NEURO-COGNITIVE EFFECTS OF NATURE EXPERIENCE ON DIRECTED ATTENTION

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by

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CERTIFICATE

This is to certify that the thesis titled **"Neuro-Cognitive effects of Nature Experience on Directed Attention"** submitted by **Ms Pooja Swami Sahni**, to the Indian Institute of Technology, Delhi, for the award of the degree of **Doctor of Philosophy**, is a bonafide record of the research work done by her under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

Humans and nature have shared a close interrelationship in the past. Natural environments have been sought for both physical as well as psychological restoration. In literature, the experiences while being in natural surroundings have been referred to as 'nature experience'. Several theoretical frameworks have proposed pathways through which nature experience may affect mental wellbeing. One of the theories suggests that 'elements' in nature effortlessly engages the attention, thus giving directed attention a chance to rest and replenish.

This doctoral research has studied the effects of nature experience on directed attention through two studies. The first study was a cross-sectional study, which examined the association of nature experience with attention. Self-reported questionnaires pertaining to different possible human-nature interaction models have been studied. The second study was a lab-based experimental study, with a pre-post design using nature audio-video as stimulus. Neurophysiological data using electroencephalography (EEG) was collected on cognitive tasks pre and post the nature stimulus.

Findings from the cross-sectional study suggest a significant relationship between the nature experience and the individual's ability to direct attention. Further, nature relatedness was found to strengthen the association of nature experience and the individual's ability to direct attention. It was also found that people who have nature in the neighbourhood and frequently visit such places report being higher on the individual's ability to direct attention. Interestingly, nature in the current neighbourhood was not found to be associated with an individual's ability to direct attention, and the relationship was significant only when the individual reported to visit the nature-rich areas frequently.

Outcomes from the lab-based EEG study has shown a significant improvement in the cognitive task performance after nature experience. During the viewing of nature audio-visual, participants self-reported that they experienced feelings of increased 'peace', 'calmness', and 'relaxation'. The

self-reported experiences also correlated with the EEG data. Spectral analysis showed a significantly enhanced alpha in frontal and theta in fronto-central regions while watching nature stimuli. This pattern is an indicator of the state of relaxation and internalized attention. ERP analysis of EEG data found a significant decrease in the N2 and P3 mean amplitudes during the cognitive tasks post nature stimuli, which suggests an improved ability to inhibit the distractions and efficient allocation of attentional resources in the fronto-parietal attentional network. Given the findings from the EEG study, this thesis argues that nature experience deactivates task-irrelevant processing and activates task-related brain areas. The deactivation of task-irrelevant processing means lower distraction and therefore, lesser mental effort required for inhibitory control.

This thesis has provided evidence using cognitive assessment, neurophysiological measurements and self-reports, which suggests that the nature experience induces a relaxed state of mind and enhances directed attention which can be attributed to improved inhibitory control. This evidence may help motivate people to connect with nature for improved cognitive performance.

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LIST OF ABBREVIATIONS

NCH	Nature in the Childhood Neighbourhood
NCU	Nature in the Current Neighbourhood
NVF	Nature Visit Frequency
NR	Nature Relatedness
MAAS	Mindfulness Attention and Awareness
NE	Nature Experience
DA	Directed Attention
ERP	Event- Related Potential
EEG	ElectroEncephaloGraphy
BDST	Backward Digit Span Test
OESR	Open Eye Resting State

GLOSSARY

Nature: Spaces consisting predominantly of flora and fauna and having little or no human constructions (Schultz, 2002).

Experience: Thoughts, feelings, emotions that we undergo when we observe a given phenomenon, it encompassing the affective and cognitive states (Price and Barrel, 2012).

Nature experience: Thoughts, feelings, emotions, including the affective and cognitive states that we undergo when we observe nature during mentally and physically being present in nature.

Nature relatedness (NR): Individual levels of connectedness with the natural world. It is an internalized identification with nature described as feelings and thoughts about one's personal connection to nature (Nisbet, 2009).

Mindfulness Attention and Awareness (MAAS): The ability to direct one's attention- informed by a sensitive awareness of what is occurring in the present (Brown and Ryan, 2003).

Directed Attention: The ability to concentrate or focus on a phenomenon. It is more focal and perceptual. According to William James, "directed attention is the taking possession by the mind, in clear and vivid form, of one out of what may seem several simultaneously possible objects or trains of thought. It implies withdrawal from some things in order to deal effectively with others" (James, 1890)

CHAPTER 1

HUMAN NATURE INTERACTION

1.1 INTRODUCTION

Humans have shared a gainful inseparable connection with nature in the past. Nature has been considered as 'provider' for human's basic needs, such as, food and shelter. Humans have also sought for natural surroundings in forests, gardens, wilderness and mountains as a refuge for psychological restoration. The stimuli presented by the natural surroundings perhaps evoked unique experiences that allowed humans to attend to their feelings, thoughts or task in a more focused way. Arguably, such focused contemplation often brought greater awareness and facilitated in modulating behaviour for an efficient day to day functioning and wellbeing.

On the other hand, in modern times, our interaction with nature has diminished and is likely to get further reduced. A United Nations report projects that two out of three people would be living in urban areas by 2050 (UNDESA, 2018). The rapid urbanisation for want of more and more land would likely affect the existing peripheral and the urban green landscapes that are seen as places for human-nature interaction. Another factor that is argued to hinder human contact with nature is the current lifestyle choices. Increasingly, most of the people are reportedly choosing to spend the majority of their time indoors or in urban environments. A study reports that people in cities are estimated to stay almost 90 % of their time in enclosed buildings or vehicles (Klepeis et al., 2001). Even children are seemingly spending lesser time in natural environments compared to previous generations (Kaplan & Kaplan, 2002). It is further reported that the predominantly urban environments present stimuli that are known to involve higher cognitive effort and fatigues the mental capacity (Kahneman, 1973; Kaplan, 1995). Arguably with lesser opportunities for nature interaction, individuals may be devoid of benefits that natural stimuli have to offer. Contrary,

increased urban exposure may cognitively overtax the individuals, which in turn could affect their day- to day functioning. It is reported that the resultant 'nature deficit' from diminished nature contact may cause changes that would be detrimental to physical as well as psychological wellbeing (Bratman, Hamilton, & Daily, 2012). A study has found that access to green spaces is one of the significant factors that was shown to matter for psychiatric illness (Lambert, Nelson, Jovanovic, & Cerdá, 2015).

Given some of the preliminary evidence for association of human-nature interaction and psychological wellbeing, recently, there is a renewed interest to study the effects of natural environments in ameliorating some of the mental health problems. Investigations have shown that experiences that one undergoes while interacting with natural environment areas are effective in restoring overall health and wellbeing (Hartig, Mitchell, de Vries, & Frumkin, 2014) and are reported to be particularly necessary for the restoration of 'mental capacity' (Kaplan, 1996). In literature, such experiences are described as 'non-ordinary', 'profound', inherently personal and are termed as 'nature experiences' (Bratman, Daily, Levy, & Gross, 2015; van den Berg, Joye, & Koole, 2016; Zylstra, 2014). It is reported that 'nature experiences' are beneficial for moods (Brooks, Ottley, Arbuthnott, & Sevigny, 2017; Ross & Mason, 2017), emotions (Berto, Baroni, Zainaghi, & Bettella, 2010; Kjellgren & Buhrkall, 2010), and mental functioning (Bosch & Depledge, 2015).

Theoretically, one possible mechanism by which nature experiences affect mental functioning is proposed by 'Attention Restoration Theory (ART)' (Kaplan & Kaplan, 1989). The theory posits that nature experience restores cognitive resources (directed attention). According to ART, urban environments heavily tax the top-down voluntary attentional control that is necessary to filter relevant from irrelevant stimuli adequately. Such demands from the urban environment deplete the cognitive resources and can thereby worsen performance on tasks that rely on the ability to direct attention (Hartig, Mang, & Evans, 1991; Kaplan & Kaplan, 1989). In contrast to urban

environments, stimuli presented by the natural environments arguably evoke ‘involuntary’ attentional mechanisms. The involuntary mechanisms are elicited by a spontaneous, effortless response to sensory stimuli (Prinzmetal, Ha, & Khani, 2010). Kaplan and Berman (2010) explained that the ‘elements’ present in the natural environments such as, clouds, trees, flowers and flowing waters etc., arouse ‘effortless attention’ which makes the individuals feel less cognitively taxed. The ‘effortless attention’ arguably lowers the demands on directed attention mechanisms, consequently, helping in the replenishment of directed attention. Refreshed attentional resources, in turn, may lead to improved attention in the tasks subsequent to the nature experience.

In this doctoral research, an attempt has been made to study the effects of nature experience on directed attention through two separate studies. In the first cross-sectional study, the association of nature experience with attention has been explored using questionnaire-based standardised inventories. In the second lab-based study, experimental investigation using EEG was carried out to understand the effects of nature experience on neuro-cognitive processes involved in directed attention. The cross-sectional study data demonstrated the pattern of how humans are interacting with nature. It also provides evidence for the positive relationship between nature experience and the individual’s ability to direct attention. Additionally, the study outcomes give preliminary evidence for the mediating effect of nature relatedness in the association of nature experience with the individual’s ability to direct attention. However, the self-report method used in this study was not sufficient to peep into the neurocognitive processes that are affected by nature experience. Neither was it sufficient to explore a causal relationship between the effects of nature interaction on directed attention. Therefore, a lab-based study was undertaken using EEG and a cognitive task before and after nature experience. The nature experience was manipulated through nature audio-visual stimuli in a controlled experimental setting. EEG provided the benefit of collecting objective data that were examined for the participant's brain responses. The subtle changes in brain responses offered a real-time temporal resolution of underlying neural processes of directed attention while

a subject performed on a cognitive task before and after nature experience. A significant relationship between nature experience and enhanced directed attention was observed in both the studies. Additionally, findings from the EEG investigation have suggested that nature experience improves inhibition control which in turn enhances attention after nature experience.

1.2 HISTORICAL PERSPECTIVE

Literature suggests that the benefits of human-nature interaction were known from pre-historic times. Various traditions have emphasised the importance of nature in providing for physical as well as mental wellbeing in different forms. In western traditions, nature is considered as a creation of God. While in some of the eastern traditions, nature is viewed as God's own manifestation. Confucianism (China), and Shintoism (Japan) also have a form of nature worship (*Konohanasakuya-hime*). Buddhist and Jain teachings have described a close inter-relatedness or interrelation between the natural environment and inhabitants, the sentient beings living within it. In Greek and Roman civilizations, nature gods (*Antheia, Gaia, Dryades, and Rhea*) were venerated. In ancient Indian texts; Sun (*Surya Devta*), Rain (*Indra Devta*), Plants (*Peepal, Tulsi*) and even some animals have been given the status of deities. In Hindu philosophical texts (*Astanga yoga sutras)*, natural environments are identified with positive 'impressions' and thoughts. People felt that meditating upon aspects of nature such as; trees, flowers, or rocks helped them to cleanse the mind and control the senses to gradually build the capability of complete attention (Yoga Sutra, 2.54-56). This 'pre-philosophical' relationship between humans and the natural world has sustained through ages (Payne, 2014), and it is only the past few decades that have seen adisconnect in human-nature interaction.

In the modern era, poets such as Thoreau wrote about the 'nature's intrinsic value' and emphasised on the intimate human-nature relationship. Nature was valued in its own right, independent of human 'economic' uses (Sahni, 2012). Appreciation of the 'non-economic' values of human-

nature relationship indicated the worth that people have given to nature. Probably, the 'non-economic' value of nature was due to the felt experiences during personal interactions with nature that influenced an individual's well-being (Rea & Munns, 2017). While attending to the natural phenomena such as passing clouds, waves of the ocean, individuals felt respite from the 'sensory bombardments' and stresses of daily life (Frawley, 2010; Tripathi, 2011). At yet another level, the experiences while in natural surroundings were expressed as moments of extreme happiness; a feeling of lightness and freedom; a sense of harmony with the whole world; moments that felt completely absorbing and that which evoked a feeling of spiritual transcendence. This account of transcendent episodes in nature has been reported across numerous cultures (Williams & Harvey, 2001). Some of the most influential scholars in transcendent experience; William James, W. T. Stace, Margharita Laski, Abraham Maslow, have also observed that nature experience has a close association with transcendent experience. Notably, the transcendental spiritual experiences were also believed to be beneficial for psychological restoration (Kaplan & Kaplan, 1989; Gray, 1995).

1.3 NEED FOR RESEARCH

Despite the lived experiences, as described in the previous section, the past few decades have seen disconnect between human-nature interactions. Concurrent with the diminished interaction with nature, there is also evidence of an increase in the worldwide prevalence of mental disorders with the ability to direct one's attention on a given task emerging as one of the major concern (Patel, Flisher, Hetrick, & McGorry, 2007. Preliminary evidence suggests that these two trends may be linked, with decreased human- nature interaction causing changes in psychological functioning (Hartig, Evans, Jamner, Davis, & Gärling, 2003; Kuo & Sullivan, 2001).

On the other hand, the traditional wealth of knowledge suggests that there are manifold benefits that interacting with nature has to offer for psychological wellbeing. In recent times where scientific evidence tends to present convincing arguments, there is a need to investigate the effects

of nature experience on factors that foster psychological wellbeing. Therefore, in light of the experiential knowledge and the theoretical framework as proposed by 'Attention Restoration Theory', this doctoral research identified the need to study the effects of nature experience on directed attention.

1.4 RESEARCH OBJECTIVE AND RELATED RESEARCH QUESTIONS

The main objective of this PhD thesis research is:

To study the effects of nature experience on directed attention.

In order to fulfil the research objective, following related research questions and sub-questions were raised, which were explored through two different studies as described in Chapter 4 and Chapter 5. The description of the study and the related questions that it aimed to address is as follows;

Study1: Association of nature experience with Directed attention: A cross-sectional study

Research Question 1: How is nature experience associated with directed attention?

a. Is the presence of nature in the neighbourhood associated with attention?
b. Is the frequency of visit to nature associated with attention?
c. Does 'nature relatedness' affect the association of nature experience and attention?

Study 2: Neurocognitive effects of Nature Experience on Directed attention: A lab-based experimental study

Research Question 2: What are the neurophysiological correlates of nature experience and directed attention?

a. What are the effects of nature experience on the EEG frequency band power in different regions of the brain?

b. What are the effects of nature experience on Event-Related Potentials (ERP) associated with attention?

c. What are the effects of nature experience on response time and accuracy in directed attentional tasks?

1.5 APPLICATION OF THIS RESEARCH

The research outcomes could be useful in several areas; mental health, urban planning, education and recreation. The evidence from this research could help in providing mental health practitioners preliminary evidence for the use of nature experience as alternate mental health therapy in cognitive dysfunctions related to attention. The arguments presented in this thesis could emphasis the need for natural spaces for wellbeing and could help urban planning committees to make informed decisions for green area preservation and development. The following subsections describe in detail the various possibilities for the use and application for nature experience.

1.5.1 POSITIVE PSYCHOLOGICAL TECHNIQUE / ALTERNATE MENTAL HEALTH THERAPY

Though the medical associations do not validate the diagnosis of 'nature deficit disorder', literature reports that the psychological, physical and cognitive costs of human alienation from nature, particularly for children in their vulnerable developing years could be detrimental for mental health (Louve,2005). Nature experience has been found to be beneficial for problems such as; depression (Dean et al., 2018; Roe, Aspinall, Mavros, & Coyne, 2013), rumination (Bratman,2015). Regular interaction with nature either through a short walk in the woods or a view from a window is found to significantly reduce stress, burnout and fatigue-related problems(Dolling, Nilsson, & Lundell, 2017). Therefore, outcomes from this research can add to the existing literature and provide

evidence on the cognitive benefits specifically related to attention that a brief nature experience can offer.

1.5.2 SOCIAL/ RECREATIONAL VALUE

The recreational value of natural environments has been described from various perspectives such as tourism, leisure, sports and exercise. Natural spaces provide opportunities for outdoor activities that enables mental and physiological restoration from fatigue (Buchecker & Degenhardt, 2015; Shanahan, Fuller, Bush, Lin, & Gaston, 2015). Recent research have provided evidence that visits to 'near-natural everyday landscapes' promotes vitality (Sparks et al., 2017; Takayama, Korpela, Lee, Morikawa, & Tsunetsugu, 2014). They are also considered places for social interactions (Kaplan & Kaplan, 2002) that are suggested to be necessary for mental wellbeing. The evidence from this research can further supplement the existing evidence for the recreational value of nature experience.

1.5.3 URBAN GREENING GUIDELINES

The Government of India Urban Greening Guidelines acknowledges the social and ecological services that urban greens can provide; however, the importance of urban greens for the psychological health of humans is yet not recognised. Furthermore, the use of human-nature interaction for improved cognitive functioning has also thus far not been acknowledged. Therefore, this research can provide evidence to the policymakers for a more holistic view of protecting and developing urban green landscapes.

1.5.4 NATURE-BASED EDUCATIONAL CURRICULUM

A growing body of evidence from the US, European and Australian studies, suggest that the nature disconnection may be causing a physical, emotional and intellectual deficit in children (Huynh, Craig, Janssen, & Pickett, 2013; Kaplan & Kaplan, 2002). To promote interaction with nature, the

curriculum can be designed in such a way that encourages children to go for outdoor learning experiences. Arguments made in light of experimental evidence from this thesis could help educators in designing pedagogical tools and defining nature-based assignments that promote learning through experience and observation in nature.

1.6 ORGANISATION OF THE THESIS

Chapter 1 has introduced the research topic, background, need for research, the research objective, research questions and usefulness and applications.

Chapter 2 entails the review of the existing literature relevant to the research area. It describes the method followed for the review of the literature in section 2.2, the definitions of 'nature' and 'nature experience' in section 2.3. The Chapter also builds a theoretical framework by categorising the human-nature interactions into three main models in section 2.4. This section also includes a brief description of the self- report scales used to measure the nature experience. Various theories that have been cited in the nature studies are described in section 2.5. The factors reported to affect nature experience, and the key outcomes of the research papers are described in section 2.6 and 2.7, respectively. Further, the literature on EEG methodology, and models of directed attention as relevant to this research are detailed in section 2.8. This Chapter ends with the gaps in the literature presented in section 2.9.

Chapter 3 describes the research methodology, study design and the rationale behind the specific experimental methodology used in each of two studies.

The experimental details, along with data analysis and reporting of results, are described in the next two Chapters. Chapter 4 describes the experiment details of the study examining the relationship of nature experience and attention. Chapter 5 describes the laboratory-based

experiment to investigate the differences in behavioural and neural mechanisms related to attention before and after nature experience.

Chapter 6 describes the discussions and the conclusions of the key findings of the two experiments. It also details the key contributions of the thesis and the areas where the research outcomes may be usefully applied. A separate section in the same Chapter also highlights the limitations of the experiments and the scope for future studies.

Appendix 1 consists of the tabulated summary and the domain wise segregation of research papers and the key findings as reported, the summary of comparative qualitative research techniques.

Appendix 2 describes the model summary of the statistical data from the cross-sectional study and the questionnaire used for the data collection.

Appendix 3 comprises of the formats, checklists, and pictures as used in the lab-based experiment. It also consists of the supplementary data analysis from the lab-based EEG data.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This section presents a summary of the literature surveyed on nature experience and its effects as reported by various studies. Literature from nature-related studies, cognitive research with focus on directed attention, Electroencephalography (EEG) data collection, analysis and interpretation techniques were reviewed.

This Chapter is divided into nine sub-sections. Section 2.2 describes the method that was followed for the literature review of nature studies. Section 2.3 includes the definitions of nature and nature experience. Section 2.4 describes the nature experience through different models of human-nature interaction. Various assessment tools used to study the nature experience are also mentioned in section 2.4. Section 2.5 details the theories that have been cited in the literature concerning human-nature interaction. A summary of different factors reported to affect the nature experience are presented in section 2.7 and 2.8, respectively. Section 2.8 describes directed attention and the tools used for its assessment. One of the tools reported in 2.8 in detail is the Electroencephalography (EEG) and its Event-Related Potentials (ERP) measures and in the last section 2.9, gaps in the literature have been presented.

2.2 METHOD OF LITERATURE REVIEW

Literature was reviewed from various disciplines, namely, environmental psychology, applied psychology, social sciences, environmental sciences, alternate medicine, tourism and recreation urban planning. Based on the research topic, key research words were; ‘nature experience’, ‘natural environment’, ‘nature’, ‘green spaces’, ‘forests’, ‘wilderness’, ‘well-being’, ‘mental

health', 'moods', 'affective', 'cognitive', and 'attention'. To get a specific research papers those which have used EEG as physiological tool, 'EEG' was used as an additional search term along with 'nature experience' related words. The search strategy was developed for EBSCOhost and applied to other databases. Expanders 'apply related words' was used to get a comprehensive search output.

The review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines (Moher et al., 2009). The protocol for the systematic review was developed in advance and registered with the International Prospective Register of Systematic Reviews (PROSPERO). A Copy is available at http://www.crd.york.ac.uk/prospero/, registration number CRD42018084563.

Key eligibility criteria for including research papers for review followed PI (E) COS format; i) Participants (any) ii) Intervention /Exposure (natural environment) iv) Comparisons (any) v) Outcomes (emotional, cognitive and neurophysiological related) vi) study design (experimental)

Review papers, discussions, book chapters, reports, or philosophical papers as relevant to the research were also considered for review. The focus of the research and review was on the nature experiences in conditions resembling everyday life. Therefore, the evaluations of extreme conditions in the wilderness or environmental catastrophes are beyond the scope of this research. The dynamics of such extreme human-environment interactions are likely to be different.

Initially 3385 research papers (EBSCO host= 2767, PsycInfo= 264, PubMed= 354) were retrieved. Removal of duplicate and non-related citations resulted in 766 potentially relevant research papers. In the first stage of screening, 528 studies were rejected based on title/abstract review (non- human studies, study protocols). In the second stage, from the full-text review of 238 papers, a total of 15 review papers, a total of 171 surveys, 52 experimental research papers (n= 5174; age range= 17 – 73), were included in the systematic review. Figure 1 depicts the year-wise distribution of

studies. In this bar chart, we can see that there is; a) a growing interest to study nature experience, and b) an opportunity to undertake studies that could provide evidence from the neuro-cognitive domain.

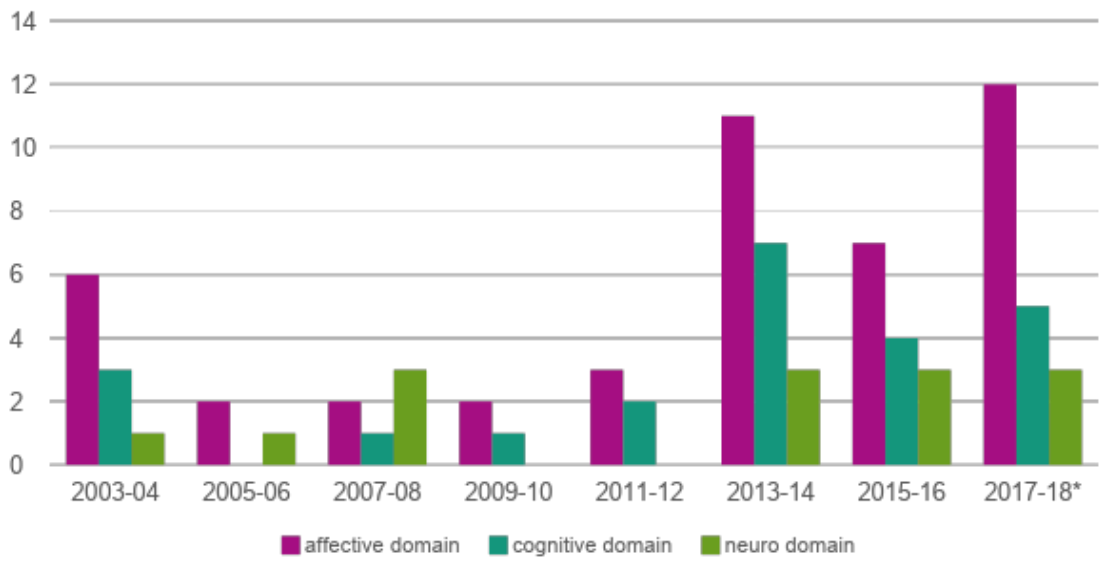


*Figure 1 Year-wise distribution of experimental research in the area of nature studies (source: Scopus), *till July 2018*

Out of the 52 papers using experimental research methods, there were 33 studies with urban settings as the comparative condition and 21 studies that assessed differences within different types of natural environments exposure. Two studies investigated both; experience in different types of the natural environment, and urban settings. Methodologically most of the studies skewed towards conventional research methods of observation, recording interviews, and questionnaires. Some of the studies have also used cognitive testing (N=19), non-invasive brain imaging techniques such as electroencephalogram (EEG) (N=11), functional Magnetic Resonance (fMRI) (N=3) and other physiological tools such as; Blood Pressure monitors (N=9), Accelerometers (N=3), and Skin Conductance (N=4) to get objective data. The study design included crossover, randomized control, and compared between groups. Frequently used stimuli in these experimental researches

were in situ (N=20) exposure, images (N=22), views from the window (N=7), videos (N=5), and one study used images and real-time exposure of the same environment.

2.3 DEFINITIONS OF 'NATURE' AND 'NATURE EXPERIENCE'

Most of the research papers define features of the natural environment relative to the comparative environment, without giving absolute definition (Bornioli, Parkhurst, & Morgan, 2018; Chun-yen Chang, Hammitt, Chen, Machnik, & Su, 2008; Morton, van der Bles, & Haslam, 2017; Tabrizian, Baran, Smith, & Meentemeyer, 2018)). Objectively, some studies also differentiate grades of biodiversity by geospatial (GIS) data and the type of flora fauna that exists in the area (Johansson, Gyllin, Witzell, & Küller, 2014).

In the context of this research, definition of nature which has been used is as follows – 'nature can be defined as spaces consisting predominantly of flora and fauna and having little or no human constructions' (Schultz, 2002). Mostly such areas are accompanied by openness and visual access that fosters mental content such as 'being away', 'extent', 'fascination' and 'compatibility' as described by 'Attention Restoration Theory' (ART) (Kaplan & Kaplan, 1989).

Nature experience has been described as 'non-ordinary', 'profound', 'difficult to describe' and 'inherently personal' (Bratman, Daily, et al., 2015; Zylstra, 2014). It has also been described as the experience one gets when one spends time in the natural surroundings (Bratman et al., 2012). Zylstra (2014) argues that nature experiences can also be triggered through both a physical encounter with nature or with more symbolic phenomena (e.g. patterns, signs, metaphors, visions) perceived in nature. Therefore, nature experience may be described as the thoughts, feelings, sensations, emotions, including the affective and cognitive states that we undergo when we observe nature during mentally and physically being present in nature.

2.4 NATURE EXPERIENCE THROUGH DIFFERENT MODELS OF HUMAN-NATURE INTERACTION AND ITS ASSESSMENT

Human - nature interactions have been reported in the literature under three types, namely, incidental, intentional and indirect. Incidental interactions are described as the interaction where though a person is physically present in nature, but the presence is an unintended result of another activity, such as by virtue of living in nature-rich surroundings or encountering vegetation whilst travelling for work (Ekkel & de Vries, 2017). Studies investigating such incidental interactions suggest that greater proximity to, and feelings of connection with the natural world could affect wellbeing (Keniger, Gaston, Irvine, & Fuller, 2013; Maas, Verheij, Groenewegen, Vries, & Spreeuwenberg, 2006). Second, the intentional interactions are those in which the participant has the intent to interact with nature, such as viewing wildlife, gardening, visiting a park or hiking in a national park. It has been proposed that the intent to visit or interact and motives may be critical for restorative experiences and mental wellbeing (Pasanen, Neuvonen, & Korpela, 2017). While in the previous two types, there is physical contact with nature, the third type of interaction does not require a person to be physically present in nature. This indirect interaction can include activities such as viewing an image or motion picture of nature or having a view of nature through a window. It is argued that the images or videos of natural environment present elements that are ‘compatible’, ‘fascinating’ and thus effortlessly absorbs the viewers’ attention (Berman, Jonides, & Kaplan, 2018). This virtual indirect interaction with nature gives a feeling of ‘being away’, and are found refreshing and restorative. Most of the experimental studies that have been conducted to test the effects of nature on cognitive functions (Keniger et al., 2013) have used viewing pictures. The findings from such studies have also suggested that both the modes of exposure; physical as well as virtual impact cognitive performance positively (Yin, Zhu, Macnaughton, Allen, & Spengler, 2018)

2.4.1 ASSESSMENT TOOLS USED TO STUDY NATURE EXPERIENCE

There are several self-report scales that measure either the subjective connection of the individual with nature or the environmental values. However, author could not find any standardised scale that can assess the incidental, intentional or indirect human-nature interaction. The studies that have investigated such interactions have relied on self-reported data through questions (Kuo & Sullivan, 2001)or GIS-based data in the case of estimating nature in the neighbourhood areas (Huynh et al., 2013; Rollings, 2013). The studies that have examined the subjective sense of connection with nature have used standardised questionnaires such as Nature Relatedness Scale (Nisbet, Zelenski, Donnellan, & State, 2013), Connectedness to Nature Scale (Mayer and Frantz, 2002), New Environmental Paradigm Scale (NEP) (Dunlap et al.,2000), and Implicit Association Test (IAT) (Schultz, Shriver, Tabanico, & Khazian, 2004).

IAT is a computer-based word classification test designed to measure the degree to which people associate themselves with nature. Logistically, it becomes difficult to administer IAT for large sample populations. Other scales such as Connectedness to Nature (CNS), Nature Relatedness Scale (NR) and New environmental paradigm scale (NEP) are paper-based inventories used to measure the feeling of connectedness and are much easier to administer to larger sample size. The new environmental paradigm (NEP) scale (Dunlap, Van Liere, Mertig, & Jones, 2000) aims to measure individuals ''primitive beliefs' concerning their relationship to the natural world. These beliefs, which comprise an individual's worldview, are thought to form the basic core of individuals' belief systems, the foundational truths about self, the physical world, and social reality (Rokeach, 1968), and are thought to impact more specific attitudes and beliefs about environmental issues. However, the NEP scale does not measure one's affective, experiential relationship to the natural environment. Connectedness to Nature Scale (CNS) aims to measure individuals' experiential sense of oneness with the natural world and evaluates whether the connectedness leads to ecological behaviour. CNE is premised on the argument that posits that the extent to which one

includes another person as part of the self, determines the closeness of the relationship (Aron, Aron, Tudor, &Nelson, 1991). Further, it is suggested that as relationship closeness increases, so does empathy and willingness to help (Cialdini, Brown, Lewis, Luce, & Neuberg, 1997). Extending this logic in the context of the natural environment, it is premised that measuring one's affective sense of connectedness to nature could shed light on the individual's ecological behaviour. Similar in concept to connectedness with nature, Nature Relatedness Scale (NRS) measure the subjective sense of connection people have with the natural environment. Both NRS and CNS have been reported to be used in several studies to get self-reports on the internalized identification with nature - feelings and thoughts about one's connection to nature. However, the short form of nature relatedness scale (NR-6) is reported to be widely used and possesses similar psychometric properties as nature relatedness scale long form with a particular advantage of being concise (Nisbet, 2013).

Although standardised questionnaires offer ease of use, scalability, validity, reliability and are inexpensive for a large data collection. However, the self-report questionnaire method also poses a possibility of interpretation issues, dishonest replies that can have detrimental effects on the outcomes of the study. On the other hand, the behavioural analysis offers a unique and essential insight into the performance of the individual on the specific cognitive tasks. Various simulations are employed to elicit a particular aspect of the cognitive functioning and the correctness, response time and latency are measured. This gives objective data with a 'predictive validity' or the extent to which performance in the assessment predicts performance in a given job. The behavioural analysis can also be used in conjugation with other methods of investigation.

Some studies also employ qualitative techniques such as subjective interviews to examine the feelings and thoughts that participants underwent while being in nature (Sparks et al., 2017; Stigsdotter, Corazon, Sidenius, Refshauge, & Grahn, 2017). Standardised questionnaires on the affective states such as Positive affect and negative affect scale (PANAS), Positive Moods Scale (POMS), or Perceived Restoration Scale (PRS) have also been reported to be used to elicit data from participants after they were physically immersed in nature (Chen, He, & Yu, 2016; Takayama, Korpela, Lee, Morikawa, & Tsunetsugu, 2014).

Assessment of cognitive parameters associated with nature experience have been studied using various standardised inventories and cognitive tasks such as; Stroop's task (Bailey, 2018), Backward Digit Span Task (Berman, Jonides, & Kaplan, 2008) and Necker cube task (Chen et al., 2016). Most of the findings have indicated an improvement in attentional capabilities with the exception of a recent study that reported no significant effect of nature experience on the Necker cube test (Chen et al., 2016). Details about these tasks are included in the 2.9 directed attention and assessment.

2.5 THEORIES FOR HUMAN NATURE INTERACTION

In literature, the theoretical basis of benefits from nature experience is conjectured to be mediated by two main pathways; affective and cognitive. This section details the most commonly cited theories that have been proposed to explain nature's restorative benefits in the affective and cognitive domains.

2.5.1 THE COGNITIVE IMPACT OF NATURE EXPERIENCE

One of the most cited theory describing the effects of nature experience has been - 'Attention Restoration Theory' (ART) by Kaplan (1995). ART postulates that restoration occurs in environments that involve four components: 'fascination', 'being away', 'extent' or 'coherence',

and ‘compatibility’. Further, it suggests that “effortless attention” or involuntary attention is drawn by the amalgamation of four elements in the natural environment that allows the neural mechanisms underlying directed attention a chance to rest and replenish.

Nature is endowed with elements that have potential to ‘fascinate’, such as, sunsets, clouds, trees, breeze, flowing water etc. which readily hold attention. ‘Fascination’ can also be derived from extreme dimensions, for example, by watching auto racing. However, natural settings have a special advantage in terms of providing an opportunity for reflection, which can further enhance the benefits of recovering from directed attention fatigue (Kaplan,1993). The second element, ‘being away’ frees one from mental activity that requires directed attention support to keep going. The sense of ‘being away’ does not require that the setting be distant. Natural environments that are easily accessible can offer a resource for resting one’s directed attention. It involves a conceptual rather than a physical transformation. This element can also be evoked through a view or an image that is rich and coherent enough to engage the mind. Natural environments have a special resonance with humans and are found highly compatible. The compatible environment requires less selectivity and hence less directed attention. While each of the four elements of the natural environment are potentially helpful, according to ART, it is the combination that is essential for the restorative experience.

2.5.2 THE AFFECTIVE IMPACT OF NATURE EXPERIENCE

Another perspective from which relationship between cognitive functions of the brain and the influence of nature experience has been studied is the stress perspective. Ulrich (1986) proposed ‘Stress Reduction Theory’ (SRT) that claims a healing power of nature that unconsciously impacts the autonomic response in individuals, especially for those who are stressed before the nature experience. He further explains that landscapes with views of the water and vegetation that contain modest depth, complexity, and curvilinearity have been most beneficial for the evolution; therefore

they are found more restorative than urban settings. More specifically, according to this view, nature scenes activates the parasympathetic nervous system in ways that reduce stress and autonomic arousal. Natural landscapes, especially grasslands with clusters of trees tended to provide human beings with “opportunities” for gain, and places of “refuge” for safety. According to Ulrich et al. (1991), viewing these types of landscapes activates our physiology in affectively beneficial ways.

Additionally, Fredrickson's ‘broaden-and-build’ theory suggests that the positive affect broadens one's awareness and encourages novel, varied, and exploratory thoughts and actions (Fredrickson, 2013). Positive affect, according to numerous theorists, facilitates approach behavior (Garland et al., 2010; Vacharkulksemsuk & Fredrickson, 2013; Conway et al., 2013). The ‘broadened’ awareness helps an individual to engage with their environments and partake in activities, many of which are adaptive for the individual (Fredickson, 2001). The adaptive bias to approach and to explore novel objects, people, or situations widens the individual's psychological, cognitive and social resources. For example, interest, a phenomenologically distinct positive emotion, broadens by creating the urge to explore, take in new information and experiences, and expand the self in the process (Csikszentmihalyi, 1990; Ryan & Deci, 2000). The ‘broadening effect’ also allows an individual to discard automatic responses and instead look for creative, flexible, and unpredictable new ways of thinking and acting (Fredrickson, 2004).

Literature suggests that the ‘fascinating elements’ of the natural environment allows one to involuntarily notice the unfolding of nature’s phenomenon. While attending to natural phenomena such as passing clouds, bird chirps, waves of the ocean, one is drawn in the exploration of the new information and experiences resulting in the expansion of the self in the process. Nature is seen as an inherent part of the self. This strong feeling of interconnectedness further builds the sense of expanded self and promotes positive affect

and approach behaviours. The broadening of perspectives and actions, aids individuals to build important and lasting physical, cognitive, psychological, and social resources.

Both ART and SRT find their roots in 'Psycho Evolutionary Theory' and 'Biophilia hypothesis' (Wilson and Kellert,1993), which suggest that since humans have been living in the natural environment for the past several millennia, therefore, they are inherently attracted towards natural environments.

2.6 FACTORS REPORTED TO AFFECT NATURE EXPERIENCE

Despite varied methodological differences, experimental studies have broadly reported common factors and similar outcomes while investigating nature experience. Factors that have been frequently reported in the literature are summarised in this section.

On broadly classifying the factors that are reported to have an effect on nature experience, two categories emerge, namely; extrinsic, and intrinsic factors. Extrinsic factors consist of factors that are external to the observer. Factors such as, the difference in spatial features within the natural environments, time and duration of the nature experience are extrinsic factors. Intrinsic factors can be those that are specific to the individual and are independent of the exposure type but are found to have a significant effect on the affective and cognitive outcomes of nature experience. Several studies have investigated extrinsic factors while controlling for intrinsic factors.

Within external factors, variance in spatial features has been more frequently researched. Other factors include preference for certain spatial features, 'concern for safety', 'company' or social factors, individual differences such as the emotional state prior to the experience, and values and beliefs towards nature. Figure 2 depicts the factors that have been reported to influence the nature experience.

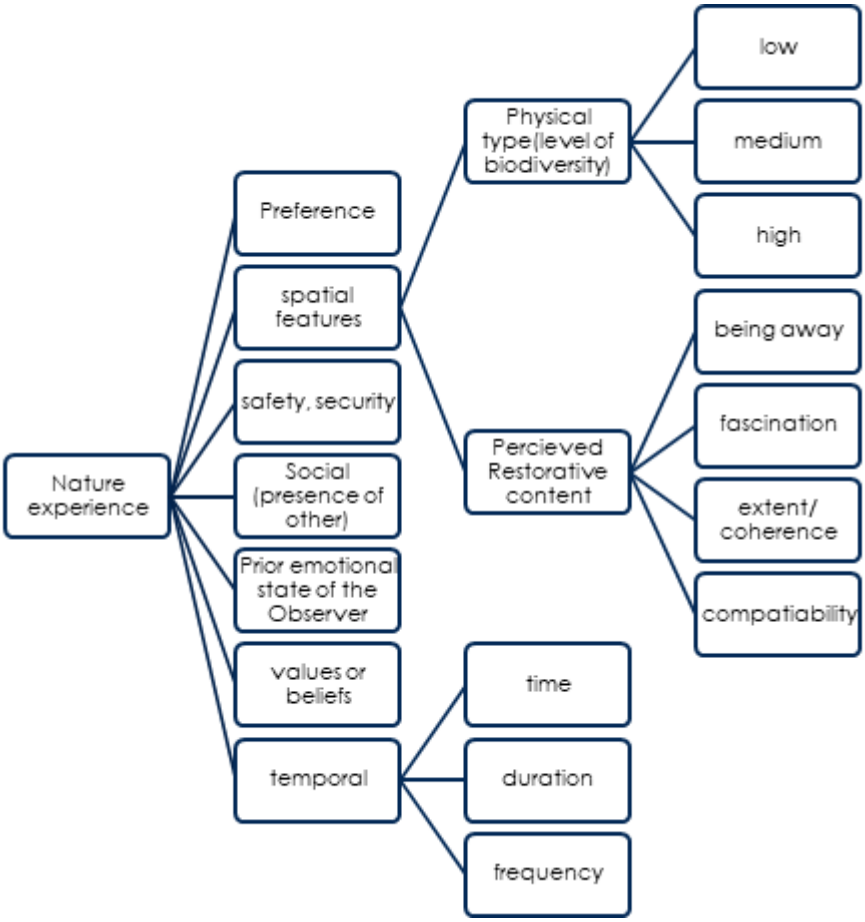


Figure 2 Factors that have been reported in the literature to affect nature experience

2.6.1 Spatial features of the Natural Environment and Preference

In literature, nature has been considered as an undifferentiated typology, in contrast to urban environments. There is converging evidence that supports natural environments are found more restorative for moods (Beute & de Kort, 2014; Stigsdotter, Corazon, Sidenius, Kristiansen, & Grahn, 2017), autonomic physiological functions (Brown, Barton, & Gladwell, 2013; Lee, Park, Tsunetsugu, & Kagawa, 2009), stress (Hartig et al., 2003; Lee et al., 2009) over the built urban areas. However, a growing number of studies have also investigated the effects of different levels of biodiversity within the given natural settings. Studies report that when comparing low and high biodiverse natural environments, the intermediate biodiverse environment is rated as most preferred by people for 'positive emotions' (Carrus et al., 2015; Johansson, Gyllin, Witzell, &

Küller, 2014). Medium-density forests were also found to be most relaxing, as measured by activity in the frontal cortex, whereas higher density forest images increased brain activity (An, Kim, Jeon, & Setsu, 2004). Further, areas with dense vegetation and trees such as; wilderness were reported to be perceived as limiting to visual access and thus low on preference as restorative settings (Herzog, Maguire, & Nebel, 2003; Martens, Gutscher, & Bauer, 2011). In another study, examining different forest settings found that spaces with more open views were rated higher than the dense views (Stigsdotter, Corazon, Sidenius, Refshauge, et al., 2017). A coherently ordered environment was reported to be found peaceful (Von Lindern, 2015), and strongly affecting positive and negative affect (Martens, Gutscher, & Bauer, 2011) as compared to complex biodiverse forests.

