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Exteroceptive influences on total mood disturbance and perceived stress during green exercise

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Dedication

I dedicate my thesis to my mum Maureen, my wife Tracey and my children

Sian, Abby, Chris, Charlie, Sammy, Alex and Amber.

Without your love and support I could never have done this, you are my

world xxx xxx

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To the people that participated in my research, thank you all so much.

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List of papers

This thesis comprises the following original papers

1. WOOLLER, J.-J., BARTON, J., GLADWELL, V. F. & MICKLEWRIGHT, D. 2015. Occlusion of sight, sound and smell during Green Exercise influences mood, perceived exertion and heart rate. International journal of environmental health research, 1-14.
2. WOOLLER, J. J., ROGERSON, M., BARTON, J., MICKLEWRIGHT, D. & GLADWELL, V. 2018. Can Simulated Green Exercise Improve Recovery From Acute Mental Stress? *Frontiers in Psychology,* 9.

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List of abbreviation

ANCOVA – Analysis of Covariance

ANOVA – Analysis of Variance

ART – Attention Restoration Theory

BMI – Body mass index

BP – Blood Pressure

EO – Essential Oils

EPPO – Estimated Peak Power Output

HR – Heart Rate

HRR – Heart Rate Reserve

MANOVA – Multivariate Analysis of Variance

PAR-Q – Physical Activity Readiness Questionnaire

PPO – Peak Power Output

PSS – Perceived Stress Scale

RPE – Rating of perceived exertion

SD – Standard deviation

TMD – Total Mood Disturbance

TSST – Trier Social Stress Test

Abstract

Exercise in a natural environment, termed green exercise, has repeatedly been shown through empirical research to be beneficial for psychological health. However, very little is known about the underlying cognitive mechanisms responsible for these benefits. Literature suggests that it may be an innate human connectedness to nature, and that natural environments do not require directed attention and therefore promote restoration. As the senses are used to interact with nature, this thesis set out to explore the relative contribution of sight, sound and smell to the green exercise effect. Chapter 2 found that, when presented with a choice of nature and urban images simultaneously, that participants preferred to view nature, particularly as exercise intensity increased. However, the images were not completely immersive for the participant. Therefore, a green lab was developed, described in Chapter 3, to enable the exploration of the senses of sight, sound and smell in relation to green exercise and psychological recovery. Results in Chapter 4 showed occlusion of sound had the largest detrimental effect on total mood disturbance, with smell and sight having little effect. Chapter 5 repeated Chapter 4 but addressed limitations with a modified protocol with sound removed (rather than occluded) and still reduced mood significantly. In Chapter 6, psychological stress was used to disturb mood prior to exposure to different sensory aspects of green exercise and the recovery after the stressor was explored. Results indicated that exercise with nature sounds, nature visual or exercise with both nature sounds and visual are better for recovery from an acute stressor than rest or exercise alone. Evidence provided in this thesis, highlights the contribution of the senses of sight and sound to green exercise psychological effects and the benefits of green exercise in recovery from acute psychological stress.

Chapter 1

Introduction

1.0 Introduction

1.1 Overview

The benefits of exercise to physiological and psychological health are well documented. Exercise has been shown to improve cardiovascular and respiratory fitness, help control body mass, both helping to lower excess body mass and maintain healthy mass (Swift et al., 2014, Swift et al., 2018). Additionally, improvements are noted in mental health and wellbeing (Biddle, 2016, Schuch et al., 2016, Stubbs et al., 2017).

There is an increasing body of empirical research that shows, being in/nearby or exercising, whilst in the presence of nature, commonly termed “Green Exercise” (Pretty et al., 2003) enhances psychological benefit further than exercise alone. Nature has long been considered beneficial to physiological and psychological health. In many cultures, past and present, a fondness for nature and behaviours reflecting this can be observed. Tomb paintings discovered in ancient Egypt, and remains found amongst the ruins of Pompeii, affirm that people brought plants into their home and gardens over 2000 years ago (Grinde and Patil, 2009). In Europe, the earliest hospitals were found in monastic communities where they used cloistered gardens, meadows and other natural elements as a part of the healing process, both physical and psychological (Marcus and Barnes, 1999, Gerlach-Spriggs et al., 2004, Grinde and Patil, 2009, Ward Thompson, 2011). Various theories have been developed and researched over the years, and these are described in this introduction.

1.2 Biophillia Hypothesis

The was introduced in 1984 (Wilson, 1984). The Biophillia Hypothesis suggests that through the evolutionary process, humans have an innate affiliation with nature and other forms of life. Wilson (1984) defines Biophillia as "the urge to affiliate with other forms of life". Due to it being only a recent event, in historical terms, that humans have lived in such large artificial urban environments, there has been little time for genetic adaptation (Wilson, 1984), therefore, humans seek nature and natural environments in order to recover from the stresses of daily life.

1.3 Stress Reduction Theory

Stress Reduction Theory, is based in emotional and physiological recovery from stress obtained by spending time in nature. Prolonged stress is detrimental to both physical and mental health by causing predictable biochemical, physiological and behavioural changes. It usually occurs when there is an imbalance between capability and demand. Stress Reduction Theory is centred around the belief that viewing or visiting natural environments, quickly promotes positive emotional reactions eliciting physiological recovery and relaxation after exposure to a stressful situation (Ulrich, 1983). It further suggests that humans are more biologically adapted to nature (having been in those settings throughout our evolutionary history) and that artificial environments, particularly built environment induces stress.

1.4 Attention Restoration Theory

Attention Restoration Theory is based in psychological recovery rather than physiological or emotional. Viewing nature can provide opportunities for restoration. It explains the beneficial effects of nature and green spaces on mental fatigue caused by the overuse of directed attention induced by artificial stimuli from modern life. Directed attention is when a stimulus needs to be attended to irrespective of whether it is interesting and despite the fact that it may lack fascination. In order to focus attention all distractions must be inhibited thereby protecting the attentional focus from competing stimuli (Kaplan, 1995). Directed attention requires effort and prolonged use of this inhibitory system therefore leads to mental fatigue and reduces a person's ability to operate at maximum capacity. In order to regain this capacity attention needs to be restored. According to ART, this needs to happen in an environment where directed attention is not necessary i.e. a restorative environment. In order for an environment to be restorative Kaplan (1995) states that it needs to fulfil four criteria, which come with brief explanations here, for more in depth explanations see Kaplan (1995):

1.Being away, freeing yourself from the situation that requires directed attention. This does not have to mean a physical change of place, it can refer to a change of gaze away from the situation such as going from looking at a computer screen to looking out of a window.

2.Extent, an environment must be coherent and rich enough that it constitutes a whole other world. It must be large enough to contain a multitude of experiences in order to occupy a substantial portion of the available space in a person's head.

3. Compatibility, there must be compatibility between the environment and the purposes for which a person intends to use it, for example if you intend to take a leisurely walk an environment full of obstacles that require climbing over or heavily brambled areas that are difficult to negotiate, will not fit the purpose for which you intend to use it.

4. Fascination, this is central to attention restoration theory, an environment high in fascination does not require directed attention, for example a walk in the country taking in the sights and sounds of nature requires no special attention or focus allowing directed attention to rest and providing the opportunity for quiet reflection. Kaplan (1995) has shown that natural environments are better for attention restoration than urban environments.

In order for attention restoration to be successful Berto (2005) postulates that all four of Kaplan's criteria are required. 'Non-environments', in this case geometric patterns, did not require directed attention to view but they do not contain all four of

Kaplan's criteria and it was found that attentional capacity was not found to be restored by them (Berto, 2005).

A number of studies have been conducted into the area of attention restoration using both rural/urban and high/low fascination environments with results supporting Kaplan's attention restoration theory, these include: Berto (2005), Felsten (2009), Berto et al. (2010), Cole and Hall (2010). As well as restoring attention in the general population, natural environments have also been found to enhance the attention of children with ADHD (Taylor and Kuo, 2009).

Research by Berto et al. (2008) supports Kaplan's (1995) fascination theory. Berto et al. (2008) tested the fascination theory with an eye tracking study. During the study, participants visual fixations were recorded whilst looking at photographs of natural and urban landscapes. The results showed that participants fixated for longer periods whilst focusing on photographs of urban landscapes than they did on natural.

From these results (Berto et al., 2008) concluded that more directed attention was required to view low fascination urban landscapes. From a cognitive view point, one explanation for not requiring as much directed attention when viewing natural landscapes compared to viewing urban landscapes is edge recognition. It is well documented that human beings can identify objects in milliseconds (ms) by shape without the use of colour or surface texture (Biederman and Ju, 1988). With that in mind it is reasonable to assume, that, this is why directed attention is not required whilst viewing a natural landscape. Throughout the world a tree is a tree and recognizable as such regardless of colour, which is not limited to greens of varying shade depending on variety, but can be brown and red also. Again, depending on the species and the season, with summer green turning to autumn brown and orange, to no foliage at all in winter. Even silhouetted on a hillside or on a moonlit night a tree can be identified by its shape almost instantly, therefore requiring little if no directed attention. Nature is abundant with fascinating objects, Kaplan (1995) described some of these fascinations as "soft fascinations" Items that readily hold attention but in an undramatic way. Objects such as leaves blowing in the breeze, sunsets, clouds and snow patterns. Viewing these patterns is effortless and thus affords ample opportunity to think about other things (Kaplan, 1995).

In contrast, according to Berto et al. (2008) buildings and urban landscapes are low in fascination and also require directed attention for which a number of explanations could be considered. Industrial and urban areas (particularly modern and highly urban estates) tend to have large numbers of buildings that are the same or similar in design, size, shape, colour etc. It could therefore be assumed that greater attention is paid to them in searching for identifiable markings to distinguish them from other surrounding buildings. Another reason could be assigned to fear of crime (Crosby and Hermens, 2018) causing individuals to be more aware of their surroundings. Areas of high unemployment and depravation tend to be littered with graffiti, broken glass, abandoned vehicles and household appliances etc. Therefore, it would be reasonable to assume that, whilst in this type of landscape, which tend to be busy places with lots going on, an individual would be using a large amount of directed attention looking for potential danger such as cars when crossing the road, obstacles to avoid such as signs, bins, uneven pavements and other people, all whilst attending to the intended purpose of their trip.

The use of edge recognition is again prevalent, but, whereas in nature nothing is uniform or straight, in an urban landscape the structure is almost all straight line and hard angles, requiring focus to organise and identify component features of the image in an individual's head separating it from other distractors. Here the use of surface, texture and colour would be prevalent in identifying objects further. For example, when looking for a red car in a car park full of vehicles, it would be more efficient to look for the car by colour than component shapes. There will likely be only a few red cars, whereas nearly all the cars will have sections of similar contours (Biederman and Ju, 1988).

Some researchers have explained the relationship between natural environments and physical activity using pre-existing psychological theories. The Ecological Dynamics is the integrated framework of dynamical systems theory and ecological psychology, with three significant features for the understanding of green physical activity: emergence of behaviours from multiple subsystems, affordances and interacting constraints (Yeh et al., 2015). Ecological dynamics suggests that constraints are related to the environment or each individual task, which interact to shape behaviours, including emotions, actions, perceptions and cognitions (Brymer et al., 2014).

Individuals perceive affordances (behavioural opportunities) directly from their surroundings and thus pick up opportunities or invitations for behaviours based on the environment. (Yeh et al., 2015). It is likely within natural settings there will be more physical activity (i.e. it helps shape behaviour) but physical activity may also enable people to experience nature more (i.e. hikes in the Lake District).

Although the research explained so far is psychology in basis, it does not attempt to explain what mechanisms are responsible for these enhanced effects of nature both at rest and when combined with physical activity. Therefore, the purpose of this thesis is to address this gap in the research and explore some of the underlying exteroceptive factors present in nature that generate alterations in psychology enhancing mood and stress during “Green Exercise”.

1.5 Green Exercise

Exercising in the presence of nature has been termed “Green Exercise” by Pretty et al. (2003). Green exercise can be broken down into three levels of engagement (Pretty, 2004, Pretty et al., 2005a):

Level 1 - Viewing nature, such as looking through a window, a book or on television.

Level 2 - Being in the presence of nearby nature, or incidental exposure, such as that that may be experienced by walking or cycling to a destination, reading in the garden or socialising with friends in the park.

Level 3 – Active participation and involvement with nature, or purposeful exposure, such as gardening, mountain biking, cross country/fell running, hiking, forestry and camping (Pretty, 2004, Pretty et al., 2005a).

1.6 Viewing Nature

This method is a very easy way for researchers to control the environment within which a study takes place, both in the laboratory and in the real world. In the laboratory confounding variables such as weather, time of day, climate and seasonal changes which include foliage colour and coverage and sky colour. By standardising environmental conditions in the laboratory researchers are able to conduct studies year-round, and avoid logistical problems such as getting participants together on days that are 'just right' and expose every participant to the exact same set of variables every time. Studies using this method include: (Akers et al., 2012, Annerstedt et al., 2013, Brown et al., 2013).

Viewing rural pleasant scenes whilst exercising in a laboratory, was found to have a greater positive effect on self-esteem and a greater reduction in blood pressure than exercise alone (Pretty et al., 2005a). Views from windows has also been investigated. Kaplan (2001) found that the presence of nature in a view from a window contributed substantially to the residents' satisfaction with their neighbourhood. Further, after reviewing and analysing hospital records of patients recovering from cholecystectomy, a common type of gall bladder surgery, at a single hospital Ulrich (1984), found that patients with a view of nature from their window, spent less time recovering in hospital after surgery, took less moderate to strong painkillers and had fewer negative evaluative comments in their nurses notes compared to those who had the view of a brick wall from their window. In order to minimalize seasonal effect (Ulrich (1984), only used data for patients that had stayed in hospital between the dates of 1st May and 20th October when the trees still had foliage on them. Within these dates, the colours that were present in the view would have been chiefly green and blue. These are high frequency colours which are associated with relaxation and calm. It would have been interesting to know how these results compared with results from the rest of the year, to see if the colours presented in nature at these times had the same effect. This may help to ascertain whether the colour was an important factor, although there would be other confounding factors including sunlight, weather, and the changed view (e.g. no leaves on trees).Similar positive effects were found in a study conducted by Diette et al. (2003). The use of nature in this study differed from Ulrich (1984), in that patients did not have a window to look out of. Instead, as part of distraction therapy Diette et al. (2003), used a poster of a natural environment, again primarily blue and green in colour, and played nature sounds through headphones, which the patients controlled the volume of,. They found that patients undergoing a flexible bronchoscopy procedure, experienced a significant reduction in pain when exposed to a view and the sounds of nature, compared to those who did not. This study again raises the question of, the colour of the image verses the content of the image, and whether nature sounds enhanced the effects induced by the visual image. Diette et al. (2003) did not separate the data collection groups into vision only, sound only and vision and sound combined leaving this question unanswered.

1.7 In the Presence of Nearby Nature (incidental exposure).

One area that studies into exposure to nearby nature has been used for, is to look at how urban areas are constructed; how much green/natural space is available to individuals, such as parks, community gardens and allotments, as they go about their daily routine, and what effect these spaces, or lack of, have on their wellbeing. Mitchell and Popham (2008) found that, in areas of income related inequalities, exposure to greener environments significantly reduced income deprivation mortality in all cases, except lung cancer and intentional self-harm. However, These data did not indicate any interaction with green space just the amount that was present. Ward Thompson et al. (2012), furthered this in an area of Scotland that had high areas of deprivation.

Using measurements of salivary cortisol (increased levels of which are associated with elevated stress levels), and self-reported measures of stress and general wellbeing, they found that, increased exposure to green space led to reduced stress in deprived communities. These conclusions are further supported by a later study (Ward Thompson et al. (2016)) where the amount green space within the neighbourhood were significant predictors of stress. Additionally (Wood et al. (2017)) demonstrated that adequate provision of green space in local neighbourhoods that was within walking distance, is important for positive mental health.

The results from all of these studies can be used by local and central government with planning and policy review. By using the results from studies such as these, planning departments can ensure adequate provision of green space in new developments and the development of useable green spaces within existing developments by the regeneration of wasteland to publicly accessible parks and allotments.

1.8 Active participation and involvement with nature (Purposeful Exposure)

Purposeful exposure to nature, encompasses a wide variety of exercise formats that can be used in studies. However, there are a number of confounding variables present which include (but are not restricted to): seasonal differences, changes in the weather and differences in the terrain between test areas, all of which, have to be taken into account when analysing data. Despite problems that arise due to confounding variables, field studies are important as they add ecological validity.

Much research has been conducted using a myriad of different exercise modes. Walking, which can be considered the most basic of exercise modes, has been used in a number of studies. It requires no specialist equipment and can be performed by both the young and the elderly who, despite being in good general health, may not be able participate in more vigorous activities such as running or cycling. Outside walking has been associated with improved mood in postmenopausal women whereas walking indoors was not (Teas et al., 2007). However, a limitation is that during the indoor walking condition a typical gym environment was recreated that had hard rock music playing at a decibel level comparable with that of a typical commercial gym exercise area (Teas et al., 2007). This genre of music may not have appealed to the women used in this study, and therefore could have had a suppressive or negative effect on mood.

A study that purely focused on walking outdoors in areas of high natural and heritage value, was conducted by Barton et al. (2009). Although visitors to the green spaces being used, already had initial high self-esteem, there was still a significant improvement to self-esteem scores after visitors had completed their walk. Interestingly, although there was still an improvement to self-esteem scores, it was found that longer stays were not associated with improved self-esteem. This suggests that short stays are as beneficial as longer visits (Barton et al., 2009). Both of the above studies show that walking, as a low intensity exercise, outside improves self-esteem and mood.

Gardening/allotment gardening, compared to walking, is a low to medium intensity activity that has been receiving a lot of attention. Studies have been conducted all over the globe (Armstrong, 2000, Milligan et al., 2004, Wakefield et al., 2007, Van den Berg et al., 2010, Wood et al., 2016, Soga et al., 2017a, Soga et al., 2017b, Martens et al., 2018). These studies looked at allotment and community gardens in a variety of settings. In all cases, benefits to health and well-being, both physiological and psychological were found. These results indicate that allotments and community gardens could play an important role in promoting health and preventing illness.

Higher intensity exercise modes have also been studied, for example, running is the preferred choice of exercise for numerous individuals looking to improve their health and physical fitness (LaCaille et al., 2004). As a mode of exercise running can be performed easily both indoors and outdoors via treadmills, running tracks (indoor and outdoor) or simply running through the streets or local green spaces. It has, however, been shown through research that there are psychological differences between running on a treadmill indoors, compared to running outdoors (LaCaille et al., 2004, Wooller, 2011). In both of these studies it was found that, although performance time was slower on the treadmill, participants' rate of perceived exertion (RPE) was higher compared with outdoor running. LaCaille et al. (2004) attributed this effect to treadmill running being less engaging or varied compared to outdoor running. Therefore, participants may have needed to make minimal adjustments to account for external and environmental conditions, allowing them to pay greater attention to negative internal sensations. In addition to lower RPE, outdoor runners had the highest levels of positive engagement, course satisfaction, revitalization and tranquillity (LaCaille et al., 2004).

Other studies that have been conducted look at multiple green exercise disciplines that are both low and high intensity with varying degrees of intensity and location. Two such studies were conducted by Mackay and Neill (2010) and Pretty et al. (2007). Mackay and Neill (2010) looked at how green exercise effected state anxiety. They analysed results from eight different green exercise disciplines: road cycling, mountain biking, mountain running, cross country running, orienteering, walking, kayaking and boxercise. Their results showed that Participants' state anxiety was significantly reduced by green exercise (Mackay and Neill, 2010). These findings strengthen the research that had previously been conducted by Pretty et al. (2007) by showing that green exercise is beneficial to psychological well-being. This study looked at the effect, that seven green exercise disciplines, conducted at ten different locations, had on health and psychological well-being and implications for policy and planning. As with the Mackay and Neill (2010) study, a diverse range of exercise disciplines were used: walking, cycling, conservation work (digging, scrub clearing) horse riding, boating, woodland activities and fishing. The results showed significant improvements in both self-esteem and total mood disturbance, with post activity improvements in anger-hostility, tension-anxiety, confusion-bewilderment and depression-dejection. The results also showed that the type, intensity and duration of green exercise had no effect on self-esteem and total mood disturbance, which suggests that any form of exercise in nature for any duration at any intensity is beneficial to psychological well-being (Pretty et al., 2007).

Shinrin-yoku (taking in the forest atmosphere or forest bathing) is a form of green exercise used in Japan. It involves taking walks out into forest environments for relaxation and stress reduction (Tsunetsugu et al., 2010). In these studies as well as the benefits of exercise the authors have looked at how volatile compounds called phytoncides, antimicrobial volatile organic compounds which stem from trees and found in forest air (Li, 2010) effect physiological responses and promote well-being. Physiological responses include increased natural killer cell (NK) activity (Li, 2010) which is part of the human immune system, and reductions in cortisol, pulse rate and blood pressure and greater parasympathetic nerve activity and lower sympathetic nerve activity (Park et al., 2010).

1.9 The Positive Effects of Green Exercise

The evidence reviewed here, overwhelmingly supports the premise that exposure to nature, either through viewing, being in the presence of or actively engaging with it, has a positive effect on the human physiological and psychological response, or at least within an adult population, however, precise mechanisms behind this beneficial effect are yet to be identified (Diette et al., 2003, Wood et al., 2012).

Despite the evidence outlining the positive effects of Green Exercise on psychological function, there is no explanation as to why this happens. One explanation is the Biophilia Hypothesis which describes humans as having an innate connection with nature (Wilson, 1984) however the work to date gives no empirical evidence to support the hypothesis. Another approach which is under-researched in relation to green exercise is cognitive psychology I.e. what are the cognitive mechanisms responsible for green exercise effect. Data needs to be collected in regards to individuals use of experience and the senses in a green environment to highlight the mechanisms involved in green exercise effect.

A recent study in the UK, looked at the effect of colour as an underlying cognitive mechanism of green exercise, specifically the manipulation of green colour, and showed that increased greenness in a video depicting a route through a natural environment lead to lower total mood disturbance and perceived exertion, compared to the same video viewed in red or grey (Akers et al., 2012).

This was the only study found that showed colour as a factor in green exercise outcomes. However, in this authors opinion, the results of this study have to be reviewed with caution. The green condition was a normal view of nature, therefore although green was the majority colour it was not the only colour on display, whereas the other two conditions were completely red and completely greyscale. Furthermore, the green condition was more “natural” requiring less directed attention. See above section 1.4 for more comments on this. Therefore, it is still not entirely clear whether the psychological benefits attributed to this research are a result of a natural image or the green within it. If this method was to be repeated it may well be worth filtering the video in green to match the red and greyscale condition and have the natural condition as a control. Alternatively, to make a study purely about nature and colour, using video of different seasons would be appropriate with spring and summer footage covering high frequency greens and blues, autumn footage would cover low frequency browns, oranges and reds and winter footage with snow coverage would be achromatic neutral colours of grey and white. The Akers et al. (2012) study is however, the first step to understanding underlying cognitive mechanisms involved in green exercise.

1.10 Exteroceptive Influences

Current literature shows there is a reasonable body of evidence to support advanced psychological outcomes for green exercise effect. However, although therapeutic effects appear to occur we have yet to understand why and this raises a number of questions. Is there a relationship between the dose of green exercise and an effect on mood and stress? What effect does green exercise have compared with exercise alone? How much of a part do the individual senses play in green exercise effect? Is viewing nature enough or do the other senses further enhance the effects of green exercise? Does environmental preference have an effect? It has been shown, that, by exposing an individual to a variety of environments, various positive outcomes will be seen. What is not understood is how green exercise effect varies between individuals and how it varies between environmental characteristics and, ultimately, what the mechanisms are, that are responsible for theses outcomes, (figure 1). Humans interact with their environment through the visual, auditory, olfactory and tactile senses. How much each of these senses contributes to an individual's ability to interact and interpret their environment is not known, but, there is a considerable amount of literature covering how the individual senses work. This will not be covered in detail, but a brief overview is given for the purposes of this thesis.

