target and standard tones were calculated and compared between the nature and urban scene conditions, also shown in Figure 15.

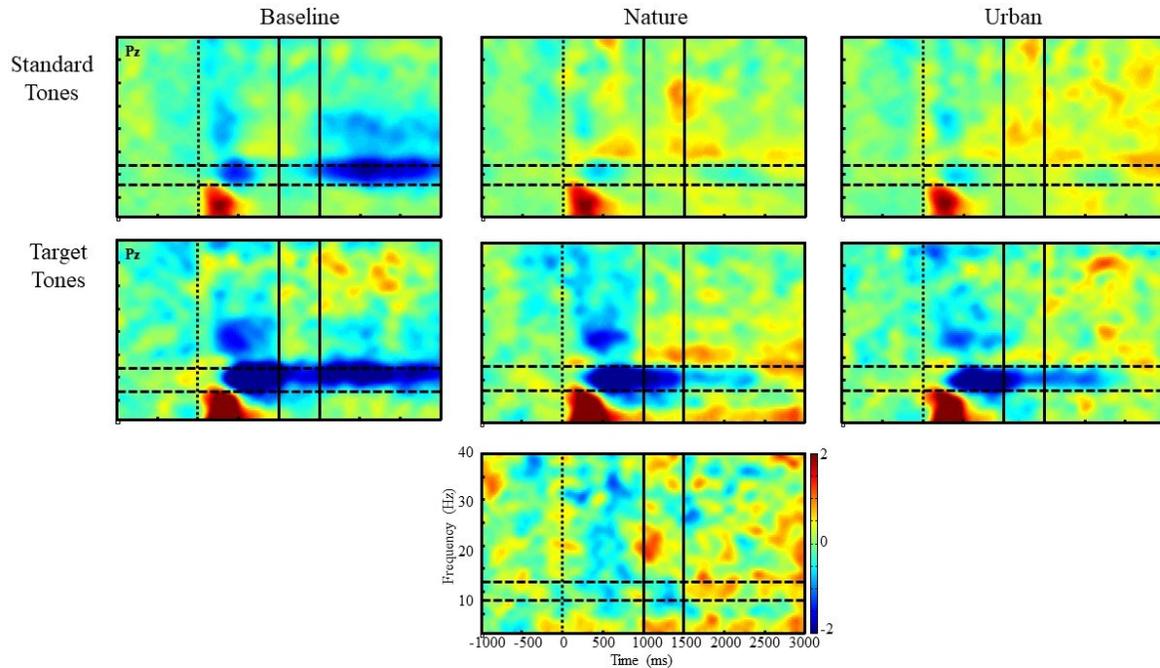


Figure 15: Auditory ERSPs for tones. ERSP plots showing activity following standard and target tones at electrode Pz. Dotted vertical lines indicate the onset of the tone, two horizontal dashed line indicate activity in the alpha frequency range (8-12Hz), and the two solid vertical lines indicate the earliest and latest time point at which the next trial would begin. The bottom-most plot shows the difference between the difference ERSP plots (target tone ERSP minus standard tone ERSP) of the nature and urban viewing conditions.

Similar results are obtained at electrode Fz. A one-way ANOVA for the early time window ($M_{baseline} = 0.0591$; $SD_{baseline} = 1.1767$; $M_{nature} = -0.0158$; $SD_{nature} = 1.4356$; $M_{urban} = -0.1074$; $SD_{urban} = 1.4480$; $F_{2,53} = 0.0671$; $p = 0.9352$) and late time window ($M_{baseline} = -1.3103$; $SD_{baseline} = 1.4218$; $M_{nature} = -1.0450$; $SD_{nature} = 1.4874$; $M_{urban} = -1.0539$; $SD_{urban} = 2.0954$; $F_{2,53} = 0.1421$; $p = 0.8679$) reveal no significant differences, as does a t-test at the early ($t(17) = 0.2303$; $p = 0.8206$) and late ($t(17) = 0.0269$; $p = 0.9789$) time windows. Topographies generated

from the early and late time windows reveal no significant differences in tone ERSP between our nature and urban viewing conditions. Figure 16 shows the differences in ERSP activity between nature and urban conditions along the midline electrodes (Oz, Pz, Cz, FCz, Fz) and the topographies of this ERSP activity difference at the early and late time windows.

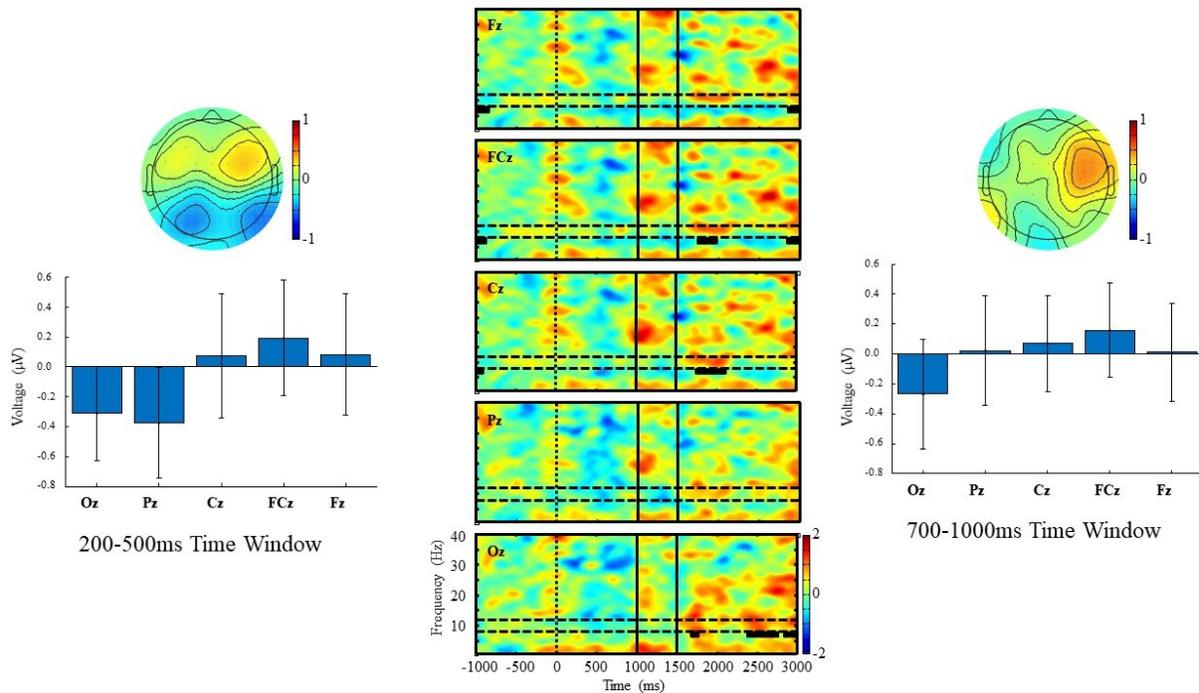


Figure 16: Comparison of auditory ERSPs for nature and urban scenes. Difference ERSP activity (target tone ERSP minus standard tone ERSP) showing the difference between nature and urban viewing conditions across each midline electrode (Oz, Pz, Cz, FCz, Fz). Dotted vertical lines indicate the onset of the tone, two horizontal dashed line indicate activity in the alpha frequency range (8-12Hz), and the two solid vertical lines indicate the earliest and latest time point at which the next trial would begin. Significant differences in activity between nature and urban viewing conditions is signified by black bars just below the 8Hz dashed line, calculated using a pointwise t-test. Topographies of the average alpha activity across the entire scalp at the early (200-500 ms) and late (700-1000 ms) ERSP time windows, along with bar plots showing this activity along the midline electrodes, are also shown. Error bars represent the standard error of the mean.