Therefore, it may be construed that a natural environment with a spatial density that supports open views is reportedly more preferred over high-density forests as restorative environments. Further, natural environments with low complexity and a moderate level of biodiversity are seemingly found most congenial for relaxing. Thus, it may be argued that neighbourhood gardens and parks with a moderate level of biodiversity that supports open views, within the urban agglomerates could perhaps provide opportunities for people to visit such places to relax and recover from day to day work-related fatigue.

2.6.2 Temporal Features-Time, Duration and Frequency of Visits

The studies have reported that the time, duration and the frequency of visit also have a role in how nature experience affects mental restoration (Shanahan et al., 2016). Several studies found that psychological benefits and wellbeing significantly correlated with the duration and frequency of visits to green areas as well as the perceived sense of restoration (van den Berg et al., 2015). Evidence suggests that spending even a few minutes in urban and peri-urban green areas lead to a greater appreciation of their restorative qualities, which resulted in more positive psychological

outcomes (Carrus et al., 2015). Another study investigating the benefits of outdoor walking suggests that duration of 30 mins for about 2- 3 days in a week was associated both with improved attentional functioning and contentment (Duvall, 2011). On the other hand, a study also reported that even 15 min of sitting in a green area was associated with the decrease in the salivary cortisol indicating a stress relief (Tyrväinen, Ojala, Korpela, Lanki, & Tsunetsugu, 2014). Hence, even a brief nature experience is reported to be beneficial for mental functioning.

2.6.3 SAFETY AND SOCIAL INTERACTION

Although humans have evolved inhabiting natural environments, however in the past few centuries, people have been living in urbanised settings. The urbanised living has made man alien to the natural environments and such places are found to be a 'bit of threatening' that is perceived as 'not safe' (Markevych et al., 2017). Further studies report that 'concern for safety' is the most significant mental impediment for accessing green space for restoration (Thompson & Aspinall, 2011). In another study, it was stated that the 'presence of others' counterbalanced the 'concern for safety' yet, both the factors were not found to positively mediate the likelihood of psychological restoration (Staats & Hartig, 2004). Social interaction was found to benefit mood changes in the wilderness (Das et al., 2018). However, social interaction was also found to be negatively related to 'reflection' and 'being away' which are reported to be important components for psychological restoration (Kaplan, 1996). Conversely, solitude in nature has been reported to enhance the restoration of attentional capacity and reduce mental fatigue (Wang, Rodiek, Wu, Chen, & Li, 2016), especially when safety is controlled (Staats & Hartig, 2004).

2.6.4 STRESS LEVEL PRIOR TO NATURE EXPERIENCE

The earliest research investigating nature experience examined its effects on stress. A number of studies reported that, if the mental state of the individual before interaction with nature is one of stress, anxiety or excessive arousal, a fascinating natural view might elicit feelings of pleasantness,

attract the attention in an ‘effortless’ way and block stressful thoughts, thereby fostering psychophysiological restoration. Ulrich (1974) conducted one of the first studies investigating effects of nature experience on stress by using physiological tools. He manipulated stress in subjects by showing a 10 mins video of workplace accidents known to produce stress. The subjects were then either shown nature scenes or images of the urban built environment. The physiological markers such as; skin conductance, pulse rate, electromyography (EMG) showed a consistent pattern of rapid and more complete recovery from stress and arousal upon exposure to vegetation-rich nature scenes. Subsequently, several studies also examined stress recovery through self-reported questionnaires to assess the changes in stress level before and after nature experience (Chiang, Li, & Jane, 2017; Hartig, Mitchell, de Vries, & Frumkin, 2014; Sparks et al., 2017). It was found that people with an initial state of mental fatigue preferred natural environments for stress recovery and relaxation more than others (Chiang et al., 2017). While invariably improvement in positive mood was reported by all participants, the effects were more pronounced for people with high-stress levels (Dolling, Nilsson, & Lundell, 2017). Possibly the natural features effectively served as pleasant distractions that diminished stressful thoughts (Ulrich, 2002). Conclusively, nature experience was reported to be an effective intervention for stress recovery.

2.6.5 VALUES AND BELIEF

Values are ‘conceptions of what ultimately good, proper is, or desirable in human life’. Traditionally, culture, social and beliefs systems define the individual’s ‘value’ for nature, among other factors (Stigsdotter, Corazon, Sidenius, Refshauge, et al., 2017). Different cultural backgrounds result in different ways of seeing a particular landscape and attaching meaning and value to it (Beiling,2014). The belief that natural surroundings aid the physical and psychological restoration is also reported to facilitate the preference for natural environments (Hartig, Evans, Jamner, Davis, Tommy, et al., 2003).

Schultz (2001) investigated the sample population from 14 countries and proposed that individuals 'value' nature based on the way their view of the human-nature relationship. An 'egocentric' view is perceived as a separation between humans and nature that fosters human domination over nature. In contrast, altruistic or biospheric view, is closer to the traditional cultural values that relate individuals, animals, community and the natural environment as fundamentally connected as a unified whole. These values are reported to determine the way an individual relates to nature and may influence the individual's perception of the need for interacting with nature for overall wellbeing (Schultz & Milfont, 2016). An 'egocentric' approach towards human-nature interaction can be assumed to correlate negatively with the need to connect with nature and arguably interferes with the full benefits nature experience has to offer. While an individual with biospheric values experiences nature in a way that is seen inseparable, thus encouraging a greater interaction that eventually affects his physical and mental wellbeing.

2.7 Effects of Nature Experience

The previous section described the factors that have been reported to affect the nature experience. In this section, effects of nature experience on different domains of human functioning, namely; affective, cognitive and neurophysiological, are discussed. Though these three domains are inevitably interlinked, yet a distinction has been made with respect to the measures that the studies have focused on investigating, in order to aid a deeper understanding of the effects of nature experience in each of the three domains. The summary and the domain wise segregation of research papers can be seen in Appendix 1 table1.

2.7.1 Affective Domain

Most of the studies that have investigated nature experience have focused on the affective measures, such as moods, emotions, commonly using self- report questionnaires. A total of 30 experimental studies (n= 2887) have focused on investigating emotions or mood, 19 studies

(n=1415) that investigated emotions together with cognitive functioning, and 11 studies (n=595) that measured emotions and neurophysiological change. Most of the studies have consistently reported the association of nature experience with a positive emotional response.

Studies that have examined mood after a natural environment exposure has reported that nature experience is considered 'pleasant' (Tyrväinen et al., 2014), restricts negative thoughts (Kjellgren & Buhrkall, 2010), reduces fatigue, tension, aggression, and confusion (Stigsdotter, Sola, Sidenius, Kristiansen, & Grahn, 2017). Affective responses reported after a nature experience included a significant increase in hedonic tone, feeling of relaxation (Bornioli et al., 2018), alertness, happiness, harmony, peaceful and clear-headed from before to after exposure (Dolling et al., 2017). In another group of studies where the mood changes were compared between natural and urban environments, nature experience was reported to be 'comforting', 'awakening', 'refreshing' in contrast to urban or other built environments (Lee et al., 2009). Summarizing nature experience provides for a positive mental state that is relaxed yet alert. Arguably such a mental state is conducive to subsequent higher-order cognitive assessment (Ulrich et al., 1991; van den Berg, Koole, & van der Wulp, 2003)

2.7.2 COGNITIVE DOMAIN

In this section, evidence from 23 studies (n= 712) that have examined the cognitive effects of nature experience has been summarized. Studies report that nature experience helps in 'clearing the head' of distracting thoughts (Berman, Jonides, & Kaplan, 2009; Bratman, Daily, et al., 2015; M. van den Berg et al., 2016). Further, a brief nature experience is also reported to be associated with higher-order cognitive functions such as; improved creativity (Tyrväinen et al., 2014) and enhanced short-term memory (Berman et al., 2013; Bratman, Daily, et al., 2015; Yin et al., 2018; Zijlema et al., 2017).

2.7.3 NEUROPHYSIOLOGICAL DOMAIN

A total of 14 experimental studies (n=676) using non-invasive tools such as; electroencephalogram (EEG) (n=577) and Functional Magnetic Resonance (fMRI) (n=99) have investigated the neurophysiological effects of nature experience. The studies using EEG have analysed the spectral power in the different regions of the brain. The dominant frequencies have been examined in the light of psychological parameters. An enhanced alpha (8-13 Hz) brainwave activity as an indicator of physiological stress is reported in association with nature experience (Chang, Hammitt, Chen, Machnik, & Su, 2008; Y. C. Chiang, Li, & Jane, 2017; Ulrich et al., 1991). Along with alpha, significantly higher power in theta (4-7 Hz) was also reported after nature experience, indicating a possibly relaxed but wakeful state (Johansson et al., 2014). Further, studies examining the right and left hemisphere alpha activity have reported that nature experience is associated with frontal EEG asymmetry, with more synchronized EEG signals on the right side (Chen-yen Chang & Chen, 2005; Chen et al., 2016; Roe, Aspinall, Mavros, & Coyne, 2013). Bratman and his colleagues (2015) found that after a short walk in the woods, fMRI of the participants displayed a decrease in cerebral blood flow in the sgPFC, a brain region that has been shown to be associated with a self-focused behavioural withdrawal linked to rumination. In the same study, the decrease in sgPFC activity was also found to be positively correlated with the self- reported rumination (Bratman, Hamilton, Hahn, Daily, & Gross, 2015). The summary of neurophysiological parameters; brain areas, neural frequencies and the tools used for investigation in the studies are presented in Table1.

Table 1 Summary of neurophysiological parameters; brain areas, neural frequencies and the tools used for investigation in the studies

Study	Brain Area	Dominant Frequencies	Outcomes after nature experience	Tools
EEG studies				
Bailey,2018	Global (mainly frontal)	theta, alpha	Presence of lower frequency waves in the frontal cortex (Theta) and stronger alpha waves in the posterior and relative global alpha power across all sensors in natural environment conditions, frontal theta remained higher even through the post-Stroop test.	Emotiv Mobile EEG
Hagerhall,2008	Frontal, parietal and temporal	alpha, beta	Maximal alpha response in the frontal region, highest beta response in the parietal region	Nervus Digital EEG Recorder
Chen Zheng, 2016	Global	delta, theta, alpha, beta	Higher direct EEG amplitude correlation, across recording sites and right hemisphere, both time domain and frequency domain, Stronger functional connectivity networks, significantly higher overall power (delta, theta, alpha, beta) correlation, average smaller shortest path lengths, stronger lateralization except in P8/P7 and O2/O1 regions and in the right hemisphere during the nature exposure than the urban exposure	Emotiv wireless headset
Chiang, 2017	Frontal	alpha	Higher the EEG-Alpha	MindBand EEG headsets by NeuroSky ThinkGear
Chang, 2008	Right and left of prefrontal	alpha	Increase in EEGa, EEGb	Pro- comp+/Biograph V2.0 Biofeedback System made by Thought Technology Ltd.
Chang, 2005	Right and left prefrontal	alpha	Higher EEGb (right side)	Procomp+/Biograph V2.0 Biofeedback System made by Thought Technology Ltd.

Choi,2017	frontal, occipital	alpha	No significant difference in EEG alpha power	EEG 100C, BIOPAC system Inc., USA, Electro-Cap, Electro-Cap International, Inc., USA.
Roe,2013	frontal, occipital, parietal and temporal	delta, theta, alpha, beta	Lower Excitement, higher Meditation, higher engagement	Emotiv EPOC
Ulrich,1981	left and right centro-parietal	alpha	Higher alpha	not known
An,2004*	frontal, parietal and occipital	beta	Beta wave at frontal, parietal and occipital regions was most intensive at 100 % stand density and least at 50 %.	Electro-Cap International Inc., USA
Johansson,2014*	frontal, parietal, temporal	delta, theta, alpha, beta	Highest delta in low biodiversity, no difference in alpha, beta highest in the frontal region of the right hemisphere for intermediate biodiversity.	Nervus Digital EEG Recorder
fMRI Studies				
Kim,2007	Frontal, temporal, parietal, occipital	Greater activity in temporal, parietal and occipital lobes, higher activity in insula and the splenium of the corpus callosum, superior parietal gyrus, anterior cingulate gyrus, postcentral gyrus, globus pallidus, putamen and head of the caudate nucleus.		3 Tesla Magnetom Trio MRI unit
Tang,2017	parietal, occipital and cingulate gyrus	Brain activity left and right cuneus, right cingulate gyrus and left precuneus		3T Bruker Medspec MRI
Bratman, 2015 b	pre-frontal	Decrease in sgPFC activity.		3-T General Electric MR750 Discovery Scanner at

*** comparison between High-low biodiversity conditions**

2.8 DIRECTED ATTENTION AND ITS ASSESSMENT

Though the evidence provided by the existing literature suggests that improved mental functioning to be associated with nature experience, yet the evidence for the relationship of nature experience with enhanced directed attention, not substantive. Further, the literature review also revealed that the cognitive and neurophysiological effects associated with nature experience are understudied (Figure 1). As discussed in section 2.7.2, the evidence from the review of nature studies suggested that nature experience perhaps enhances one's ability to direct attention (Berman et al., 2013). Therefore, additionally, papers that have examined attentional processes and their neurophysiological mechanisms were searched. For the search of experimental research articles, the keywords used were, 'cognitive processes', 'attention' and 'neurophysiological mechanisms'. The inclusion criteria for the selection of papers was; i) experimental study design and, ii) the assessment of neurophysiological mechanisms of directed attention using EEG. A total of 16 papers were found and reviewed. The key findings from the review are discussed in the following section.

In this section, directed attention and its methods of assessment of as relevant to the context of this thesis are discussed. The literature describes that different models of attention are derived from three broad aspects of attention; activation, selection, and control. The selection mechanism helps to choose particular relevant information, internal train of thoughts, or a specific course of action for priority processing (Rueda, Pozuelos, & Cómbita, 2015). It is argued that the directed attention processes employ voluntary and 'effortful' control of action, as opposed to well-learned automatic behaviour (Kaplan & Berman, 2017). Further, the voluntary attention mechanism is suggested to involve 'control' or inhibition of automatic responses for selecting appropriate response or behaviour. The efficiency of the directed attention is also argued to be affected by the conditions in which the level of 'activation' is compromised, such as fatigue. In sum, directed attention is

referred to as a state in which an optimal level of activation is available that allows inhibiting irrelevant information in order to control the course of our actions and selecting relevant information or an appropriate response.

Further, the cognitive control processes are argued to operate via three predominant subordinate cognitive processes; conscious detection, inhibition and conflict processing (Posner & DiGirolamo, 1998). Several cognitive tasks such as; Stroop task, Necker Cube, Backward Digit Span Test (BDST) and experimental paradigms such as go no go, rule inhibition have been employed to examine these cognitive sub-processes. Figure 3 depicts some of the assessment tasks used in the literature to measure attentional sub-processes.

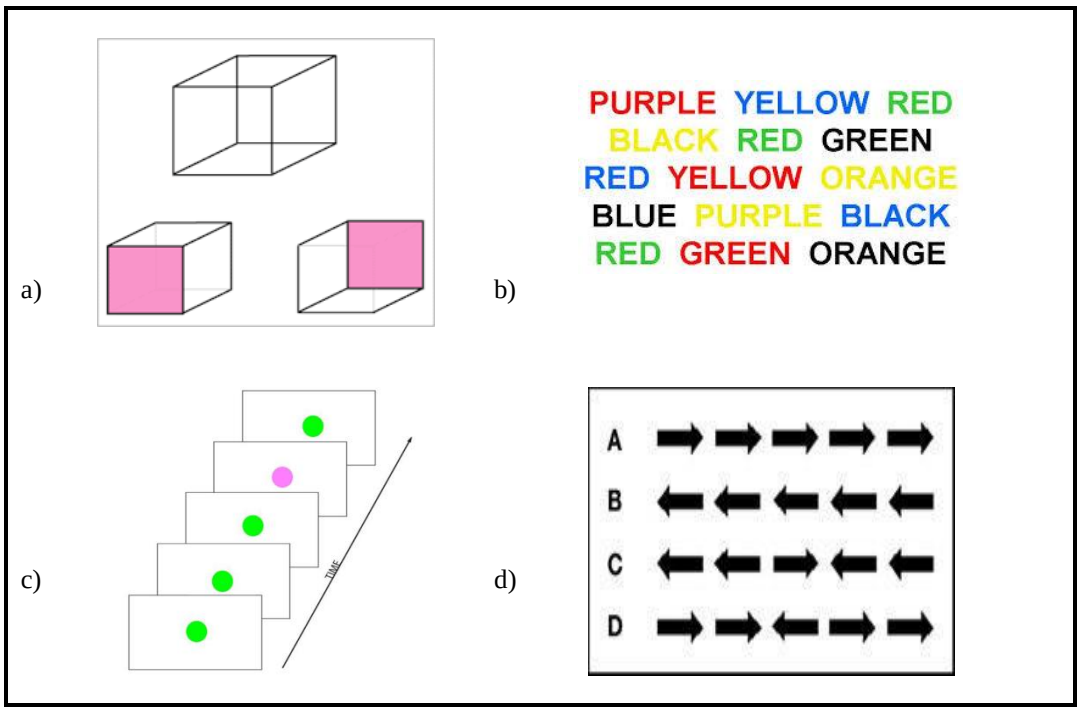


Figure 3. Examples of cognitive assessment for attention. A) Necker cube b) Stroops task c) Oddball paradigm d) flanker task

Cognitive control is commonly assessed using performance on Stimulus-Response Compatibility (SRC) tasks, such as the Stroop, Flanker, and Simon tasks (Stroop, 1935; Simon, 1969; Eriksen

and Eriksen, 1974). Typically the SRC tasks consist of inducing conflict between responses by instructing participants to execute a subdominant response while suppressing a dominant tendency. These are forced-choice reaction time tasks that require participants to selectively attend and respond to target stimuli while ignoring goal-irrelevant distracting stimuli and response options. Most commonly, the primary measure of conflict interference is provided by the well-known flanker task, where conflict is induced by presenting distracting information that suggests an alternative incorrect response (Eriksen and Eriksen, 1974). The presence of distracting information that is incongruent as opposed to congruent with the appropriate response produces conflict and engages all the three cognitive sub-process of; detection, inhibitory control, and conflict processing. Literature reports that conflict is associated with an electrophysiological response that is reported to be detected as early as 200ms after the onset of the stimuli (Rueda et al., 2015). This response has also been associated with activation of a number of brain regions, including the anterior cingulate and prefrontal cortices, and is modulated by levels of dopamine and serotonin in the brain (Petersen & Posner, 2012).

The studies indicate that the detection of infrequent trials reliably evoke transient activity in prefrontal cortical regions (PFC). It is argued that in the case of the infrequent trial, the previous response must be inhibited to make an appropriate response. Therefore, for appropriate responding cognitive control centres of the prefrontal cortical regions are activated (Daffner et al., 2000). Whereas, in the case of frequent trials, the subject makes the same response repeatedly; the repeated action becomes efficiently coded and can be made in the absence of prefrontal cognitive control. In another cognitive control model, it is contended that PFC accesses, inhibits, or changes behavioural strategies. In case of the frequently occurring tasks, subjects predict the likely response and thus set up a response strategy that is biased toward the frequent trials (Huettel & McCarthy, 2004). When an infrequent trial occurs, the subjects must inhibit this response strategy so that they can correctly respond. However, in both the suggested models the resolution of the conflict from

incongruent stimulation in the flanker task was found to activate the dorsal portion of the ACC together with other areas in the lateral prefrontal cortex (Fan, Flombaum, McCandliss, & Al., 2003).

In the further classification of the cognitive sub-processes viz brain activations suggest that the Anterior Cingulate Cortex (ACC) is involved in conflict detection and monitoring, while lateral frontal and parietal areas are in charge the conflict processing and resolution (Botvinick, Braver, & Barch, 2001). It was further reported that although performing different conflict tasks activate distinct structures of the prefrontal cortex, but shows a common burst of activation in the ACC (Fan et al., 2003). Altogether studies reveal that the attentional sub-cognitive processes show some degree of integration and interaction at the functional level. They are commonly known to involve the fronto-parietal network (M. I. Posner & Petersen, 1990). The trinity model of attention, involving fronto-parietal network, proposed by Posner & Petersen, is shown in Figure 4.

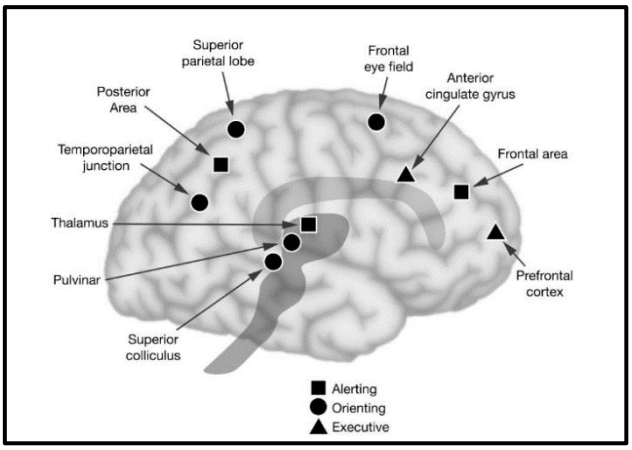


Figure 4. Anatomy of three attentional networks: alerting, orienting, and executive attention (source: Posner & Rothbart 2007)

Additionally, the review of studies that combine neuroimaging techniques with attention paradigms shows detection of infrequent targets has been related to increased activation in the right-lateralized network of ventral fronto-parietal structures (Corbetta & Shulman, 2002) as

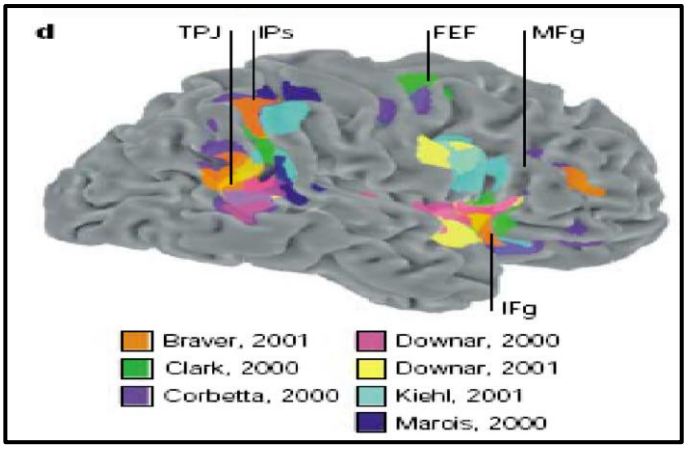


Figure 5 Brain areas implicated in directed attention by various studies (source: Corbetta & Shulman, 2002)

shown in Figure 5. The literature on methods used to study neural correlates of cognitive processes of attention using electroencephalography been presented in the next section.

2.8.1 ELECTROENCEPHALOGRAPHY (EEG) STUDIES AND NATURE EXPERIENCE

In this subsection Electroencephalography (EEG), as a technique to examine the neurophysiological correlates of cognitive processes is discussed. It also describes ways to analyse and interpret the raw data. EEG measures cortical brain potentials. Though very few studies have been reported where EEG has been used to study the nature experience, there are plenty of other EEG studies where the effects of an intervention on the brain have been studied. Most commonly, such studies using EEG have reported analysis of spectral power of specific brainwaves and the Event-Related Potentials (ERP).

2.8.1.1 SPECTRAL POWER ANALYSIS

Brain dynamics are characterized by oscillations in different frequency bands which reflect cognitive processes. Frequency bands have been categorized into five basic groups namely; delta

(0.5-3.5 Hz), theta (3.5-7.5 Hz), alpha (7.5-12.5 Hz), beta (13-30 Hz), gamma (>30 Hz) (Brain Products Analyzer Manual ver2.2).

The power spectrum from raw EEG is derived through Fourier transform and analysed for certain dominant frequencies. These derived frequencies are continuous and may range from 0 Hz up to one half of the sampling frequency. Often studies examine the dominant frequencies in association with the psychological states such as; sleep, relaxed, meditative, anxious or alert states.

In the self-report based nature studies, nature experience is reported to be associated with a peaceful and relaxed mental state. Limited evidence from nature studies has indicated the increased presence of alpha brainwaves during nature experience (Chiang et al., 2017; Ulrich et al., 1991). Further, Roe et al. (2013), reported significantly high levels of theta brainwaves along with higher alpha when exposed to images of natural spaces.

In the absence of sufficient evidence from nature studies using EEG, additionally, literature was searched for studies which reported the use of interventions such as; music, meditational, and mindfulness techniques to examine further the association of psychological states with various frequency band power. Several studies that have investigated some or the other form of mediation suggest that peaceful mental states produce mid-range alpha and theta frequency (Davis, Lin, Gillett, & Kozma, 2017). In another study, it is suggested that difference in frontal and posterior theta activity may underlie some of the experiences associated with reduced awareness of one's surroundings and even deep feelings such as unity with the self and nature. Further, reduced theta over posterior areas of the brain, especially the left hemispheric sensory regions is reported to be linked to the increase in frontal theta activity (Baijal & Srinivasan, 2010). Based on the findings from mediation studies and limited evidence from nature studies, it seems that dominant frequencies found during nature experience possibly are similar to as observed during a meditative experience.

2.8.1.2 EVENT-RELATED POTENTIALS

EEG has also been used to examine the event-related potentials (ERP) - that reflect electrical activity locked to a specific task event. These brain responses relate to a specific event and offer a real-time temporal resolution of neural processes underlying task performances (Luck, 2005). The studies design experiments based on the fundamental assumption that ERP can be separated into different components, each indexing the degree of activity of a particular cognitive function. The experimental task is designed in such a way to identify the conditions that invoke the function, the type of data that the function processes, and the nature of the computation performed by the function (Donchin, Karis, Bashore, Coles, & Gratton, 1986). In this view, each ERP component is defined by its amplitude, polarity, latency, and scalp distribution which, by systematic experimental manipulation, can be shown to be functionally related to the underlying cognitive process (Coles & Rugg, 1995; Donchin, Ritter, & McCallum, 1978).

As described in previous subsection 2.9, during flanker task, cognitive processes, involved in directed attention, namely; cognitive control; conscious detection, inhibition, and conflict processing are anticipated to get evoked over time that ranges in the order of tens of milliseconds. Literature reports that analysis of the ERPs defines the time course of the cognitive processes activation with often much smaller amplitudes than spontaneous EEG (Luck, 2014). Further, the studies report using the digital averaging of epochs technique to cancel out the spontaneous background EEG fluctuations to get the ERPs for both congruent and incongruent trials in the flanker task. The average ERP thus can reflects, with a high temporal resolution, the difference in patterns of neuronal activity evoked by congruent and incongruent flanker task before and after stimuli. Details of ERP extraction are presented in Figure 6.

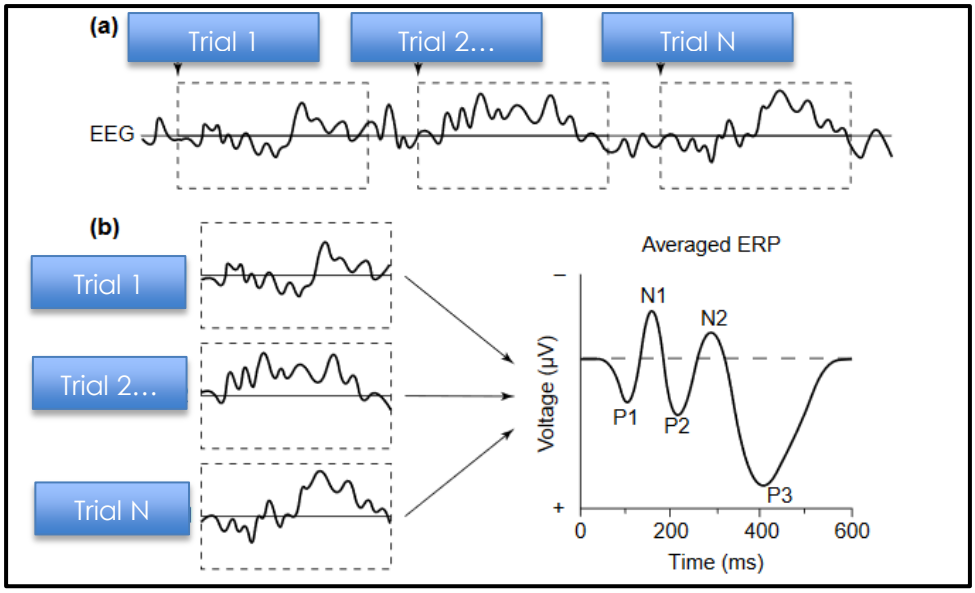


Figure 6. Extraction of the ERP waveform from the ongoing EEG. (a) trials (1... N) are displayed while the EEG is being recorded, but the specific response to each trial is too small to be seen in the much larger EEG (b) to isolate the ERP (source: Trends in Cognitive Sciences)

Most commonly elicited ERP components have been illustrated in Figure 6b. Although for each of the ERP components P1, N1, P2, N2 and P3, several related subcomponents are reported in the literature in association with specific cognitive processes. In this section, the main ERP components, as applicable to this research, as evoked by flanker task, have been discussed.

Since there has been no study till date that has investigated the effects of nature experience using ERP analysis, literature from studies that specifically, have employed flanker task to examine the attention were reviewed. The ERP components most frequently reported are; significant lower amplitude for P2, the more negative amplitude of N2 (Norris, Creem, Hendler, & Kober, 2018), the lower amplitude of P3 (Andreu, Cosmelli, Slagter, & Franken, 2018) for incongruent trials.

The second positive peak P2 is one of the early processing centres for the brain's attentional network and is the index of normal response to visual stimuli (Freunberger et al., 2009). It is commonly understood to be a part of the cognitive matching system that compares sensory input with stored memory (Luck, Hillyard, 1994). P2 amplitude was found to be related to performance

accuracy and inversely associated with the ongoing stimulus processing (Chernyshev and Medvedev, 2016). Therefore, increased P2 may indicate lower stimulus processing requirements. The lower stimulus processing can also be construed as attentional lapse if it is producing errors; however, in case of a correct response, it is argued as efficient processing. Further, for the incongruent flanker trial, P2 is reported to be correlated with suppression of irrelevant information processing (Alho et al., 1987; Coenen, 2012; Melara et al., 2009).

The N2 refers to frontal-central negativity elicited in both, oddball paradigm by infrequent events, and in the flanker task by the incongruent trials (Kopp, B., Rist, F. & Mattler, 1996; Norris et al., 2018; Xie, Ren, Cao, & Li, 2017). It corresponds to the avoidance of inappropriate responses, possibly reflecting the inhibition of automatically primed responses (Kopp, B., Rist, F. & Mattler, 1996). The presence of conflict modulates the N2 potential. The N2 amplitude increases in incongruent trials relative to congruent ones. In a recent study, Norris and his colleagues (2018) suggested that greater N2 for incongruent trials can be interpreted as an improved cognitive process and attentional control after brief mindfulness practice. The effect has been related to control processes arising in the ACC. Along with behavioural measures, findings from such studies are associated with the efficient allocation of cognitive resources. In recent research, Sanger and his colleagues (2018) also found larger N2 using the oddball paradigm, in association with enhanced inhibitory control of attention.

The P3 appears across the parieto-central area of the cortex (Polich, 2007). The P3 wave occurs when the subject is actively engaged in the task of detecting the targets. Its amplitude varies with the likelihood of the targets. A study on brief mindfulness practice on response inhibition found that lower P3 amplitude might indicate less-effortful response inhibition after the mindfulness-practice (Andreu et al., 2018) and latency is affected by the level of difficulty for discriminating the target stimulus from the standard stimuli.

Altogether, the evidence from studies investigating brief mindfulness practice suggest the efficiency of allocating cognitive resources, leading to improved self-regulation of attention.

2.9 GAPS IN LITERATURE

This research was conceived in light of the increasing interest in the potential for natural environments to provide benefits for physical and mental health. Benefits from human-nature interaction are commonly suggested to accrue through enhanced affect and cognition. However, the empirical evidence is unclear on the underlying neurocognitive mechanism.

- The evidence is not sufficient on the relationship of presence of 'nature in the neighbourhood' or frequency of visit to nature-rich spaces such as parks, gardens, urban greens, forests or wilderness areas with a subjective sense of connectedness.
- Further, the association of nature in the neighbourhood, frequency of visit and individual's attentional ability has also not been sufficiently studied.
- It was found that not much evidence is available in the literature which has studied the impact of 'nature experience' on directed attention.
- Literature review of nature studies found that not much evidence is available from studies with physiological observations. Specifically, the use of physiological tools such as EEG to study the neurophysiological markers of nature experience has not been sufficiently reported in the literature.
- Most of the literature on nature research have reported studies which were conducted in urbanized western cultures and research with Indian population has not been reported.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

As described in Chapter 1, the objective of this research was to 'study the effects of nature experience on directed attention'. In order to fulfil the research objective, related research questions were also identified and are described in section 1.4. To seek an answer to the research questions, the approach adopted in this thesis was mixed-method research design. Two separate studies were conducted to investigate the two different sets of research questions. The flowchart of the research methodology is presented in Figure 7. Mixed methods were employed to collect data from multiple sources in an attempt to develop a richer understanding (Denzin, 1978). The mixed-method approach has also been seen as a method for corroborating findings, creating rich data, robust and comprehensive analysis and as a test for validity as well (Patton, 1999; Minocha, 2006).

This chapter is divided into three sections. Section 3.2 comprises of the type of research methods used, Section 3.3 includes the details of the data analysis techniques employed and Section 3.4 details the measures taken in the experimental design to overcome the limitations of the research methodology adopted for the research.

3.2 OVERVIEW OF RESEARCH METHODS FOR TWO STUDIES

This section presents an overview of the research methods used in both the studies and the rationale behind selecting the particular method. The detailed description of each of the methods and measures are presented in Chapter 4, Section 4.3 and Chapter 5, Section 5.3, along with the experiment details.

In this research, two separate studies were conducted and both the studies had employed different research methods. Study 1 was designed using the cross-sectional research design and aimed to answer the first research question;

Research Question 1: How is nature experience associated with directed attention?

a. Is the presence of nature in the neighbourhood associated with attention?
b. Is the frequency of visit to nature associated with attention?
c. Does 'nature relatedness' affect the association of nature experience and attention?

There were no before-after tests, rather data of past experiences were collected from participants from different age groups using questionnaires. Prior to the selection of the questionnaire to be employed, literature was screened for reported measures for the assessment of nature experience and attention, as described in Chapter 2 Section 2.4. The focus during the selection of the questionnaire was to identify oft used questionnaires from the literature that have been successfully applied to the sample from the Indian population. The standard questionnaire thus selected were 'nature relatedness scale' (NR-6; Nisbet, 2013) consisting of 6 items, rated on 5 point scale and 'Mindfulness Awareness and Attention Scale' (MAAS; Brown and Ryan, 2013) consisting of 15 items, rated on 6 point scale. The nature experience through different human- nature interaction models as described in Section 2.4 was assessed through additional questions to assess the 'nature in the neighbourhood' both in the current and childhood and 'frequency of visit'.

Prior to the collection of research data using the selected questionnaires, a pilot test on 20 respondents was done. The questionnaire was administered to the respondents, and they were asked to fill their choices. Personal, one on one, interviews post-pilot test was conducted to understand the suitability of the flow of questionnaires, time taken to respond, the difficulty level of questionnaires and respondent's sustained interest in answering the questions. It reported by the respondents that the questionnaires did not have any difficulty in understanding, and the flow was suitable.

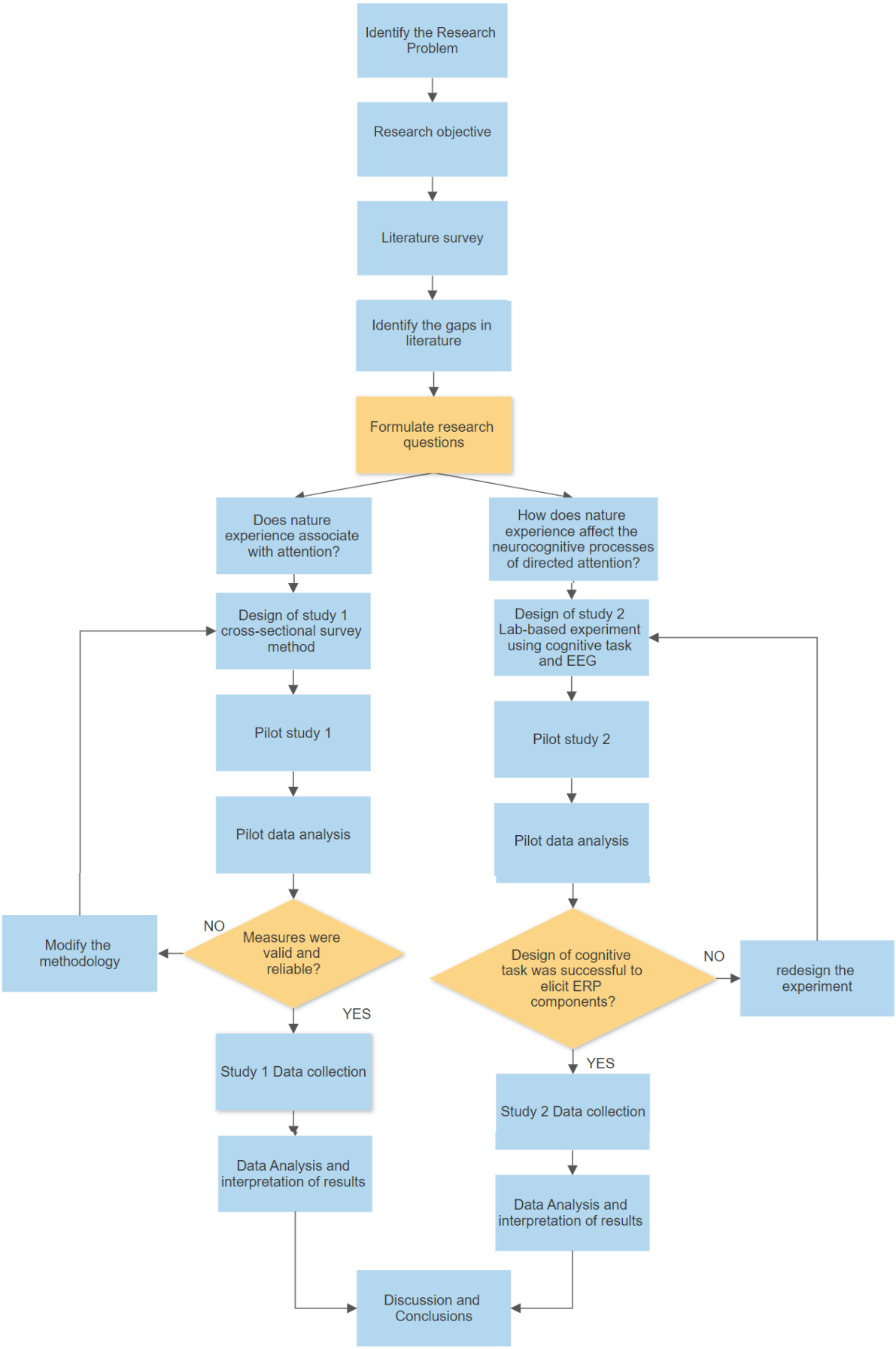


Figure 7 Flowchart of the Research Methodology

After the pilot, the collected data from 334 participants were analysed for relationship between nature experience and attention using statistical correlation and analysis of variance. Finally, regression and structural equation modelling techniques were used to establish the predictor variables and confirm the proposed model. Details of analysis techniques are mentioned in Section 3.3.

