Using 360-degree virtual reality to explore physiological benefits of forest environments for forestry workers

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Abstract

Reducing stress in our daily lives is important for long-term health and well-being. The relaxation and stress reduction benefits of experiencing natural environments such as forests are well-established. Research has also found that the virtual experience of nature through virtual reality technology can have similar benefits to real natural environments. However, few studies have explored the stress reduction benefits of forests in working populations outside of office workers, and no research was found that has examined forestry workers. This group engages directly with forest environments regularly and the health benefits of this may be beneficial to the sector where attracting workers can be challenging.

Using virtual reality, this study explored physiological stress of forestry and office workers exposed to 360-degree videos of actual forest environments. The forestry group (n=15) and the office group (n=15) participated in a within-subject, virtual reality experiment which explored three different types of forest: A native forest, a production forest and a harvested forest site. Heart rate, heart rate variability, galvanic skin response and perceived relaxation were measured, and a short semi-structured interview conducted. The quantitative data was statistically analysed using R Studio and a thematic analysis of the qualitative data was facilitated by NVivo.

There were clear differences in perceived relaxation and interview responses between forestry and office workers in the psychological results. Some physiological measures indicated that forestry participants had higher parasympathetic nervous system activity than office workers, suggesting forestry workers were more relaxed in the forest environments. The native forest was perceived overall to be the most relaxing compared to the production and harvested forest scenes but there were no physiological differences in stress reduction. These findings show some support for forests providing stress reduction benefits for forestry workers compared to office workers. This could have positive implications for recruiting workers into the sector. Given the complexity that surrounds human physiology and nature interactions in a forestry work context, further research is suggested to explore larger samples, more diverse workers and forests, addition of olfactory stimulants and modified research designs.

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Abbreviations

ANOVA – Analysis of variance

ART – Attention restoration theory

ANS – Autonomic nervous system

BR – Breathing rate

ECG – Electrocardiogram

GSR – Galvanic skin response

HF – High frequency

HR – Heart rate

HRV – Heart rate variability

LF – Low frequency

PNS – Parasympathetic nervous system

RMSSD – Root mean square of successive differences

RSQ – Relaxation state questionnaire

SCL – Skin conductance level

SCR – Skin conductance response

SD – Standard deviation

SEM – Sensor electronic module

SNS – Sympathetic nervous system

SRT – Stress reduction theory

ULF – Ultra low frequency

VLF – Very low frequency

VR – Virtual reality

Chapter 1: Introduction

1.1 Purpose

The purpose of this research is to investigate the health benefits of working in a forest environment, using virtual reality. Forestry workers are consistently immersed in forested environments, environments which have been shown to have multiple benefits for human health and well-being (Jimenez et al., 2021). Virtual reality is a useful tool for creating an immersive environment (Groth et al., 2021) without the complications of visiting forests in person. By using biosensors to record participants' physiological responses to virtual forests, alongside methods for capturing how participants are feeling, we can begin to understand the potential benefits of different forest environments on forestry worker health.

1.2 Background

Natural environments, such as forests, have long been investigated for their restoration properties (Berto et al., 2014). This investigation has led to the development of theories, such as the biophilia hypothesis (Wilson, 1984), Attention Restoration Theory (Kaplan & Kaplan, 1989), and Stress Reduction Theory (Ulrich et al., 1991). The simple act of viewing nature has been shown to reduce stress in populations such as hospital patients (Ulrich, 1981), university students (Gladwell et al., 2012), office workers (Largo-wight et al., 2011) and elderly (Elsadek et al., 2021). Forestry workers are in a unique position where they experience contact with a natural environment every day in their workplace, however in this research area they are underexplored.

Reducing the amount of stress in our everyday lives is important for reducing the likelihood of detrimental health conditions such as burnout, cardiovascular disease and depression (Fan & Baharum, 2024). Relaxation, the state of low psychological or physiological arousal (Steghaus & Poth, 2024), can reduce stress in individuals. Nature’s ability to provide relaxation and stress reduction therefore can have a large influence on overall health and well-being. The reduction in stress when viewing natural environments can be measured physiologically using biosensors to measure nervous system responses, and psychologically through self-report questionnaires and interviews (Yao et al., 2021). Physiological measurements provide an insight into the unconscious processing of the brain and the body, allowing for greater insight than psychological measurements alone (Mygind et al., 2021; Pham et al. 2021). Using these methods, the reduction in physiological stress when viewing forests can now be quantified, providing objective evidence for the benefits of forest environments for health. Combined with qualitative methods for capturing perceptions, a greater understanding of the health benefits of virtual reality forests for forestry workers can be explored. This is important for the forestry sector, which is undergoing workforce recruitment and retention difficulties.

This research contributes to a growing body of knowledge of the health benefits of exposure to nature, beginning to fill the gap for forestry workers in this research area. Furthermore, the results could be used to improve perceptions of forestry careers, attract new workers to the sector and improve retention by highlighting the health and lifestyle advantages of the industry.

1.3 Research questions

This research takes a mixed methods approach, combining qualitative and quantitative measures to provide a robust exploration into the health benefits of forests for forestry workers. For the quantitative methods, the research follows a quasi-experimental, within-subjects design and uses semi-structured interviews as the qualitative method with a thematic analysis process.

This study aims to explore the health benefits of working in a forest environment by measuring the relaxation effects of forest environments. Using virtual reality to display 360-degree videos of real forest environments in an Aotearoa New Zealand context, we gathered physiological (heart rate, heart rate variability, galvanic skin response) and psychological (Relaxation State Questionnaire, semi-structured interview) data from office-based workers and forestry workers. This research also explores if forest environments with different characteristics induce greater relaxation than others. The research questions are as follows:

1. Compared to office workers, do forestry workers show evidence of greater psychological and physiological relaxation when viewing virtual forest environments?
2. Is there a difference in psychological and physiological relaxation measures between a native forest, a production forest, and a clear-fell harvested site?

From these research questions, the following hypotheses are proposed:

Hypothesis 1: Forestry workers will relax more in virtual forest environments than office workers. This will be seen through:

- A decrease in heart rate.
- An increase in vagal heart rate variability measures.
- A decrease in galvanic skin response.
- A higher Relaxation State Questionnaire score.

Hypothesis 2: Virtual reality forest environments will be more relaxing than baseline, with native and production forest environments the most relaxing.

Forestry workers spend more time outdoors in forest environments than office workers and therefore, it is hypothesised they experience stress reduction benefits through this contact with nature. Forestry workers will thus demonstrate lower physiological stress levels than office workers.

The forest environments are hypothesised to be more relaxing than baseline due to the relaxing and stress reducing impact of viewing nature. The native and production 360-degree scenes are hypothesised to be the most relaxing due to their forest characteristics of trees and vegetation.

1.4 Thesis outline

Figure 1 outlines the thesis structure and the chapter titles. The thesis will thoroughly explore the existing knowledge in Chapter 2 with a literature review of the health benefits of nature exposure, outlining the concepts that help shape the research questions, and discussing the psychological and physiological measurements used in the experiment.

Chapter 3 will then detail the research design, including ethical considerations, specific methods and equipment used in the study, and the data analysis process. Results of the research will be presented in Chapter 4, beginning with the statistical analysis of the quantitative data and a thematic analysis of qualitative interview data. Lastly, Chapter 5 will provide an in-depth discussion of the results and their implications, with recognition of the limitations of the research and recommendations for future work. A complete reference list and appendices are included after Chapter 5.

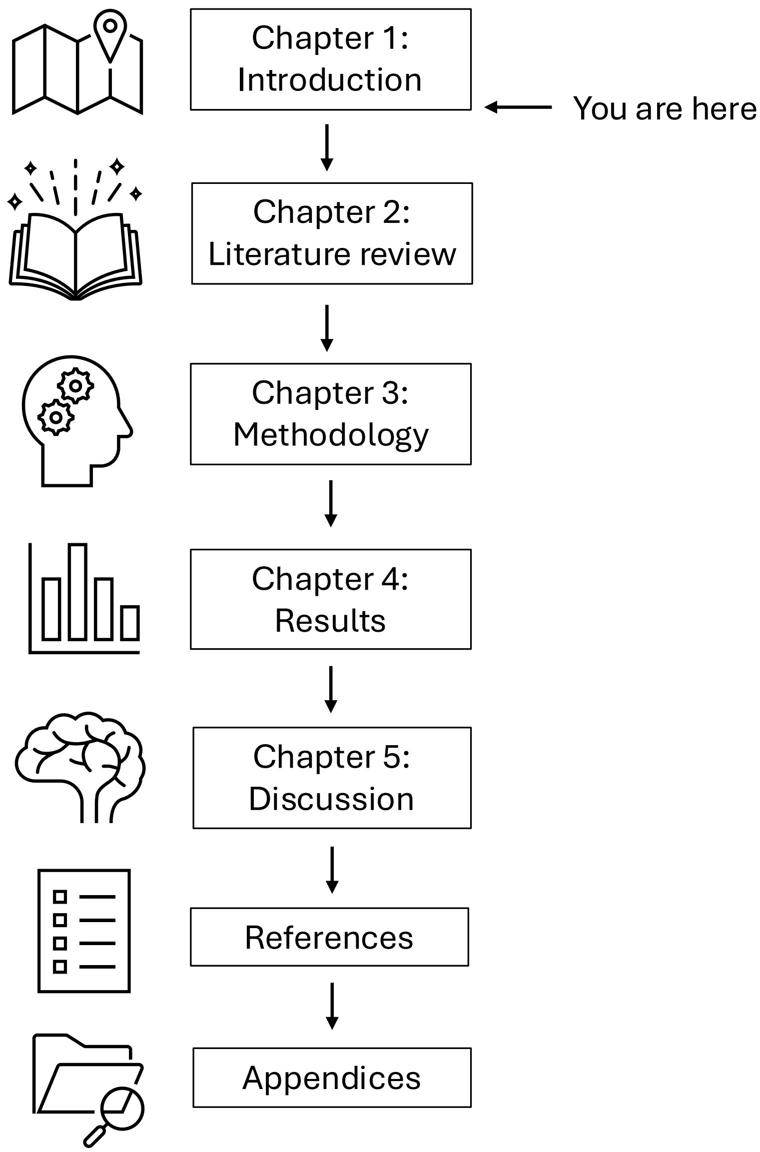

Figure 1. Outline of the thesis structure and chapters

Chapter 2: Literature review

2.1 Introduction

Planted forestry is Aotearoa New Zealand's fourth largest primary industry, with forest exports estimated to reach a value of $6.6 billion by June 2029 (Ministry for Primary Industries, 2025). The forestry and wood processing sector currently represents 11.1% of the food and fiber workforce, employing over 40,000 individuals (New Zealand Forest Owners Association, 2024). Despite the predicted growth, the forestry industry has been facing workforce challenges with significant shortages of skilled workers and an increasing proportion of older workers in the workforce (New Zealand Forest Owners Association, 2018). Almost all respondents of a 2018 survey of forestry sector professionals reported some difficulty with recruitment, with many of the respondents commenting directly on the difficulty retaining staff (New Zealand Forest Owners Association, 2018). Some of the drivers identified within the survey were workers leaving for better pay, better working conditions, or moving away from the region (New Zealand Forest Owners Association, 2018), which were echoed in a later forestry workforce survey conducted by the New Zealand Institute of Economic Research in 2021 (Nixon et al., 2021). Further to this, as the forestry industry continues to become more mechanised, workers are required to have a higher level of training and skill (Nixon et al., 2021). Training accessibility and pathways, alongside poor perception of forestry as a career for young people, also contributes to the difficulty of recruitment and the increasing proportion of older workers (New Zealand Forest Owners Association, 2018). To ensure the forestry industry can continue to provide economic and environmental benefits for New Zealand, it is apparent that the attraction and retention of forestry workers is vital.

One attractive quality of working in forestry is the ability to spend lots of time outdoors in the forest. As we spend a large proportion of our daily life at work, our work environment can directly impact on our health and well-being. Urban environments and indoor lifestyles have been linked to increased stress due to the higher demand for executive processing, increased decision making, and in some cases limited access to natural environments (Dolling et al., 2017; Li et al., 2021). Stress is recognised as a significant global health challenge and has been referred to by the World Health Organisation as the "health epidemic of the 21st century" (Gentile et al., 2023, p. 341). Stress can be defined as a psychological or physiological response within an individual to a particular stimuli, situation or demand that is perceived as threatening to well-being, often generating feelings of fear and anxiety (Gentile et al., 2023; Reyes-Consuelo et al., 2024). Stress can be acute, where the stressor is short or momentary, or chronic, where the individual is exposed to the stressor long term (Gentile et al., 2023). A buildup of acute stress without opportunity for rest can lead to chronic fatigue which can cause mental and physical disorders such as depression, cardiovascular disease, obesity, and burnout (Dolling et al., 2017; Fan & Baharum, 2024). The environment in which we live and work plays a large role in the amount of stress we are exposed to day-to-day. For example, nature and natural elements have been incorporated into office environments to improve the environment for workers. Research has shown a positive correlation between work environments that have contact with natural features such as indoor plants and windows, with increased job satisfaction (Dravigne et al., 2008), reduced stress and improved worker health (Largo-Wight et al., 2011). Providing relaxation and restoration for the mind and body from the everyday and long-term stressors of the modern lifestyle is important for long term human health. This is where natural outdoor environments, such as forests, can play an important role.

Exposure to nature can provide many health benefits (Jimenez et al., 2021), one of these being a reduction in stress (Kondo et al., 2018). Forestry workers are in a unique position where they get to spend time outdoors in the forest every day, yet the benefits of working in a forested environment are underexplored. The health and well-being of the forestry industry workforce is a crucial priority for the future prosperity of the logging sector. Due to this relationship between natural environments and stress reduction, forestry workers may obtain health benefits from working in the forest. Having scientific evidence of this could help attract new workers to the sector, reshape perceptions of forestry careers, and improve retention by highlighting the health and lifestyle advantages of the industry. With the use of technologies such as virtual reality (VR) and physiological biosensors, it is possible to investigate the health benefits of forest environments for forestry workers.

This literature review will outline the implemented search strategy and present the related concepts and previous studies that informed the current research. The main topic of the literature review is the health benefits of nature. There is a large body of research on these benefits covering a wide range of topics, so this literature review will focus on psychological and physiological relaxation, stress reduction, and restoration specifically. Another related term in this area of research is psychophysiology, the study of how mental and physiological processes interact with and influence each other (Stern et al., 2000). Psychophysiological measurements include galvanic skin response and heart rate variability, which are touched on in this literature review. Figure 2 outlines the scope of the literature review and research, showing which topics are out of scope and therefore will not be included in the literature review. The topics chosen to be in scope directly relate to the research questions, outlined in section 1.3.

We begin at section 2.2 with presentation of the search terms and databases used to inform the literature review for transparency and reproducibility. Section 2.3 will explain the research related to nature and human health, outlining important theories that have shaped the topic and describe previous studies of general nature exposure, leading into forest environments specifically. Section 2.4 will introduce the virtual reality technology and how this has been implemented in nature exposure research, providing important background and justification for the use of virtual reality in this study. After this, section 2.5 will outline the physiological measurements that are commonly used in previous research and detail the specific measures to be used in this study. Psychological measures will follow in section 2.6. Chapter 2 will end with a summary of the literature review, ready for presentation of the research design in Chapter 3.

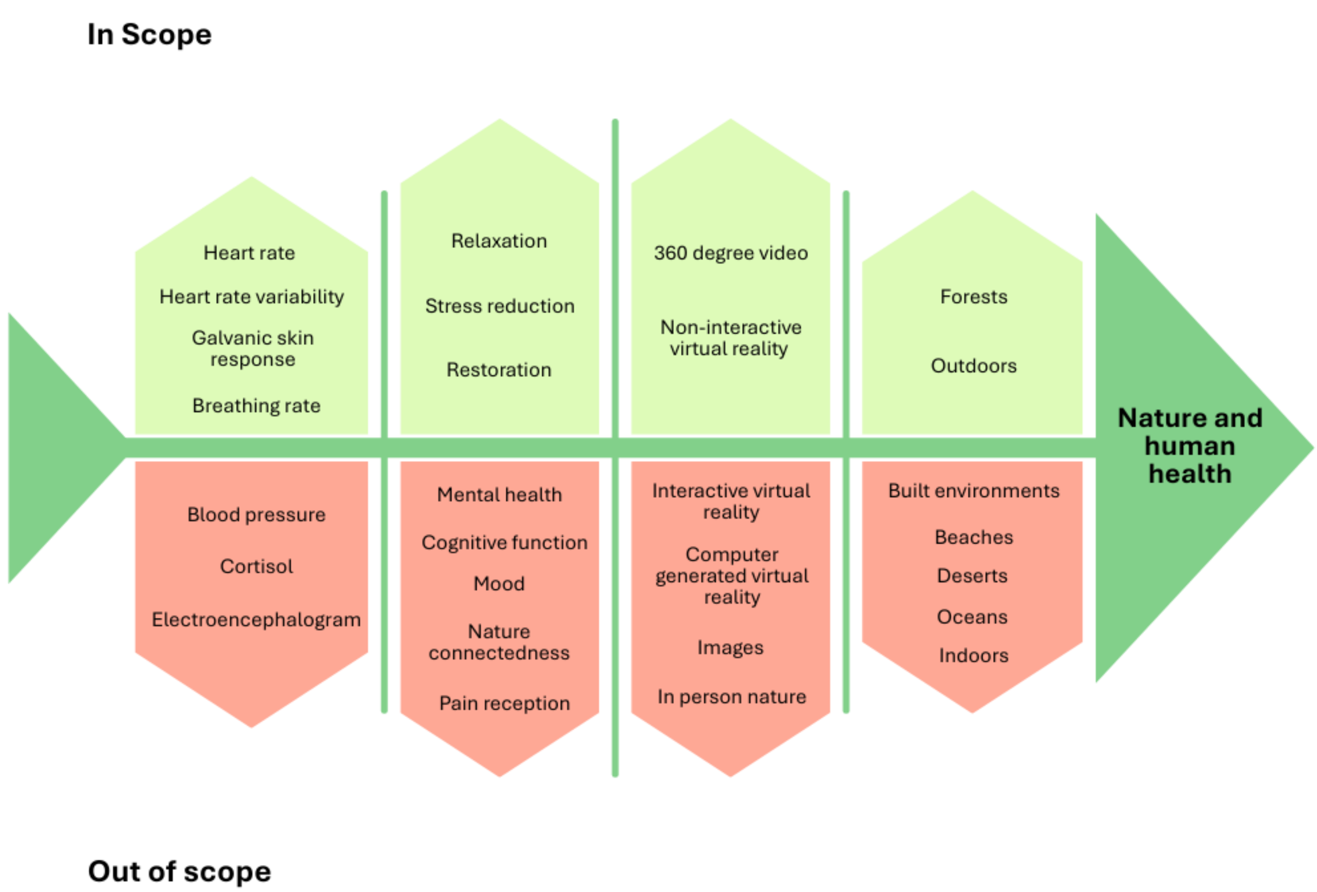

Figure 2. Scope of the literature review and research topics.

2.2 Search strategy

Relevant articles and review papers were searched for using three databases: Massey University Discover, Scopus and Google Scholar. Keywords used include "nature exposure", "health", "restoration", "virtual reality" and "psychophysiology". Multiple search strings were used in each database to pick up additional papers (Appendix 1). The year of publication was not limited and only references in English were sought. Relevant papers referenced in articles that had not been picked up in the search strings were also included in the review. The databases were searched in May 2025 and again in March 2026.