Picture Onset ERSP Analysis

We also analysed the ERSPs elicited by the pictures themselves to understand if there are any differences in activity in the alpha frequency range across conditions. Since the alpha frequencies are most strongly related to visual attention, any differences should be most prominent following picture onset. For the picture ERSP analysis our early time window was 200-700 ms post-picture onset while our later time window was 1500-2000 ms post-onset. This later time window was chosen since it corresponds to 500 ms before the earliest time a tone could be presented in any given trial. Figure 17 shows ERSP activity following onset of the pictures at electrodes Oz and Pz, along with difference plots comparing ERSP activity between both nature and urban conditions.

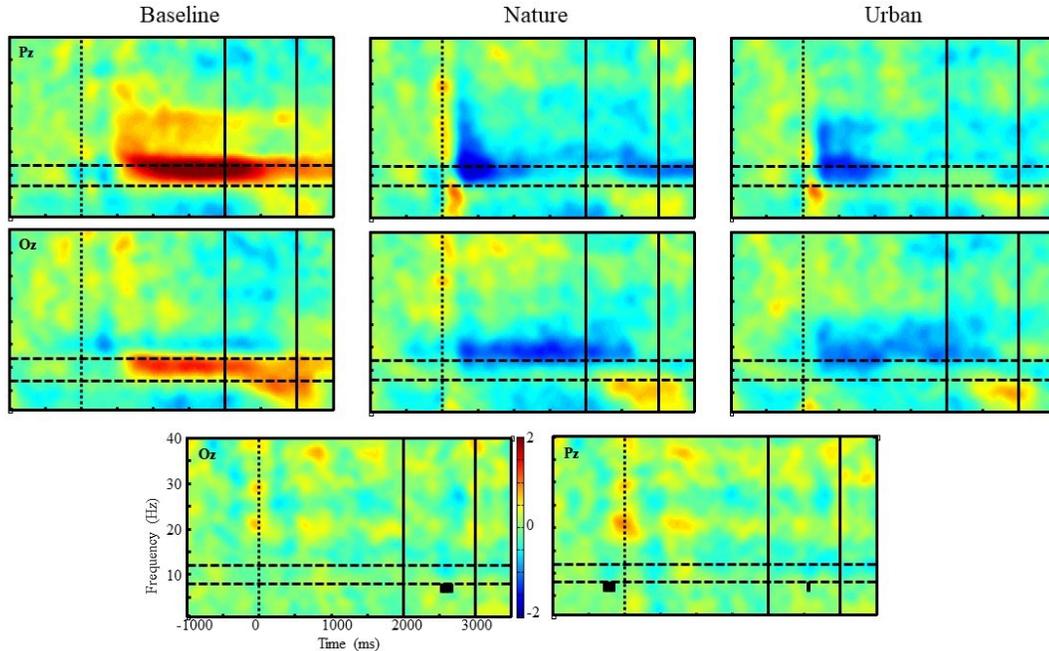


Figure 17: Visual ERSPs for pictures. ERSP plots showing activity following picture onset at electrode Pz and Oz. Dotted vertical lines indicate the onset of the picture, two horizontal dashed line indicate activity in the alpha frequency range (8-12Hz), and the two solid vertical lines indicate the earliest and latest time point at which the next tone would be played. The bottom-most plots show the difference between the difference ERSP plots (target tone ERSP minus standard tone ERSP) of the nature and urban viewing conditions. Significant differences in activity between nature and urban viewing conditions is signified by black bars just below the 8Hz dashed line, calculated using a pointwise t-test.

A one-way ANOVA at electrode Pz for the early time window shows no significant difference across conditions ($M_{baseline} = 0.0184$; $SD_{baseline} = 1.0534$; $M_{nature} = -0.7825$; $SD_{nature} = 1.1502$; $M_{urban} = -0.6797$; $SD_{urban} = 1.2914$; $F_{2,53} = 2.5011$; $p = 0.0920$) but we observe a significant difference during the late time window ($M_{baseline} = 1.4110$; $SD_{baseline} = 1.2371$; $M_{nature} = -0.1090$; $SD_{nature} = 0.7285$; $M_{urban} = -0.0509$; $SD_{urban} = 0.8416$; $F_{2,53} = 14.4653$; $p < 0.001$). However, two-tailed t-tests comparing nature and urban pictures at the early ($t(17) = -0.7199$; $p =$

0.4814; $\alpha = 0.05$) and late ($t(17) = -0.2908$; $p = 0.7752$) time windows show no differences between these conditions.

Similar results are obtained at electrode Fz. A one-way ANOVA for the early time window ($M_{baseline} = -0.0450$; $SD_{baseline} = 1.0491$; $M_{nature} = -0.6022$; $SD_{nature} = 1.1740$; $M_{urban} = -0.7193$; $SD_{urban} = 1.2559$; $F_{2,53} = 1.7282$; $p = 0.1878$) reveals no differences but late time window ($M_{baseline} = 1.0989$; $SD_{baseline} = 1.2164$; $M_{nature} = -0.5552$; $SD_{nature} = 0.8369$; $M_{urban} = -0.4008$; $SD_{urban} = 1.0427$; $F_{2,53} = 13.7984$; $p < 0.001$) suggests significant differences across viewing conditions. There, however, appears to be no difference between our nature and urban viewing conditions as revealed by a two-tailed t-test at the early ($t(17) = 0.8512$; $p = 0.4065$) and late ($t(17) = -0.8234$; $p = 0.4217$) time windows. Again, topographies comparing picture ERSPs for both the nature and urban viewing conditions showed no significant differences at any electrode and at either time window. Figure 18 plots the difference in ERSP activity between nature and urban scenes along the midline electrodes (Oz, Pz, Cz, FCz, Fz) and the topographies of this ERSP activity difference at the early and late time windows.

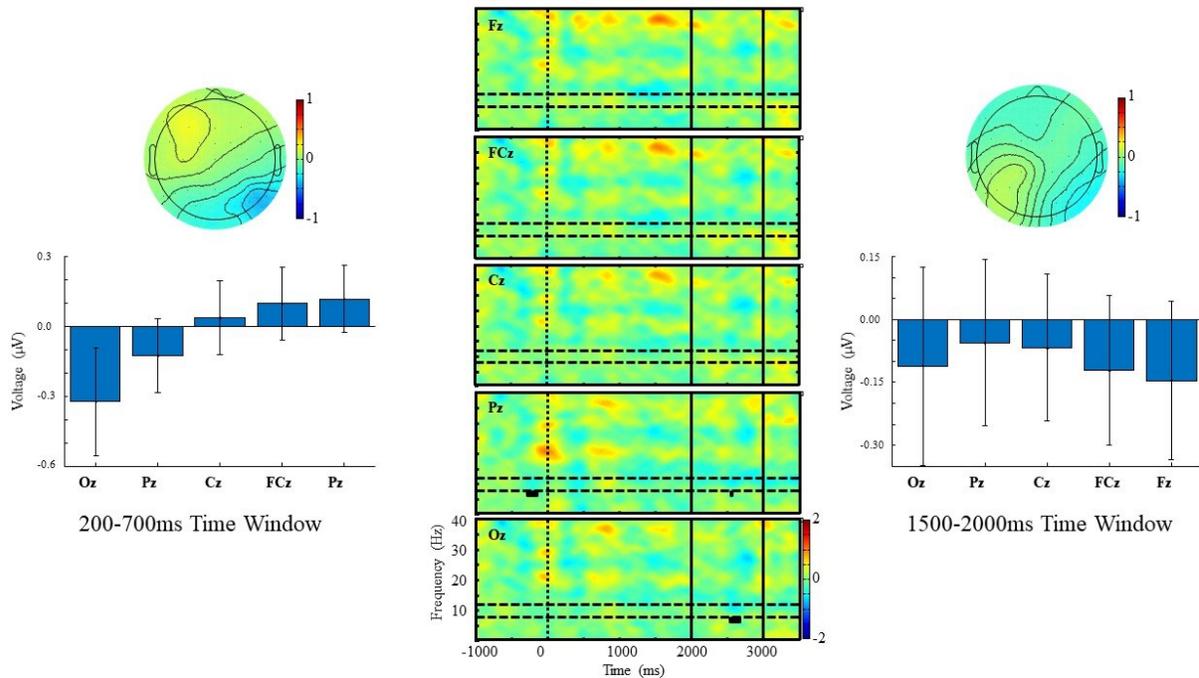


Figure 18: Comparison for visual ERSPs for nature and urban scenes. Difference ERSP activity (nature picture ERSP minus urban picture ERSP) showing the difference between nature and urban viewing conditions across each midline electrode (Oz, Pz, Cz, FCz, Fz). Dotted vertical lines indicate the onset of the picture, two horizontal dashed line indicate activity in the alpha frequency range (8-12Hz), and the two solid vertical lines indicate the earliest and latest time point at which the next tone would be played. Significant differences in activity between nature and urban viewing conditions is signified by black bars just below the 8Hz dashed line, calculated using a pointwise t-test. Topographies of the average alpha activity across the entire scalp at the early (200-700 ms) and late (1500-2000 ms) ERSP time windows, along with bar plots showing this activity along the midline electrodes, are also shown. Error bars represent the standard error of the mean.