Though the correlational research gives the strength and the direction of the relationship, however, the causation may not be implied from such a research design. Therefore, study 2 was designed with a lab-based experiment, and objective measurement techniques were used.

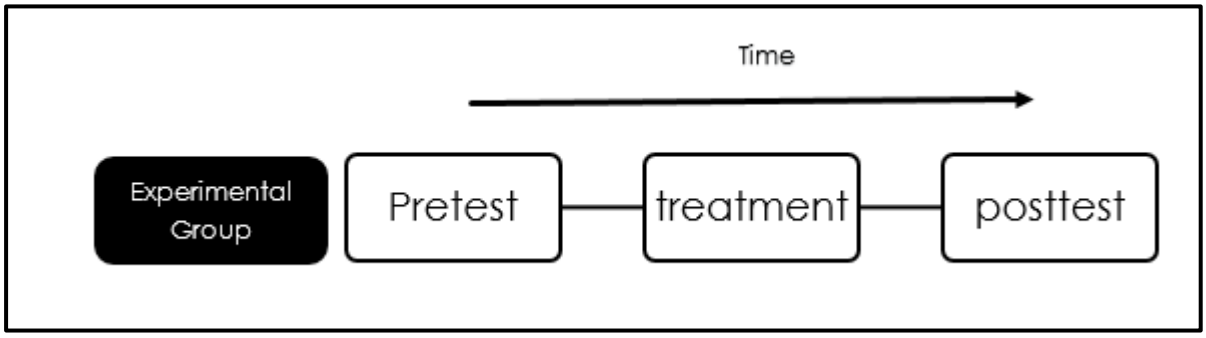


Figure 8 One Group Pre-test- Post-test experimental research

In Study 2, lab-based experiments were conducted where physiological data using EEG was collected on cognitive tasks pre and post nature audio-visual stimuli to seek answers to the second research question;

Research Question 2: What are the neurophysiological effects of nature experience on directed attention?

a. What are the effects of nature experience on the EEG frequency band power in different regions of the brain?
b. What are the effects of nature experience on Event-Related Potentials (ERP) associated with attention?

c. What are the effects of nature experience on response time and accuracy in directed attentional tasks?

Both qualitative and quantitative data were gathered to investigate the effect of nature experience on the neurocognitive mechanisms underlying directed attention. The study employed a modified pre-test-post-test research design, as shown in Figure 8. The research design consisted of a controlled environment in which nature experience was manipulated through an audio-visual of natural environment setting. The presentation of audio-video stimuli has also been previously reported in the literature to elicit nature experience (Berg, 2003; Choudhry et al., 2015). The audio-video to be used as the nature experience stimuli were selected through a two-step procedure; first, by peer review and in the second step by experts rating based on the close representativeness of the audio and visuals with the real-time nature, the detailed description is presented in Section 5.3.3. This approach to the selection of the stimuli was adopted to select a nature experience stimuli objectively and to reduce the effects of a researcher's bias. Cognitive (Flanker) task was administered, and continuous EEG was recorded in both the pre-test and post-test conditions to examine neurocognitive processes involved in directed attention. The details of the experimental setup are discussed in Chapter 5, Section 5.3.

The aim of adding a pre-test measurement, prior to the introduction of the nature experience stimuli, was to collect baseline data and for comparison purposes. An open eye resting state (OERS) added to pre or post-test condition. The difference in the cognitive task performance was determined by comparing pre-test and post-test scores (Gay et al., 2009) for both nature experience and open eye resting state in the pre-test and the post-test condition. The outcomes from this type of pre-test-post-test research design indicated a difference in performance caused by either of the open eye rest condition (OERS) or nature experience (NE). Such research designs have also been successfully employed while examining the effectivity of mindfulness practice in or without natural settings (Lymeus, Lindberg, & Hartig, 2018).

Further, the pre-test-post-test research design is reported to offer two advantages (Leedy & Ormrod, 2013). First that the subject acts as his own control for the factors that cause variability between subjects. Second, fewer subjects need to be recruited, trained and compensated to complete the entire experiment for the desired effect size. Inclusion of an open eye resting-state helped to maximize the yield of individual experiments (Bausell, 2015). The challenge in this type of experimental design is to account for other explanations that could cause a change in scores. This challenge was overcome by introducing control measures, as described in Section 3.4.

By definition, nature experiences are 'subjective, profound and difficult to describe'. Therefore, along with quantitative methods, subjective reports consisting of a personal description of nature experiences by each participant after the experiment was collected. In literature, the analysis of the qualitative data has been reported by using techniques like Phenomenological analysis (Price & Barrell, 2012), Grounded theory (Charmaz, 2006), Discourse analysis, Narrative research, Case study method etc. A comparison of the different techniques has been presented in Appendix 1, Table 2. Based on the comparison, an adapted version of phenomenological analysis was selected. Distinctively from other qualitative techniques, the phenomenological analysis aims to understand the lived experience of the phenomena through; conducting non-directive semi-structured interviews. The underlying purpose is to understand the meaning participants place on the observed phenomena, which in the context of this research was the 'nature experience'. There were two underlying objectives of conducting the interview; primary was to understand the 'nature experiences' of participants that were elicited while viewing nature audio-video stimuli and, secondary was to find out which salient features in the nature audio-video stimuli elicited those experiences. In this study, semi-structured questions, along with probing questions, were asked during the debriefing interview after the experiment. The format of the interview, recording of responses, coding and emerging themes are included in Annexure 3. The interviews were recorded, and the transcripts were examined under two categories; i) the 'nature experience', and

ii) the elements of nature that most aroused that 'experience'. Different expressions under each category were coded according to their emerging theme. The emerging themes in these two categories were then analysed for frequency through a word cloud analysis using ATLAS.Ti Scientific Software Development GmbH version 8.1. A copy of the form used for data collection and recording log is included in Appendix3 Table3.

3.3 STATISTICAL ANALYSIS TECHNIQUES USED IN THIS RESEARCH

As the first step to data analysis, descriptive statistics were used to summarise the basic features of the data. Some of the important features of the study sample were also represented through graphical representations for visually appreciating the trends in data.

Study 1 yielded data from the questionnaires on demographics, nature experience and measure of attention. The trends in raw data were examined by analysing individual items of interest in the nature experience (nature in neighbourhood current and childhood), visit frequency, along with nature relatedness and the dependent variable (a measure of attention) in terms of percentages of the sample population and their tendencies. The percentage analysis brought forth the ease in a comparative understanding of the distribution of the data.

3.3.2 UNIVARIATE AND MULTIVARIATE ANALYSIS OF VARIANCE

In study 1, to examine the association of nature experience with attention, one -way ANOVA was used for statistical hypothesis testing and for deducing significant results. ANOVA is suggested to be used for categorical independent variable and continuous dependent variable. Additional to correlation analysis, the univariate analysis provides the quantitative measure of the significant effect (effect size) and allows the examination of significant differences in the categories (For example; low, moderate, high). Estimated Marginal means were plotted to adjust for the covariate by plotting the means of Dependent variable for each level of the factor at the mean value of the covariate and independent variable. A test result was reported statistically significant, and the hypothesis

accepted when a probability (p-value) was less than a threshold ($p<0.05$). By design, hypothesis testing limited the rate of Type I errors (false positives leading to false scientific claims) to a significance level.

In study 2, all comparisons were made using, 2 (congruent/incongruent) x 2 (pre/post) repeated-measures ANOVA. A within-subject factor of the repeated measures ANOVA was used to find differences in the observation of one subject. Before ANOVA, the assumption for sphericity was checked through *Mauchly's test* ($p>0.05$) and in case of assumptions not met, Greenhouse-Geisser corrections were applied. Here again, a test result was reported significant if the p-value was <0.05.

3.3.3 CORRELATION ANALYSIS

In study 1, the correlation coefficient was used to indicate the strength and direction of a linear relationship between nature experience and attention, and it did not imply causation. Most commonly used coefficient technique by Karl Pearson was used to obtain the correlation coefficient by the division of the covariance of the two variables with the product of their standard deviations. Study 2, correlation analysis was employed between latency and response time to examine the association between behavioural and neurophysiological parameters of attention.

3.3.4 REGRESSION ANALYSIS

In study 1, to explore the role of nature relatedness in the association of nature experience with attention following regression equations were estimated: First, the nature experience (independent variable) must affect the 'nature relatedness' in the first equation; second, the nature experience must be found to affect the attention (dependent variable) in the second equation; and third, the nature relatedness must bring a change in the attention (Baron and Kenny,1986). Coefficients for

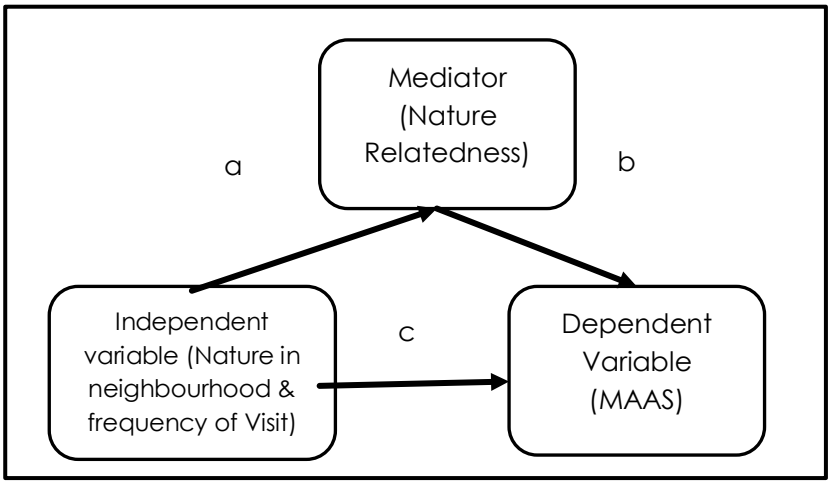


Figure 9 Mediational analysis (Baron and Kenny, 1996)

each equation are estimated and tested.

Hierarchical or stepwise regression was employed to compute the regression coefficients. The three regression equations provide the tests of the linkages of the mediational model (Figure 9). The three conditions were checked for the predicted direction. Further, the lower effect of the nature experience on the attention variable in the third equation than in the second signified a successful mediation. Further, to quantify the indirect effects, the difference in regression coefficient in equations with and without mediator was calculated (Judd & Kenny, 1984). Additionally, similar steps were also followed for examining the role of nature relatedness in the association of the nature in the neighbourhood (as the independent variable) and the frequency of visit (as dependent variable).

Since the 'nature relatedness' is an internal, psychological variable, it is likely to be measured with error. The presence of measurement error in the 'nature relatedness' tended to produce an

underestimate of the effect of the mediator and an overestimate of the effect of the independent variable on the dependent variable when all coefficients are positive (Judd & Kenny, 1981a). This is not a desirable outcome because a successful mediator could be overlooked. Therefore, a multiple indicator approach was adopted to estimate mediation paths by latent-variable structural modelling methods, as explained in the next Section.

3.3.5 PATH ANALYSIS/ STRUCTURAL MODELLING TECHNIQUE

In study 1, Path Analysis as a structural modelling procedure was used to estimate feedback models and find the best fit model. The major advantages of structural modelling techniques was that: all the relevant paths were directly tested, and none got omitted as in ANOVA. Also, complications of measurement error, correlated measurement error, and even feedback were incorporated directly into the model. LISREL-8 was used as it is one of the most common computer program used to estimate structural equation models. The model was tested based on the Goodness of fit index>0.90. Other fit indices used include RMSEA, CGFI, p-value.

3.4 MEASURES IN EXPERIMENT DESIGN FOR RESEARCH ETHICS AND ACCURACY OF THE RESEARCH

This section describes the measures and strategies that were incorporated into the study design to ensure the ethics and accuracy of the research undertaken. The objective was to increase the methodological rigour within the given resources available. Since experimentation involves huge costs in terms of monetary value and human effort, another related goal of introducing control measures was also to maximize the yield of individual experiments- a consideration increasingly becoming important in the era of limited resources (Bausell, 2015). The control measures were also adopted to eliminate the alternative explanations for the experimental results as possible. Some of the common artifacts that are reported to confound the pre-test-post-test study outcomes and the respective control measures included in the study design are described below:

Good -subject phenomena: There is a tendency of the participants to provide desirable responses or outcomes while answering to self-report questionnaires in study 1 or during interviews following intervention in study 2. Prior to the recruitment, in both the studies, the participants were given a brief about the experiment without disclosing the research objective. Participants were informed that the experiment in no way aims to judge their abilities. Further, they were guaranteed that the responses will be analysed in complete anonymity and that the outcomes of the study will only be used for research purposes.

Placebo effect: In study 2, participants were carefully explained the EEG data collection protocols without divulging the information about the research hypothesis. Conscious efforts were made to avoid conveying any sense of urgency with respect to desired experimental outcomes to both participants and the research team. This was done to avoid a response due to the participant's belief that effective treatment is being given during the experiment.

Maturation effect: Participant's outcome values tended to change over an experimental interval as a function of physical or mental conditions or time. Therefore, in study 2, the likelihood of the maturation effect was reduced by keeping the duration of the experiment brief. In study 1, age was considered as the control variable for all the statistical analysis.

Repeated testing: There is a tendency of the participants to exhibit higher scores the second time they were administered the cognitive task resulting from familiarity to the task itself. Though there is a varying opinion about the strength of this type of effect and its occurrence across the sample population (Bausell, 2015). However, the cognitive task in study 2 was designed in such a way that massed practice in a pre-baseline period was included to reduce task familiarity effects as also reported in previous studies (Goldberg et al., 2015). Additionally, the randomization of trial types in the task design also ensured that there was a minimum effect due to the familiarity of the task.

Instrumentation effects: Changes can also occur due to due to change in data collection format. In both the study, this effect was reduced by following the same measures and tools for data

collection. In study 2, a checklist was developed prior to the data collection stage and applied uniformly for each participant during the experiments. A protocol was also developed for the research team to follow while conducting the experiments.

Extraneous or External Events: In study 2, EEG data recording is sensitive to a loud noise, voltage and light fluctuations. A controlled lab-settings ensured that there was no external interference during the experiment. Minimum movement in the surroundings of the experiment room was ensured. Electricity supply, light and temperature were uniformly maintained for the entire duration of the experiment.

The Hawthorne effect: There is a tendency that the participants behaved differently as a function of being in an experiment or observed. To avoid such effects, a controlled lab- settings with a separate room each for participants and observation was used. The observation room and the experiment room were separated by a glass window coated with a one- way film. This type of settings enabled the observer to observe without making the subject conscious of being observed. Minimal interference in the experiment room was also ensured after the start of the experiment to maximize the immersive effect of the experimental settings.

CHAPTER 4

STUDY 1: ASSOCIATION OF NATURE EXPERIENCE WITH DIRECTED ATTENTION: A CROSS-SECTIONAL STUDY

4.1 INTRODUCTION

This study was constructed to understand the association between nature experience and directed attention. Questions pertaining to individual's nature experience through different models of human-nature interaction as defined in Section 2.4 were asked along with a standardised measure for the subjective sense of connection with nature, and individual's ability to direct attention. As detailed in Section 2.4.1, several measures have recently been created which attempt to quantify the concept of a subjective sense of connecting with nature (Mayer & Frantz, 2005; Nisbet, Zelenski, Donnellan, & State, 2013; Schultz, 2002). In the context of this research, subjective sense of connection with nature is examined using Nature Relatedness Scale (NR-6). Distinctively, Nature Relatedness Scale (NR-6) measures people's interest in, fascination with, and desire for nature contact while being short and concise. This scale has also been successfully applied to a sample from the Indian population in previous studies (Gerofsky, 2016). Nature experience through incidental human-nature interaction- through the presence of nature in the neighbourhood (during childhood years and current) and by intentional human nature interaction-through frequent visit to nature-rich areas were examined by including additional questions. Further, for assessing the individual's ability to direct attention, Mindfulness Attention and Awareness Scale (MAAS; Brown and Ryan 2003) was used. This scale has been reported to have successfully been applied to Indian sample population (Singh et al., 2016). Details on methods and measures are provided in Section 4.3.

To seek the answer to the research question (RQ) 'How is nature experience associated with directed attention?' and the related sub-question (RQ1a) 'Is the presence of nature in the neighbourhood associated with attention?' as well as (RQ1b) 'Is the frequency of visit to nature associated with attention?', following hypothesis were formulated;

H1: There will be a positive correlation between nature experience (NE_Combined) and MAAS

H1b: There will be a positive correlation between nature experience (NE_Combined) and NR.

H2- There will be a positive association of nature in the childhood neighbourhood (NCH) and MAAS

H3: There will be a positive association of nature in the current neighbourhood (NCU) and MAAS

H4- There will be a positive association of the frequency of visit (NVF) and MAAS

To seek an answer to the third sub-question (RQ1c) 'Does 'nature relatedness' affect nature experience and attention?', two possible pathways were explored through the following hypothesis;

H5- Nature relatedness (NR) will mediate the association of nature in the current neighbourhood (NCU) and frequency of visit (NVF)

H6-Nature relatedness (NR) will mediate the association of nature experience (NE_Combined) and MAAS

The proposed theoretical model for nature in the neighbourhood (childhood and current), nature relatedness, visit frequency and directed attention is depicted in Figure 10.

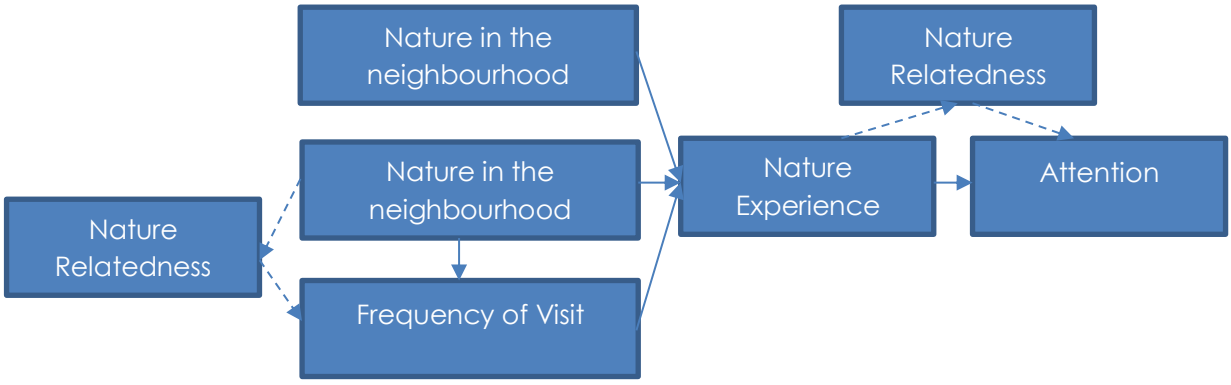


Figure 10 Proposed model for the association between nature in the neighbourhood, frequency of visit and Individual's ability to direct attention

4.2 BACKGROUND

Kellert (2015), describes that since humans evolved and adapted in response to mainly natural forces, therefore, they have an inherent need to affiliate with nature. The fulfilment of the 'need' to connect with nature by physically being with nature could explain the underlying mechanism through which nature connection affects positive psychological wellbeing (Capaldi A., Dopko L., & Zelenski, 2014; Cleary, Fielding, Bell, Murray, & Roiko, 2017).

Studies have described incidental nature experiences as either through: a) nature in the neighbourhood, i.e. the presence of green spaces such as parks, gardens, woodlands (Ekkel & de Vries, 2017; Gascon et al., 2015), and or by intentional nature interaction through b) 'frequency of visit,' e.g. a walk in the park (Berman et al., 2009; Zelenski & Nisbet, 2014). The neighbourhood nature approach assumes that people who live near natural environments will visit them more often (White, Pahl, Wheeler, Depledge, & Fleming, 2017) and thus would reap benefits of interacting with nature. An assumption of the effect of 'frequency of visit' tends to be that exposure through voluntary visits is beneficial for mental health(Shanahan et al., 2015).

Both neighbourhood nature and visit frequency may nurture nature relatedness which in turn is argued to have a role in human-nature interaction (Capaldi A., Dopko L., & Zelenski, 2014; Nisbet et al., 2013). It may be argued that nature relatedness could influence the choice of the neighbourhood with nature-rich surroundings. Additionally, the choice of the neighbourhood could also be governed by other socio-economic factors which are not in the scope of this research. Therefore, for this study, nature in the neighbourhood is considered as an independent variable.

Nature relatedness is also suggested to foster an urge for nature connection (Zelenski & Nisbet, 2014), which in turn could influence an individual's frequency of visit to the nature-rich places. Thus, nature relatedness is anticipated to play a role in more than one way in the association of nature experience and mental health. Figure 10 depicts the proposed model of the association of nature experience through nature in the neighbourhood, frequency of visit and individual's ability to direct attention with possible interaction effects of nature relatedness.

4.3 METHOD

Questionnaires consisting of a total of 27 items out of which nature experience was measured through; 2 items on nature in the neighbourhood (both in current and in childhood), one item on the frequency of visits to nature-rich areas (gardens, forests, wilderness) and the subjective sense of connection with nature through 6 items from the standard 'Nature Relatedness Scale' (NR). Individual's ability to direct attention was measured through 15 items from the 'Mindfulness Attention and Awareness Scale' (MAAS). In the questionnaires, the remaining 3 items were on demographic details (age, gender and qualification).

4.3.1 PARTICIPANTS AND PROCEDURE

The sample comprised 334 individuals (59.5 % females) with the mean age, (M)= 36.8 years, and standard deviation (SD) = 13.1 years. Initially, an iterative pilot with a total of 20 participants was done in person, as explained in Section 3.2. The entire questionnaire comprising of 27 items was

administered to the participants, one at a time, where they had to tick the boxes in Likert scale using google form. A post-test subjective interview was conducted to gather feedback. The learnings from the pilot study were incorporated into the final questionnaire.

After the pilot studies, the data from another 334 participants were collected using the edited google form. Prior to completing the survey, participants were required to read the statement on the general purpose of the study. The information was also provided for their right to confidentiality. The participants were asked for their consent to participate through a dichotomous question. Copy of the google form is included in Annexure 2.

4.3.2 MEASURES

The questionnaire was presented in three subsections. Demographic questions regarding age, gender and qualifications were administered followed by questions on the nature experience through nature in the neighbourhood areas both childhood (NCH) and current (NCU), frequency of visit (NVF), nature relatedness, and the last section consisted of questions on individual's ability to direct attention. The construct of nature relatedness and individual's ability to direct attention was examined through standardised inventories; Nature Relatedness Scale- short form (NR-6) and Mindfulness Attention and Awareness Scale (MAAS), respectively, while nature experience was assessed through additional questions drafted for the study. Reliability statistics were analysed for standardised questionnaires to check the Cronbach's alpha and was found acceptable. A Cronbach alpha (α) = .70 or higher indicated that the scale was acceptable (Gliem & Gliem, 2003).

Nature Experience was assessed through a self-reported measure of nature in the neighbourhood (childhood and current) and frequency of visit to nature-rich areas. Often studies investigating the effects of nature in the neighbourhood have estimated the nature richness by data from geographical information system (GIS) or by some other geophysical tools. However, during the pilot study, some of the participants had reported spending childhood at diverse locations, and it

was found difficult to get a uniform GIS-based information on nature in the neighbourhood. Therefore, in this study, it was decided to get the individual's rating of natural spaces around his neighbourhood. This method of individual ratings for nature in the neighbourhood areas as successfully been employed in previous studies(Kuo & Sullivan, 2001). Participants were asked to rate 'the presence of nature in the neighbourhood' for both 'childhood' (NCH), and 'current' (NCU) on the scale of '1=not much', '2= somewhat', '3= mostly' and '4= very much'. Similarly, participants were asked to report the frequency of visit (NVF) to a nature-rich area such as parks, gardens on the scale of '1= almost never', '2= 1 or 2 days in a week', '3= 3 to 5 day in a week' '4= almost every day'. The cumulative score of the three items was termed as Nature experience Combined (NE_Combined).

Nature Relatedness (NR) is described as individual levels of connectedness with the natural world. It is an internalized identification with nature - feelings and thoughts about one's connection to nature. Nature Relatedness (NR) was assessed by the 'Nature Relatedness Scale' (NR-6) (NR-6; Nisbet and Zelenski, 2013). NR-6 scale comprises of 6 items on the "self" and "experience" dimensions of the way an individual relates to nature. The questions are rated from 1=strongly disagree to 5= strongly agree. The items assess nature relatedness elements (e.g. "I feel very connected to all living things and the earth") rather than environmental attitudes. It demonstrates good internal consistency (α=0.89). The reliability statistics for this study sample was found acceptable (Cronbach alpha= 0.711).

Mindfulness Attention and Awareness Scale (MAAS) assesses the mental state of being attentive to and aware of what is happening in the present (Brown and Ryan, 2003). MAAS with 15 items (α = 0. 82) was used to measure attention- informed by a sensitive awareness of what is occurring in the present. The scale employs 15 items, rated on 6-point scales with endpoints 1 = almost always and 6 = almost never, which measures the extent to which an individual is aware of and attends to current experiences. Items describe mindless experiences (e.g., ''I could be experiencing some

emotion and not be conscious of it until sometime later''), higher total scores denote greater mindfulness. The reliability statistics for this study sample was found acceptable (Cronbach alpha= 0.908)

4.3.3 STATISTICAL ANALYSIS

A series of steps were followed for data analysis using IBM SPSS Statistics 20. The procedure followed with the key parameters analysed is depicted in Figure 11. First, a descriptive analysis was done to identify outliers and examine the sample characteristics. The percentage analysis was performed to understand the trends and patterns in raw data. Second, univariate analysis was used to test the hypothesis for mean differences. Next, a regression analysis was performed to examine the role of 'nature relatedness' in the association between nature experience and MAAS. Role of 'nature relatedness' was also explored in the association of nature in the neighbourhood and frequency of visit. Finally, path analysis was done for the confirmation of the proposed model.

Data from the google forms were entered into SPSS 20.0 spreadsheet for analysis. Scores were computed for Nature experience combined (NE_combined) (independent variable), 'nature relatedness' (NR) (independent variable) and 'Mindfulness Attention and Awareness Scale' (MAAS) (dependent variable). Further, individual items of nature experience comprising; nature in the neighbourhood childhood (NCH) and current (NCU), visit frequency (NVF) were also retained for assessing their association with NR and MAAS.

Study variables were examined for independence using bivariate correlations; no correlation coefficients reached recommended thresholds for multicollinearity (Tabachnick & Fidell, 2001).

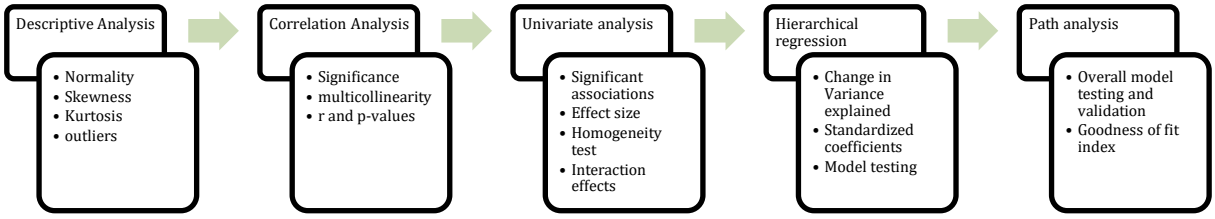


Figure 11 Stepwise procedure followed for data analysis along with parameters that were checked at each step.

4.4 RESULTS

Before analysis, the descriptive statistics of the sample population were examined. No cases with partially filled responses were found and hence none deleted. All variables were assessed for normality, skewness and kurtosis. All values were within the limit skewness (Sk = 2.0; Tabachnick & Fidell, 1996) and kurtosis (K = <7.0; Curran, West, & Finch,1996) therefore all analyses were performed on untransformed data. Descriptive results for all variables are shown in Table 2.

Table 2 Descriptive statistics for nature experience (NE_combined) nature in the neighbourhood (NCH and NCU), frequency of visit (NVF), and Mindfulness attention and awareness (MAAS)

	Mean	Std. Deviation	Skewness	Kurtosis
NE_Combined	7.6707	1.92172	.123	-.433
NCH	2.9581	1.01255	-.614	-.750
NCU	2.1437	1.04134	.512	-.913
NVF	2.5689	.97092	.161	-1.037
NR	25.7246	3.27639	-1.082	1.879
MAAS	59.7246	14.81646	-.161	-.776

A search for extreme values and box plots were utilized to test for outliers. Figure 12 shows the boxplots for nature in the neighbourhood, frequency of visit, and Mindfulness attention and awareness scores. Findings did not reveal any critical outliers. Therefore, none of the cases was deleted.

4.4.1 SAMPLE CHARACTERISTICS

To summarise the basic features of the data, some of the important features of the study sample were represented through graphical representations for visually appreciating the trends in data. Percentage analysis was conducted to define the characteristics of the sample population in the study. Notably, 71 % of the respondents rated the presence of nature in the neighbourhood during their childhood (NCH) as 'very much' or 'mostly', whereas only 28 % gave the same ratings for current neighbourhood areas (Figure 13). Most of the participants reported visiting nature-rich places for 2-3 days in a week (Figure 14). Further, almost 68.3% of the participants visit nature-rich places because they find it 'fascinating' and such places are perceived as 'places for being away'.

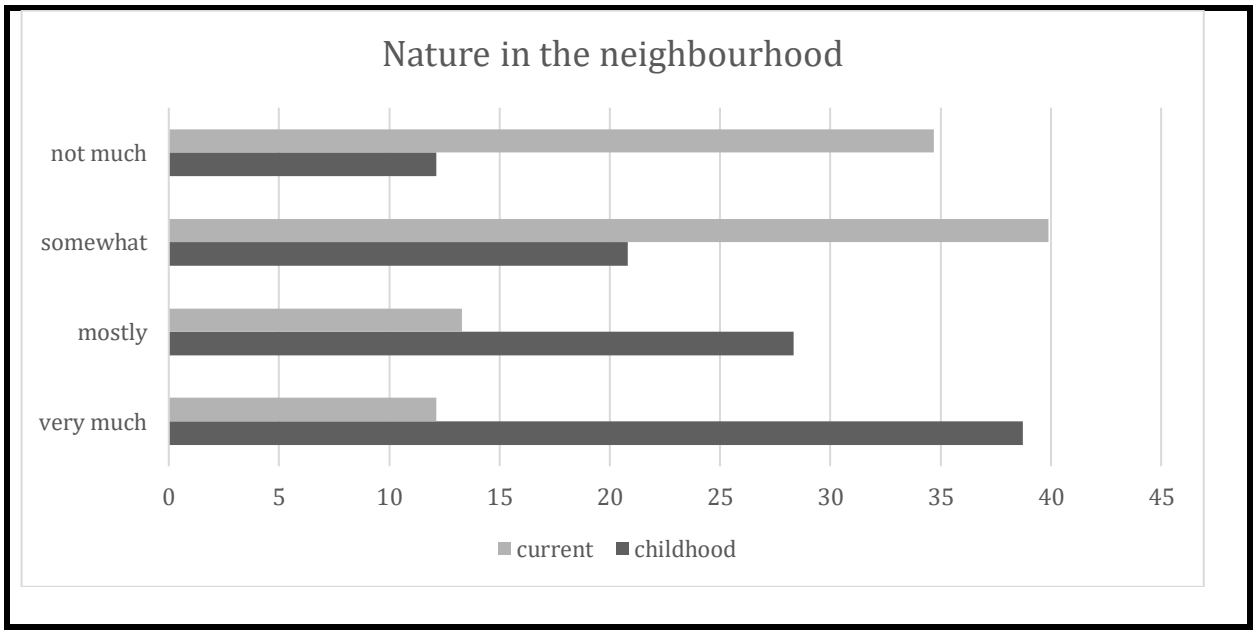


Figure 13 Percentage distribution for nature in the neighbourhood; Current and Childhood

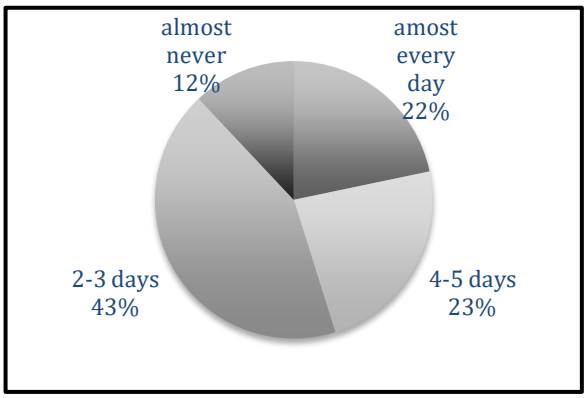


Figure 14 Percentage distribution of frequency of visit

About 55 % found it difficult to pay attention to their current emotions and 47 % to the present task as presented in Figure 15. About 60 % feel connected with nature, as presented in Figure 16.

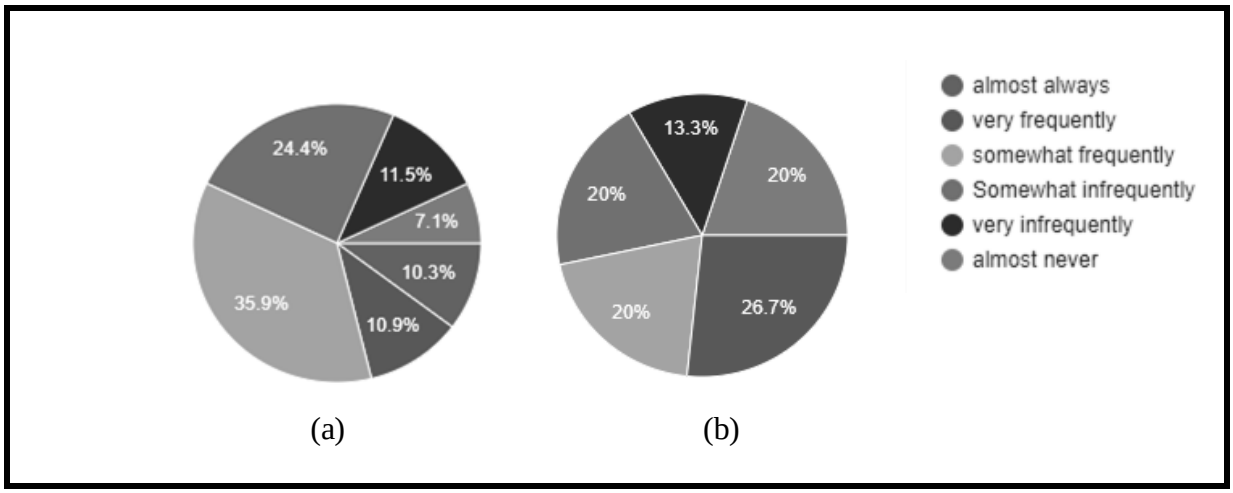


Figure 15 Percentage distribution of people who find it difficult to pay attention to their (a) emotions (b) tasks

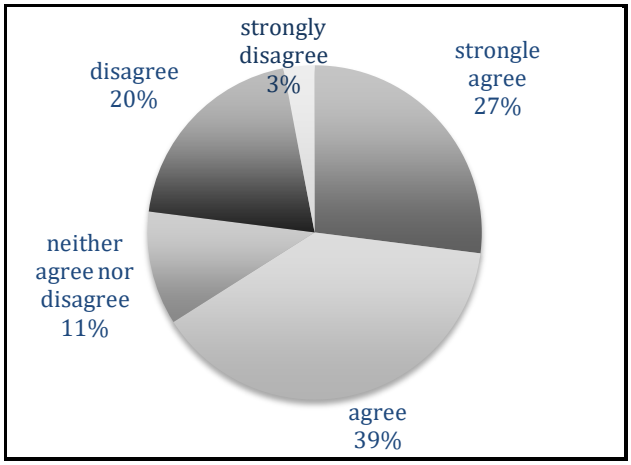


Figure 16 Percentage distribution of people 'feeling connected with nature.'

The demographic variables, age and gender had no significant association with either neighbourhood nature or frequency of visit ($p>0.05$). Furthermore, There was no association of age, and gender for the NR mean score ($p>0.05$). There was also no significant association of gender with the Mindfulness Attention and Awareness Scale (MAAS) ($p>0.05$) in the sample population. However, age had a marginally significant association with the older population reporting a higher score for MAAS. Therefore, in the analysis of variance and regression analysis, the effect of age was removed by including it as a control variable.

4.4.2 CORRELATION ANALYSIS

To test the hypothesis H1: There will be a positive correlation between nature experience (NE_Combined) and MAAS, a correlation analysis was employed for both NE- combined and its individual items. It was found that while nature experience (NE_ combined) positively correlated with MAAS ($r=.303$, $p<0.01$), there was no significant correlation between NCU and MAAS. However, there was a positive and significant correlation between MAAS, NCH ($r=0.168$, $p<0.01$) and NVF ($r=0.160$, $p<0.01$).

To test the hypothesis H1b: There will be a positive correlation between nature experience (NE_Combined) and NR. It was found that NR had a significant and positive correlation with nature experience (NE_combined) ($r=0.300$, $p<0.01$), NCH ($r=0.245$, $p<0.01$), NCU ($r=0.124$, $p<0.05$) and NVF($r=0.206$, $p<0.01$). The correlation coefficients and the alpha values of standardised questionairres (NR-6 and MAAS) are presented in Table 3.

Table 3 Correlation matrix

	NE_Combined	NCH	NCU	NVF	NR	MAAS
NE_Combined	1	.555**	.675**	.677**	.300**	.203**
NCH			.000	.055	.245**	.168**
NCU				.263**	.124*	.062
NVF					.206**	.160**
NR					(0.711)	.303**
MAAS						(0.908)

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.4.3 UNIVARIATE ANALYSIS

Univariate analysis was used to examine the association of nature in the neighbourhood (NCH and NCU), frequency of visit (NVF) with mindfulness attention and awareness scale (MAAS). A series of between groups one-way ANOVA was performed to test the mean score differences and the effect size.

Before conducting ANOVA, the assumption of normality was evaluated and determined to be satisfied with skewness and kurtosis less than 2.0 and 9.0 respectively (Schmider, Ziegler, Danay, Beyer, Buhner, 2010; see Table 2).

4.4.3.1 NATURE IN THE CHILDHOOD NEIGHBOURHOOD (NCH), AND MAAS

Prior to testing conducting ANOVA, the assumption of homogeneity of variance was tested and satisfied based on Levene's test, p= 0.801. The one- way ANOVA results yielded a statistically significant effect of NCH, $F\ (2,331) = 11.474,\ p<0.001$, η^2 =0.065 on MAAS. Further, to evaluate the differences between the mean of 'not at all', 'somewhat', 'mostly' and 'very much' presence of nature in the neighbourhood (childhood), the posthoc Bonferroni's multiple comparisons were conducted. To make the sample size equal, the category 'not at all' was merged into 'somewhat'.

Therefore, the post- hoc comparison was conducted for tree groups; ‘somewhat’, ‘mostly’ and ‘very much’. There was a significant difference between the group with ‘very much’ nature in the neighbourhood when compared with ‘somewhat’ and ‘mostly’ (all ps<0.001). However, there was no significant difference between ‘somewhat’ and ‘mostly’ nature in childhood neighbourhood groups (p >0.05). The graphical depiction of means and 95% confidence intervals across nature in childhood groups is presented in Figure 17**.**

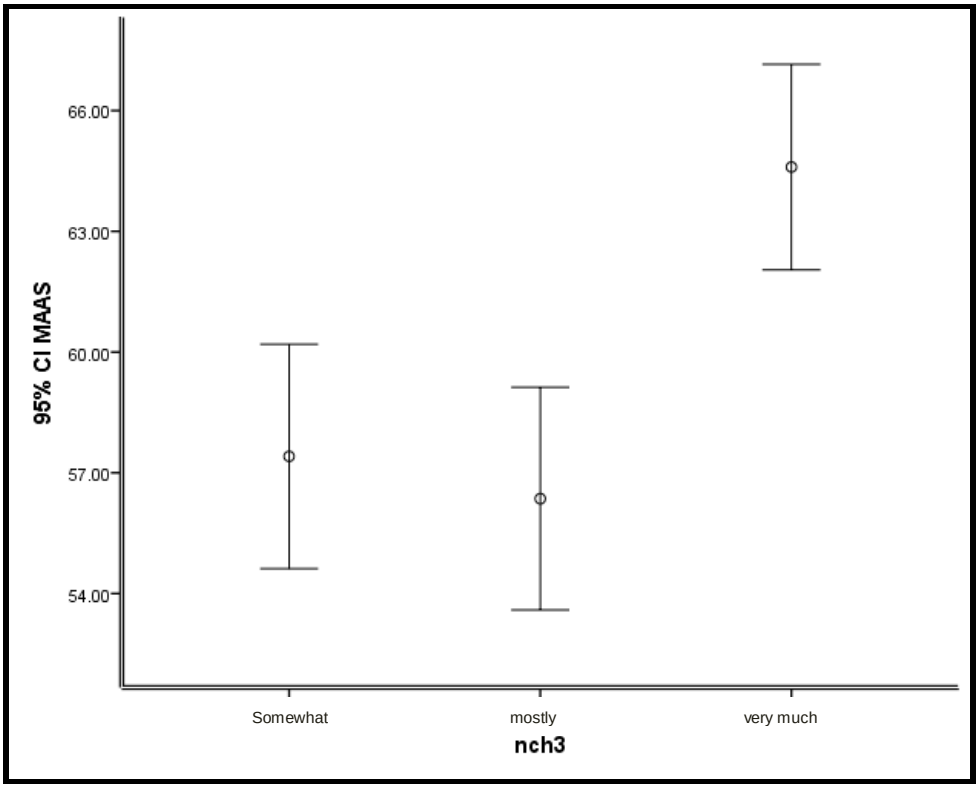


Figure 17 Bar chart with MAAS means and 95 % confidence intervals across nature in childhood groups

4.4.3.2 NATURE IN THE CURRENT NEIGHBOURHOOD (NCU), AND MAAS

It was found that the effect of NCU on MAAS was not significant (p>0.05). Therefore, no further analysis of differences between the means was conducted.

