Green exercise: Combined influence of environment and exercise to promote wellbeing

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Dedication

I dedicate my thesis to Ken Wall, my Grandad, an inspiration

He is not here to enjoy this success, but I enjoy the thought of sharing it with him

"That's the way to do it!"

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Abbreviations

ANOVA – Analysis of variance

ANCOVA – Analysis of covariance

bpm – beats per minute

CI – confidence interval

HRR – Heart Rate Reserve

kcal – kilocalories

MANOVA – Multivariate analysis of variance

POMS – Profile of Mood States

PSS – Perceived Stress Scale

RPE – Rating of Perceived Exertion

RSE – Rosenberg Global Self-Esteem Scale

TMD – Total Mood Disturbance

VO_2peakInt - intensity (speed and gradient) that elicited participants' VO_2peak

VO_2max - Maximum volume of oxygen

VO_2R – Reserve volume of oxygen

Summary

Exercise participation is linked to mental health and wellbeing. However, we need to identify optimal settings for promoting exercise-associated wellbeing outcomes, and for promoting exercise adherence. The literature suggests environmental settings may be important. The aim of this thesis was to rigorously test influences of environmental settings on exercise-related wellbeing outcomes. These over-arching research questions guided the experimental chapters: (i) is there an optimal green exercise environment for promoting wellbeing? (ii) When exercise is controlled, are findings consistent with previously reported psychological outcomes? (iii) Do environmental settings influence social outcomes of exercise or intentions to repeat exercise behaviours?

Via field-based sampling, Chapter 3 found large proportions of affective benefits were universally obtainable across four typical green exercise environments, and suggested that the processes component of green exercise warranted further investigation; however, this method lacked control. Chapter 4 used laboratory-based methodology to control exercise and isolate the visual environment; consistent with both theory and previous research, nature environments facilitated wellbeing-related attention restoration. However, this method did not provide an accurate multisensory experience, therefore lacking ecological validity. Chapter 5 investigated methodologies for controlling the exercise component, comparing wellbeing-related outcomes of indoor *versus* outdoor exercise. This was important because previous research had not rigorously controlled exercise, therefore potentially confounding its findings. Results for environment-related exercise differences and affective outcomes were inconclusive. Chapter 6 merged laboratory-based methods with the indoor *versus* outdoor exercise paradigm, ensuring control *and* ecological validity. Environmental setting did not influence perceived exertion or mood; green settings

promoted attention restoration and social interaction; for green exercise, social interaction predicted exercise intentions.

Green exercise promotes wellbeing improvements; environmental influences on affective outcomes may be contributed to by differences in exercise performed. Independent of exercise differences, green environments promote attention restoration and social interaction during exercise, which may in turn influence exercise intentions.

Chapter One: Introduction

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Elements of this chapter are published as a chapter within a book:

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* *

Green exercise is defined as engaging in ‘physical activities whilst being directly exposed to nature’ (Pretty et al., 2003, Pretty et al., 2005). The notion of green exercise has become an area of research interest over the last 15 years, building on the considerable existing literature reporting beneficial outcomes of physical activity, and of exposure to nature environments independently. Although various forms of green exercise activity have been performed for centuries (for example, in the form of farming), recent research has sought to measure the quantitative and qualitative outcomes that might be attained from such participation.

It has been suggested that this potentially synergistic combination of exercise and exposure to nature ‘could be used as a powerful tool to help fight the growing incidence of both physical inactivity and non-communicable disease’ (Gladwell et al., 2013). This introduction describes the concepts and current states of physical activity and psychological wellbeing in the UK. Next, it outlines influences of exercise and of exposure to nature environments on elements of psychological wellbeing. It then critically discusses existing literature in the area of green exercise. Topics addressed are those of psychological wellbeing (including measures of affective state), social experience, and physical activity behaviours.

1.1 CURRENT STATE OF PHYSICAL ACTIVITY IN THE UK

Physical activity can be defined as bodily movement produced by the contraction of skeletal muscle that requires energy expenditure in excess of resting energy expenditure. Exercise is a subset of physical activity that comprises planned, structured, and repetitive bodily movement, performed to improve or maintain one or more components of physical fitness (USDHHS, 1996, Sigal et al., 2004). Within the current thesis, the terms 'physical activity' and 'exercise' are used interchangeably.