1.11 Visual Perception

Visual perception allows us the freedom to move around freely, read, watch movies, see the faces of those we are interacting with, keep us safe when we are crossing the road by allowing us to judge the distance of the oncoming traffic and a multitude of other tasks that, for all intents and purposes, are taken for granted (Eysenck and Keane, 2010). Although visual perception appears simple and effortless, in fact, it is highly complex with multiple processes involved in transforming and interpreting sensory information. It should therefore be of no surprise that, far more of the cortex is devoted to vision (especially the occipital lobes) than any other sensory system (Eysenck and Keane, 2010).

For the purposes of this thesis, only a basic understanding of the processes involved are required and are as follows:

Light enters the eye through the cornea and passes onto the iris (the iris gives the eye its distinctive colour). The amount of light entering the eye is controlled by the pupil. The lens then focuses the light onto the retina which are situated at the back of the eye. The lens works to focus the image on the retina. The retina contains 2 types of visual receptor, rods and cones. There are 6 million cones which are used for sharpness and colour vision. There are 125 million rods which are used for vision in dim light and movement detection. Once these processes are complete the visual information then passes on to the cortex via the retina-geniculate-striate pathway (Eysenck and Keane, 2010).

1.12 Colour

There is colour information in all visual stimulus processed by the human perceptual system and humans react in an appropriate manner to colour stimuli according to the situation that colours are presented in (Elliot and Maier, 2007). For example, red, depending on the context in which it is viewed, can elicit a variety of behavioural responses, in a situation involving traffic lights or lights on a level crossing red represents danger and stop, therefore red is associated with avoidance behaviour (Elliot et al., 2009). In a relationship context red has been associated with love, which can be visually represented by red hearts on a Valentine’s Day card and red roses, passion and sexuality all of which can be associated with approach behaviour (Elliot and Maier, 2007, Meier et al., 2012, Kaya and Epps, 2004). Although these examples are completely different responses to the same colour, red in both instances is stimulating which corresponds to known information about the visual colour spectrum where low frequency colours such as red, oranges and yellow (see Fig.1.1) are reported as being stimulating and high frequency colours such as green, blue and purple are said to be calming (Ballast, 2002). In contrast to this reds and oranges can also be regarded as instilling feelings of happiness and pleasure when viewed as a sunset (Doherty et al., 2010), feelings which can be associated with a sense of calm. Many colours, both low and high frequency have been associated with nature when

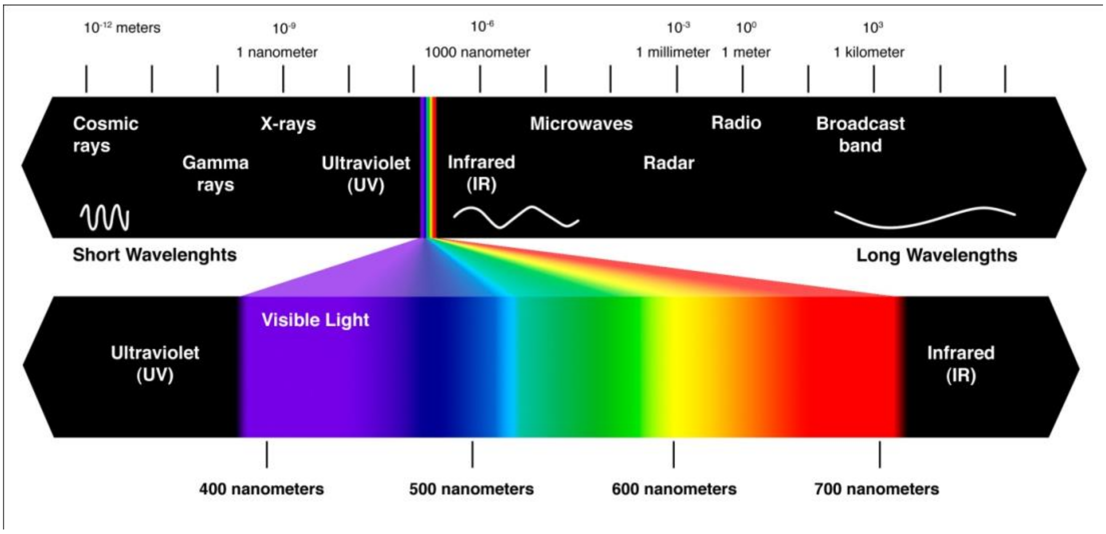


Figure 1.1 The visual colour spectrum. Long wavelength/low frequency colours have a stimulating effect whereas short wavelength/high frequency colours have a calming effect.

viewed in experimental conditions, and had both positive and negative emotional responses. Yellow was said to make people feel happy because it was associated with flowers, summer time and the sun, yellow-red with autumn, green was seen as calming and relaxing whilst being associated with nature and trees, blue-green the sky and ocean (Kaya and Epps,2004). Increased greenness of the environment whilst

exercising reduces total mood disturbance (TMD) and rate of perceived exertion (RPE) (Akers et al., 2012). Exposure to green also enhances creativity (Lichtenfeld et al., 2012). Even achromatic colours had associations with nature, grey was seen to be an emotional negative as it elicited feelings of sadness, depression and boredom as it reminded people of bad weather, rainy, cloudy and foggy days whereas white made people think of snow and doves (Kaya and Epps, 2004). Beneficial effects of nature are not just associated with visual responses, the auditory and olfactory senses have also been shown to play their part.

1.13 Auditory Perception

Hearing is the term used to describe the perception of sound, and is used for both communication and signalling danger. Human hearing is extremely sensitive with a dynamic range of 150db and able to detect sounds within a range of 20 and 20,000 Hz (Ling and Catling, 2012).

In order to hear sounds they have to be received in the receptors, converted into electrical signals and processed to indicate information such as volume, pitch and location. This is accomplished by sounds passing in through the outer ear, into the middle ear, on to the inner ear and finally to the auditory pathways. For a more in depth explanation see Ling and Catling (2012).

1.14 Natural Sounds

Studies into the effects of nature based sounds have covered a variety of areas and produced positive results. When played to patients under mechanical ventilator support, it was found that nature based sounds decreased environmental stimulation, thus reducing anxiety and physiological signs of stress. Promoting relaxation and therefore creating a reduction in potentially harmful physiological changes that stem from anxiety. Physiological measurements of heart rate, respiratory rate and blood pressure were taken immediately prior to the intervention, at the 30th, 60th and 90th minute during and 30 minutes post intervention. Agitation and anxiety levels were assessed using the Richmond Agitation Sedation Scale and the Faces Anxiety Scale respectively (Saadatmand et al., 2012). As reported previously, Diette et al. (2003), found pain was significantly reduced in a group of patients undergoing a flexible bronchoscopy procedure when they were exposed to sights and sounds of nature, compared to a control group who were not. A recent study conducted by Alvarsson et al. (2010a) suggests that recovery from sympathetic nervous system arousal is affected by type of sound, and recovery was faster when exposed to nature sounds when compared to the sounds of noisy environments. Alvarsson et al. (2010a) suggest that the mechanisms underlying the faster recovery could be due to positive emotions aroused by nature sounds, as had been previously suggested by Fredrickson et al. (2000).

From an environmental perspective, the use of nature based sounds to mask unwanted sounds in urban environments such as parks has attracted scholarly interest (Coensel et al., 2011). Research suggests that by adding a pleasant water sound to an environment dominated by road traffic noise the overall pleasantness of the environment may increase (Rådsten-Ekman, 2010). Research conducted by Coensel et al. (2011) also found that adding a water sound, in this case a fountain, may reduce the loudness of road traffic noise in soundscapes dominated by such. However, it must be noted that significant results were only found for freeway and major road traffic noise or those cases where the traffic noise had a low temporal variability.

Although there are only a few examples shown here, it would seem never the less, that experimental results are positive for environments that include nature based sounds, both medically and aesthetically, and that this area of exposure to nature warrants further investigation in relation to psychological wellbeing.

1.15 Olfactory Perception

According to Ling and Catling (2012) what we are able to smell comes in 3 detectable classes of odours:

1. Volatile – these must be able to evaporate easily at normal temperatures, this enables the molecules of a given substance to be carried through the air such as those studied by Li (2010) & Park et al. (2007).
2. Water Soluble – are required to pass through mucus in the nasal cavity in order to reach the olfactory cells.

3. Lipid-Soluble – olfactory hairs are made up primarily of lipids, there are also lipids contained within the surface of the olfactory cells (Ling and Catling, 2012).

1.16 Natural Smells

Despite the fact that there are enormous differences in human olfactory perception between individuals, with large variations being reported in the pleasantness and intensity of a given odour (Keller et al., 2007), there has been a large amount of research that focuses on human responses to natural odours with positive results. Plants produce volatile compounds called phytoncides which are olfaction related elements of a forest environment within which trees have species-specific scents (Tsunetsugu et al., 2010). The scent from wood chips made from the Japanese cedar tree has been shown to significantly reduce systolic blood pressure (Miyazaki et al., 1999). Itai et al. (2000) studied the effect of Hiba tree oil and lavender on mood and anxiety in female patients being treated with chronic haemodialysis. Aromatherapy effects were measured using the Hamilton rating scale for anxiety (HAMA) and the Hamilton rating scale for depression (HAMD). Results showed that lavender aroma significantly reduced mean scores for HAMA and Hiba oil aroma significantly decreased mean scores for both HAMA and HAMD (Itai et al., 2000). Ambient odours of lavender and orange were used in a study of mood and anxiety in dental patients waiting for a procedure. Analysis of results showed that waiting patients exposed to ambient odours of lavender and orange had improved mood and reduced anxiety compared to a control group (Lehrner et al., 2005).

These few studies show that natural aromas are beneficial to physiological and psychological wellbeing, even though olfactory responses to aroma are perceived differently between individuals there seems to be little if any effect on the overall outcomes.

1.17 Conclusions

Natural environments and environments enhanced by nature, have been shown to restore attention (Berto, 2005, Berto et al., 2010, Felsten, 2009, Hartig et al., 2003, Kaplan, 1995, Raanaas et al., 2011), reduce stress (Ulrich, 1983, Ward Thompson et al., 2016, Ward Thompson et al., 2012) and improve mood (Barton et al., 2012, Barton et al., 2009, Brown et al., 2013, Pretty et al., 2005a).

It is well established that exercise is good for both physiological and psychological wellbeing. It is also well documented that Green exercise is more beneficial to psychological wellbeing than exercise alone (Barton et al., 2012, Barton et al., 2009, Barton and Pretty, 2010, Pretty, 2004, Pretty et al., 2003, Pretty et al., 2005b, Pretty et al., 2007, Pretty et al., 2005a). What is not clear however, are the mechanisms behind this increased benefit. The purpose of this thesis is to address the gaps in the literature that relate to the underlying exteroceptive influences of green exercise.

1.18 Research Questions

1. Whilst exercising at varying intensities, what will individuals choose to look at when presented with a choice of a Nature or urban environment?

2. Which of the senses of sight, sound and smell will have the greatest influence on mood, in relation to the green exercise?

3. When exposed to a stressor, which sense or combination of senses will have the greatest restorative effect?

4. Will exercise alone have the same restorative effect as green exercise?

For the purposes of this thesis the authors definition of nature and urban can be found in table 1.1.

Table 1.1 Definition of nature and urban.

Term	Definition
Nature	Natural elements such as: Plants, flowers, trees, grass, hedgerows, rivers, lakes. Products of the earth, not man made.
Urban	An environment containing high levels of man-made elements such as: housing estates, town centers, offices, vehicles and no or limited natural elements.

Chapter 2

What to look at?

Visual Choices Made During Exercise of Varying Intensities.

2.1 Introduction

Environment can be classified into two categories, nature and urban (see Chapter 1). The restorative properties of each has been the subject of previous literature (Kaplan, 1995, Hartig et al., 2003, Berto, 2005). In order for an environment to be restorative, Kaplan (1995) posits that it needs to fulfil four criteria, see chapter 1. Berto (2005) conducted a series of experiments looking at how restorative and non-restorative environments facilitate attention restoration. Experiment 1 used a series of images of environments which were natural, built, and a mix of the two and had been rated for their restorative qualities. In this experiment Berto (2005) found only those that had been exposed to a restorative environment regained attentional capacity. Directed attention is due to the amount of focus required. A restorative environment facilitates recovery as it does not require directed attention (Kaplan, 1995). Berto (2005) second experiment used geometric patterns, which were considered effortless to view and should therefore facilitate attention restoration after. They compared these results with the results of experiment 1, where they used restorative and non-restorative environments and found that although attention was effortless the geometric patterns were not restorative (Berto, 2005).

A preference for viewing nature scenes over urban has been shown by Franěk et al. (2018). They investigated the differences in eye movements across nature scenes and two categories of urban scenes, ordinary urban and scenic images of old cities, in relation to attention restoration theory (Kaplan, 1995). Franěk et al. (2018) found that there were lower eye movements while viewing nature scenes requiring less cognitive effort. Less cognitive effort has been supposed to be one of the contributing factors of psychological restoration (Franěk et al., 2018). This is in line with the findings of Berto et al. (2008) where they showed that eye movements were lower across high fascination environments and that these findings suggest that viewing nature scenes requires less effort (Berto et al., 2008). Building on these findings Valtchanov and Ellard (2015) investigated the influence of low-level visual properties on scene preference, eye movements and cognitive load. Results supported previous findings for a preference of nature images over urban cities (Valtchanov and Ellard, 2015) Other studies have also compared the effects of nature and urban environment images when combined with exercise (see Chapter 1 and (Brown et al., 2013, Berto et al., 2010). However, none of these studies have offered a choice of view simultaneously. To explore green exercise to a greater extent, the current study was set-up to identify, if given a choice, would an individual choose to look at a natural scene over an urban one. Furthermore, would exercise intensity alter the choices made. To do this the following information was analysed:

1. The amount of times a nature or urban element was looked at – Frequency
2. How long nature or urban was looked at – Duration
3. What was looked at first nature or urban – Primary Gaze

It was important to look at all of these elements and compare them to one and other to get as complete a picture as possible. For example, it may be that urban was looked at for the longest time – Duration but nature was looked at the most times – Frequency and first – Primary Gaze. Which is likely to mean in this instance that although the most time was spent looking at urban, the preference was for nature as it was looked at first and the most times.

To address this gap in the current literature the following research questions were presented:

1a. If there is a choice of nature and urban images whilst at rest, what do participants spend the most total time looking at?

1b. Does this change with exercise intensity?

2a. If there is a choice of nature and urban images whilst at rest, what do participants look at most frequently?

2b. Does this change with exercise intensity?

3a. Is a participant’s primary gaze at a nature or urban image?

3b. Does this change with exercise intensity?

It was hypothesised that:

1. Participants will choose to look at nature elements over Urban.
2. This preference for nature will increase with exercise intensity.

2.2 Methods

2.2.1 Participants

Eleven healthy participants (9 males and 1 female) were recruited for this study. Only healthy individuals free from chronic conditions, illness and injury were used for the study and this was verified by use of a physical activity readiness questionnaire. Age, height, mass and body mass of participants were: 20.3 ± 1.2 years, 182.3 ± 7.5 cm, 74.6 ± 9.7 kg and 22.4 ± 2.3 $kg.m^2$. (Male: 20.2 ± 1.2 years, 182.4 ± 8.1 cm, 76.9 ± 7.5 kg and 23.1 ± 1.5 $kg.m^2$; Female: 21 ± 0 years, 181 ± 0 cm, 58 ± 0 kg and 17.7 ± 0 $kg.m^2$) Written informed consent was provided by all participants and the study and its associated procedures were approved by the University of Essex ethics committee.

2.2.2 Design

A within-subjects experimental design was used for this study. Participants were only required to attend the laboratory on one occasion. Testing was conducted in a quiet laboratory, standard methods of climate control using air conditioning were used to maintain a temperature of 20°C in the laboratory at all times. Only ambient background noise from air conditioning and the cycle ergometer, were audible during testing.

The visual condition was presented to the participants in the form of still images of both nature and urban environments. The images were presented simultaneously side by side with a white gap separating them (Figure 1.1). The visual images were presented during three exercise conditions at different intensities: Rest, 35% Heart Rate Reserve (HRR) and 70% HRR. HRR was calculated using the Karvonen formula:

Exercise Heart Rate (HR) = % of target intensity $(HR_{Max} - HR_{Rest}) + HR_{Rest}$

In order to keep laboratory visits to one, true max HR was not used, instead the method of 220 – age was used to predict max HR. Therefore, all % HRR figures are predicted. Condition orders were randomised to prevent any order effects.

2.2.3 Laboratory Set Up

The image was projected from an Epson EH – TW450 HD ready projector (Epson (UK) Ltd. Hemel Hempstead, Hertfordshire, UK) positioned 240cm above the participants head in such a way that they did not cast a shadow onto the screen and 300cm from the screen. The screen itself was freestanding and positioned 96 cm in front of the cycle ergometer. This placed the participant at an approximate distance of 150 cm from the screen see Figure 2.1. Using this set-up, the image size produced was 175 cm x 106 cm which included a 10cm white gap in the centre of the two images. The bottom of the image sat at a height of 126 cm from the ground see Figure 2.2.

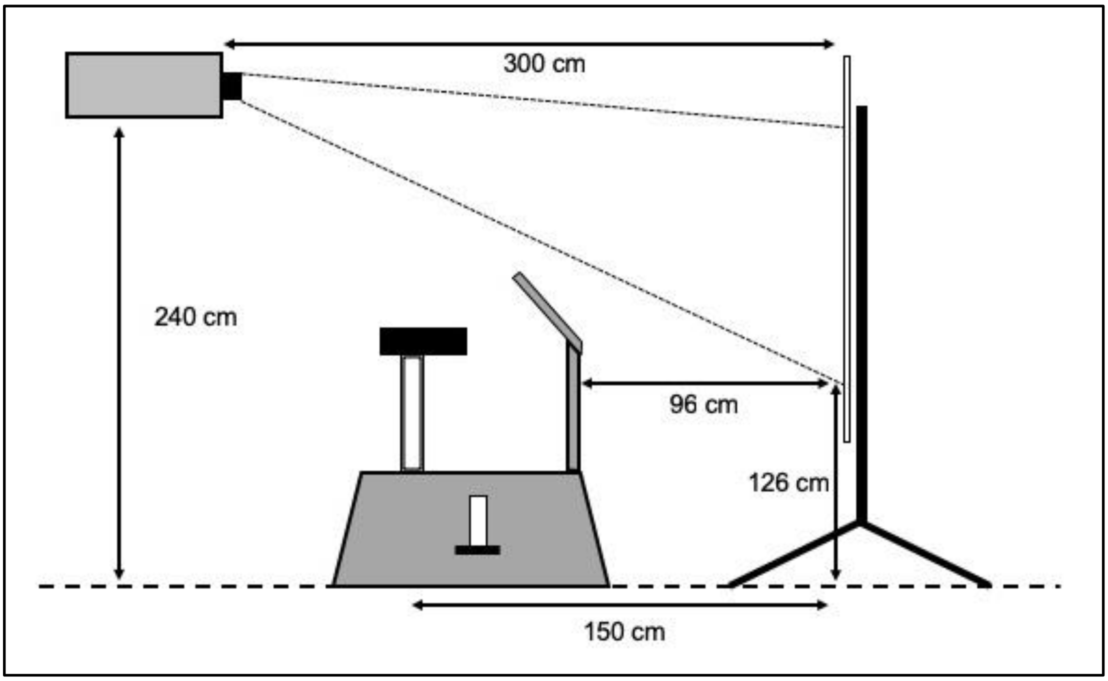


Figure 2.1 Laboratory set up with dimensions, side view.

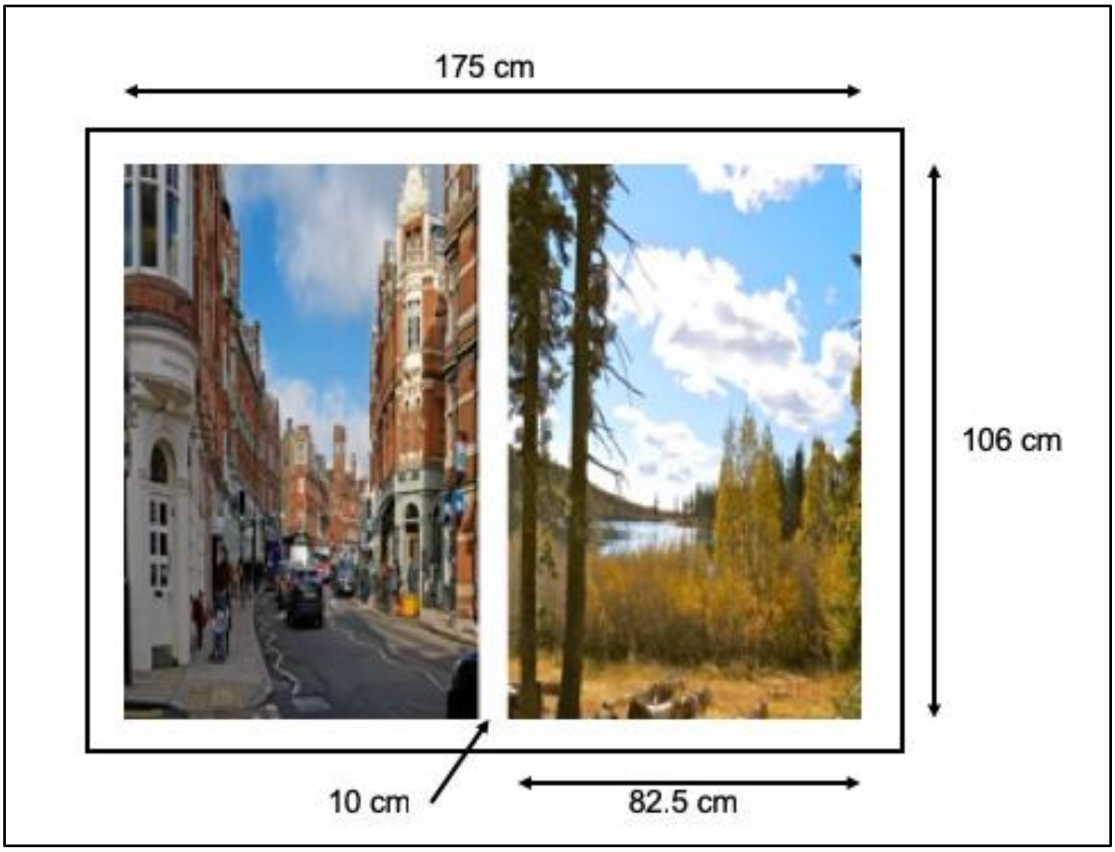


Figure 2.2 Screen view with dimensions.

2.2.4 Eye Tracking

An ABUS itracker smi hs-10 eye tracker (SensoMotoric Industries GmbH, Germany), was used to record participants' visual fixations whilst the images were being presented to them. To maintain accuracy the eye tracker was calibrated at the start of each visual condition to ensure accurate recording. This was achieved using a plain white slide with a cross in each corner and one in the centre of the screen. Participants were instructed to look at the cross in the top left corner and then move their eyes only, to each other cross in a clockwise direction, on instruction from the tester, finishing on the middle cross. As this was done a tester would complete the calibration of the eye tracker, using SMI I tracker software installed on a Kenova Think Pad (Lenovo, Morrisville, North Carolina, United States). Although participants vision was binocular, the eye tracker only tracked the movement of the left eye. Glasses used for vision correction interfere with the accuracy of the eye tracker which is unable at times to follow the movements of the eye through the glasses. Therefore, participants who need glasses were excluded from this study.