To explore the cases in which the NCU could have an association with MAAS, an interaction effect of NCU*NVF and NCU* NR was examined through a two way ANOVA. There was a

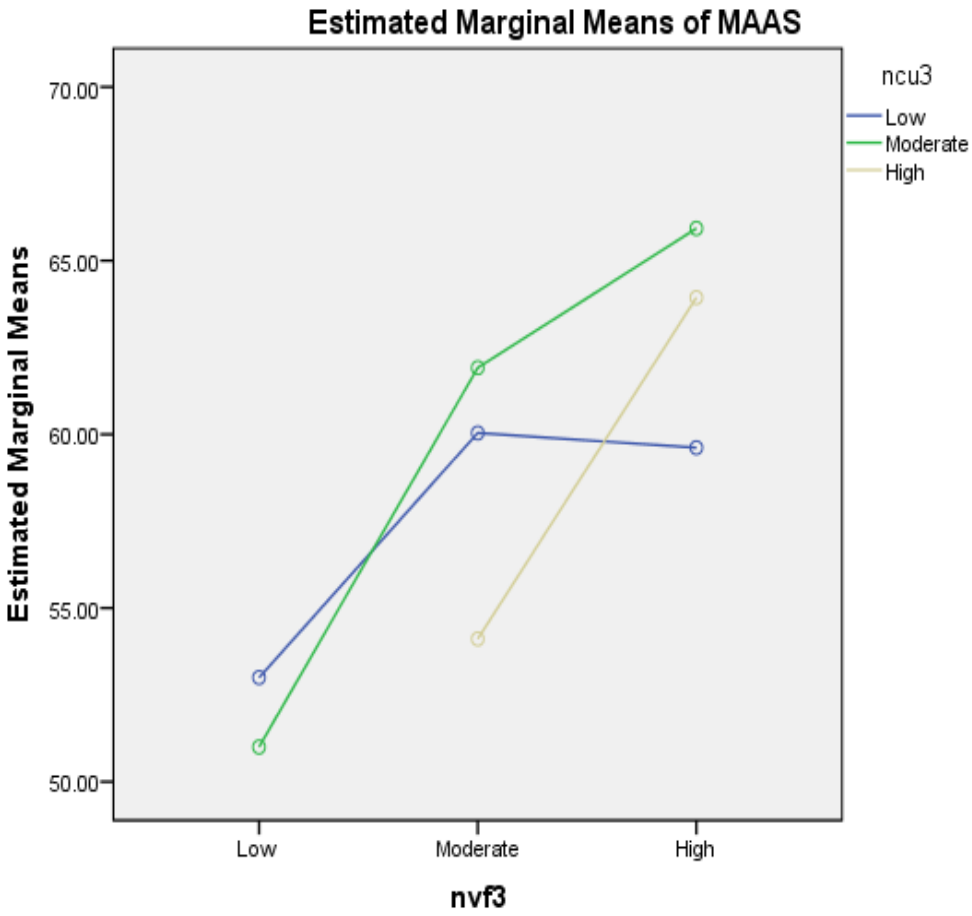


Figure 18 Marginal Means Plot of MAAS with different groups of nature in current neighbourhood and frequency of visit groups

significant interaction effect of NCU* NR F= 2.73, p<.001, η_p^2 =.216 on MAAS. It was also found that there was a significant interaction effect of NCU*NVF F= 2.50, p<.01, η_p^2 =.059 on MAAS. The graphical depiction presented in Figure 18 shows that the frequency of visit increases with increase in nature in the current neighbourhood areas. Further, it is also indicated that mindfulness attention and awareness (MAAS) is reported to be high with a higher frequency of visit for all nature in current neighbourhood groups.

4.4.3.3 Frequency of Visit (NVF), and MAAS

Prior to ANOVA, the assumption of homogeneity of variance was tested and satisfied based on Levene's test, p= 0.911. There was a significant effect of NVF on MAAS, $F\ (3,329) = 4.04$, $p<0.01$, η^2 =0.148. Further, to evaluate the differences between the mean of 'almost never', '1 or

2 days in a week', '3 to 5 day in a week' and 'almost every day' posthoc Bonferroni's multiple comparisons were planned. However to make the sample size equal, The categories were merged and recoded; 'almost never' as low, '1 or 2 days in a week' as moderate, '3 to 5 days in a week' and 'almost every day' to a high frequency of visit, The posthoc Bonferroni's multiple comparisons revealed significant differences between the groups with low visit frequency compared with high and moderate visit frequency (both ps<0.05). However, there was no significant difference in groups with the moderate and high frequency of visit (p=0.682). The graphical depiction of means and 95% confidence intervals of MAAS is presented in Figure 20.

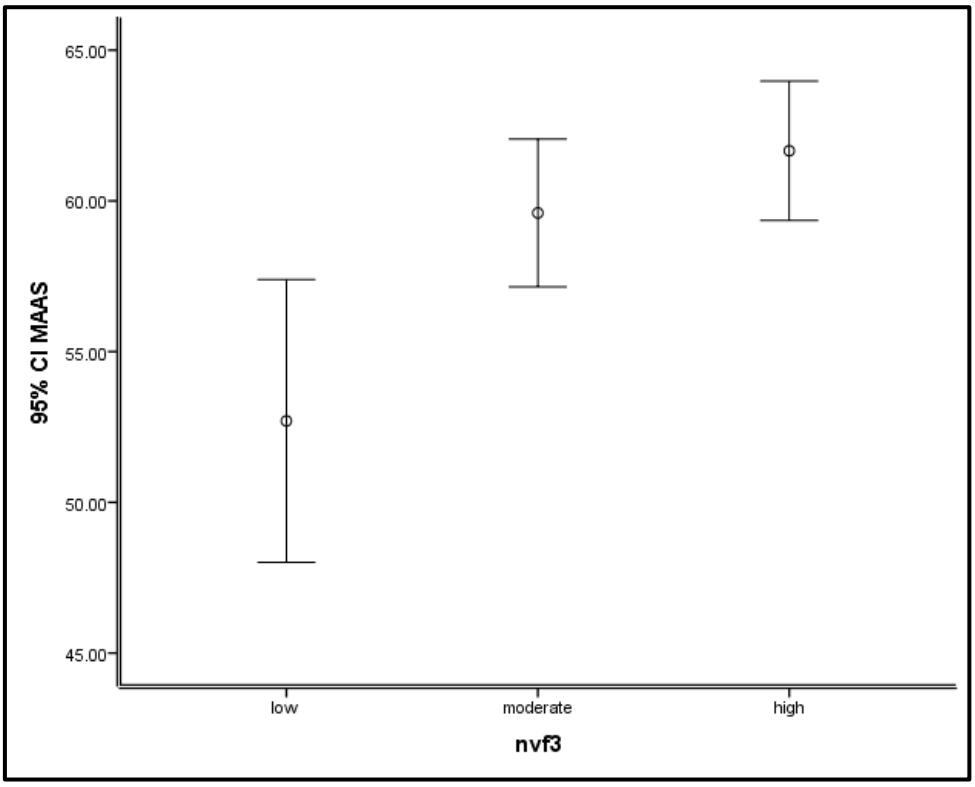


Figure 19 Bar chart with MAAS means and 95 % confidence intervals across frequency of visit groups

4.4.3.4 ROLE OF NATURE RELATEDNESS (NR) IN THE ASSOCIATION OF NATURE IN THE CURRENT NEIGHBOURHOOD (NCU) AND FREQUENCY OF VISIT (NVF)

To examine the hypothesis H5 that Nature relatedness (NR) will mediate the association of nature in the current neighbourhood (NCU) and frequency of visit (NVF).

The first condition for mediational analysis is that the independent variable (NCU) must significantly affect the mediator (NR). There was a no statistically significant effect of NCU on NR $p>0.05$. Therefore mediation analysis was not carried further.

However, the association of nature in the current neighbourhood (NCU) and the frequency of visit (NVF) was tested. ANOVA results demonstrated that there was a difference in the means of NCU, $F\ (1,330) = 10.064,\ p<0.001$, $\eta^2 = 0.084$. Further, to evaluate the differences between the mean of 'not much', 'somewhat', 'mostly' and 'very much' nature in the neighbourhood (current), the posthoc Bonferroni's multiple comparisons were conducted. To make the sample size equal, the category 'very much' was merged into 'mostly'. There was a significant difference between the group with 'mostly' nature in the neighbourhood compared with 'not much' (ps<0.001). However, there was no significant difference between 'not much' and 'somewhat' (p=0.751) nature in current neighbourhood groups on the frequency of visit mean scores. There was also no difference between the mean scores of 'somewhat' and mostly' in current neighbourhood groups (p= 0.135). The graphical depiction of means and 95% confidence intervals across the frequency of visit is presented in Figure 20.

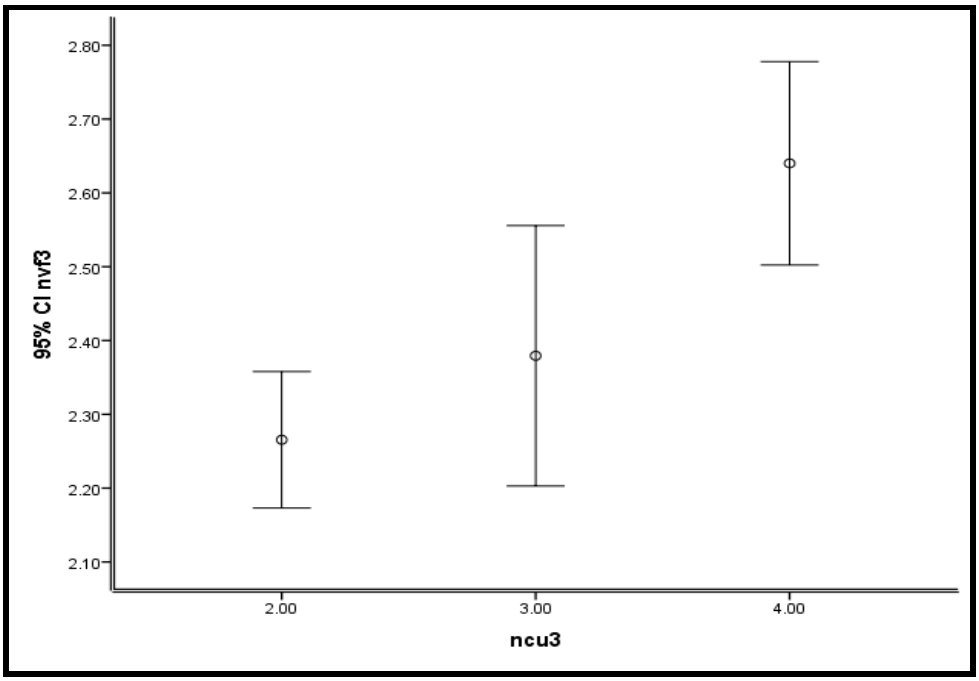


Figure 20 Bar chart with frequency of visit means and 95 % confidence intervals across nature in current neighbourhood groups

4.4.3.5 ROLE OF NATURE RELATEDNESS (NR) IN THE RELATIONSHIP OF NATURE EXPERIENCE (NE_COMBINED) AND MAAS

To examine the hypothesis H6 that Nature relatedness (NR) will mediate the association of nature experience (NE_Combined) and MAAS, hierarchical regression was conducted to evaluate the prediction of MAAS from NE_Combined. In the first stage, the control variable, age was include. In the second stage, NE-Combined and in the third stage, NR was added. The assumption for multicollinearity was examined using VIF statistics.

The first condition for mediational analysis is that the independent variable (NE_combined) must significantly affect the mediator (NR). There was a significant effect of NE_combined $F\ (2,331) = 24.241\ p<0.001$, with an R^2 of 0.12.

The second condition that independent variable (NE_ combined) must significantly affect the dependent variable (MAAS) was found satisfied, with a significant effect of NE_ combined *F(2,331) =34.314, p<0.001*, with an R^2 of 0.17.

In the third condition, mediator (NR) must significantly affect the dependent variable (MAAS), was also met. There was a significant effect of NR *F (2,331) =40.828, p<0.001*, with an R^2 of 0.19.

The fourth condition, the effect of the independent variable (NE_combined) (Model 2; β_2= 0.146, p <0.01) on the dependent variable (MAAS) should be weaker or non-significant (Model 3; β_3= 0.092, p= 0.074) when including mediator in regression equation was also satisfied as shown in Model 3 of Table 4. Regression analysis shows that there was a full mediation effect of NR in the association of nature experience and attention. The regression coefficients of NE_combined, NR with MAAS as the dependent variable are shown in Table 4. Further, to quantify the indirect effects, the difference in regression coefficient in equations with and without mediator was calculated (Judd & Kenny, 1984);

$$\beta_{indirect} = \beta_2 - \beta_1$$

Substituting β values from Model 2 and Model 1 as presented in Table 4;

$$\beta_{indirect} = 0.146 - 0.092 = 0.054$$

The hierarchical regression output tables are presented in Appendix 2.

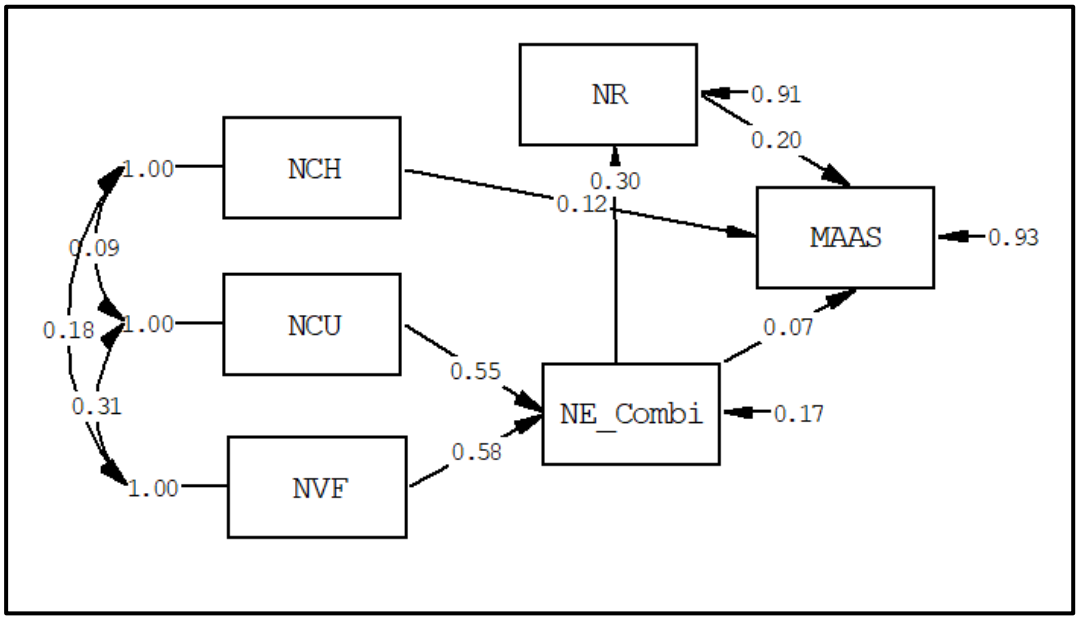
Table 4 Regression coefficients for dependent variable MAAS

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	46.563	1.869		24.916	.000
	age	7.527	.979	.389	7.685	.000
2	(Constant)	38.720	3.295		11.751	.000

	age	7.087	.981	.366	7.226	.000
	NE_Combined	1.123	.390	.146	2.875	.004
	(Constant)	20.251	5.890		3.438	.001
3	age	6.339	.983	.327	6.451	.000
	NE_Combined	.713	.398	.092	1.790	.074
	NR	.891	.238	.197	3.751	.000

4.4.4 PATH ANALYSIS

The relationships revealed in regression analyses were confirmed using path analysis with LISREL software. Figure 21 depicts the results for the full model with hypothesized associations among nature in neighbourhood both childhood (NCH), and current (NCU), frequency of visit, nature experience (NE_Combined), Nature Relatedness (NR) and Mindfulness attention and awareness (MAAS). Associations between nature experience (NE_combined), nature relatedness (NR), and MAAS was significant. Further, there was a direct effect of NCH on MAAS, which was not significant for NCU and NVF. Path analysis confirmed that Nature experience (NE_Combined) had both a direct and indirect effect on MAAS as described in Section 4.4.3.5. Most commonly reported fit indices based on McDonald and Ho (2002) were examined. The results on these indices were: chi-square (6) =943.28, $p < .05$; CFI = .91; RMSEA = .065. The chi-square statistic is highly sensitive to large sample sizes such that it is uncommon to find a non-significant test value suggestive of a good fit; of the remaining indices, the CFI value (i.e., it was >.90) and the RMSEA (i.e., it was <.08; McDonald & Ho, 2002) suggested an acceptable fit.



Chi-Square=943.28, df=6, P-value=0.00000,

Figure 21 Path diagram depicting the total effects of Nature experience (nature in neighbourhood, frequency of visit), nature relatedness and directed attention (MAAS). The coefficient are unstandardises regression coefficients.

CHAPTER 5

STUDY 2: NEUROCOGNITIVE EFFECTS OF NATURE EXPERIENCE ON DIRECTED ATTENTION: A LAB-BASED EXPERIMENTAL STUDY

5.1 INTRODUCTION

This chapter describes the lab-based experimental study, which was undertaken to seek an answer to the second research question (RQ2)- 'What are the neurophysiological correlates of nature experience and directed attention?'. An experiment was designed using EEG as the physiological measurement tool, a cognitive task for performance measurement, and an audiovisual to manipulated nature experience in controlled lab settings.

EEG data provided the benefit of being objective and aided the analysis of the participant's brain responses in pre and post nature experience cognitive tasks. Brain responses through the Event-related potentials (ERP) gave a real-time temporal resolution of neural processes underlying task performances (Luck, 2005). Fundamental assumptions of ERP research is that; i) the cognitive task can be designed in such a way that elicits a specific neural cognitive and, ii) the ERP can be separated into different components, each indexing the degree of activity of a particular cognitive function.

Attention Restoration Theory (ART) postulates that nature experience implicates involuntary attention. The evidence suggests that involuntary attention mechanisms perhaps requires lesser 'inhibitory control' than required for directed attention (Posner, Sheese, Odludaş, & Tang, 2006; Prinzmetal, Zvinyatskovskiy, Gutierrez, & Dilem, 2009). Therefore, it is argued that nature experience may help in the recovery of the 'inhibitory control' cognitive processes reflected in the improved performance in a subsequent cognitive task, with greater 'inhibitory control', as an indicator of efficient and enhanced attention.

Neurocognitive processes involved in the 'inhibitory control' and directed attention were elicited through flanker task. The task was designed to elicit differences in cognitive processing due to the absence or presence of conflicting and distracting information. Most commonly, EEG studies have reported the implication of fronto-parietal cortical brain regions with the neurocognitive processes involved in attention. Particularly, a fronto-central negative peak- N2 appearing around 180- 325 msec (Kopp, B., Rist, F. & Mattler, 1996; Xie, Ren, Cao, & Li, 2017) and centro- parietal positive peak- P3 appearing around 350-500 msec (Cahn & Polich, 2006; Norris, Creem, Hendler, & Kober, 2018) after the stimulus onset has been reported to be associated with inhibitory control and directed attention.

In this study, the neurophysiological correlates of nature experience and directed attention were examined by the change in cognitive performance (reaction time and accuracy), event-related potentials associated with cognitive processes of attention (P2, N2 and P3) in before and after conditions. To seek answers to first sub-question **(RQ2a)** – What are the effects of nature experience on response time and accuracy in directed attentional tasks? Following hypothesis were formulated;

H1a- There will be a significant difference in the mean response times on the cognitive task in before and after nature experience condition,

H1b- There will be a significant difference in the mean response times for congruent and incongruent trials of the cognitive task in both before and after nature experience.

H1c- There will be a significant difference in the mean response time in the before and after open eye rest condition.

H2a- There will be a significant difference in the mean accuracy scores for the cognitive task in before and after nature experience condition,

H2b- There will be a significant difference in the mean accuracy scores for the congruent and incongruent trials of the cognitive task in both before and after nature experience.

H2c- There will be a significant difference in the accuracy scores in the before and after open eye rest condition.

To examine the second sub-question **(RQ2b)** - 'What are the effects of nature experience on the EEG frequency band power in different regions of the brain?' it was hypothesised that;

H3- There will be a significant difference in the theta and alpha power before and after experience condition in all six brain regions.

The third sub-question **(RQ2c)-'**What are the effects of nature experience on Event-Related Potentials (ERP) associated with attention?' was examined through the following hypothesis;

H4a- There will be a significant difference in the mean activity for event-related potentials-P2 (160-225ms), N200 (180-325ms) and P300 (250- 600ms) in the fronto-parietal regions for before and after nature experience condition,

H4b- There will be a significant difference in the mean activity for incongruent trials than congruent trials of the cognitive task for event-related potentials-P2 (160-225ms), N200 (180-325ms) and P300 (250- 600ms) in the fronto-parietal regions both before and after nature experience condition.

Section 5.3 describes the methods and measures that were employed. It also includes detailed data analysis techniques that were used. In Section 5.4, the results of the experiment are presented.

5.2 BACKGROUND

In this experiment, it was assumed that viewing of nature audio-video would generate a nature experience similar to real-time nature. Earlier studies have found that both real and virtual

exposure to the natural environment, impact cognitive performance positively (Bornioli et al., 2018; Yin et al., 2018). The underlying assumption is that both the audio-video or real-time natural environment presents 'soft fascinating' stimuli that evokes nature experience. According to ART (Attention Restoration Theory; details presented in Section 2.5), nature experience implicates a feeling of 'being away', a sense of 'coherence' and are found 'compatible' for the restoration of mental capacity (Kaplan, 1995). Further, ART posits that the 'soft fascinations' presented by the natural environment, capture the attention 'involuntarily' which does not require effort. The activation of involuntary attention offers the executive functions mechanisms (directed attention) time to rest and recover, pessimistic thoughts are blocked, and positive emotions replace negative ones (Bratman, Daily, et al., 2015). The recovered directed attention mechanisms may then get reflected in the cognitive performance on a task subsequent to nature experience. An open eye resting state (OERS) was introduced in the experimental design as an alternate setting to examine the differences in cognitive recovery of attentional resources in the two comparative conditions. It was assumed that an open eye resting-state might not necessarily provide restoration of attention. The rationale behind this assumption was that OERS arguably is devoid of 'fascinating' stimuli, or a feeling of 'being away', and may lack a sense of 'coherence'- the elements according to ART necessary for the restoration of attentional capacity. Therefore, during OERS, the individuals may likely get engaged in self- generated thoughts (mind-wandering) about past or future events. Studies report that cognitive mechanisms involved in mind-wandering tend to recruit brain networks associated with executive functioning (Gonçalves et al., 2018) and thus may not help in the recovery of attentional resources. In this study, the difference in cognitive performance was evaluated for both OERS and nature experience to elucidate the unique effects of nature experience on directed attention.

5.3 METHODS AND MEASURES

This study examines the differences in EEG waveforms in a lab experiment conducted with a cognitive (Flanker) task before and after nature experience. Nature experience was manipulated through nature video with real-time natural sounds as stimuli in a controlled lab setting. Both the cognitive task and the nature experience stimuli were presented on a 42-inch monitor. The participants were briefed about the experiment and were told about the EEG data collection method prior to their coming to lab. They were also asked for any intake of medication or extreme emotional state that they may have undergone recently. The experimental briefing and debriefing protocol are described in supplementary materials, and the experiment details are presented in this section.

5.3.1 PARTICIPANTS

Total of 41 male participants with a mean age of 25 years (range 20-33 years) was included in the experiment. All participants were right-handed, had normal or corrected to normal vision and were from the student community of Indian Institute of Technology Delhi. None of the participants had any prior expertise or background in neuroscience or studies in nature experience. Exclusion criteria included extreme stress, sleep deprivation, a current diagnosis of a physical or psychiatric illness or regular use of medication. The participants were asked to sign their consent for participation prior to the experiment. They were compensated with food coupons after the experiment.

5.3.2 PROCEDURE

A continuous electroencephalographic activity was recorded from the scalp with a 64-channel active electrode system (ActiCHamp, Brain Products GmbH, Germany) based on 10/20 system, while participants performed on the Flanker task before, after and during the viewing of nature

audiovisual. Participants were administered four blocks of the flanker task, two blocks in the beginning and again two blocks at the end of nature experience. An open eye resting state (OERS) was included in between the two blocks before and after nature experience, as shown in Figure 22. The raw EEG was sampled at 500 Hz, referenced to default reference FCz and offline re-referenced to mastoids. Impedance was maintained below 20 kΩ. All experiments were conducted in a quiet, dimly lit room where each participant was seated in a comfortable chair ~75 cm from an LG 42″ computer monitor with a refresh rate of 60 Hz and a view angle 178 degrees.

The participants were briefed at the beginning of the experiment procedure and were instructed to remain relaxed and avoid eye or gross body movement during the experiment. They were instructed to imagine as if they were actually taking a walk through the scenes/landscapes shown in the video. They were also asked to make a mental note of their feelings, sensations, thoughts and experiences that they may undergo during nature audio-video viewing. The experiment ended with a debriefing and a short subjective interview session.

A checklist of instructions and steps to be followed during data collection was prepared in advance and was uniformly applied for each participant. A copy of the checklist is placed at Appendix 3. The overall flow of the experimental procedure is depicted in Figure 22.

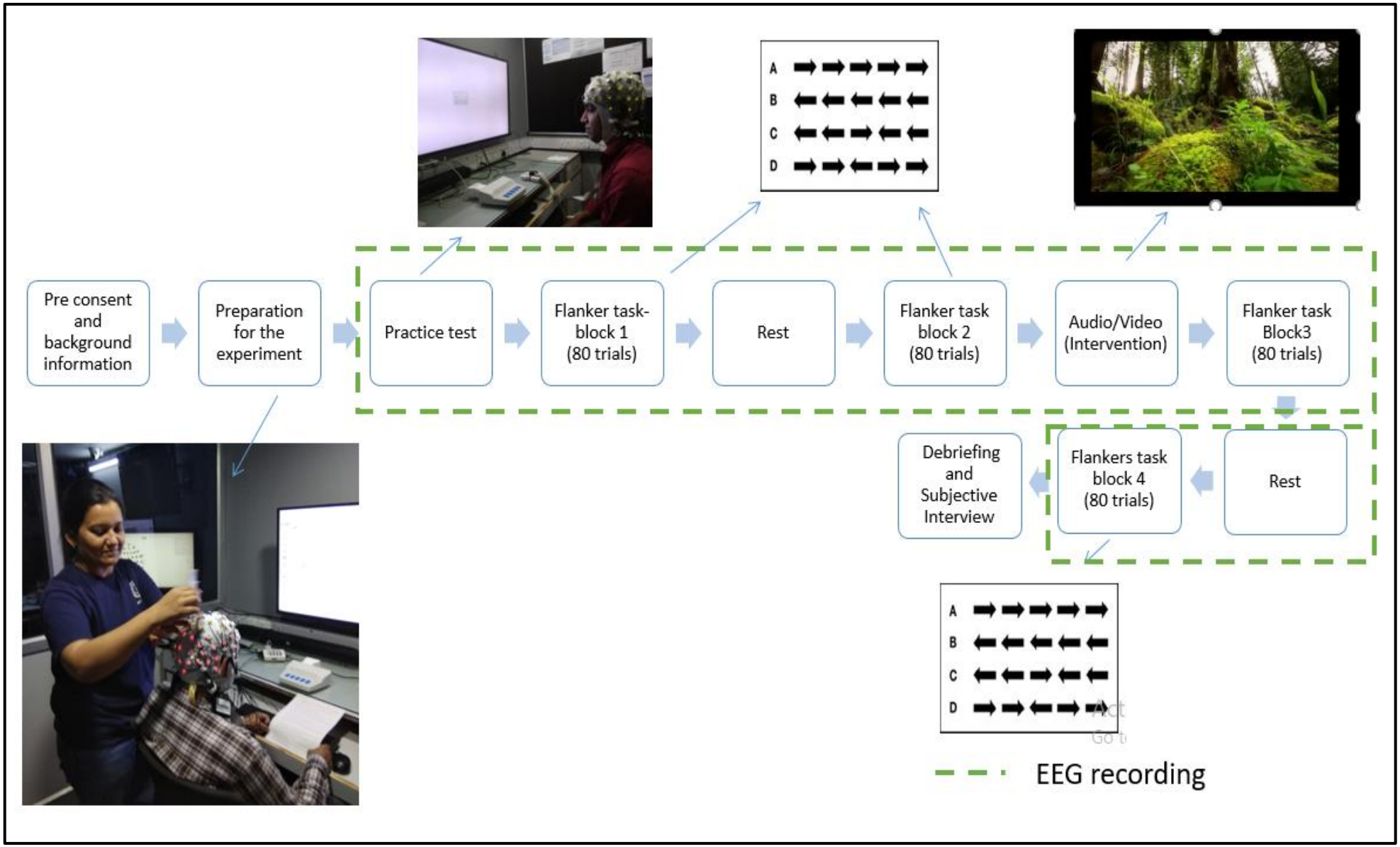


Figure 22 Step wise depiction of experimental procedure

5.3.3 SELECTION OF STIMULI FOR THE EXPERIMENT

The nature audio-video (AV) included as nature experience stimuli in the experimental paradigm were selected in a two-stage selection procedure. Open source videos available at BBC, National Geographic and YouTube were searched with “nature” OR “natural environment”, AND “Natural Sounds”. The main selection criteria was a video consisting of the spatial features with medium density flora that resembles everyday nature that can be found in the urban areas. Since earlier studies have reported that a 10 mins exposure to the natural environment is also restorative, a video length of 15 mins was considered appropriate for the experiment. Twenty videos that matched the selection criteria were shortlisted for evaluation. Audio-video (AV) with longer duration were truncated at 15 mins to maintain consistency. A peer group of research scholars did first stage screening. The screening process involved rating each video on the scale of 0-5, based on two factors. First, the representativeness of A/V with respect to natural surroundings that are likely to be found in the neighbourhood or peri-urban areas. Second, on the immersive effect of the AV to elicit the nature experience. In the first level screening, four AVs that had received the maximum rating was shortlisted. In the second level screening, all four shortlisted AVs were shared with four subject experts each from environmental sciences, natural sciences, psychology and social sciences for their ratings. AV which received the highest score was selected.

5.3.4 COGNITIVE (FLANKER) TASK

Several adaptations of flanker task are known to involve focused attention, selective attention and directed attention cognitive mechanisms and are traditionally used to measure the efficiency of attentional processing (Eriksen & Eriksen, 1974; Kopp, Mattler, & Rist, 1994; Larson, Clayson, & Clawson, 2014; Pires, Leitão, Guerrini, & Simões, 2014). Participants were required to focus attention on the direction of the centre, target arrow while inhibiting the direction of the flanking arrows and press either the left or the right arrow button on the response box based on the direction

of the central arrow. Conflict is induced by the incongruent trials (central arrow point towards opposing direction than the flanking arrows) where the presence of distracting information suggests an alternative incorrect response (Eriksen and Eriksen, 1974). The presence of distracting information that is incongruent as opposed to congruent with the appropriate response produces conflict and engages all the three cognitive sub-process of; detection, inhibitory control and conflict processing. As a result, incongruent trials elicit an electrophysiological response that is reported to be detected as early as 200ms after the onset of the stimuli (Rueda et al., 2015). An example of a flanker task is depicted in Figure 23.

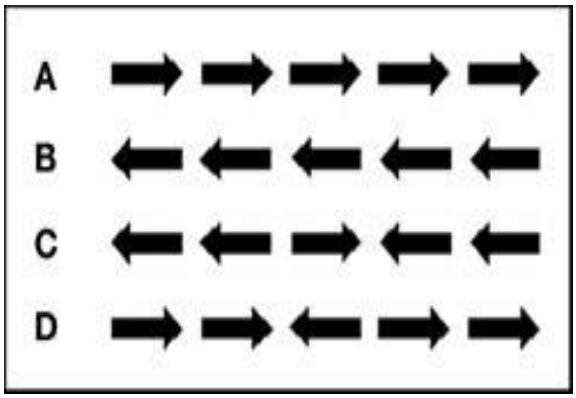


Figure 23 Example of flanker task A& B Congruent C& D incongruent

5.3.5 EXPERIMENTAL SETUP

Flanker task and the nature stimuli were presented using E-Prime presentation software (E-Prime 3.0 Professional, Psychology Software Tools, Inc.) with predefined task lists. Trials in the flanker tasks were randomised and presented in black against a white background on a screen. The response time was restricted to 2000 ms with a fixation period of 1000ms. A fixation point (+) was presented at the centre of the screen during the fixation period.

Chronos®, a multifunctional USB based response collection and stimulus device, was used to record the responses. Chronos® supports the custom-designed silicone rubber keys that consist of

an oversized activation area to ensure accurate presses and releases. The device can record simultaneous button presses with full n-key rollover and customize debounce intervals to ensure data collection never suffers from missed responses. The response box was connected to the recorder device through an input/output (I/O) expander. The I/O expander provides up to 16 digital inputs and 16 digital outputs. The I/O expander is also programmed along with task events in E-Prime, to deliver synchronised markers to the EEG data. Figure 24 depicts the picture of a participant with the experimental setup. Figure 25 shows the different components of the experiment.

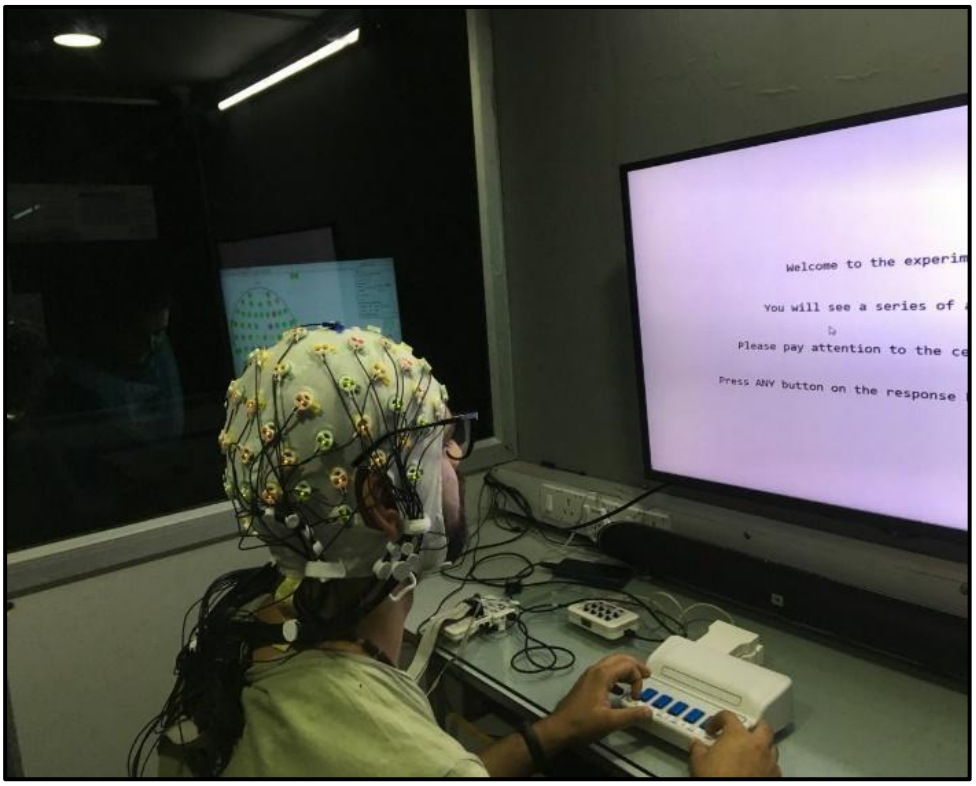


Figure 24 Picture depicting a participant with the experimental setup

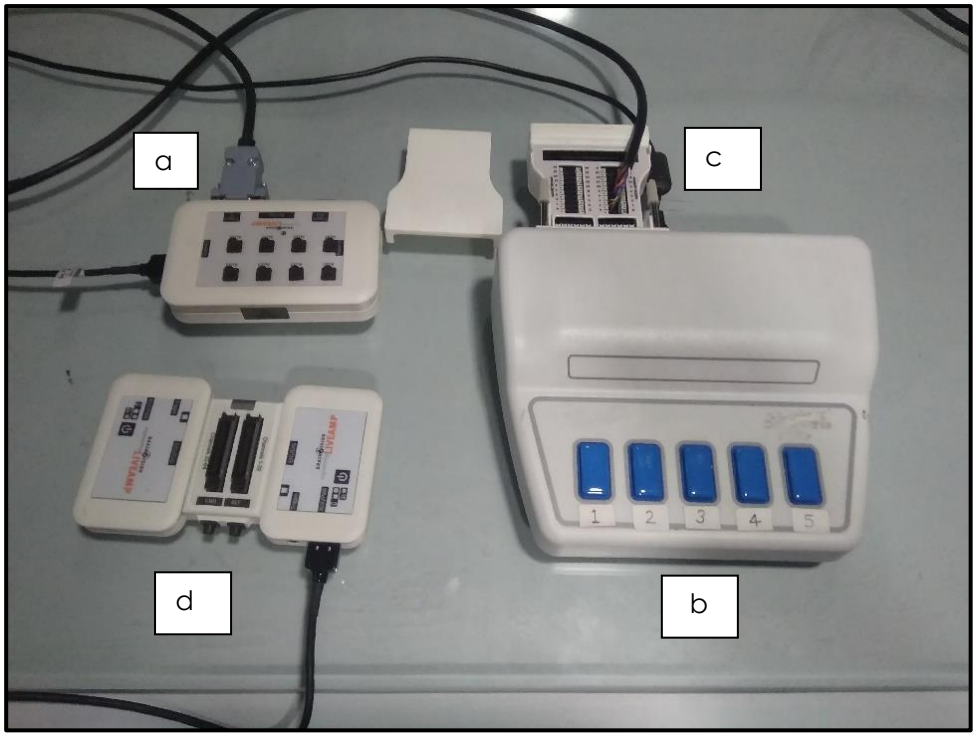


Figure 25 Picture of the (a)trigger box extension (b) Response box (Chronos®) (c) Chronos I/O Expander (d) Amplifier 64(32+32) channel electrode system

5.3.6 ELECTROENCEPHALOGRAPHY

Data was collected from a 64-channel active electrode system (LiveAmp, Brain Products GmbH, Germany) at 500 Hz, referenced to default reference FCz, and all electrodes impedances were kept below 20 kOhms. Figure 26 shows the distribution of electrodes in a 10-20 system of electrode placement.