2.3 Health benefits of nature exposure

2.3.1 Theoretical background

Natural environments can provide people with an opportunity for rest and relaxation within an otherwise busy and stressful world. This idea has been widely studied in the research literature (Yao et al., 2021) and a number of theories proposed to explain the underpinning mechanisms of this. The three main theories relating to humans and natural environments are the Biophilia Hypothesis (Wilson, 1984), Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989) and Stress Reduction Theory (SRT) (Ulrich et al., 1991).

The Biophilia Hypothesis, introduced by Edward O. Wilson (1984), describes how humanity's evolutionary dependence on natural environments has shaped our innate need to affiliate with nature. This connection to nature and living organisms is driven by our ancestral dependence on nature for survival, forming the basis of our cognitive and physiological responses to nature exposure. This theory underpins various studies into how and why natural environments provide psychological and physiological benefits, such as improved mood, increased cognitive function, enhanced recovery and restoration, increased productivity and reduced stress (Jimenez et al., 2021). The biophilia hypothesis has a largely biological basis, with acknowledgement of some influence from cultural and social differences (Gaekwad et al., 2022). This theory has since developed into a design philosophy termed “biophilic design”, which incorporates natural elements such as live plants, natural light or wood material into the built environment to improve well-being (Holzman et al., 2025; Yildirim et al., 2024).

Expanding upon the Biophilia Hypothesis, nature's ability to provide restoration from mental fatigue and reduce stress are explored through two environmental psychology theories: the Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989) and the Stress Reduction Theory (SRT) (Ulrich et al., 1991). ART proposes that natural environments provide restorative qualities that allow our directed attention to recover from fatigue and restore our mental capacity. Natural environments tend not to overload our attentional system, activating our involuntary attention, which allows our directed attention to rest. This then provides cognitive benefits, such as an improved ability to concentrate and complete tasks (Berman et al., 2008). There are four mechanisms in which ART proposes that an environment will provide mental restoration. (1) “being away” from stressors of everyday life, (2) stimuli that are “softly fascinating”, (3) exposure to expansive environments (extent), and (4) “compatibility” with an individual's needs (Anderson et al., 2017; Ohly et al., 2016). Although largely accepted, ART has been criticised by Joye and Dewitte (2018) as underdeveloped, arguing that there is little support for the theory and it has failed to test its predictions.

SRT proposes that unthreatening natural environments provide a greater capacity for stress reduction than urban environments due to our evolutionary relationship with nature (Ulrich et al., 1991). SRT developed from Ulrich’s ‘psycho-evolutionary theory’ (1983) in which exposure to nature triggers an automatic, unconscious response due to the evolutionary reliance of humans on nature for survival, that leads to stress reduction through reduced physiological arousal and positive emotional change. This means that, psychologically and physiologically, humans are less stressed when exposed to nature because they are adapted to living in a natural environment. The two theories are complimentary, one focusing on mental fatigue and one on stress, but both pointing to natural environments as restorative (Berto, 2014).

The terms relaxation, stress reduction, and restoration are similar and are sometimes used interchangeably within this area of research. For example, SRT often uses the terms stress reduction and restoration interchangeably (Ulrich, 2023). In this literature review, relaxation is defined as a state of low psychological or physiological arousal (Steghaus & Poth, 2024). Stress reduction is the process of lowering stress levels, in which relaxation is a tool. Restoration is a broader term that refers to the improvement of psychological or physiological functioning from a place of stress or depletion. A state of relaxation can provide stress reduction in individuals, allowing for physical and emotional restoration (Steghaus & Poth, 2025). Natural areas that allow for a positive change in psychological or physiological stress indicators are restorative environments (Berto, 2014).

2.3.2 Nature and human health

Building on the foundational theories of the Biophilia hypothesis, SRT and ART, studies have explored nature exposure in a range of contexts such as in the laboratory (Gladwell et al., 2012; Ulrich, 1981), through surveys of perceived stress and access to nearby nature (Wells & Evans, 2003), in real natural environments such as urban nature (Lanki et al., 2017) or forests (Park et al., 2010) and many more. Nature is a loosely defined term in the research literature, with examples including forests, urban green space, beaches, indoor plants and window views, where people can be exposed through images, slideshows or being physically present in the environment (Shuda et al., 2020). Exposure to natural environments has been linked to relaxation and restorative effects in many studies. A well-known example is a study by Ulrich (1984) in which hospital patients who had a view of trees out their window recovered from surgery faster and consumed less pain medication than patients who had a view of a building wall. Another well cited early work is by Wells and Evans (2003), who explored proximity to nearby nature and psychological stress in children. Wells and Evans (2003) found that nature provides restorative opportunities, allowing children to deal with stressful events more effectively and experience lower stress levels. Other studies also found similar results in surveys of adult populations. Both Grahn and Stigsdotter (2003) and Nielsen and Hansen (2007) found having access to and spending time in green areas to be associated with less stress.

Evidence for relaxation and stress reduction from natural environments has also been explored through quantifiable physiological measurements of the autonomic nervous system (ANS). These measurements provide an indicator of stress within the nervous system, providing a greater insight into the effects of nature exposure on physiological stress. One method to explore this is for participants to be induced into a state of stress to measure their recovery or restoration from the stressor in natural versus urban environments. For example, Brown et al. (2013) compared participant stress recovery after viewing natural or urban environment images, finding that heart rate variability (HRV) increased after the stressor when nature images had been viewed, but not when built environments had been viewed. This indicated that participants recovered better after viewing natural environments rather than built environments.

Participants can also be measured from a baseline state to measure relaxation, the state of low physiological arousal (Gladwell et al., 2012). Ulrich (1981) investigated psychological and physiological changes in individuals from an unstressed state, viewing slides of natural versus urban environments, finding natural environments provided greater benefits than the urban environments. Gladwell et al. (2012) also explored how viewing nature would impact the ANS, without prior stress induction, in a lab environment. Using the biomarker HRV, Gladwell et al. (2012) found that participant HRV increased significantly while viewing a slideshow of natural scenes compared to built environment scenes, providing evidence for nervous system relaxation, in line with Ulrich's (1981) findings. These two studies indicated that viewing nature alone can induce positive changes in the ANS, not just from a stressed state.

A meta-analysis by Mygind et al. (2021) on the effects of nature on stress responses found that seated relaxation and walking in natural environments increased HRV more than in control conditions, providing further evidence for the stress reducing benefits of nature. They did however find the stress indicator of cortisol to have inconsistent results and mention tentative empirical support for the stress reducing effects of exposure to natural environments due to small sample sizes and weaknesses in methodologies. Yao et al. (2021) also conducted a meta-analysis on the effect of nature exposure on stress reduction and found that increased exposure to natural environments was associated with decreased blood pressure, salivary cortisol and HRV, alongside a decrease in self-reported stress and an increase in restorative outcomes. They do, however, mention heterogeneity in results between studies and a high risk of bias. Both Mygind et al. (2019) and Yao et al. (2021) came to similar conclusions that further research should aim to be more rigorous to strengthen the support for the stress reducing effects of natural environments.

This popular research area continues to grow, with topics covering a wide range of natural aspects. One of these is the influence of auditory and olfactory stimuli. Natural stimuli other than visual may play an important role in relaxation and stress reduction. Annerstedt et al. (2013) investigated the influence of sound on physiological restoration in virtual natural environments, finding that the natural environment that contained natural sounds facilitated stress recovery, over a natural environment with no sound. This showed there could be an influence of auditory stimuli on restoration. Further research has shown a combination of natural stimuli can have this influence. Hedblom et al. (2019) explored the effect of visual, auditory and olfactory stimuli of virtual urban, park and forest environments, finding that the park and the forest provided significant stress reduction, but not the urban environment. This showed support for the positive effect of natural auditory and olfactory stimuli on stress reduction over urban stimuli. Olfactory stimuli has further shown to have relaxation effects in a study by Song et al. (2019), which found an additive effect of combined visual and olfactory stimuli. Yildirim et al. (2024) explored multisensory benefits in a workplace context, finding a significant relationship between smell and perceived restoration in a biophilic office environment. A recent study by Ascone et al. (2025) investigated visual, auditory and olfactory stimuli presented either on their own or in combination, finding all groups to show significant psychological stress recovery, with partial additive benefits of all three stimuli presented together. Overall, there is support for auditory and olfactory stimuli contributing to stress reduction and relaxation.

Research into forests and forest bathing contributes to a large amount of research literature, discussed in the next section 2.3.3.

2.3.3 Forest environments

Many nature exposure studies use forests as their representation of a natural environment. In Yao et al. (2021) review of the effect of nature exposure on stress reduction, just over half the studies included in the review used a forest environment as their natural environment, with the rest being urban park environments. Forest environments have been especially noted for their wide range of benefits for human health such as providing a quiet or pleasing auditory environment, volatile organic compounds beneficial for health or pleasing olfactorily, shade, and improved air quality (Gillerot et al., 2025; Song et al., 2016). A Japanese practice called shinrin-yoku is the act of interacting with and taking in the forest atmosphere (Park et al., 2010). Shinrin-yoku is used as a form of medicine, also referred to as forest therapy or forest bathing. Practice and research with shinrin-yoku has mainly taken place in Asian countries but now more recently in Europe also (Vermeesch et al., 2024). Studies have shown that engaging in shinrin-yoku can lead to a reduction in stress across multiple stress biomarkers and in self-report questionnaires (Bielinis et al., 2018; Hansen et al., 2017; Park et al., 2010). For example, Park et al. (2010) found that a walk in forest environments reduced cortisol, pulse rate and blood pressure. Simpattanawong et al. (2024) found similar results, with a guided forest-bathing walk reducing heart rate and blood pressure. Bielinis et al. (2018) investigated psychological states when viewing a winter forest, finding positive emotional and restorative outcomes. McEwan et al. (2021) also echo these findings, with forest bathing just as beneficial as an established well-being initiative in psychological and physiological outcomes. There are several review articles on the topic of shinrin-yoku, with some focusing on blood pressure (Ideno et al., 2017), HRV (Farrow & Washburn, 2019), cortisol (Antonelli et al., 2019), psychological well-being (Siah et al., 2023) and stress physiology and immune function (Bandyopadhyay et al., 2026), while others discuss the topic more broadly (Antonelli et al., 2022; Denche-Zamorano et al., 2024; Krala-Szkaradowska et al., 2024; Vermeesch et al., 2024; Wen et al., 2019). Overall, shrinrin-yoku is regarded as providing significant physiological and psychological benefits, with practical applications to improve health outcomes.

Research has also been undertaken to understand if there are differences in stress reduction between forest environments with different species or characteristics. Biodiversity is one way to describe and measure these differences, in terms of the amount of different species in an area. The link between biodiversity and stress reduction is not always clear. Some studies have found psychological benefits improve with biodiversity in urban greenspaces (Carrus et al., 2015; Wood et al., 2018). However, Schebella et al. (2020) found a nonlinear relationship between biodiversity and stress recovery, with the low biodiversity park environment providing the best stress recovery in the indicators HR and perceived anxiety. Song et al. (2025) also found a nonlinear relationship when investigating vegetation proportion in window views and psychological outcomes, alongside Wang et al. (2019) who found the most natural environment did not have the greatest stress reducing effect. There have also been differences found between physiological and psychological results. Yao et al. (2024) explored psychological and physiological responses to different types of forests – coniferous, broad leaved and mixed. They found that the different forest environments had differing effects on participants' psychological and physiological markers. The mixed coniferous forests had the most positive effect on physiological stress, while the mixed coniferous and broad leaf forest was the best for psychological stress. Other characteristics that have been explored are forests versus park environments (Beute et al., 2023) and seasonal changes (Kim & Lee, 2023).

Participants can be exposed to nature through physical presence in the environment, 2-D media such as photos and slideshows, and through virtual reality (VR) media such as 360-degree videos and images. The use of virtual reality in this research area is discussed in the section below.

2.4 Virtual Nature

Virtual reality (VR) has become a popular tool in nature exposure research. VR is a realistic simulation that immerses a person in a multisensory interactive environment they can look around, move within, and engage with (Bolouki, 2024). VR has been used in research for over 30 years, utilised across multiple disciplines such as neurosurgery (Paro et al., 2022), education (Christou, 2010) and military training (Pallavicini et al., 2016), to name a few. VR can be computer generated, which allows for interactivity, or created from 360-degree photos and videos of real environments (Spano et al., 2023). 360-degree videos provide the user with a deeply immersive experience (Groth et al., 2021) and have the benefit of looking more realistic than computer generated VR. VR technology has improved vastly over the years and has become more accessible, with increased computing power and greater range of devices available (Stanney et al., 2020). Nature exposure research has implemented this technology within the field, using VR to present participants with virtual natural environments in laboratory settings.

In previous nature exposure research before VR, physical presence in the environment or two-dimensional images of nature were used either printed or displayed on a screen. With an advance in VR technology, studies have moved away from using traditional images in laboratory studies to using VR nature. VR allows for greater control of experimental conditions such as weather, sounds and smells than exposing participants to real outdoor environments (Mostajeran et al., 2021). Virtual nature has also been shown to have similar restorative effects as physical presence in a real natural environment, although physical presence in a real natural environment can evoke stronger effects (Browning et al., 2020; Fan & Baharum, 2024; Mavrantza et al., 2023; Reese et al., 2022). Nature experienced in VR also provides a higher sense of presence than traditional two-dimensional images (Mostajeran et al., 2021). VR nature can be a useful tool for populations who may find it difficult to access real natural environments such as elderly, city dwellers, hospital patients and the mentally unwell (Browning et al., 2020).

Physiological and psychological results using virtual nature are somewhat mixed but mostly point towards improved relaxation or stress reduction parameters. Li et al. (2021) provided a mini review of VR for nature exposure experiments finding that VR may contribute to psychological and physiological relaxation. A study of factory workers over a 12-week period found that those who were exposed to 30-minute VR nature videos during their break had a significant improvement in the physiological stress marker of HRV (Ho et al., 2023). Gerber et al. (2017) found that VR nature videos had a physiological relaxing effect on intensive care unit patients. Wang et al. (2019) collected blood pressure and heart rate (HR) information from participants after recovering from a stressor while watching a VR forest video. They found that natural environments had a positive effect on stress reduction. Hedblom et al. (2019) found that 360-degree VR park and forest photos provided significant stress reduction compared to an urban environment. Although there are many studies showing benefits, there are also studies that have found no clear results or inconsistencies. For example, Spano et al. (2023) conducted a systematic review and found inconsistent results for many physiological parameters. However, they did find that for perceived relaxation, virtual nature provided stress reduction in most cases. Yu et al. (2018) found that blood pressure and HR decreased regardless of the VR environment shown (urban vs forest). Mostajeran et al. (2021) found this also, but with the physiological measures of galvanic skin response (GSR) and HR.

They also found that the photo slideshow was more successful at lowering GSR than 360-degree videos. This, however, could be due to the use of a VR head mounted display to present the images, which is different again from traditional slideshow images on a computer screen.

There are limitations to using VR for displaying natural environments. VR use can induce uncomfortable feelings and side effects in the user, known as cybersickness or visually induced motion sickness (Page et al., 2023). This can be caused by vection, the feeling that the body is moving due to visual stimuli, although there is no actual movement taking place (Chang et al., 2020). Cybersickness side effects can include nausea, disorientation, drowsiness, headaches, vertigo and eye strain amongst other discomforts (Page et al., 2023; Stanney et al., 2020). Cybersickness symptoms can persist in some people even after the VR exposure has ended (Stanney et al., 2020). There are some mitigations that can be applied to try to reduce the amount of cybersickness a person will experience. One of these is to reduce the length of time in the simulation (Chang et al., 2020). Stanney et al. (2003) found that users experienced worse cybersickness the longer they experienced VR. However, short VR use of less than 10 minutes has also been shown to induce cybersickness in some users (Dennison et al., 2016). These effects are likely to be exacerbated by the type of simulation the user is experiencing. A VR simulation that increases vection, the conflict between the visual and vestibular system, can increase the severity of cybersickness experienced (Groth et al., 2021) and therefore reduces the duration the user can handle before feeling sick. Further to this, the posture of the user in relation to the activity they are experiencing in VR can impact on vection. It is noted that many VR users prefer being seated, but overall, it can depend on the simulation being experienced (Zielasko & Riecke, 2024).

Multiple review articles have commented on the large heterogeneity and possible bias in the methodology and selection of results in the studies of stress reduction from exposure to nature (Bolouki et al., 2025; Corazon et al., 2019; Hansen et al., 2017; Shuda et al., 2020; Yao et al., 2021). The wide range of physiological measures, exposure methods, durations and environments makes it difficult to directly compare results. Many research reviews, however, have concluded support for an increase in psychological and physiological relaxation when participants are exposed to nature (e.g., Gentile et al., 2023; Spano et al., 2023; Yao et al., 2021). Most studies in this research area have used university students as participants (Corazon et al. 2019), with some more recent research focusing on other groups such as elderly, stroke patients and adults with mental illness (Bettmann et al., 2024; Elsadek et al., 2021; Hansen et al., 2017; Vermeesch et al., 2024). No studies were identified in the current literature search that have explored VR to display natural environments using forestry workers, a population of people who are consistently exposed to real forest environments.

2.5 Physiological measures

Physiological measurements are a popular way to objectively observe the impact of exposure to nature on human health (Mygind et al., 2021). They provide a direct insight into the nervous system response of the body to different environments that cannot be captured through self-report questionnaires or interviews. There are a multitude of stress biomarkers, each with a focus on different systems in the body, with varying levels of intrusiveness and complexity to measure. Stress markers can be related to cardiac, electrodermal, hormonal and brain functions within the body, to name a few. More than one physiological measure is often used in studies in this area of research, with combinations of heart rate (HR), heart rate variability (HRV) (Kumpulainen et al., 2024), blood pressure (cardiac), cortisol level (hormonal) (Park et al., 2010), galvanic skin response (GSR) (electrodermal) (Sun et al., 2023) and electroencephalogram (brain) (Jing et al., 2024). Recording multiple measures allows for validation between results and targets a range of physiological processes.

Relaxation, a state of low arousal, is physiologically linked with the autonomic nervous system (ANS) (Gaertner et al., 2023). The sympathetic nervous system (SNS), the “fight or flight” branch of the ANS, is responsible for reacting to stressors and arousing the body. The parasympathetic nervous system (PNS) is the “relax response” side of the ANS, regulating the body back to a balanced state (Pham et al., 2021). Increased activity of the PNS is therefore associated with physiological relaxation and stress reduction and a decrease in SNS activity associated with a shift to a more relaxed physiological state

(Gaertner et al., 2023). The physiological biomarkers, such as HRV or GSR, can represent the activity of the SNS, PNS or the interaction between the two. There are many stress biomarkers that can be measured for this area of research. However, as outlined in figure 2 of section 2.1, the measures within the scope of this literature review are HR, HRV, breathing rate (BR) and GSR. These measures have been used in previous studies investigating nature exposure in VR (Gladwell et al., 2012; Sun et al., 2023) and the details are outlined in the following sections.