2.2.5 Visual Stimulation

Slides were created in Microsoft PowerPoint 2010 (Microsoft Corporation, Redmond, Washington, United States). Using previous research to assist in image selection for this study, all nature images included: water, grass, trees, and sky (Nordh et al., 2009). All urban images included: buildings, signs, people and sky (Henderson and Ferreira, 2004). Twelve nature and twelve urban images, Figure 2.3, were selected that fulfilled the above criteria. Each image was displayed for 10 seconds (Nordh et al., 2013) and was separated from the next image with a 1 second fixation slide. The fixation slide was white, with a cross in the centre, and was used to ensure participants eyes were fixated in the same place at the start of each image exposure. Each slide show lasted 2 minutes 11 seconds (12 x 10 second image slides and 11 x 1 second fixation slides).

Figure 2.3 Example of a nature and urban image used in the slideshows with the white gap shown between. Images were projected onto a screen, with each image measuring 82.5 cm x 106 cm with a 10 cm white gap in the centre.

2.2.6 Video Coding

The video that was captured by the eye tracker had to be coded in order to analyse what participants were looking at. In order to do this a programme called VideoCoder, developed by Dr Tom Foulsham at the University of Essex was used. VideoCoder allowed for frame by frame analysis of the video and the coding of each individual fixation with a pre-programmed code. Rural Sky, Trees, Grass, Water and Animals were classified as nature, whereas Urban footage included: Urban Sky, People, Road/Vehicles, Buildings. There was also a category for other, this was used when participants gaze was not fixed on either image i.e. any time that participants gaze moved away from the test images for any reason including the blank space between, or off the screen including the floor.

Once analysed the data for each coded category was entered into Excel (Microsoft Corporation, Redmond, Washington, United States). Total time viewing different aspects of images was calculated and then from this, percent of total time was calculated. Additionally, frequency of viewing was calculated for each category: nature, urban and other. Furthermore, the object that was looked at initially (primary gaze) was identified and coded into nature or urban for each individual.

2.2.7 Cycling Ergometry

For the study a 100p/100 k Ergoselect cycle ergometer (Ergoline, Bitz, Germany) was used. The cycle saddle was set so that when the crank was in the bottom position the knee had an extension of approximately 175° - 180°. When completing the cycling conditions participants were given two minutes to raise their HR to the desired level (± 10%) and were instructed to cycle at as close to 70rpm as possible. However, during the test conditions participants were told to replicate the speed as best they could without looking as this may have caused the participants to continually take their eyes of the screen in order to check their speed. After each cycling condition participants rested until their HR returned to resting levels (± 10%). A tester manually adjusted the ergometers wattage during the test whilst HR was monitored throughout and recorded every 30 seconds to ensure the required intensity was being maintained. For the 35% HRR condition, participants began cycling at 50 Watts (W) and for the 70% HRR condition participants began cycling at 100W. Participants were required to continue cycling throughout each condition, including whilst giving Rate of Perceived Exertion (RPE) levels and during calibration of the eye tracking equipment in order to maintain the required HRR intensity.

2.2.8 Heart Rate Measure and Heart Rate Reserve (HRR) Calculation

Using a Polar Heart Rate Monitor to record HR, participants were rested for five minutes, sitting in silence on the cycle ergometer, to obtain a resting HR. This measure was then used to calculate 35% and 70% HRR values with the Karvonen Equation as described above. Maximum heart rate was estimated at 220-age.

2.2.9 Statistical Analysis

Statistical data analyse was conducted taking into account nature and urban views only as this is the primary interest. Wilcoxon Ranked Tests were used to analyse percent of gaze duration and the number of times nature elements were looked at. Primary gaze was analysed using a Chi-square test.

2.3 Results

All 11 participants completed the trial but due to technical reasons data was lost for one participant. Therefore, subsequent statistical analysis was then undertaken on n=10.

2.3.1 Primary Gaze

Nature verses Urban primary gaze was analysed using a Chi-Square Test (Table 2.1). Significance was found when exercising at 70% HRR (P=0.011) and nearly reached significance when exercising at 35% HRR (p=0.058) but was not significant at rest.

Table 2.1 Type of image for Primary gaze at rest, 35% Heart rate reserve and 70% Heart rate reserve. N=10. * shows significant differences.

	Rest	35% HRR	70% HRR
Nature	6	8	9
Urban	4	2	1
Ratio	6:4	8:2	9:1*

2.3.2 Frequency Nature Elements were Viewed

The frequency that nature elements were viewed compared to urban elements were compared for each intensity using a Wilcoxon test. Although Nature views were more frequently looked at this showed no significant difference between Nature and Urban at each intensity: Nature rest v Urban rest p=0.799, nature 35% HRR p=0.333 and nature 70% HRR v urban 70% HRR p=0.386 (figure 2.5)

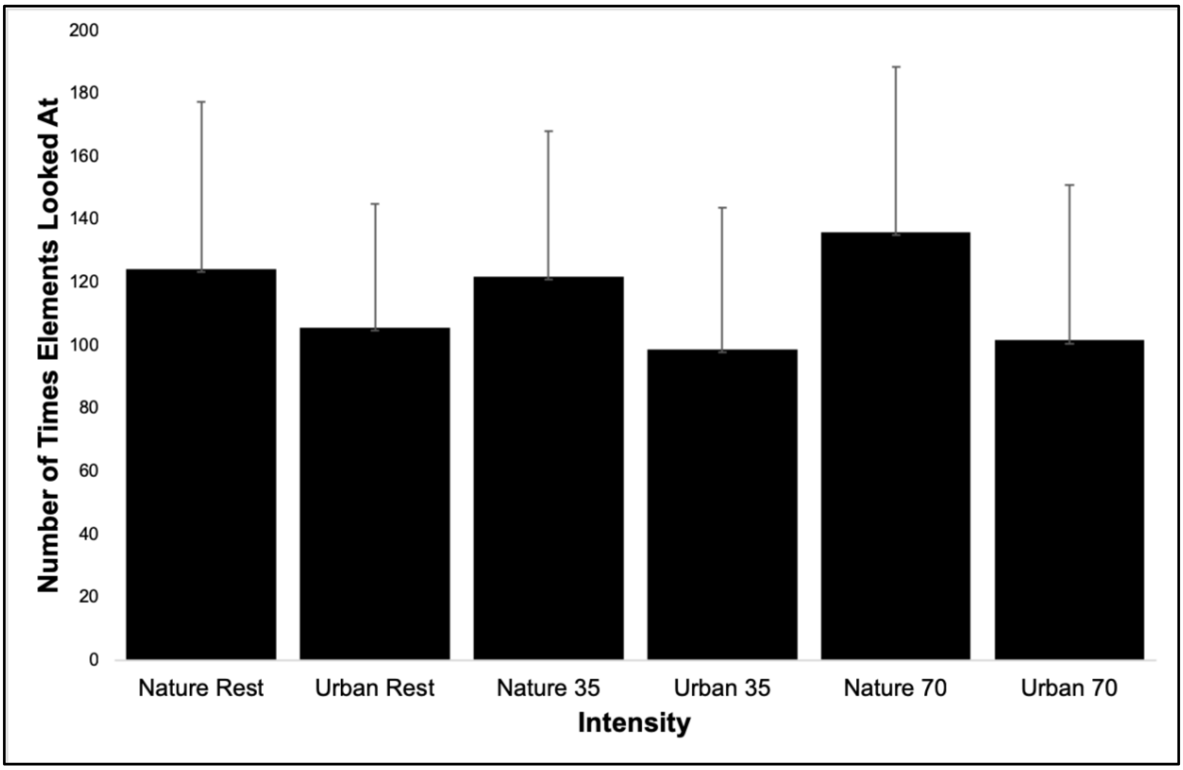


Figure 2.4 Number of times elements in nature or urban looked at
Number of times Nature or Urban elements were viewed. Error bars are standard deviation. N=10

2.3.3 Percent of Gaze Duration

Nature v Urban percentage gaze duration were compared for each exercise intensity using a Wilcoxon test. This showed no significant difference between Nature and Urban at each intensity: Nature rest v Urban rest p=0.799, Nature 35% HRR v Urban 35% HRR p=0.445 and Nature 70% HRR v Urban 70% HRR p=0.333 (Figure 2.5).

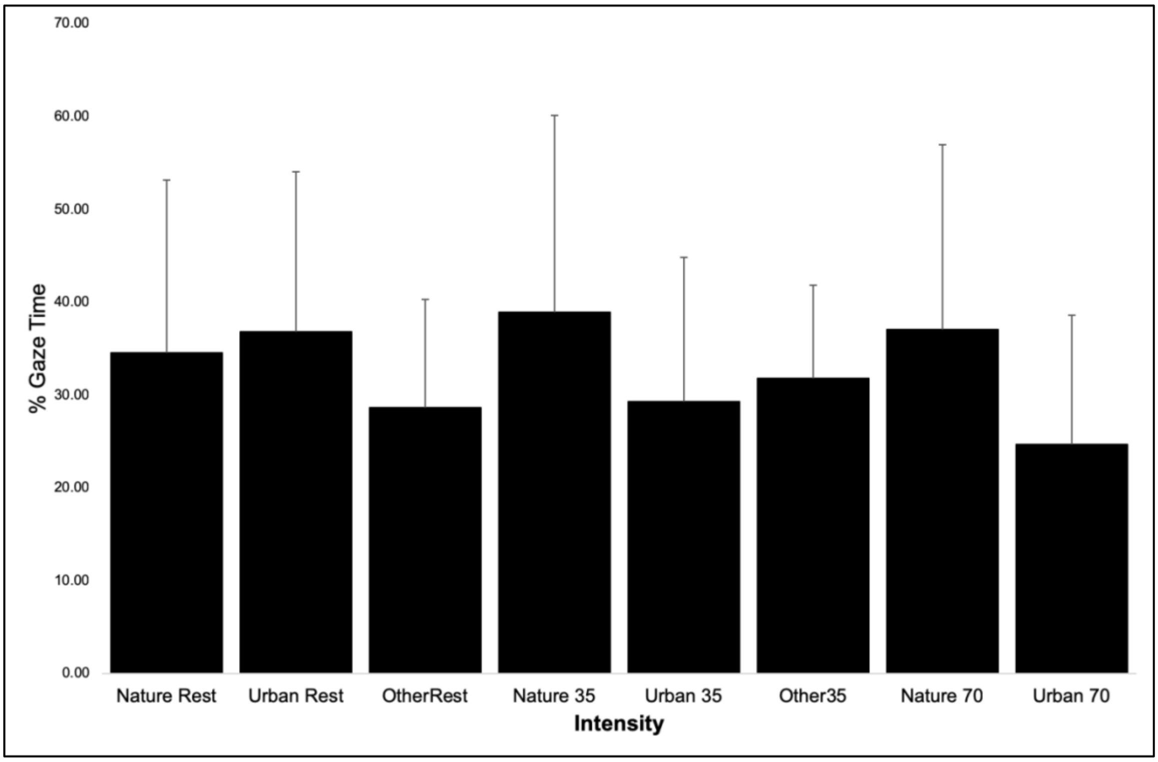


Figure 2.5 Percentage of gaze time looking at Nature or Urban views at Rest, 35% and 70% HRR.
. Error bars are standard deviation. N=10

2.3.4 Comparison with looking at Other

Comparisons of looking at Other (when participants gaze was not fixed on either image i.e. any time that participants gaze moved away from the test images for any reason including the blank space between, or off the screen including the floor) was compared with Nature and Urban % gaze time. These are presented in Table 2.2. Wilcoxon signed Rank Tests revealed no significant difference between Other, Nature and Urban conditions $P>0.05$.

Table 2.2 percentage of time looking at different conditions nature,urban and other. Mean and 1 standard deviation. N=10

	Rest Mean	± SD	35% HRR Mean	± SD	70% HRR Mean	± SD
Nature	34.54	18.66	38.91	21.19	37.08	19.92
Urban	36.80	17.25	29.29	15.54	24.70	13.88
Other	28.67	11.64	31.80	10.03	38.22	16.18

2.4 Discussion

When the analysis was conducted the only significant difference that was found was for primary gaze at 70% HRR. However, when the data is looked at as a whole the main finding was, that although there are limited significant differences, it can be seen that with the exception of percent gaze time at rest, in all other conditions participants chose to look at nature in preference to urban elements, which is in line with the previous research of (Berto et al., 2008, Valtchanov and Ellard, 2015) and supported by the recent research findings of Franěk et al. (2018). This preference increased with increased intensity in all cases. This shows a definite trend in participants preferring to look at nature elements over urban with increasing intensity.

The first hypothesis, that participants would choose to view nature over urban elements was not supported by the percent gaze time data although this data was almost evenly split with participants choosing nature 35% of the time compared to 37% for Urban. My second hypothesis that the preference for viewing nature elements would increase with exercise intensity was supported by all data. The images presented were only in front of participants and not encompassing their entire field of vision, participants were able to, even though they were instructed not to, allow their gaze to wander of the screen, this data was recorded as other. There was also a white gap between the nature and urban image which was in the centre of the screen and therefore this to received viewing fixations and was also recorded as other. This is why total gaze time for nature and rural do not add up to 100%. From this information, it was decided that all other studies in this thesis would require the development of a green laboratory. This was achieved by adding extra nature elements. A full description of how the lab was developed is in chapter 3.

This is the first study to offer a choice of view between nature and urban scenes whilst exercising at different intensities. Significant findings have been shown for primary gaze in favour of nature over urban scenes. There was also an increase in the number of fixations and amount of time spent looking at nature as intensity of exercise increased, although this was not significant. Additionally, this indicates that there is a potential preference for the natural environment as physical stress increases.

There are limitations to this study that have to be acknowledged: The images that were used in the study may be biased in that there may be elements in either condition that were high in fascination for certain individuals. It therefore, cannot be said for certain that there will always be a difference in favour of nature but may dependent on the time of images that are presented. Equally it cannot be said that there would not be enhanced differences if different nature pictures are used. were as high as image viewing time. The primary field of vision needs to be considered when presenting participants with images, as the data considered as Other was high at rest and two intensities of exercise.
Future directions that should be considered are the use of moving imagery comprising as close as possible and even divide between nature and urban fascinations. Further for the purposes of laboratory based studies the use of virtual reality suites should be considered as should the use of mobile eye tracker technology that can be used in field based studies. These avenues were not explored as part of this thesis but rather the intention was to investigate exteroceptive influences involved with the psychological effects of green

exercise, to understand which senses may play a role and thus expand what has already been established in this area.

2.5 Conclusions

Research questions and the results of this study are summarised in table 2.3.

Table 2.3. Summary of research questions and results.

QUESTION	RESULT	Did Result Support Hypothesis?
1a. If there is a choice of nature and urban images whilst at rest, what do participants spend the most total time looking at?	Participants looked at urban images longer than rural but there was not a significant difference.	No
1b. Does this change with exercise intensity?	Participants gaze shifted to nature with increased intensity.	Yes
2a. If there is a choice of nature and urban images whilst at rest, what do participants look at most frequently?	Participants looked more times at nature than urban elements but result not significant.	Yes
2b. Does this change with exercise intensity?	Yes	Yes
3a. Is a participant's primary gaze at a nature or urban image?	Nature was the primary choice of participants	Yes
3b. Does this change with exercise intensity?	Yes	Yes

Results of this study have shown that nature is preferred over urban, a result that increases with intensity, although lacks significance. Lack of statistical significance is possibly due to the small sample size used, and further studies in this area should include a greater number of participants. The future direction is to look at what particular elements of nature are responsible for this preference? Colour has already been looked at by Akers et al. (2012). To address a gap in the research, the contribution of the individual senses of sight, hearing and smell to the psychological benefits of green exercise. In order to do this, and to address a limitation of this study, it was necessary to create a green laboratory so that all elements could be strictly controlled, see chapter 3.

Chapter 3

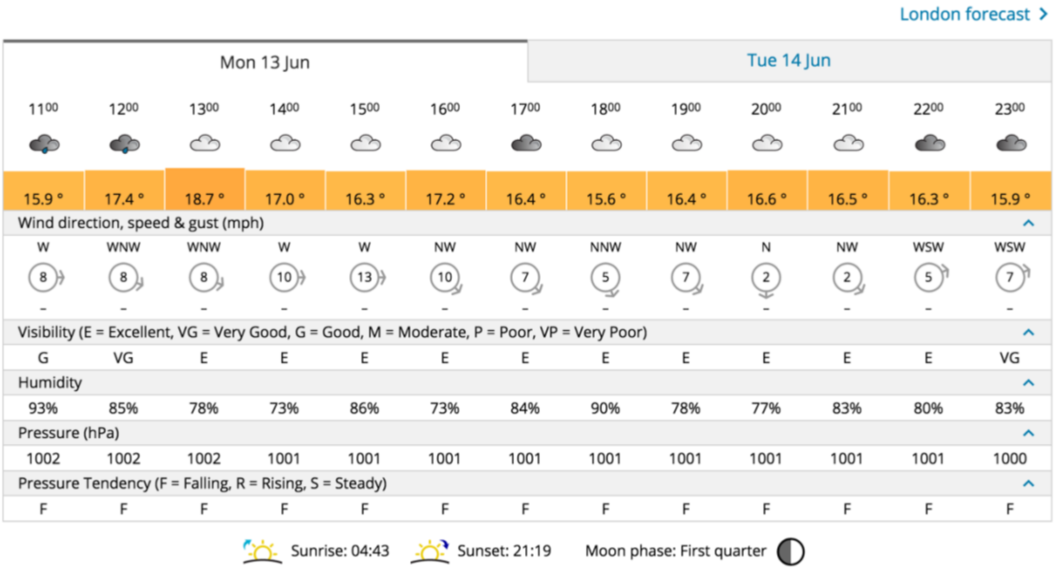
Design Rationale

for the

“Green Laboratory”.

3.1 Introduction

Multiple studies have been conducted in Green Exercise both in the laboratory and in the field. Lab based studies are fully controllable resulting in high quality empirical data but are less ecologically valid than a field study. However, field studies come with many more confounding variables: weather, time of year, time of day, third parties and unaccountable noises. The weather in the UK is unpredictable at best. Unlike some countries that have long periods of consistently good weather, the weather in the UK can change quite considerably from hour to hour let alone day to day. It is quite common to see warm, sunny conditions in the morning and strong winds and rain in the afternoon, even during the summer months. The time of year in the UK also adds to the complications of field based studies, and not just from volatile weather changes. The majority of landscape fauna in the UK is deciduous, leading to colour changes; leaves change from green to brown to none at all. General ambient conditions change also. In autumn, winter and spring the ground outside tends to be much damper and softer (except in cases of severe frost when it is frozen) and the air cooler. Time of day is also a big factor to take into account when in the field. Light intensity, colour and quality changes throughout the day and during the autumn through to spring months this happens faster due to the shorter days. In the summer, it is often cooler in the morning and warmer in the afternoon with changes in wind speed and humidity also see Figure 3. Third parties such as motorists, dog walkers, pedestrians and cyclists and unaccountable noises such as planes, traffic, bird scarers and the conversations of passers-by, also add to the long list of confounding variables. All of the above make it impossible to control conditions between participants over any length of time.



	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Temperature	15.9 °	17.4 °	18.7 °	17.0 °	16.3 °	17.2 °	16.4 °	15.6 °	16.4 °	16.6 °	16.5 °	16.3 °	15.9 °
Wind direction, speed & gust (mph)	W	WNW	WNW	W	W	NW	NW	NNW	NW	N	NW	WSW	WSW
	8	8	8	10	13	10	7	5	7	2	2	5	7
	-	-	-	-	-	-	-	-	-	-	-	-	-
Visibility (E = Excellent, VG = Very Good, G = Good, M = Moderate, P = Poor, VP = Very Poor)	G	VG	E	E	E	E	E	E	E	E	E	E	VG
Humidity	93%	85%	78%	73%	86%	73%	84%	90%	78%	77%	83%	80%	83%
Pressure (hPa)	1002	1002	1002	1001	1001	1001	1001	1001	1001	1001	1001	1001	1000
Pressure Tendency (F = Falling, R = Rising, S = Steady)	F	F	F	F	F	F	F	F	F	F	F	F	F

Figure 3.1 Example of the weather in London UK on 13-06-2016. It can be seen how quickly the weather changes in a short space of time. Between 1100 and 1500 (4 hours) temperature rises 2.8°C then drops 2.4°C, wind speed increases by 5mph and humidity drops 20% then rises 13%. Source Met Office, http://www.metoffice.gov.uk/public/weather/observation/gcpvj0v07 accessed on 14-06-16 at 12.07pm.

In the case of laboratory based studies, nature has been presented to participants in a variety of ways: still photographs of various nature scenes (Pretty et al., 2005c), the available view from a window (Ulrich, 1984, Kaplan, 2001), video imagery (Akers et al., 2012), Nature based sounds (Saadatmand et al., 2012, Alvarsson et al., 2010a) and natural smells (Lehrner et al., 2005, Itai et al., 2000). In general these studies have stimulated one sense at a time (Saadatmand et al., 2012, Lehrner et al., 2005, Akers et al., 2012) or at most have simulated two which have tended to be vision and hearing (Diette et al., 2003). However, in all of these studies it has not been attempted to re-create nature as a whole sensory experience. Looking at controlled, repeatable and accurate measurements from methods used in previous laboratory research and taking into account the inherent problems associated with field based studies in the UK, the decision was taken to recreate nature as closely as possible within the laboratory for the research associated with this thesis; to build a Green Laboratory.

3.2 The Green Lab

In order to make the studies detailed within this thesis and as ecologically valid as possible, whilst maintaining the stringent control measures required for an empirical study, it was necessary to create a green laboratory. The Laboratory was designed to stimulate sight, sound and smell in a way that was as close to nature as possible. This required extensive pilot testing of different laboratory set ups before a suitable environment was created.

3.3 Visual Stimulation

Research of previous studies revealed various methods have been used to stimulate the visual system with images of nature in the laboratory which include: a single image or poster (Diette et al., 2003), several changing still photographs (Pretty et al., 2005c) and video imagery such as that used by Akers et al (2012). As the goal was to create a lab that gave the impression that participants were “out in nature” and exercise was an integral part of the study; moving video imagery was chosen as the best format to achieve this, whilst participants would remain stationary exercising on a cycle ergometer. The idea being that cycling whilst viewing a moving video, would be the closest comparison to a ride through a natural environment that could be achieved in a laboratory environment.

In order to get as much nature with as little man-made influence as possible, it was necessary to review various available video resources. Video images depicting large roads with vehicles on them were excluded, as were videos that contained people such as pedestrians or cyclists. After a lengthy review process, a commercially available exercise DVD “Fitness Journeys - Through the Forest” (Isis Visuals, UK) was chosen. The chapter “Redwoods and Oaks” depicted a small track winding through forest settings. The last five minutes of footage contained no other people or moving vehicles; coupled with the fact that playback of this chapter was designed to simulate a 20km.ph^{-1} cycle ride, meant that it was ideal for the studies requirements of simulating a leisurely ride through a natural landscape.