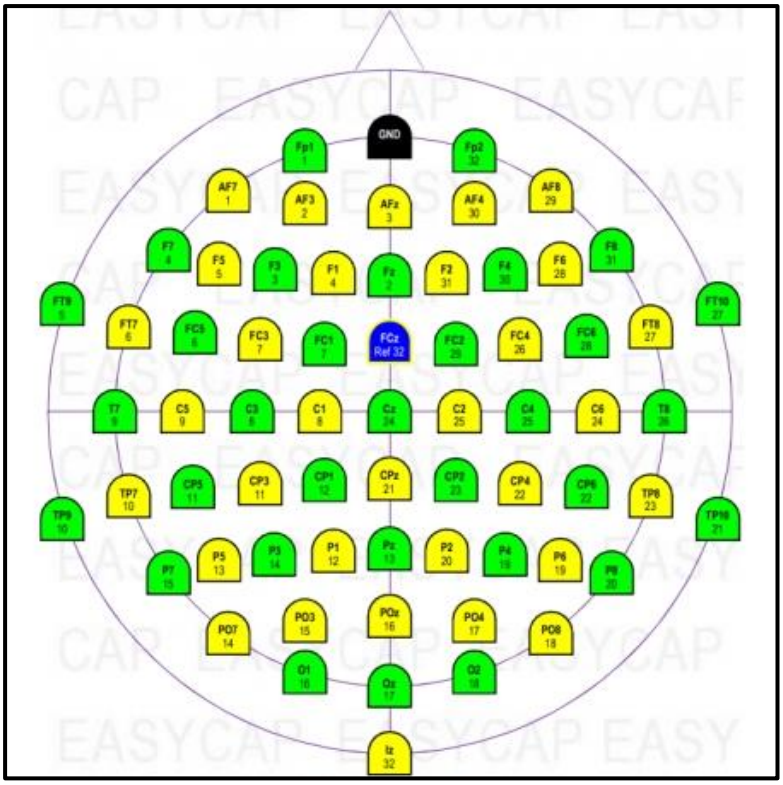


Figure 26 Distribution of 64 channel 10/20 system of electrode placement (source: EasyCap)

5.3.7 Control Measures

As described in the literature review Chapter 2, Section 2.7, both internal and external, are found to affect the nature experience and the experimental outcomes. Therefore, the experiment design of this research included measures to control such factors. Internal factors such as prior stress level were controlled by screening all participants for any extreme stress level through questions before the experiment. A copy of the questions asked before the experiment are included in the checklist presented in Appendix 3. In order to reduce the effect of stress due to the daily activities of the participants, all the experiments were undertaken at the same time of the day between 11:00 to 2:00 pm. Further, it was also ensured that the experiments are not conducted during the examination period to avoid exam-related stress. Other factors, such as safety and company of others, did not apply to the study design. The experiments were conducted in a lab and therefore

posed no safety issues. External factors were controlled by a careful selection of the audio-video stimuli as explained in Section 5.2.3

The experiment design also included measures to control confounding factors as described in detail in Chapter 3 Section 3.4; such as; repeat measure effects, Hawthorne effect and good-subject behaviour. Repeat measure effects were controlled by including a practice block before collecting a baseline or pre-test data. Hawthorne effects were avoided by maintaining a controlled lab setting with a separate experiment and observation room, which ensured that the participants are not made conscious of being watched. The participants were briefed about the experiment and clearly communicated on the blind review and confidentiality of the results that will have no bearing on them to avoid any 'good subject behaviour' effects especially in the subjective interviews.

5.3.8 DATA ANALYSIS

The analysis was conducted on the data collected from three different sources during the experiment; a) behavioural data obtained from E-prime, and b) spectral data analysis, and event-related potential data analysis from the data collected from EEG, and c) First-person experience reports.

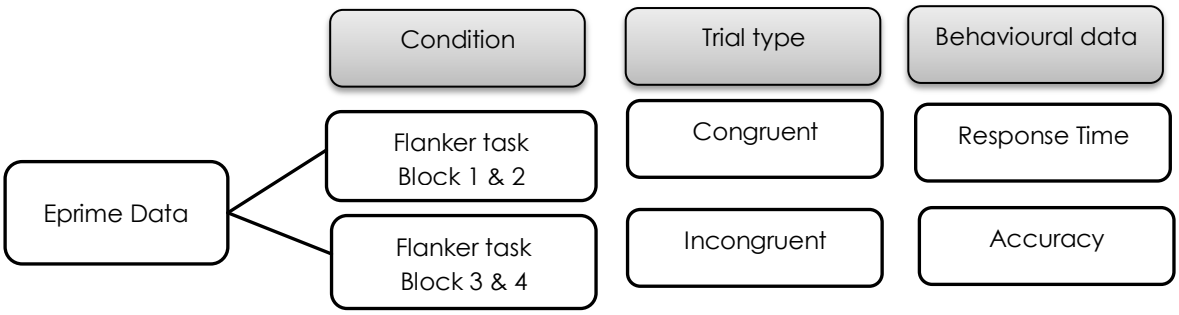


Figure 27 Data classification of the Eprime data

The behavioural data were retrieved from the data file of E-prime software. The response time for each of the trials was segregated based on the test block (Figure 27). Further, they were also

classified based on the trial type. The information on the correct or incorrect response for both congruent and incongruent trial type was examined for calculating percentage accuracy for each of the two test blocks in the before and after nature experience condition.

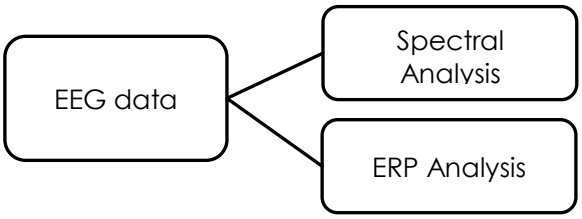


Figure 28 Segregation of EEG data analysis

EEG data analysis was performed using Brain Vision Analyzer software ver. 2.0 (Brain Products GmbH, Germany). The EEG data were analysed for dominant frequencies using spectral analysis techniques and for ERP using methodology as described by Luck (2005), as shown in Figure 28. The steps followed for pre-processing, and data extraction is presented in Figure 29. Data were re-referenced to the average of the left and right mastoids (TP9 and TP10)(Bertrand, Perrin, & Pernier, 1985; Sänger, Bechtold, Schoofs, Blaszkewicz, & Wascher, 2014; Tucker, Liott, Potts, Russell, & Posner, 1994), The artifact correction was performed using the method included in the Brain Vision Analyser manual. The steps followed for pre-processing were same for ERP and spectral analysis. However, there was a difference in processing pipeline after segmentation as described below.

For spectral analysis, the data after pre-processing was downsampled to 256 Hz to get a maximum resolution of 0.5 Hz. The segmentation was done based on markers for a before and after audio-video viewing sessions. Fast Fourier transform was performed on epochs of 0.5 ms with 50 % overlap on both the segments. The frequency band power was calculated for both the segments in the pre and post- audio-video viewing. Data were analysed for following frequency bands: theta (3.5–7.5 Hz), and alpha (7.5–12.5 Hz). The mean frequency band power for the alpha and theta was calculated for six regions- frontal, fronto-central, central, centro-parietal, parietal and parieto-

occipital. Statistical analysis for theta and alpha was undertaken using a series of paired sample t-test for all regions before and after nature experience.

Before the analysis of variance, Mauchly's test of sphericity was used to check the sphericity. Where appropriate, the Greenhouse-Geisser correction was applied for sphericity. In all comparisons, 2 (congruent/incongruent) x 2 (pre/post) repeated-measures ANOVA significant effects of conditions on the grand average waveforms for each time window. Bonferroni's contrast was employed to examine the differences between conditions.

The difference in inhibition was computed as the difference wave for the P2, N2, and P3 waveforms at frontal (Fz) and parietal (Pz) electrodes, respectively, between grand averaged incongruent trials, and grand averaged congruent trials for both pre and postcondition. Paired sample t-test was used to examine the significant differences.

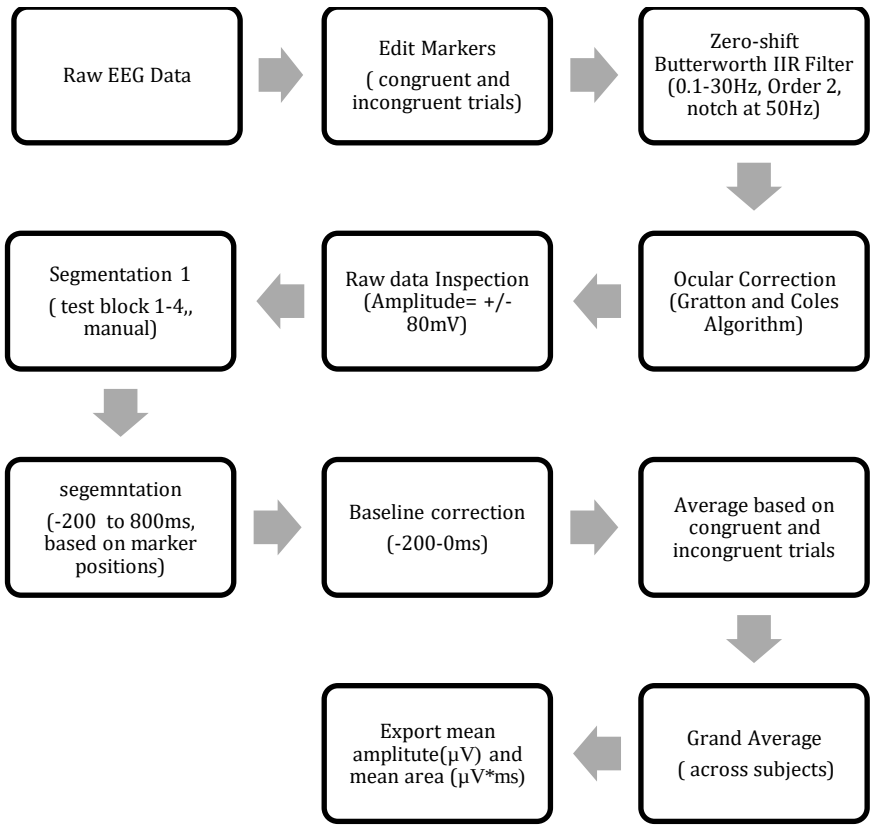


Figure 29 Stepwise EEG data analysis using Analyser Ver 2.0

The third type of data collection techniques included subjective reports after the experiment session (Figure 30). The data was collected using format consisting of open-ended questions pertaining to the participants' experience during the viewing of nature audio-video stimuli. The

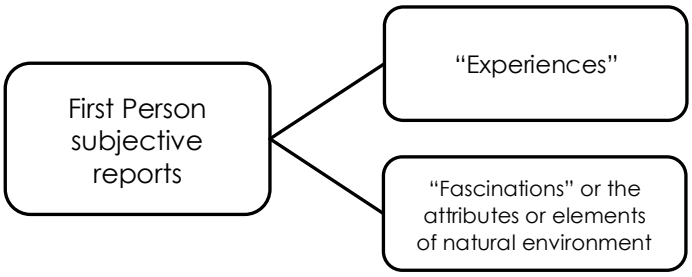


Figure 30 Subjective data analysis segregation

subjective first-person experience reports were analysed for the content of the experiences and for what the participants found fascinating in the audio-video stimuli. The questionnaire used to record the responses is presented in Appendix 3. The self -reports were examined through several stages; i) The raw recordings were manually transcribed, ii) Initial coding for all the descriptions for 'experiences' and elements of nature that were found 'fascinating' was done in vivo iii) In the third stage, the codes were analysed for emerging themes and code groups were formed and iv) The code groups were then analysed for frequency through frequency analysis. The output was obtained as a pictorial representation using the word cloud. The analysis of self- report data was done using ATLAS. Ti Scientific Software Development GmbH version 8.1.

5.4 RESULTS

This subsection is divided into three types of analysis conducted on the; a) behavioural data obtained from E-prime, and b) spectral data analysis, c) event-related potential data analysis from the data obtained from EEG. Data from two participants were excluded prior to analysis, due to loss of marker information during EEG recording. Preliminary analysis using t-test shows that there was no significant difference with respect to age, or qualification for the response time and accuracy (all $p>0.05$).

5.4.1 BEHAVIOURAL ANALYSIS

The effect of nature experience (NE) on response time examined through the test of the hypothesis; **H1**- There will be no difference in the mean response times on the cognitive task in before and after nature experience condition, and **H1b**- There will be no difference in the mean response times for congruent and incongruent trials of the cognitive task.

The difference in mean response time across two conditions (before and after nature experience) X 2 congruency types (congruent and incongruent trials) was examined using within-subject measure ANOVA. Since the assumption for sphericity was not met (*Mauchly's W*= 0.239, $p<0.05$), the Greenhouse-Geisser adjustments were applied. The results show significant effect of condition (nature experience) on response time F (1.56, 99) =14.75, $p<.001$, $\eta^2_p=0.305$. Further, the comparisons revealed significant effect of nature experience on the response time for congruent trials F (1,33) =11.03, p <.002, $\eta^2_p=0.251$ and incongruent trials F (1,33) =9.27, $p<.005$, $\eta^2_p=0.219$. Mean and Standard deviations are presented in Table 6.

Table 5 Mean and Standard Deviation (SD) for Response Time and Accuracy for Flanker task in before and after nature experience

	Response Time		Accuracy	
	Mean	SD	Mean	SD
Congruent Before NE	544.81	147.70	.90	.01
Incongruent Before NE	594.15	147.61	.94	.14
Congruent After NE	483.75	98.39	.90	.01
Incongruent After NE	531.78	101.52	.96	.04

As expected by the experimental paradigm of the flanker task there was a significant effect of congruency on response time in both before $F(1,33)= 25.225$, $p<.001$, $\eta^2_p=0.433$, after nature experience, $F(1,33)= 25.86$, $p<.001$, $\eta^2_p=0.48$ with increased response time for incongruent trials in both before and after nature experience. Figure 31 represents the mean, median, and the variance in the overall response times and Figure 32 and Figure 33 represents data for congruent and incongruent trials, respectively.

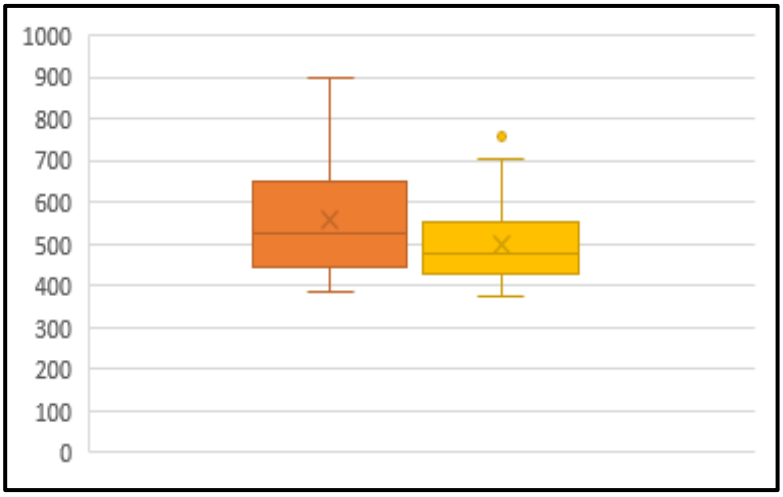


Figure 31 Response time averaged across congruent and incongruent trials for before and after nature experience

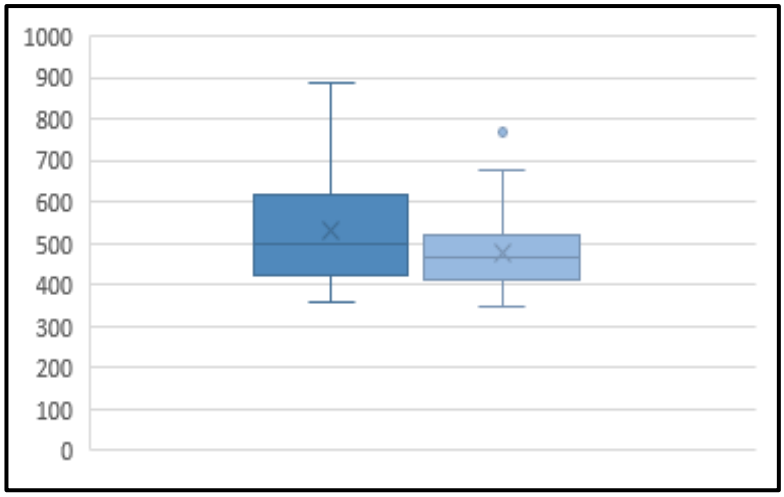


Figure 33 Response time averaged for incongruent trials before and after nature experience

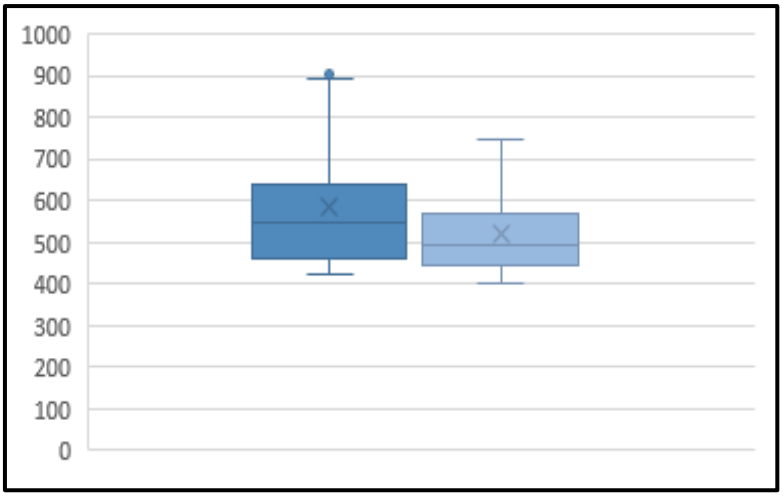


Figure 33 Response time averaged for congruent trials before and after nature experience

The examination of **H2$_0$-** that there will be no difference in the mean accuracy scores for the cognitive task in before and after nature experience condition, **H2b$_0$-** that there will be no difference in the mean accuracy scores for the congruent and incongruent trials of the cognitive task was done across two conditions (before and after nature experience) X 2 congruency types (congruent and incongruent trials). The repeated measure ANOVA results show that there was a no significant effect of condition on the accuracy of either congruent trials or incongruent trials ps>0.1. However, there was significant effect of congruency on accuracy for before F (1, 50) = 94.54, p<0.001, η^2_p=.75 and after F (1, 50) = 47.5, p<0.001, η^2_p=.60 NE, with more accuracy scores for incongruent trials than congruent trials. Figure 34 depicts the distribution of accuracy (mean and standard deviation). Mean, and the standard deviation is given in Table1. Noteworthy is that there was a marginal increase in the accuracy for incongruent trials in after NE flanker task.

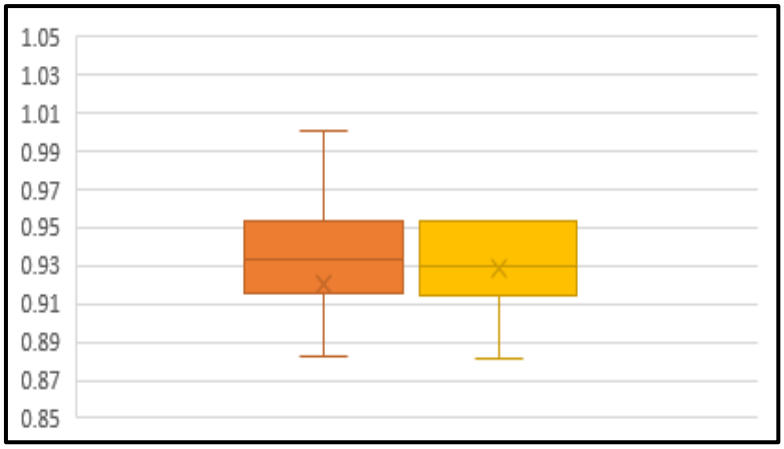


Figure 34 Accuracy averaged across incongruent and congruent trial in before and after nature experience condition

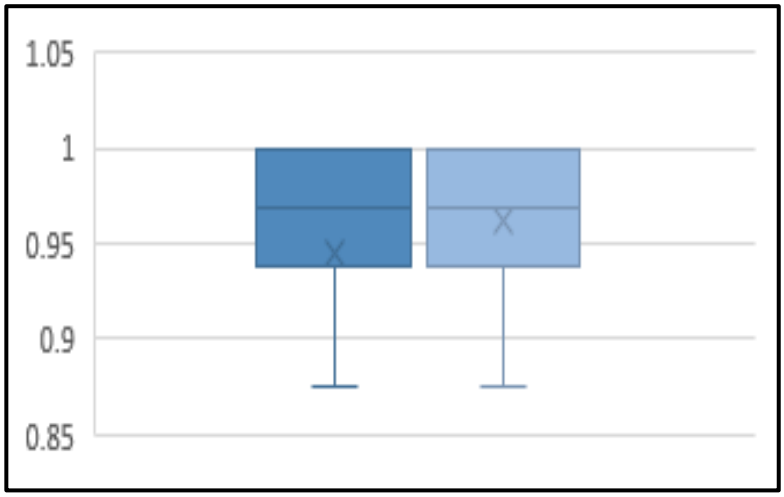


Figure 35 Accuracy averaged for incongruent trials in the before and after nature experience conditions

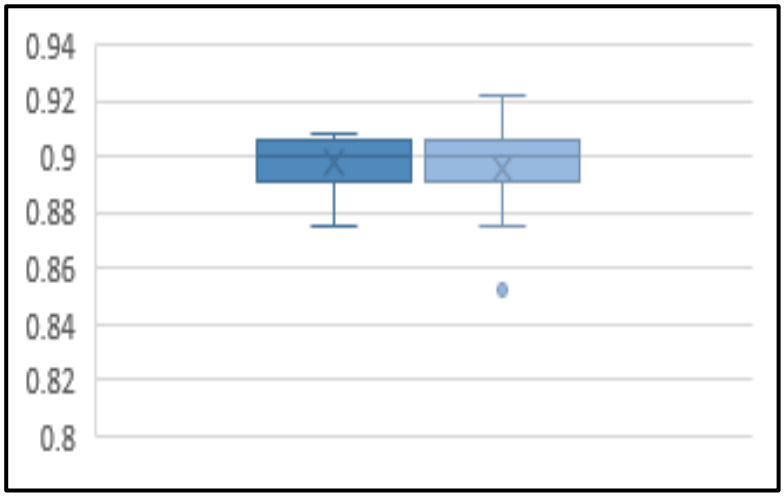


Figure 36 Accuracy averaged for congruent trials in the before and after nature experience conditions

In this study, the experimental design had 80% congruent trials and 20 % incongruent trials. The error rate of congruent trials was more and remained the same for before and after nature experience. The error rate of incongruent trials decreased for after nature experience (Table 6). Figure 34 represents the mean, median, and the variance in the overall response times and Figure 35 and Figure 36 represents data for congruent and incongruent trials, respectively.

To examine the hypothesis **H1c-** that there will be no difference in the mean response time in the before and after open eye rest condition, and **H2c$_0$-** There will be no difference in the accuracy scores in the before, and after open eye rest condition, the mean difference across open eye rest condition was examined. There was no significant difference in response time for the two test blocks in the before (block 1 and 2) and after (block 3 & 4) (all ps>0.05), demonstrating two aspects that there was on the difference on performance due to repeated measurement and that open eye rest condition had no significant effect on performance. For further EEG data analysis, the data from two test blocks in the before and after were combined and referred to as before and after nature experience flanker task.

5.4.2 SPECTRAL ANALYSIS

For testing our third hypothesis a paired-samples t-test was conducted. There was a significant difference in the mean alpha activity in all the 6 brain regions in before and after nature experience, frontal (t (32) = 3.83, p<0.001), fronto-central (t(32)=3.72 ,p<0.001), central (t(32)=3.20, p<0.005), centro-parietal (t(32)=3.14, p<0.005), and parietal (t(32)=3.50, p<0.001 regions. Means and Standard Deviations (SD) are presented in Table 5. There is a significant increase in alpha in the after nature experience condition. The results signify that increased alpha mean activity, indicating decreased arousal associated with an increase in alpha.

Table 6 Mean and Standard Deviation (SD) for Theta (4-7.5 Hz) and Alpha (7.5-12.5Hz)

		Mean Theta (4-7.5 Hz)		Mean Alpha (7.5-12.5Hz)	
		Mean	SD	Mean	SD
Frontal	Before	.33	.16	.32	.18
	After	.43	.28	.55	.41
Fronto-Central	Before	.27	.12	.32	.19
	After	.35	.21	.50	.36
Central	Before	.18	.08	.28	.19
	After	.24	.14	.40	.28
Centro-Parietal	Before	.15	.06	.31	.20
	After	.19	.11	.42	.29
Parietal	Before	.12	.04	.31	.19
	After	.15	.10	.43	.28
Parietooccipital	Before	.14	.05	.36	.23
	After	.17	.11	.49	.31

There was a significant difference in the mean theta activity in the frontal (t (32) = 2.23, p<0.05), fronto-central (t (32) = 2.57,p<0.01), central (t (32)=3.07, p<0.005), and centro-parietal (t(32)=2.50, p<0.05), regions in before and after nature experience. However, there was no significant difference in the parietal and posterior regions (ps>0.05). Specifically, results indicate a significant increase in fronto-central theta associated with improved inhibition control.

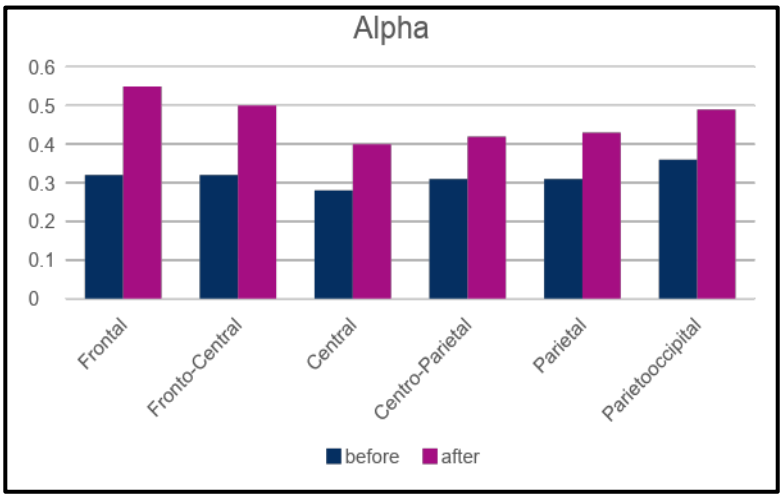


Figure 37 Graphical representation of the difference in the alpha power (μV2/Hz) in before and after nature experience in six brain regions

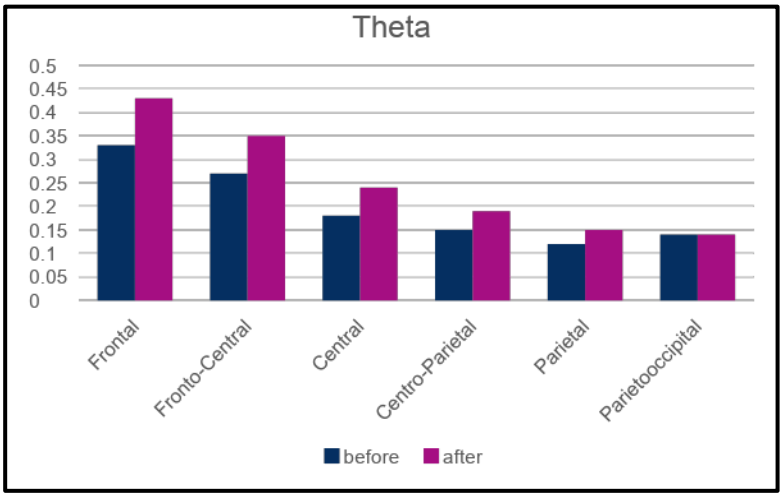
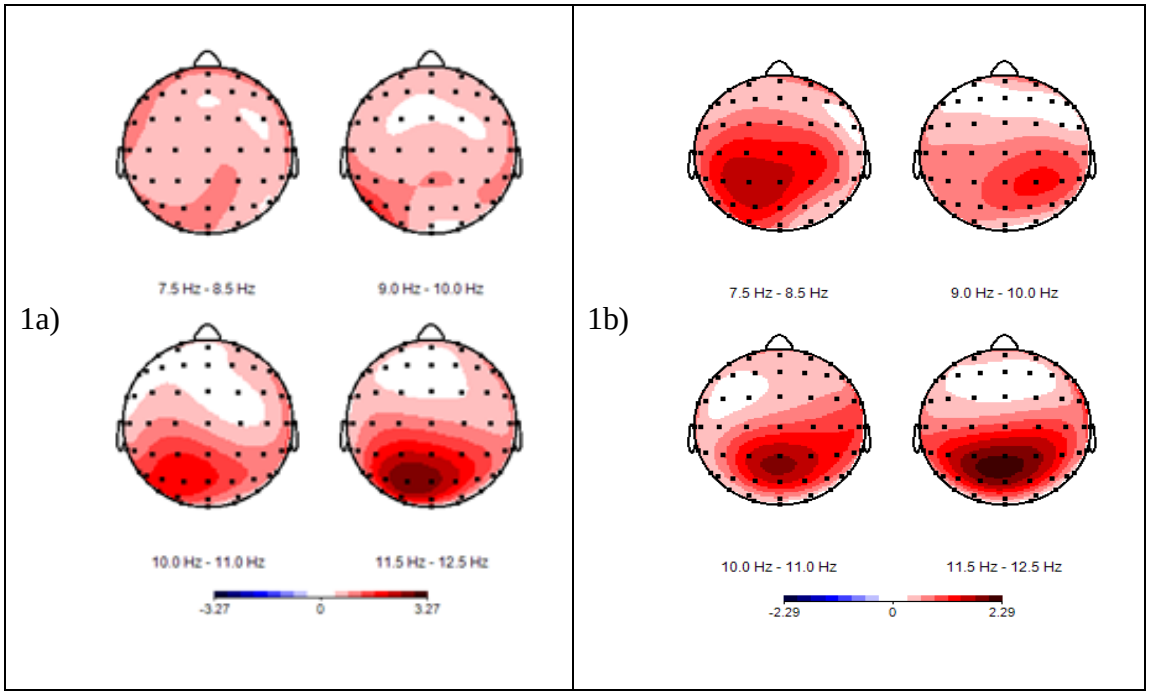


Figure 38 Graphical representation of the difference in the theta power ($\mu V^2/Hz$) in before and after nature experience in six brain regions

The topographical representation shows that there is an increased lower-alpha in the left parietal region after nature experience. There is also increased theta in the frontal areas after nature experience. Higher frontal and fronto-central theta are suggested to be associated with greater cognitive control.



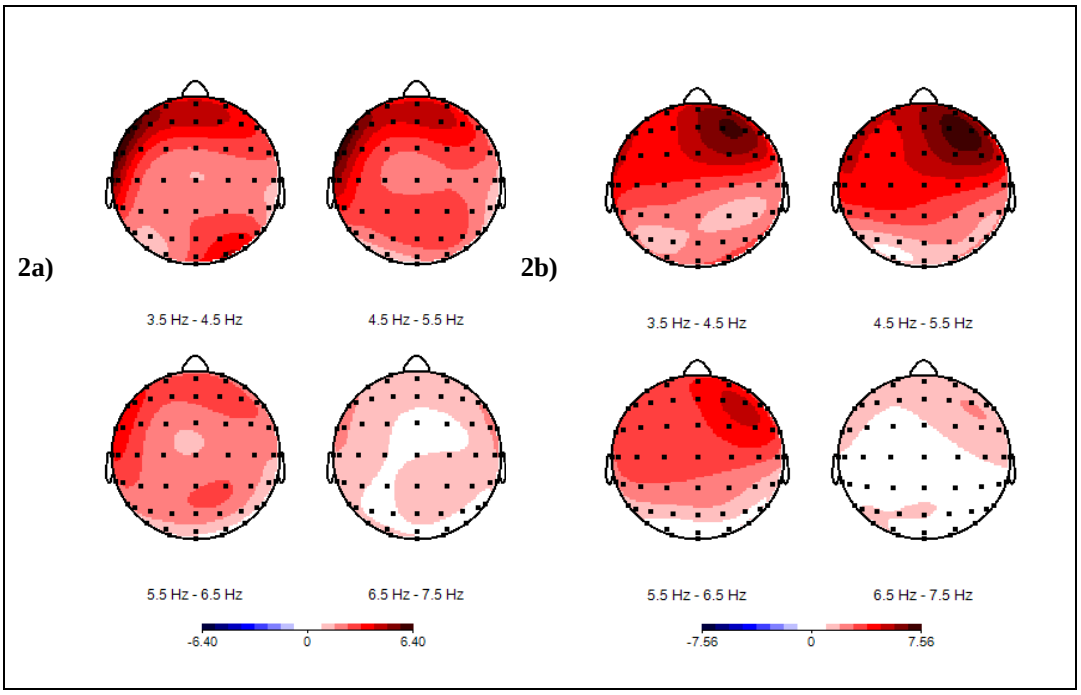


Figure 39 Topographical representation of the 1a) alpha before, 1b) alpha after, 2a) theta before, and 2b) theta after nature experience

Significant higher alpha, as depicted in Figure 37, shows that there is lower activation in the after than before nature experience condition. Figure 38 also shows a significant increase in theta. The topographical representation of alpha and theta in the difference wave for the incongruent and congruent trials as shown in Figure 39 demonstrate that there is higher alpha in the posterior regions in the after nature condition and higher theta in the right frontal regions.

5.4.3 ERP Analysis

To test the fourth hypothesis H4- that there will be significant difference in the mean activity for event-related potentials-P2 (160-225ms), N200 (180-325ms) and P300 (250- 600ms) in the fronto-parietal regions for before and after nature experience condition, and that $H4b_0$- There will be a no difference in the mean activity for incongruent trials than congruent trials of a cognitive task in both before and after nature experience condition, steps, as described in Section 5.2.8 Data Analysis, was followed.

Prior to analysing the difference between ERP before and after nature experience, a graphical examination of the ERPs evoked by the flanker task was conducted. Table 4 presents the list of ERP components, latency, scalp distribution and the associated cognitive processes that were evoked by flanker task in this experiment. The representative grand averaged waveform, as shown in Figure 40, shows the ERP components evoked during the incongruent flanker trials before and after nature experience with their respective latency and scalp distribution. The waveform indicates that the attention-related ERPs P2, N2 and P3 were evoked through the experimental manipulations.

Table 7 List of ERP components evoked by flanker task, latency, scalp distribution and the associated cognitive processes

Peak	Latency	Scalp distribution	cognitive process
P2	160-225ms	Fronto-central	Stimuli detection and suppression of irrelevant information, inversely related to ongoing stimulus processing, directly related to performance accuracy
N2	280-325ms	Fronto- central	Inhibition control and conflict resolution
P3	350-550ms	Central and parietal	application of 'task rules' and information processing

To test the difference between the before and after nature experience, before the statistical analysis, the difference wave between the after and before nature experience grand averaged for incongruent trials was examined. The topographical representation of the grand averaged waveform, as shown in Figure 41, suggests a positive difference for P2 and negative difference for N2 and P3 for incongruent trials. Whereas, the topographical representation of the grand averaged waveform as shown in Figure 42 shows no difference for P2 in the fronto-central region and negative difference for N2 in frontal and positive difference P3 in temporal regions for congruent trials.

Next, statistical analysis using within-subject measures analysis of variance (ANOVA) with two factors: condition (before/after) and Congruency of the flanker trial (congruent/incongruent) was conducted to see whether these differences were significant or not. Before ANOVA, the assumption for sphericity was checked through *Mauchly's test.* (*Mauchly's test p*=0.63).

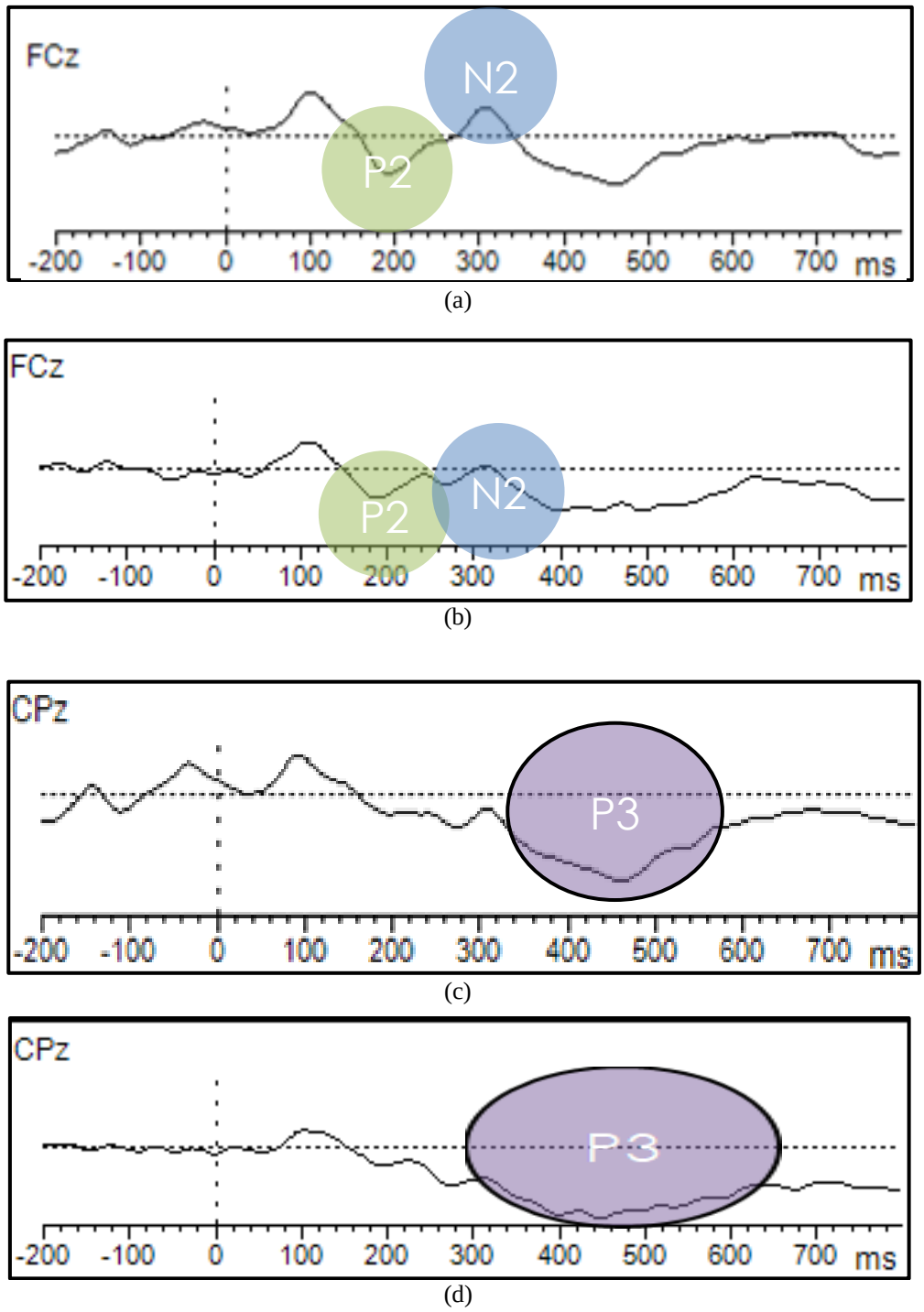


Figure 40 ERP components elicited by the incongruent trials of flanker task P2, N2 before and after nature experience (NE) at FCz a) after NE, b) before NE and P3 at CPz c) after NE d) before NE

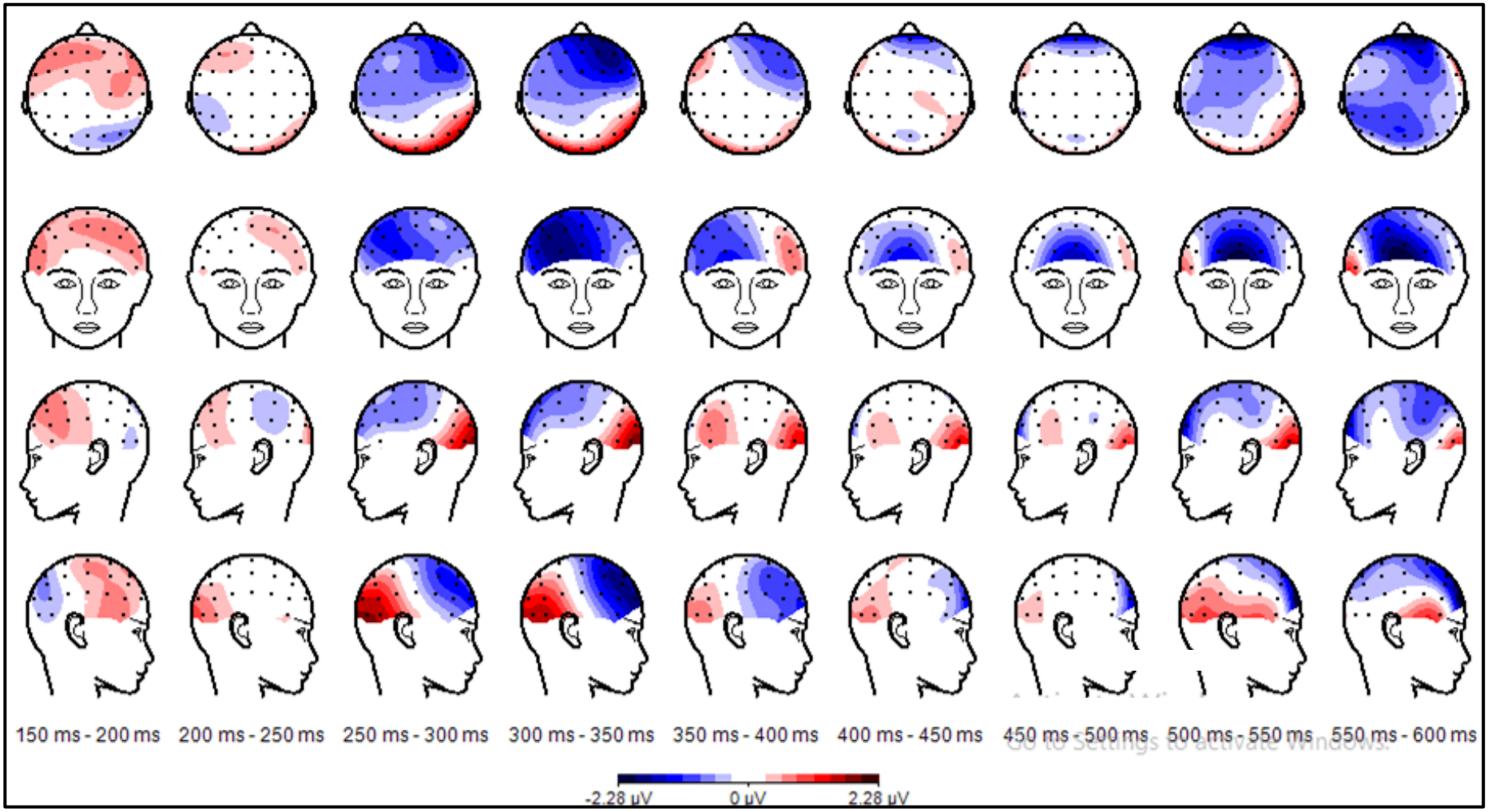


Figure 41 Topographical representation of the grand averaged difference wave for incongruent trials (blue colour in the figure signifies negative difference and red a positive)

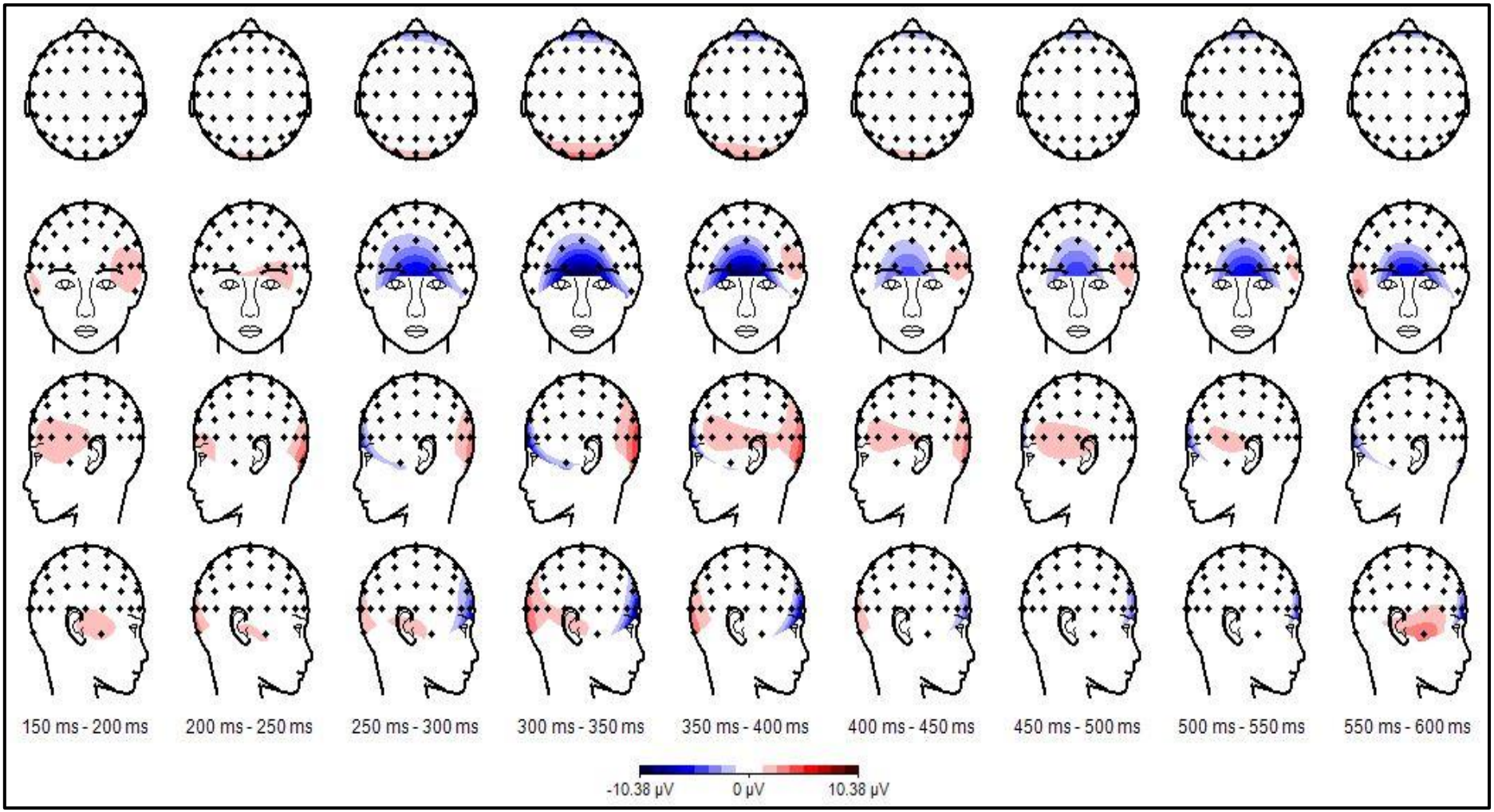


Figure 424 Topographical representation of the grand averaged difference wave (after minus before) for congruent trials (blue colour in the figure signifies negative difference and red is a positive)

Fronto -Central P2

There was no significant difference in the mean amplitude across congruency (congruent and incongruent) and conditions (before and after nature experience) and incongruent trials for both before and after nature experience conditions (all ps>0.05). However, there was a significant difference in the incongruent trials, though the difference was small.