2.5.1 Heart rate

One method for exploring cardiac physiological response to nature is heart rate. Heart rate is measured using an electrocardiogram (ECG) and is reported as the number of heart beats per minute. Heart rate is influenced through both the sympathetic and parasympathetic branches of the ANS, therefore reflecting the interaction of activity from both the PNS and SNS (Shaffer et al., 2014). The two systems constantly work together to maintain balance in autonomic function (Pham et al., 2021). The SNS (fight or flight) increases HR and the PNS (relax response) slows heart rate (Berto, 2014; Pham et al., 2021). HR has been used in previous studies as an indicator of ANS activity, with an increased HR associated with physiological arousal or higher stress (Yildirim et al., 2024). HR can provide complimentary information when paired with other ANS measurements such as GSR or HRV.

2.5.2 Heart rate variability

Another cardiac measure to index physiological stress is HRV. HRV is commonly used to explore ANS control and is representative of both psychological and physiological systems (Hinde et al., 2021; Pham et al., 2021). HRV is the fluctuation in inter-beat intervals, also known as R-R intervals, which are the time intervals between one heartbeat and the next (Shaffer & Ginsberg, 2017). R-R intervals refer specifically to the time between R-wave peaks in an ECG, while inter-beat interval is a more general term. The constant influence from both the sympathetic and parasympathetic branches of the ANS to regulate the body and adapt quickly to stressors causes constant fluctuation in inter-beat intervals (Sharma & Shenoy, 2023). A high HRV therefore represents high ANS ability to react and adapt to external stimuli, whereas a low HRV shows low adaptability of the ANS and is related to fatigue and stress (Hinde et al., 2021). Of particular interest in the use of HRV is the ability to measure specifically the activity of the PNS, the relax response of the nervous system, also known as vagal tone (Laborde et al., 2017). Like HR, HRV is measured using an ECG.

HRV can be calculated through time-domain analysis, frequency-domain analysis and non-linear indices. Laborde et al. (2017) provides a summary of the main HRV parameters and their physiological origin. Most commonly, time-domain and frequency-domain indices are used (Gaertner et al., 2023). A common parameter calculated through time-domain analysis is the root mean square of successive differences (RMSSD) due to its representation of vagal tone. RMSSD is considered a robust variable for measuring HRV and is reported in milliseconds (Malik, 1996). Time-domain measurements are less influenced by breathing rate (BR) or body movements than frequency-domain indices (Gaertner et al., 2023). Frequency-domain measurements analyse the distribution of power from the different systems that regulate HR, across the four frequency bands. These are ultra-low frequency (ULF; <0.003 Hz), very low frequency (VLF; 0.003 to 0.04 Hz), low frequency (LF; 0.04 to 0.15 Hz) and high frequency (HF; 0.15 to 0.4 Hz) (Pham et al., 2021). The absolute power of HF is an indicator of PNS activity (Laborde et al., 2017). There is debate that HF may also contain activity from the SNS, but it is still commonly used and accepted (Gaertner et al., 2023). LF/HF ratio was considered to represent the balance between the SNS and the PNS activity, but this has been highly criticised and the current recommendation is to use other more robust indices such as RMSSD and HF (Laborde et al., 2017). In summary, HRV is a non-invasive measure that can provide an index of PNS and SNS activity, and for this reason has become a popular physiological stress biomarker.

2.5.3 Breathing rate

BR is the measurement of how many breaths a person takes per minute. In a relaxed state, BR is lower and in an aroused state, BR is higher. HF HRV has been shown to only reflect vagal tone when BR is between 9 and 24 breaths per minute (Laborde et al., 2017).

Due to this high influence of BR on HF HRV, it is important to measure BR to determine if the HF results are due to changes in BR or PNS activity. As reported in Laborde et al. (2017), the advice is to have participants breathe naturally through the trial and measure their BR to later assess when interpreting HF HRV results. It is also important to ascertain that there are no significant differences in BR between the groups and treatments being assessed.

2.5.4 Galvanic skin response

Galvanic skin response (GSR), also known as electrodermal activity, is the measure of the continuous changes in the electrical conductivity of the skin (Boucsein et al., 2012). GSR measures in psychophysiological research date back to as early as 1879 (Boucsein et al., 2012; Posada-Quintero & Chon, 2020). It provides a fast, non-invasive method for measuring nervous system arousal, making it a useful tool for psychophysiological research. The sympathetic nervous system (SNS) controls the activation of the sweat glands in response to external stimuli, responding with increased activation of the sweat glands, causing the electrical conductivity of the skin to increase (Li et al., 2022; Navea et al., 2019). An increase in skin conductance therefore represents an increase in sympathetic activity of the ANS. The electrical conductivity is measured by applying two electrodes to the skin, using microsiemens (μS) as the unit of measurement. The electrodes are often applied on the hands and feet where the highest number of eccrine sweat glands in the body are found (Pop-Jordanova & Pop-Jordanov, 2020; van Dooren & Janssen, 2012). The electrodes can be placed on the distal or medial phalange (finger), palmar (hand) or plantar (foot) regions of the body (Bennett, 2024). The eccrine sweat glands are measured as they are representative of psychological processes rather than other sweat glands that relate to thermoregulation (Posada-Quintero & Chon, 2020; van Dooren & Janssen, 2012). GSR has been used to determine mental stress, such as emotional or cognitive, but recently has also been used as an indicator of SNS arousal more generally (Posada-Quintero & Chon, 2020).

Skin conductance is typically measured through two primary components: tonic (baseline) and phasic (response-related) activity. The phasic component - skin conductance responses (SCRs), are small, rapid changes in skin conductance induced from an external stimulus characterised by an increase from the initial level to a peak, followed by a decrease and return to baseline (Boucsein et al., 2012; van Dooren & Janssen, 2012). SCR's often last several seconds and occur approximately 1-5s after a stimulus (Boucsein et al., 2012; van Dooren & Janssen, 2012). The tonic component includes non-specific skin conductance responses and skin conductance level (SCL). Non-specific skin conductance responses are SCRs that are not related to specific stimuli, often termed "spontaneous", and are therefore classified as tonic (Boucsein et al., 2012; Posada-Quintero & Chon, 2020). SCL in the tonic sense represents the gradual changes in skin conductance absent from SCRs (Bennett, 2024; Boucsein et al., 2012; Posada-Quintero & Chon, 2020). SCL is often used to describe the absolute value of skin conductivity including both the tonic and phasic components (Posada-Quintero & Chon, 2020). Mean SCL from a period of continuous sampling is calculated to show changes in skin conductivity over longer (Posada-Quintero & Chon, 2020; van Dooren & Janssen, 2012). This is referred to as GSR for this thesis.

2.6 Psychological measures

Unlike physiological measurements which aim at measuring bodily processes, psychological measures focus on perceptions, thoughts and feelings of participants. They are important for capturing subjective information, through self-report questionnaires and validated scales. Psychological measures that are often investigated in nature exposure studies are affective response, e.g., positive and negative affect schedule (Bielinis et al., 2018), stress e.g., Perceived Stress Scale (Shuda et al., 2020), restoration e.g., Restorative Outcomes Scale (Song et al., 2025), relaxation e.g., Relaxation State Questionnaire (RSQ) (Knaust et al., 2022b) and mood e.g., Profile of Mood States (Yao et al., 2024). Many studies use more than one scale to gather information across different areas, similar to physiological measurements. Studies can use psychological measurements on their own to only capture subjective responses or combine with physiological measurements to gather both subjective and objective information (Bolouki, 2024). Self-report scales for measuring relaxation have often included questions focused on long-term relaxation and do not capture participants' current state of relaxation

(Steghaus & Poth, 2025). A relatively new scale, the Relaxation State Questionnaire (RSQ) (Steghaus & Poth, 2022) has been created to capture short-term changes in relaxation, outlined in the section below.

2.6.1 Relaxation State Questionnaire

The Relaxation State Questionnaire (RSQ) has been used to measure participants' perceived relaxation in research trials. The RSQ, developed by Steghaus and Poth (2022), allows researchers to assess an individual's state of relaxation at the time rather than focusing on long term effects of relaxation. Therefore, it can be used to compare immediate relaxation effects of different types of environments. The self-report questionnaire consists of 10 questions split across four subscales of physiological and psychological relaxation. The physiological subscales of relaxation are cardiovascular activity (2 statements) and muscle tension (3 statements). The psychological subscales of relaxation are general relaxation (2 statements) and sleepiness (3 statements) (Pizzoli et al., 2025; Steghaus & Poth, 2022). Participants rate their agreement with each statement on a 5-point Likert scale. The RSQ has been psychometrically validated in a German population (Steghaus & Poth, 2022) and Italian population (Pizzoli et al., 2025) and has been used in studies to assess momentary relaxation (Gaertner et al., 2024; Gaertner et al., 2025; Knaust et al., 2022b; Pizzoli et al., 2025; Richter et al., 2025; Steghaus & Poth, 2024, 2025). Steghaus and Poth (2025) used the RSQ to compare participants' perceived relaxation before and after completing relaxing and non-relaxing exercises, finding the RSQ to be successful at reflecting changes in participant relaxation states. As this is a relatively new questionnaire, there are only a few studies that have used the RSQ in nature-based VR (Knaust et al., 2022b; Richter et al., 2025; Seel et al., 2025). Knaust et al. (2022b) used the RSQ in a feasibility study on relaxation effects of nature videos for patients with post-traumatic stress disorder. Richter et al., (2025) investigated immersion ability as an influence on participant relaxation, finding VR to increase relaxation through the subjective measurement of the RSQ. In another recent study, Seel et al. (2025) used the RSQ when investigating if VR natural environments could enhance a mindfulness-based stress reduction meditation, finding no difference in relaxation between conditions. These studies provide examples of successful use of the RSQ in nature-based virtual reality studies.

2.7 Summary

As has been outlined throughout the literature review, natural environments, even virtual ones, have been shown to provide an opportunity for relaxation and stress reduction. It is a research area that has gained a lot of interest, with many studies investigating the psychological and physiological benefits of engaging with nature. Forests in particular are highly regarded as beneficial for human health, as can be seen through the implementation of shinrin-yoku in Japanese culture. Although studies are now starting to investigate these benefits in groups of people other than students, no studies found in the literature review have investigated the effect of nature exposure on forestry workers, a population of people who spend a lot of time in a forest environment.

Chapter 3: Methodology

3.1 Research design

This chapter explains the research approach taken to explore the potential physiological benefits of working in a forested environment. The research strategy is grounded in a post-positivist approach, which is the view that an objective reality exists but it cannot be fully understood or explained, only interpreted through partial segments to get closer to the truth (Levers, 2013). Post-positivism supports the use of qualitative methods, accepting multiple perspectives as knowledge, while also using multiple measures and rigorous methods to contextualise and validate findings (Creswell & Poth, 2016). This research lens therefore supports the use of the Relaxation State Questionnaire (RSQ) and interviews to capture perceptions, combined with quantitative physiological measurements to examine how exposure to virtual forests affect worker stress and relaxation responses. Incorporating mixed methods by combining objective physiological data with subjective self-report measures and semi-structured interviews provides a greater understanding of participant responses to virtual reality forest environments, contributing to the development of the knowledge base.

The research employs a quasi-experimental, within-subject design to assess changes across controlled environmental conditions, acknowledging the practical constraints of working with an industry workforce. Figure 3 outlines the sequence of the research design. The research methodology was designed with influence from previous studies in this research area, such as the use of heart rate (HR), heart rate variability (HRV) and galvanic skin response (GSR) (Gladwell et al., 2012; Sun et al., 2023), RSQ and semi-structured interviews (Knaust et al., 2022b) and virtual reality 360-degree videos (Yu et al., 2018) to allow for comparison of results and meaningfully contribute to the growing knowledge base. Ethical considerations were thoroughly considered and peer reviewed, with ethical approval for the research obtained from the Massey University Human Ethics Ohu Matatika 3, Application OM3 25/34. Ethical considerations are discussed in detail in section 3.9. Pilot trials were conducted to test the methodology and contributed to the final research design, outlined in section 3.7. Following the pilot trials, participants were recruited in line with the ethical guidelines (section 3.2), the data then collected and analysed (section 3.10). This chapter will outline this process in detail in the following sections.

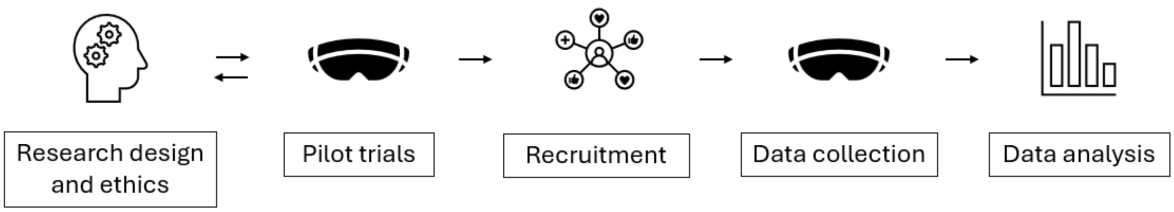

Figure 3. Research sequence diagram.

3.2 Participant recruitment

This research focuses on forestry workers who spend time at work directly in production forest environments. To contrast this, the control group are people who spend most of their time working in an indoor office environment. A convenience sampling method was employed at AgResearch, Lincoln, where staff were invited to participate through a site-wide email and promotional posters (Appendix 2). Access to the organization was established via existing professional relationships between the researcher and the institution. Interested participants were sent an information sheet (Appendix 3) and could choose from a range of times that suited them to complete the experiment. Forestry workers were recruited from multiple different companies through email, promotional posters (Appendix 2) and word of mouth, inviting participation. Some of those who had chosen to take part also shared the invitation to participate with their colleagues. The study was further advertised at the Forest Growers Research conference, October 2025, Auckland, to spread awareness of the research. Interested participants were sent an information sheet, and a dedicated time to complete the experiment was scheduled.

3.2.1 Participants

A total of 15 office workers and 15 forestry workers took part in the research. All participants were males between the age of 20 and 69 and stated that they had no underlying heart conditions and were on no cardioactive medication. All participants completed the informed consent form (Appendix 4) before beginning the experiment.

3.2.2 Sampling choices

Physiological biomarkers to measure stress are often chosen based on factors such as the research questions, study design, and equipment available to the researchers. For this study, the measures needed to be non-invasive and easy to apply to multiple participants with available equipment that was robust, accurate, and measured continuous data. Aligned with previous research (Gladwell et al., 2012; Sun et al., 2023), heart rate (HR), heart rate variability (HRV), breathing rate (BR), and galvanic skin response (GSR) were chosen as the physiological stress biomarkers.

Tegegne et al (2018) found that age and sex are the most important determinants when interpreting HRV data. Given this, and as males account for 82% of the forest industry workforce (New Zealand Forest Owners Association, 2024), only men were asked to participate. Ethnicity data was not collected as it was not considered relevant to the research questions in this exploratory study.

A within-subject design was chosen for this study. A within-subject design is when each participant experiences all experimental conditions, serving as their own control. Within-subject design is highly recommended as it reduces the impact of external factors that can impact results such as smoking and alcohol and requires less participants due to an increase in statistical power (Laborde et al., 2017). The sample size for this study was determined using R studio (Posit team, 2025) pwr package (Champley, 2016), with an effect size of 0.40, power of 0.8, alpha 0.05 and a 3 level x 2 block group size. This produced 14 as the approximate size per group required, a minimum total of 28 participants.

3.3 Experimental conditions - virtual reality environments

Three different VR forest environment videos were selected as conditions for this study: a production forest, a native forest, and a clearfell site. These forest types were chosen to compare potential differences across forest characteristics.

A production forest is a plantation of trees that is managed and grown for the purpose of timber harvesting. A native forest in this study is described as a forest that occurs naturally in the area that consists mainly of tree species native to Aotearoa New Zealand. Clearfell is a production forest harvesting method where all the trees in a given area are removed. The production forest used in this study was a mature, unpruned *Pinus radiata* stand within the West Melton Forest in Canterbury, South Island, New Zealand (Figure 4a). Pinus radiata accounts for 91% of the planted forested area in Aotearoa New Zealand (New Zealand Forest Owners Association, 2024) and is therefore a suitable representation for the forestry environment. The native forest used was a *Fuscospora solandri* (black beech) forest near the Wharfedale walking track in the Oxford Forest Conservation area, Canterbury, South Island, New Zealand (Figure 4b). The clearfell block was a site in Mcleans Forest, Canterbury, South Island, New Zealand where trees had been removed three to five months prior (Figure 4c).

Figure 4a. 360-degree image of a mature *Pinus radiata* stand in the West Melton Forest in Canterbury, South Island, New Zealand, taken by author.

Figure 4b. 360-degree image of a native *Fuscospora solandri* (black beech) forest near the Wharfedale walking track in the Oxford Forest Conservation area, Canterbury, South Island, New Zealand, taken by author.

Figure 4c. 360-degree image of a 3 to 5-month old clearfell block in Mcleans Forest, Canterbury, South Island, New Zealand, taken by author.

3.3.1 Video capture

All three forest videos were captured in January 2024 with the Insta-360 X3 (Insta360, Shenzen, China) in 360-degree mode with 5.7K resolution, 30 frames per second and original audio. Each video was taken on a tripod with an Insta360 Invisible Selfie Stick attached, set to 1.9m height. The videos were taken during similar weather conditions, with temperatures between 19-22°C. The videos were uploaded into the Insta360 Studio desktop software where the Invisible Selfie Stick was automatically removed from the video by the software. Normal stitching and flowstate stabilisation were applied. The videos were exported at a resolution of 5760 x 2880 and a bitrate of 100. Adobe Premiere Pro (Adobe Inc., California, United States) was used to combine the separate forest scenes into one video, with a separate video made for each combination of viewing orders for randomisation within the experiment. The cross-dissolve transition in Adobe Premiere Pro was applied before and after each video to soften the change between scenes. The videos were exported to MP4 format and uploaded onto the HTC VIVE Focus 3 VR headset (HTC Corporation, Taiwan) (Table 1, a).

3.3.2 Video presentation

The HTC VIVE Focus 3 VR headset was used to present the 360-degree videos in this experiment due to its design features and combability with other devices. Importantly, it was made to be easily taken on and off, with a quick release button, detachable face cushions, and ability to fit over glasses. Further, the headset has an adjustable interpupillary distance to ensure a clear and comfortable viewing experience for most people, reducing the chance of eye strain. It also has a battery life of 2 hours of continuous use, which allows for multiple experiments in a row without charging the device in-between. Each 360-degree scene was presented for 5 minutes, with 40 seconds in between to allow the Relaxation State Questionnaire to be completed, outlined in section 3.5.

3.4 Physiological measurements

The Equivital EQ02+ LifeMonitor (Hidalgo, United Kingdom) was used to capture the physiological measurements of participants. The LifeMonitor is a wearable physiological measurement device capable of recording multiple continuous parameters at once. It has been used in previous research to obtain physiological stress measurements such as heart rate variability (HRV) (Cvejic et al., 2018; Cvejic et al., 2017; Liu et al., 2013) and has been proven to provide reliable results for collection of physiological data (Akintola et al., 2016; Chapman et al., 2024; Liu et al., 2013). From this device, the participant’s electrocardiogram (ECG) and galvanic skin response (GSR) are recorded. Heart rate (HR), HRV and breathing rate (BR) information is obtained from the participant ECG.