The playback software used was Real Player (Real Networks Inc, Seattle, WA, USA). The image was projected from an Epson EH – TW450 HD ready projector (Epson (UK) Ltd. Hemel Hempstead, Hertfordshire, UK) positioned above the participants head in such a way that they did not cast a shadow onto the screen. The screen itself was freestanding and positioned 96 cm in front of the cycle ergometer. This placed the participant at an approximate distance of 150 cm from the screen. Using this set-up, the image size produced was 180.3 cm x 92.5 cm and sat at a height of 126 cm from the ground. The image size was such that it occupied the majority of the participants’ vision with the exception of the peripheral. To further enhance nature imagery within the lab two potted conifers were positioned either side of the screen. This gave a 'real life' visual cue of nature to participants an idea supported by previous research where it was found that, in windowless offices, workers are approximately five times more likely to bring in plants and three times more likely to have images of nature in their workspace than workers with windows (Bringslimark et al., 2011) in effect bringing nature indoors when it was not possible to view it otherwise. The conifers also served a secondary function for olfaction which will be discussed later.

3.4 Auditory Stimulation

Recreating the sounds of nature was perhaps the least challenging process in the setting up of the green laboratory. In the early planning stages, a search of the internet a site was found that would fulfil what was needed. The site, www.naturesoundsfor.me, enables the creation of nature sound mp3's that can then be downloaded for free. Various combinations of bird song, wind, rain and other nature sounds can be mixed together to give the desired effect required. However, when the nature journeys through the forest DVD (Isis Visuals, UK) arrived, it was apparent that the accompanying sound track was perfect for the study as it had bird song throughout the video footage.

There are three soundtracks to accompany the Redwood and Oaks chapter, and after review it was decided that auditory stimulation for the study would be provided by the DVD soundtrack title "audio 1" as it was primarily birdsong and some wind sound which, it was felt, best matched the visual imagery. The audio was played through speakers positioned behind the participant. During the pilot phase the speakers were placed various positions, angle and height, in order to achieve the best sound effect. Participants (n=5) reported that the sound was best when the speakers were at head height and angled away from them at 45 degrees. This positioning of the speakers gave the impression that sound was coming from all directions and so this set up was chosen. Volume was the next consideration. During pilot testing the volume was gradually increased in the laboratory. Participants (n=5) reported when they felt that the sound was neither hard to hear or overbearing and most closely resembled what they felt would be the closest match to birdsong in a forest. Volume settings were recorded and the most commonly selected by participants was chosen. At the chosen volume setting, sound levels ranged from 49.9db's at the lowest level, to 75db's at the loudest, as measured by a CEM DT-8820 Environment Meter (Clinipath Equipment Ltd. Hull, United Kingdom).

3.5 Olfactory Stimulation

Replicating the smell of nature and the outdoors was the most complicated and challenging process in the creation of the green laboratory. Several approaches were discussed and piloted before a suitable method was found, the details of which are outlined below.

Cut grass has long been associated with the smells of nature and the outdoors particularly in the summer months. It was considered as a viable option as long as fresh cut grass was used each time a participant attended the lab. This in itself would not be a problem as the university grounds have large areas of grassland and therefore a plentiful supply of grass. Permission to cut grass in an area away from main walkways was granted by the grounds keepers. The grass was put into shallow plastic boxes and placed in a room approximately the same size as the laboratory that was to be used for the study. The decision to use a room instead of the laboratory for primary testing was made so that the lab space remained free for other studies that were ongoing at the university and using that facility. Initially the smell of cut grass was quite noticeable; test participants (n=5) would spend thirty seconds at a time in the room and then leave for ten minutes before returning. Initially reports indicated that the smell was remaining strong and constant but over the course of a relatively short period of time, approximately one hour, the smell dissipated and on return to the test room participants reported that the smell was barely noticeable. To account for the possibility that the participants had become accustomed to the smell and therefore could no longer detect it, individuals who had not been into the test room or exposed to the grass cuttings at any time were asked for their opinion. They confirmed that the smell of cut grass was barely noticeable. This meant that in order to use grass cuttings to recreate the smell of nature the cuttings would have to be replaced at such short intervals that it would interfere with the study. A second problem that came to light was when one of the participants reported that the grass had triggered their hay fever. This meant that even without the logistics of trying to replace the grass cuttings during a participant visit, the risk of triggering a hay fever episode made the use of grass cuttings unviable.

Flowering potted plants were considered as experience had shown that florist shops always have a fragrant natural smell, but several limitations became apparent during discussions. The cost would be high as the plants would need to be regularly replaced due to a limited flowering cycle. Also, availability of the same plants throughout the year would be difficult and therefore that would change the independent variable during the study. It was also considered that very few forests smell heavily of flowers, and review of the DVD showed no extensive floral areas in the footage which was to be used. Therefore, a floral smell would be in contrast to the visual image. Finally, lessons learned from the cut grass pilot i.e. the risk of aggravating hay fever in some participants meant that this idea was taken no further.

Ornamental garden bark chippings were piloted as they replicated a forest floor and are readily available from garden centres throughout the year. As the use of shallow boxes had initially worked with the cut grass, that method was used again with the bark chippings. Four boxes were positioned in the corners of the room and left for thirty minutes before anyone entered to allow the aroma to build up in the room. As with the grass cuttings pilot participants (n=5) spent thirty seconds at a time in the room and then ten minutes outside to prevent their sense of smell becoming accustomed to the aroma. Even after ninety minutes participants reported that the aroma was still strong and reminded them of woodland walks in the summer. After these promising initial reports, the bark chippings were moved from the test room that was being used and into the laboratory environment. Again, they were left for thirty minutes to allow the aroma to build up before the laboratory was entered. However, when the testers returned to the lab, there was only the faintest of smells. Unlike the room that was initially used to trial the different methods of recreating the smell of outdoors, the laboratory was air conditioned. This environment had severely reduced the smell produced by the bark chippings, possibly due to the fact that the air in the laboratory was much drier due to the air conditioning. This meant that this scent delivery method could not be used and also highlighted the fact that all future tests had to be conducted in the lab or at the very least an air-conditioned room.

Aroma therapy oils or essential oils (EO) were the next option to be considered. They are cheap to buy, readily available and come in a multitude of different scents. An aromatherapy company, Materia Aromatica (Materia Aromatica, Strode House, Ivybridge, UK) was contacted for advice on which scents they feel would give a good representation of outdoor nature and how long the scents would last in a room before they would require replenishing. They advised that duration of scent would depend on the type of diffuser being used and that Eos are volatile so would only last for 1 or 2 hours at most before requiring replenishment. The oils suggested by them as a good starting pace were: cedarwood, spruce, eucalyptus, myrtle, ravintsara, cajeput, frankincense, lemon and bergamot. In order to get a broad perspective on which scents to use two other aroma therapists were consulted and they suggested using: Camomile and Pine from one and thyme, basil, pine or silver fir from the other.

Oil testing took place over 3 weeks. This was so participants (n=5) were only exposed to 1 EO in a day. Three oils were chosen from the options provided: pine, silver fir and eucalyptus because it was felt that these oils would give a fresh natural smell. Three identical oil burners were used as the scent delivery system. These types of burners use a tea light candle as a heat source which heats up water that the EO has been added to and is vaporised into the atmosphere. The three oil burners (Windhorse, Cambridge, UK) were evenly placed behind the cycle ergometer and hidden from view by screens. It was important to hide the burners from view as it was a requirement that participants did not make a visual association with the oil burners and the scent in the room, as this would give them knowledge the scent was not from a natural source.

The testing began with 0.1ml of oil was added to each burner and this increased by 0.1ml on each visit until 0.5ml was reached. Participants were asked to rate the smell on a scale of 1 to 10 with 1 being unnoticeable and 10 extremely overpowering, and whether the smell reminded them of nature? On each visit. At the end of testing, pine oil was chosen as it was revealed that this was the smell most effective in making participants feel that they were exercising outdoors in nature. The smell of pine also complimented the images on the DVD and the potted conifers either side of the screen, in fact 3 of the pilot test participants said that they had believed that the scent was coming from the potted conifers. A concentration of 0.3ml of oil was the strength that was deemed noticeable without being overpowering. However, the air conditioning in the laboratory reduced the length of time the smell remained noticeable to approximately 45 minutes. Therefore, to ensure that the smell remained consistent for each participant throughout the length of their visit, 30 minutes before a participant was due to arrive 0.3ml of pine oil (Amphora Aromatics, Bristol, UK), measured using a Gilson P1000 Pipette (Gilson, Inc. WI, USA) was added to the 3 oil burners, each containing 60ml of water. A further 0.2ml of pine oil was added every subsequent 30 minutes until the test session was completed.

The Green Laboratory took 3 months to develop, once complete however, it gave an environment that was controllable and repeatable at any time of the year. Through pilot testing it was possible to create an environment within the laboratory that was as close to a natural environment as possible.

Chapter 4

Occlusion of Sight, Sound and Smell During Green Exercise Influences Mood, Perceived Exertion and Heart Rate

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4.1 Introduction

The benefits to wellbeing of interacting with nature have frequently been demonstrated (Haluza et al., 2014, Hartig et al., 2014, Marselle et al., 2013, Matsuura et al., 2011, Park et al., 2010, Thomson Coon et al., 2011) and explained in terms of both the innate affiliation with nature that humans may have (Wilson, 1984), as well as the restorative effects nature can have on attention processes (Berman et al., 2008, Hartig et al., 2003, Kaplan, 1995, Kjellgren and Buhrkall, 2010, Tennessen and Cimprich, 1995). Of interest is how perceptions of nature are constructed from the integration of various types of exteroceptive sensory information (Heerwagen, 2009). This mechanism is of particular importance because many scientific investigations and nature simulations are seldom fully immersive but instead target selected or isolated senses. Improved recovery from surgical procedures was found when nature was viewed through a window thus being an exclusively visually orientated intervention (Ulrich, 1984). Sometimes bi-modal exposure to nature is used, for instance in studies where patients reported less pain when exposed to both sights and sounds of nature while undergoing flexible bronchoscopy (Diette et al., 2003) and bone marrow biopsy procedures (Lechtzin et al., 2010). In contrast to such studies, it has also been found that visual images of nature in the absence of corresponding sounds can have a negative effect on wellbeing (Kjellgren and Buhrkall, 2010), with participants indicating detachment from nature making comments such as, "…something is missing. I cannot experience nature with all of my senses…", and, "[I am] missing the smells and sounds…", and "[It is] too quiet…"(Kjellgren and Buhrkall, 2010). Natural scents have also been used to stimulate the olfactory system and shown to reduce anxiety and improve mood (Lehrner et al., 2005). The integration of different sensory inputs potentially leads to enhanced positive feelings when exposed to natural environments, and that missing, incomplete or spoilt sensory information may reduce any potential positive therapeutic effects.

In recent years there has been growing interest in Green Exercise, combining physical activity with natural environments (Pretty et al., 2005c). The nature aspect appears to give additional benefits to exercise including self-esteem and mood (Barton et al., 2012, Barton et al., 2009, Barton and Pretty, 2010, Park et al., 2011, Teas et al., 2007, Thompson et al., 2012).

Little is known about the underlying sensori-perceptual mechanisms that may underpin previously reported psychological and therapeutic benefits of Green Exercise (Haluza et al., 2014, Hartig et al., 2014, Marselle et al., 2013, Matsuura et al., 2011, Park et al., 2010, Thompson Coon et al., 2011). One study found higher mood disturbance and perceived exertion among cyclists when a video of the green forest ride was presented to them in greyscale and with a red filter (Akers et al., 2012). Whilst this study provides evidence that modifying visual sensory inputs can influence the psychological outcomes, further work is needed to better understand multimodal sensory mechanisms of Green Exercise (Heerwagen, 2009). Of particular interest is how perceptions of natural environments result from the integration of different sensory inputs. Interactions between senses such as sound and vision (Russell, 2002), and vision and taste (Hoegg and Alba, 2007) have been found to be an important influence on consumer behaviour. In a similar way, sensory congruence may also be related to the Green Exercise effect, yet even if this assumption is accepted, a further unanswered question around sensory dominance remains. Previous Green Exercise studies where images have been presented without corresponding sounds and smells (Bratman et al., 2012, Mackay and Neill, 2010, Reed et al., 2013), indicates that vision perhaps has a dominant sensory influence on Green Exercise compared to the other senses. Vision as a more dominant influence on human perception than hearing has been recognised for some time, as most clearly demonstrated in the

Colavita visual dominance effect (Colavita, 1974) and the McGurk effect (McGurk and MacDonald, 1976b).

The aim of this study was to identify the relative contribution of sight, sound and smell on the perceptual and psychological effects of Green Exercise. Consistent with the previously reported visual dominance effects, it was hypothesised that occluding visual sensory input of natural environments during exercise would have a greater diminishing effect on perceived exertion and mood compared to occlusion of the auditory and olfactory senses.

4.2. Methods

4.2.1. Participants

Twenty-nine healthy participants (15 male and 14 female) were recruited for this study. Only healthy participants without illness, chronic conditions and musculoskeletal injury took part in the study and this was verified using a physical activity readiness questionnaire (PAR-Q). The age, mass, height and body mass of participants was 25.6 ± 8.6 years, 69.3 ± 12.6 kg, 172.3 ± 10.3 cm and 23.4 ± 4.1 $kg.m^2$. (Male: 24.2 ± 6.4 years, 73.4 ± 11.2 kg, 179.7 ± 7 cm and 22.7 ± 3.1 $kg.m^2$; Female: 27 ± 10.5 years, 65 ± 12.9 kg, 164.3 ± 6.5 cm and 24.1 ± 5 $kg.m^2$) All participants provided their written informed consent and the study and its associated procedures were approved by the University of Essex ethics committee.

4.2.2. Design

A mixed-factor within- and between-subjects experimental design was used in which participants visited the laboratory on two occasions. During the first visit participants performed a ramped cycling protocol to volitional exhaustion to establish peak power output (PPO). During the second visit, participants were randomly allocated to one of three sensory occlusion conditions (between-subjects factor) which were visual occlusion (n=10), auditory occlusion (n=9) and olfactory occlusion (n=10).

Randomization procedures were balanced to ensure an approximately equal allocation of participants to conditions. During the second visit participants performed a 5 minute warm-up at 20% PPO. After HR had fallen below post warm up levels, they then performed a 5 minute cycling task at 40% PPO whilst watching a video of a cycle ride in a forested environment accompanied by simulated forest sounds and smells. After 5 minutes of cycling whilst exposed to the combined simulated senses, participants entered a rest period to allow HR to fall below post warm up levels. During this time one of the senses was occluded (according to the condition they had been allocated) then cycling commenced for a further 5 minutes. This oscillation between full-sensory and sensory-occlusion was repeated three times (within-subjects factor) with the same sense occluded.

Mood, heart rate (HR) and rate of perceived exertion (RPE) were measured at the beginning and end of the test, and at the end of each full-sensory and sensory-occlusion phase. The experimental design is illustrated in Figure 4.1.

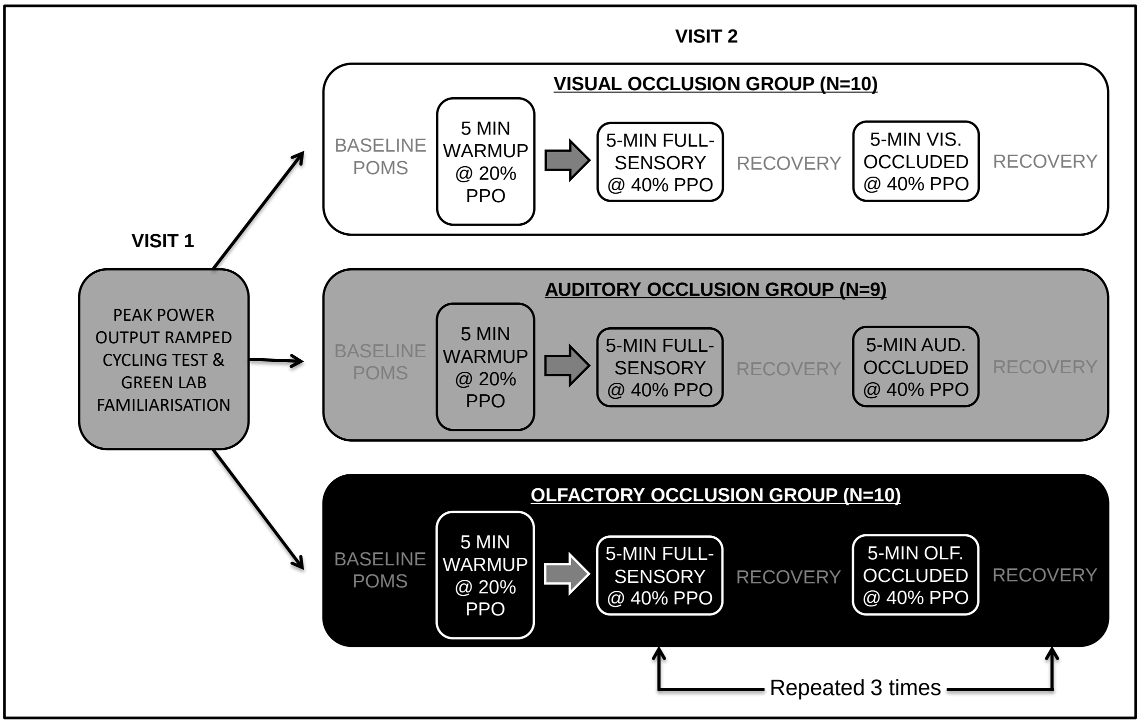

Figure 4.1. Experimental design showing the visual, auditory and sensory occlusion groups. At the end of each 5-minute exposure RPE, HR and POMS were measured. Participants recovered between exposures until their HR returned to post warm-up levels. Full Sensory and Occluded exposures were repeated 3 times alternatively.

4.2.3. Cycling Ergometry

During the first visit, participants performed a ramped cycling test to volitional exhaustion, on a Lode Excalibur electromagnetically braked cycle ergometer (Lode, Groningen, Netherlands) to establish PPO. Saddle height was set so that when the crank was at the bottom position, the knee joint was at approximately 175-180º extension with the foot parallel to the floor. The test began at a power level of 50 W and increased by 1 W every 2 seconds. When a participant indicated that they were no longer able to continue, the power level (W) achieved at point of cessation was recorded, this reflected PPO. HR was also recorded as a physiological measure to reflect maximal exercise.

During the second visit participants performed a 3 minute warm-up at 20% PPO at 70 rpm on 100p/100k Ergoselect cycle ergometer (Ergoline, Bitz, Germany) using equivalent positional settings as the PPO ramp test. Immediately afterwards they performed a 30 minute cycling test, comprising of six individual 5 minute bouts, at 40% PPO at 70 rpm in a simulated green environment both with full sensory exposure and with partial sensory occlusion. The Ergoselect cycle ergometer was used during the experimental trial because it was much quieter than the Lode ergometer and as such was less of an auditory presence during the sensory occlusion interventions.

4.2.4. Simulation of Green Environment

A Green Exercise laboratory was created incorporating visual, auditory and olfactory components in order to simulate natural forest environment for participants to be exposed to while cycling. Visual simulation was created by showing participants a commercially available exercise DVD (Fitness Journeys – Through the Forest, Isis Asia Ltd, Manila, Philippines) which was projected onto a large screen in front of them. The imagery presented consists of a single lane track moving through various woodland landscapes. Screenshots of some of these landscapes are shown in Figure 4.2.

Figure 4.2. Screenshots taken Fitness Journey – Through the Forest DVD. Redwoods and Oaks Chapter.

Each participant, when positioned on the cycle ergometer, was approximately 150 cm from the screen. Image size was 180.3 cm x 92.5 cm at a height of 126 cm from the ground. The last 5 minutes of the "Redwoods and Oaks" DVD chapter was used because there were no other people or moving vehicles within it. Playback speed simulated moving at approx. 20 $km.hr^{-1}$ to give a realistic cycling optic flow experience.

Auditory simulation of the forest environment was created by playing recordings of birdsong through speakers positioned behind the participant. The speakers were angled away from the participant at approximately 45 degrees which gave the effect that sound was coming from all directions. Bird song sound levels ranged from 49.9 db to 75 db.

A variety of methods were piloted to simulate natural forest smells and burning pine oil was chosen because it was the most effective at creating the ambience of nature within the indoor lab as determined by a pilot group of participants (n=10). It was also the easiest method to standardise for smell consistency which was achieved by precisely pipetting 0.3 ml of pine oil to three oil burners each containing 60 ml of water, 30 minutes before each participant commenced the test. A further 0.2 ml of pine oil was added every 30 minutes until the test was completed.

Basic methods of climate control using air conditioning were used to keep the laboratory environment as similar as possible between sessions as well as during each participant session. There was no difference between conditions in mean temperature (Vis. 21.2±1.5˚C vs. Aud. 21.2±1.5˚C vs. Olf. 21.2±1.5˚C; $F_{2,28}=1.1$, $p=0.34$), relative humidity (Vis. 65.5±7.3% vs. Aud. 66.5±7.0% vs. Olf. 66.2±3.4%; $F_{2,28}=0.1$, $p=0.94$) or barometric pressure (Vis. 760±11 mmHg vs. Aud. 755±11 mmHg vs. Olf. 762±10 mmHg; $F_{2,28}=1.1$, $p=0.3$).

4.2.5. Sensory Occlusion

During the first visit, 15 minutes after completing the PPO cycling protocol, participants were familiarised with the method of sensory occlusion associated with their allocated condition. This was done to minimise novelty effects of the simulation and occlusion methods.

Vision was occluded using blacked out swimming goggles which allowing participants to keep their eyes open, just as they would in the full sensory condition. Sound was blocked using a combination of foam in-ear plugs with commercial ear-defenders over the top. Smell was occluded using a re-useable sprung nose clip.

4.2.6. Mood State Measures

Mood was measured using the shortened "right now" version of the Profile of Mood States (POMS) questionnaire (McNair et al., 1992, McNair et al., 1971). The shortened version of POMS uses a 30 point questionnaire, scored on a five point Likert scale, from which it was possible to calculate subscale scores for Tension, Depression, Anger, Vigour, Fatigue and Confusion. Total mood disturbance (TMD) was calculated by subtracting the score for Vigour from the sum of the other five subscales. This gave an indication of overall mood. Baseline mood was recorded on arrival for visit 2, and measured immediately at the end of each 5 minute full-sensory and occluded segment. All POMS questionnaires were completed in a quiet waiting area outside of the lab while HR was monitored to check recovery to post warm-up levels. Between phase recovery away from the laboratory also allowed sensory resetting to reduced residual confounding effects of prior sensory manipulations. As soon as HR had returned to post warm-up levels, participants were returned to the lab where they resumed cycling and the next simulated phase commenced.

4.2.7. Heart Rate and Perceived Exertion Measures

HR was recorded continuously during each visit using a Garmin 405 forerunner heart rate monitor. HR was taken as the average last 30 seconds of each 5 minute full-sensory and occluded segment. Rating of perceived exertion (RPE) was measured in the last 10 seconds of each 5 minute segment using the Borg 6-20 scale (Borg, 1970). Prior to each test participants were familiarised with the RPE scale and the scale was anchored and administered as per standardised instructions (Borg, 1998). At the end of each sensory segment HR was monitored and the next sensory segment was not commenced until HR had returned to post warm-up levels. This ensured that HR was the same at the start of each segment.

4.2.8. Statistical Analysis

All data is presented as means with one standard deviation. Two-way between and within-subjects ANOVA's were used to analyse HR, RPE and Total Mood Disturbance (TMD). An alpha level of 0.05 was used to indicate significant difference. A two-way between and within-subjects MANOVA was used to analyse POMS subscales of Tension, Depression, Anger, Vigour, Fatigue and Confusion. Effect sizes are shown as partial eta-squared (ηp2). Post hoc analyses were conducted using paired-samples t-tests.