We are in the midst of a global pandemic of physical inactivity that has already gathered momentum; physical inactivity is the fourth leading cause of death worldwide (Kohl et al., 2012). Physical inactivity costs the UK economy a total of £7.4 billion per year, £0.9 billion of which is via the National Health Service (Scarborough et al., 2011). As assessed by self-reported data, in England only 67% of men and 55% of women aged 16 and over meet the current UK government recommended physical activity guidelines of 150 minutes per week of moderately intensive physical activity, in bouts of ten minutes or longer, or 75 minutes per week of vigorous physical activity, or a combination of the two. Further, 26% of women and 19% of men are classed as inactive. In children aged 5-15, only 21% of boys and 16% of girls meet current guidelines for children and young people of at least one hour of moderately intensive physical activity per day (HSCIC, 2015b). However, self-reported data is often over-inflated, and the most up-to-date survey using objective measures found that as few as 6% of men and 4% of women met the Government's physical activity guidelines (HSCIC, 2015b). Factors that function as obstacles to physical activity include low motivational status, self-efficacy beliefs, negative learning history with exercising, lack of coping skills, and aversive environmental characteristics such as reduced access to physical activity facilities, high costs of training programs, low social and cultural support, and time barriers (Sherwood and Jeffery, 2000, Dalle Grave et al., 2010). For individuals, physical inactivity can increase risk of poor physiological health (such as cardiovascular disease, diabetes and some cancers) and aspects of mental wellbeing (such as stress, anxiety and depression) (Warburton et al., 2001, Warburton et al., 2006).

1.2 UNDERSTANDING AND DEFINING WELLBEING

There are three main approaches to mental wellbeing; namely those of hedonic wellbeing, eudaimonic wellbeing and positive psychological wellbeing. A hedonic approach considers an existence of '*subjective wellbeing'*, which encompasses evaluation of life in terms of satisfaction and balance between positive and negative affect (Keyes et al., 2002).

The hedonic perspective views 'subjective wellbeing' as a multi-dimensional construct, comprising moderately correlating, but independent components which include momentary feelings of positive affect and negative affect, and more considered cognitive components of life satisfaction and satisfaction within important domains (Diener et al., 2003, Carruthers and Hood, 2004, Diener et al., 2009, Gale et al., 2013).

Contrasting with this, a eudaimonic perspective considers individuals' '*psychological wellbeing'* as involving one's perception of engagement with existential challenges of life (Keyes et al., 2002). Eudaimonic wellbeing is based on individuals' feelings and appraisals of meaning and virtue (Waterman, 1993, Ryan and Huta, 2009, Hasnain et al., 2014). The eudaimonic approach primarily views wellbeing as related to one's feelings of self-actualisation, that is, self-fulfilment as a functioning individual (Maslow, 1954, Maslow et al., 1970, Deci and Ryan, 2000, Keyes et al., 2002). Self-determination theory suggests that wellbeing is related to fulfilment of three domains: competency, autonomy and relatedness (Deci and Ryan, 2000).

The positive psychological approach to wellbeing draws on elements of both the hedonic and eudaimonic perspectives (Sin and Lyubomirsky, 2009). Authentic happiness theory suggests components of the pleasant life (one which maximises pleasurable and positive experiences), the good life (individuals develop their strengths and virtues or signature strengths in activities that the individual enjoys and is passionate about), and the meaningful life (individuals apply their signature strengths in activities that contribute to the greater good, such as parenting, developing friendships or servicing the community) (Seligman, 2002, Norrish and Vella-Brodrick, 2008).

The current thesis does not commit to one view of wellbeing over others. However, measures of affect are used frequently, perhaps resonating most with the hedonic and positive psychological approaches. The terms 'wellbeing', 'psychological wellbeing' and 'affect' are all used throughout this thesis, somewhat interchangeably, to refer to the notion of psychological wellbeing in general rather than with the intention to align to one approach over others.

Wellbeing can be defined as the balance point between an individual's resource pool and the challenges faced, whereby individuals experience stable wellbeing when they possess the psychological, social and physical resources needed to meet a particular psychological, social and/or physical challenge. When individuals have more challenges than resources, the see-saw dips, along with their wellbeing, and vice-versa (Dodge et al., 2012) (Figure 1.1).