The LifeMonitor harness fits around the chest (Table 1, b), measuring ECG on two channels through three electrodes embedded in the belt. Chest based monitors have been found to have significantly greater accuracy than wrist-based devices (Lindsey et al., 2023). From the ECG, R-R interval data is obtained to calculate HRV. The sensor electronic module (SEM) (Table 1, c) sits in the side pocket of the harness, recording and storing the data. The harness has an additional ancillary connector which allows the connection of an extra sensor (peripheral oxygen saturation or GSR) or a battery pack. The Equivital GSR sensor (Hidalgo, United Kingdom) (Table 1, d) was used in the ancillary connector for this study. Two disposable foam electrodes (Cardinal Health, Ireland) (Table 1, e) were used to record GSR, connected to the GSR sensor and attached to the participant’s palm, (as pictured in Figure 5) to measure palmar eccrine sweat gland activity. The clinical setting was used as recommended in the Equivital and LabChart Getting Started Guide (ADInstruments, 2017) when using Bluetooth ancillaries. ECG was sampled at 256 Hz, BR at 25.6 Hz and GSR at 16 Hz, the highest sampling ability of the SEM. The Equivital USB Bluetooth device was used to transmit the participant data in real time from the SEM to Labchart 8.1.3 software (ADInstruments, Dunedin, New Zealand) on a laptop computer. This allows the researchers to see in real-time the participant data and make any adjustments for poor electrode connections or an incorrectly set up harness. Markers within the software were used to indicate the timings of different activities throughout the experiment to provide the sample blocks for data analysis.

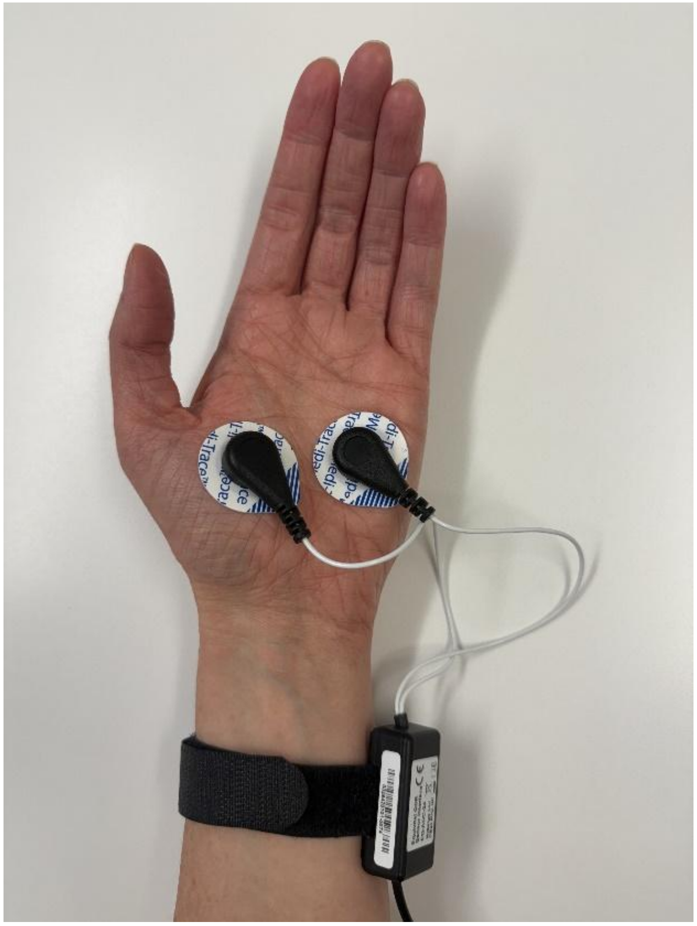

Figure 5. The Equivital galvanic skin response (GSR) sensor with disposable electrodes placed on the palm to measure palmar eccrine sweat gland activity.

Table 1. The equipment used in the study and its purpose. Image sources: a,c,d,e) taken by author, b) (Equivital, 2023).

Equipment	Purpose	Image
(a) VIVE Focus 3 VR headset	Displays the 360-degree forest scenes	
(b) Equivital EQ02+ chest harness	Contains 3 electrodes to record ECG	
(c) Equivital EQ02+ SEM	Records and stores the collected ECG and GSR data	
(d) Equivital GSR sensor	Records GSR from participants palm	
(e) Disposable electrodes	Attaches to the snap leads of the GSR sensor and participant palm to record GSR	

3.5 Relaxation State Questionnaire

The Relaxation State Questionnaire (RSQ) (Steghaus & Poth, 2022) was used to gather perceived relaxation information from participants during the experiment. Following the within-subject design, each participant was asked to answer the questionnaire before the first 360-degree condition and then after each following condition. To reduce the time spent wearing the VR headset, limit the total experiment time, and to avoid repetitively taking the headset on and off, only the general relaxation subscale of the RSQ was used. This was to ensure participant comfort during the experiment and avoid fatigue, while still allowing the capture of psychological data. This decision has been made by previous researchers, with Knaust et al. (2022a) using a single item to evaluate perceived relaxation in their within-subject design trial. The general relaxation subscale comprises two questions that have high face validity and focus on the mental effects of momentary relaxation (Steghaus & Poth, 2022). The two questions, “I’m feeling very relaxed” and “Right now, I am completely calm” were presented to participants on-screen in the VR environment between each 360-degree forest video (Figure 6). Participants were asked to verbally rate their agreement with the statements on a 5-point-Likert scale (1 = “Not at all true”, 5 = “Completely true”) based on (Pizzoli et al., 2025). Figure 6 shows what the participants could see.

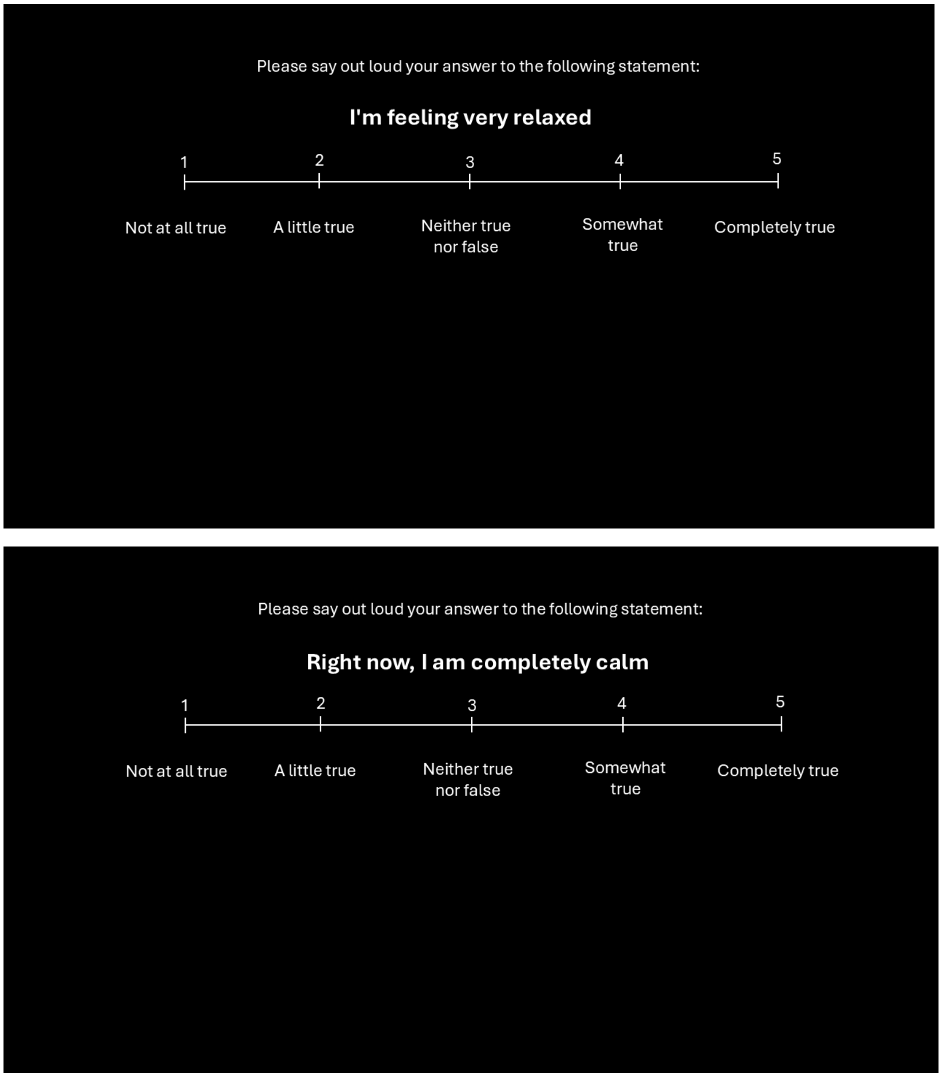

Figure 6. The two questions from the general relaxation subscale of the Relaxation State Questionnaire that the participants viewed in the headset before and in-between each 360-degree forest scene.

3.6 Semi-structured interviews

Interviews are a qualitative research method for understanding the interviewee experience and perceptions on a particular topic (Edwards & Holland, 2013). They occur as a conversational exchange between the participant and the researcher, which can follow a structured, semi-structured or unstructured process. A structured interview is a rigid approach, where all participants receive the same questions in the same order, with no flexibility in the questions asked (Edwards & Holland, 2013; Taylor, 2005). A semi-structured interview, however, has increased flexibility by following an interview guide, which are questions the researcher wishes to cover, but can ask further questions or expand in areas that are not laid out in the interview guide (Edwards & Holland, 2013; Taylor, 2005). An unstructured interview has the most flexibility, with open, free-flowing dialogue and no interview schedule.

A semi-structured interview process was chosen for this research to allow for further questions and exploration during the interview, while also allowing for comparison across participants' answers by following an interview guide. The semi-structured interview was chosen over other qualitative research methods such as focus groups to keep participant confidentiality and to gather individual responses from participants rather than group insights.

The semi-structured interviews were conducted after the participants had experienced the VR scenes and removed the VR headset. The interview guide (Table 2) was constructed by the researcher to get further in-depth information about the VR experience for the participants, giving them an opportunity to expand on why they felt the way they did in answering the RSQ and exploring further background information that may influence or explain the physiological and psychological results. The forestry and office worker interview guides were similar, with the first four questions asked about the experience of the trial. The questions then moved onto participants personal experience in forestry or experience working in nature for office workers. Finally, the last questions aimed to explore participants' use and enjoyment of forests. The interviews were recorded using the Olympus DM-720 (Tokyo, Japan) voice recorder and then were later transcribed using the Microsoft Word (Washington, United States) transcribe feature.

Table 2. Semi-structured interview guide.

Forestry workers	**Office workers**
Did you feel any discomfort during the VR experience? – If yes, can you please explain the discomfort?	Did you feel any discomfort during the VR experience? – If yes, can you please explain the discomfort?
Which scene did you like the most and why?	Which scene did you like the most and why?
Which scene did you feel most relaxed and why?	Which scene did you feel most relaxed and why?
Overall, do you feel more relaxed now than before the experiment?	Overall, do you feel more relaxed now than before the experiment?
What roles in forestry have you had over the years?	Have you ever had a workplace environment working in nature or forests?
What do you enjoy about working in forestry?	Do you use forests recreationally? E.g walking, biking – If yes, do you use production or native forests, or both? – If yes, what do you think you enjoy about visiting the forest?
Do you use forests recreationally? E.g. walking, biking – If yes, do you use production or native forests, or both? – If yes, what do you think you enjoy about visiting the forest?	

3.7 Pilot Trials

Five pilot trials were conducted to test the equipment and the research processes. Feedback and experience were collected from the trials and implemented into the final research protocol. Four key lessons were learnt:

One, participants could be in-between sizes of the Equivital sensor belts. If the belt is not firm against the participants' skin, the sensor is more susceptible to movement artifacts. To combat this issue, a velcro strap was made available to tighten around the chest belt to obtain a more secure fit for those in-between sizes. Two, the diagram outlining the experimental procedure (Figure 7) was reported as being useful by the participants and so this was made larger to be more visible to be referenced throughout the experiment. The approximate time of each procedure was also added to the procedure diagram. Three, during one pilot trial a set of data contained a lot of artifacts, likely due to a poor connection between the electrodes and the skin. With all future experiments, it was checked that the electrodes were damp enough to provide a good connection with the skin. Four, in another trial, a technical difficulty with the VR headset occurred where the device froze and had to be restarted to continue. This occurred at the beginning of the trial before the participant had viewed any videos. It was useful for the researcher to be aware of this possibility and know the action to take to resolve the issue if it happened in future experiments.

3.8 Experimental procedure

This study was a case control, within-subject design with all participants viewing each 360-degree forest scene. The experiments were carried out in locations that were convenient for the participants. Each set of experiments was conducted in a room between 20-25°C and completed during the day between 10am and 4pm. The time of day (morning or afternoon) was not controlled due to the availability of the participants to take part in the study. Participants were randomly assigned a viewing order of the videos, and the number of participants to view each viewing order in each group (office worker vs forestry worker) was counterbalanced using an excel spreadsheet with a formula that randomly assigned viewing orders based on the combinations that had been used the least.

After the consent process, the experimental procedure (Figure 7) was explained to the participants and then they were instructed on how to wear the physiological sensor belt (Appendix 5) which they put on themselves in a private space. The participants were assisted with attaching the GSR electrodes to the palm of their hand. The participants then verbally responded to a short questionnaire on demographic, health and nature related questions (Appendix 6) while resting in a seated position with their hand on the chair arm or their thigh. Participants were instructed to limit movement during the experiment as much as possible. The sensor measurements recorded during this time were used as the baseline physiological measurements. Participants were then introduced to the VR headset and given a short demonstration on how to correctly put on the head-mounted display for optimal comfort and visibility. Participants were given a short period to acclimatise to the feeling and use of the VR headset and confirm their set up was comfortable.

The VIVE Video app was used to view each environment in the VR headset, set to 360-degree monoscopic view and the audio set to level 80. In a seated position on a swivel office chair, participants viewed each 360-degree forest scene through the VR headset. The two RSQ questions were shown to the participant before the forest scenes were viewed, between each forest scene, and at the end of the final scene. The RSQ questions appeared within the VR environment on a blank screen (Figure 6) for 20 seconds each. Each forest scene was shown for 5 minutes. Participants were able to turn around in the swivel chair to view the full scene but were asked to stay seated and limit movement of their torso and hand during the experiment. Screen casting between the VR headset and an iPhone 16 pro (California, United States) using the VIVE manager app was used to view what the participants were seeing during the experiment to accurately apply markers within the data in Labchart. Once all three scenes had been viewed, participants slowly removed the VR headset. Finally, a short semi-structured interview was undertaken with the participants to understand their thoughts and preferences of the scenes and further information around their perceptions and use of forests (Table 2).

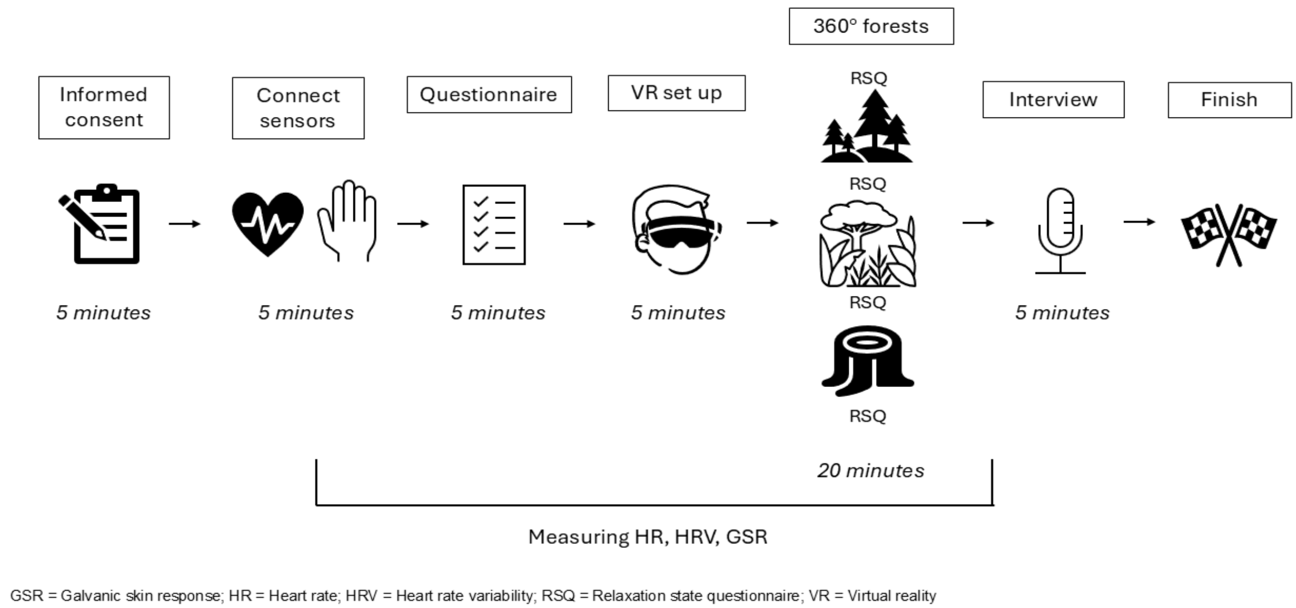

Figure 7. Outline of the experimental procedure. GSR = Galvanic skin response; HR = Heart rate; HRV = Heart rate variability; RSQ = Relaxation state questionnaire; VR = Virtual reality.

3.9 Ethical considerations

Ethical considerations present in this research were addressed in relation to the Massey University Code of Ethical Conduct for Research, Teaching and Evaluations Involving Human Participants (Massey University, 2017). The universal ethical principles (autonomy, avoidance of harm, benefit, justice and special relationships) and the Treaty of Waitangi principles (whakapapa (relationships), tika (purposefulness) manākitanga (cultural and social responsibility) and mana (justice and equity) (Massey University, 2017) are woven throughout the research design of this study. The principle of autonomy was upheld by voluntary recruitment of individuals, through a comprehensive participant information sheet (Appendix 3) and informed consent process (Appendix 4). Protection was considered with respect to upholding mana (personal authority). Participants had the right to withdraw any time during the experiment, the right not to answer questions and the right to withdraw the use of their data within a two-week period of data collection. Respect for confidentiality and privacy was upheld by anonymising the data collected and storing it securely on a password-protected, encrypted system. Manākitanga was upheld through the de-identification of participants in any published data and through the participants having the option to have the transcripts of their interviews returned to them for checking, amending and release.

Several aspects of the research methods when using the VR headset and physiological sensors were designed to respect the principle of non-maleficence and to observe tikanga (Māori customs). For example, there is a risk of experiencing motion sickness when using a VR headset, so the HTC VIVE VR headset was selected for its design to reduce motion sickness and discomfort. The VR session duration was short (~17 minutes) to prevent fatigue or strain. Clear instructions and opportunities to ask questions were provided before the experiment to ensure participants understood the procedures and potential risks. Special care was taken using the VR headset as the upoko (head) is tapu (sacred) in Māori culture. Participants put the headset on their own upoko and adjusted it themselves after a demonstration on how to wear it was given. Verbal consent to touch the participant's upoko or to help with adjusting/removing the headset was sought before assisting participants. In further observance of tikanga, the content shown in the headset was not considered to be a risk to participant well-being.

The participants were monitored throughout the period of VR use by the researcher and an assistant. The researcher was trained in first aid, and a first aid kit was available during the experiments in case any participants experienced discomfort. To protect the participants, the physiological sensor (Equivital EQ02+ LifeMonitor, Hidalgo, United Kingdom) is non-invasive, FDA 510K approved, and the company is certified to ISO13485, a standard for medical devices. While the measurements collected were not for medical purposes or to provide medical advice, if any anomalies were found in the heart data, the participant would be informed by a phone call from the researcher to advise them to discuss this with their health practitioner. All equipment was sanitized between use to maintain hygiene and participant safety. All participants were given a private area to put on the Equivital sensor belt.