Experiment Three

Behavioural Analysis

Executive attention of the ANT was assessed by calculating the difference in response time and accuracy between congruent and incongruent trials, both before and after participants viewed the nature and urban pictures. A two-way ANOVA of response times shows no difference between trials before and after picture viewing ($M_{\text{before}} = 108.5$ ms; $M_{\text{after}} = 98.8$ ms; $F_{1,88} = 1.19$; $p = 0.2792$), no difference between conditions ($M_{\text{nature}} = 110.0$ ms; $M_{\text{urban}} = 97.3$ ms; $F_{1,88} = 2.03$; $p = 0.1573$) and no significant interaction ($M_{\text{before:nature}} = 118.7$ ms; $M_{\text{before:urban}} = 98.2$ ms; $M_{\text{after:nature}} = 101.2$ ms; $M_{\text{after:urban}} = 96.4$ ms; $F_{1,88} = 0.79$; $p = 0.3769$). Figure 19a shows the executive attention scores before and after viewing either nature scenes or urban scenes. Average response times for congruent and incongruent trials are also shown.

A two-way ANOVA of accuracy shows a significant difference between trials before and after picture viewing ($M_{\text{before}} = 2.83$; $M_{\text{after}} = 1.30$; $F_{1,88} = 5.16$; $p = 0.0256$), no difference between our two conditions ($M_{\text{nature}} = 1.91$; $M_{\text{urban}} = 2.28$; $F_{1,88} = 0.21$; $p = 0.6509$) and no significant interaction ($M_{\text{before:nature}} = 2.57$; $M_{\text{before:urban}} = 3.09$; $M_{\text{after:nature}} = 1.26$; $M_{\text{after:urban}} = 1.35$; $F_{1,88} = 0.11$; $p = 0.7464$). Figure 19b shows the accuracy difference between congruent and incongruent trials, before and after viewing nature or urban scenes. Figure 19b also shows the accuracy for congruent and incongruent trials, both before and after scene viewing.

A two-tailed t-test of the ratings participants assigned to each picture indicates a significant difference in ratings between our nature and urban images ($M_{\text{nature}} = 2.59$; $M_{\text{urban}} = 1.78$; $t(23) = 6.3372$; $p < 0.001$). Figure 19c plots the average participant ratings of the presented nature scenes and urban scenes, with higher bars indicating a greater preference for that type of scene.

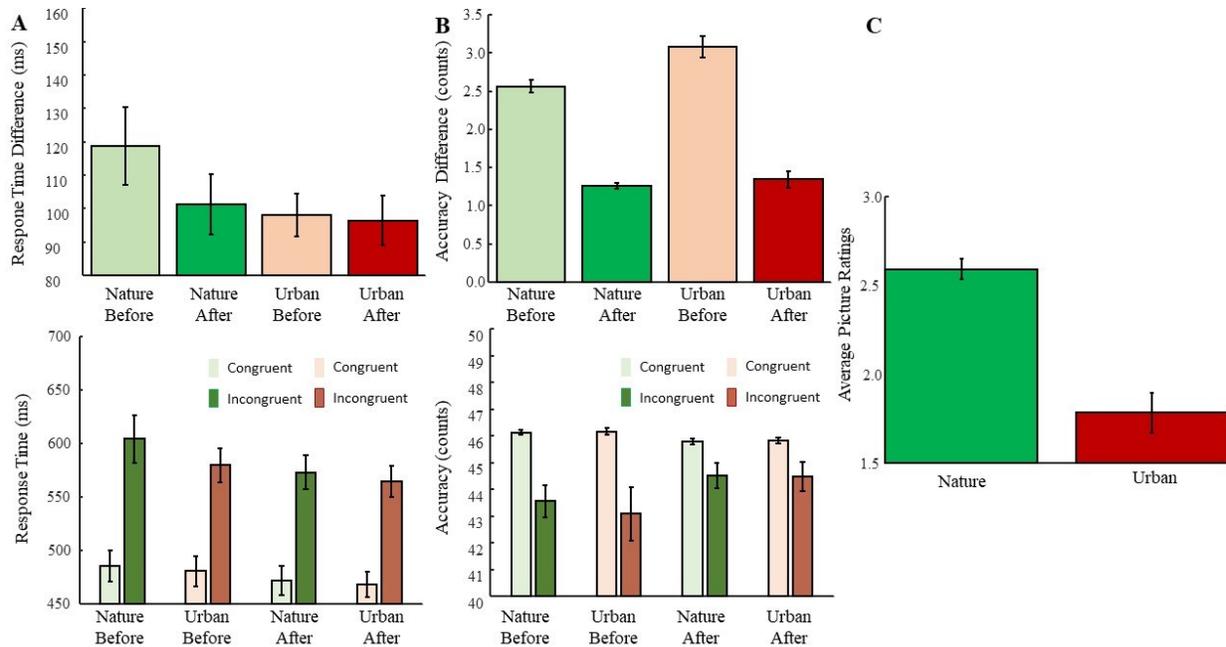


Figure 19: Executive attention scores, response times, accuracy, and ratings for ANT. A) Bar plots showing the average executive scores (congruent minus incongruent trial response times) both before and after viewing either nature or urban pictures. Bar plot below this shows the average response time (ms) for congruent and incongruent trials, before and after viewing either nature or urban pictures. B) Bar plot showing the accuracy difference (congruent minus incongruent trials) before and after viewing either nature or urban pictures. Bar plot below show the average accuracy for congruent and incongruent trials, before and after viewing either nature or urban pictures. C) Bar plot showing the average ratings for nature and urban pictures. Error bars represent the standard error of the mean.

Chapter 4: Discussion

Results from experiment one and two suggest there is no difference in P3 amplitude when participants are engaged in an auditory oddball task while simultaneously viewing nature scenes, urban scenes, or blank images. For experiment three we also failed to replicate previous findings showing a benefit in the executive attention dimension of the ANT when participants view nature scenes in comparison to urban scenes. These results seem at odds with what is currently understood regarding natural environments, attention restoration, and the attentional networks influenced by such restorative processes. There are several areas we need to further explore to understand why we observed no difference in P3 magnitude across our viewing conditions, and to develop further studies which may allow us to better define cognitive differences in the P3, and other related ERP components, that are elicited by the features of natural environments and attentional restoration.

P3 and Attentional Networks

While many studies show that the P3 response is related to contextual-updating of information (Datta et al., 2007; Nakajima & Imamura, 2000) and the P3 magnitude can be influenced by attentional demands placed on the participant (García-Larrea & Cézanne-Bert, 1998; Polich, 1986; Sawaki & Katayama, 2008) it is unclear what aspects of attention most strongly influence the P3 response. Fan et al. (2005) showed that the alerting, orienting, and executive attention networks elicit activation in a variety of cortical regions including the thalamus, parietal cortex, and anterior cingulate cortex respectively. Many of these regions have also been shown to be activated in association with rare target stimuli following a variety of oddball paradigms (Linden, 2005), suggesting that each of the attention networks play some role in responding and attending to unexpected stimuli. Orienting attention seems to play a large role

in modulation of the P3, which should not be surprising due to the general unexpectedness of target/deviant tones allowing them to quickly attract attention. However, Posner (2008) suggests that certain stimuli can provide information and activate both alerting and orienting attention networks. Posner (2008) also indicates that a rare stimulus may influence an individual's response to subsequent presentations or stimuli, with this idea supported by other research.