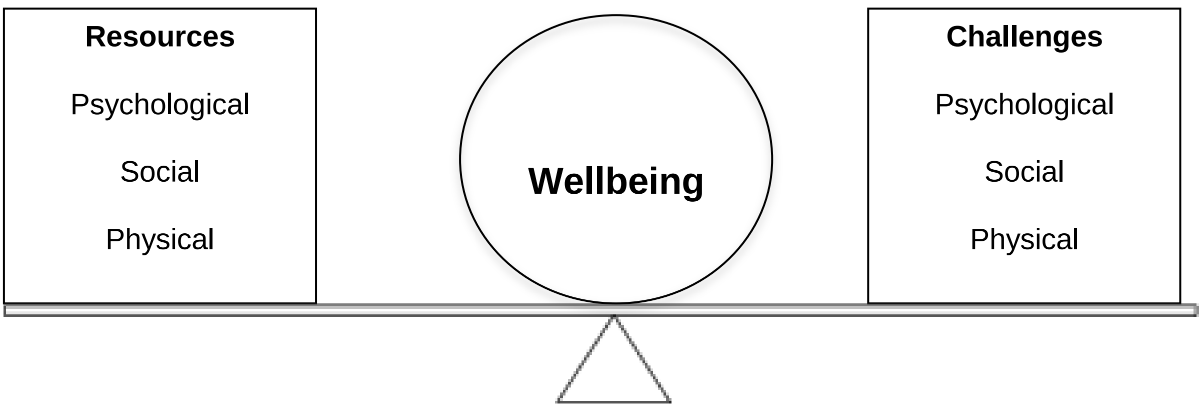


Figure 1.1 Dodge et al.'s definition of wellbeing

1.3 CURRENT STATE OF PSYCHOLOGICAL WELLBEING IN THE UK

The mental health sector is warning of a crisis (Gilburt, 2015). The last population-level survey of mental health in England found that 17.6% of the population aged 16-64 could be classified as experiencing at least one common mental health disorder within the past week (McManus et al., 2009). Further, increasing by 4.9% from 2013/14, 1,835,996 people were in contact with mental health services in 2014/15 (HSCIC, 2015a). Young people's mental wellbeing worsened between 2009/2010 and 2012/2013, and 18.0% of young people still currently report high levels of anxiety (Statistics, 2015). The number of people in the UK experiencing depression is due to rise to 1.45 million by 2026, with the cost of depression-related services in England rising 76% to £3 billion (although without assumptions regarding real unit prices and inflation, this figure would be approximately £2.1billion) (McCrone et al., 2008).

1.4 PHYSICAL ACTIVITY AND WELLBEING

Exercise and physical activity are associated with quality of life and a range of mental and physical health outcomes such as positive affect, mood states, and emotional, functional and spiritual elements of wellbeing (Lane and Lovejoy, 2001, Penedo and Dahn, 2005, Warburton et al., 2006, Reed and Buck, 2009, Pasco et al., 2011). Indeed, the evidence that regular physical activity has important and wide-ranging health benefits is overwhelming (Blair, 2009). The current section outlines influences of physical activity on outcomes of psychological health and wellbeing; namely, the outcomes of mood, affect and self-esteem.

Acute bouts of moderate-intensity (50–70% VO_2max) exercise enhance positive affect and ameliorate negative affect (McGowan et al., 1996, Yeung, 1996, Bartholomew et al., 2005). This can occur via a number of mechanisms. Exercise promotes secretion of beta-endorphins, which in turn promote positive affect (Daniel et al., 1992, Shamus and Cohen, 2009). Disparately, transient hypofrontality hypothesis suggests that exercise ameliorates negative affect via temporary inhibition of specific brain regions, in order to provide increases in motor cortex functioning during large-scale bodily motion (Dietrich and Sparling, 2004, Dietrich, 2006). It both reduces excessive neural activity in ventromedial pre-frontal cortex regions, thus reducing the relative imbalance between ventromedial pre-frontal cortex and dorsolateral pre-frontal cortex activities (which is associated with anxiety); and impairs activity of the amygdala, which itself is associated with negative affect (Dietrich and Sparling, 2004, Dietrich, 2006). Regular physical activity also promotes positive affect enhancement. Reed and Buck's (2009) meta-analysis of 105 studies identified a 10–12 week program of low intensity (~30% VO_2R), 30–35 min, 3–5 days per week to be optimal for improving positive-activated affect (Russell, 2003, Reed and Buck, 2009).