4.3. Results

4.3.1. Total Mood Disturbance (TMD)

Total mood disturbance scores were compared using a two-way between- and within-subjects ANOVA which showed a condition-by-group interaction ($F_{2.7,35.6}$=4.1, p=0.015, η_p^2=0.24), a condition main effect ($F_{1.4,35.6}$=11.1, p=0.001, η_p^2=0.30) and a group main effect ($F_{2,26}$=7.2, p=0.003, η_p^2=0.36). Condition-by-group TMD interactions are presented in Figure 4.3A along with post-hoc paired-sample t-test outcomes, and raw TMD data for sensory and occlusion condition repetitions is presented in Figure 4.3B. Mean (SD) POMS TMD data are given in Table 4.1.

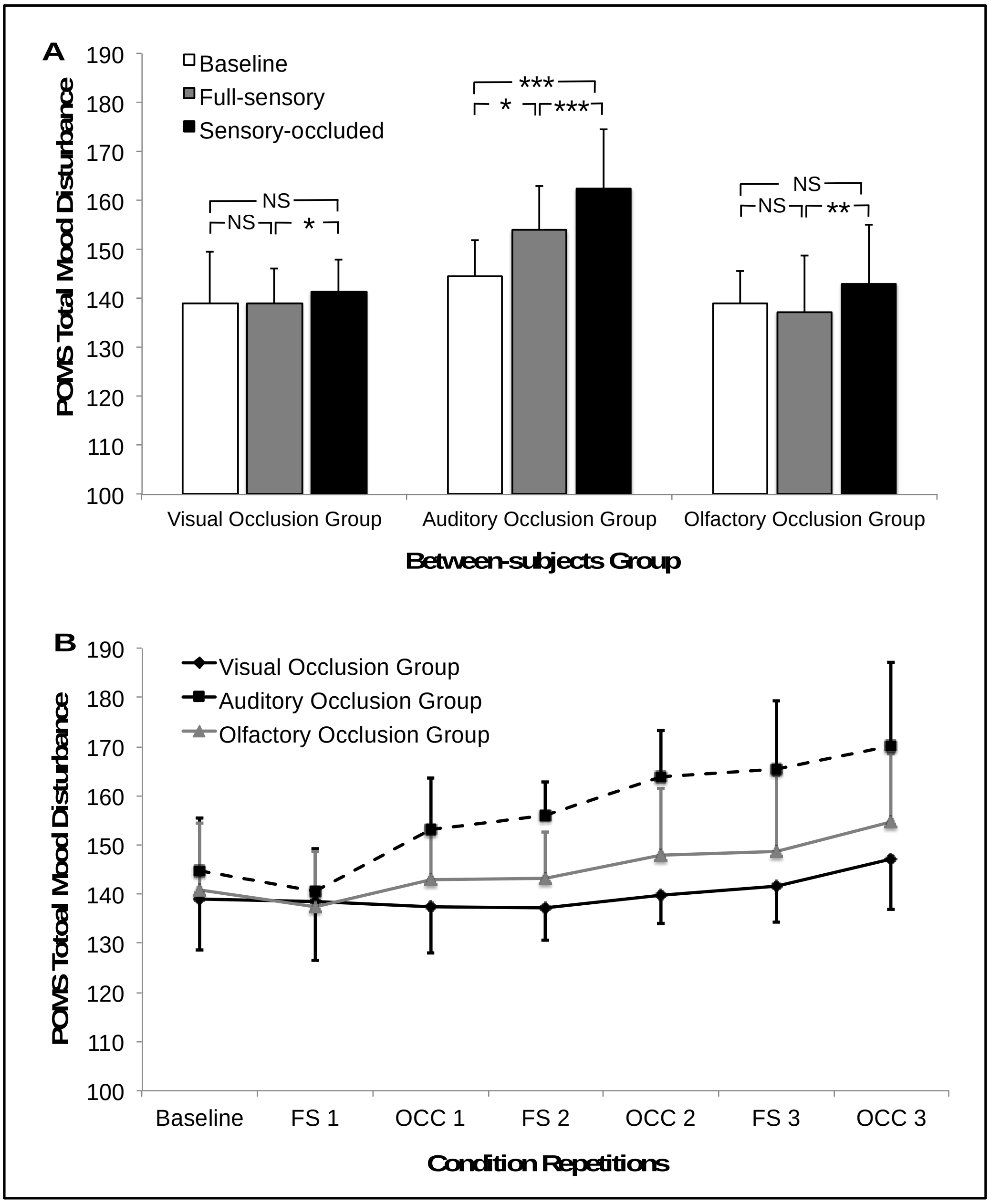

Figure 4.3. Group-by-condition TMD interactions (A) and condition repetition TMD outcomes (B). [NS denotes not significant; * denotes p<0.05; ** denotes p<0.01; *** denotes p<0.005. FS = full sensory; OCC = sensory occluded].

4.3.2. Profile of Mood State Subscales

Profile of mood state subscales were analysed using a two-way between- and within-subjects MANOVA which revealed a group-by-condition interaction ($F_{24,200}$=1.8, p=0.016, η_p^2=0.18), and a condition main effect ($F_{12,96}$=3.4, p<0.0001, η_p^2=0.30) but no group main effect ($F_{12,44}$=1.3, p=0.281, η_p^2=0.25).

Post-hoc two-way univariate ANOVA's showed that Confusion was the only POMS subscale to show a group-by-condition interaction ($F_{4,52}$=5.8, p=0.001, η_p^2=0.31) (Figure 4.4A). Further post-hoc t-analysis showed increases in Confusion among the auditory group only during the full-sensory and sensory-occlusion conditions compared to baseline.

Condition main effects were found for Tension ($F_{2,52}$=3.6, p=0.033, η_p^2=0.12), Vigour ($F_{2,52}$=4.5, p=0.016, η_p^2=0.15), Fatigue ($F_{2,52}$=10.2, p<0.0001, η_p^2=0.28) and Confusion ($F_{2,52}$=5.5, p=0.007, η_p^2=0.17) but not for Depression or Anger (Figure 4.4B) Further post-hoc t-test analysis showed lower Tension during the full-sensory condition and lower Vigour during the occluded condition but with higher Confusion. Compared to resting baseline, Fatigue increased during both full-sensory and sensory-

Table 4.1. Sensory occlusion group and condition mean(SD) values for mood, RPE and heart rate. * denotes p<0.05; ** denotes p<0.01; *** denotes p<0.005.

	Visual Occlusion Group			Auditory Occlusion Group			Olfactory Occlusion Group		
	Resting Baseline	Full Sensory	Sensory Occluded	Resting Baseline	Full Sensory	Sensory Occluded	Resting Baseline	Full Sensory	Sensory Occluded
		* (Full vs Occluded)		* (Resting vs Full); *** (Resting vs Occluded)	*** (Full vs Occluded)			** (Full vs Occluded)	
Total Mood Disturbance	139 (10)	139 (7)	141 (6)	144 (10)	153 (9)	162 (12)	139 (13)	137 (11)	143 (12)
POMS Subscales									
Tension	32.1 (1.4)	32.1 (2.2)	32.5 (2.3)	34.0 (2.2)	32.8 (2.4)	33.9 (2.8)	33.9 (2.3)	32.1 (1.1)	32.2 (1.3)
Depression	37.0 (0.0)	37.0 (0.1)	37.2 (0.4)	37.7 (1.0)	37.3 (0.7)	37.6 (0.9)	37.2 (0.4)	37.1 (0.1)	37.2 (0.5)
Anger	37.2 (0.6)	37.5 (1.2)	37.9 (1.5)	37.7 (1.4)	37.6 (0.8)	37.9 (1.4)	37.5 (1.1)	37.1 (0.3)	37.2 (0.5)
Vigour	40.0 (7.8)	40.8 (5.6)	40.6 (5.8)	38.0 (6.3)	33.2 (2.3)	30.4 (2.5)	42.0 (11.1)	41.5 (5.5)	38.2 (5.7)
Fatigue	38.5 (3.7)	38.8 (4.0)	39.3 (3.9)	38.4 (3.1)	42.1 (4.6)	45.0 (5.7)	37.5 (2.4)	38.9 (4.4)	40.4 (4.6)
				*** (Resting vs Full); *** (Resting vs Occluded)			* (Resting vs Full)	*** (Full vs Occluded)	
Confusion	34.3 (1.5)	34.4 (2.3)	35.1 (2.5)	34.9 (2.9)	37.1 (3.5)	38.5 (4.2)	34.9 (2.2)	33.5 (1.8)	34.2 (1.7)
RPE	-	11.0 (2.5)	11.5 (2.1)	-	12.3 (1.3)	13.9 (1.8)	-	12.2 (2.0)	13.1 (2.0)
Heart Rate	103 (21)	120 (21)	124 (19)	100 (12)	112 (7)	112 (7)	109 (12)	123 (14)	123 (15)

occluded cycling conditions. Mean (SD) POMS subscale data are given in. A between- and within-subjects ANOVA indicated a condition main effect for RPE ($F_{1,26}$=19.0, p=<0.0005, η_p^2=0.42) but no group main effect.($F_{2,26}$=2.4, p=0.111, η_p^2=0.16) and no condition-by-group interaction ($F_{2,26}$=1.8, p=0.178, η_p^2=0.12) (Figure 5) Mean RPE data are given in Table 4.1.

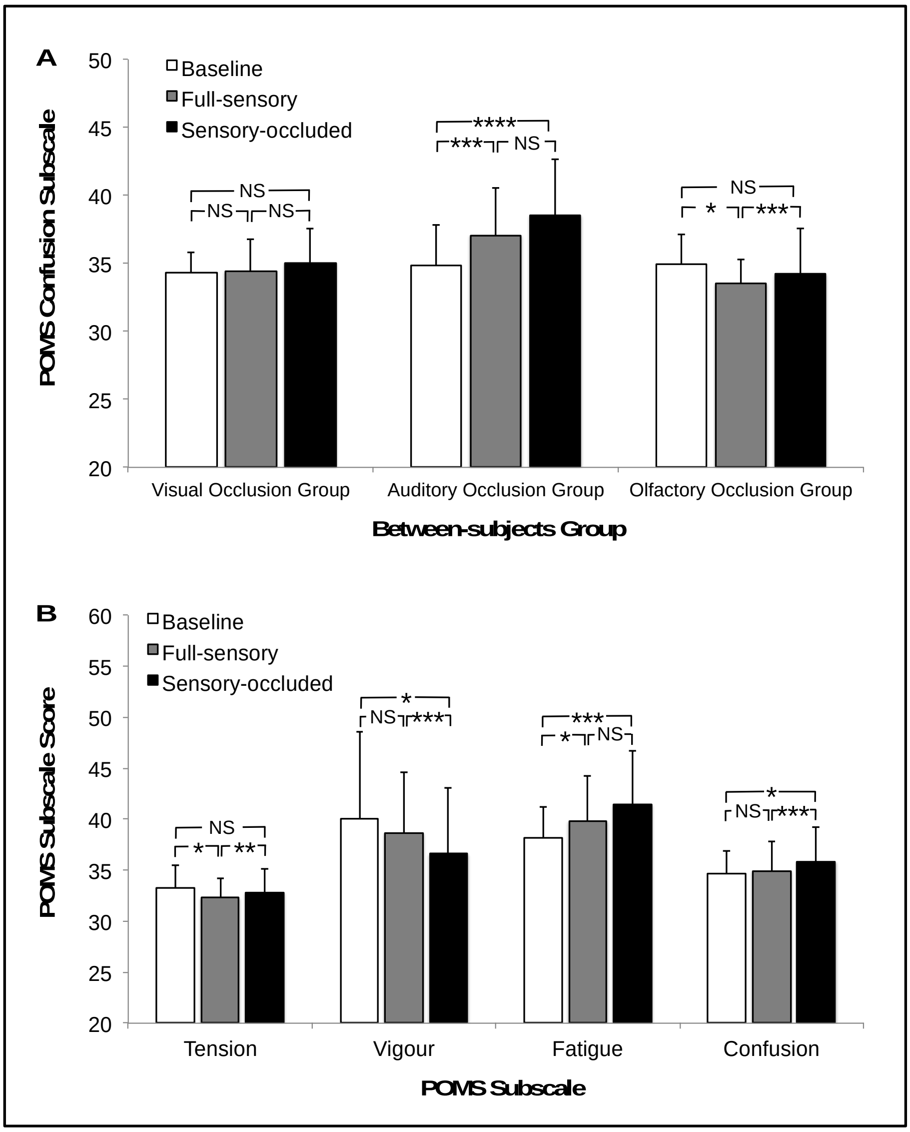

Figure 4.4 Group-by-condition interaction for POMS Confusion (A) and condition main effects for POMS Tension, Vigour, Fatigue and Confusion (B). [NS denotes not significant; * denotes p<0.05; ** denotes p<0.01; *** denotes p<0.005.]

4.3.3. Ratings of Perceived Exertion

A between- and within-subjects ANOVA indicated a condition main effect for RPE ($F_{1,26}$=19.0, p=<0.0005, η_p^2=0.42) but no group main effect ($F_{2,26}$=2.4, p=0.111, η_p^2=0.16) and no condition-by-group interaction ($F_{2,26}$=1.8, p=0.178, η_p^2=0.12) (Figure 5) Mean RPE data are given in Table 4.1.

4.3.4. Heart Rate

A two-way between- and within-subjects ANOVA indicated a condition main effect for HR ($F_{1.2,32.2}$=102, p<0.0001, η_p^2=0.80) but no group main effect ($F_{2,26}$=1.2, p=0.322, η_p^2=0.08 and no condition-by-group interaction ($F_{2.5,32.2}$=2.1, p=0.134, η_p^2=0.14 (Figure 4.5). Mean HR data are given in Table 4.1.

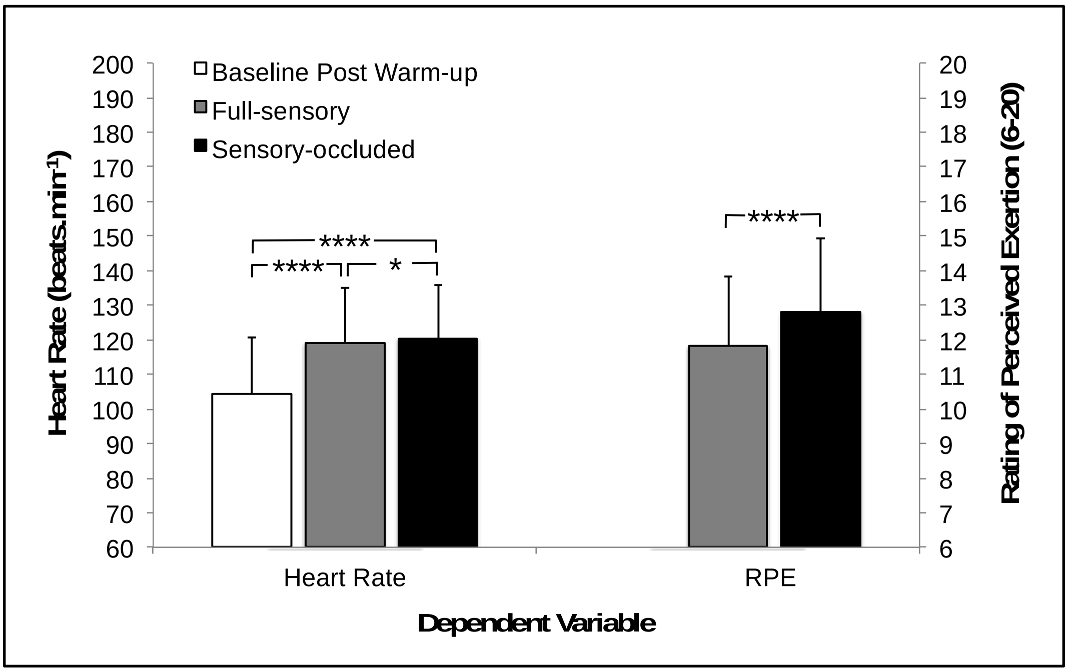

Figure 4.5. Condition main effects for heart rate and RPE. [* denotes p<0.05; **** denotes p<0.0001.]

4.4. Discussion

The main finding of this study is that sensory occlusion results in increased TMD (decreased mood), RPE and HR during Green Exercise. These effects were strongest when the sounds of nature were blocked but, contrary to our hypothesis, were virtually absent when vision was blocked. The change in TMD during sensory occluded states were characterised by increased Fatigue and Confusion, and reduced Vigour. A reduction in Tension and Vigour, and an increase in Fatigue was found during exercise with all senses simulated, which is consistent with previous Green Exercise findings (Akers et al., 2012, Barton et al., 2012, Barton et al., 2009, Barton and Pretty, 2010, Mackay and Neill, 2010, Park et al., 2011, Pretty et al., 2005a).

In an attempt to strengthen our confidence that any observed changes in mood were attributable to variations in sensory exposure, our design switched between 5-minute episodes of full-sensory and sensory occlusion. As can be seen from Figure 3B, TMD does seem to oscillate in a consistent way with the switching on and switching off cycles of sensory occlusion. The pattern is most noticeable among the auditory group followed by olfactory occlusion group, and least evident among the visual occlusion group. The general upward trend in TMD across the 6 exposures is most likely an effect of the overall exercise duration, which is in line with our expectations. What is significant about this finding is that by the third occlusion cycle (FS3 and OCC3), TMD was above baseline levels in all groups perhaps indicating that there is a point at which the duration of Green Exercise has negative effects on mood. Because of the intermittent design of our study, whereby bouts of exercise were intercalated with period of rest, the precise effects of exercise duration on mood are difficult to conclude. Nevertheless, our observations are in line with previous analyses of dose effects in which 5 minutes of Green Exercise was found to provoke the greatest effect on mood with longer durations having a diminished effect (Barton and Pretty, 2010). Dose-response relationships continue to be of importance to Green Exercise research, and as the between-group differences in rate of mood change show, optimal dose may vary according to the quality of the sensory experience, certainly in simulated natural environments.

Given that visual sensation is known to be a more dominant influence on perception than other senses (Colavita, 1974, Hoegg and Alba, 2007, McGurk and MacDonald, 1976b), it was a surprise to observe virtually no change in mood, RPE or HR when the visual system was occluded during Green Exercise. One possible explanation is that, having first experienced the full-sensory condition, participants may have been mentally visualising the natural environment while their vision was occluded. Furthermore, the sounds and smells of nature they were exposed to during visual occlusion may have strengthened their mental visualisations which is consistent with previous findings that show that olfaction is a particularly strong memory cue (Herz, 1996, Herz et al., 2004). The effect of smell in evoking memories and corresponding emotions is sometimes referred to as the Proust phenomenon, after the French writer who in the book Swann's Way (Proust, 1960) explains how the smell of a madeleine biscuit dipped in tea evokes strong feelings of joy and memories of childhood. A limitation of our study is that we did not investigate strategies that participants used during sensory occlusion so we are unable to conclude that visualisation was used. Nevertheless, what is interesting about this idea is the possibility that Green Exercise effects are strengthened by congruent (Russell, 2002) multimodal sensory inputs (Heerwagen, 2009). Of further interest is the notion that the smell of a natural environment can trigger memories which help compensate for missing information from other senses. This cross-modal sensory interdependence and perceptual filling may allow individuals to experience positive perceptions of natural environments in circumstances such as darkness or poor visibility, where visual inputs are impeded, or when listening to music through headphones, when auditory inputs do not correspond with the natural environment (Herz, 1996, Herz et al., 2004).

Perhaps the most noticeable but unexpected outcome of this study is the significantly greater rise in TMD among the auditory occlusion group. TMD was elevated compared to baseline during both full sensory and auditory occlusion (Figures 3A and 3B) and therefore it is not possible to suggest that the increased TMD in this group is attributable to the auditory occlusion. If that were the case then we would have seen a much greater drop in TMD every time there was a switch from the auditory occlusion to full sensory condition. Closer inspection of Figure 3B shows that compared to baseline, TMD fell among the auditory occlusion group as a consequence of their first full-sensory exposure (FS1). This initial improvement in mood is actually consistent with the previously reported positive effects of Green Exercise (Akers et al., 2012, Barton et al., 2012, Barton et al., 2009, Barton and Pretty, 2010, Park et al., 2011, Pretty et al., 2005a, Reed et al., 2013). However, as soon as participants are exposed to their first episode of auditory occlusion (OCC1), TMD rises steeply and remains elevated regardless of whether subsequent exposures involved full-sensory or auditory occluded simulations.

A possible explanation is that the auditory occlusion methods we used had adverse effects and residual effects on mood. Instead of just switching the nature sounds off, ear-plugs inner ear-plugs were used in conjunction with external ear-defenders, completely blocking out all sounds including background noises in the lab, such as the cycle ergometer and the projector fan. If this had not been done an incongruent sensory effect would have been created of combining the sight and smell of nature with the artificial sounds of the lab. However, by using this set-up, the internal sounds such as participant’s own respiration and maybe even heartbeat, were amplified. This was probably an unfamiliar experience for some participants and perhaps a factor responsible for the increased TMD. It is therefore difficult to conclude if the increased TMD among the auditory occlusions group (Figure 4A) were due to the complete absence of sounds or the absence of natural sounds in the experimental situation. While we acknowledge this as a clear limitation of the study, alternative pseudo-occlusion methods, such as switching the sounds off, introduce different problems. In spite of the methodological issues associated with auditory occlusion, we are able to conclude that the magnitude of negative mood disturbance was on average less in the full sensory condition compared to the auditory occluded condition. While it has been found that moderate intensity exercise generally improves mood (Bartholomew et al., 2005, Peluso and Andrade, 2005, Polman et al., 2007, Rokka et al., 2010), our observations of the auditory occlusion group seem to indicate that any potential exercise effects on mood were offset by the occlusion of auditory senses.

There are several limitations of our study associated with the simulated green environment and the sample size we used. While the simulated green environment is clearly weaker for ecological validity compared to a field study, this was necessary in order to be able to carefully control the sensory occlusion and exercise interventions, as well as ensure consistency in the environment that is not easy to achieve in a field study. Consequently, we have a high level of confidence that the effects on mood and heart rate that we observed were attributable to the sensory occlusion rather than some other extraneous or confounding variable. Haluza et al. (2014) suggest that at least 200 participants are needed in studies where small effects are expected but, owing to the practical complexities of our experimental design and measurement methods, this was not viable in the present study and this is also acknowledged as a limitation. Nevertheless, small to moderate effect sizes were found for most of our outcome measures, indicating that despite the sample size used the occlusion of certain senses causes changes in mood and heart rate responses to green exercise.

4.5. Conclusions

From the current study, we are unable to make any firm conclusions about the relative contribution or dominance of particular senses on Green Exercise effects, yet there are two clear conclusions we can make. The first is that occluding individual senses worsens mood, as characterised by reduced Vigour and increased Tension, Fatigue and Confusion (Figure 4.4B). The second is that when combined sensory simulation of natural environments is used, mood tends to improve compared to the occluded states in terms of increased Vigour and reduced Tension, Fatigue and Confusion (Figure 4.4B). Furthermore, RPE was higher in the sensory-occluded compared to full-sensory conditions supporting previous evidence that perceptual effort during exercise is not exclusively due to interoceptive feedback but is influenced by exteroceptive sensory information (Parry et al., 2012, Parry and Micklewright, 2014). Multimodal sensory interactions, redundancy and perceptual compensation, as previously highlighted (Akers et al., 2012, Heerwagen, 2009), warrant much more careful investigation if the sensori-perceptual and cognitive mechanisms of Green Exercise are to be better understood.