Escera, Alho, Winkler, & Näätänen (1998) had participants complete a forced-choice visual discrimination task while simultaneously completing an auditory oddball task, with a common auditory tone, rare deviant tone, or rare novel tone being presented before each visual stimulus. Participants were instructed to ignore tones and classify the visual stimuli as quickly as possible. Novel tones were shown to elicit a P3 response despite participants being instructed to ignore them. Visual target accuracy decreased and response time increased following novel tones as well. Berti (2008) showed a similar influence of novel stimuli in the processing of subsequent events. Participants were tasked with sorting tones based on length. Two tones of identical pitch but different lengths were presented along with a rare deviant tone that was similar in length but different in pitch. Participants were told to either refocus their attention and correctly sort the deviant tones based on length, or to reorient their attention and simply ignore the deviant tone. For both the refocus and reorient conditions, deviant tones that immediately followed the presentation of a previous deviant tone produced a smaller-magnitude P3 response and such modulations were also found in other ERP components. While it could be argued that, in each study, successful suppression of irrelevant stimuli requires some engagement of the executive attention network, the generation of a P3 response shows this suppression was not completely successful and the auditory tones were capturing attention through an involuntary attention network. Along with orienting and alerting attention, these studies suggest that executive

attention plays a role in modulation of the P3 and that the P3 response is related to, and influenced by, information provided by previous stimuli.

Barcelo, Escera, Corral, & Periáñez (2006) had participants complete a visual discrimination task with auditory tones presented before each visual stimulus. Participants were required to attend to the auditory tones as they would indicate how to sort the visual stimuli, either repeat the previous sorting rule or switch rules. Occasionally, a novel tone was also played shortly after the “repeat” cue. As expected, the novel cue elicited a typical P3 response but a P3 response was also elicited by the cue tones, although the P3 response to “repeat” cues were reduced in comparison to “switch” cues. To relate these ERPs to executive attention, the authors showed that response times of participants with the largest P3 amplitudes following “switch” cues were least affected by costs associated with task switching. While differences were not found in the ERPs elicited by the visual stimuli, this was not the case for SanMiguel, Morgan, Klein, Linden, & Escera (2010) who showed participants a series of complete or scrambled faces while sounds were presented every 1.2s. These sounds would be either common standard tones or rare catch sounds consisting of environmental noises. The authors found that visual ERPs following a catch tone produced a larger P3 response compared to standard tone trials, while other ERP components such as the N170 remained relatively unaffected, suggesting that alerting, orienting, and executive attention networks may all play some role in this P3 modulation effect. Daffner et al. (2003) further examined the role of executive attention by having healthy controls, frontal lobe patients, and parietal lobe patients complete a 3-stimulus visual oddball task involving standard, target, and novel images. P3 latency was found to be longer for frontal patients, who also showed a smaller P3 to novelty stimuli. Parietal patients showed a decreased P3 response following target stimuli, suggesting that frontal and parietal sites support different

functions in the generation of a P3 response. Even though both regions share some functionality in alerting, orienting, and executive attention networks (Fan et al., 2005), the results of Daffner et al. (2003) further demonstrate that each of these networks are involved in some aspect of the P3 response.

Previous research has shown that the P3 component is influenced by attentional demands placed on the participant, with tasks that inhibit the ability of participants to attend to rare, target stimuli resulting in a reduced P3 response. It has also been shown that the ability to direct attention to specific objects or tasks relies on a limited resource which can be depleted as more demands are placed on directed attention. Depleted attention resources can recover when exposed to restorative environments, such as a natural setting, since it is suggested that such environments primarily rely on involuntary, automatic forms of attention and allow directed attention resources to recover. Based on previous research, we were expecting the P3 response to be modulated based on the type of environment viewed by participants as they completed an auditory oddball task. A larger P3 response was expected when viewing nature scenes and a smaller P3 response was expected when viewing urban scenes. Interestingly we found no significant difference in our P3 responses across our viewing conditions. While several factors may explain this lack of difference in P3 magnitude, such as a lack of fatigue, it would be expected that the attention-sensitive P3 component would be influenced by nature or urban environments, which are suggested to place less or more demands on directed attention respectively. Even though the P3 response has been shown to contain a directed attention component it is unclear to what extent directed attention modulates the P3 response, particularly in comparison to automatic attention components such as alerting and orienting. The auditory oddball tasks used in experiments one and two are rather simple tasks since participants are

presented with only two very distinct tones and are only required to press a button to one tone.

As such, any influences the difference scenes have on directed attention and P3 amplitude are not apparent may be due to the simplicity of the task. This would also explain why we did not observe any significant differences in response times for our target tones across viewing conditions; performance may have been at ceiling regardless of any directed attention benefits or detriments associated with the different scenes. A more cognitively demanding task which relies on directed attention performance, such as a three-stimulus oddball task, may better highlight any differences specific environments have on the P3 response.

Are Attentional Fatigue and Awareness of Nature Necessary?

Since it is unclear to what extent each network contributes to P3 generation, it is possible that the executive attention network plays a smaller role compared to both orienting and alerting attention networks. If this is the case, and since it has been shown that natural environments most strongly influence executive attention (Berman et al., 2008; Gamble, Howard, & Howard, 2014), it could be that viewing nature images alone is insufficient in influencing the executive attention aspects associated with the P3 response. An attentional and cognitively demanding task, such as the SART or Stroop task, may be needed to initially deplete executive attention in order to highlight any potential influences natural environments may have in modulating the P3 response. This initial attentional fatigue may only be needed for certain cognitive measures however, since Joye, Pals, Steg, & Evans (2013) were able to demonstrate nature benefits with affective and attentional measures without attentional depletion. These factors were assessed using the affect misattribution procedure, the dot probe paradigm, and a cognitively effortful task assessing visual targets, respectively. Participants completed each task while viewing either nature or urban scenes. The authors found that participants tended to rate natural scenes as more pleasant

and would perform better at detecting the location of a dot when viewing nature scenes. Performance for the cognitive task did not differ when viewing either nature or urban scenes however, suggesting that attentional fatigue may be necessary to bring out certain influences of natural scenes. Joye et al. (2013) raise an interesting point where they suggest that it is unclear exactly how fascinating environments, such as nature, influence attention; are such environments better able to focus attention for a brief moment, maintain a hold on attention for longer durations, or some combination of both? Future research would be needed to better understand which aspects of attention natural environments are able to influence.

While one potential criticism of the results obtained by Joye et al. (2013) and ourselves, relating to attention, is that in both tasks it could be possible that participants were not able to fully attend to the restorative aspects of the natural scenes. Our measures, be it performance or P3 amplitude, would not be influenced by the restorative effects of nature if participants were not fully aware of the features of each scene. This may not entirely be the case since Lin, Tsai, Sullivan, Chang, & Chang (2014) were able to demonstrate that attention modulates the restorative benefits of nature but is not necessary to observe those benefits. Participants were shown images of urban streetscapes containing either trees or no trees, and attention was manipulated in three ways. Minimal attention was achieved by rapidly flashing the trees themselves for 30 ms every 5 s, moderate attention involved the presentation of trees for the entire viewing duration, and maximal attention had trees presented for the entire duration but participants were encouraged to directly attend to the trees themselves. Awareness of the trees was checked by asking participants to identify the number of plant species, with the 'no trees' group performing similar to the 'minimal attention' group and suggesting that the attention manipulations were effective. Attentional fatigue was induced by having the experiment take

place directly after a class attended by the participants. Each participant completed a backwards digit-span task before and after viewing the images, and rated each image based on its perceived restorativeness. While some differences were found in how participants rated the restorativeness of each scene, the most interesting result was that attentional performance in the digit span task increased in all attention conditions. Participants who were encouraged to attend to the trees showed the biggest performance benefit while those in the minimal and moderate awareness conditions showed similar performance increases. The results obtained by Joye et al. (2013) and Lin et al. (2014) suggest that not all measures of nature restoration require attentional fatigue and differences in performance can be observed when elements of nature are outside of awareness. However, cognitive tasks appear to require some level of fatigue to observe restorative effects. Attending to specific elements of nature is not necessary to observe attentional benefits. In our study this idea suggests that having participants fixate solely on the central fixation when images are presented does not necessarily explain the lack of a P3 difference between viewing conditions.