In respect to beneficence, participants had the opportunity to learn about the health benefits of forests, experience VR and receive a short report of the results if they indicated their interest on the consent form. As a token of appreciation for participant time in participating in the research, a $30 grocery voucher was offered to each participant. Acknowledging the potential impact of coercion in the special relationship between the participants and their employer, this was managed by recruiting the participants independent of their employer. Researchers and participants who were known professionally or personally were managed through clear communication of voluntary participation and confidentiality protocols. The conflict of interest between the funder, researcher's employer and Massey University was managed by maintaining transparency, reflection of supervisor and advisor feedback, reporting accurate results, and disclosing the funding source in all publications and presentations.

3.10 Data analysis

Participants were excluded from the data analysis if there was missing data for a particular measurement or if they requested to withdraw their data from the study within two weeks of the experiment, as set out in the consent form (Appendix 4).

3.10.1 Demographics

Responses from the short questionnaire (Appendix 6) were collected to gain an overview of the participants' characteristics. Age range, years of experience in forestry, VR experience, caffeine intake, nicotine intake, alcohol intake, physical activity level, time spent in nature and living environment were assessed.

3.10.2 Physiological measures

3.10.2.1 Data processing

Heart rate (HR) and heart rate variability (HRV) data were extracted from the electrocardiogram (ECG) recording using LabChart 8.1.3 software (ADInstruments, Dunedin, New Zealand). Markers were placed in the data to indicate the different stages of the experiment for analysis. The HRV module within labchart was used to calculate HR and HRV, performed on the 5-minute blocks of data indicated by the markers (baseline, production forest, harvested forest, native forest). The HRV analysis was calculated on the ECG channel that had the clearest connection and was kept consistent throughout the individual analyses. The HRV analysis module automatically detects the R-wave markings on the ECG trace and classifies beats as normal or ectopic based on the complexity and R-R interval. The ECG trace was visually inspected for incorrect R-wave detections or missed beats. Beats were manually added where there were missed detections. Ectopic beats were excluded from the HRV analysis.

Mean HR, BR, root mean square of successive differences (RMSSD), high frequency (HF) power and mean GSR were calculated for each 5-minute block. For GSR , the mean of the absolute value of skin conductivity, including the phasic and tonic components, was calculated (see section 2.5.4 Galvanic skin response for further details). The time domain parameter RMSSD and the frequency domain parameter HF HRV were chosen for analysis as they both represent vagal tone as discussed in section 2.5.2. Analysing two parameters that represent vagal tone to check that the results echo the same findings is recommended in the literature (Laborde et al., 2017). As recommended by (Malik, 1996) the absolute power of HF is presented.

3.10.2.2 Statistical analysis

R studio (Posit team, 2025) was used to statistically analyse the data. Data were assessed to meet the assumptions of analysis of variance (ANOVA) tests. The Shapiro-wilk test and Q-Q plots were used to determine if the data were normally distributed. Where data did not fit a normal distribution, they were log transformed or analysed with a non-parametric test. Both RMSSD and HF were log transformed. 15 forestry and 15 office participants were included in the HRV, HR and BR analyses.

A four (condition: baseline, production, harvested, native) x two (group: forestry, office) repeated measures ANOVA was used to analyse each of lnrmssd, lnHF and HR. The assumption of sphericity, that the variances of the differences between all combinations of the conditions are the same, was automatically checked using Mauchley's test. The Greenhouse-Geisser correction was applied when sphericity was violated. Post-hoc analyses were conducted for significant results, using Holm-bonferroni adjustment or Tukey HSD adjustment. BR had several outliers even when log transformed, so was instead analysed using the Aligned Rank Transformation.

For GSR data, one forestry participant was excluded from analysis due to missing values from equipment failure. A total of 15 office and 14 forestry participants were included in the analysis. GSR data did not meet the assumptions of ANOVA and contained several outliers so was analysed using Aligned Rank Transformation. A significance level (statistical priori) of alpha = 0.05 was used for all statistical tests.

3.10.3 Relaxation State Questionnaire

Mean total relaxation scores were calculated for the general relaxation subscale (2 items) for the baseline, post production forest, post harvested forest and post native forest scenes. One participant in the forestry group did not answer the baseline RSQ and therefore was removed from the analysis, resulting in 14 forestry and 15 office participants included in the analysis. A one-way ANOVA with Greenhouse-Geisser correction was used to analyse the effect of order on mean RSQ score. A repeated measures ANOVA was used to analyse mean RSQ score.

3.10.4 Semi-structured interviews

All 30 participants' interviews were included in the analysis. The interviews lasted between 2 and 12 minutes. Each interview was transcribed using the Microsoft Word transcribe feature with errors manually corrected by listening to the recorded interview. No participants requested to have their interview transcript returned to them for amendment.

A thematic analysis was conducted on the transcribed interviews using Nvivo 13 (Lumivero, 2020) to address research question 2. The reflexive thematic analysis process was followed as outlined in Braun and Clark (2006). An inductive approach was taken, whereby the themes and subthemes are derived from the data, rather than guided by a theoretical framework (Braun & Clarke, 2006). This aligns with the post-positivism lens of the research design by accepting that knowledge is constructed from multiple perspectives and that perceptions of events can be developed to explain "the whole" through partial views (Levers, 2013).

The analysis started with re-reading of the transcripts and familiarisation with the data. Next, the initial coding of participant transcripts was undertaken by tagging and naming individual segments of text. These initial codes were then reviewed, with initial codes with the same meaning combined into one code. The revised codes were then sorted into potential themes and subthemes. These themes were then reviewed in regard to the overall data set and relevance to the research questions, with refining and renaming where appropriate. All final themes and subthemes were peer-reviewed by the research team. Quotes were selected to illustrate the themes and reproduced verbatim. Figure 8 shows the process that was undertaken by the researcher. The researcher's involvement in the interviews and analysis meant that the researcher cannot be considered a passive observer of the data but rather a co-constructor.

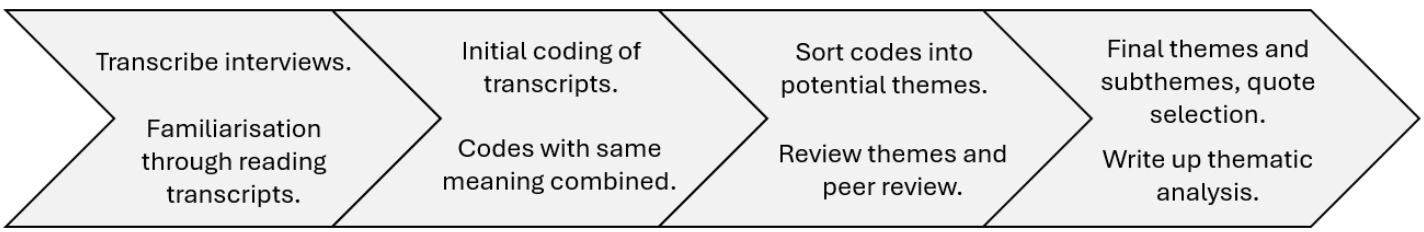

Figure 8. The reflexive thematic analysis process applied to the data collected from the semi-structured interviews.

Chapter 4: Results

This chapter outlines the results obtained from the VR experiments investigating the potential health benefits of forests for forestry workers. The chapter begins by outlining the demographics of the participants, presenting the analysis of the questionnaire that was answered at the beginning of the experiment (see section 3.8 and Appendix 6). Then, the results of the physiological measurements of heart rate (HR), heart rate variability (HRV), breathing rate (BR), and galvanic skin response (GSR) are reported in section 4.2. The chapter continues with the presentation of the psychological results from the Relaxation State Questionnaire (RSQ) in section 4.3 and finishes with a thematic analysis of the semi-structured interviews in section 4.4.

4.1 Demographics

No participants chose to withdraw their data within the two-week period following the trial as was outlined in the participant information sheet (Appendix 3) and as part of ethical considerations. This resulted in a total of 15 forestry and 15 office participants in the sample. Table 3 shows the results of the demographic questionnaire.

A third of all participants were in the age range of 30-39 years. The forestry group were represented by younger participants than the office group (Figure 9). Over half of the participants (57%) had not used VR with a head mounted display before, 11 of these within the forestry group, and only two participants (both in the office group) reported being very familiar with VR.

Of the 30 participants, 83% had consumed caffeine in the 12 hours before the experiment. 10% of all the participants had consumed nicotine in the previous 12 hours before the experiment, and 43% had consumed alcohol in the last 24 hours. Only one participant had consumed all three.

Table 3. Results from the demographic questionnaire.

Question	Response options	Forestry n (%)	Office n (%)
Age	<20 20-29 30 –39 40-49 50-59 60-69 70+	0 4 (27%) 5 (33%) 2 (13%) 3 (20%) 1 (7%) 0	0 1 (7%) 4 (26%) 5 (33%) 4 (27%) 1 (7%) 0
Years of experience in forestry?	0 <1 1-9 10-19 20-29 30+	0 0 6 (40%) 3 (20%) 3 (20%) 3 (20%)	15 (100%)
Do you have any experience using virtual reality (VR) with a head-mounted display?	No, never used before Yes, have used a few times Yes, very familiar	11 (73%) 4 (27%) 0	6 (40%) 7 (47%) 2 (13%)
Have you had any caffeine in the last 12 hours?	No Yes, less than 1 hour ago Yes, 1 – 6 hours ago Yes, 6+ hours ago	2 (13%) 3 (20%) 9 (60%) 1 (7%)	3 (20%) 7 (47%) 4 (27%) 1 (7%)
Have you had a cigarette or nicotine vape in the last 12 hours?	No Yes	13 (87%) 2 (13%)	14 (93%) 1 (7%)
Have you had an alcoholic beverage in the last 24 hours?	No Yes	9 (60%) 6 (40%)	12 (80%) 3 (20%)
Have you completed any vigorous physical activity in the last 24 hours?	No Yes	5 (33%) 10 (66%)	12 (80%) 3 (20%)
How often do you engage in moderate to vigorous physical activity	Everyday 1-4 times a week Once a fortnight Once a month Hardly ever	7 (47%) 6 (40%) 1 (7%) 0 1 (7%)	4 (27%) 9 (60%) 2 (13%) 0 0
How often do you spend time in nature for recreation, work or other purposes?	Everyday 1-4 times a week Once a fortnight Once a month Hardly ever	8 (53%) 6 (40%) 0 1 (7%) 0	1 (7%) 6 (40%) 3 (20%) 3 (20%) 2 (13%)
Do you live in a rural or urban environment?	Rural Urban Other	5 (33%) 9 (60%) 1 (7%)	0 13 (87%) 2 (13%)

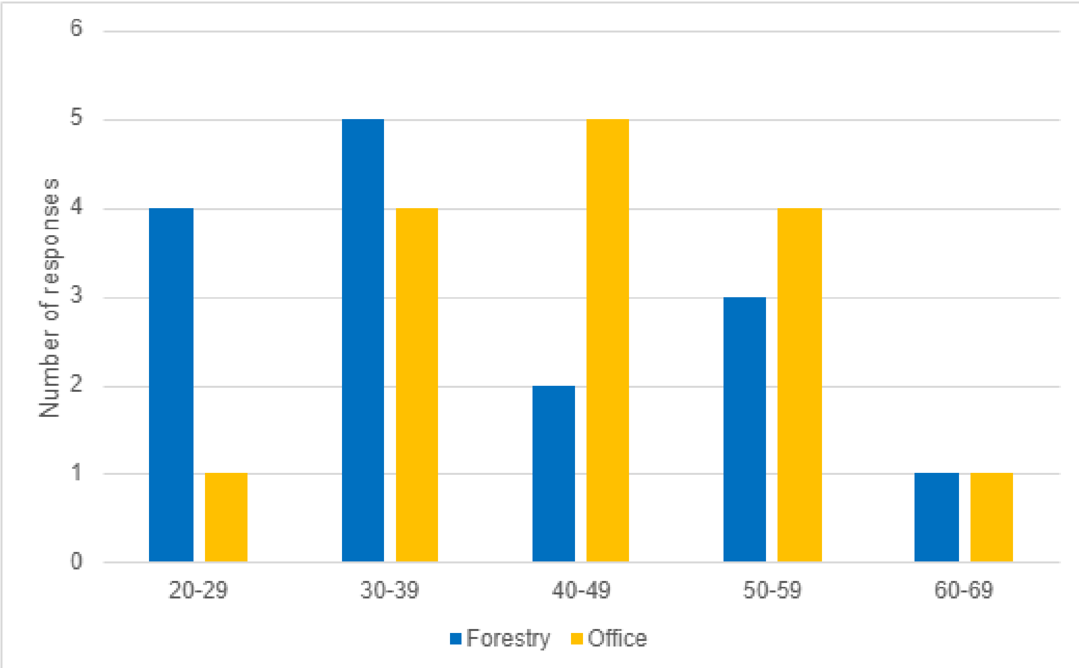

Figure 9. Age ranges of the participants by group.

43% of participants had completed vigorous physical activity in the previous 24 hours before the experiment with most of these (77%) in the forestry group (Table 3). In terms of physical activity level, 47% of forestry participants reported engaging in moderate to vigorous physical activity every day, with 40% exercising one to four times per week. Within the office group, 27% reported exercising every day, with 60% exercising one to four times a week.

For the forestry group, 40% of participants reported that they had between one and nine years of experience in forestry, with 20% of participants in each of the other experience ranges (10-19, 20-29 and 30+ years). None of the office participants had any experience in forestry. 53% of forestry participants spend time in nature every day, and 40% were in that environment between one and four times a week (Table 3). Only one office worker reported spending time in nature every day, with 40% reporting one to four times a week in nature. 83% of all the participants reported living in an urban environment. 33% of forestry participants reported living in a rural environment. All office participants reported living in an urban environment or “other”, for example, semi-rural or urban-fringe (Table 3).

4.2 Physiological measures

Table 4 shows the mean and standard deviations for the physiological measurements.

Table 4. Mean ± standard deviation (SD) values for heart rate (HR, bpm = beats per minute), breathing rate (BR), heart rate variability (HRV) and galvanic skin response (GSR) indices of office and forestry participants in each forest environment.

		Mean (SD)				
Environment	**Group**	**HR (bpm)**	**BR (breaths per minute)**	**lnRMSSD**	**lnHF power**	**GSR (μS)**
Baseline	Office	74.7(14.0)	19.1(3.16)	3.38(0.39)	5.62(0.91)	9.95(4.38)
	Forestry	74.4(12.5)	18.2(3.56)	3.34(0.46)	5.62(1.05)	9.47(3.51)
Production	Office	71.1(12.1)	17.4(3.60)	3.21(0.45)	5.44(0.87)	8.50(4.33)
	Forestry	69.2(10.2)	16.9(3.89	3.41(0.55)	5.67(1.28)	9.06(3.93)
Native	Office	70.7(12.3)	16.9(3.58)	3.25(0.455)	5.46(0.98)	8.83(4.89)
	Forestry	68.9(10.2)	16.8(4.28)	3.40(0.580)	5.73(1.30)	8.91(3.60)
Harvested	Office	71.3(12.6)	17.7(3.48)	3.21(0.433)	5.42(0.92)	8.76(4.28)
	Forestry	69.2(10.4)	17.5(4.24)	3.40(0.578)	5.71(1.25)	10.0(3.91)

Boxplot results are displayed for the physiological measures in Figure 10.

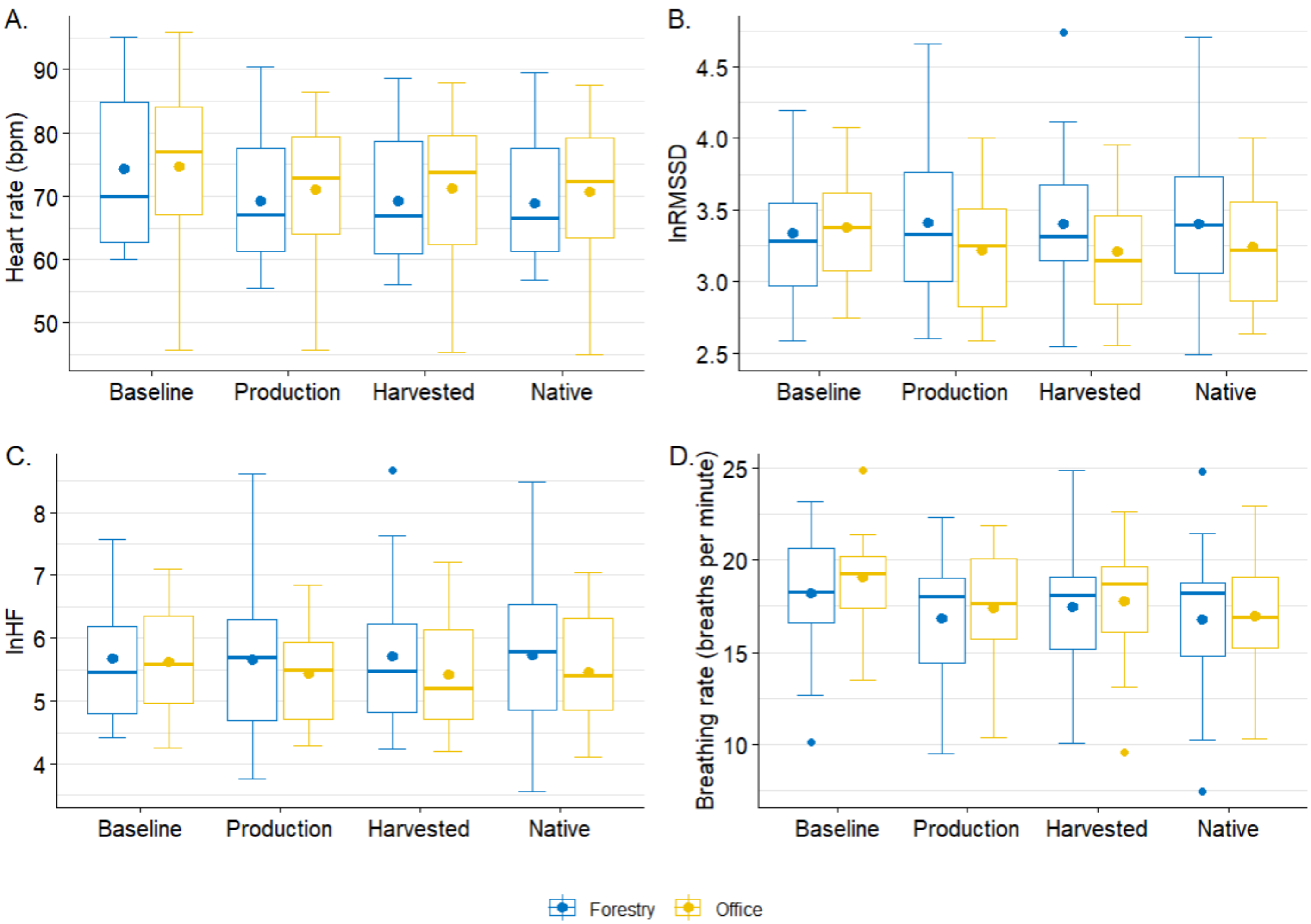

Figure 10. Boxplot results for mean cardiovascular measurements A. heart rate (HR), B. log transformed root mean square of successive differences (lnRMSSD), C. log transformed high frequency (lnHF), and D. breathing rate (BR). The middle line within the box represents the median, while the dot inside the box represents the mean. The bottom and top lines of the box show the interquartile range, and the vertical lines extending from the ends of the box indicate variability outside the upper and lower quartiles. Outliers are represented by solid dots outside the upper and lower quartile variability.