As mentioned previously, one of the limitations of this study was how the senses were occluded particularly hearing. It was discussed that the method used to occlude sound would have resulted in the amplification of internal sounds such as respiration and maybe heart rate, which would have been unfamiliar to participants. To that end, future research must look at alternative methods of removing the sounds of nature. What was also of note, is the limited, if any, effect on TMD that was seen during the visually occluded condition. Given that vision is more dominant in influencing perception than the other senses (Colavita, 1974, Hoegg and Alba, 2007, McGurk and MacDonald, 1976a).

We posited that this may have been due to participants being exposed to the full sensory condition first, and therefore were possibly able to visualise nature and minimise the effects on TMD during the occluded condition. These limitations are the basis of Chapter 5 and thus will be addressed in this Chapter.

Chapter 5

Removing sight and sound influences mood, perceived exertion and heart rate during Green Exercise.

5.1 Introduction

The previous study, (chapter 4), was found to have isolated an individual sense by intentionally occluding the other senses. Results from our previous research found that, occluding sight only, had no significant effect on mood. It was suggested that this could be due to a participants' ability to use the sounds of nature to visualise the natural environment more effectively and therefore minimalizing the effect of the loss of vision by occlusion. Further, the methods used to occlude sound, although effective, led to another potential confounding variable, in that the internal sounds of participants breathing and possibly heart beat were amplified. This would probably an unfamiliar sensation to some participants and could therefore be a factor in increased Total Mood Disturbance (TMD). Therefore, it was difficult to determine whether or not these increases were due to the lack of natural sounds in the experimental condition i.e. reduction in exteroceptive influence or due to an increase in internal stimuli. The aim of this study was to address these limitations found in Chapter 4.

These potential issues raised the following research questions:

1. During the Auditory condition, would removing sound rather than occluding it, result in TMD increasing above baseline measures?
2. During the visual removed condition, would removing sound as well as vision, minimise the participant's ability to visualise nature and therefore increase TMD?

It was hypothesised that removing nature sound, as opposed to occluding it, would have a detrimental effect on TMD, and that the removal of sound and vision together would also increase TMD by limiting a participant's ability to visualise nature.

5.2 Methods

5.2.1 Participants

Twenty healthy participants (14 males and 6 females) were enlisted for this study. Only healthy individuals free from chronic conditions, illness and injury were used for the study and this was verified by use of a physical activity readiness questionnaire. Age, height, mass and body mass of participants were: 25.7 ± 9.1 years, 174.3 ± 8.7 cm, 74 ± 14.6 kg and 24.5 ± 5.2 $kg.m^2$. (Male: 22.9 ± 7.1 years, 178 ± 6.2 cm, 74.8 ± 14.2 kg and 23.5 ± 4.3 $kg.m^2$; Female: 32 ± 10.8 years, 165.5 ± 7.3 cm, 72.3 ± 16.8 kg and 26.6 ± 6.9 $kg.m^2$). Written informed consent was provided by all participants and the study and its associated procedures were approved by the University of Essex ethics committee.

5.2.2. Design

A mixed-factor within- and between-subjects experimental design was used in which participants visited the laboratory on two occasions. During the first visit participants performed a ramped cycling protocol to volitional exhaustion to establish peak power output (PPO). During the second visit, participants were randomly allocated to one of two removal conditions (between-subjects factor) which were visual and audio removal (n=10), or auditory removal (n=10). Randomization procedures were balanced to ensure an approximately equal allocation of participants to conditions.

During the second visit participants performed a 5 minute warm-up at 20% PPO. After HR had fallen below post warm up levels, they then performed a 5 minute cycling task at 40% PPO whilst watching a video of a cycle ride in a forested environment accompanied by simulated forest sounds. After 5 minutes of cycling whilst exposed to the combined simulated senses, participants entered a rest period to allow HR to fall below post warm up levels. During this time either the auditory sense or the visual and auditory senses combined were removed (according to the condition they had been allocated) then cycling commenced for a further 5 minutes. This oscillation between full-sensory and sensory-removed was repeated three times (within-subjects factor) with the same sense or senses removed.

Mood, heart rate (HR) and rate of perceived exertion (RPE) were measured at the beginning and end of the test, and at the end of each full-sensory and sensory-removed phase. The experimental design is illustrated in Figure 5.1.

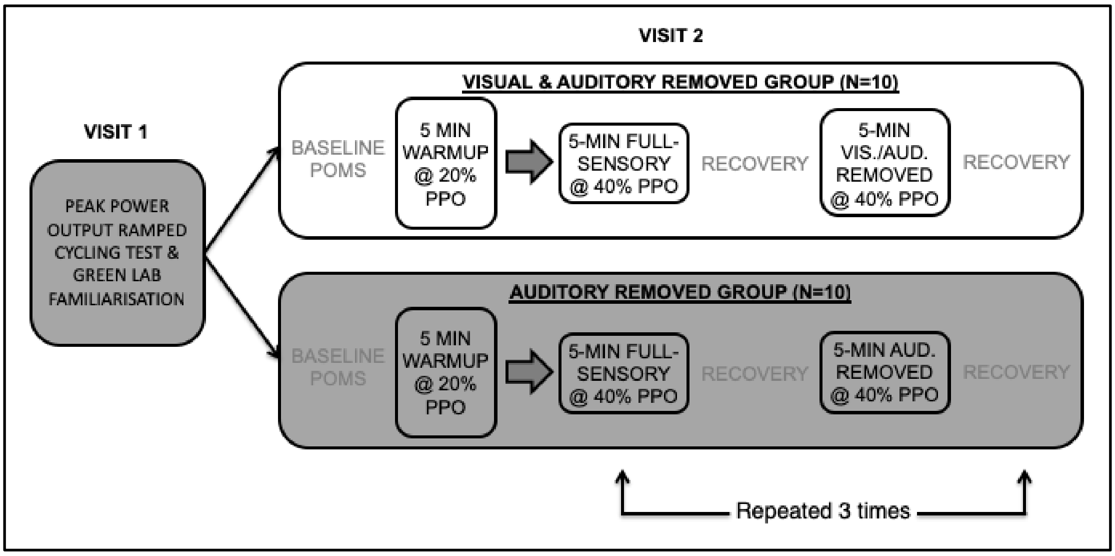

Figure 5.1. Experimental design showing the visual, auditory and sensory occlusion groups. At the end of each 5-minute exposure RPE, HR and POMS were measured. Participants recovered between exposures until their HR returned to post warm-up levels. Full Sensory and removed exposures were repeated three times

5.2.3. Cycling Ergometry

The cycling ergometry protocol was repeated as it was in chapter 4. During the first visit, participants performed a ramped cycling test to volitional exhaustion, on a Lode Excalibur electromagnetically braked cycle ergometer (Lode, Groningen, Netherlands) to establish PPO. Saddle height was set so that when the crank was at the bottom position, the knee joint was at approximately 175-180º extension with the foot parallel to the floor. The test began at a power level of 50 W and increased by 1 W every 2 seconds. When a participant indicated that they were no longer able to continue, the power level (W) achieved at point of cessation was recorded, this reflected PPO. HR was also recorded as a physiological measure to reflect maximal exercise.

During the second visit participants performed a 3 minute warm-up at 20% PPO at 70 rpm on 100p/100k Ergoselect cycle ergometer (Ergoline, Bitz, Germany) using equivalent positional settings as the PPO ramp test. Immediately afterwards they performed a 30-minute cycling test, comprising of six individuals 5-minute bouts, at 40% PPO at 70 rpm in a simulated green environment both with full sensory exposure and with partial sensory occlusion. The Ergoselect cycle ergometer was used during the experimental trial for two reasons:

1. The cycle is designed in such a way that it automatically adjusts wattage to remain constant regardless of cycling cadence. In this way participants did not need to focus on cycling leaving them free to focus on the test protocol.

2. It was much quieter than the Lode ergometer and as such was less of an auditory presence during the sensory occlusion interventions.

5.2.4. Simulation of Green Environment

The Green Exercise laboratory that was used for this study, was the same set-up as that used for the study in chapter 4. However, it differed slightly in that the olfactory sense was not included, as it was previously found to have no significant impact on mood. Images of the green laboratory set up can be seen in Figure 5.2.

Figure 5.2 A. Laboratory set-up. B. As seen during test protocol. C. Participant during full sensory repetition.

5.2.5. Sensory Removal

A familiarisation protocol was used to minimalize novelty effects, this was conducted after the ramped protocol on visit 1 as in chapter 4. For this study, sound was removed during the testing protocol in the laboratory, by turning off the computer speakers, leaving only ambient sounds from the projector and cycle ergometer in the laboratory. No external methods such as ear defenders were used as in chapter 4, this was done so that there could be no effect on TMD results from unfamiliar amplified internal sounds such as respiration and heartbeat. These unfamiliar internal sounds were discussed in chapter 4 as a possible reason for the increased TMD (reduced mood) during the auditory occluded condition.

Vision was removed by using blacked out swimming goggles (see Figure 5.3) which allowed participants to keep their eyes open as they would in normal conditions. Sounds were also removed (turning off computer speakers) during the vision removed condition. This was to minimalize the ability to visualise nature which was highlighted as a limitation in the occlusion study in chapter 4.

Figure 5.3. Blacked out swimming goggles used to remove vision but still allowing participants to keep their eyes open.

5.2.6. Mood State Measures & HR and Perceived Exertion Measures

Mood was measured using the shortened "right now" version of the Profile of Mood States (POMS) questionnaire (McNair et al., 1992, McNair et al., 1971). Baseline mood was recorded on arrival for visit 2, and measured immediately at the end of each 5 minute full-sensory and removed segment. All POMS questionnaires were completed in a quiet waiting area outside of the lab while HR was monitored to check recovery to post warm-up levels. As soon as HR had returned to post warm-up levels, participants were returned to the lab where they resumed cycling and the next simulated phase commenced.

5.2.7. Statistical Analysis

All data are presented as means with one standard deviation. Mean data was calculated from the total scores of the participants in each group for each of the conditions: baseline, full-sensory and removal of sensory (audio only or audio and visual). This was then used in two-way between (group i.e. removal audio group or removal of audio and vision) and within-subjects (condition i.e. baseline, full sensory or sensory removed) ANOVAs were used to analyse TMD, RPE and HR. To indicate significance an alpha level of 0.05 was used. Post hoc analyses were conducted using paired samples *t*-tests (to identify differences between conditions) or independent t-tests (differences between groups).

A two-way between and within-subjects MANOVA was used to analyse POMS subscales of Tension, Depression, anger, Vigour, Fatigue and Confusion. Effect sizes are shown as partial eta-squared (η_p^2).

5.3. Results

5.3.1 Total mood disturbance

For the audio removed group, TMD across the experiment showed a slight improvement in mood (decrease in TMD) in the first full sensory repetition but there after there was a gradual increase in TMD (i.e. worse mood) (Figure 5.4). For both vision and audio removed there was a slight improvement in mood after the full sensory and then it remained at similar levels for the rest of the experiment (Figure 5.4).

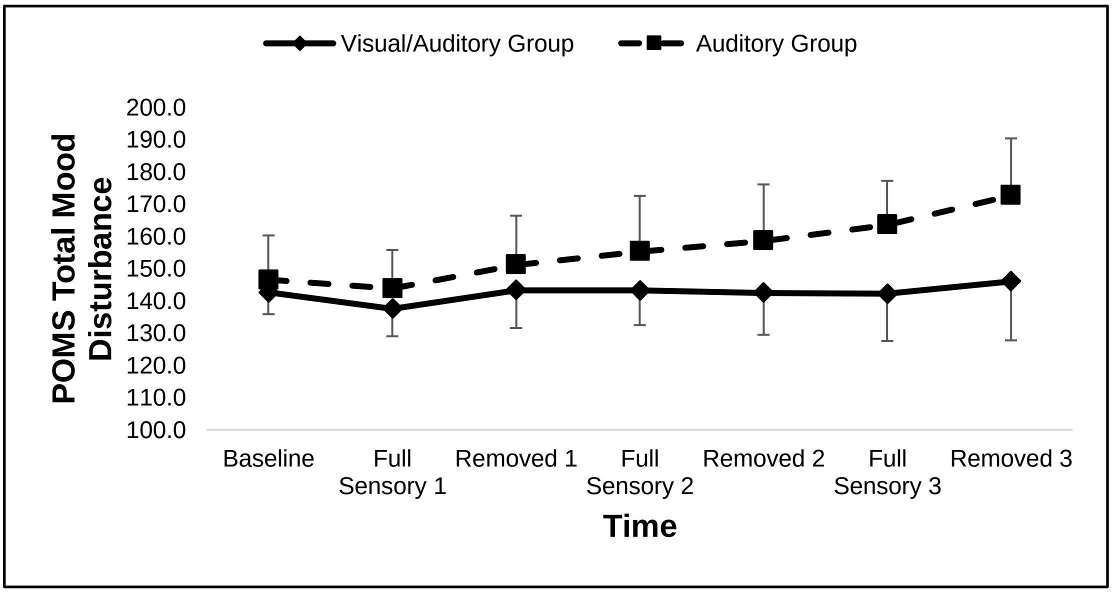

Figure 5.4 Total Mood Disturbance outcomes for both groups across the experiment showing baseline, three repetitions of Full sensory and three repetitions of removal of senses. Means ± SD are shown.

For each group, the mean for TMD scores for the three repetitions of each condition were calculated (i.e. Baseline, Full Sensory and Removed) and compared using a two-way between and within subjects ANOVA. There was a condition main effect ($F_{2,36}$=4.3, p=0.021, η_p^2=0.194), and group main effect ($F_{1,18}$=6.0, p=0.025, η_p^2=0.25). There was no condition by group interaction ($F_{2,36}$=3.1, p=0.57, η_p^2=0.148).

For the vision and audio removed group post hoc paired sample *t*-tests revealed no TMD changes between baseline and full-sensory conditions (142.6±6.8 vs. 140.9±9.7, t_9=0.6, *p*=0.594, η^2=0.038), baseline and removed conditions, (142.6±6.8 vs. 143.9±13.6, t_9=0.4, *p*=0.691, η^2=0.017) or full sensory and removed conditions (140.9±9.7 vs. 143.9±13.6, t_9=0.9, *p*=0.40, η^2=0.083) (Figure 5.5).

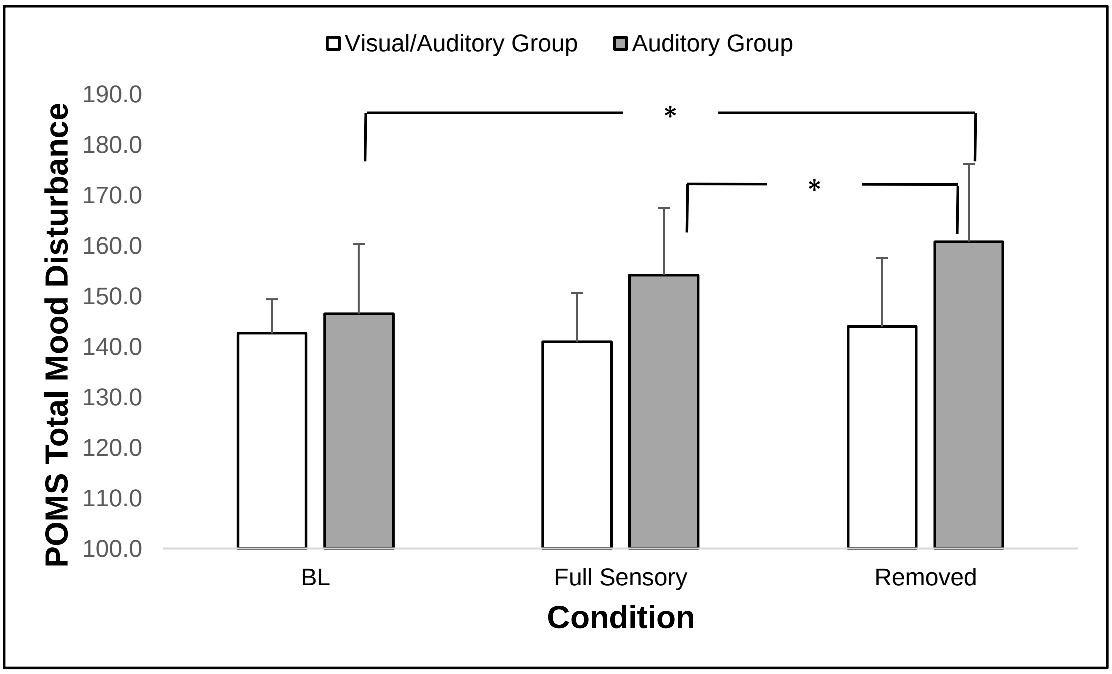

Figure 5.5 Group by condition interactions for total mood disturbance * denotes significance P≤ 0.05. BL= baseline.

Independent-samples post hoc t-tests revealed no difference between groups for baseline TMD (142.60±6.8 vs. 146.5.813.8, t_9=-0.804, p=0.432) but there was a significant difference between the groups for the full sensory condition (140.9±9.7 vs. 154.2±13.3 t_9=-2.556, p=0.020) and the sensory removed condition (143.9±13.6 vs. 160.8±15.4, t_9=-2.587, p=0.019).

5.3.2 POMS subscales

POMS subscales were analysed using a two way between and within subjects MANOVA which revealed a condition main effect ($F_{12,64}$ = 2.2, p=0.022, η_p^2=0.292), no group by condition interaction ($F_{12,64}$ = 1.04, p=0.429, η_p^2=0.16), and no group main effect ($F_{6,13}$ = 1.2, p=0.385, η_p^2=0.348). A condition main effect was found for fatigue only, which was higher during occluded only ($F_{1.44,25.83}$ = 9.5, p=0.002, η_p^2=0.345).

5.3.3 Ratings of perceived exertion

RPE scores were compared using a two-way between and within subject's ANOVA which showed a condition main effect ($F_{1,18}$ = 11.34, p=0.003, η_p^2=0.39), no condition by group interaction ($F_{1,18}$ = 2, p=0.171, η_p^2=0.10), and no main effect for group ($F_{1,18}$ = 3.2, p=0.09, η_p^2=0.15) (Figure 5.6).

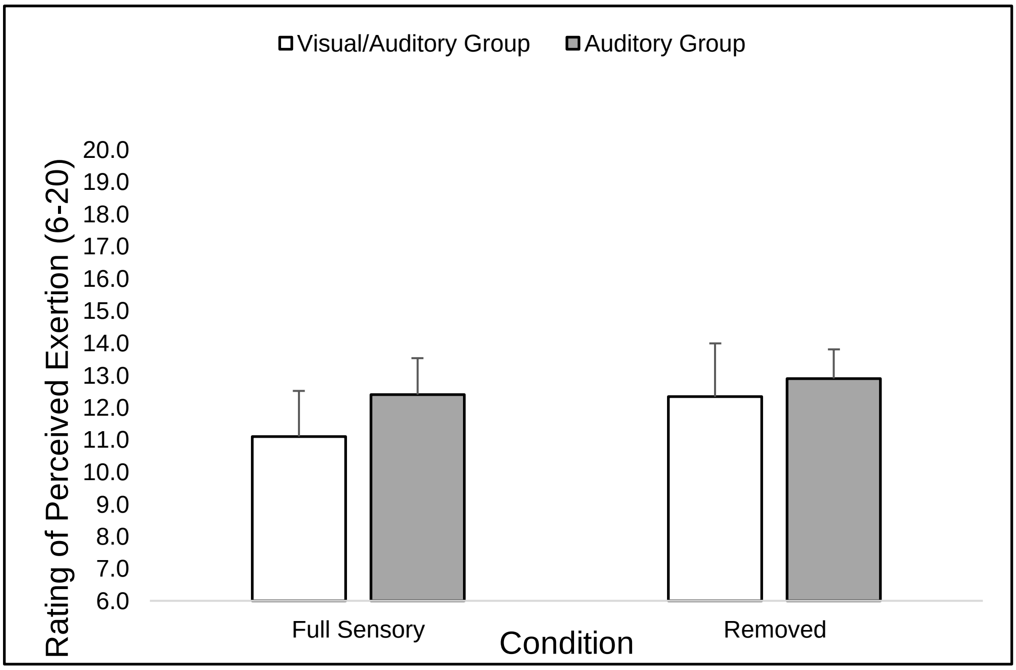

Figure 5.6 Condition main effects for Rating of Perceived Exertion *denotes p≤ 0.05.

5.3.4 Heart Rate

A two-way between and within subjects ANOVA revealed a main effect for condition ($F_{1,12}$ = 13.7, p=0.003, η_p^2=0.53) but no main effect for group ($F_{1,12}$ = 0.11, p=0.752, η_p^2=0.009) and no condition by group interaction ($F_{1,12}$ =0.23, p=0.642, η_p^2=0.19

A two-way between and within subject's ANOVA revealed a main effect for condition ($F_{1,12}$ = 13.7, p=0.003, η_p^2=0.53) but no main effect for group ($F_{1,12}$ = 0.11, p=0.752, η_p^2=0.009) and no condition by group interaction ($F_{1,12}$ =0.23, p=0.642, η_p^2=0.19)

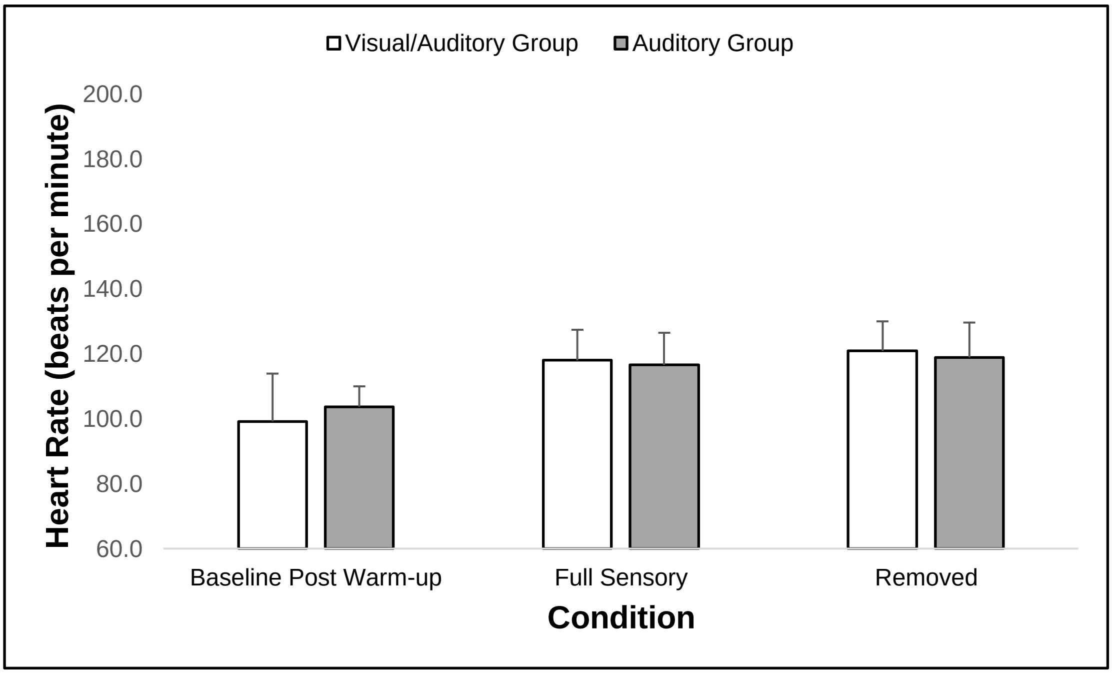

Figure 5.7 Condition main effects for Heart rate.