Physical activity functions to ameliorate and protect individuals from negative affect and future occurrence of depression (Dimeo et al., 2001, Dunn et al., 2005, Knubben et al., 2007, Mead et al., 2009, Rimer et al., 2012, Cooney et al., 2013, Mammen and Faulkner, 2013). One pathway by which physical activity influences psychological wellbeing and occurrence of depression is that of self-esteem. There are two ways in which this influence can occur. The vulnerability model suggests that low self-esteem contributes to depression, whereas the scar model states that depression erodes self-esteem (Beck, 1967, Zeiss and Lewinsohn, 1988, Coyne et al., 1998, Sowislo and Orth, 2013). Indeed, the vulnerability model and the scar model may not be mutually exclusive because both processes can operate simultaneously (Kuster et al., 2012). Nine-year and four-year longitudinal studies found that low self-esteem predicted depression symptoms, but depression did not predict self-esteem (Orth et al., 2009). Indeed, although the results of Franck and De Raedt (2007) suggest that the stability of self-esteem may be more predictive of vulnerability to depression than state of self-esteem, regression analyses by Orth et al. (2008) and a meta-analysis by Sowislo and Orth (2013) more directly support the vulnerability model. Interventions aimed at increasing self-esteem might be useful in reducing the risk of depression (Orth and Robins, 2013). The exercise and self-esteem model suggests a pathway by which exercise influences global self-esteem via physical self-esteem (Elavsky and McAuley, 2005, Elavsky et al., 2005, McAuley et al., 2005). Physical activity and self-efficacy influence each other, as well as the state of physical parameters of an individual, which in turn influence physical and then global self-esteems (see Figure 1.2).

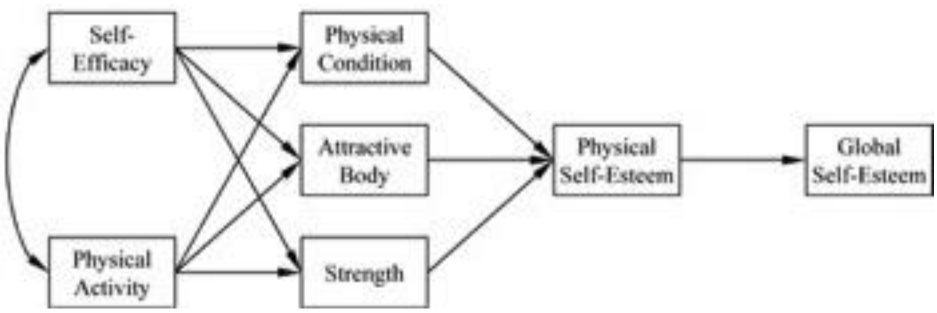


Figure 1.2 McAuley et al.'s revised Exercise and Self-Esteem Model (McAuley et al., 2005)

Contextualising the exercise and self-esteem model, social cognitive theory suggests that behaviour change results from links between behaviours, the environment (e.g., peer support), and psychosocial variables (e.g. self-efficacy and self-esteem) (Bandura, 1986b). There is a link between the psychological outcomes of acute physical activity participation and behaviour change towards regular physical activity. If acute affective exercise outcomes influence longer-term motivation for and adherence to exercise behaviours (Williams et al., 2008, Kwan and Bryan, 2010a, Kwan and Bryan, 2010b, Ekkekakis et al., 2011), this has important implications for improving UK activity and wellbeing patterns. Moderate intensity physical activity improves self-esteem and affective state; however, higher intensity activity can be detrimental (Ekeland et al., 2005, Peluso and Andrade, 2005, Ekkekakis et al., 2011). Further knowledge regarding the optimal type, intensity, frequency and duration of exercise may further support its potential clinical application for improving psychological wellbeing (such as instances of anxiety and depression) (Ströhle, 2009). Understanding the preferred setting that may promote greater adherence to regular exercise participation is also imperative.

1.5 NATURE ENVIRONMENTS AND WELLBEING

Within the literature, references to environments that comprise features and characteristics of nature vary in their terminology. Within urban settings, parks are an example of what may be referred to as ‘greenspace’ – a term frequently used within government planning and policy, which can often also be deemed to mean that the park contains elements of nature, such as trees, grass or river. That is, the term ‘greenspace’ does not refer directly to the existence of the colour green. Indeed, parks, as well as many other greenspaces, can be considered to be ‘nature-based environments', in that the predominant features of these places are those of nature. The term 'nature environment' is also sometimes used. Most frequently, this term suggests the described environment to contain relatively fewer man-made features, or perhaps to be less obviously or less directly managed or maintained by humans. Within the current thesis, the terms 'nature environment', 'nature-based environment' and 'greenspace' are used somewhat interchangeably.

A growing body of evidence shows that exposure to nature has positive health and wellbeing benefits (Mayer et al., 2008, Bowler et al., 2010, Van Den Berg and Custers, 2010, Van den Berg et al., 2010, Thompson Coon et al., 2011, Lee et al., 2012). Individuals have both lower mental distress and higher wellbeing when living in urban areas with more greenspace compared to less greenspace (White et al., 2013). Indeed, there is a positive relationship between levels of neighbourhood greenspace and mental health and wellbeing (De Vries et al., 2003, Sugiyama et al., 2008, Richardson et al., 2013, Romagosa et al., 2015). A direction of causality might be inferred for this literature, as for individuals tracked over a 5-year period within which they moved house between the second and third years, those who moved house from a 'less green' to a 'more green' area showed significantly improved mental health in the three post-move years, compared to pre-move years (Alcock et al., 2014). However, this study could not confidently confer causality, as the models presented did not control for all potential time-varying factors.