P2 Time Window Differences, What is the Role of the P2?

Even though we were unable to observe significant differences in our P3 amplitudes across viewing conditions, and no significant differences were observed between nature and urban scenes across all electrodes (aside from O2) during the P3 time window, we did observe differences in many central and parietal electrodes across the earlier 150-250 ms time window. The P2 response precedes onset of the P3 component and is typically located during this 150-250 ms time window, with P2 activity generally being maximal at electrode Cz (Crowley, 2004). Many EEG research studies do not seem to focus on the P2 component and those that do suggest that its activity is highly dependent on the preceding N1 component (Crowley, 2004). However,

it has also been suggested that the P2 component does represent an independent process and is involved in stimulus processing and evaluation during auditory and visual tasks.

Tremblay, Kraus, McGee, Ponton, & Otis (2001) demonstrated that the N1-P2 components are related to speech perception, whereby the N1-P2 component increases as speech perception becomes more accurate. The authors were also able to demonstrate that following speech-perception training, the N1-P2 component would subsequently increase and could serve as a cognitive marker of perceptual performance. Participants were consistently tested and trained on the ability to distinguish similar speech sounds. After training participants were better able to distinguish the different speech sounds, and this increase in performance was reflected by an increased N1-P2 component. This change in the N1-P2 suggests that this component plays a role in the perception and identification of sounds. Shahin, Bosnyak, Trainor, & Roberts (2003) provide further evidence supporting the role of the P2 component in auditory perception. Non-musicians, professional violinists, and professional pianists listened to pure, violin, or piano tones, with results indicating a larger P2 response being elicited by the musicians when their respective tone was presented. The N1 response was not found to differ between participants. Follow-up studies further support his distinction between the P2 and N1 components, and show that the P2 is modulated by the spectral complexity of auditory tones (Shahin, Roberts, Pantev, Trainor, & Ross, 2005; Shahin, Roberts, Miller, McDonald, & Alain, 2007). Further studies even suggest this P2 modulation does not require training but may be related to consistent presentation of auditory tones and does not require active perceptual discrimination (Sheehan, McArthur, & Bishop, 2005). Results from these studies suggest the P2 component plays a role in auditory stimulus discrimination and reflects an individual's ability to perceive or attend to a particular sound. With respect to the results obtained in experiment two, where a difference in the P2 time

window (150-250 ms) appears between our nature and urban viewing conditions, such activity may suggest participants were able to better discriminate between the standard and target tones when viewing nature scenes. The ideas of ART predict that natural scenes place less demand on directed attention and suggest that more attentional resources may be available to other processes, such as attentional and perceptual processes indicative of the P2 response. While behavioural or P3 differences were not observed across viewing conditions, further attentional fatigue and/or a task focused on auditory tone discrimination may reveal behavioural and P3 differences while further exacerbating the apparent P2 differences observed across scenes.

Several studies have also demonstrated the role of the P2 component in processing visual stimuli. These results may help to explain differences we have observed in the ERPs following the onset of each scene. Similar to perception of auditory stimuli, the P2 seems to be related to the evaluation of visual stimuli and can be modulated by changing certain characteristics of a visual display. Federmeier & Kutas (2002) manipulated certain words in sentences shown to participants, and demonstrated that unexpected words (those that did not match the scene described by the sentence) elicited a larger P2 amplitude. Similar results were also obtained by Potts (2004) who showed that task-relevant stimuli result in a larger P2 response. Participants performed a visual oddball task, with targets presented on 20% of the trials, and were asked to respond with a keypress, silently count target stimuli, or simply observe the stimuli. A P2 response was observed following the rare, target stimuli and this response was largest when a keypress was made. The P2 response was also found to be the first ERP component to distinguish the presentation of targets and non-targets. Even though a P2 response was observed for target stimuli, the results from Potts (2004) and Federmeier & Kutas (2002) suggest the P2 is responsible for attending to deviant or unexpected stimuli and evaluates current stimuli based on

previous information. Visual stimulus quality was also found to influence the P2 response as evidenced by De Cesarei, Mastria, & Codispoti (2013). Participants were shown images that had varying amounts of low and high spatial frequency removed, resulting in changes in the amount of spectral power (contrast) for each image. The authors found that P2 response amplitude increased as the degree of spatial power increased for both the low and high spatial frequency images. Since the lateral occipital cortex (LOC) shows similar activity in response to spatial frequency changes, the authors suggest that P2 activity is linked with that of the LOC. While the characteristics of the P2 response do not seem to be influencing our visual ERPs in either experiment one or two, it is possible that the pictures are influencing the P2 response following the auditory tones. Haga, Halin, Holmgren, & Sörqvist (2016) demonstrated that attributing sounds to either a nature or urban source can influence how participants rate those sounds. Participants listened to pink noise intermixed with white noise and were told the sounds originated from a nature environment, urban environment, or were not informed about the sounds origin. Ratings of perceived restorativeness were higher and ratings of perceived exhaustion were lower when participants were told the sound was of a natural origin. Also, urban environmental noise is typically concentrated around 2000Hz or lower (Slabbekoorn & Peet, 2003). Our standard and target tones may be more typical of an urban setting (our tones were 1000Hz and 1500Hz respectively) compared to a natural scene. We may be observing a P2 difference because such lower frequency sounds are not associated with nature environments and so are more unexpected, recruiting more attentional resources to process the tones.

While we did not observe a significant difference in the P3 response across our viewing conditions, we were able to identify differences in our auditory ERPs corresponding approximately to the P2 region. This unexpected finding suggests that the visual scenes are

modulating cognitive activity following the presentation of our tones, at least to some degree. According to Figure 9, differences in the P2 region correspond to ERP activity following the target tones rather than the standard tones. This would suggest that this P2 difference is related to the ability of participants to efficiently and accurately process the target-relevant stimuli (Potts, 2004) whereas if this P2 difference was primarily found in the ERP activity following standard tones, this would suggest that such activity is related to the ability of participants to successfully inhibit task-irrelevant stimuli (García-Larrea, Lukaszewicz, & Mauguière, 1992). However, any differences in processing the target tones did not result in differences in response times and this again may be due to the relatively easy and simple task used in experiments one and two. A more complex auditory classification task would likely rely more on the neural processes related to the P2 and response time differences when viewing different environments may become more apparent. For example, using tones that are more similar (1000Hz and 1100Hz) would make the task more difficult and would more likely rely on the ability of participants analyse and differentiate the tones. Such a task may result in further differences in the P2 response, as well as bring about differences in our responses times and P3 response which are dependent on the type of scene being viewed.

Can Visual ERPs Distinguish Nature and Urban Scenes?