A mixed design repeated measures ANOVA of HR (Figure 10A) showed a significant main effect of condition ($F(1.27, 35.52) = 30.89$, $p < 0.001$) indicating that mean HR differed across the environment conditions. Post hoc pairwise comparisons (Holm-adjusted), collapsed across groups, showed that native (mean difference = 4.73 bpm, SE = 0.79, $t(28) = 5.97$, $p < .0001$), production (4.39 bpm, SE = 0.77, $t(28) = 5.68$, $p < .0001$), and harvested environments (4.34 bpm, SE = 0.75, $t(28) = 5.76$, $p < .0001$) had significantly lower HR than baseline measures. No other pairwise comparisons were significant after Holm correction. This means that HR significantly decreased in the forest environments compared to baseline, however there is no difference between the forestry and office groups and no interaction effect, meaning both forestry and office workers respond with a similar decrease in HR.

A repeated measures ANOVA of HRV lnRMSSD (Figure 10B) showed a significant group by condition interaction ($F(1.58, 42.6) = 4.27$, $p = 0.028$) meaning lnRMSSD was significantly different for forestry and office groups. However, after post-hoc analysis with Tukey adjustment for pairwise comparisons, lnRMSSD did not differ significantly between forestry and office groups in baseline, production, native or harvested conditions. A repeated measures ANOVA showed no significant differences in HRV lnHF (Figure 10C) for group, condition and interaction effects.

Analysis of BR (Figure 10D) using Aligned Rank Transformation showed a significant overall condition effect ($F(3, 84) = 5.56$, $p = 0.001$). Holm-adjusted pairwise contrasts on the aligned ranks showed that breathing rate in native and production conditions was significantly lower than baseline BR measures ($p = <0.001$ and $p = 0.03$ respectively). However, there is no difference between groups and no interaction, meaning both office and forestry workers responded with a similar BR.

Overall, as shown in Figure 10, there is a trend of higher lnRMSSD, lnHF, and lower HR in forestry workers, suggesting higher PNS activity than office workers.

Aligned rank transformation on GSR data showed no significant differences for group, condition and interaction effects (Figure 11), meaning there was no difference in GSR between forestry and office workers, or between the environmental conditions.

Figure 11. Boxplot results for galvanic skin response (GSR) data.

4.3 Relaxation State Questionnaire

Table 5 shows the mean and standard deviations for the mean RSQ scores for each group and environmental condition.

Table 5. Mean ± SD values of total Relaxation State Questionnaire (RSQ) scores for office and forestry participants in each forest environment.

Group	Environment	Mean (SD)	Overall
Baseline	Office	4.20 (0.92)	4.4 (1.0)
	Forestry	4.30 (1.08)	
Production	Office	4.03 (0.99)	4.4 (0.5)
	Forestry	4.84 (4.4)	
Harvested	Office	3.3 (1.07)	4.05 (0.75)
	Forestry	4.79 (0.43)	
Native	Office	4.53 (0.58)	4.74 (0.39)
	Forestry	4.95 (0.20)	

A one-way ANOVA was conducted to determine whether mean RSQ score differed across the order the conditions were displayed (Figure 12). The test was non-significant, indicating that the order the condition was displayed had no effect on mean RSQ score. A repeated measures ANOVA with Greenhouse-Geisser correction determined there was a statistically significant difference in mean RSQ score between baseline and the environmental conditions ($F(2.33, 63.02) = 7.56$, $p < 0.001$). There was a statistically significant difference between the two groups (F(1,27) = 10.14, p = 0.004), with the forestry group reporting higher RSQ scores than the office group. In addition, there was a significant interaction between group and environmental conditions following Greenhouse-Geisser correction (F(2.33, 63.02) = 7.69, p < 0.001). This shows that the forestry workers reported feeling more relaxed across the conditions than the office workers.

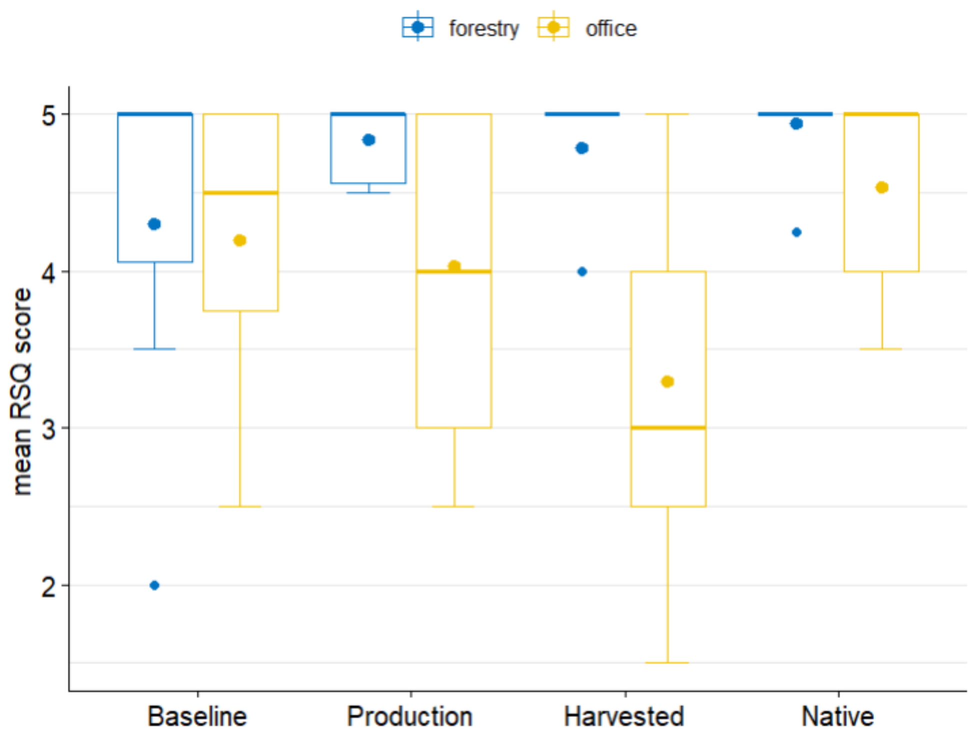

Figure 12. Boxplot results for Relaxation State Questionnaire (RSQ) scores from forestry and office participants in each forest environment.

4.4 Semi-structured interviews

Semi-structured interviews were undertaken with participants to get an in-depth understanding of their thoughts and perceptions related to the VR environments they were exposed to and forests environments. Four main themes emerged from the thematic analysis of the semi-structured interviews: (1) Variety and diversity of forests, (2) personal forest connection, (3) forests as restorative environments, (4) working in forestry (Table 6). Key themes are further developed by subthemes which are outlined in detail in the following sections. Quotes from the interviews that illustrate the themes and subthemes are identified by the participant's assigned identifier and reproduced verbatim.

Table 6. The key themes and subthemes that emerged from the thematic analysis of the semi-structured interviews.

Theme	Description	Subthemes
Variety and biodiversity of forests.	The characteristic attributed to the perceived difference in relaxation between the native, production and harvested environments.	
Personal forest connection.	How participants' personal connection to forests influences their preferences.	Memories Professional lens
Forests as restorative environments.	Attributes of the forest that contribute to a restorative experience.	Getting away and switching off Sensory immersion Wildlife
Working in forestry.	Positives of working in the forestry industry.	Outdoors and variety Identity and purpose Community and people

4.4.1 Variety and biodiversity of forests

This theme describes the perceived difference in relaxation of the native, harvested, and production forests due to the characteristics of increased biodiversity. Some participants felt that the native scene had more variety and biodiversity than the harvested or production scene. The variety and biodiversity of the native forest scene was an important difference for those who chose this scene as their favourite. In particular, participants mentioned the undergrowth and ferns.

“More diversity, like the fern on the floor, and it was just easier to look at and just observe, be in the present moment I guess” - P13

“Probably the one with the ferns, just because it's got undergrowth” - P18

Participants liked the undergrowth as there was more to engage with in the scene. Both the production and the harvested VR scenes had no undergrowth and ferns, which made the participants feel they had less to look at. The biodiversity was seen as an integral part of what made the environment relaxing to be in. For some participants, it was simply having more to look at within the scene. For others, the randomness within diversity was important.

“It's the haphazard nature of nature that brings the calm with it” - P3

When compared directly with the production forest, which was one species of *Pinus radiata* planted in rows, or the harvested block where the trees had been removed, participants noticed a difference in biodiversity. Alongside the ferns and the undergrowth, participants felt that the native scene had more happening, such as the birds and birdsong, colours of the scene and movement in the trees.

“There was more going on, birds and things, much more activity like that to see” - P10

The native scene had a pīwakawaka (New Zealand fantail, *Rhipidura fuliginosa*) that flew about in the trees in the beginning of the video. The scene was presented with the original audio that had the tweeting of the bird as it flew around in the canopy of the beech trees. This was an engaging aspect of the native scene which often captured participants' attention. This was observed during the experiment as the participants moved their head around to find the pīwakawaka in the 360-degree video.

“There's always somewhere to grab your attention” - P2

The ability of the native scene to hold the attention of participants through more variety and biodiversity helped some participants feel fully immersed in the environment and stay in the present moment. For example, the sounds of the pīwakawaka and the movement of the trees helped one participant to feel more intimately surrounded by the forest:

“The second one [native]. Again, probably due to there being a little bit more movement, the birds, sounds, and again, being surrounded more intimately with the environment.” – P11

Overall, compared to the production and harvested environments, participants felt that the native scene was more diverse. This was mentioned in characteristics such as undergrowth variety, colours, movement and birdlife, which kept the participants engaged and made them feel calm and relaxed.

4.4.2 Personal forest connection

Participants’ individual experiences and backgrounds, which impact their personal connection or lack thereof to a forest environment, influenced their responses. The two groups, office and forestry, responded differently to the forest environments, but differences were also apparent within the office group due to differences in personal connections to the environments. The forestry group was more inclined to like all the VR scenes, while the office group was more drawn to the native scene. The two subthemes: (1) memories and (2) professional lens, outline the main connections the participants had to the environments that shaped their perception.

4.4.2.1 Memories

The first subtheme, memories, outlines how participants' individual memories from certain forests shaped their perception of the environment. Participants often described specific memories they remembered from experiences in a particular environment that explained why they liked that environment, as exemplified in the next quote.

"I think I preferred the last one [production]. It's just that it looked a bit more open and I was imagining myself, you know, going back to my childhood days and thinking of a book called The Woodland Stories" - P5

Participants recalled specific positive memories which connected them to one or multiple environments. Participants who had fond memories of those forest types enjoyed spending time in that virtual scene. These memories were often linked to recreational activities participants use the different forests for.

"I'm very, very similar with [my preference for] the first [production] and the last [native]. The first one I felt like it was more like a family environment where I'd be with my son and the last one was more like bushwhacking on the bike. So, there's kind of like the calm and then the activity" - P7

Mountain biking in production forests was a commonly mentioned activity, which provided a positive memory or personal attachment to production forests. Mountain biking can be performed in both native and production forests, but production forests are commonly used due to being easier to access and closer in proximity. Participants who mountain bike therefore are quite familiar with production forests and didn't mind the production scene. For example,

"Well, funnily enough, definitely preferred the first one [native], but kind of felt quite relaxed in the second one [production], just because it's familiar to me... so I sort of thought of riding bikes... like building tracks and stuff, so it's probably more personal" -P6

These personal connections to production forests through memories and leisure activities positively influenced participants' perception of those environments. For participants who perhaps did not have a personal connection to production forests, they were more inclined to enjoy the native forest.

4.4.2.2 Professional lens

The second subtheme, professional lens, describes how the forestry participants experienced the forest environments differently to the office group due to their work experience and professional view of the forests. Many of the forestry participants were thinking about work when they were viewing the VR production and harvested scenes, as noted in the quote below.

*"The second [production] with the standing trees I look at the attributes and I'm like, I'm probably too much of a logger because I'm like oh double leader that'd be a p**ck to cut down" - P30*

The professional lens of the forestry participants meant they observed the trees from a completely different perspective to the office participants. The forestry participants were often assessing the trees in the virtual scenes, thinking about how they would complete the job, with many curious afterwards about which forests the videos were taken in.

"You know, when I was in the forest, I was cruising the trees. And I was looking at the cutover. I was assessing the cutover. So the native was kind of-- I was just chilling and enjoying it. So I guess I enjoyed the first two from a professional perspective and the last for just enjoyment." - P28

Most forestry participants still felt all the forest scenes were relaxing even if they were thinking about work while viewing them as the next quote highlights.

"The first scene [harvested] was quite relaxing in the cut over. It seemed like a finished product from a working point of view. Everything was cut, everything was picked up, completed probably" - P26

This was also reflected in the RSQ results, with forestry participants finding all three scenes similarly relaxing. The production and harvested scenes are very familiar to the forestry workers, who see these environments often. For most of the forestry participants, thinking about work in the forestry scenes was a positive experience, and they still found the harvested and production scenes relaxing. In contrast, some preferred the native forest scene because it removed them from thinking about work as noted by participant 21.

"Probably the last one [native] because the first one [production] just feels like I'm still at work" - P21

As the forestry environment is very familiar to the forestry participants, seeing something different, such as the native scene, was more relaxing for those who didn't want to think about work. Furthermore, forestry participants had a connection to the forest through their past work experience.

“You're looking at something that you may have planted 10, 15, 20 years before, or like that last setting [harvested], I was looking for seedlings... and if your career started at that point, you're still connected to that growing side of it, the green finger side.” - P27

The forestry workers have an inherent connection to the forest through their direct engagement with the landscape through the forestry lifecycle. All the participants would have engaged with the trees at some point in their career, whether it be through planting, harvesting or management of the forest estate.

In summary, the forestry participants were familiar with harvested and production forest landscapes, which they viewed from a professional lens. Their work experience influenced their perception of the scenes, which could also be seen in the perceived relaxation results of the RSQ.

4.4.3 Forests as restorative environments

When participants were asked what they enjoy about visiting the forest, many found it difficult to describe or narrow down to one thing. One participant stated,

“I don't know, [its] just my happy place” - P19

For many participants, it is not one thing, but a combination of multiple things that make the forest a relaxing and enjoyable place to visit. This theme emerged as three subthemes about what participants most enjoy about visiting the forest and the attributes that contribute to a restorative experience.

4.4.3.1 Getting away and switching off

Participants described forests as spaces where they can get away to a calm environment, allowing them to switch off, reflect and relax. Two example quotes are, *"It makes me calm, makes me relaxed. I can turn my head off when I go to the forest." - P23*

"Going out in the forest every morning, you know, it pretty much separates me from everything else… it's so calming." - P20

The forest provides a quiet space where people can mentally detach from the stressors of everyday life. When people are dealing with an issue or problem, they can go into a forest to find a calm, peaceful environment that can take them away from what they are currently dealing with. In contrast, the forest can also provide a place for thinking and reflection for some participants.

"It's kind of a place where I can kind of think things through and just be at peace" - P7

Participants can use the forest to switch off and get away from everyday life or use it to think through what is on their mind and clear their thoughts. For many participants, this leaves them feeling more relaxed and less stressed once they have visited the forest. Forests environments can also provide a relief from the busy everyday life of an urban environment. One participant expressed it as,

"It gets you away from people and the crowded environments that we live in… it's just nice to go into a calmer environment where there's less rush and hustle and bustle." - P28

As forests are quiet and calm environments, they provide a change of pace to a busy urban lifestyle. Forests are often in remote locations, away from cities and crowds of people, providing a place where people can be away from stressors such as traffic, noise and pollution. Participants also mentioned being able to visit the forest alone, providing a moment of solitude and opportunity of being uncontactable by phone.

Overall, forests were regarded as peaceful, calm environments that allow the participants to get away from stressors, switch off their minds, providing moments for reflection and rest.

4.4.3.2 Sensory immersion

Throughout the interviews, there were many mentions towards the sensory experience of forests. Being immersed in natural elements such as vegetation, sounds, smells and fresh air contributed to the restorative effect of forests. For many, the views within the forest are important.

“It's just being close to nature, the trees around, and you feel some sort of a connection with nature when you're in the midst of so many trees” - P5

“I really like all the green... the green stuff is, like, good vibes” - P16

Participants enjoy going into the forest and seeing the greenery and the trees. Large trees and beautiful views from the top of a forest hillside can evoke a sense of awe. Going into the forest provides an opportunity to admire and feel connected to nature. Alongside the visual, participants described other multisensory qualities of the forest, such as olfactory stimuli:

“It's all the smells... you can smell the air, you can smell the mosses, you can smell the ferns” - P2

“I almost felt the smell” - P1

The fragrance of the trees, wood, earth, mosses, and vegetation were all specifically mentioned by participants. Certain forests and tree species can have strong distinct smells which contribute to a relaxing, immersive experience. Participants could recall what it smells like to be in those kinds of forests. Auditory sense was also discussed by participants, with the quiet soundscape of the forest and birdsong mentioned frequently. For example,

“Quieter, more bird sounds, less human sounds” - P3

“It was nice to hear the birds” - P15

The soundscape of the forest is very different from that of an urban environment. The forest provides a much quieter environment, with natural sounds such as the rustling of leaves or birdsong. Participants found these sounds to be calming. It also allows for a break from the loud sounds of an urban environment, described by some as “less human sounds”. This also connects to the getting away and switching off subtheme, as the quiet soundscape of the forest allows participants to get away from the busy urban lifestyle, to switch off or reflect. Alongside the sights, smells and soundscape, the feeling of fresh air in the forest was also discussed, mainly by forestry workers who highly value being outside rather than working indoors.

“...fresh air every day, you can't beat that, rather than stuck in the office and get no fresh air” - P21

Being out in the forest is an opportunity to get outdoors into fresh air. Further to this, as forest environments are often in remote locations, there is likely to be less pollution in the area than in an urban environment, contributing to the feeling of inhaling “fresh”, clean air. Altogether, these factors bring about a full sensory experience when visiting the forest, which seems to contribute to the restorative effect of forest environments.

4.4.3.3 Wildlife

Participants highlighted the presence of wildlife as a key contributor to the forest as a restorative environment, describing encounters with birds, insects, and animals as enriching the overall experience of visiting the forest. For example,

“The animals mainly, and then the other sounds and being out in a natural environment.” - P15

“Just seeing all the little birds and animals just going about their business” - P6

Observing animals in the forest is an important factor that makes the forest enjoyable to visit for many. Participants expressed enjoying observing natural wildlife in the forest that they likely do not get to see or hear often in an urban environment. Wildlife-related sounds, such as birdsong, were an integral part of creating a relaxing atmosphere, linking into the above subtheme of sensory immersion. When comparing the VR production and native forest environments, one participant mentioned:

“The birds actually made all the difference.” - P9

The production forest scene had a quiet soundscape and very little bird sound. As noted earlier, the native scene had a pīwakawaka which was chirping in the canopy, which participants noticed and enjoyed. For some participants, seeing wildlife is one of the main things they enjoy about visiting a forest.

4.4.4 Working in forestry

The qualitative data from the semi-structured interviews found that working in forestry provides the participants in the forestry group an immersive outdoor lifestyle that they find fulfilling, with plenty of variety to keep things interesting, and a community of good people to work with. For many participants it was evident that forestry is more than just a job; forestry participants have a genuine passion for the industry and a belief in the value of what forestry produces. These concepts are outlined below in three subthemes: Outdoors and variety, identity and purpose, and community and people.