5.4 Discussion

The main finding of this study is that audio removal increased TMD (reduced mood), despite full sensory "green exercise" between each removal of the audio and vision still being available. This supports the work that was completed in Chapter 4. Only in the first Full sensory condition does mood seem to improve (Figure 5.4). Then as in the previous study, it increased above baseline levels after the first bout of sensory removal and continued to increase throughout the remainder of the session regardless of full sensory or audio removed. Contrary to the second hypothesis, during the vision and audio removed condition effects on TMD were virtually absent, (similar to Chapter 4).

The vision and audio removed group improved after the first full sensory exposure, but showed minimal change in results throughout the remainder of the session with no significant difference between baseline and intervention measurements.

This is interesting because it was suggested in Chapter 4 that a possible reason for the lack of effect on TMD, was the participants ability to visualise nature from prior exposure to the full sensory conditioned coupled with the fact they could still hear the sounds of nature. In the current study, there were no nature sounds playing so they could not influence visualisation. It is likely that the act of exercising (in a normal set-up on a bike) protected participants mood from adverse effects (decreased mood).

In terms of when full sensory was available it may be that there was no increase in Mood as the mood was already good and was difficult to improve further. In future studies, it would be interesting to worsen mood first and then see what improvements could be made with different senses be available rather than removing or occluding them

5.5 Conclusions

The main findings of this study support those of chapter 4, using the modified protocol to address limitations in the previous study.

This study was developed specifically to further explore the findings of chapter 4. By eliminating the two main limitations of the study, these were the way the senses were occluded resulting in:

1. The possible use of sound to assist in internal visualisation within the vision occluded group

2. The possibility of amplified internal sounds such as breathing and heart rate caused by the use of ear defenders in the auditory occluded group adversely affecting TMD.

This having been achieved, it can be seen that once again the auditory sense appears to be an important exteroceptive contributor to mood. Although firm conclusions still can't be made due to the small sample size of participants. However, these results further strengthen the conclusions of the previous study in chapter 4 in that; firstly, removing the individual senses worsens mood, and secondly, when the combined sensory stimulation of a natural environment is used, mood tends to improve when compared to the removed states.

This study adds to the growing body of evidence, that the individual senses, in particular the auditory sense, play an important role in the effects of green exercise on mood and therefore warrants further study when mood is altered, maybe by increasing stress levels prior to experiencing green exercise with different senses stimulated. This is what will form Chapter 6.

Chapter 6

Can simulated green exercise improve recovery from acute mental stress?

A version of this chapter was published. The reference is:

WOOLLER, J. J., ROGERSON, M., BARTON, J., MICKLEWRIGHT, D. & GLADWELL, V. 2018. Can Simulated Green Exercise Improve Recovery From Acute Mental Stress? *Frontiers in Psychology,* 9.

6.1. Introduction

Psychological stress is defined as “a state of mental or emotional strain or tension resulting from adverse or demanding circumstances” (EOLD, 2018). Although stress tolerance varies between individuals due to the appraisal of the stressor, prolonged exposure to stress is considered a risk factor of poor health, due to the sustained physiological changes in response to the psychological demands (MHF, 2018). The psychological stress response is mediated by a cascade of hormones from the central nervous system and peripheral organs (Chrousos, 2009). Chronic psychological stress increases risk of health problems including cardiovascular, neurological, and mental ill health (including depression) (Oken et al., 2015).

Mental ill-health is one of largest factors in global disease burden, with depression the leading cause of disability (Vos et al., 2015). Each year in the UK, around 12 million adults seek medical advice about their mental health, many relating to anxiety and depression which are often associated with, or triggered by, high levels of stress (MHF, 2018). In 2016/17 work-related stress alone was responsible for 12.5 million lost work days in the UK, accounting for half of all absences due to ill health (HSE, 2017). Longitudinal studies and systematic reviews have indicated that work-related stress is associated with anxiety, depression, heart disease and some musculoskeletal disorders (HSE, 2017). A clearer understanding of the interventions that ameliorate stress and enhance recovery is needed (Danielsson et al., 2012), especially given the wider negative consequences it has on individual health, society and the economy (HSE, 2017).

Nature and green environments contribute to an enhanced level of physical and mental health (Ward Thompson et al., 2012, Pearson and Craig, 2014, Gladwell et al., 2013, Hartig et al., 2014, Akpinar et al., 2016, van den Berg et al., 2016, Douglas et al., 2017, Ekkel and de Vries, 2017, Wood et al., 2017, Hazer et al., 2018). Over the last decade, epidemiological studies have shown positive associations between quantity of local green space and improved health outcomes (Mitchell and Popham, 2008, Maas et al., 2009, Beyer et al., 2014, Kardan et al., 2015, Ward Thompson et al., 2016). Being in green spaces may relieve stress since lower perceived stress has been associated with greater weekly exposure to green spaces (Hazer et al., 2018). Thus, links between engagement with green spaces and wide-ranging health benefits have become a focal point for research.

It has been suggested that modern day humans have an innate connection with nature and living things due to our hunter-gatherer past (Kellert and Wilson, 1995). Natural environments can be enjoyed without having to deliberately focus attention, concentrate or expend mental effort. This has led some to claim exposure to nature has restorative effects on mental fatigue and attention (Kaplan, 1995, Berman et al., 2008). Nature and natural environments have been found to counteract the negative effects of stress, specifically with respect to stress recovery (Brown et al., 2013), mental fatigue reduction (Berman et al., 2008, Taylor and Kuo, 2009, Berman et al., 2012) and cognitive restoration (Kaplan, 1995, Grahn and Stigsdotter, 2003, Berto, 2005, Bowler et al., 2010, Rogerson and Barton, 2015).

Direct contact with nature is not necessary for it to facilitate recovery from stress. Viewing nature through a window (Ulrich, 1984, Kaplan, 2001), by means of still or moving images projected onto a screen (Brown et al., 2013, Wooller et al., 2015), and through virtual reality (Annerstedt et al., 2013) have all improved recovery from acute stress.

Viewing images of nature 10 minutes prior to being subjected to an acute mental stressor was sufficient to positively affect the recovery of the autonomic system (Brown et al., 2013). Recovery from a virtual reality version of the Trier Social Stress Test (TSST) was found to be best when exposed to a simulated natural environment comprising both sounds and images, rather than just images of nature or a control condition absent of all nature images and sounds (Annerstedt et al., 2013). Using similar sensory isolation methods combined with moderate intensity cycling, positive effects on mood were found when the simulated green environment included both video graphic and auditory components (Wooller et al., 2015). Unexpectedly, the largest mood improvement occurred when the sounds of nature were excluded from the simulation compared to the removal of the sight or smell of nature (Wooller et al., 2015).

Exercise performed in conjunction with exposure to nature is known as green exercise (Pretty et al., 2005c) and has been associated with a variety of psychological and physiological benefits (White et al., 2013, Weng and Chiang, 2014). Green exercise improves mood, attention and physiological markers such as heart rate, blood pressure and cortisol compared to exercise in built man-made environments (Focht, 2009, Li et al., 2011, Thomson Coon et al., 2011, Rogerson and Barton, 2015). While these and other effects of green exercise are well documented, less is known about which senses might have the greatest contribution to the reported outcomes. Previous green exercise research showing beneficial effects on attention and psychological recovery (Focht, 2009, Li et al., 2011, Thomson Coon et al., 2011, Rogerson and Barton, 2015) can be furthered by investigating in more detail the contribution of individual senses and multi-sensory integration in situations where a state of stress has been intentionally induced.

Using simulated green exercise in a laboratory environment minimizes less controllable variables such as the weather, terrain and contact with other people, whilst enabling control of the exercise intensity, mode and stimulated senses.

The purpose of this exploratory study was to investigate the effects of simulated green exercise used as a recovery intervention following exposure to acute mental stress on immediate mood and stress levels and whether any recovery effects persisted following a further 10 minutes of rest. Additionally, to explore the influence of visual and auditory senses, these senses were manipulated to allow sight or sound to be the main contributing sense during the green exercise simulation. The olfactory sense was excluded for this study as previous work showed that smell had a limited impact on the green exercise outcomes (Wooller et al., 2015). The hypotheses were that: (i) recovery of mood and stress from a state of psychological stress would be greater following simulated green exercise compared to resting recovery, (ii) simulated green exercise would facilitate better recovery compared to exercise alone and, (iii) these effects would remain 10 minutes following simulated green exercise (iv) visual stimuli alone would enhance recovery of mood and stress from a state of psychological stress compared to sound.

6.2. Methods

6.2.1 Participants

Fifty healthy participants were recruited for this study (Age 27.2 ± 10.2 years; Stature 173.8 ± 9.1 cm; Body Mass 78.3 ± 16.4 kg; Body Mass Index 25.8 ± 4.7 kg.m^2) constituted of 34 males (Age 25.7 ± 9.5 years; Stature 178.4 ± 6.2 cm; Body Mass 83.3 ± 15.8 kg; Body Mass Index 26.2 ± 4.9 kg.m^2) and 16 females (Age 30.4 ± 11.3 years; Stature 164.2 ± 6.1 cm; Body Mass 67.5 ± 11.9 kg; Body Mass Index 25.0 ± 4.3 kg.m^2). Only healthy individuals free from chronic conditions, injury and illness were permitted to take part, this was verified by use of a physical activity readiness questionnaire (PAR-Q). Written informed consent was provided by all participants and the study and its associated procedures were approved by the University of Essex ethics committee.

6.2.2 Design

A between-subjects experimental design was used in which participants attended the laboratory on two occasions. The first visit was to establish participants estimated peak power output (EPPO) using a CatEye ergociser (EC-1600, CatEye Co. Ltd., Osaka, Japan). On the second visit participants were randomly allocated to one of five stress recovery groups: i) Rest, ii) Cycling without nature simulation, iii) Cycling with simulated nature sounds, iv) Cycling with simulated nature video or v) Cycling with simulated nature sounds and video combined. Quota sampling methods were used to ensure an even number of participants (n=10) per condition. Participants were not aware of their grouping prior to the recovery intervention. Further, the tester inducing the stress was not aware of the group the participant was in.

During the second visit, participants carried out a stress induction task (described in 6.2.4 below) followed by 5 minutes of moderate intensity cycling under the simulated green exercise conditions associated with the condition they had been assigned to (see 6.2.5). A variety of dependent variables were recorded including mood, perceived stress, heart rate and blood pressure. All measurements were taken before and after the stress induction task. Mood and perceived stress were also taken immediately after the green exercise cycling task, and ten minutes after resting recovery. The measurement trials in relation to the stress induction task, recovery intervention and further 10 minute rest period are indicated above the x-axis on Figure 1.

6.2.3 Cycling Ergometry

During the first visit, estimated peak power output (EPPO) was calculated using the YMCA bicycle submaximal fitness test (Golding et al., 1989) programmed into a CatEye ergociser as used by Rogerson et al. (2016). During the experimental conditions, a 100p/100k Ergoselect cycle ergometer (Ergoline, Bitz, Germany) was used. The Ergoselect allowed stringent control of exercise intensity, by continually adjusting pedalling cadence to maintain constant intensity wattage. Exercise intensity was set at 40% EPPO, in accordance with previous methods used to replicate moderate exercise (Wooller et al., 2015).

6.2.4 Stress Induction

Each participant individually carried out a Trier Social Stress Test (TSST) in accordance with the methods of Kirschbaum et al. (1993). Participants were first taken into a plain room where two testers, seated behind a table, explained the test. Participants were instructed to stand on a marker positioned on the floor in front of the testers which they were told was necessary for video capture purposes. Participants were bought into the room at a time when they could see one of the testers adjusting the camera equipment which was visible from the marker position. At the end of all testing, participants were debriefed that in fact no recordings were made, and that the presence of the camera was intended to add to their stress. The testers explained to participants that they would be required to complete a mathematics and English task but provided no further details. Participants were then invited to wait outside of the room and permitted five minutes to mentally prepare themselves for the upcoming tasks.

After five minutes, participants were bought back into the room. The testers were instructed to show no signs of emotion or assist the participants in anyway. One tester administered a mathematics task, which required the participant to count backwards by 13 from 1677. In the event of a mistake, a loud beep was sounded, and the participant was instructed to start again from 1677. The second tester administered an English task, which required participants to spell words, ranging from seven to ten letters long, backwards. Again, in the event of a mistake a loud beep was sounded, and the participant was asked to spell that word again. Each task lasted for five minutes and participants were randomly assigned to order counterbalanced tasks.

6.2.5 Stress Recovery Interventions

Each participant performed one of five stress recovery interventions according to the condition they had been randomly assigned. Standardization of the recovery environment, to minimize confounding or extraneous effects on the dependent variables, was achieved by having participants complete all conditions in identical laboratory settings, seated on a cycling ergometer positioned in front of a projector screen. All recovery interventions lasted for five minutes which has previously been found sufficient for green exercise effects to occur (Barton and Pretty, 2010, Wooller et al., 2015).

Participants in the rest condition sat quietly on the cycle ergometer in front of a grey screen. During exercise without simulated nature, participants cycled at 40% EPPO in front of a grey screen. In the three remaining simulated nature cycling conditions, participants cycled at 40% either a grey screen and the soundtrack of birdsong (simulated nature sounds only), video images of nature but no sounds played (simulated nature scenes only) or while both the simulated sounds and video images of nature were presented.

Nature sounds and images were taken from a commercially available exercise DVD (Fitness Journeys – Through the Forest, Isis Asia Ltd, Manila, Philippines) and projected onto a large screen positioned approximately 150 cm in front of the participant. Video image size was 180.3 cm x 92.5 cm and 126 cm from the ground. To ensure an environment where no other people or moving vehicles were present, the last five minutes of the DVD chapter “Redwoods and Oaks” was used. Playback speed simulated moving at approximately 20 $km.hr^{-1}$ which, together with the proximity of the screen to the participant, gave a realistic simulated cycling experience of forwards movement. This DVD and screen set up had been used in our laboratories in a previous study conducted (Wooller et al., 2015).

Dependent variables were captured immediately after each stress recovery intervention and then participants were asked to rest in silence in front of a grey projector screen while remaining seated on the cycle ergometer for a further 10 minutes. Dependent variables were recorded again at the end of the 10-minute rest period.

6.2.6 Psychological and Physiological Measurements

Mood State

The shortened “right now” version of the Profile of Mood States (POMS) questionnaire (McNair et al., 1971, McNair et al., 1992) was used to measure mood. This version uses a 30-point item, scored using a five-point Likert scale ranging from “0=Not at all” to “4=Extremely”. Subscale scores for Tension, Depression, Anger, Vigour, Fatigue and Confusion were calculated. Total mood disturbance (TMD) was then calculated by subtracting the vigour score for from the sum of the other five subscales. This gave an overall value for TMD between 112 and 282, giving an indication of overall mood with higher TMD suggesting lower mood. POMS was measured four times: i) baseline on arrival; ii) immediately after the stress induction task; iii) immediately after the recovery intervention and iv) after 10 minutes of rest.

Stress Measures

Stress was measured using the Perceived Stress Scale (PSS) (Cohen et al., 1983, Cohen and Williamson, 1988). PSS comprises ten statement items to measure an individual’s self-appraisal of how potentially stressful their life is (Cohen and Williamson, 1988). A modified version of the ten item PSS was used, in accordance with (Rogerson et al., 2015), to measure 'right now' state measurements of perceived stress. Item statements such as 'In the last month, how often have you been upset because of something that happened unexpectedly?' was edited to say 'I feel upset', with an accompanying instruction asking participants to 'indicate how you feel right now, at this moment'. On the original PSS responses were made using a Likert scale scored from 0 – 'Never' to 4 – 'Very Often'. The modified PSS used descriptors instead from 0 – 'Strongly Disagree' to 4 – 'Strongly Agree'. The range of aggregated scores was 0-40 with higher scores indicate a greater level of stress. PSS was administered at the same time points as POMS described above.

Heart rate and blood pressure measures

Heart rate (HR) and blood pressure (BP) were recorded at baseline and throughout the stressor using a Mobil-O-Graph 24h PWA Monitor (I.E.M. GmbH, Stolberg, Germany) to establish physiological. The recorder was set to measure HR and BP every two minutes, the minimum time interval available, (only data for the last 30 seconds of the stressor was used).

6.2.7 Statistical analysis

A manipulation check was carried out using a series of mixed two-way (5x2) ANOVAs to test whether the stress induction task had actually provoked negative changes in heart rate, blood pressure, mood and perceived stress as intended. The between-subjects factor was the recovery condition participants were assigned to, and the within-subjects factor was the measurement trial (pre- versus post-Trier Social Stressor measurement).

Total mood disturbance and PSS changes following the 5 minute stress recovery intervention and 10 minute rest period were analysed using mixed two-way (5x3) ANOVAs. The between-subjects factor was the recovery condition participants were assigned to, and the within-subjects factor was the measurement trial (post stress induction task, post stress recovery intervention and post 10 minutes recovery). Two-way (5x3) ANCOVAs, using baseline scores as a covariate, were used to examine mood and PSS changes once individual variation in acute stress responses had been controlled for.

An alpha level of 0.05 was used to indicate statistical significance in all ANOVA and ANCOVA tests and where sphericity assumptions were violated, Greenhouse-Geisser outcomes are reported as indicated by adjusted degrees of freedom. Significant interactions were followed up using post-hoc paired samples *t*-tests separately for each group to examine changes in mood and perceived stress before and after the recovery intervention, and after the 10 minute rest recovery period. A Bonferroni corrected alpha level of 0.013 was used to indicate significance. Effect sizes are reported as eta-squared (η^2) and partial eta squared (η_p^2). All data analysis was conducted using SPSS v 24 (IBM Inc, New York).

6.3. Results

6.3.1 Missing Data Imputation

Of the 50 participants, three (6%) had missing data. Total mood disturbance data for all four trials were complete, however among the PSS data there was one response missing from the post stress induction trial and two responses missing from the post recovery intervention trial equating to total missing PSS data of 1.5% (3/200).

Missing items were filled using iterative Markov Chain Monte Carlo multiple imputation methods incorporating linear regression to scale variables using a maximum of 10 iterations. The imputation model was constrained to produce integers only within the possible PSS minimum and maximum score range of 0 to 40 respectively, ensuring the imputed values corresponded with the PSS response scoring system. All missing data was resolved, and the resultant imputed dataset was used for all further analysis.

6.3.2 Manipulation check of the Trier Social Stress Test

The Trier Social Stress test provoked changes in heart rate ($F_{1,42}$= 29.7, P<0.0001, η_p^2 = 0.41); systolic blood pressure ($F_{1,42}$= 44.4, P<0.0001, η_p^2 = 0.51); diastolic blood pressure ($F_{1,42}$= 97.3, P<0.0001, η_p^2 = 0.70); TMD score ($F_{1,45}$= 33.0, P<0.0001, η_p^2 = 0.42); and PSS score ($F_{1,43}$= 47.2, P<0.0001, η_p^2 = 0.49). As indicated in Table 1, all dependent variables significantly decreased, apart from TMD which increased (i.e. a decrease in mood) ($P< 0.001$). This indicates that a raised state of acute stress had been induced as intended.

6.3.3 Recovery of Total Mood Disturbance

A two-way (5x3) ANOVA revealed an interaction effect between the intervention group and post stress task trial changes in TMD. This was accompanied by a trial main effect but no group main effect. Controlling for baseline TMD using a two-way (5x3) ANCOVA, produced a similar strength group-by-trial interaction however the trial main effect, although still significant, was diminished. Statistical outcomes are reported in Table 6.2.

Post-hoc analyses showed reductions in TMD after 5 minutes of cycling among the nature sound group (t_9=4.4, P=0.001, η^2=0.68, 95%CI=16.2-51.0), nature video group (t_9=5.4, P<0.0001, η^2=0.76, 95%CI=16.4-40.2) and the combined nature sounds and video group (t_9=2.9, P=0.009, η^2=0.49, 95%CI=7.8-60.2). Over a subsequent 10 minute resting recovery period, there was no further significant TMD change among the sound group (t_9=-0.8, P=0.222, η^2=0.07, 95%CI=-17.2-8.2), video group (t_9=-1.2, P=0.136, η^2=0.13, 95%CI=-9.7-3.1) or combined sound and video group (t_9=0.2, P=0.43, η^2<0.01, 95%CI=-11.3-13.4). There was no significant TMD change in the exercise only group or the rest group following the initial 5-minute recovery intervention period, however compared to the post-stressor measurements the exercise only group did exhibit lower TMD over a subsequent 10 minute resting recovery period (t_9=3.2, P=0.006, η^2<0.53, 95%CI=4.0-23.6). Mean changes in TMD are given in Table 6.1 and presented in Figure 6.1A.

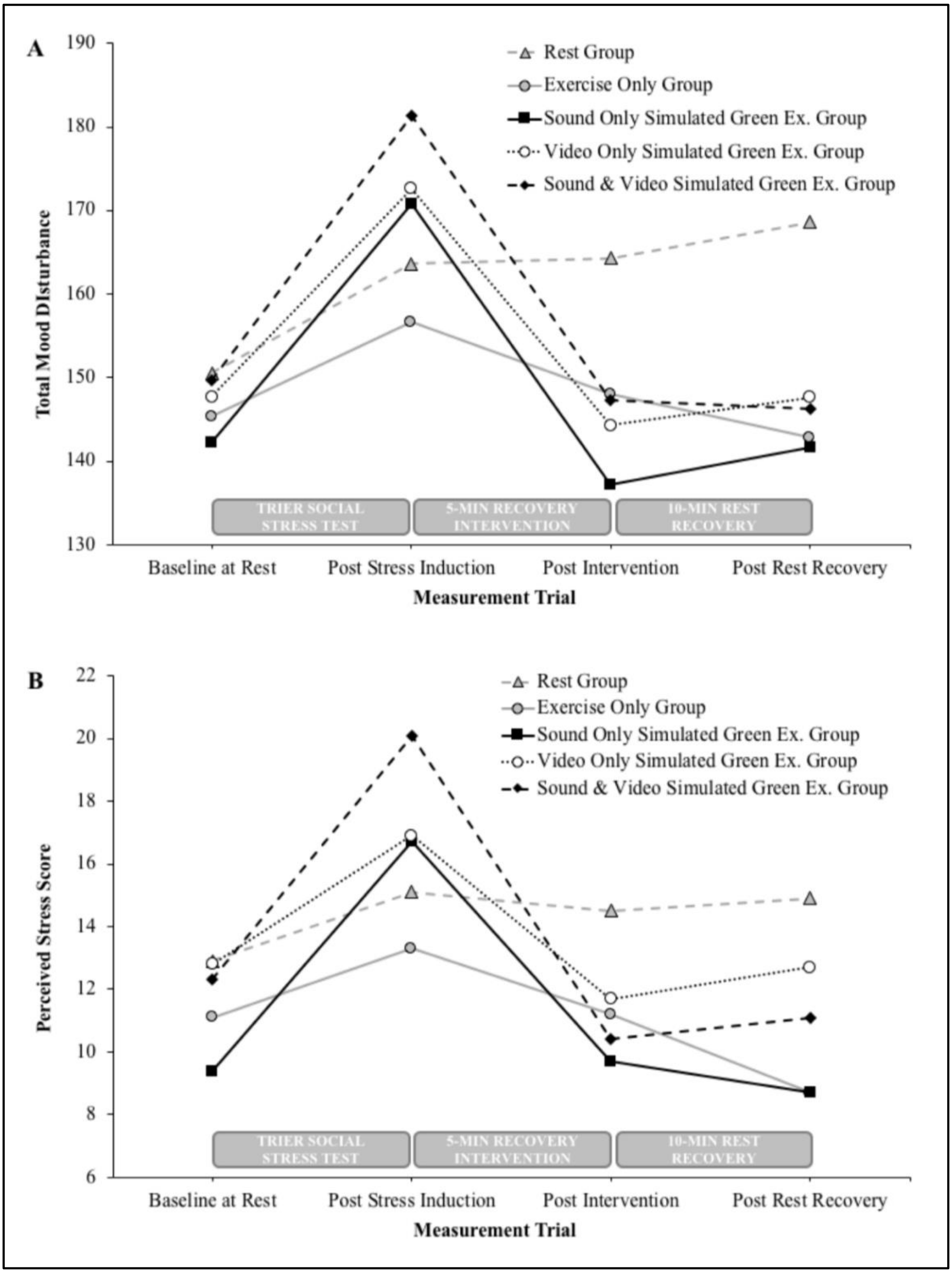

Figure 6.1. Between group changes in total mood disturbance (A) and perceived stress (B) following the stress induction task, 5-minute recovery intervention and 10-minute resting recovery.