Of notable interest was the differences in ERPs elicited by our nature and urban pictures, particularly for experiment two. Both early and late ERP differences were obtained and these differences are likely due to specific properties associated with natural and urban scenes. Groen, Ghebreab, Lamme, & Scholte (2012) modeled the characteristics of scenes using three different statistical models (Weibull statistics, Fourier statistics, Distribution statistics) and were interested in the ability of these models to distinguish which scenes participants were shown, based on the

obtained visual ERPs. The Weibull function classified scenes based on two parameters; the overall contrast of the image (classified as the beta parameter) and the spatial coherence or overall complexity of the image (gamma parameter). These parameters were calculated by applying a variety of contrast filters to each image and then calculating the average contrast of each image using several different scales. The contrast distribution obtained from each possible filter and scale combination are then averaged together, with the beta and gamma parameters calculated from this averaged contrast distribution using maximum likelihood estimation. The Fourier function classified images by calculating the Fourier transform of each image to determine the power spectrum, averaging across all directions, and then determining the slope and intercept of the average power spectrum. Finally, the Distribution statistics function determines the overall contrast distribution of each image using a center-surround filter, with skewness and kurtosis parameters obtained from the overall contrast distribution. Participants were shown a series of “dead leaves” images (essentially a varying number of circles of random size and location superimposed on top of one another) and these images were manipulated based on the size of the circles, their distribution, opacity, and the amount of perceived depth. Single images were either passively viewed or two images were presented and participants indicated if the images were identical. Visual ERPs were then compared to the image distributions calculated by each of the three models, with the Weibull model best accounting for the variation among the visual ERPs and for performance in the discrimination task. The area with the largest amount of ERP variance, and the region which was best explained by the Weibull model, occurred approximately 100-200 ms after image onset. This result suggests that image classification occurs very early in the ERP and is largely influenced by the contrast and complexity of a given image.

These results were then further expanded and shown to apply to an entire visual scene where Groen, Ghebreab, Prins, Lamme, & Scholte (2013) showed participants images of nature or urban scenes and asked them to classify each scene based on its perceived naturalness. Images were again sorted based on their contrast and complexity parameters but this time each individual parameter was used to estimate the variance in the visual ERPs. Naturalness ratings were influenced by both parameters, although ratings were more highly correlated with the complexity of each image. Similar to the results mentioned above, the largest correlations occurred 100-200 ms following image onset but was also sustained up to about 250 ms. The authors suggest these early processes are responding to the most basic scene information, such as the amount of complexity, and this information may be pooled from several cortical regions for deeper scene processing occurring later in the ERP waveform. However, these later components may be influenced by attentional demands as evidenced by Groen, Ghebreab, Lamme, & Scholte (2015). In this study participants were again shown a series of nature or urban scenes, with varying contrast and complexity values, but were also asked to perform one-of-three tasks designed to change the focus of attention. Activity in the early ERP components were still highly correlated with scene complexity and did not differ across the three attention conditions, although later components (approximately 250-450 ms) were influenced by attention. When attention was focused on the images, differences observed in the early ERP were prolonged and more apparent across other electrode sites. The authors propose that this relates to deeper processing of the scenes, such as categorisation, which relies on processing during the earlier component but also relies on attentional processes for more effective categorisation.

These results have been supported by other research (De Cesarei, Peverato, Mastria, & Codispoti, 2015; Cichy, Khosla, Pantazis, & Oliva, 2016) and may account for the differences

observed in our visual ERPs obtained from experiment two. Early ERP differences were observed in the 100-250 ms time window at predominantly occipital and parietal electrode sites while differences observed in the later 300-600 ms time window were observed at central and frontal electrode locations. These results are consistent with the research mentioned previously and likely reflect the time-course of scene processing. These ERP patterns also correspond to the relative contrast and complexity of each individual image, making it possible to predict which image participants were shown based on the ERPs elicited by the individual images. Even though participants were not tasked with categorising each image, late ERP differences were observed and have been related to such deeper, top-down processing. Their appearance suggests that attention, even though centered on the fixation cross, was not completely focused away from the images themselves and did allow for bottom-up and top-down processing of the images. Differences in the processing of nature and urban scenes could likely be manipulated further by having participants classify each image while performing the auditory oddball task, serving to both enhance any visual ERP differences and possibly further fatigue attention.

Differences in our visual ERPs could likely be enhanced if the nature and urban images used were classified based on the spatial coherence and contrast energy, similar to Groen et al, (2013). With such a classification it may be possible to show how the visual ERP changes based on these two factors but we may also better understand how our nature images differ from the urban images based on these factors. Classifying our images may also bring about changes in our P3 response such that the largest modulations of the P3 may occur for images with specific patterns of spatial coherence and contrast energy. It is possible that, when averaged together, our nature and urban scenes possess similar levels of spatial coherence and contrast energy. This

may partly explain why our P3 response is similar across our viewing conditions since overall, in terms of spatial coherence and contrast energy, our scenes may be very similar.

What's Special About Nature? – Fractals

To encourage success in identifying cognitive markers associated with the restorative effects of nature it is important to understand the characteristics of a nature scene which encourage such restoration. Many studies have examined specific visual qualities of nature scenes, while other researchers have focused on using fractals, patterns, and complexity to distinguish between nature and urban environments.

It has been suggested that fractal patterns are common among nature settings (Mandelbrot, 1983) and typically consist of repeating patterns of varying complexity and randomness. Since fractals are predominant in nature they may contribute to nature restoration and influence how individuals respond to natural environments. Bies, Blanc-Goldhammer, Boydston, Taylor, & Sereno (2016) used fractal patterns as analogues to nature scenes and wished to understand how individuals respond to exact fractals compared to statistical fractals. Both types of fractals consist of patterns of varying complexity but statistical fractals incorporate random characteristics, resulting in two visually distinct patterns. Both fractals were manipulated along four features; dimensionality, symmetry, recursion, and segment number. The factors represent the ratio of course and fine detail, pattern similarity, pattern repetitions, and number of patterns respectively. Results showed that participants' preference for exact fractal patterns increased as dimensionality increased and statistical fractal patterns were preferred when dimensionality was lower, suggesting that exact and statistical fractals are processed differently.

Street, Forsythe, Reilly, Taylor, & Helmy (2016) were able to support and expand upon previous results, examining fractal preference across cultures and gender. While they were able

to show a general preference for fractals containing mid-range dimensionality, exact preferences vary across individuals with culture and gender playing an influential role in fractal preference. Van den Berg, Joye, & Koole (2016) were able to apply these results from fractal preference to natural and urban scenes, showing a preference for increased complexity. Participants were shown images of natural and urban scenes of varying complexity, along with magnified versions of the same scenes, and were asked to rate each scene with regards to complexity, beauty, relaxation, and positive affect. Overall nature scenes were rated higher and viewed longer, and these ratings increased with perceived complexity and magnification. Interestingly, highly complex urban scenes were rated more positively, similar to nature scenes, but perceived complexity decreased as magnification increased. Fractal patterns seem to be an inherent part of natural environments, influencing the complexity of such scenes. Results from the previous articles emphasise the role of fractal/scene complexity and individual perceptions, suggesting that individuals tend to prefer more complex scenes and that this complexity is not driven purely by increased randomness, as is the case with statistical fractal patterns. While fractal patterns themselves are likely not the only quality determining the restorative effects of nature, as several other studies has shown a multitude of factors moderating restorativeness, fractal patterns could be applied to urban designs to make such environments more like their natural counterparts.

What's Special About Nature? – Other Features

Several other characteristics have been shown to influence perceptions of natural environments and these factors likely influence restorative benefits associated with such environments. ART suggests that inherently fascinating environments are influenced by four main factors (being away, extent, fascination, and compatibility) but Herzog, Maguire, & Nebel (2003) wished to expand on these variables to show how perceived restorative potential (PRP),

preference, openness, visual access, movement ease, and setting care are influenced by natural and urban environments. Participants rated several nature and urban scenes and, as the authors expected, ratings were generally higher for nature scenes across all factors. Although the authors suggest some measures may be redundant (such as extent and fascination), the results still show a variety of factors, such as the perceived accessibility of a scene, can further explain perceptual differences between nature and urban settings.

Bottom-up and top-down processing, based on visual features and information, have also been shown to influence perception. Kardan et al. (2015) determined colour (hue, saturation, brightness) and spatial (edge density, number of straight edges) information of various scenes to understand how such manipulations would influence participant preference and naturalness ratings for each scene. Low-level visual features, such as decreased hue and more diverse saturation in a scene, resulted in higher preference and naturalness ratings while the number of straight edges, and the ratio of straight-to-curved edges, predicted lower ratings. As expected, this pattern of visual features was found to be more common among nature images. The authors also used these low-level visual variables to predict naturalness ratings in comparison to obtained naturalness ratings, and they found their model does not account for all ratings equally. Their model was better able to predict fast responses, suggesting such ratings are primarily driven by low-level features and bottom-up processing, but their model was less able to predict slower responses. This may suggest that these slower responses are driven by top-down processes influenced by high-level information, such as experience, rather than low-level information.