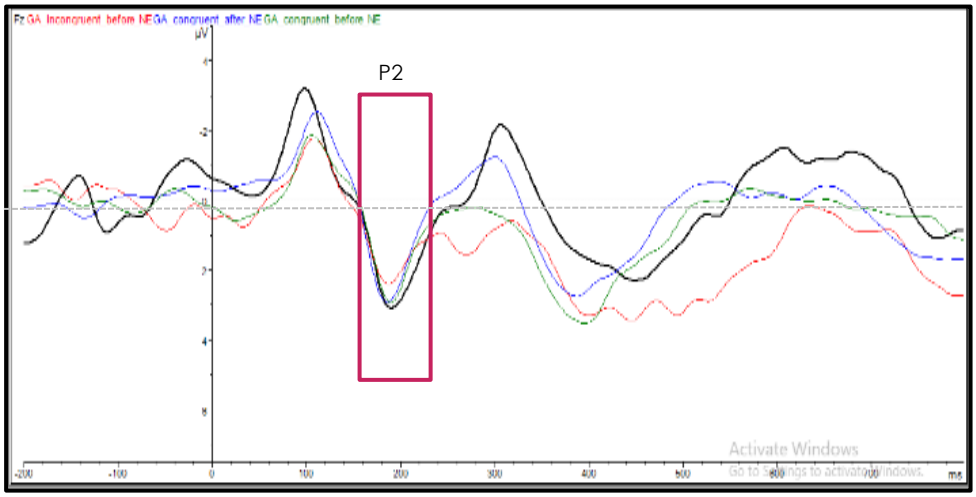


Figure 43 Grand averaged wave form at the medial frontal electrode (Fz) for all four conditions.

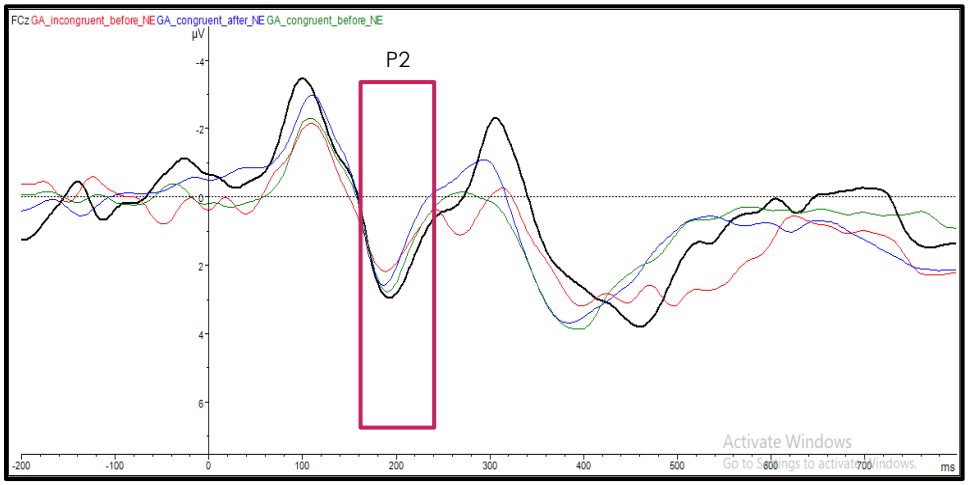


Figure 445 Grand averaged wave form highlighting P2 at the medial frontal electrode (FCz) for all four conditions.

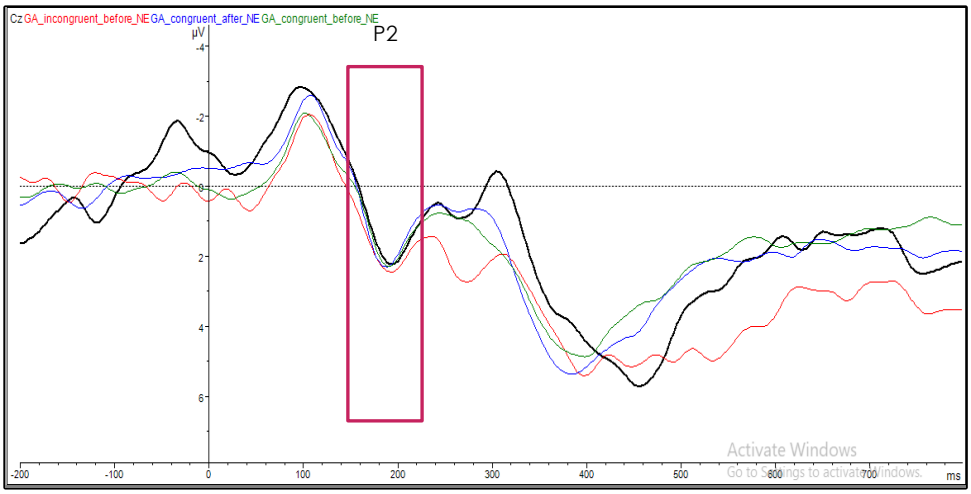
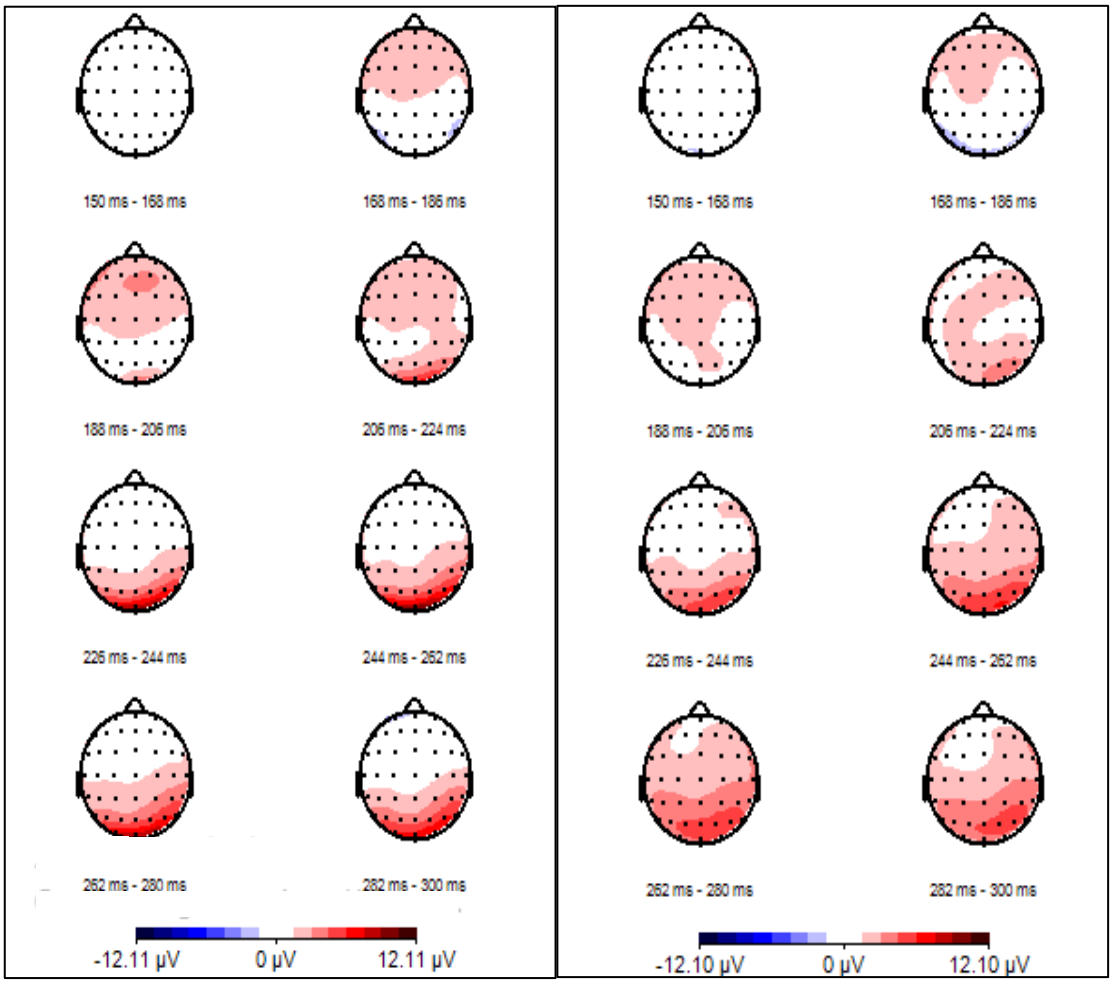


Figure 45 Grand averaged wave form highlighting P2 at the medial Central electrode (Cz) for all four conditions.



(a) **(b)**

Figure 46 Topographical representation of the grand averged P2 wave form for the incongruent trials of flanker trials for before and after nature experience (a) before NE and (B) after NE

Fronto-central N2

The difference in mean amplitude for the N2 component was analysed for averaged fronto-central electrodes Fz, FCz, and Cz within the time window 280–350ms. Prior to statistical analysis, the EEG waveform was plotted for 0- 400 ms for frontal and fronto-central midline electrodes (Fz, FCz, and Cz). The Figures 46- 48 shows that N2 was maximal at Fz, and this electrode was therefore used to derive peak latencies. An initial ANOVA assessed a significant effect of condition (nature experience) on N2 mean activity F (3,93) = 4.62, p<0.05, η^2_p=0.113, such that more negative N2 values were observed during the incongruent task trials. However, there was no significant effect of nature experience for congruent trials p>0.1. There was also a significant effect of nature experience on post congruency F (1,31) =7.76, p<.01, η^2_p =0.200. There was also a significant effect of congruency F (1,31) =6.23, p<0.05, η^2_p=0.167 in the both before and after nature experience condition. For the latency analysis, Fz with maximum mean amplitude for N2, there was a significant effect of condition (nature experience) on N2 Peak Latency F= 3.33, p<0.05, η^2_p=.085, with shorter latencies after the nature experience.

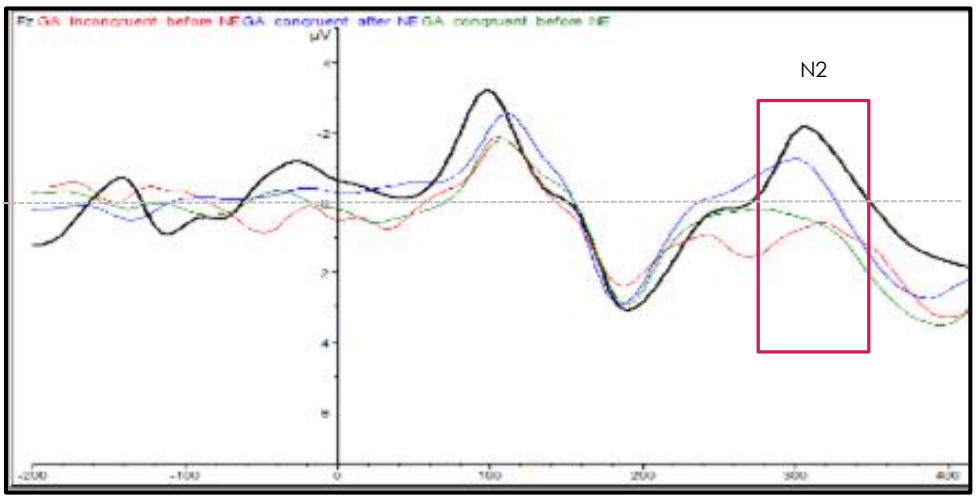


Figure 47 Grand averaged waveform highlighting N2 at the medial frontal electrode (Fz) across all four conditions.

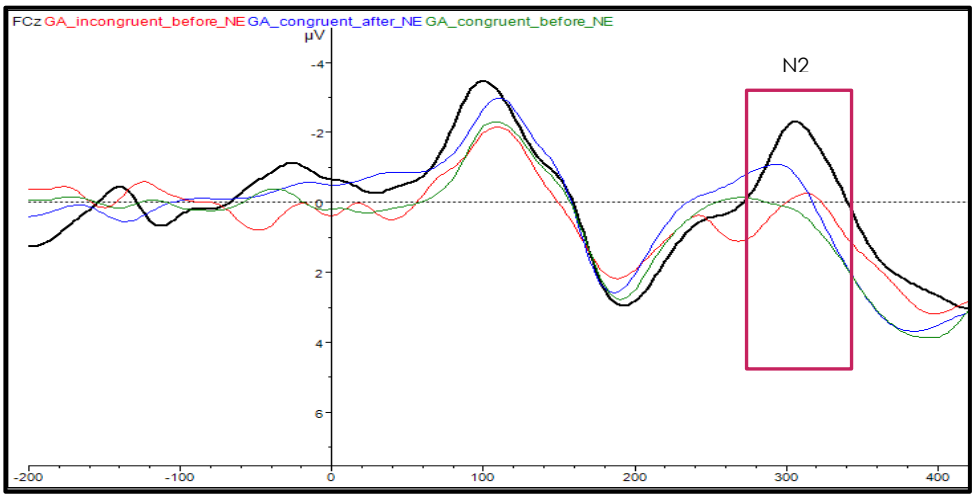


Figure 48 Grand averaged waveform highlighting N2 at the medial frontal (FCz) electrode across all four conditions.

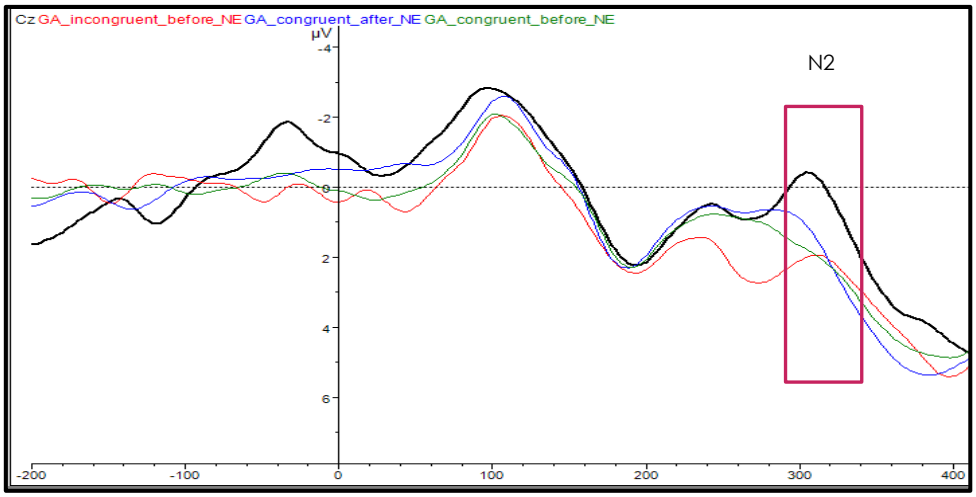
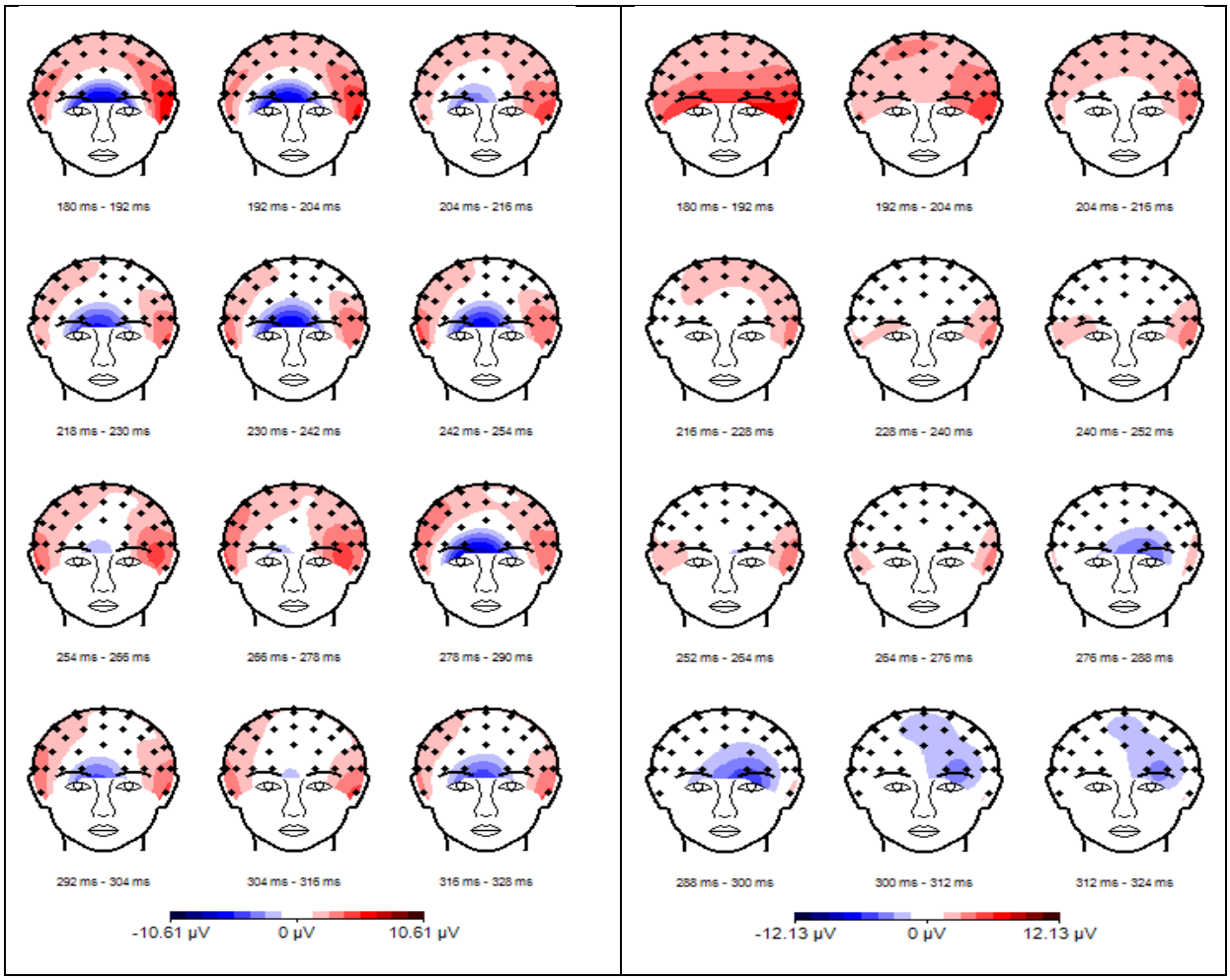


Figure 49 Grand averaged waveform highlighting N2 at the medial central electrode across all four conditions.

Figure 47-48 shows that the peak amplitude for N2 is maximum negative at Fz for the incongruent trials in the after nature experience condition. Further, there is significantly more negative N2 amplitude for the incongruent trials in the after than the before nature experience conditions for Fz, FCz and Cz electrodes. However, for the congruent trials, the waveform, as depicted in Figure 47-49 shows no significant difference for Fz, FCz, and Cz. The topographical representation, as depicted in Figure 50, shows that N2 was more negative in the

left side of the fronto-central regions for the 280-325ms for the incongruent trials in the after nature experience condition. Analysis for this condition was of interest since control of inhibition to the flanker for incongruent trials is expected to reflect in the nature experience waveform after nature experience, and improvement would indicate more efficient control of inhibition.



(a) (b)

Figure 50 Topographical representation of the grand averaged waveform for incongruent trials in the frontal region in the a) before and b) after nature experience

Centro-Parietal P3

The difference in the mean amplitude of P3 was analysed for averaged midline central and parietal electrodes Cz, CPz, and Pz. There was a significant effect of condition (nature

experience) on P3 mean activity F (3,108) =2.69, p<.05, η^2_p=0.069 with lower peak amplitude for incongruent trials in the after nature experience condition. There was no significant effect of NE on congruent trials p=0.49. There was also a significant effect of congruency F (1,36) =3.45, p=0.070, η^2_p=.088 in both before and after nature experience conditions, with higher peak amplitude for incongruent trials.

For the latency analysis, CPz with maximum amplitude for P3 was used to derive peak latency. There was a significant effect of nature experience on P3 Peak Latency F (3,99) =10.55, p<.001, η^2_p=0.242.

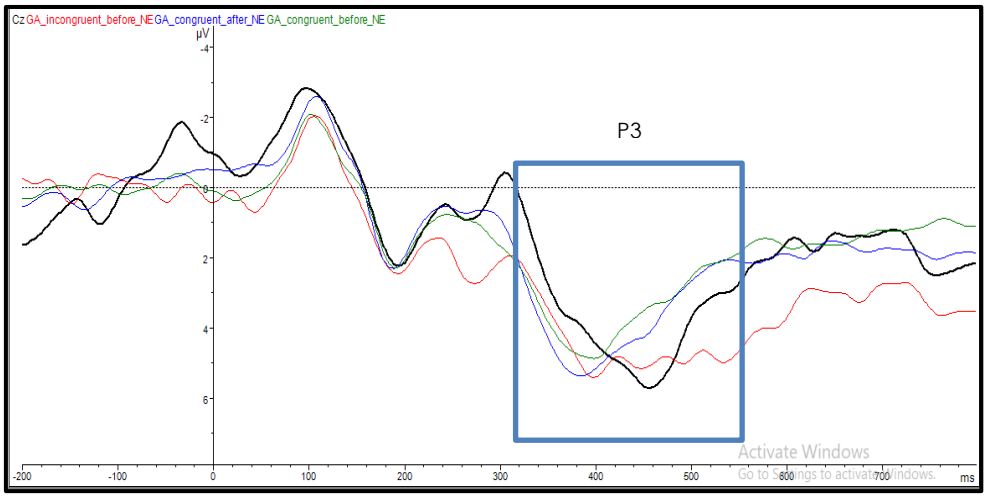


Figure 51 Grand averaged waveform highlighting P3 at the medial central electrode across all four conditions

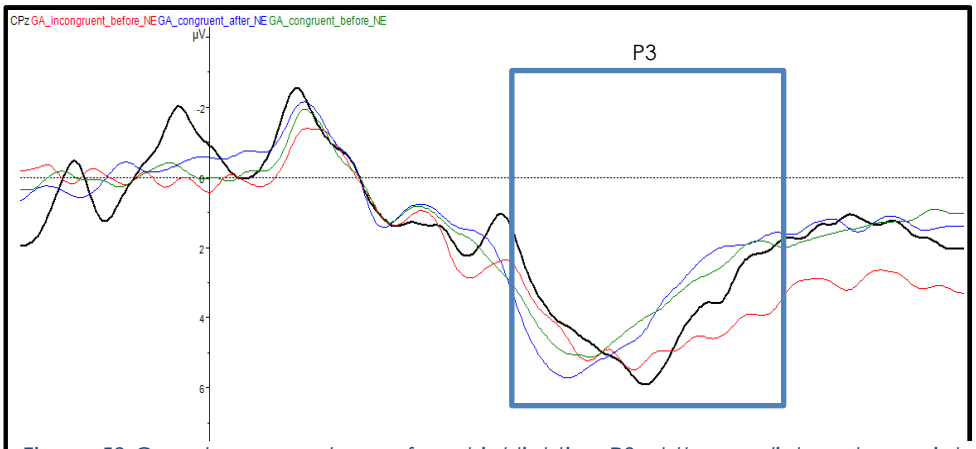


Figure 52 Grand averaged waveform highlighting P3 at the medial centro-parietal (CPz) electrode across all four conditions

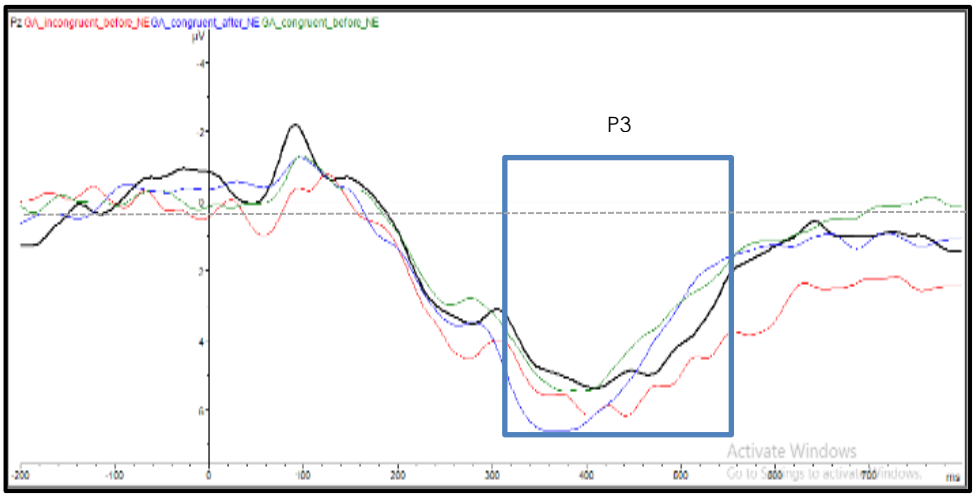
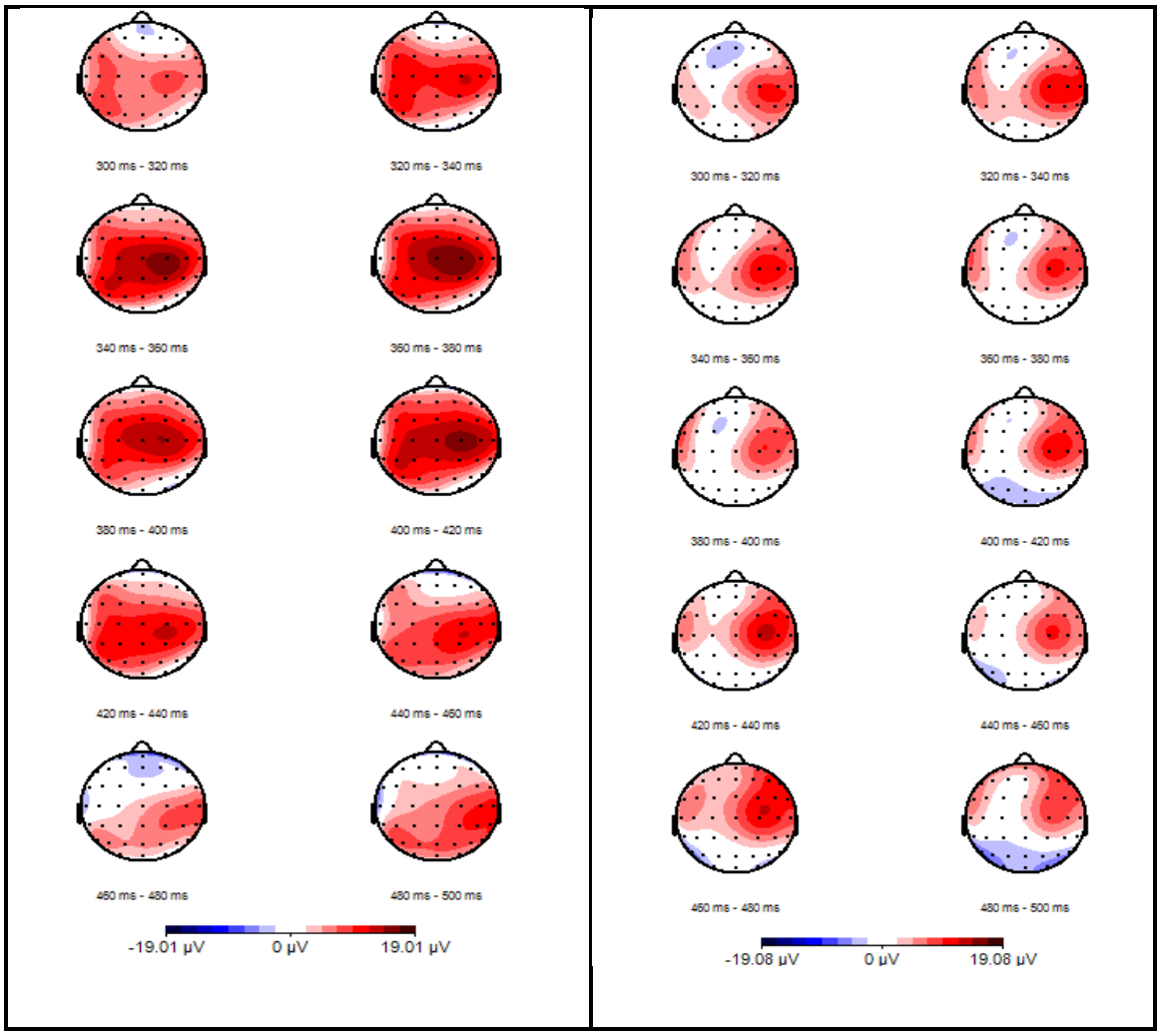


Figure 53 Grand averaged waveform at the medial parietal (Pz) electrode across all four conditions identifying P3



(a) (b)

Figure 54 Topographical representation of the grand averaged waveform for incongruent trials in the a) before and b)after nature experience condition

Figure 52 shows that the peak amplitude for P3 is maximum at CPz for the incongruent trials in the after nature experience condition. Further, there is significantly lower P3 mean amplitude for the incongruent trials in the after than the before nature experience conditions for Cz, CPz and Pz electrodes. However, for the congruent trials, the waveform, as depicted in Figure 51-53 shows no significant difference for Cz, CPz, and Pz. The topographical representation shows that P3 mean amplitude was lower in the right side of the centro-parietal regions for the 300-450ms for the incongruent trials in the after nature experience condition. Notably, the topographical representation in Figure 54 also shows that there is a significant activity in the right fronto-parietal brain network for the incongruent trials.

5.4.4 DEBRIEFING AND INTERVIEW

The frequency analysis revealed that almost 90 % of the participants reported feeling 'relaxed' and 'peaceful' after watching the audio-video stimuli. Furthermore, the most commonly mentioned elements of nature that were found 'fascinating' were waterscapes (waterfall and flowing water) (35%), followed by forests/wilderness (27%), birds chirping (20%) and others (mountains, sky, flowers) (18 %). As such, waterscapes seem to be the most salient source of relaxation from natural environments, as discussed by participants. The pictorial representation of the frequent terms used to describe the experiences and the elements that aroused those feeling and were found 'fascinating' is shown as word clouds in Figure 55 and Figure 56, respectively.

Figure 55 Word cloud depicting frequent phrases used by the participants to describe their experiences

Emergent elements of nature and their associations with experiences

The flowing water was reported by the participants to give a feeling of relaxation and refresh. On probing, participants revealed that flowing water presented a source of alternative focus that 'distracted one from problems at hand', as well as that it presented settings that were 'easy' to process and attend to. For several participants, these associations related to peace and calmness as Participant 2 when probed about his experiences while viewing flowing water notes:

> *"In normal situation I can feel impatient easily, doing things in a rush... it (watching flowing water) kind of slowed me down, calmed me and kind of removed my restlessness and frustration."*

Figure 56 Word cloud of elements that were frequently described by the participants as 'fascinating'

Forests and green natural landscapes were reportedly associated with a feeling of 'being away' and with memories associated with positive emotions and recreation places. Similarly, participants noted that being in the gardens and urban green spaces also provided them with a form of relaxation. Participant 35 describes gardens, 'gave a feeling of open spaces where the urban city sounds stop, and I was hearing the natural sounds. I felt the breeze flow… It is different, and it gave a feeling which is not describable... like peace of mind." Such associations were reportedly related to a break from the routine, and the enjoyment during being at such places as Participant 12 also notes;

> *"In forests I feel calm, peace of mind and completely absorbed. Free from routine thoughts, beyond thoughts"*

Birds chirping were reported as a welcome distraction, and participants' responses suggest that bird sounds capture the attention involuntarily. Participant 3 described bird sounds as "a part of being; it is not something that's imposed upon me'. This view was supported by comments from Participant 27, who noted that natural sounds, including bird chirps, are "all relatively low-key, as background noise, so the sound does not impose on one." Participant 32 used a passive expression to describe the process of distraction achieved through listening to the bird's chirp, supporting the notion that this process is effortless: "again, it takes my mind off that

particular piece of work that am trying to concentrate." Together, these responses suggest that bird sounds may be experienced in a bottom-up manner that is not effortful or likely to place further demands on attention.

To summarize, altogether the responses appear similar to the concept of 'fascination', 'being away' and 'open spaces' in ART (Kaplan, 1995; Kaplan & Kaplan, 1989), which suggests that elements in nature captures the attention effortlessly and can provide a source of alternative focus that is beneficial for restoration of attention. The self-reports also cross validates our findings from spectral analysis and ERP analysis, suggesting a state of lower distraction and enhanced attention after nature experience.

CHAPTER 6

DISCUSSION AND CONCLUSIONS

6.1 INTRODUCTION

The main objective of this doctoral research was to study the effects of nature experience on directed attention. Two separate studies were undertaken to seek answers to the research questions related to the research objectives, as presented in Section 1.4. Results from both studies indicate that nature experience is positively associated with directed attention. A detailed discussion on findings from the first study, which was to study the association between nature experience and directed attention, has been presented in Section 6.2. Outcomes of the second study, which was to examine the neurophysiological correlates of nature experience and directed attention, has been discussed in Section 6.3.

Further, in light of the literature available on the mental states that are most commonly associated with a value-based behaviour, this thesis presents arguments on how nature experience can possibly have an effect on promoting human values towards nature in Section 6.4. Further, Section 6.5 presents the limitations of this thesis research, along with the future scope of studies to understand the neural basis of nature experience.

6.2 ASSOCIATION OF NATURE EXPERIENCE AND DIRECTED ATTENTION

The purpose of the cross-sectional study was to explore the association of nature experience, with the self-reported measure of attention. The results as described in Section 4.4 showed that people who interact with nature more frequently through visits to the nature-rich spaces such as parks, gardens, forests or wilderness areas, reported higher scores self-report measure of

individual's ability to direct attention. It is argued that since natural surroundings have fewer artificial sounds and landscapes, such areas are possibly found as less demanding for executive functions. Therefore, nature experience through a frequent visit to nature or by the presence of nature in the neighbourhood may have a positive effect on the cognitive functioning related to attention. However, in our study, as reported in Section 4.3.3.2, it was found that the presence of nature in the neighbourhood alone does not have a significant effect on attention. Though an improved physical environment in such nature-rich neighbourhoods could be envisaged to provide the residents with better living conditions than the neighbourhoods devoid of nature, it had no bearing on an individual's attention measured through MAAS. The possible explanation to this observed anomaly can be derived from the evidence on the current lifestyle of people. A study shows that people are spending almost 90 % of their time indoors (Klepeis et al., 2001). So, it may be reasoned that though people may have nature around their places, but they are not 'connecting' with nature. Another interesting finding of this study is that nature relatedness has a significant interaction effect with nature in the neighbourhood on an individual's ability to attend. It is argued that people who feel more connected with nature are likely to experience nature through incidental nature interactions as well such as; a view from a window (Ekkel & de Vries, 2017) which engages their attention involuntarily giving voluntary attentional mechanisms an opportunity to rest. Furthermore, people who interact with nature through regular visits, irrespective of whether such spaces are in the neighbourhood or not, reported being more attentive to their present experiences. Although, as reported in earlier studies (Markevych et al., 2017; Ward Thompson & Aspinall, 2011), this study also found that people are more likely to visit nature-rich places if such places were in neighbouring areas.