4.4.4.1 Outdoors and variety

For forestry participants, working in an outdoor environment and the day-to-day variety that provides was a large appeal of forestry work. Participants appreciated the constantly changing natural environments, the ability to access remote forest locations, and the freedom from spending all day indoors or in an office environment. One illustrative quote is,

"It's true that at times it can be quite hard exposed to the elements, like the heat and the cold, the frost, snow sometimes, but I reckon if I have to choose, I keep choosing, working outdoors over indoors." - P16

Even though the work can be tough at times, forestry participants seem to prefer to work outdoors every day than spending their time in an indoor work environment. As discussed in in section 4.4.3.2, forestry workers value being out in fresh air every day. Forestry participants also highly value the variety that working in an outdoor environment provides.

“...it's not even like you're going to the same place outside every day. It's different forests, different environments, different ecosystems” - P17

Forestry workers often work in different areas and forests. This variety seems to be valued as it was noted that this helps to not get bored of their surroundings. Participants also appreciate that with this variety, they will get to visit forests and environments they otherwise couldn't access. For example a participant stated,

"Being outside in a cool spot that [I] otherwise wouldn't be able to go to" - P24

Participants also mentioned the ability to access the forest out of work time, learning the best spots to take themselves or their families for a walk or run in the forest.

4.4.4.2 Identity and purpose

For many forestry participants, forestry was more than just a job – it formed a core part of their identity and provided a strong sense of purpose.

"I've done heaps. I've loved it. Forestry is my life... I'm just pretty passionate about it" - P26

Working in forestry engages the forestry participants in work they feel matters, helping contribute to a sense of purpose and pride for their industry.

"I feel like in general I'm doing quite meaningful work." - P17

One area of forestry work in particular that was identified as being meaningful was the direct involvement in helping trees grow. Forestry workers can physically see the outcome of their hard work, supporting the sense of accomplishment. They enjoy working in the industry because they believe in the work they are doing and the benefits it can provide.

"Helping stuff grow. Helping a land use, establishment of a land use, which I think is a pretty good one." - P25

Alongside the sense of purpose and pride, the legacy and impact of forestry emerged. Some of the forestry participants had worked their entire careers in forestry, noting the impact that the industry has had on their lives:

"It's made us all. What we've got now, is made by forestry" - P30

This highlights the impact that the forestry industry has on these participants, providing them with a livelihood they are passionate about and fostering a sense of identity, pride and purpose among those who dedicate their careers to it.

4.4.4.3 Community and people

A strong sense of community was apparent throughout the forestry participant responses, with many emphasising the value of the people who work in the forestry sector.

"I love the people, love the machines. Yeah, good, honest, most of them are honest, bunch of people." - P26

Forestry participants spoke fondly of the people in the industry. They often highlighted the value of being surrounded by good people within and beyond their crews. For example,

"We're a real good group of people that I'm working with being in the crew, so it makes the work a bit lighter than what it should be" - P21

Strong crew relationships can help ease the physical and mental demands that can come with forestry tasks, making the work more enjoyable. Passion for the job from people within the industry was also mentioned.

"You've always got some pretty good hearty people that work in it, and they work in it because they love forestry." - P27

This passion for the job highlights again how those who work in the industry love what they do. Beyond crew engagement and passion for the job, working with the community is also a valued aspect of forestry work.

"Working with some of our community stakeholders as well is really great, so being able to do stuff with people in the community" - P22

These accounts help to explain that the forestry participants highly value the people and the community within the forestry sector, contributing to their overall satisfaction of a career in forestry.

4.5 Summary

In summary, four themes emerged from the semi-structured interviews that outlined the participants perspectives on the VR scenes, their personal connections to forests, what they enjoy about visiting the forest and what the forestry workers enjoy about working in the forestry industry. These perspectives provide valuable insight into how forest environments might be restorative for office and forestry workers and the different factors that can impact this. These findings complement the results of the physiological measurements in building a more comprehensive picture of the possible mechanisms that influence stress reduction in forest environments.

Chapter 5: Discussion

The purpose of this research was to investigate the health benefits of working in a forest environment, using VR. This study aimed to do this by assessing physiological and psychological responses of forestry and office workers when viewing different virtual forests. In the following sections, the findings of the research are discussed in relation to the research questions and hypotheses. The two research questions were based around the potential difference in responses between the forestry and office workers and the differences between the VR forest scenes. Section 5.1 discusses the results of Hypothesis 1 and section 5.2 discusses the results of Hypothesis 2. The results are interpreted within the context of previous literature and related theories of health benefits of nature and virtual nature, which are outlined in Chapter 2 sections 2.3 and 2.4. The discussion continues with findings around the use of virtual reality in section 5.3, and outlines implications for the forestry workforce in section 5.4. Limitations of the research are presented and discussed in section 5.5, with opportunities for future work building upon the current study outlined in section 5.6. This chapter finishes with the conclusions of the research.

5.1 Comparing forestry and office workers

The first hypothesis of this study was that forestry workers would relax in virtual forest environments more than office workers (section 1.3). This was hypothesised due to the stress reducing effects of nature exposure and that forestry workers are consistently exposed to forest environments through their job.

5.1.1 Physiological findings

There was some support for this hypothesis in the physiological data. Vagal heart rate variability showed a trend towards higher results in forestry workers. There was a significant result for temporal heart rate variability (RMSSD), with the forestry group having higher heart rate variability than the office group across all the environmental conditions. Although there was no significant difference after post-hoc analysis, this trend suggests forestry workers had higher levels of parasympathetic nervous system activity than office workers when viewing the forest environments. High frequency heart rate variability was also trending higher in the forestry group than office group, though this difference was not statistically significant. Heart rate results did not support this hypothesis, as there was no difference in heart rates between the forestry and office groups.

In terms of sympathetic nervous system activation, there were no significant differences in galvanic skin response between forestry and office workers, meaning the two groups responded similarly to the VR forest environments. These results suggest that office and forestry workers had similar levels of sympathetic nervous system activation. Forestry workers did have higher average sympathetic nervous system activation than office workers in production and harvested environments, which could suggest a higher level of cognitive arousal than office workers. Increased galvanic skin response is attributed to an increase in cognitive arousal (Posada-Quintero & Chon, 2020). The higher means could be due to the production and harvested environments evoking thoughts of work while the forestry workers were viewing the scene (discussed in section 4.4.2.2). Some forestry participants mentioned they felt most relaxed in the native scene because it didn’t feel like they were at work. The galvanic skin response differences were not statistically significant however, and overall were similar between forestry and office workers. In addition, the forestry group had high self-reported Relaxation State Questionnaire scores in all three virtual reality environments, suggesting they still felt relaxed in the production and harvested scenes.

5.1.2 Psychological findings

Psychologically, the forestry group reported significantly higher Relaxation State Questionnaire scores across the environments than the office group, showing they felt more relaxed in the environments and further supporting the first hypothesis. The forestry group found all three virtual reality scenes to be more relaxing than baseline, and rated the production, harvested and native scenes similarly relaxing to each other. The office group, however, found the production and harvested scenes to be less relaxing than baseline, with the harvested environment the least relaxing.

These Relaxation State Questionnaire results were also supported by the interview responses, as there were differences in how the groups perceived the environments, outlined in section 4.4.2 (personal forest connection) in the thematic analysis. This theme describes how forestry and office workers were personally connected to the forests in different ways, through previous activities, memories and the professional lens of the forestry workers. Overall, forestry workers are more familiar and connected with production and harvested environments, which may explain why they felt more relaxed in these environments than office workers.

Personal history with a natural environment has been shown to improve psychological outcomes (McAnirlin et al., 2024) and has been noted as one of the potential reasons for the variation in psychological and physiological results across studies in this research area (Fan & Baharum, 2024). Alongside personal history, environmental preferences have been found to be closely associated with psychological restoration (Hartig & Staats, 2006; Song et al., 2025; van den Berg et al., 2003). The level of restoration experienced is suggested to be influenced by personal preferences, as people may feel more relaxed in the environments that align with their preferences (Song et al., 2025). This idea is also supported by the Attention Restoration Theory, which discusses an environment's "compatibility" with an individual's needs (Ohly et al., 2016). The harvested environment was perceived as incompatible for relaxation by many office workers, reflected in the low Relaxation State Questionnaire results and in the interview responses. In contrast, the native environment was preferred by most of the participants and had high Relaxation State Questionnaire scores. Therefore, in the office group, personal preference may have had a strong influence on the results. Physiologically though, there was no difference between the environments.

5.1.3 Sample size

It is possible that with a larger sample size, the trends of greater physiological relaxation in forestry participants could become clearer and more prominent. Gladwell et al. (2012) mention that physiological changes are harder to capture from participants who are already in a relaxed state. This was the case for our participants who did not experience a stressful task before viewing the virtual reality environments. Therefore, the non-significant results are not surprising with the small sample size of the study. However, it is promising to see some significant and trending physiological differences, showing some support for differences in physiological responses between forestry and office workers when viewing virtual reality forests.

Overall, there are some differences between forestry and office workers' responses to virtual reality forest environments. Psychological results were the strongest, with clear differences in Relaxation State Questionnaire responses and within the interview responses. The physiological results were more equivocal, requiring further investigation.

5.2 Comparing forest environments

The second hypothesis of this study was that virtual reality forest environments would induce greater relaxation than baseline, with native and production forest environments the most relaxing. Native and production forest environments were hypothesised to be the most relaxing due to their natural characteristics of trees and vegetation.

5.2.1 Physiological findings

There was a significant decrease in participant heart rate from baseline in the native, production and harvested environments. This result supports the hypothesis and provides evidence for the relaxing effect of virtual nature. However, there was no significant difference in heart rate between native, production or harvested environments, showing similar relaxation in all virtual environments. Heart rate variability indices also showed no significant difference from baseline or between the environments. Although there were some small, trending differences between the virtual forest environments in galvanic skin response, there were no significant differences. Therefore, the physiological findings partially support the premise that virtual reality forests induce greater relaxation but do not support the hypothesis that native and production forests would be the most relaxing. Native, production and harvested environments were equally relaxing physiologically and, depending on the measure, no different from baseline.

Breathing rate was analysed due to its strong influence on high frequency heart rate variability. In native and production scenes, the breathing rate was significantly lower than baseline. Relaxation can cause changes in breathing rate, with a lower breathing rate a sign of increased relaxation (Gladwell et al., 2012). However, the difference seen in this study could possibly be due to the research design, rather than relaxation. Participants' baseline physiological measurements were recorded while the participants were answering the demographic questionnaire. The choice was made to administer the questionnaire while baseline recordings were taken to reduce the time of the overall experiment for practical and ethical reasons. As the participants verbally responded to the questionnaire, their breathing rate is likely to be higher than when they are sitting in the virtual reality scene and not speaking. Therefore, it cannot be determined if the lower breathing rate is attributed to relaxation or is a methodological effect. All three virtual reality scenes had lower average breathing rate than baseline, even though the breathing rate in the harvested environment was not significantly different.

The physiological findings are consistent with other studies that have investigated forest or vegetation characteristics. The results reported in the literature are often nonlinear, that is, the environment with the most biodiversity or vegetation is not always the most effective at reducing physiological stress. Song et al. (2025) examined different levels of vegetation from virtual window views and the impact this had on physiological measures and relaxation states. They found no significant differences in galvanic skin response or heart rate for window views with different levels of vegetation and found a significant increase in heart rate variability for most levels of vegetation. Schebella et al. (2020) found that average heart rate recovery following a stress inducing test was significantly greater in the low biodiversity park environment compared to the moderate biodiversity park environment. Wang et al. (2019) found significant heart rate differences in environments that contained some artificial elements, but not in the most natural environment. For participants who physically visited the forest environments, Yao et al. (2024) found no significant differences in heart rate variability between different forest types of mixed biodiversity, though they found the pure coniferous forest had the lowest average heart rate. Overall, however, Yao et al. (2024) found mixed coniferous and broad-leaved forests to be most effective at relieving physiological and psychological stress. Kim and Lee (2023) found no physiological changes in university students exposed to forests in different seasons with different seasonal characteristics (e.g., green in spring, fallen leaves in autumn). However, they did find an improvement in mood states in the spring forest compared to the other seasons, thought to be due to the temperature and green colour of the spring forest. Generally, it seems that further research is needed to better understand forest characteristics and their influence on physiological responses in people.

5.2.2 Psychological findings

Psychologically, the Relaxation State Questionnaire showed that participants felt a significant difference in how relaxed they were feeling between baseline and the virtual reality environments. Combining the results of the two groups, more relaxation was seen following the native scene than at baseline and the native forest was the most relaxing scene overall. The relaxation state following the production scene was the same as that at baseline and the state following the harvested was less relaxed than at baseline. These results were also apparent in the interview responses. One of the main reasons participants felt that the native forest was the most relaxing was due to the variety and biodiversity in the scene (discussed in section 4.4.1). Previous literature on the relationship between biodiversity and psychological stress reduction has mainly found that higher biodiversity in an environment leads to better outcomes of perceived stress reduction and restoration. Wood et al. (2018) found the restorative benefit of parks, measured through self-reported surveys of restoration, attention-grabbing distractions, being away and preference, to be predicted by increased biodiversity in the environments. Yao et al. (2024) found that a mixed coniferous and broadleaved forest had the best stress-relieving effect psychologically on participants compared to other forests with either single or mixed species. In Song et al.'s window view study (2025) discussed above, it was found that views with more vegetation evoked more perceived relaxation, calmness, and attention restoration for people than those with less vegetation in the window view. These findings are in line with our study's findings. In contrast, Schebella et al. (2020) found no differences in perceived stress, anxiety or calmness in low, moderate and high biodiversity environments.

5.2.3 Contrasting findings

Contrasting physiological and psychological results are commonly reported in the existing literature. The environment that supports psychological stress reduction is not always the same as the environment that shows physiological benefits. Song et al. (2025) is an example of this where the optimal level of vegetation in a window view for positive benefits is different for psychological and physiological aspects. This was seen in our results also. The harvested environment had a significantly lower Relaxation State Questionnaire score than the other environments, but physiologically it was no different. As discussed in section 5.1, personal connection, preference or familiarity of the environment could play a role in these differences. Overall, these results highlight the complexity of human-nature interactions.

5.2.4 Forest characteristics

Participants discussed the characteristics of forests that they enjoy in the section about forests as restorative environments (4.4.3). The three main subthemes in this theme were the ability to “get away” or “switch off”, sensory immersion (sight, sounds, smells), and the wildlife in the forest. The getting away and switching off subtheme directly relates to the Attention Restoration Theory mechanism of “being away” (Kaplan & Kaplan, 1989). This mechanism states that nature provides an environment where people can “be away” from everyday stressors and reflect on mental concerns, allowing for mental restoration (Anderson et al., 2017; Ohly et al., 2016). The participant responses in the current study support this theory. Many participants commented on how going into the forest allows them to mentally detach from everyday stress or provides a place where they can think through their thoughts, getting away from busy everyday life.

The sensory immersion subtheme described the different sensory aspects that participants like about the forest. Natural sounds, such as birdsong, have been found to enhance physiological and psychological responses (Annerstedt et al., 2013; Li & Liu, 2024; Yoon & Jeon, 2022). In this study, the native virtual reality scene had the most natural sounds compared to the production and harvested environments which had very little noise. Our results agree with these previous findings that sounds can provide an improved experience. Although there were no significant physiological differences between the environments, psychologically the native scene was found to be the most relaxing, and the sounds of the birds in the native scene were mentioned by many participants in the interviews. Alongside sounds, the smell of the forest was another sensory factor that was mentioned by participants. More recently, olfactory stimuli have been investigated in some nature exposure studies (Ascone et al., 2025; Hedblom et al., 2019; Kim & Song, 2022; Song et al., 2019). Ascone et al. (2025), Song et al. (2019) and Hedblom et al. (2019) all found some benefits to multisensory exposure across both physiological and psychological indicators. Kim and Song (2022) found that fir tree essential oil had relaxation effects on university students compared to room air even with no visual stimuli such as virtual reality. Our findings suggest that olfactory components of the forest could be important for relaxation and should be investigated further.

To summarise, some physiological measurements showed support for stress reduction in virtual forests, but there were no differences between the native, production and harvested environments. Psychologically however, there were significant differences between the virtual environments, with the native found to be most relaxing. This could be attributed to aspects relating to the Attention Restoration Theory, sensory characteristics and biodiversity as discussed in the thematic analysis of the semi-structured interviews. Contrasting results between physiological and psychological measures have been found previously, possibly as a result of personal preferences and familiarity with environments.

5.3 Virtual reality

A main component of this study was the use of virtual reality to display immersive forest environments for stress reducing purposes. For 57% of participants, using the virtual reality headset was a novel experience. Some participants mentioned a feeling of excitement or apprehension of using new technology and participating in a trial. They were unsure if they felt more relaxed after viewing the forest scenes or because the experiment was now underway or over. While this nervousness for the trial and using unfamiliar technology could have been an unintended stressor for some participants, it does seem that the participants physiologically relaxed throughout the experiment, as most means were below baseline even if not statistically significant.

5.3.1 Virtual reality headset comfort

Feedback was received from participants in the semi-structured interviews on comfort of the virtual reality headset. Most of the participants found the headset to cause no discomfort. There were no reports of serious cybersickness such as nausea or dizziness, with no participants choosing to end the experiment early. The headset was not perfect however, and some participants were more susceptible to discomfort with the headset than others. The focus, weight, and firmness of the headset were reported as points of discomfort. Participants were given time to adjust the visual focus on the headset to their desired setting at the beginning of the VR section of the trial, but some found it difficult to get to a point where the view felt clear for them. The 360-degree videos in the VR headset are not crystal clear to begin with and most participants had never used a VR headset before so some may have been expecting a clearer image than the 5.7K resolution could provide.

Further to this point, the clarity of the focus was somewhat dependent on the position of the headset on the face. If the headset was not secured firmly enough or positioned optimally on the face, the image focus could be impacted. Participants were guided through this process and told that the video would not be completely clear even when the headset and focus were correctly adjusted. Participants were reminded they could stop and should let the researcher know if they felt eye strain or other discomfort in the duration of the experiment. During the duration of the research, a new Insta360 camera was released that has 8K resolution. It is recommended that future 360-degree videos are recorded with this higher quality camera to improve the focus and clarity of the videos for the users.

Some participants felt that the VR headset was heavy or felt tight across the forehead. As mentioned above, the headset requires a firm position on the head to improve the focus. This firmness was uncomfortable for some participants. No participants reported that the headset gave them a headache, but some did feel that the headset was heavy when moving their head around to look at the scene. Virtual reality discomfort from a heavy headset has been reported previously, reducing the duration a user can use virtual reality before experiencing discomfort (Chang et al., 2020).

If the participants were required to wear the headset for a longer period of time, it is likely these issues would have been more prevalent and potentially worse for those who experienced them. On the other hand, there were participants who felt so relaxed, they said they could have fallen asleep. These individual differences in how participants experience VR could potentially influence their responses to the VR environments. Participants who felt the headset was uncomfortable may have felt less relaxed throughout the experiment.