Further exploring high-level information, Kotabe, Kardan, & Berman (2016) showed participants nature and urban images containing either scrambled colours or edges, and participants were asked to rate each image in terms of disorder and naturalness. This was done to

understand if colour or edges better predict image coherence and to determine which factor accounts best for feelings of naturalness. With respect to images where colour and edges remained intact, disorder ratings for scrambled colour images showed little correlation while naturalness ratings of scrambled edge images did not significantly correlate with their unaltered counterparts. The results suggest that high-level information regarding the naturalness of the entire scene may be reflected in the low-level colour information, rather than edge information, of that scene.

To better understand how low and high-level information influences scene processing, Valtchanov & Ellard (2015) also presented scrambled images to participants, who had to rate each image based on pleasantness and ease of identifying objects within the scene. Eye-fixations and blink rate, indicating cognitive load, were also measured. Images were scrambled by altering the phase or amplitude, or by removing either low or high spatial frequency information. Greyscale images were also used, eliminating possible colour influences. Unscrambled urban images elicited more fixations and higher blink rates compared to scrambled and nature images, supporting the idea that urban scenes place greater demands on directed attention and cognitive load. However, cognitive load seemed to be associated with low spatial frequency information since when this information was removed there was no significant difference in blink rate between nature and urban images. Pleasantness ratings were also higher for nature scenes until either high spatial frequency information was removed or the amplitude of the image was altered, resulting in similar ratings between nature and urban scenes.

The results of the previously discussed papers suggest that low and high spatial frequencies carry information about a particular scene and this information is used in different ways in order to make evaluations of the scene, with alterations of that frequency information

resulting in different scenes being treated more or less similarly. With regards to the images used in our study, while they were obtained from a previous experiment demonstrating restorative effects (Berman et al., 2008), it is unclear how these images differ in relation to their fractal information, spatial information, and other characteristics. Another interesting note is that many of the nature images used contained water in some fashion, but this was not the case for the urban images. The presence of water has been shown to modulate how participants respond to scenes, and water even influences behaviours differently based on if it is present in a mostly natural or mostly urban setting (White et al. 2010).

The current literature highlights several visual properties that are generally associated with either nature or urban scenes. With these properties in mind it would be interesting to understand cognitive changes associated with, for example, high and low spatial frequency information between nature and urban images, and if these cognitive changes are related to possible nature restoration benefits. Further work is needed to better understand what factors are specifically related to the benefits associated with restorative environments. Previous research has shown that fractal patterns, straight edge density, contrast energy, spatial coherence, hue, saturation, water, and many other factors are associated with nature and restorative benefits but it is unclear how each individual component contributes to restoration and how each of these factors may interact with each other. Attention restoration is unlikely to be inherent in nature itself but rather the result of specific features that are more common across certain nature environments. This seems to be the case since some studies were unable to find evidence for a restorative effect of nature (Bratman, Dail, Levy, & Gross, 2015) or have found increased task performance following exposure to urban environments (Joye et al., 2013). The lack of a restorative effect of nature can partly be attributed to a lack of understanding of how the many

characteristics that compose a nature environment influence attention restoration and which characteristics are needed for a restorative experience. Also we must acknowledge the possibility that there is no restorative effect as a direct result of nature exposure but rather any attention restoration may be the result of specific characteristics and their influences on perceptual and attentional mechanisms. The restorative or non-restorative aspects of a nature or urban environment may be due to characteristics common to specific environments rather than to the category of an environment.

Nature, Visual Scenes, and Alpha Frequency

We also analysed the ERSPs elicited by both the tones and pictures themselves to understand any changes in frequency activity that may be occurring. Particularly we focused on the alpha band frequencies (8-12Hz) since these frequencies are related to attention and visual inhibition (Adrian & Mathews, 1934; Busch, Dubois, & VanRullen, 2009; Ergenoglu et al., 2004; Lindsley, 1952; Mathewson, Beck, Fabiani, & Ro, 2009). Several studies have shown that brief visual targets are less likely to be detected if the target is presented during periods of high alpha power, and more likely to be detected when alpha power is low (Busch, Dubois, & VanRullen, 2009; Ergenoglu et al., 2004; Mathewson, Beck, Fabiani, & Ro, 2009). There is also evidence to suggest a cross-modal effect, whereby auditory tones or visual targets can modulate the alpha frequency to either better detect a visual target or inhibit interference from a visual distractor to devote attentional resources to processing an anticipated auditory tone (Banerjee, Snyder, Molholm, & Foxe, 2011; Fu et al., 2001).

Several studies have used EEG to examine changes in spectral activity when individuals view fractal patterns of increasing dimensionality. Hägerhäll et al. (2008) showed participants silhouette fractals, described as like looking at the skyline and landscape of a scene, of various

fractals dimensions while EEG data was recorded. The authors were able to show that mid-level increases in fractal dimensionality resulted in the largest increases in frontal alpha and parietal beta activity. This increase in beta activity is thought to be related to the relaxing qualities of the fractal pattern and for processing spatial characteristics of the pattern, respectively. In a follow-up study Hägerhäll, Marcheschi, Boydston, Taylor, (2015) wished to further previous results by using EEG data to understand perceptual differences in exact and statistical fractal patterns. Participants were shown exact and statistical fractal patterns which varied along dimensionality and randomness, while EEG data was recorded from seven electrode sites. For each electrode alpha activity was found to increase as the amount of randomness in the fractal pattern increased, suggesting that alpha power is strongest for statistical fractals. Similar to previous results alpha power was found to be the largest at frontal electrodes for mid-level dimensionality, but it was also found that parietal and temporal alpha power was highest for lower levels of dimensionality. Since these electrode sites are closest to occipital regions, where changes in alpha power are mostly closely related to visual inhibition, these results could suggest that alpha power increases for fractals that are less complex and likely less visually interesting.

Such results may be applicable to our visual ERSPs where we observe an increase in alpha activity in the baseline condition but a decrease in alpha and beta activity following the onset of nature and urban pictures. This increase in alpha for the baseline condition is possibly due to the baseline image being a blank grey square, not a particularly interesting stimulus, and so alpha power is decreased to ignore the grey image and perhaps focus attention toward the upcoming tone. This contrasts with the nature and urban scene conditions where actual images are displayed and are likely much more interesting compared to a blank grey square. As such we get a decrease in alpha activity to possibly devote more attention to the images themselves. The

observed beta decrease may also indicate a modulation of attention since it has been shown that beta activity is related to external attention and alertness (Kolb & Wishaw, 2008). We also see a large decrease in alpha activity following the presentation of our target tones, which may be due to the rarity of the tone and its ability grab the attention of the participant. Onset of the target tone likely encourages the participant to refocus their attention back to the task in order to quickly respond, with a decrease in alpha activity perhaps allowing participants to better attend to the offset of the current image which indicates the start of the next trial. A lack of significantly different alpha activity following onset of both the nature and urban pictures is at odds with previous research showing that more complex fractal patterns are associated with nature and these complex fractals result in an increase in alpha activity due to their relaxing nature. However, such studies generally had participants simply viewing fractal patterns rather than performing a cognitive task.