Another plausible pathway through which nature interaction may have beneficial effects on attention could be that nature-rich areas provide for pleasant distractions that diminish absorption in the past, or fantasies and anxieties about the future, thus, bringing the attention

to the present experiences. Alternatively, the sensory experience of touch, see, feel, hear in the natural environment is positively valenced and potentially feeds the need for an individual's connection with nature. While the former pathway may act as a passive stimulus, the latter is more active engagement and 'attending to', what Kaplan (2011) term as 'soft fascinations' from the elements present in the natural environment. This effect of sensory stimuli arguably would be more in the case where the individual feels more related to nature than in the case where a personal connection with nature is not seen. The study also found that the association of nature experience with attention was strengthened through nature relatedness, thus suggesting a mediational role of nature relatedness. To summarize, people who relate with nature and reported high nature experience also reported an enhanced ability to attend to their present moment experiences than people who do not relate with nature.

6.3 Nature Experience and Neurocognitive Correlates of Directed Attention

The second study was a lab-based study using EEG, which was undertaken with an aim to examine the neurocognitive effects of nature experience on directed attention. The findings from ERP analysis, as reported in Section 5.4.3, suggests that improved control of inhibition is central to the enhanced directed attention associated with nature experience. Section 5.4.2 on the outcomes from spectral analysis, reports the presence of lower frequencies in frontal and parietal regions during cognitive task after nature experience, suggesting lower activation for task-relevant processing.

Attention is a limited resource and is prone to fatigue (Kahneman, 1973). Our day to day activities which require constant use of directed attention for the successful execution of tasks thus could deplete this limited resource. On the other hand, this study suggests that nature experience through a brief interaction with the natural environment may help people in

recovery and enhancement of directed attention. Though this study has investigated the effects of nature experience through virtual interaction in a controlled lab setting, however earlier studies have reported that both virtual and real-time nature experience such as visits to the forest, park, garden or urban green spaces have similar outcomes(Yin, Zhu, Macnaughton, Allen, & Spengler, 2018).

Nature experience and behavioural parameters of directed attention

In the lab-based experiment, it was found that response time improved for both congruent and incongruent flanker task after nature experience with a large effect size (η^2_p >0.20), with greater benefits in the case of incongruent trials as reported in Section 5.4.1. Often in the pre-post study design, the improved response time is also attributed to the repeated measure effects, which confounds the real effects of the intervention. However, the inclusion of a pre-baseline practice test ensured that the participants were familiar with the task and had stabilised their performance with no significant change in the number of errors made. Thus practice test reduced the possibility of improvement in response time due to repeated measurement. Further, the analysis of cognitive performance before and after open eye resting state (OERS) revealed no significant effect on response times or accuracy. This finding supported the argument that nature experience affects the mind in a unique way beyond providing a resting state, such that the effects are seen on improved response time. Most of the previous nature experience studies used similar attention tasks such as the Stroop task, Backward digit Span (Bailey, 2018; Beute & de Kort, 2014; Bratman et al., 2012) and attention network test (ANT) (Berman et al., 2008) have also reported improved response times after nature experience.

Further analysis demonstrated that there was no significant change in accuracy for congruent trials and only marginal improvement in incongruent trials after nature experience. Since accuracy scores (>0.90) for the participants were in the upper limit of the instrument, it may be argued here that the participants may have found the flanker task used in the experiment only

moderately difficult. Studies suggest that when many subjects have scores on a variable at the upper limit of what an instrument reports, data analysis provides inaccurate information known as ‘ceiling effects’ because some actual variation in the data is not reflected in the scores obtained from that instrument (Vogt, 2005). Notably, the accuracy scores for incongruent trials were higher since incongruent trials are infrequent and also considered to be higher in difficulty. Thus participants found such trials challenging and likely paid more attention while choosing an appropriate response. While in the case of congruent trials which frequently appeared in the task, participants were likely to make an error due to repeated action attentional lapse irrespective of before and after nature experience condition.

Nature experience and Alpha along with Theta

Results, as described in Section 5.3, show that there were significant differences across frontal and fronto-central regions in theta and frontal and parietal regions for an alpha , in the before and after the nature experience. It is anticipated that the alpha and theta that may have been produced during nature experience continued during the cognitively demanding flanker task after the nature experience. Previous studies have suggested that enhanced theta indicates the improvement in the capacity to control one’s locus of attention (Cahn & Polich, 2006). Therefore it can be argued that increased theta in this study may have been instrumental in the improved focus or inhibition to distractors in the cognitive task after nature experience. Further, in light of existing studies that have investigated the significance of alpha, the increase in alpha as reported in the result Section 5.3, can be interpreted as a state of relaxation and improvement in directed attention capacity (Aftanas & Golocheikine, 2001; Lomas, Ivtzan, & H.Y.Fu, 2015; Shaw, 1996). Therefore, together with higher theta, higher alpha during nature experience may indicate a mental state that is relaxed yet alert.

Nature experience and P2 mean amplitude for a subsequent cognitive task

In this study, P2 was found to be evoked as a part of the normal response to the visual stimuli presented by experimental manipulations, as described in Section 5.2. The analysis showed that there was no significant difference in the P2 mean amplitude before and after nature experience conditions. It may be reasoned here that since the visual features of the two trial type did not differ, therefore there was no difference in P2 mean amplitude. No difference found in the accuracy score also supports the earlier claims of a study that suggested an association of P2 amplitude with performance accuracy (Chernyshev and Medvedev, 2016).

There was a marginally higher amplitude for incongruent trials in the after than before nature experience condition that may be interpreted as suppression of irrelevant information. According to previous research, P2 amplitude is reported to be inversely related to the intensity of ongoing stimulus processing (Chernyshev and Medvedev, 2016). Therefore, higher P2 amplitude for incongruent trials in the after nature condition may be argued as a sign of lesser cognitive processing required for making an appropriate response in the after nature experience task. The lower stimulus processing can also be construed as attentional lapse if it is producing errors; however, in case of a correct response, it is argued as efficient processing.

Nature experience and N2 mean amplitude for a subsequent cognitive task

Relation of nature experience with enhanced inhibition control and direct attention, as indicated in the previous two subsections were further investigated through the ERP analysis of N2. There were significant differences in the mean amplitude of N2 for incongruent trials after nature experience with a substantial effect (η^2_p=0.113) suggesting an improved ability to inhibit distractions from incongruent flanker arrows in the subsequent flanker task. Greater negative mean amplitude of N2 were found in the frontal and fronto-central regions, which is reported to be associated with conflict resolution (Fan et al., 2003). Previous research using flanker task has also implicated association of greater N2 negativity in fronto-central topography with cognitive control (Folstein & Van Petten, 2008; Kopp, B., Rist, F. & Mattler, 1996) mainly

related to the suppression of irrelevant stimuli (Folstein & Van Petten, 2008; Moore, Gruber, Derose, & Malinowski, 2012; Sanger & Dorjee, 2016). Arguments presented above, coupled with the outcomes from the behavioural analysis, suggest that improved response time could be due to efficient conflict inhibitory control in the case of incongruent trials after nature experience.

Nature experience and P3 mean amplitude for a subsequent cognitive task

As reported by previous studies(Wintink, Segalowitz, & Cudmore, 2001), in this research also, we found that the detection and conflict control presented by incongruent trials was associated with the activation in a right- fronto-parietal network (as depicted in Figure 54). Further, P3 mean amplitude was observed to be significantly lower after nature experience in the centro-parietal regions. P3 is reported to be an index of resource allocation (Polich, 2007). Therefore, lower P3 mean amplitude observed in this research may indicate lower cognitive resources employed for the flanker task after the nature experience. Lower P3 amplitude also indicates an efficient application of 'task rules' for an appropriate response. Particularly, localized right parietal activity could suggest 'task-relevant' resource allocation. The shorter latency is indicative of faster decision-making; that is, there was a faster rely to motor neurons for an appropriate response for the after nature experience cognitive task. The arguments are in line with the neural efficiency hypothesis, suggesting that the effective performance on a cognitive task may not depend on how hard the brain works but rather on how 'economically' the resources are put to use to get an appropriate response (Shcherbakova, Gorbunov, Golovanova, & Kholodnaya, 2014). Altogether indicating an efficient neurocognitive response

Interestingly, the neurocognitive findings from our study trends with the outcomes reported by the studies investigating meditation and or mindfulness. Such studies also suggest an emergence of theta and alpha waves in the attention-related frontal and parietal regions (Aftanas & Golocheikine, 2001; Baijal & Srinivasan, 2010; Lagopoulos et al., 2009). Greater

N2 negativity is reported after meditation and mindfulness practice in association with a greater ability to focus (Norris et al., 2018; Sänger, Bechtold, Schoofs, Blaszkewicz, & Wascher, 2014). The decreased P3 mean amplitude is associated with more effective brain resource allocation after mindfulness practice (Slagter et al., 2007;Kozasa et al., 2012; Moore et al., 2012), and suggested superior attention due to an improvement in top-down inhibition (Cahn & Polich, 2006). Parallels can be drawn between the mental state achieved after a nature experience and meditative states as described in Indian philosophy. According to Indian philosophy, a meditative mental state is described as "*Ekagra*" where the mind is relaxed but not sleepy (Deepeshwar, Nagendra, Rana, & Visweswaraiah, 2019). Also, there is mention of a state called "*Nirodha*", where the mind is fully absorbed in the object of focus (Baijal & Srinivasan, 2010). "*Nirodha*" is the state of complete attention and concentration (Baijal & Srinivasan, 2010). In the yogic literature, nature experience is suggested to be one of the techniques that can be used to achieve 'pratyahara' that is described as the ability to attend to objects at will. Therefore, the preliminary evidence from this study does indicate that there could be an association between nature experience and meditative experience as also observed by scholars of transcendental experience. Altogether, this study provides evidence that nature experience helps the mind to control the inhibitions resulting in enhanced attention efficiently.

6.4 POSSIBLE EFFECTS OF NATURE EXPERIENCE ON UNIVERSAL HUMAN VALUES

As an extension of the findings, it is argued here that nature experience may help promote general wellbeing and promote human values. Literature and the evidence gathered in this research suggests that nature experience is conjectured to modulate human behaviour through several interrelated pathways. One useful approach that this thesis has adopted is to study the

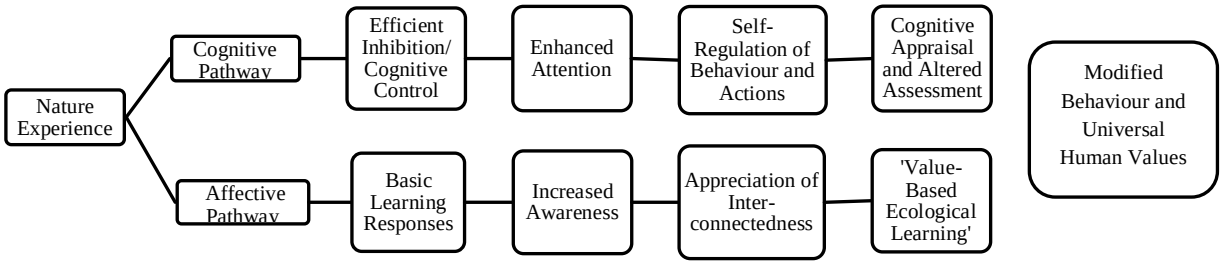


Figure 57 Proposed affective and cognitive pathways through which nature experience may have an effect on human values

affective and cognitive effects of nature experience separately. The evidence for the cognitive benefits of nature experiences suggests that nature experience produces such cognitive states that may eventually help in self-regulation of behaviour and actions. Findings from the cross-sectional study as described in Chapter 4 and the conclusions drawn in light of evidence from literature, suggests that nature experience is associated with mindful attention and awareness. Evidence for the neurocognitive effects of nature experience as described in Chapter 5 shows that an enhanced alpha and theta indicators of the state of relaxation and internalised attention induce a relaxed state of mind. Further, it also suggests that such a relaxed mental state helps improve one's ability to inhibit the distractions and to focus and direct attention at the task in hand. On the other hand, studies investigating the benefits of mindfulness have found that efficient inhibition control and enhanced attention significantly predict self-regulation of behaviour and positive emotional states (Brown & Ryan, 2003). In literature, self-regulation refers to controlling emotions and actions in the pursuit of higher-order goals. Further, it is also argued that self-regulation tasks and executive-functioning tasks interact with each other, suggesting that they may share cognitive resources. Evidence from a recent meta-analysis of research on the neural markers of cognitive and behavioural self-regulation also implicates

broadly similar fronto-parietal networks for both, cognitive regulation of executive-functioning and emotional self-regulation effectiveness (Langner, Leiberg, Hoffstaedter, & Eickhoff, 2018).

Therefore, combining the neuro-cognitive evidence from our research and the evidence from the literature on mindfulness studies, it may be construed that enhanced attention through nature experience may also promote a self -regulation of behaviour. Further, the regulation of spontaneous behavioural responses is often suggested to help in cognitive reappraisal, a process that modifies the emotional impact of events by changing people's assessments of the events or task in hand (Koole, 2009). This altered assessment perhaps then can be instrumental in promoting a sound moral judgement or the value-based decision –making.

The other plausible pathway through which nature experience can be explained to influence human value system is through affective route. The nature experience is also accompanied by keen observation of the phenomena in nature, the sensory and informational richness and dynamic qualities of such phenomena evoke basic learning responses (Kellert, 2015). When we see, touch, feel, sense nature, we increase our personal connection with it, we develop an appreciation for and understanding of our interconnectedness with all other living things on the earth. This understanding and personal connection with nature bring the feeling of empathy for other living things, and self is seen as part of, rather than separate from, the natural environment. Therefore, one is less likely to behave destructively since damaging nature will be seen as damaging one's self (Conn, 1998; Feral, 1998).

Basic learning also happens when natural phenomena are viewed in association with universal attributes. Often trees and plants are appreciated for their 'giving character or quality', organisms such as; ants and bees for 'togetherness and order', and water for 'calmness'. The process of ecosystem functioning itself is an ultimate example of cooperation and coexistence.

Thus, nature experience which provides an opportunity for first-person observation of such phenomena of the ecosystem could potentially act as a direct way of imbibing universal human values. This direct learning may lead to what can be termed as 'value-based ecological learning'.

Hence, it is argued here that a strong connection with nature inspires value-based behaviour. It motivates people to gain a deeper understanding of each organism's place in the complex functioning of ecosystems and respect for the system as a whole. The more individuals are connected to nature, more likely they will be aware of their own actions and concern for all living things (Schultz, 2000). This ecological -based learning is often associated with less self-interest and more consideration of the broader environment, in other words, more value-based behaviour and actions.

6.5 CONCLUSIONS

This doctoral thesis has concluded following findings against each of the research question below.

Research question 1: How is nature experience associated with directed attention?

Nature experience was found to be significantly associated with attention (Section 4.4.2)

a. *Is the presence of nature in the neighbourhood associated with attention?*

   No, presence of nature in the current neighbourhood was not found to be significantly correlated with attention (Section 4.4.2, Section 4.4.3.2).

   However, the presence of nature in the childhood neighbourhood was found to be significantly associated with attention (Section 4.4.2, Section 4.4.3.1)

b. *Is the frequency of visit to nature associated with attention?*

   Yes, the frequency of visit was found to be strongly associated with attention (Section 4.4.2, Section 4.4.3.3). Additionally, it was found that nature

relatedness mediated the relationship between nature in the current neighbourhood and frequency of visit.

c. *Does 'nature relatedness' affect the association of nature experience and attention?'*

   Yes, it was found that there was a full mediation effect of 'nature relatedness' in the association of nature experience and attention (Section 4.4.3.5, Section 4.4.4)

Research Question 2: What are the neurophysiological correlates of nature experience and directed attention?

d. *What are the effects of nature experience on the EEG frequency band power in different regions of the brain?*

   It was found that there was a significant increase in theta and alpha power in the fronto-parietal regions after nature experience.

e. *What are the effects of nature experience on Event-Related Potentials (ERP) associated with attention?*

   There was no significant difference in the mean amplitude of P2. However, there was a significant difference in the N2, and P3 mean amplitude, with lower mean amplitudes found in the after nature experience.

f. *What are the effects of nature experience on response time and accuracy in directed attentional tasks?*

   There was a significant decrease in the response time for the after nature experience cognitive task. However, no difference in the accuracy was found in the before and after nature experience scores for this study.

To conclude, the outcomes from this research indicate that people who interact more with nature report to be higher in attention. This research also demonstrated that nature experience

improved inhibitory control (indicated by lower N2 mean amplitude) and enhanced directed attention (indicated by lower P3 mean amplitude) for a subsequent cognitive task. The evidence from this research is of direct relevance to present-day needs for improving one's ability to focus and direct attention at the task in hand.

6.6 LIMITATIONS AND SUGGESTED FUTURE STUDIES

This section describes some of the limitations of the cross-sectional study and the lab-based experimental study and also suggests scope for future studies. The first study was a cross-sectional study which assessed the construct of 'nature in the neighbourhood' through a single item for each for the current neighbourhood and childhood neighbourhood. Now that this research has found some correlational evidence, it is suggested that multiple items with details of multiple aspects of the construct of nature in the neighbourhood may be constructed and studied. Though the cross-sectional design provided evidence for the significant associations between nature in the neighbourhood, frequency of visit and mindfulness, however, a causal relationship could not be derived. Future studies may be able to establish a causal relationship. It is suggested here that apart from the use of objective measures like GIS, future studies may develop a mixed method technique through which nature in the neighbourhood could be measured. Further, even though the frequency of visit in the study shows a significant association with the mindfulness, the variance explained here was moderate. There may be other factors that affect mindfulness (e.g. personality traits) and interfere with nature experience. This study did not account for such factors.

Notably, the preliminary results of this study have shown that childhood nature interactions positively associate with mindfulness in adulthood. This association could be further explored in future studies. Evidence from such studies could provide educators to develop innovative pedagogical techniques based on nature interactions for improved mental wellbeing.

The lab-based study employed a single group pre-post-test design. This method has been widely used in EEG based experiments but has a limitation on not being a true experimental design. Some of the limitations include; regression to the mean (RTM), maturation, history and test effects. Though control measures were taken in the experiment design to overcome these limitations, yet such a single group pre-post test study design does not offer the rigour of true randomised control experiments.

Further, the experiments were designed in a controlled lab condition, and nature experience was simulated through an audio-visual media. Future research could include a real-time scenario to explore the outcomes as listed in this study. The findings of this study are based on brief nature experience, the inclusion of the effect of time and duration of nature experience could provide evidence for effectivity of nature experience as an intervention.

Another limitation for the lab study was that the sample consisted of only male participants as only male participants were available to the researcher who volunteered. Also, as the need for a mixed-gender sample was not felt to be critical to the research question, further efforts to solicit female participants was not done. Though, there are references in literature that challenges the requirement of a mixed-gender sample population for a research study by providing evidence towards no significant differences in the assessment of psychological constructs (Hyde, Fennema, & Lamon, 1990; van den Berg et al., 2016). However, it may be interesting to conduct ERP studies of both the genders separately in future. Lastly, findings from both the studies are based on the sample population from primarily urban settings. Perhaps a mixed group sample from both urban and rural settings could shed more light on the common associations and differences. Nevertheless, given the limitations of the study as described above, one advantage of the current design is that it gives a good reflection of the association of nature experience with attention and the likely effects of nature experience on inhibition control and attention enhancement.

6.7 CONTRIBUTIONS OF THIS THESIS

1. A significant contribution of this thesis is that it provides preliminary evidence towards the neurocognitive mechanisms that are affected by nature experience.
2. The outcomes suggest that improved control of inhibition could be one of the aspects of enhanced directed attention that is associated with nature experience.
3. To our knowledge, this is the first study that attempts to understand the effects of nature experience on the neurophysiological, cognitive processes involved in attention through ERP components P2, N2 and P3.
4. This thesis has extended the existing evidence on the relationship between EEG oscillations and nature experience. It has examined both alpha and theta during a cognitive task subsequent to nature experience.
5. Further, the cross-sectional study also validates the claims of the neuro-cognitive research that nature experience enhances attention, by providing evidence for a significant relationship between self-reported frequency of visit to nature-rich places and attention.
6. Lastly, it was interesting to observe that the effects of nature experience as reported in our experiment are similar to findings reported by studies on mindfulness and meditative states in yogic literature. The study provides preliminary evidence towards the yogic theory for the use of nature experience as a form of '*pratyahara'* to control the mind to attain a meditative state.

Altogether, the evidence from this research is of direct relevance to present-day needs for improving one's inhibition control, and the ability to direct attention at the task in hand. Given the current scenario where the ability to focus on a task is often found as one of the major challenges for most of the people, the findings of this research provide a major contribution

towards providing evidence for using nature experience as an alternate therapy for attention-related issues.

APPENDICES

APPENDIX 1: SUPPLEMENTARY INFORMATION TO LITERATURE REVIEW

Table 1 Summary of the Studies

Study	First author, Year, Location	Aim of the study	journal	Participants (P)	Mean age (yrs.) or age range	mode	Intervention/Exposure (E)	features	main outcomes (O)	affective/ cognitive/ neuro	tools	method / Study Design (S)
Effects of Forest Stand Density on Physio psychological Changes	An,2004 Japan	To investigate the influence of forest stand density on human's physio psychological changes.	Faculty of Agriculture, Kyushu University	18	19-23	images	different density forest	Spatial	**p:** beta wave at frontal, parietal and occipital regions was most intensive at 100 % stand density and least at 50 %. **a:** Emotional stability at 50 % stand density, 'tension-anxiety' greatest for 100 % (p<0.05)	a, n	EEG, POMS	within subject
Cognitive benefits of walking in natural versus built environments	Bailey,2018 USA	To explore the changes in mental state under testing and walking conditions in natural and built environments.	World Leisure Journal	10	20	visit	Indoor exposure to Aquatic recreation centre and outdoor exposure to natural trail	Spatial	**c**: stroops test=both environments (F1,18 = 15.625, p = .008, ηp2 = 0.331), 1.50 seconds faster after walking outside versus 0.25 seconds faster after walking inside **a**: the meditative (p = .033) and relaxed (p = .58) mindsets demonstrated a linear trend	c, n	Stroop test, BDST, Emotiv EEG	crossover
Why viewing nature is more fascinating and restorative than viewing buildings: A closer look at perceived complexity	Berg, 2016 The Netherlands	To study which visual features trigger people's often more positive affective responses to natural compared to built scenes	Urban Forestry & Urban Greening journa	40	21.8	images	40 images of natural and built environments	Spatial	**a:** significantly more restorative, b = 1.37, 95% CI = 1.12–1.62, ps < 0.001, equally complex as their built counterparts, b = 0.07, 95% CI = −0.16–0.30, p > 0.27, viewing times, b = 1.16, and restorative quality, b = 1.37, of the unmagnified scenes, ps < 0.001	a	questionnaire	RCT
Environmental preference and restoration: (How) are they related	Berg,2003 The Netherlands	To examine the inter-relationships between environmental preference and restorative effects	Environmental Psychology	106	22	video	natural and urban environment with or without water	Spatial, prior emotional state	**a**: depression: F=9:93; anger: F=9:68; tension: F= 8:98; overall happiness: F= 7:53; all p<0.01 Overall stress: F=6:64; p<0.05, for urban p > 0.10. Effect of environment on beauty ratings was b = 0:76; t=11:58; p<0.001. NE beautiful (M = 6.75) than U (M = 3.26),effect of environment on affective restoration was b= 0:32; t= 3:27; p<0:01 , preferences partially mediated by differences in affective restoration z =2:27; p<0:05(sobel's test) **c**: concentration index, F= 2:79; p= 0:098 and the speed index, F= 2:74; p= 0.10	a, c	POMS, happiness and Stress scale, Mental Concentration Test	RCT
Interacting with Nature Improves Cognition and Affect for Individuals with Depression	Berman,2012 USA	To explore whether walking in nature may be beneficial for individuals with major depressive disorder	Affect Disorder	20	26	visit	natural or urban environment	Spatial	**c**: Short term memory (BDST) increases= 3.67, p < .005, time × location = 20.5, p < 001, ηp2 = .53,effect was nearly 5 times larger than in depressive state (ηp2= .14) **a**: positive affect increases(nature vs. urban), location F = 16.85, p < .001, time no effect of time F(1,16) = 2.04, Changes in PA did not correlate with changes in BDS performance after either walk (ps >.19),	a, c	BDI, PANAS, BDST	RCT
The Cognitive Benefits of Interacting with Nature	Berman,2008 USA	To compare the restorative effects of interactions with natural versus urban environments on cognitive functioning	Psychological Science	38	22.6	visit	natural vs urban	Spatial	**c**: Short term memory (BDST)improved F=6.055, prep = .95 **a**: F (1, 35) 5 9.639, prep 5 .98, correlation with cognitive change not significant (nature: r 5 .206, prep 5.80; downtown: r 5 .029, prep 5 .54)	a, c	PANAS, BDST	crossover
	Berman,2008 USA	2)to test ART by using the Attention Network Test	Psychological Science	12	24.5	images	natural vs urban	Spatial	**c**: Directed Attention (ANT) improved F=17.089, prep =5 .99, Short Term Memory (BDST) improved-nature t = 2.972, prep = .96, urban areas, t=1.436, prep=.83 **a**: no change in mood, t=0.03, prep =.51. , more refreshing, t=54.45, prep5.99, enjoyable, t= 3.35, prep 5 .97, than pictures of urban areas.	a, c	ANT, BDST, PANAS	

An exploratory study of the effect of high and low fascination environments on attentional fatigue	Berto,2010 Italy	To test if performing an attention-orienting task in a state of attentional fatigue costs less in a high fascination than in a low fascination condition	Environmental Psychology	31	22	images	natural vs urban, fascinating vs non fascinating	prior emotional state	**c:** memory-The interaction FASCINATION NATURALNESS significant, F =10.77, p < .001, no difference in natural vs built. Attention: no difference in natural vs built. Fascinating significant for both F (1, 31) = 4.99, p = .03.	C	SART, attention task (based on Posner's attention-orienting paradigm), free recall test	within subject design
Natural resistance: Exposure to nature and self-regulation, mood, and physiology after ego-depletion	Beute,2014 The Netherlands	To test whether viewing natural scenes can also improve self-regulation	Environmental Psychology	90	22	images	natural vs urban	Spatial, prior emotional state, preference	**c**: Attention- Stroop test RT for depletion (M=1432.42, SE=27.57) than Non-depletion (M= 1336.43, SE =28.29) condition. No change in OSPAN, Stroop test RT for natural scenes (M=1355.56, SE =103.91) than after No content (1432.41,SE=115.75) or urban scenes (M=1436.87, SE=105.61) E: SAM Pleasure significant (F=5.5, p=0.023, 0.10) and preference (F=49.34, p<.001), Preference mediated effect of Environment on SAM-pleasantness (Z=2.06, p=.010),	a, c	typing task, Stroop Task, OSPAN, Activation-Deactivation adjective Checklist, UWIST Mood Adjective Checklist, PTE, HRV, SAM	between-subjects design
Study-2	Beute,2014 The Netherlands	To investigate the possibility of buffering or 'instigative' rather than restorative effects of nature	Environmental Psychology	121	21	images	natural vs urban	Spatial, prior emotional state, preference	**a**: increased hedonic tone after viewing natural scenes irrespective of depletion, higher preference (M=5.05, SE= .16) than for Urban (M = 3.54, SE = .16), marginally mediation effect of preference on hedonic tone (p = .068).	a, c	typing task,2-back task -working memory span task, AS HRV	between-subjects design
Linkages between landscapes and human well-being: An empirical exploration with short interviews	Bieling, 2014 Germany	How the biophysical features of a specific area contribute towards the well-being of the people attached to it	Ecological Economics	262	na	Visit	forest (4 types)	Spatial, values and beliefs	**a**: 'Mountains', 'forest, woodland' and 'water bodies' most prominent landscape forms b) Spatial features interlinks 'landscape values' and wellbeing c) practices correlates with relationships (r = 0.56, p ≤ 0.001)	a	face-to-face interviews	open interview
Psychological Wellbeing Benefits of Simulated Exposure to Five Urban Settings: An Experimental Study from the Pedestrian's Perspective	Borniolia, 2018, UK	To assess the affective outcomes associated with several urban walking settings.	Journal of Transport & Health 9 (2018) 105–116	269	18-67	video of simulated walk	urban pedestrian and green park walk	Spatiall	**a:** Relaxation increases, Hedonic tone increases (p<.001)	a	Mood Adjective Checklist (UWIST MACL scale), PRS scale-short version	mixed within-between subject
The benefits of nature experience: Improved affect and cognition	Bratman ,2015 USA	To study the impact of nature experience on affect and cognition	Landscape and Urban planning	70	m=22.9	visit	walk in natural or urban area	Spatial	**a:** decrease in anxiety, rumination, and negative affect, maintained positive affect, **c:** increase verbal working memory	a,c	questionnaires, PANAS, STAI, RRQ, and cognitive testing OSPAN, change detection task, Attention Network Task, backward digit span test	Pre-post test
Nature experience reduces rumination and subgenual prefrontal cortex activation	Bratman, 2015 b USA	To study the impact of nature exposure on rumination	PNAS	38	Mean age = 26.6	visit	walk in natural or urban area	Spatial	**C:** RRQ- decreases mean score prewalk = 35.39, SE = 1.60; mean score postwalk = 33.06, SE = 1.61], no such effect for the urban group (mean score prewalk = 30.11, SE = 2.61; mean score postwalk = 30.16, SE = 2.50). **P:** decreases in sgPFC activity.	n	CBF pre-post walk through MRI, RRQ	pre-post test
Viewing Nature Scenes Positively Affects Recovery of Autonomic Function Following Acute-Mental Stress	Brown, 2013 USA	viewing nature scenes (composed of trees, grass, fields) prior to a stressor will lead to higher HRV in recovery when compared to viewing scenes of built environments	Environmnetal Science and technology	25	19-65	slideshow	slides of natural or built environment	Spatial, temporal	**a:** main effect of view (F1, 22 = 11, p = 0.003, ηp 2 = 0.33) and time (F1, 22 = 7.7, p = 0.011, ηp 2 = 0.26), b) enhanced self-esteem and no effect on positive mood. c) HRV as a marker of ANS function increased during stress recovery	a,n	PANAS, POMS, forward digit span test	crossover

Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas	Carrus, 2015 Italy	To study whether urban residents' evaluations of urban and peri-urban natural settings and the positive outcomes deriving from contact with such settings vary as a function of their biodiversity	Landscape and Urban Planning	569	41	visit	Urban /peri urban X high & low Biodiversity	Spatial-physical, temporal	**a:** subjective wellbeing, perceived restorativeness score - higher scores biodiversity green areas b) self-reported benefits and well- being significantly correlated with length of visit to green areas (r = .15; p = .000; n = 566), biodiversity level (r = .22; p = .000; n = 569), perceived restorativeness (r = .68; p = .000; n = 568). c) length of visit and level of biodiversity) independent of each other (r = .08; p = .06; n = 566)	a	PRS, open ended questions, questionnaire measuring time and frequency of visits, preference, and physical and psychological benefits	between groups (2 X2 factorial design)
Psychophysiological responses and restorative values of natural environments in Taiwan	Chang, 2008 Taiwan	To establish the recovery/ restoration benefits response to natural environments and to correlate between psychological and physiological reactions.	landscape and urban planning	110	-	images	Environments representing components of ART	Spatial,Perceived Restorative Content	**n:** EEGa, EEGb, and EMG measures increasing and BVP decreasing, **a**: congruence between the actual PRS scores and the theorized restorative environments of ART	a,n	PRS, EEG, EMG, BVP	pre-post-test design
Human Response to window views and indoor plants in workplace	changchen, 2005 Taiwan	To study the effects of window views and indoor plants on human psychophysiological response	HortScience	38	-	images	window views	Spatial-restorative components	**n:** greatest effect EEGb (M=1.11, SD=2.360 lowest BVP (M=9.80, SD=0.21) **a:** Anxiety level lower (M=69.50) for view of nature and indoor plant	a, n	State Anxiety Scale, EEG, BVP	
Enhanced functional connectivity properties of human brains during in-situ nature experience	Chen Zheng, 2016 China	To study the impacts of in-situ nature and urban exposure on human brain activities and their dynamics	PeerJ, Vol 4, p e2210 (2016)	32	m =20.6	visit	urban/natural scene (1/f statistics, beta value)	Spatial	efficient and stronger brain connectivity, higher global EEG correlation , both time domain and frequency domain , direct EEG amplitude correlation across recording sites, higher correlation in the right hemisphere than left hemisphere , significantly higher correlation of overall electrodes during nature exposure compared to that during urban environment exposure (F(1,420) = 14.68, p < 0.001), significantly higher overall power(delta, theta, alpha , beta) (F(1,134) = 120.14, p < 0.001), higher power correlation observed during nature exposure delta (T(13) = 10.76, paired by electrodes, p < 0.001), theta (T(13) = 6.73, paired by electrodes, p < 0.001), alpha (T(13) = 6.25, paired by electrodes, p < 0.001) and beta (T(13) = 5.06, paired by electrodes, p < 0.001) frequencies. Exposure (F(1,134) = 120.14, p < 0.001), average smaller shortest path lengths (Lmean),stronger lateralization for most brain regions except P8/P7 and O2/O1 regions. E: subjective affect, more restorative experience, higher fascination (T(28.93) = 3.23, p = 0.003), higher coherence (T(30) = 3.00, p = 0.005), increased perception of being away (T(30) = 4.31, p < 0.001) and higher compatibility (T(30) = 6.68, p < 0.001), less fatigue, more positive emotions, more sustained esteem and less Total Mood disturbance, no significant changes in attention	a, c, n	EEG, POMS, PRS, NCPCT, NEO personality test(neuroticism)	pre-post-test design
Wild or tended nature? The effects of landscape location and vegetation density on physiological and psychological responses	Chiang, 2017 China	To demonstrate the positive impacts of contact with nature on people's physiological and psychological health.	Landscape and Urban Planning	180	21.4	images using 3 D glasses	high, medium, low density conditions in natural environment	Spatial	**n:** higher the EEG-Alpha, less arousal and stress **a:** stress levels did not vary based on vegetation density, more positive mood and more negative mood and TMD in forest exterior **c:** enhanced attention evoked by forest interior	a, c, n	POMS-SF, Stroop task, EEG at Fp1	pre-post-test design
Physiological and psychological responses of humans to the index of greenness of an interior space	Choi,2017 South Korea	To identify the optimal index of greenness in terms of psychophysiological	Complementary Therapies in Medicine	103	21.6	images	images differing in % of greenness	Spatial	a: Greeness preferred 50 % from 20, 30, 80 %, semantics chosen for 50 %- fresh, comfortable P: No significant difference in EEG alpha power	a, n	Subjective index, EEG	pre-post-test design

		responses and subjective preference										
High altitude with monotonous environment has significant impact on mood and cognitive performance of acclimatized lowlanders: Possible role of altered serum BDNF and plasma homocysteine level	Das,2018 India	To investigate the impact of monotonous environment in remote HA on mood and cognitive performance of human volunteers	Journal of Affective Disorders	205	23-35	visit	high altitude natural environment	Spatial and temporal	C: cognitive impairment increased from 8 mths to 12 mths - 9.28 to 17.56 %, a: mild depression and severe depression increased for small group size -11.53(<5) vs 18.57 % (>10) and 1.55(<5) vs 3.7 % (>10)	a, c	MDCST, BDI	pre-post and within group design
Stress recovery in forest or handicraft environments – An intervention study	Dolling, 2017 Sweden	To test whether an outdoor forest environment would be more relaxing than an indoor handicraft environment.	Urban Forestry & Urban Greening	46	m= 48	visit	forest and handicraft environment	Spatial, temporal	**a:** lower levels of fatigue (CIS score), stress (PSQ score) and burnout (SMBQ score), No significant change in self-esteem (SCQ), equally improved general health, less tired and worn out, improved mental health. c)more relaxed, alert, happy, harmonious, peaceful and clearheaded. d)Physiological parameter: no significant change in sleep latency for those who visited forest environment.	a	Self-Concept and Short Form CIS, PSQ, SCQ, SMBQ, SF-36	longitudinal study design Pre-post test
Enhancing the benefits of outdoor walking with cognitive engagement strategies	Duvall, 2011 USA	To study how engagement in and interaction with the outdoor environment enhance well-being	Journal of Environmental Psychology	66	40-69	visit	walk in natural areas (engagement vs no engagement)	Spatial, temporal	**C:** Engagement condition- significant increases in attentional functioning (M=0.40, p<0.001) **E:** increase in feelings of contentment (M=0.39, p<0.001), significant decrease in feelings of frustration (M=-0.39, p<0.001), more time in outdoor increases contentment (M=0.42, p<0.005)	a, c	New General Self-Efficacy Scale, Attentional functioning Index - measuring vitality and affective experience, walking log, accelerometer	pre-post-test design
When walking in nature is not restorative—The role of prospect and refuge	Gaatersleben, 2013 UK	To examine restoration in natural settings with different levels of accessibility, prospect (clear field of vision) and refuge (places to hide).	Health and Place	269	22.5	images	natural forest area- segregated as prospect/refuge	Spatial	a: Prospect–refuge significantly predicted fear (B= 1.09, p<.001) and fear significantly explained perceived restoration (B= .68, p<.001), prospect–refuge significantly explained perceived restoration (B=1.04, p<.001)	a	Self-rated perceived restoration. Fear and danger	within subject and between subject
Study-2	Gaatersleben, 2013 UK	To examine whether people who are exposed to natural environments with high prospect and low refuge are more likely to recover from stress and mental fatigue than respondents exposed to a natural environment with low prospect and high refuge		17 17	23 21	visit video	natural forest low prospect high refuge vs high prospect low refuge	Spatial	**a:** positive affect more in high prospect–low refuge environments (M=2.50) than low prospect high refuge environments (M=1.36; F=47.78, p<.001), sadness decreased in low refuge environment(M= 0.03) increased in low prospect–high refuge(M=1.04), Anger/aggression- reduced(M= -1.16) increased in low prospect and high refuge (M=0.25; F=56.72, p<.001), Fear arousal- high prospect low refuge (M= 0.52) low prospect–high refuge (M=0.25; F=23.72, p<.001). **C:** Attention - NCPCT score reduced high prospect–low refuge(M=0.42) increased low prospect–high refuge (M=0.61; F=8.74, p<.01)	a, c	ZIPERS, NCPCT, HR monitor	within subject and between subject
Investigations of human Eeg Response to viewing fractal patterns	Hagerhall,2008 Sweden	what responses do fractals induce in the observer	perceptions	31	18-64	images	landscape silhouette (computer simulations of fractal horizons)	Spatial	n: maximal alpha response in the frontal region, highest beta response in the parietal region	n	EEG,	within subject and between subject
Tracking restoration in natural and urban field settings	Hartig, 2003 USA	To compare psychophysiological stress recovery and directed attention restoration in natural and urban field settings	Journal of Environmental Psychology	112	mean age = 20.8	insitu	urban and natural environment	Spatial	a: increase in positive affect and decline in anger/ aggression C: performance at NCPCT improved slightly	a, c	blood pressure, ZIPERS, OHS, NCPCT	pre- post-test design