5.3.2 Duration of VR exposure

The duration of the experiment was influenced by the minimum length of time needed for reliable HRV recordings. A minimum of five minutes of HRV recording has been the 'golden rule' for HRV research as set out by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (Malik, 1996). This rule has been challenged, and shorter recordings have been proven to be reliable (Munoz et al., 2015). In this study, it was decided to use five-minute recordings of HRV to keep in line with the Task Force and many previous studies while allowing for a reduction in recording time, if necessary, due to technical failure or the impact of the headset.

Further to this, the duration of the experiment is influenced by how long it takes to see visible stress reduction in participants. Suppakittpaisarn et al. (2023) found that five minutes was the optimal length of exposure for promoting stress recovery, while Beverly et al. (2022) found that only three minutes of exposure could significantly reduce stress. In this study, some participants commented on the length of VR exposure, mentioning that five minutes in each scene felt like a long time. In future research, a reduced recording time could be adopted to reduce the time the participant has to wear the VR headset. A between-subject design could also be implemented to reduce participant time in the headset, although this would come with the cost of reduced experimental control, reduced statistical power, and require more participants (Laborde et al., 2017). Ultimately, there is support for shorter durations but the pros and cons of this should be carefully considered by the researchers and justification provided for the choices made.

5.4 Workforce implications

One of the purposes of this study was to understand the potential benefits of forest environments on forestry worker health to try address some of the workforce challenges in the industry. Currently, the forestry sector is experiencing recruitment difficulties and poor perception of the career amongst young people (New Zealand Forest Owners Association, 2018). The results of this study could be beneficial for addressing current and future workforce challenges in the forestry sector. The working in forestry theme of the thematic analysis (section 4.4.4) outlined three main subthemes that current forestry workers enjoy about working in the forestry industry. Participants showed a strong appreciation for working outdoors with a variety of people in diverse environments and places. These draw cards, alongside the physiological benefits of working in forestry as seen in the trend of lower physiological stress in forestry participants, helps to highlight some of the unique qualities of the forestry industry. These factors could be used to attract new people into the sector. The identity and purpose expressed by participants suggests that once individuals enter the sector, they can develop a strong relationship with the industry. These important positives of working in forestry could be used to improve the perception of forestry careers and attract more young people into the industry.

5.5 Limitations

As with all research, this study has some limitations. Firstly, this study had only male participants. The decision to include only male participants was made because 82% of the forestry industry are men. In most previous studies, either one gender has been used or differences in gender have not been explored. One study that has investigated gender differences of nature exposure is Bielinis et al. (2018). They explored gender-based differences in their study of winter forest bathing in Polish students, but found that the results were not clear, and recommended further research into this area. In further research, it would be beneficial to extend the sampling criteria to include females. Even though women represent a small proportion of overall forestry workers, it is still important to understand if working in forest environments has health benefits for women in the forestry industry. Findings could then be used to attract more women into the industry and improve gender diversity in the forestry sector.

Secondly, there was a slight skew in the age groups of the participants between the forestry and office group. The forestry group contained younger participants, which could influence the results as heart rate variability decreases as you get older (Tegegne et al., 2018). Further statistical analysis could be completed to test if age is influencing the HRV results.

Thirdly, not all confounding variables were controlled for in the analysis. Caffeine intake, alcohol intake, and smoking were recorded but not controlled. These variables can alter the cardiovascular system, which in turn affects heart rate variability (Laborde et al. 2017). It is possible these could have impacted on the physiological results of the participants who had consumed these substances within 24 hours before the experiment. Additionally, the time of day was not controlled in this study due to the availability of participants and the logistics of scheduling the experiments. Alongside this, forestry workers reported a higher activity level than office workers and a greater number had completed vigorous exercise in the 24 hours before the experiment. For HRV research, it is recommended that participants do not engage in intense physical exercise the day before the experiment (Laborde et al., 2017). HRV decreases during vigorous exercise and can take up to or more than 48 hours to recover depending on the intensity and the fitness of the individual (Stanley et al., 2013). In this study it was not possible to control exercise engagement due to the physical nature of forestry work and the practicalities of recruiting participants. This information was instead recorded and is recognised as a possible influencing factor on results. However, the within-subject design of the study sought to reduce the impact of these potentially confounding variables. Moreover, since the data about these potential confounders was recorded, further analysis could be undertaken to see if they had any influence on the results.

Fourthly, another potential limitation in this research is the applicability of the results from the use of virtual reality. Although previous research has found virtual nature to have similar stress reducing results to actual nature (Browning et al., 2020; Mavrantza et al., 2023; Reese et al., 2022), it is not certain that the results of this study apply in real life forest contexts. Further research could explore the differences between virtual forest environments versus real forest environments in forestry worker populations, to confirm that the virtual results are representative of real-life experiences.

Lastly, as mentioned in section 5.1.3, this study had a relatively small sample size. It was anticipated in the design-phase of the study that it would be challenging to recruit a large number of suitable participants due to the nature of forestry work which is often done in remote areas, with no suitable indoor location to complete the trial. Additionally, the scope of this research considered the requirements of a master's thesis of this size and the associated time constraint and so was designed as an exploratory study. Therefore, the sample size for the current study was deemed acceptable. Sample size has been noted as a limiting factor in this research area by others and one which reduces the quality of research (Yao et al., 2021). This exploratory study provides a solid base for future research where a larger sample size could allow for clearer results and enhanced quality.

5.6 Future work

There are several opportunities for future work in this area of research beyond those noted in the limitations section above. Expanding the current study, including an olfactory element, such as essential oils derived from trees while the participants are in the VR environment, could create an even more immersive environment and contribute to greater relaxation and stress reduction effects. As already discussed, many participants highlighted the smell of the forest as an important aspect of enjoyment and relaxation (4.4.3.2 and 5.2.4). In a recent study, Ascone et al. (2025) explored unimodal versus multimodal VR forest bathing using visual, auditory and olfactory stimuli on psychological responses of participants. Building on Ascone et al.'s (2025) research, the inclusion of the current study's methods using physiological biosensors alongside the inclusion of an olfactory stimulus would provide a greater understanding of the influence of olfactory experience on relaxation and stress reduction.

Some small changes to the study design could enhance results. In the current study, the baseline was recorded during the demographic questionnaire. In future research, it would be beneficial to have a baseline that includes the wearing of the VR headset in the same conditions as the experimental conditions. Another change that could be beneficial is implementing a stressor before viewing the VR environments. Including a stressor could improve the likelihood of seeing physiological changes as the participants would not be starting from an already relaxed state. This would also allow the researchers to investigate stress recovery in forestry workers which would be an extension to the work that already exists in this area, for example in university staff (Brown et al., 2013), healthy adults (Knaust et al., 2022a) and pregnant women (Sun et al., 2023).

There are opportunities to expand the 360-degree videos to other kinds of forests not used in the current study, such as Douglas fir or eucalyptus species. The interaction between forest characteristics and stress reduction is still not well understood and would benefit from further research with different forest scenes. A further option is to compare forests to other environments such as farmland, alpine and coastal areas. Forests and greenspace have been well studied but other environments, particularly outdoor work environments, have received less research attention (Bolouki et al., 2025). It is recommended that future 360-degree recordings use the Insta360 camera with 8K resolution to improve the quality in the VR headset and help improve the user experience.

A further research opportunity is to expand the sampling to include a third comparison group of students to represent a younger, technologically savvy demographic. This would provide more insights into the potential future workforce to help address the concerns around the aging forestry workforce. Further to this, virtual reality could be investigated as a recruitment tool for the forestry industry. 360-degree forest scenes could be used to explore perceptions of forestry as a career for potential recruits such as students, investigating if positive virtual reality experiences can influence perceptions of the forestry industry or intentions to start a career in forestry. Computer generated VR could also be explored for use as a recruitment tool due to its interactive nature, which may attract more interest from younger potential workers who generally have more experience with technology. The general acceptance of the VR headset in this study, outlined in section 5.3, provides evidence for the feasibility of its use in other contexts such as for training purposes.

5.7 Conclusions

This research explored the health benefits of forest environments for forestry workers, using biosensors to measure physiological stress and virtual reality to present 360-degree virtual forests. It focused on using rigorous methods to measure physiological indices, combined with qualitative semi-structured interviews to incorporate participant perceptions.

There was some evidence of increased parasympathetic nervous system activity in forestry workers compared to office workers, however, not all the physiological measures had significant results. Psychological results were stronger, showing clear differences in perceived relaxation between forestry and office workers, with participants' personal connections to the forest highlighted as a contributing factor.

Physiologically there were no significant differences between native, production and harvested 360-degree forest scene videos. Psychologically however, participants discussed a preference for the native environment in the interviews, with RSQ results reflecting this. Forestry participants relaxed in all the environments, possibly influenced by their familiarity and connection to these environments.

The findings from this study could have a positive impact on the forestry industry workforce, through improved perception of the career. Although the physiological stress benefits of forestry work need further research, the interview responses highlighted some of the other positives of working in forestry which are important to note such as working outdoors, identity and purpose associated with meaningful work, and the people and community within the industry.

Overall, these findings highlight the complexity of human physiology and nature interactions particularly when applied to a forestry work context. This study provides a platform for future research opportunities such as including olfactory stimuli, investigating different environments and expanding on the sampling characteristics such as increased sample size and inclusion of both genders.

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Appendices

Appendix 1: Literature search string

"nature exposure" AND (health OR restora* OR relax* OR "well being"), "natur* exposure" AND (health OR restora* OR "well being") AND (physiolog* OR psychophysiolog*), "nature exposure" AND (health OR restora* OR "well being") AND ("virtual" OR "virtual reality" OR vr), Biophilia AND (health OR restora* OR "well being") AND (physiolog* OR psychophysiolog* OR hrv OR "heart rate variability"), "Nature therapy" AND (health OR restora* OR "well being"), "New Zealand" AND (forestry OR logging) AND industry AND work*.

Appendix 2: Participant recruitment materials

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION | FOREST GROWERS RESEARCH | TE KUNENGA KI PŪREHUROA MASSEY UNIVERSITY UNIVERSITY OF NEW ZEALAND | TE KURA HAUORA TANGATA COLLEGE OF HEALTH

Volunteers Wanted!

Masters research project involving

VIRTUAL REALITY

Explore forest environments in a virtual reality setting

45 minutes to 1 hour of your time

$30 grocery voucher

CONTACT

[redacted]

for more information

Are you:

- A male over 18 years old with NO heart conditions?
- Taking no cardioactive medication?
- Working in a forest environment?

Appendix 3: Information sheet

Exploring physiological and well-being benefits of forest environments for forest harvesting workers, using virtual reality

PARTICIPANT INFORMATION SHEET

Researcher introduction

My name is Georgia Dickson, and I am a research technician at Scion, undertaking a Master of Health Science at Massey University. My student research project is exploring physiological and well-being benefits of forest environments, using virtual reality (VR).

Project summary

Nature and natural environments, even virtual, have been shown to provide a range of health benefits to humans. The purpose of this project is to use VR to compare forest scenes, along with measuring heart rate variability and skin conductance to understand certain physiological changes in the body when viewing forests.

You are invited to take part in the research project. This participant information sheet will help you decide if you'd like to take part. It sets out why we are doing the project, what your participation would involve, and what would happen after the project ends.

If you agree to take part in this project, you will be asked to sign the consent form. You will be emailed a copy of both the participant information sheet and the consent form to keep. Please make sure you have read and understood what the research involves and your rights as a participant.

Recruitment and selection criteria

We are looking for people who meet all four of the following criteria:

- Male participants over 18 years of age.
- Participants with no underlying heart conditions.
- Participants on no cardioactive medication (antidepressant, antihypertensive, antipsychotic).
- Participants who work in either forest harvesting or office-based work environments.

We are only asking men to participate due to significant differences between male and female heart rate variability measures.

To acknowledge the time taken for you to participate in the research, a koha of a $30 grocery voucher is offered.

What is involved?

VR allows you, the participant, to look around each forest environment in a controlled way while we capture the way your body automatically responds.

If you choose to participate you will answer a short questionnaire, then be required to wear the HTC Vive VR Headset (Figure 1) and view three 360-degree forest scenes for 5-minutes each. During this time, you will wear an Equivital monitor chest belt (Figure 2) that measures your breathing rate and electrocardiogram (ECG) to record the electrical activity of your heart. From this information we can gather heart rate information. You will also wear two electrodes on your palm to measure the sweat on your skin. Afterwards, there will be a short interview where I will ask you a few questions about the VR experience and nature, which will be audio recorded and later transcribed by myself. Around 1 hour of your time is needed.

Figure 1. The HTC Vive VR Headset

Figure 2. The Equivital monitor

The physiological measurements are not for medical purposes or medical advice. It is important to note that VR can cause motion sickness for some people.

Confidentiality

Your individual information will remain confidential to the researcher(s), and your name will not be linked to the final documentation. Participation or non-participation in this research will have no impact on your employment. The information collected may be included in a thesis, reports, presentations and publications associated with the Scion human factors program and Massey University.

All field notes, interview records and analysis workings will be held at a secure location on the Massey University OneDrive system and will only be available to project team members. Raw data will be stored for 5 years and then destroyed.

Participant Rights

Your participation in this project is entirely voluntary. You have the right to:

i. Decline to participate or to answer any particular question.
ii. Withdraw from the project at any time during your participation.
iii. Withdraw permission to use the information collected during the two-week period following your participation.
iv. Ask any questions about the project at any time during participation.
v. Provide information on the understanding that your name will not be used unless you give permission to the researcher.
vi. Ask for the recorder to be turned off at any time during the interview.
vii. Be given access to a summary of the project findings when it is concluded.

Contact

Thank you and if you have any questions about this research, or for further information, please contact:
Georgia Dickson | Mobile [redacted] | Email [redacted]
Dr Nicola Green | Email [redacted]

This project has been reviewed and approved by the Massey University Human Ethics Ohu Matatika 3, Application OM3 25/34. If you have any concerns about the conduct of this research, please contact the Chairperson, Massey University Human Ethics Ohu Matatika 3, email humanethics3@massey.ac.nz.

Appendix 4: Consent form

Exploring physiological and well-being benefits of forest environments for forestry workers, using virtual reality

PARTICIPANT CONSENT FORM

I have had the opportunity to read the participant information sheet for this Massey University and Scion research project and to discuss the project with the researcher.

I understand my rights as a participant and that my participation in this research project is confidential and that no material that could identify me will be used in any reports on this project.

Please tick each statement below if you would like to participate:

- ☐ I have been given a full explanation of this project and have had the opportunity to ask questions.
- ☐ I understand what is required of me if I agree to take part in the research.
- ☐ I understand that participation is voluntary, and I may withdraw at any time during the procedures and up to two weeks after.
- ☐ I agree to the interview being sound recorded.
- ☐ I understand that any information or opinions I provide will be kept confidential to the researcher and that any published or reported results will not identify me.
- ☐ I understand that all data collected for the project will be kept in secure facilities and/or in password protected electronic form.
- ☐ I understand that I can receive a report on the findings of the project.
- ☐ I understand that I can contact the researcher for further information.
- ☐ By signing below, I agree to participate in this research project.

Please circle:

I wish/do not wish to have the transcription of the interview returned to me to read and amend if necessary.

I wish/do not wish to receive a report of the findings of the project.

Signature ______________________ Date ____ / ____ / 2025

Name ______________________

Phone ______________________ Email: ______________________

This project has been reviewed and approved by the Massey University Human Ethics Ohu Matatika 3, Application OM3 25/34. If you have any concerns about the conduct of this research, please contact the Chairperson, Massey University Human Ethics Ohu Matatika 3, email humanethics3@massey.ac.nz

Appendix 5: Sensor belt instructions for participants

Connecting the sensor belt

Please connect the sensor belt under all shirts and singlets. It is essential that the three silver patches (electrodes) are always touching the skin.

1. Hold up the sensor belt with the electrodes facing towards the body.

2. Place the belt around the body with the clip at the front.

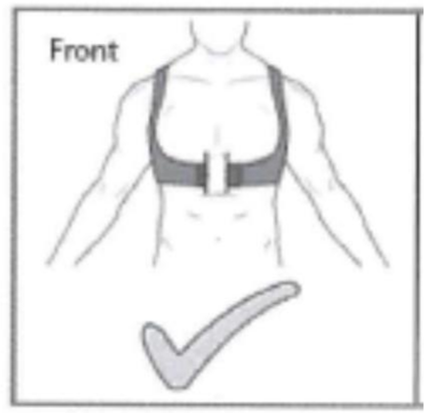
3. Place the straps over each shoulder.

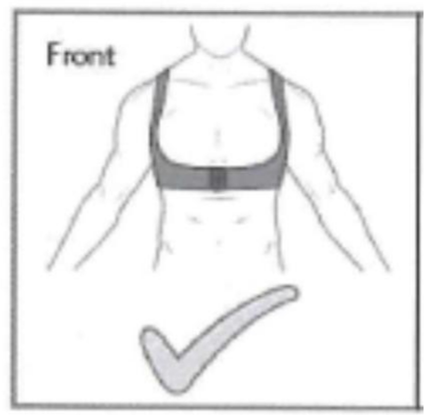
4. Connect the belt together at the front using the clip. Use the setting which feels most comfortable for you while also keeping the electrodes in contact with the skin.

5. The belt should be firmly contacting the body but not uncomfortable. You should be able to push your finger down between the belt and your body.

   Important: If the fit feels uncomfortable or too loose, please let Georgia or Brionny know so they can get you a different size.

6. If necessary, once the clip is connected, gently rotate the belt so the clip is sitting at the front of the body near the centre of the chest.





Appendix 6: Demographic questionnaire

Exploring physiological and well-being benefits of forest environments for forest harvesting workers, using virtual reality

This is a short questionnaire to find out a bit about you and your interactions with nature. All information collected will be treated confidentially and you will not be identified at any time.

I will read the question and the answers for you to choose from. If no answer feels right to you, please choose the one that feels closest.

Age:

❑ <20

❑20-29

❑ 30 –39

❑40-49

❑50-59

❑60-69

❑ 70+

Occupation:

Years of experience in forestry:

❑ 0

❑ <1

❑1-9

❑10-19

❑20-29

❑30+

Do you have any experience using virtual reality (VR) with a head-mounted display?

❑ No, never used before

❑ Yes, have used a few times

❑Yes, very familiar

Have you had any caffeine in the last 12 hours?
This could include coffee, energy drinks, soft drinks, caffeine supplements (No-Doz etc.)

❑ No

❑ Yes, less than 1 hour ago

❑ Yes, 1 – 6 hours ago

❑ Yes, 6+ hours ago

Have you had a cigarette or nicotine vape in the last 12 hours?

❑Yes

❑No

Have you had an alcoholic beverage in the last 24 hours?

❑Yes

❑No

Have you completed any vigorous physical activity in the last 24 hours?
Vigorous physical activity means you are breathing hard and fast, with an increased heart rate. Examples are running, cycling, swimming laps, lifting weights, sports

❑Yes

❑No

How often do you engage in moderate to vigorous physical activity?

❑Everyday

❑1-4 times a week

❑ Once a fortnight

❑ Once a month

❑Hardly ever

How often do you spend time in nature for recreation, work or other purposes?
Nature can include parks, forests, walking tracks, beaches

❑Everyday

❑1-4 times a week

❑ Once a fortnight

❑ Once a month

❑Hardly ever

Do you live in a rural or urban environment?

❑Rural

❑Urban

________________________________ ❑Other (please specify):

Appendix 7: Research outputs

The research premise, methods and preliminary results were presented at the Human Factors and Ergonomics Society New Zealand (HFESNZ) conference, Christchurch, October 2025. The title of the presentation was “Forests, health and virtual reality”.