While our ERSP activity following the auditory tones suggests no significant difference when viewing either nature or urban scenes, Figure 15 shows that we are measuring different activity between our target and standard tones and that this activity does differ between our baseline and scene viewing conditions. Alpha activity decreases following target tone onset and this decrease may be associated with the upcoming trial; alpha activity may be lowered in order to devote more attention to the upcoming trial and onset of a new image. This decrease is more prominent during the baseline condition, for both target and standard tones, and may be because the baseline image is rather uninteresting and so more attention may be devoted to the upcoming trial which may contain a more interesting nature or urban scene. We also observed differences in ERSP activity following the onset of the baseline images in relation to both the nature and urban scenes, as depicted in Figure 17. Following baseline image onset we observed an increase

in both alpha and beta activity. We suspect the increase in alpha activity is related to the uninteresting baseline image and so visual attention is suppressed, possibly to devote more attention to the upcoming auditory tone. The observed increase in beta activity may seem at odds with the change in alpha activity since increased beta activity has been associated with increased attention (Gola, Magnuski, Szumska, & Wróbel, 2013). However, it is possible that the increased beta activity reflects more attention being devoted to the upcoming auditory tone since the baseline image itself is task irrelevant and uninteresting. While our visual ERSPs show similar activity following nature and urban scenes, both of the scene conditions differ from the baseline condition. Following scene onset, we observed a decrease in upper alpha activity and a decrease in beta activity. This predominant decrease in beta activity may reflect the need for participants to suppress attention for the more visually interesting scenes in order to better focus and respond to the upcoming auditory tones. Further research is needed to better understand how changes in alpha and beta activity reflect processing and attention towards auditory and visual stimuli.

Explanations for ANT Results- Why No Nature Benefit?

We were unable to demonstrate changes in ANT executive attention scores after participants viewed nature scenes, with these results contradicting some previous research (Berman et al., 2008; Gamble et al., 2014) but in line with others (Bratman, Daily, Levy, & Gross, 2015; Emfield & Neider, 2014; Michaelis, 2011). Modifications were made to the ANT task which may account for the lack of an effect. In contrast to Berman et al. (2008) participants completed both picture viewing condition tests after a short break (approximately 10 minutes) rather than separating the tests by one week. Perhaps because of this much shorter break, participants became fatigued after the first test (which consisted of the ANT, picture viewing, and then the ANT again) but this should not be the case since the order of the picture viewing

conditions was counter-balanced. Also, if fatigue had a significant impact then it could be argued that we should have observed a large difference between our nature and urban viewing conditions since urban pictures would either have no influence on fatigue or exacerbated it while the nature pictures would have promoted attentional recovery.

Another issue may be that the ANT we used only contained central cues rather than the spatial and no cue conditions as is typical of the ANT (Fan et al, 2002; Fan et al., 2005). This modification was done for several reasons; executive attention scores are determined by calculating the difference in response times between congruent and incongruent trials and then collapsing across cue types, and so that the entirety of the task could be completed in such a time so that participants do not become tired. Collapsing across cues types is designed capture any executive attention processes that may be occurring in each of the different cueing conditions, but this may not be the best practice per McConnell & Shore (2011). The authors suggest each cue may reflect a different executive control process, making the executive scores difficult to interpret when collapsed across cue type. To determine any relationships between the three attention networks McConnell & Shore (2011) had participants complete the ANT under several conditions and found a significant interaction between cue and flanker type. This suggests that executive scores across different cue and flanker types are not as highly correlated as expected. Different executive attention processes are involved and collapsing across cue or flanker type may not accurately reflect scores in the three attention networks. Several other authors have also found significant interactions among the attention networks and show that aspects of executive attention can be modulated by the alerting and orienting networks (Callejas, Lupiáñez, & Tudela, 2004; Callejas, Lupiáñez, Funes, & Tudela, 2005).

Collapsing across cue or flanker type may not provide the most accurate measures of attention, but several other methods have been identified that may provide more accurate, independent measures of attention. In order to alleviate potential intra and inter-network interactions, Wang et al. (2014) developed an alternative method of calculating attentional network scores and compared this new method to the older model (Fan et al., 2002). The new method does not collapse across cue or flanker type but instead calculates the response time difference between specific cue and flanker combinations, and this method is also able to determine relationships between pairs of attention networks (executive attention with an alerting effect, for example). Both the old and new methods show significant measures of each attentional network, although the new method calculated a larger alerting and smaller executive score. The new method also identified relationships among the three networks. This new method for calculating ANT attention scores offers benefits over the old method and while dependencies among the networks are still present, the new method does allow for quantification and better understanding of those relationships.

Aside from behavioural responses, EEG and ERP data is also related to specific networks of the ANT. Neuhaus et al. (2010) were able to demonstrate differential N1 and P3 activity based on cue type and target congruency respectively. Specifically, a larger N1 following target onset in alerting and orienting attention conditions, with the P3 showing an increase in frontal areas and decrease in parietal areas for executive attention following incongruent targets. Galvao-Carmona et al. (2014) also found that cue type modulates activity in the N1 and the contingent negative variation (CNV) components. The CNV typically occurs between the presentation of a cue and a target stimulus, thought to be related to planning, decision making, and preparatory motor responses (Rohrbaugh & Gaillard, 1983; Brunia, 1993). Consistent with results reported

by Neuhaus et al. (2010), Galvao-Carmona et al. (2014) showed the expected changes in N1 and P3 amplitude but they also found differences in the CNV based on cue type. It was found that the more informative a cue was about the location of a target, the CNV increased in amplitude.

Since it is unclear if the various ERP components are measuring independent attentional networks or if they are influenced by relationships between networks, with previous research suggesting that the latter is likely the case, further research is needed to understand which specific ERPs, if any, respond strictly to one attentional network and not the others. Such ERP research, combined with alternative behavioural analyses such as those proposed by Wang et al. (2014), would allow for more accurate measures of alerting, orienting, and executive attention networks.

While we failed to replicate previous research showing that exposure to nature influences executive attention scores of the ANT, other researchers have also failed to replicate these results as well. Bratman, Dail, Levy, & Gross (2015) had 70 participants complete a nature and urban walk rather than viewing images of nature or urban scenes and failed to replicate previous ANT results and was unable to show an attentional benefit following exposure to nature. Emfield & Neider (2014) had 202 participants view nature and urban scenes, listen to nature or urban sounds, or presented participants with both images and sounds. Emfield & Neider (2014) also failed to replicate previous ANT findings, putting into question the idea that nature exposure primarily influences executive attention. As previously mentioned, many factors likely influence such results including the age of participants, the visual characteristics of each image, the presence or lack of water, and the relationships between each of the attention networks. More research is needed to better understand how each of these factors influence attention, cognitive performance, and which may contribute to any restorative effect that is occurring. On a more

positive note, we were able to replicate previous results showing that nature images are rated more positively compared to urban images. Also as expected, response times and accuracy performance was greater for congruent trials compared to incongruent trials, regardless of the scenes participants were shown between each ANT. However, more positive ratings for these specific nature images used should not be surprising when considering the quality difference compared to the urban images. The nature images are very clear and of higher quality when compared to the urban images which depict scenes that appear to be several decades old and are of noticeably lower quality. While participants were encouraged to rate the scenes depicted in the images rather than the quality of the images, ratings were likely still influenced by image quality.

Conclusions and Closing Remarks

Reprieves from stressful situations, demanding working conditions, and cognitively draining tasks in general are a boon to not only physical health but emotional and psychological wellbeing. Inherently fascinating environments, such as those involving nature, allow for such relaxation and promote physical, mental, and emotional recovery. These benefits have been shown in a variety of contexts, from complete immersion in nature to simply viewing images of natural scenes, showing that such restoration is possible even in unideal settings such as isolated offices. Research has also provided evidence for an attentional benefit of nature exposure whereby resources regulating our ability to voluntarily direct our attention to various aspects of our environment are restored. While this recovery can be observed following the completion of an attentional task, little research has demonstrated the cognitive influences associated with nature and attention recovery. The goal of the current research was to explore the possibility of utilising the P3 component of an ERP as a cognitive index of both recovery and attentional fatigue induced by various scenes. It was expected that P3 magnitude would be largest after viewing nature scenes and smallest following urban scenes, but no difference was found between viewing conditions. However, early auditory ERP components, such as the P2, and differences in visual ERPs elicited by the scenes themselves provide avenues for further study. Identification of cognitive components associates with nature and attentional recovery would allow for online measuring of attentional resources and restoration, and also allow us to further understand the characteristics of nature which promote a restorative effect so that such qualities can more easily be incorporated into urbanised environments, benefitting the physical, emotional, and psychological wellbeing of society.

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