Restorative effects of natural environment Experiences	Hartig,1991 USA	To study the restorative effects of wilderness	Environment and Behaviour	68		visit	wilderness vs non-wilderness	Spatial	a: overall happiness, positive affect, negative correlation with anger, aggression. wilderness experience has restorative effects, recovery from mental fatigue (behavioural measures) proofreading and	a, c	wilderness-urbanism scale (Hendee, Catton, Marlow & Brockman,1968), ZIPERS, OHS, Proof reading task	pre-post measurements and group comparisons
Study-2	Hartig,1991 USA			34	20	visit	natural (NE) vs urban(U) vs passive relaxation(R)	Spatial	a: Significant difference in restorative effects- NE (M=80.8),U(M=66.2), R (M=57.8), OHS NE(M=81.4),U (M=74.4),R(M=71.8), Anger depression NE(M=1.14), U(1.30), R(1.44), Positive Affect NE(3.02), U(2.59),R(2.55) C: stronger impact of NE on mental fatigue recovery (M=56 %) (M=49.5%) R(M=48 %)recovery	a, c	ZIPERS, OHS, Proof reading task adapted from Glass and Singers (1972), BP/Pulse Monitor, Skin Conductance, PRS	pre-post measurements and group comparisons
Assessing the restorative components of environments	Herzog,2003 USA	To measure the four components of a restorative environment proposed by attention restoration theory (ART)	Journal of Environmental Psychology	512	-	images	urban and forest natural environment	Spatial	a: PRP significantly correlates with preference, being away, extent, fascination and compatibility p<0.001	a	rating, questionnaire	between group comparison
A dose of nature: Tree cover, stress reduction, and gender differences	Jiang,2014 Hong Kong	To establish the dose–response curve	Landscape and Urban planning	158	21.2	video (3D)	Street views with natural elements such as trees	Spatial, gender	significant gender difference in salivary cortisol level reduction between women and men (t = −2.91, p < .01), a marginally significant gender difference in skin conductance level reduction (t = 1.83, p = .07	a	Trier social stress test (TSST), Skin Conductance, Salivary Cortisol	
Does biological quality matter? Direct and reflected appraisal of biodiversity in temperate deciduous broad-leaf forest	Johansson,2014 Sweden	To investigate direct (perceptual, emotional, and physiological responses [qEEG]) and reflected (preference, attitude, and intention to accept conservation measures) appraisal of different levels of biodiversity in temperate deciduous broad-leaf forest biotopes.	Urban Forestry & Urban Greening	35	20-66	images	forest of different levels of biodiversity	Spatial	E: BEI-H biotope rated highest followed by the I biotope, which in turn was rated higher than the L biotope ,emotional response (BEP) was positive (¯x>3.00) for all biotopes, emotional response was appraised significantly more positive in the I biotope, followed by the H biotope and the L biotope, I biotope was rated significantly higher in preference than the H biotope, and the L biotope, i.e. the quadratic trend showed the largest effect size P: highest frequencies (Beta), there was a significant quadratic trend between the environments in the frontal region of the right hemisphere, with higher power for the I biotope than for the Hand L biotope, alpha power showed no trend	a, n	Biodiversity experience index (BEI-index), anticipated emotional response BEP (Basic emotional response), Environmental preference, attitude towards conservation, EEG recordings	within subject design
Human brain activation in response to visual stimulation with rural and urban scenery pictures: A functional magnetic resonance imaging study	Kim,2007 Korea	To explore the common and differential activation maps yielded by viewing two extreme types of scenery,	Science of the Total Environment	30	28	images	rural vs urban environment	Spatial	n: brain regions, including the temporal, parietal and occipital lobes, showed greater activity during rural scenery viewing while the frontal lobe was dominant during urban scenery viewing (p<0.01), insula and the splenium of the corpus callosum showed much higher activities during rural scenery viewing, the superior parietal gyrus (z-score, 3.72), anterior cingulate gyrus (z-score, 3.12), postcentral gyrus (z-score, 2.94), Globus pallidus (z-score=2.58), putamen (z-score=2.46) and head of the caudate nucleus (z-score= 2.28) (p<0.01).	n	fMRI	crossover
A comparison of the restorative effect of a natural environment with that of a simulated natural environment	Kjellgren, ,2010 Sweden	To compare the restorative effects of 30 min relaxation in a natural environment with an indoor simulation of the same natural environment	Journal of Environmental Psychology	18	m= 37	images	natural environment vs simulated condition with pictures from same environment	Spatial, mode, prior emotional state	a: no significant change in stress, higher altered states of Consciousness (EDN) after natural environment than after the simulated natural environment. Verbal descriptions six categories; Intensified sensory perception; A feeling of harmony and union with nature; Well-being and quality of life; Renewed energy and awakening; ‘‘Here-and now’’ thinking; A sense of tranquillity.	a	Phenomenological Psychological method (EPP), hospital anxiety depression scale (HAD). Stress-Vassalages I-II (Holmquist,1974), Altered States of Consciousness Scale (EDN)	repeated-measure design
What’s wrong with virtual trees? Restoring	kort,2006, The Netherlands	To investigate the importance of immersion in a	Journal of Environmental Psychology	80	m =24	virtual	immersive projection of natural	mode, prior emotional state	positive affect after nature viewing irrespective of screen size, sense of presence not influenced by screen size	a	questionnaire and skin conductance,	pre-post-test design/betw

from stress in a mediated environment		mediated environment in relation to restoration.					environment film without sound				heart period (EKG) measurements	een subject design
Selective attention and heart rate responses to natural and urban environments	Laumann,2003 Norway	To study that exposure to nature stimuli restores depleted voluntary attention capacity and affects selective attention	Journal of Environmental Psychology 23	28	18-24	video	nature and urban video	Spatial, prior emotional stress	C: for nature group- increase in the IBI during the post-video attention orienting-task compared to the pre-video attention-orienting task, F=12:51; p = 0:001, Mean IBI was also significantly longer during the post video attention-orienting task compared to the mental load phase, F= 54:49; p<0:001,IBI was longer during the video than during the baseline, F=19:18; p<0.001.	C	attention-orienting task	pre-post-test/between group
Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes	Lee, ,2009 Japan	The restorative effects of viewing real forest landscapes were examined through field experiments by comparing the effects of urban landscapes	Scandinavian Journal of Forest Research	12	m= 21	visit	urban vs natural environment	Spatial, time	a: significantly differences in psychological responses comfort (forest 2.9, urban 1.3; p<0.01), soothening- awakening (3.3, urban 1.1; p<0.01), refreshing (forest 61.1, urban 49.7; p<0.05) significantly higher subjective scores in forest	a	index of stress response)	Crossover design
Walking in "wild" and "tended" urban forests: The impact on psychological well-being	Martens,2011 Switzerland	To study if positive effect of natural environment is consistent in different natural conditions namely wild and tended urban forests.	Journal of Environmental Psychology	96	mean age= 37.6	visit	wild or tended forest	Spatial - physical, temporal, Safety, values and beliefs	a: Post treatment with controlled pre-treatment- a stronger increase of "positive affect" (wild M= 5.67, tended M=6.24, p<0.05) and a stronger decrease of "negative affect" (wild M=0.77, tended M=0.38 p<0.05) "Activation" and "arousal" did not show differences between the conditions. No change in morning evening.	a	self-rated well-being, perceived attractiveness.	pre-post treatment design
Seeing our self-reflected in the world around us: The role of identity in making (natural) environments restorative	Morton,2017 UK	To study how salient identities, modify how people's response to natural environments	Journal of Environmental Psychology	140	19.23	images	urban or natural environment	Spatial, values and beliefs	a: rural identity saliency- exposure to natural (versus urban) images increased the relative importance of intrinsic over extrinsic aspirations, F= 8.76, p= 0.004, urban identity saliency- exposure to urban (versus natural) images increased the relative importance of intrinsic over extrinsic aspirations, F= 9.92, p =0.002,	a	Salient identity questionnaire, aspiration index	between subjects
Engaging the Brain: The Impact of Natural versus Urban Scenes Using Novel EEG Methods in an Experimental Setting	Roe, ,2013 UK	To explore if electroencephalography (EEG) technology could detect emotional change to the experience of landscape vs urban scenes	Environmental Sciences	20	m= 30	images	urban vs natural environment	Spatial	a: more positively on the preference scales (i.e. attractiveness-NE(M=8.220), U(M=3.93), willingness to visit NE(M=8.09), U(M=3.60) and valance ratings NE(M=7.52), U(M=4.52), arousal NE(M=4.27), U(M=5.03) (p<0.000). n: EEG output Excitement NE(M=1.80) U(M=4.62), LT excitement NE (M=1.70) U(M=4.35), Meditation NE(M=3.47) U(M=2.58), engagement NE(M=3.26) U(M=2.71)	a, n	EEG, Subjective preference	within subject design
The Influence of the Environment on Directed Attention, Blood Pressure and Heart Rate—An Experimental Study Using a Relaxation Intervention.	Sahlin, ,2014 Sweden	To explore if relaxation indoors and in nature differently affect directed attention.	Landscape Research	51	45	Visit	natural environment and relaxation technique	Spatial-physical, perceived restorative content	C: NCPCT Outdoor before (M=5.27) after(M=4.78), between conditions (95% CI), Wilks' lambda-relaxation (0.30), Environmental effect (-0.64), interaction effect (0.37), Parkside (0.59), wood edge (-0.07), Cognitive weariness- less weary outdoor diff. (0.95) indoor (0.50); More weary outdoor diff. (0.56) indoor (0.06)	c	cognitive weariness "Shirom-Melamed Burnout Questionnaire, NCPCT	case cross over design, pre-post design ;
Where to recover from attentional fatigue: An expectancy-value analysis of environmental preference	Staats,2003 The Netherlands	To test hypotheses about restoration as a basis for environmental preferences	Journal of Environmental Psychology	101	21	images	urban and natural environment images in form of slides	Spatial	NE walking- attentional fatigue (M=6.1), no attentional fatigue (M=5.8), preference and attitude strongly correlated, U(r = 0:88, p<0:01) NE (r = 0:80, p<0:01),Likelihood of Recovery NE (M= 5:8), U(M=3.3), attentionally fatigued (M = 6.2),no attentional fatigue condition (M = 4.8);Reflection U(M=3.50, NE(M=5.4) ,attentionally fatigued (M = 4.0),no attentional fatigue condition (M = 5.3); Social Stimulation-U(M = 5:6) , NE(M= 2.6)	a	questionnaire, environmental preference, behaviour, attitude	between subject and within subject
Alone or with a friend: A social context for psychological restoration and environmental preferences	staats,2004, The Netherlands	To test the propositions about the influences of social context and need for psychological restoration on	Journal of Environmental Psychology	106	21	images	urban, natural environment images in form of slide show.	prior emotional state, company,	attitude towards natural environment walking in attentional fatigue(M=6.1) non attentional fatigue(M=5.9), alone(M=5.9), in company (M=6.1) vs urban attentional fatigue(M=3.9) non attentional fatigue(M=5.0), alone(M=4.1), in company (M=4.8),	a	Scenario technique, questionnaire	between subject and within subject

		preferences for natural and urban environments						safety, attitude	C: likelihood of recovery natural environment (M=6.0), Urban(M=3.8), reflection natural environment (M=5.5), Urban(M=4.2) , recovery in attentionally fatigued (M=6.2), no attentional fatigue(M=5.3) and reflection in attentionally fatigued (M=4.2), no attentional fatigue(M=5.6), social stimulation in Urban (M=5.8), NE(M=3.0) all p's <0.001 correlation between company and safety urban (r=0.11, p>0.23) NE(r=0.25, p<0.01 company alone did not predict likelihood of recovery (b= 0.05, i.e.=0.16, n's.) company predicted safety (b=0.25, t=2.68, p<0.01) and safety predicted recovery (b=0.45, t=4.90, p<0.001), company negative effect on reflection (b=- 0.19, t=1.92, p<0.06).			
It is not all bad for the grey city – A crossover study on physiological and psychological restoration in a forest and an urban environment	Stigsdotter, 2017a Denmark	To gain further knowledge of the restorativeness of a best case urban and natural environment	Health and Place	51	20-36	Visit	forest and urban environment	Spatial-physical, perceived restorative component	a: reduction in mood disturbance (M=7.32 to M=3.51) (p < 0.05) "Tension-Anxiety" (M=2.95 to M=2.26), "Fatigue-Inertia" (M=6.70 to M=5.49) and "Confusion-Bewilderment" (M=5.60 to M=4.77) were substantially reduced by the forest walk.	a	HRV, BP, POMS, PRS, PSS	crossover design
Forest design for mental health promotion--Using perceived sensory dimensions to elicit restorative responses	Stigsdotter, 2017b Denmark	To identify which qualities and perceived sensory dimensions (PSD) of a forest environment is psychologically restorative	Landscape and Urban Planning	26	-	visit	8 different natural environment viz sensory dimensions	Spatial-perceived restorative components (sensory dimensions)	Most restorative -serene, followed by rich in species, nature and refuge. less restorative; prospect, social, space, and culture.	a	interpretative phenomenological approach	crossover study, using mixed method
Exploring perceived restoration potential of urban green enclosure through immersive virtual environments	Tabrizian,2018 USA	Examine the effects of green space enclosure on perceived restorativeness and perceived safety in two urban setting	Journal of Environmental Psychology	87	20	virtual	18 digitally manipulated photo-realistic Immersive Virtual Environments (urban green enclosure)	Spatial - perceived restorative component, safety	main effects of Spatial arrangement and permeability on PR were non-significant. Significant differences in PS were found between Spatial arrangement levels (F= 45.24, p < .001). PS ratings were significantly lower in 4-sided condition than the 1-sided condition	a	PRS, Perceived safety	mixed factorial design with between and within subject design
Emotional, Restorative and Vitalizing Effects of Forest and Urban Environments at Four Sites in Japan	Takayama,2014 Japan	To investigate the well-being effects of short-term forest walking and viewing ("forest bathing")	Environmental Research and Public Health	45	21	visit	4 forest areas of Japan and urban down towns	Spatial	a: Significant correlation of ROS and confusion(r=-0.416) p<0.01; Tension-Anxiety(r=-0.251), p<0.01; Anger- hostility (r= -0.332) p<0.05	a	POMS, PANAS, ROS, SVS	Crossover
FATIGUE-RECOVERING EFFECT OF A HOUSE DESIGNED WITH OPEN SPACE	Tanaka,2013 Japan	To examine the effects of such an open space on recovery from mental fatigue.	Explore	16	43.5	visit	house designed with nature open space and no open space	Spatial	Open condition- Relaxation (M=51.6 to M=65.8), Comfort (M=53.7 to M=70.7), fatigue (M=28.8 to M=24.9) Closed condition- Relaxation (M=51.8 to M=55.9), Comfort (M=55.6 to M=57.6), fatigue (M=27.0 to M=26.8)	a, c	VAS, ATMT	Crossover
Using functional Magnetic Resonance Imaging (fMRI) to analyse brain region activity when viewing landscapes	Tang,2017 Taiwan	To compare the restorative value of four types of landscape environments (urban, mountain, forest, and water)	Landscape and Urban Planning	31	20-30	images	urban, mountain, forest, and water environment	Spatial	PRS -mountain and water landscapes, followed by Forest landscapes, urban settings scored the lowest. P: Brain activity that was most closely associated with the "urban versus mountain" contrast was located in the left and right cuneus). "urban versus water" con-tract was located in the left and right cuneus and the right cingulate gyrus and left precuneus were also activated.	a, n	PRS Questionnaire, FMRI	within subject design
Restorative urban forests: Exploring the relationships between forest stand structure, perceived restrictiveness and benefits gained by	Tomao,2018 Italy	To know which forest stand structure features and indicators are linked to actual or perceived psychological restoration	Ecological Indicators	218	41.7	visit	forest with various stand structure	Spatial	Being-away, fascination and compatibility proved to be important predictors of PSB even when stand structure variables were considered and the socio-demographic characteristics of participants were used as control factors	A	PRS, Self-reported psychological and physical benefits	between subjects

visitors to coastal Pinus pine forests												
The influence of urban green environments on stress relief measures: A field experiment	Tyrvainen,2014 Finland	To investigate the psychological (perceived restorativeness, subjective vitality, mood, creativity) effects of short-term visits to urban nature environments.	Environmental Psychology	77	47.6	visit	a built-up city centre (as a control environment), an urban park, and urban woodland	Spatial temporal	a: increase of feelings of restoration (Forest M=5.2, Park M=5.0, City M=4.2) and positive mood (Forest M=4.5, Park M=4.4, City M=3.8) C: feelings of creativity were higher in green environments (M=2.8 to M=3.8) (Forest M=3.8, Park M=3.7, City M=2.8)	a, c	Focus of Attention scale, ROS, SVS, PANAS, PRS, and Creativity	within subjects
Natural Versus urban scene: some psychophysiological effects	Ulrich,1981 Sweden	To study the alpha wave amplitude and heart rate differences by exposure to different type of landscape scenes	Environment and behaviour	18	20-27	images	nature with water, nature with vegetation and urban environment	Spatial-physical	a: Unpleasantness- Pleastness W(M=4.77), V(M=4.43) U(M=2.68), Ugly- Beautiful W(M=5.10), V(M=4.53) U(M=2.76) n: alpha was higher for vegetation and water as compared to urban viewing. ($p<0.01$)	a, n	EEG, emotional states, HR	within subjects
Cognitive and affective responses to natural scenes: Effects of low level visual properties on preference, cognitive load and eye movements	Valtchanov,2015 Canada	To investigate the influence of low-level visual properties on scene preference, cognitive load, and eye-movements	Environmental Psychology	55	-	images	natural and urban environment	Spatial	a: Pleasantness - NE(M=4.48) U(M=3.77), C: blink rates for urban scenes were significantly higher than baseline (M =24.8), t= 27.3, $p < 0.001$, while blink rates for nature scenes did not differ from baseline, t= 1.36, p = 1.36, n's. These results indicated that viewing urban scenes increased blink rates and cognitive load. Fixations for nature scenes were significantly longer across image variants, F=9.75, p =0.003.	a, c	eye tracker	between subject design
Stress recovery and restorative effects of viewing different urban park scenes in Shanghai, China	Wang, 2016 China	To explore the stress recovery effects of different videotaped scenes, using six urban parks and one urban roadway scene	Urban Forestry & Urban Greening	140	22.4	video	natural based vs hardscape components	Spatial, presence of others	SCR reducing value highest by watching Lawn w/people (84.20), followed by Lawn w/o people (83.50), Small Lake (79.20), Walkway (79.15), Plaza w/o people (74.15) and Plaza w/people (56.20), while the SCRreducing value was lowest by watching Urban Roadway (37.10), all six urban park scenes had a significant positive effect on state-anxiety relief, compared with the Urban Roadway scene (F= 11.59, $p < 0.001$,), which had a negative influence on state-anxiety. difference of reduced state-anxiety between Lawn w/people and Plaza w/o people was 7.50 (p = 0.468); between Lawnw/people and Plaza w/people was 4.50 (p = 0.910). restorative potential was significantly higher in Lawn w/o people (4.96) and Small Lake(4.95), compared to Plaza w/people (3.95)and Plaza w/o people (3.96) C:attentional levels improved significantly after watching the Lawnw/people ($p < 0.001$, Cohen's d = 1.09), Lawn w/o people (p = 0.001, Cohen's d = 0.97), Plaza w/o people ($p < 0.001$, Cohen's d = 1.17), Small Lake (p = 0.007, Cohen's d = 0.58) and Walkway (p = 0.001, Cohen's d = 0.73)	a, c	Skin Conductance Response (SCR), state (short-term) version of the State- Trait Anxiety Inventory (STAI-S), the Digit Span Backwards (DSB) test, and the Perceived Restorativeness Scale (PRS).	pre-post-test design
Physiological and cognitive performance of exposure to biophilic indoor environment	Yin,2018 USA	To examine the physiological and cognitive responses to natural elements in an office building	Building and Environment journal	28	23-42	visit	biophilic indoor design and without biophilic design	Spatial, mode	C: scored 14% (95%CI: 5.3%–23.2%) higher in short term memory in the biophilic environment compared to non-biophilic environment a: participants in the biophilic environment reported lower stress and frustration levels, higher engage-ment and excitement level compare to their responses in the non- biophilic environment.	a,c	blood pressure, galvanic skin response and heart rate, cognitive test-visual reaction time task, Stroop task; visual backward digit span task	crossover study design

Table 2 Comparative table of some of the qualitative research techniques

Approach	Method	Focus	Prework	Theory building/hypothesis	Sampling	Data collection methods	Level-1 coding	Level-2 Coding	Analysis	Theory formulation/ reporting
Inductive approach	Phenomenological Study (Price & Barrell,2012)	People who have experienced a phenomena	context to the phenomena	no hypothesis or theory	sample size 5-25 interviews	Lived experience of phenomena, conducting non directive interviews, reading documents or written or oral self- reports, watching videos, or visiting places and events, to understand the meaning participants place on the observed phenomena, conduct many interviews to build a sufficient dataset and look for emerging themes. Use different set of participants to validate the findings. Description of subjects experience, including their thoughts, feelings, images, sensations, memories - their stream of consciousness - along with a description of the situation in which the experience occurred	semantics, meaning of descriptions	abstraction of themes , "without which the experience would not have been the same"	thematic analysis, collective themes, individual themes(avoid interpretations) or content analysis (Intercoder reliability)	goal in phenomenological research is to describe the essential meaning of participants' lived experience, reporting means to expand the the themes & relate them to similar experiencesfrom literature sources. theme analysis is subjective, so ability to generalize is limited.
inductive approach	grounded theory (Charmaz, 2006)	develop a theory from grounded in field data	no literature survey required,' open minded not empty minded'	no prior theory or hypothesis, justa research theme , it provides an explanation or theory behind the events during the research	sample size 30-60	multiple same subject in depth interviews, document readings,look for deviant cases, data collection and analysis go hand in hand	open coding (line-by line coding) in vivo	axial coding (focused coding)	main categories to theme by data to data and data to concepts comparisons,	
Inductive approach	narrative research (Czarniawska,2004)	individual experience & sequence			1 to 2	In-depth interviews or documents/ reports , story building from events, surveys, narratives, stories from individuals and documents. Order of events and sequencing matter.				
Inductive approach	ethnography	context or culture	Researchers himself experiences the culture, Focus on practices	no hypothesis or theory generally	_	Rather than relying on interviews or surveys, researcher experience the environment first hand Observation, as a "participant observer." & interviews				
	case study	organisation, entity, individual or a specific event				interviews, documents, reports, observations				
deductive analysis	framework analysis and content anaylsis		extensive literature survey	pre concieved theory and hypothesis	purposive sampling	interviews, documents	categories or themes	subcategories or code list with defined parameters	content or framework analysis by data comparision tables, themes or central view point	verification of theory by top down approach

APPENDIX 2 :SUPPLEMENTARY INFORMATION FOR CROSS-SECTIONAL STUDY

Questionnaire

(A copy of the questions included in Google form used for collecting responses in the cross-sectional study)

This survey is a part of the doctoral research being done at IIT Delhi. The records of this study will be kept strictly confidential and would be used for research purpose ONLY.

I agree to participate in this survey.
Email address

Section 1: About me and my surroundings…

1. Age
2. Gender
3. Qualification

Below are questions that describe the surroundings that you live in or have lived in.
Please read the following questions carefully and answer accordingly. *Mark only one oval.*

4. The surroundings I spent my childhood years in, was rich in nature?
5. The surroundings I presently live in is, rich in nature?
6. How often do you visit a place rich in nature eg. parks, gardens, or any other type of green areas?

Section 2: How I feel...

For each of the following, please rate the extent to which you agree with each statement, using
the scale as shown below. Please respond as you really feel, rather than how you think "most people" feel.

7. My ideal vacation spot would be a place rich in nature.
8. My relationship with nature is an important part of who I am.
9. My connection to nature and the environment is a part of my spirituality.
10. I always think about how my actions affect the environment.
11. I take notice of nature wherever I am.
12. I feel very connected to all living things and the earth

Section 3: My experience...
Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience.

Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

13. I could be experiencing some emotion and not be conscious of it until sometime later.
14. I break or spill things because of carelessness, not paying attention, or thinking of something else.
15. I find it difficult to stay focused on what's happening in the present.
16. I tend to walk quickly to get where I am going without paying attention to what I experience along the way.
17. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.
18. I forget a person's name almost as soon as I've been told for the first time.
19. It seems I am "running on automatic," without much awareness of what I am doing.
20. I rush through activities without being really attentive to them.
21. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.
22. I do jobs or tasks automatically, without being aware of what I'm doing.
23. I find myself listening to someone with one ear, doing something else at the same time.
24. I drive places on 'automatic pilot' and then wonder why I went there.
25. I find myself preoccupied with the future or the past.
26. I find myself doing things without paying attention.
27. I snack without being aware that I'm eating.

Supplementary Statistical Results

Table 3 ANOVA results for the between-subjects analysis of the effects of nature in the current neighbourhood (NCU) on nature relatedness (NR)

Tests of Between-Subjects Effects

Dependent Variable: NR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	258.646[a]	4	64.662	6.415	.000	.072
Intercept	29685.174	1	29685.174	2945.231	.000	.900
age	201.924	1	201.924	20.034	.000	.057
NCU	55.714	3	18.571	1.843	.139	.017
Error	3316.012	329	10.079			
Total	224600.000	334				
Corrected Total	3574.659	333				

a. R Squared = .072 (Adjusted R Squared = .061)

Table 4 ANOVA results for the between-subjects analysis of the effects of nature in the current neighbourhood (NCU) and frequency of visit (NVF) on Mindfulness attention and awareness scale (MAAS)

Dependent Variable: MAAS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17068.560[a]	15	1137.904	6.458	.000
Intercept	90971.314	1	90971.314	516.273	.000
age	9700.348	1	9700.348	55.051	.000
NCU	393.482	3	131.161	.744	.526
NVF	1794.333	3	598.111	3.394	.018
NCU * NVF	3448.043	8	431.005	2.446	.014
Error	56034.098	318	176.208		
Total	1264488.000	334			
Corrected Total	73102.659	333			

a. R Squared = .233 (Adjusted R Squared = .197)

Table 5 ANOVA results for the between-subjects analysis of the effects of nature experience combined (NE_combined) on Mindfulness attention and awareness scale (MAAS)

Dependent Variable: MAAS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14632.006[a]	10	1463.201	8.083	.000
Intercept	87236.475	1	87236.475	481.906	.000
age	8869.760	1	8869.760	48.998	.000
NE_Combined	3590.604	9	398.956	2.204	.022
Error	58470.653	323	181.024		
Total	1264488.000	334			
Corrected Total	73102.659	333			

a. R Squared = .200 (Adjusted R Squared = .175)

Table 6 ANOVA results for the between-subjects analysis of the effects of nature experience combined (NE_Combined)on nature Relatedness (NR)

Dependent Variable: NR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	557.521[a]	10	55.752	5.969	.000
Intercept	23228.109	1	23228.109	2486.687	.000
age	121.351	1	121.351	12.991	.000
NE_Combined	354.589	9	39.399	4.218	.000
Error	3017.138	323	9.341		
Total	224600.000	334			
Corrected Total	3574.659	333			

a. R Squared = .156 (Adjusted R Squared = .130)

Model Summary for the Regression of Nature experience on Attention

Table 7 Model Summary for the proposed relationship between nature experience and Mindfulness attention and awareness (MAAS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.389[a]	.151	.148	13.67229	.151	59.067	1	332	.000
2	.414[b]	.172	.167	13.52505	.021	8.268	1	331	.004

a. Predictors: (Constant), age

b. Predictors: (Constant), age, NE_Combined

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11041.402	1	11041.402	59.067	.000[b]
	Residual	62061.257	332	186.931		
	Total	73102.659	333			
2	Regression	12553.814	2	6276.907	34.314	.000[c]
	Residual	60548.845	331	182.927		
	Total	73102.659	333			

a. Dependent Variable: MAAS

b. Predictors: (Constant), age

c. Predictors: (Constant), age, NE_Combined

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	46.563	1.869		24.916	.000					
	age	7.527	.979	.389	7.685	.000	.389	.389	.389	1.000	1.000
2	(Constant)	38.720	3.295		11.751	.000					
	age	7.087	.981	.366	7.226	.000	.389	.369	.361	.976	1.025
	NE_Combined	1.123	.390	.146	2.875	.004	.203	.156	.144	.976	1.025

a. Dependent Variable: MAAS

Model Summary for Regression of Nature experience on Nature relatedness

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.238[a]	.057	.054	3.18682	.057	19.982	1	332	.000
2	.357[b]	.128	.122	3.06917	.071	26.940	1	331	.000

a. Predictors: (Constant), age
b. Predictors: (Constant), age, NE_Combined

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	202.932	1	202.932	19.982	.000[b]
	Residual	3371.727	332	10.156		
	Total	3574.659	333			
2	Regression	456.698	2	228.349	24.241	.000[c]
	Residual	3117.961	331	9.420		
	Total	3574.659	333			

a. Dependent Variable: NR
b. Predictors: (Constant), age
c. Predictors: (Constant), age, NE_Combined

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	23.940	.436		54.961	.000					
	age	1.020	.228	.238	4.470	.000	.238	.238	.238	1.000	1.000
2	(Constant)	20.728	.748		27.721	.000					
	age	.840	.223	.196	3.775	.000	.238	.203	.194	.976	1.025
	NE_Combined	.460	.089	.270	5.190	.000	.300	.274	.266	.976	1.025

a. Dependent Variable: NR

Model Summary for Regression of Nature Relatedness on Mindfulness Attention and Awareness Scale (MAAS)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.389[a]	.151	.148	13.67229	.151	59.067	1	332	.000
2	.445[b]	.198	.193	13.30984	.047	19.328	1	331	.000

a. Predictors: (Constant), age

b. Predictors: (Constant), age, NR

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11041.402	1	11041.402	59.067	.000[b]
	Residual	62061.257	332	186.931		
	Total	73102.659	333			
2	Regression	14465.432	2	7232.716	40.828	.000[c]
	Residual	58637.227	331	177.152		
	Total	73102.659	333			

a. Dependent Variable: MAAS
b. Predictors: (Constant), age
c. Predictors: (Constant), age, NR

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	46.563	1.869		24.916	.000					
	age	7.527	.979	.389	7.685	.000	.389	.389	.389	1.000	1.000
2	(Constant)	22.438	5.781		3.881	.000					
	age	6.499	.982	.336	6.620	.000	.389	.342	.326	.943	1.060
	NR	1.008	.229	.223	4.396	.000	.303	.235	.216	.943	1.060

a. Dependent Variable: MAAS

Hierarchical Regression of NE_Combined and NR on MAAS

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.389[a]	.151	.148	13.67229	.151	59.067	1	332	.000
2	.414[b]	.172	.167	13.52505	.021	8.268	1	331	.004
3	.453[c]	.206	.198	13.26573	.034	14.067	1	330	.000

a. Predictors: (Constant), age
b. Predictors: (Constant), age, NE_Combined
c. Predictors: (Constant), age, NE_Combined, NR

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11041.402	1	11041.402	59.067	.000[b]
	Residual	62061.257	332	186.931		
	Total	73102.659	333			
2	Regression	12553.814	2	6276.907	34.314	.000[c]
	Residual	60548.845	331	182.927		
	Total	73102.659	333			
3	Regression	15029.388	3	5009.796	28.468	.000[d]
	Residual	58073.271	330	175.980		
	Total	73102.659	333			

a. Dependent Variable: MAAS
b. Predictors: (Constant), age
c. Predictors: (Constant), age, NE_Combined

d. Predictors: (Constant), age, NE_Combined, NR

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	46.563	1.869		24.916	.000					
	age	7.527	.979	.389	7.685	.000	.389	.389	.389	1.000	1.000
2	(Constant)	38.720	3.295		11.751	.000					
	age	7.087	.981	.366	7.226	.000	.389	.369	.361	.976	1.025
	NE_Combined	1.123	.390	.146	2.875	.004	.203	.156	.144	.976	1.025
3	(Constant)	20.251	5.890		3.438	.001					
	age	6.339	.983	.327	6.451	.000	.389	.335	.317	.935	1.069
	NE_Combined	.713	.398	.092	1.790	.074	.203	.098	.088	.902	1.108
	NR	.891	.238	.197	3.751	.000	.303	.202	.184	.872	1.146

a. Dependent Variable: MAAS

APPENDIX 3: SUPPLEMENTARY INFORMATION FOR LAB-BASED STUDY

Instruction to the Participants

Please read the instructions carefully and try best to follow them during the experiment.

1. Notice any external sensations present in your body in the present moment; feet, hands, face or any other part of your body and make a note of it.
2. Make yourself comfortable in the chair.
3. Familiarize yourself with the white coloured response box kept in front of you.
4. Use only the first key for the left press and fifth key for the right press on the response box. Press the buttons only with your left and right hand index finger. Ask for a demonstration if not sure.
5. When you take rest time in between the test blocks, please keep your eyes open, please do not close them.
6. Notice your energy levels now, how you feel right now.
7. Notice your internal state of mind now, notice your thoughts as they come and go in that moment, notice your emotions, notice what is going inside your mind and make a note of it mentally.
8. Notice every change that you would be undergoing while watching the audio-video stimuli. The change could be sensations in the body or change in the kind of thoughts that come and go in that moment. The change could also be in the emotional state that you may undergo. Please make a note of all these states and let them come and go naturally.
9. The experiment will be followed by a debriefing interview to understand your experience during the experiment.
10. You will shortly begin with the test. Further instruction will be displayed on the screen. In case you have any questions, please feel free to ask the experimenter.

Table 8 Checklist for the research team

Step	Checklist/Action	Time	Comments
Pre-settings	1) Experiment/Interview room temperature at comfortable level of 25* C. 2) Things on the table: notepad and pencil. No other clutter/ distractions. 3) PC1 in the experiment room 4) PC2 data recorder in the observation room 5) PC3 screen display for impedance check in the observation room 6) Open E-prime on PC1 and set to run. 7) Check the EEG system assembly Amplifier connection with EasyCap Amplifier connection with I/O expander Charging of the amplifier Disconnect the amplifier from the mains Open Brain Products recorder in PC2 8) Fill two syringes with gel.	10mins	Switch on and check
Introduction / Purpose	1) (Greetings) I am glad you could take out time to participate in this study. 2) I hope you are feeling Ok to participate. Just as a mandatory clause, I hope you are not under any prescribed medication. 3) I hope you had a full night sleep are not feeling sleep deprived. 4) Hope you are not under any kind of extreme stress or anxiety. 5) It would take about 1 hr; I hope you do not have any urgency or task to attend to now or immediately after that? 6) Broadly we are trying to understand your experience during and after this experiment. 7) During the experiment you will be given a test, shown a video followed by a test again. 8) Please watch it with attention and notice your inner experience. Be aware of what is directly in that present experience (like taking a snapshot of whatever is happening). It could be sensations, perceptions, feelings,	2 mins	

	moods, thoughts or emotions 9) After you are finished with the experiment, we would discuss what your experience was like. 10) Do you have any questions? (if yes, answer them briefly being as close as possible to be factual and not let any information pass that could possibly create biases or affect the study data) 11) We request that you watch this video in one continuous session. However, if you feel the need to pause, you can press the first button on the response box. 12) A notebook with a pencil is kept just in case you may need them.		
Consent	1) We would be audio recording the debriefing and interview after the experiment session. Is it ok with you? 2) The data we collect during the interview will be purely used for research, and your identity will not be disclosed at any point of research. 3) Please fill up this form and sign the consent letter. (paper form of consent letter) 4) Shall we start ?	1min	
EEG	1) Prepare the Subject by placing the easycap on his scalp. 2) Inject the gel in each electrode till the impedance of each electrode reaches <20kΩ and a green LED is lit for each electrode. Close PC3 display screen. 3) Switch of the experiment room and observation room lights. 4) Ask if the subject is ready to start the experiment 5) Start recording on PC2	10 mins	
E-prime	Practice Block Pre-test flanker task (2 blocks with rest in between)	10 mins	note the start time here t1
Audio/visual	15 mins audiovisual	15mins	
Post-test	Post-test flanker task (2 blocks with rest in between)	10 mins	
EEG	Stop recording Unplugging the cap from participants head	2 mins	note the stop time here t2
Rest	Break for the participant	2 mins	
Interview	Start		note the start time here t3

Dos and Don’ts while conducting the Interviews

Do’s

1) Concentrate on hearing and comprehending what the subject is saying.
2) Pay attention to pauses, facial expression, and hand gestures. -
3) Remove distractions eg; thoughts (do not schedule any other task around the interview), senses (keep the room temperature comfortable, chair and seating must be comfortable, ensure no peculiar smells or sounds during the interview, remove all audio-video distractions from nearby areas that may affect the interviewee), emotions (ensure no positive or negative emotions to be present before conducting interview).
4) Give sufficient pause for interviewee to complete to listen to what he has to say
5) Paraphrase to ensure the correct meaning and confirm and refine understanding.
6) Notice the paralanguage eg. Voice modulation, rate of speech, tone, pitch and inflection
7) Allow pause for the portions of discussion you want to hear more on.

Don’ts

1) Don’t assume where the interviewee is leading to in the discussion.
2) Don’t interrupt or fill up for what the interviewee is about to say.
3) Don’t speak over the interviewee.
4) Don’t give him lead words
5) Don’t over emphasize on the things/words/phrases you may want to hear.
6) Avoid overly positive feedback for biases
7) Refrain use of leading probes or prompts/own perspectives.

Codebook (Notes to filling up the datasheet)

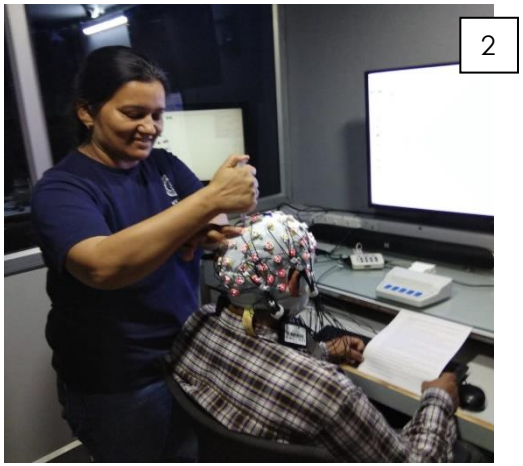
Observation	**Classification**
Facial expression	**Joy, Surprise, Disgust, Sadness, Anger, Fear, Neutral.**
Tone	**Whispered, soft, neutral, loud, and shouted.** The speech data to be analysed in terms of: i) sound intensity level, ii) sentence duration and silence duration.
Body language (Posture/ Movement)	**Dynamic Body Language and Static Body Language**. Dynamic body language refers to the transition from one posture or facial expression to another, which is represented by movements of the limb or head. Emotions, attitudes and information will be communicated during the movements. Nodding heads and waving hands are examples of dynamic body language. Static body language is static postures and facial expressions. For example, a person sits in front of a desk, cross-legged, with both ankles locked together and the head tipped slightly to one side and a palm supporting the face. This is a static posture, which might express criticism, hatred or negation against the speaker in social intercourse; therefore, this static posture is a static body language.

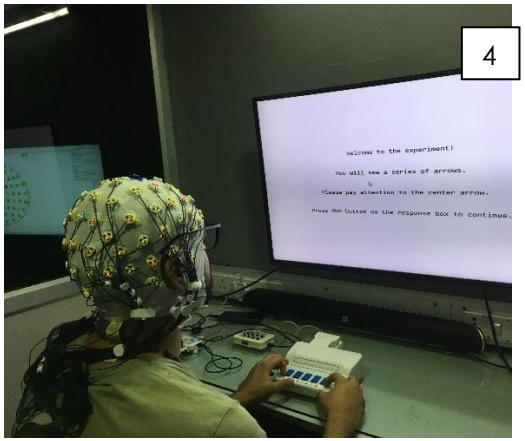
Table 9 Format for recording the responses from the debriefing interview in the lab-based study

UID	
Name	
Age	
Gender	female=1, male =2
Qualification	higher school=1, graduate=2, post grad=3
Place of residence	urban=1, semi urban=2, rural=3
Frequency of visit	rarely=1, often=2, very often=3

Classification	**Questions**	**transcriptions**	**tone**	**expression**	**gesture hand/ body**	**Initial Coding**	**Focused Codes**	**Categories**	**Memos**
Experience	So how was your experience while watching the video?								
Fascinations-attributes/conditions	Can you describe what you saw?								
Experience	What were your feelings or emotions at that time?								
Fascinations-attributes/conditions	What parts of the video did you enjoy the most?								
Experience	What did you notice was going on inside you at that time? Like in your thoughts, feelings, emotions anything that you noticed								
Fascinations-attributes/conditions	At what point of time did you experience *that*?								
miscellaneous	Is there anything more that you would like to add?								

Experiment Pictures





Picture 1 preparing the subject for the experiment by putting gel in 64 electrode system.

Picture 2 Subject reading the written instructions for the experiment.

Picture 3 picture depicting dimmed light in the experiment room before the start of the experiment.

Picture 4 Subject in the experiment start position with the right and left index fingers on the Chronos (response box)

Picture 5 A view from the observation room before the start of the experiment. The red LEDs show that the impedance limit of <20KΩ is not yet achieved, Green LEDs show the impedance level of <20 KΩ

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List of Publications Associated with this Doctoral Research

1. Sahni, P. and Kumar, J. (2015) 'Phenomenology of Higher Order Conscious Experiences and Spiritually Oriented Ecology' In: Pratibha Rai, Prem Kumari Srivastava. Eds. 'Spiritual Ecology and Sustainability: Practice and Confluence' ISBN 978-93-5207-386-3
2. Sahni, P., and Kumar, J.(2019) 'Impact of Nature Experience on Directed Attention: An ERP study', *Annals of Neurosciences, Sage Publication, Accepted for July-October 2020.*
3. Sahni, P. and Kumar, J.(2019) 'Re-exploring the relationship of Human-Nature Interaction and Mindfulness: An experimental study, Journal of Mental health, Religion and Culture, *under review*
4. Sahni, P., and Kumar, J.(2019). Neuro-Cognitive Effects of Nature Experience, presented at The Science of Consciousness conference, Interlaken, Switzerland.
5. Sahni, P., and Kumar, J.(2018). Nature and Brain: Integrated Study of Inner Experience and Brain Oscillations, presented at The Science of Consciousness conference, University of Arizona, Tucson, Arizona, USA.
6. Sahni,P., and Kumar, J.(2017).The Benefits of Eco-human Interaction: Integrating Eastern beliefs and Western Science, presented at The Science of Consciousness conference, university of Arizona, Tucson, San Diego, USA
7. Sahni, P., and Kumar.(2015). Effects of Nature Experience on Cognition, presented at Culture, Cognition and Consciousness conference , NIAS, IISc Bangalore (Awarded as Invited Young Scholar)

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- Post Graduate Course in 'Qualitative and Quantitative Research Methodology', University of Amsterdam, The Netherlands, Coursera Specialization, 2016-17

Course Work at IIT Delhi

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- Environmental Dynamics and Management, 3- Credit Course, 2014, GPA 10.0