Table 6.1. Changes in Total Mood Disturbance and Perceived Stress following the stress induction task, 5 minute recovery intervention and 10 minute resting recovery.

	Baseline	Post Stressor		Post Intervention		Post 10-minute Rest Recovery	
	Absolute Values	Absolute Values	Δ from Baseline	Absolute Values	Δfrom Post Stressor	Absolute Values	Δ from Post Stressor
Total Mood Disturbance							
Rest	150.5±19.8	163.6±28.7*	13.1±30.4	164.3±29.6	0.7±12.4	168.6±32.4	5.0±14.5
Exercise Only	145.3±19.6	156.6±26.4*	11.3±14.0	148.0±25.2	-8.6±16.2	142.8±15.7†	-13.8±13.7
Sound Only	142.3±15.8	170.8±36.1*	28.5±24.1	137.2±13.2†	-33.6±24.3	141.7±21.4†	-29.1±25.0
Video Only	147.7±13.1	172.6±23.9*	23.0±16.4	144.3±12.0†	-28.3±16.7	147.6±15.4†	-25.0±18.5
Sound & Video	149.6±18.4	181.3±36.9*	34.6±43.1	147.3±16.3†	-34.0±36.7	146.3±20.5†	-35.0±24.9
Perceived Stress							
Rest	12.9±5.7	15.1±6.7*	2.3±5.2	14.5±6.7	-0.6±4.6	14.9±7.6	-0.2±4.2
Exercise Only	11.1±8.4	13.3±8.0*	3.2±3.4	11.2±8.1	-2.6±4.1	8.7±7.1†	-4.6±3.0
Sound Only	9.4±5.8	16.7±10.1*	6.6±7.9	9.7±5.6†	-7.1±6.8	8.7±6.3†	-8.0±9.2
Video Only	12.8±4.3	16.9±2.5*	4.1±4.1	11.7±1.9†	-5.2±2.9	12.7±2.3†	-4.2±3.8
Sound & Video	12.3±3.4	20.1±4.1*	3.2±5.4	10.4±4.7†	-8.4±8.1	11.1±4.3†	-7.7±6.7

Note: * indicates a significant increase post-stressor compared to baseline (P<0.0001); † indicates significant reduction compared to post-stress induction outcomes. All outcomes reported as mean ± 1 standard deviation.

Table 6.2. Effect differences in post intervention TMD and PSS outcomes when baseline stress has (ANCOVA) and has not (ANOVA) been controlled for.

	Total Mood Disturbance				PSS			
	F	*(df)*	*P*	η_p^2	*F*	*(df)*	*P*	η_p^2
Trial Main Effects								
ANOVA	38.0	(1.6, 70.3)	<0.0001	0.46	36.0	(1.6, 71.6)	<0.0001	0.45
ANCOVA	7.0	(1.5, 68.3)	0.004	0.14	0.3	(1.6, 70.8)	0.76	0.01
Group Main Effects								
ANOVA	0.9	(4, 45)	0.50	0.07	0.9	(4, 45)	0.46	0.08
ANCOVA	0.4	(4, 44)	0.78	0.04	0.7	(4, 44)	0.60	0.06
Trial-by-Group Interactions								
ANOVA	4.1	(6.2, 70.3)	0.001	0.27	4.6	(6.4, 71.6)	0.0004	0.29
ANCOVA	4.0	(6.2, 68.3)	0.002	0.27	4.8	(6.4, 70.8)	0.0002	0.31

Non-integer degrees of freedom (*df*) values indicate use of Greenhouse-Geisser outcomes. Partial eta-squared (η_p^2) effect sizes are reported.

Table 6.1

6.3.4 Recovery of Perceived Stress

A two-way (5x3) ANOVA revealed an interaction effect between the intervention group and post stress task trial changes in PSS. This was accompanied by a trial main effect but no group main effect. Controlling for baseline PSS using a two-way (5x3) ANCOVA, produced a similar strength group-by-trial interaction however the trial main effect, although still significant, was diminished. Statistical outcomes are reported in Table 6.2.

Post-hoc analyses showed reductions in PSS after 5 minutes of cycling among the nature sound group (t_9=3.2, P=0.005, η^2=0.54, 95%CI=2.1-11.9), nature video group (t_9=5.8, P<0.0001, η^2=0.79, 95%CI=3.2-7.2) and the combined nature sounds and video group (t_9=4.5, P=0.001, η^2=0.69, 95%CI=4.8-14.6). Over a subsequent 10 minute resting recovery period, there was no further significant PSS change among the sound group (t_9=0.7, P=0.248, η^2=0.05, 95%CI=-2.2-4.2), video group (t_9=-1.3, P=0.115, η^2=0.16, 95%CI=-2.8-0.8) or combined sound and video group (t_9=-0.7, P=0.26, η^2=0.05, 95%CI=-3.1-1.7). There was no significant PSS change in the exercise only group or the rest group following the initial 5 minute recovery intervention period, however compared to the post-stressor measurements the exercise only group did exhibit lower PSS (t_9=4.8, P=0.001, η^2<0.72, 95%CI=2.4-6.8). Mean changes in PSS are given in Table 6.1 and presented in Figure 6.1B.

6.4 Discussion

A key finding of this exploratory study is that all variations of simulated green exercise were more effective than both rest and indoor cycling at recovering from an episode of induced acute stress. A further, important contribution this study makes, is to extend our understanding of the sensory basis of green exercise, a critical early step in trying to move towards more explanatory, mechanistic models. Since the senses are first in the cognitive information processing cascade, an important finding of the present study is that green exercise simulations involving visual feedback during cycling appear to have the strongest impact on mood and perceived stress recovery.

It was also found that the positive states of recovery observed in all green exercise conditions, and to a lesser extent in the non-green exercise condition, were preserved during a subsequent 10-minute rest period.

6.4.1 Green Exercise and Stress Recovery

The method of inducing an acute stress response that we used was effective as indicated in the significant increases in heart rate, blood pressure, mood disturbance and perceived stress. Inducing acute stress in this way is an important development in green exercise research because it carries high ecological validity in the sense that, owing to the complex array of stressors prevalent in contemporary society (HSE, 2017, MHF, 2018), it is not uncommon for individuals to frequently experience sudden episodes of intense stress. In this context, our findings that green exercise facilitated recovery of mood and perceived stress quicker compared to those resting or exercise alone, has several important implications.

The first is that, notwithstanding the known barriers to readily accessing natural environments (Dahmann et al., 2010, Sister et al., 2010, Jennings et al., 2012), green exercise is an option that individuals may choose to quickly and effectively cope with stress. Consistent with previous findings (Faber Taylor and Kuo, 2009, Barton and Pretty, 2010, Brown et al., 2013), we also found that green exercise was effective after just 5 minutes which adds to its viability as a coping strategy, particularly among those for whom the availability of time is a contributory stressor. For instance, those working in stressful environments with limited time to break such as teachers, drivers, construction workers, health professionals and many others.

The second important implication is that, as previously suggested (Barton and Pretty, 2010, Thompson Coon et al., 2011), our results indicate that experiencing nature can further enhance the psychological effects of exercise. Specifically, we observed improvements in TMD and PSS immediately following simulated green exercise conditions that were of a magnitude not seen in the exercise only condition. It is not that exercise is not effective but rather, as illustrated in Figure 6.1, seems to have a more gradual recovery course compared to the apparent immediate effects of green exercise. After only 5 minutes of green exercise, mood and perceived stress had, fallen back to baseline levels with just one exception, perceived stress in the simulated nature sound condition (Table 6.1). Interestingly, there appears to be a continued downward trend in both TMD and PSS in the 10-minute post-intervention suggesting a longer time period following the intervention should be explored, to better understand the enduring benefits of a single exposure to green exercise.

Controlling for variations in baseline mood and perceived stress only slightly dampened the interaction between recovery intervention and therapeutic effects (Table 6.2), and the post hoc analysis revealed very high effect sizes for all green exercise conditions. Consequently, we are able to report with high confidence, that green exercise was the best of all interventions we tested in recovering from acute stress.

6.4.2 Sensory Factors in Green Exercise and Stress Recovery

Green exercise undertaken outdoors has multi-sensory aspects (Franco et al., 2017). Simulating green exercise enabled exploration of the relative influence of visual and auditory stimuli on green exercise recovery from acute stress. Large effect sizes were found in all green exercise conditions indicating that nature simulations involving isolated auditory feedback, isolated visual feedback and combined audio-visual feedback are all effective in recovering from acute stress. Isolated visual feedback was found to have the greatest influence on mood and perceived stress, with very large effect sizes of >0.75 measured in both instances. This is not surprising given that vision is considered to be the dominant sense, as demonstrated in classic studies of the ventriloquist effect (Thurlow and Jack, 1973, Warren et al., 1981) and McGurk effect (McGurk and MacDonald, 1976a). Studies exploring the benefits of nature have mainly focused on visual aspects (Franco et al., 2017), however, our previous study that occluded nature stimuli found removal of sound to have the greatest impact on mood in comparison to removal of visual cues (Wooller et al., 2015).

In the current study, what is less clear is why the green exercise effect for vision alone was stronger (according to effect size) than combined audio-visual simulation of nature. Counterintuitively, it appears that the compound effects of audio-visual simulation are not as strong a visual input alone. This is unexpected given that audio-visual simulation is arguably more realistic than those simulation involving isolated audio or visual sensory inputs. A potential explanation might be found in the known complexities of cross-modal interactions on perception (Shams and Kim, 2010). Auditory emotional cues have, as the net result of competing task-relevant emotional priming and divided audio-visual attention demands, been found to enhance the processing of target visual information (Zeelenberg and Bocanegra, 2010). In the context of the green exercise simulations used in our study, the resultant effects on mood and perceived stress may therefore be due to the extent to which demands on attention compete with the cues from other senses. Since limited attentional capacity is divided in the audio-visual simulation, this might account for why the effect size was weaker compared to the isolated visual and auditory sensory conditions.

Another interesting and relevant body of work concerns cross-modal perceptual plasticity where enhanced sensory compensation has not only been found in those with visual or hearing impairments (Cecchetti et al., 2016) but also in those temporarily impaired, for instance through the use of a blindfold (Lee and Whitt, 2015). Cross-modal perceptual plasticity may in fact help explain why the effects were so strong in the isolated sensory conditions of our experiment, where auditory nature cues might have triggered relevant associated mental imagery of nature and vice-versa as previously reported (De Volder et al., 2001). What is clear is that, as our findings highlight, the sensory and perceptual mechanisms of the green exercise effect are most likely a product of complex cross-modal interactions and sensory compensatory processes that warrant further detailed investigation.

6.4.3 Future Directions

The current study contributes to the growing body of research that has shown the use of green exercise, as an intervention when either physical or psychological systems have been negatively affected, to be a beneficial factor in recovery (Tsunetsugu et al., 2007, Barton and Pretty, 2010, Thompson Coon et al., 2011, Gladwell et al., 2013). It also adds to the previous research into the mechanisms of green exercise effect by identifying the role of individual and combined senses (Alvarsson et al., 2010b, Saadatmand et al., 2013, Aghaie et al., 2014, Rogerson and Barton, 2015, Wooller et al., 2015). We suggest that the use of nature sounds and sights in conjunction with exercise may well promote the recovery of TMD and PSS after a stressor. This could aid in the development of cost-effective stress reducing strategies both in the workplace and personal life. It is important, however, to establish in future studies how long the effects may be sustained, what constitutes the best “stimulus” for stress recovery and who might benefit. Future study designs should also consider the level of connectedness to nature participants have prior to starting the study (Capaldi et al., 2014, Mayer and Frantz, 2004). This would further current understanding of how different individuals may benefit from green exercise participation. Certainly, future green exercise studies should include exploration of the use of virtual reality as it can offer more immersive experiences than currently achieved within current laboratory studies, but still allows control of confounding factors. Multi-sensory and non-sensory elements should be included where possible. Further, green exercise should be conducted in “real” natural spaces, with different duration and types of exposure e.g. including level of engagement with nature, in a range of different cohorts. Outcome measures should be recorded for over 24 hours.

6.5 Conclusions

Exercise combined with nature, in whole or in part, can facilitate recovery of mood and perceived stress after an acute psychological stressor. The results indicate that exercise with nature sounds, nature visual or exercise with both nature sounds and visual are better for recovery from an acute stressor than rest or exercise alone, as shown by measures taken immediately post intervention and ten-minutes post intervention. Future work is required to explore the importance and mechanisms of each of the senses during exercise in contributing to improvements in TMD and PSS following a stressor. Overall, these results indicate that, environmental exercise settings which include nature sounds, visual nature or nature sounds with visual nature should be considered when using of exercise as a recovery from acute psychological stress and could be restorative of positive emotions which may help to buffer stress.

Chapter 7

Discussion

7.1 Summary

The main aim of this thesis was to address the gaps in current literature that relate to the underlying exteroceptive influences of green exercise, using robust testing methods. As there is currently minimal research in this area relating to green exercise it was identified as an important area of research (Chapter 1). The experimental chapters sought to do this using rigorously controlled testing protocols within a laboratory setting. Several overarching questions were presented to guide the research:

1a. When presented a choice of nature and urban images what will individuals choose to look at?

1b. Will this choice change with exercise intensity?

These are important questions because they would identify whether or not natural environments would be a preferred choice of visual stimulus and what impact exercise intensity has on that choice? This is explored in chapter 2, and is the first study to offer a choice of natural or urban view whilst exercising.

2. What is the relative contribution of sight, sound and smell on the perceptual and psychological effects of green exercise?

This is an important question, as it aims to identify underlying exteroceptive influences of green exercise. This is the first time that individual senses have been isolated and examined in relation to green exercise (Chapter 4 & 5).

3a. Will green exercise have a greater effect on the recovery of mood and stress after an acute psychological stressor than exercise alone or rest?

3b. What are the relative contributions of the senses on recovery of mood and stress after an acute psychological stressor?

These are important questions because in modern society it is not uncommon for individuals to be exposed to periods of acute stress, and identifying key psychological components used in stress recovery will help in the development of strategies to buffer stress in everyday life (Chapter 6).

Chapter 2 addressed the questions of choice of view and the effects of exercise intensity on that choice. This was the first study to do this and is therefore unique to this thesis. Previous studies have examined the effects of nature and urban images combined with exercise (Berto et al., 2010, Brown et al., 2013). However, none of them have offered views of nature and urban images simultaneously. This study was specifically designed to offer that choice and further explore green exercise. The data was analysed for the following areas: when presented with a choice of nature or urban image what would be looked at first (primary gaze). How many times nature or urban elements within the images were looked at (frequency), And how long these elements were looked at (duration). This data was collected over three exercise intensities, Rest, 35% Heart Rate Reserve (HRR) and 70% HRR. Visual fixations were captured using An ABUS itracker smi hs-10 eye tracker (SensoMotoric Industries GmbH, Germany) and analysed using VideoCoder, developed by Dr Tom Foulsham at the University of Essex. This software allowed frame by frame analysis. Results indicated that there was a preference for viewing nature over urban images and that this preference increased with exercise intensity. The experience was not deemed to be immersive as participants also viewed other areas of the screen, floor and ceiling. It was felt that a more immersive experience needed to be developed.

Chapter 3 is concerned with the development of an immersive green laboratory which would provide as close a natural experience within an indoor setting as possible. The development of the green laboratory took 3 months and required extensive pilot testing. To our knowledge this is the first time a reusable green laboratory has been designed, with the specific mandate that it can be used for multiple studies at any time of year, and therefore the design and usage protocols for the green laboratory are unique to this thesis. Visual and auditory simulation were provided by a commercially available exercise DVD "Fitness Journeys - Through the Forest". The chapter "Redwoods and Oaks" depicted a small track winding through forest settings with the sounds of birdsong and breeze. The last five minutes of footage contained no other people or moving vehicles; playback speed of this chapter was designed to simulate a 20km.ph^{-1} cycle ride, which meant that it was ideal for simulating a leisurely ride through a natural landscape. The most challenging part of developing the green laboratory was developing a controllable and repeatable olfactory stimulation. Various methods were piloted, as described in chapter 3 before the use of aromatherapy oils was settled on. Pine oil gave a fresh natural smell in the lab and also complimented the video footage which depicted large areas of coniferous trees. Through extensive and rigorous pilot testing it was possible to create an environment within the laboratory that was as close to a natural environment as possible, that was controllable and repeatable at any time of the year.

Chapter 4. The aim of this study was to identify the relative contribution of sight sound and smell to green exercise effect. A protocol that oscillated between full sensory and occluded conditions whilst exercising at 40% of peak power output (peak power output was established at a previous visit) was used in conjunction with standardised tests for mood, Profile of Mood States (POMS), shortened "right now" version (McNair et al., 1971, McNair et al., 1992), and exertion was recorded using Rating of Perceived Exertion (RPE) Borg 6-20 scale (Borg, 1970) and was administered as per standardised instructions (Borg, 1998). Heart rate (HR) was recorded and monitored using a Garmin 405 Forerunner commercial heart rate monitor. The hypothesis was that occluding visual sensory input of natural environments during exercise would have a greater diminishing effect on perceived exertion and mood compared to occlusion of the auditory and olfactory senses. Contrary to this hypothesis results indicated that blocking sound had the strongest effect on mood but these effects were virtually absent when vision was blocked.

Chapter 5. The aim of this chapter was to address limitations that had been raised in the study in chapter 4. It was deemed necessary to do this as the previous study was the first of its kind and we wanted to support the findings and strengthen our conclusions. These limitations were 1) the way in which sound had been occluded would have amplified internal sounds such as respiration and possibly heart rate. Both of which would have been unfamiliar sensations to participants and could therefore had an adverse effect on mood. 2) when vision was occluded the sounds of nature were still present. It was felt that due to this, participants may well have been able to visualise nature and thus be responsible for the minimal effects on mood that were seen in the results. A modified protocol was developed to address these limitations. This time, rather than occlude sound with external ear defenders, the sound was removed by switching off the computers speakers. This negated any amplification of internal sounds. Vision was still removed in the same way, the use of blacked out swimming goggles, but sound was also removed from the visual condition to prevent participants using the sounds of nature to internally visualise it. Results from this study support the previous findings. Sound removal had the strongest effect on mood and effects were again virtually absent in the vision and sound removed condition. Interestingly, mood did not change with Full sensory in the vision and audio removed condition. It may be that a ceiling effect of mood was reached in these participants. Therefore, it was felt that the psychological state of the individual should be changed prior to being exposed to green exercise. This could be done using a psychological stressor.

Chapter 6. This chapter explored the effects of green exercise on mood and perceived stress after exposure to an acute stressor. Results indicated that exercise with nature sounds, nature visual or exercise with both nature sounds and visual are better for recovery from an acute stressor than rest or exercise alone.

7.2 Significance of Findings

As has already been discussed in chapter 6, prolonged exposure to stress, due to the sustained physiological changes in response to psychological demands, is considered a risk factor of poor health (MHF, 2018). In the United Kingdom, around 12 million adults seek medical advice about their mental health each year, many relating to anxiety and depression, which are often associated with, or triggered by, high levels of stress (MHF, 2018). In relation to the global disease burden, mental ill-health is one of the largest factors, with depression the leading cause of disability (Vos et al., 2015).

Overall results in this thesis support previous research into green exercise

whilst exploring new areas of research. Of significant note is the role of nature sounds as a mechanism of green exercise effect, given that visual sensation is known to be a more dominant influence on perception that the other senses (Colavita, 1974, Hoegg and Alba, 2007, McGurk and MacDonald, 1976a). Also noteworthy was the results showing that exercise with individual or combined natural element is more beneficial to psychological recovery after an acute stressor than rest or exercise alone.

The experimental results in this thesis need to be explored further and incorporated into interventions and buffers against stress in daily life. These results could also guide governmental planning departments, when designing new living areas, making sure they incorporate adequate green space to assist with recovery from, and buffer against stress and stress related conditions.

7.3 Limitations

The limitations of the research chapters 2,4,5 and 6 are described in their respective discussion sections. There are, however, some overarching limitations to the thesis. Firstly, in each of the studies the participant sample size was small, n=10, for each intervention, and was primarily made up of students from the University of Essex. Although the results within this thesis support previous research into the benefits of green exercise, which to some ends justifies the decisions made, using a larger sample size from more diverse backgrounds would lend the results more strength and give a more complete picture in terms of population. Secondly, the term green exercise, refers to exercising in all forms of nature, however, throughout the thesis, images and video of nature only used green environments in summertime. Which although in line with previous research, such as Ulrich (1984) and Barton et al. (2012) does not explore exercising in autumn, winter or spring environments. Further, doesn’t explore other natural environments such as water based or blue exercise environments such as those researched by White et al. (2016), White et al. (2010). However, as researching each of these areas would have each been a thesis of their own, it would not have been practical to attempt to include them in this thesis. Thirdly the only exercise medium used within this thesis was cycling. Although this is a well-recognised exercise medium and has been used and validated in many research projects (Parry et al., 2012, Rogerson et al.,

2016) it did not allow for a comparison of results using other popular exercise modalities such as walking (Barton et al., 2009, Brown et al., 2014, Marselle et al., 2013) or jogging/running (Rogerson et al., 2015) Although the author of this thesis was involved in the latter study, it does not form part of this thesis.

7.4 Future Research

The initial research study in this thesis used eye tracking to establish preference of view nature or urban when exercising at various intensities. For this thesis, a static laboratory based system was used. However, the use of a mobile eye tracking system would allow for real world exploration. Future studies should utilise this technology and take research into the field using actual exercise modalities, walking, running, cycling rather than simulated. This would also allow data collection from participants preferred exercise environments as opposed to artificial environments and thus give far more empirical results.

The purposeful development of a green laboratory for research purposes is unique to this thesis. However, future researchers would benefit from a laboratory that is created on a far larger scale. The laboratory developed here was more than fit for purpose and was created within the time constraints available. A laboratory built utilising the core set up of the laboratory presented here, but placed in something like an established bio dome, would create a much more immersive experience and afford far greater research opportunities with interchangeable exercise modalities.

Future researchers should also consider the use of virtual reality suites. These have already been used by Annerstedt et al. (2013). However, they only used vision and sound in their green exercise experiment. There are systems available that can introduce smells into the virtual reality environment and thus produce a fully immersive experience for participants. From the results shown in the experimental chapters in this thesis it is clear that future research needs to be conducted to a greater extent in order to fully understand sensory influences on green exercise effect. In addition, sensory influences need to be explored to further test the symbiotic relationship between nature and exercise and the combined benefits to psychological recovery.

7.5 Conclusions

This thesis used a combination of exercise environment and psychological questionnaires to assess the relative contributions of sight sound and smell on mood and stress recovery. Using a series of unique studies, evidence has been provided for the senses as cognitive mechanisms for green exercise effect. Of specific importance is the revelation that sounds of nature have a prominent role. Evidence provided in this thesis, highlights the contribution of the senses of sight and sound to green exercise psychological effects and the benefits of green exercise in recovery from acute psychological stress.

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