Acute influences of exposure to nature on affect and wellbeing have also been reported. Often compared with urban or 'built' environment types, simple exposure to nature environments is psychologically restorative (Chang et al., 2007) and has beneficial influences on individuals' emotions (Ulrich, 1979, Ulrich et al., 1991, Mayer et al., 2008) and ability to reflect on life problems (Mayer et al., 2008). After viewing a frightening movie, viewing a video of a nature environment elicits greater improvements in mood and concentration than does viewing a video of an urban environment (Van den Berg et al., 2003). Affective influences of nature environments have also been reported in relation to physical activity in nature environments; however, these findings are outlined in a latter section of this chapter. Individuals who report high negative mood are more likely to also select a natural place, rather than other places, as their favourite place (Korpela, 2003). This suggests that individuals are innately aware of the mood-enhancing and restorative properties of natural environments, and might utilise them accordingly. These findings suggest that individuals' desire for contact with nature is not just the result of a romanticised view of nature, but is an important adaptive process, which appears to aid optimum functioning (Van den Berg et al., 2007). Indeed, short-term recovery from stress or mental fatigue, and long-term overall improvement of health and mental wellbeing, are among the most frequently identified health-related influences of simply viewing nature (Velarde et al., 2007).

The discussed research findings indicate direct psychological benefits of simply being exposed to nature environments. This is disparate from the previously outlined evidence that physical activity can also acutely promote wellbeing improvements and recovery from stress (Daniel et al., 1992, Shamus and Cohen, 2009). There may therefore be reason to expect that selecting nature environments as settings for exercise participation might maximise wellbeing outcomes of that exercise.

Theoretical explanations for the reported influences of nature environments on human psychological wellbeing have been suggested. The following sections briefly outline these theories.

1.5.1 Biophilia hypothesis

For many thousands of years, humans have had regular contact with nature; from their roles as hunter-gathers and farmers to more recent times, actively seeking natural spaces to reduce the stress of modern life (Fawcett and Gullone, 2001). Biophilia hypothesis is the notion that humans experience an innate affiliation with the natural world and other living things within it (Wilson, 1984, Kellert and Wilson, 1993).

Biophilia hypothesis suggests psychological and behavioural manifestations of a biophillic disposition. A review of findings from the field of environmental psychology found that humans are aesthetically attracted to natural environmental content (Joye, 2007). However, it is contended that (i) the notion of biophilia is open to various and even conflicting interpretations; (ii) findings that support biophilia hypothesis can often be accounted for by alternative hypotheses; and (iii) the evolutionary reasoning behind the biophilia hypothesis tends to be unclear, and sometimes even inaccurate (Joye and De Block, 2011). Natural places are over-representatively chosen as a favourite place and under-representatively mentioned among unpleasant places (Korpela et al., 2001, Dopko et al., 2014). Over a period of 10-months, whereas extensively managed natural settings (mainly urban woodlands) and waterside environments are most commonly reselected as individuals' favourite places, indoor and outdoor urban environments had the lowest stability as favourite places (Korpela et al., 2009). However, as the study surveys were administered in October and August, participants' selection of favourite places might have been influenced by the season (i.e. winter, summer) and the weather at the time of responding. Whilst research seems to support the biophilia hypothesis (Kellert, 1993, Kellert and Wilson, 1993, Kahn, 1997, White and Heerwagen, 1998, Fawcett and Gullone, 2001, Joye, 2007, Grinde and Patil, 2009, Windhager et al., 2011), it is unclear exactly how it might work (Kellert and Wilson, 1993), which genetic mechanisms are involved and whether they are affected by behaviour or living environment. That not all individuals demonstrate preference for nature environments suggests that individual differences exist, and therefore, responses to nature environments vary between individuals.

Exposure to nature environments has a positive effect on human functioning and can reduce stress (Joye, 2007). This is of importance to wellbeing, as elements of wellbeing and perceived stress are inversely related (Schiffrin and Nelson, 2010, Teh et al., 2015). Stress Reduction Theory and Attention Restoration Theory suggest ways in which exposure to and interactions with nature environments can enhance psychological functions. The following subsections outline these theories.

1.5.2 Stress Reduction Theory

Stress reduction theory, partly derived from psycho-evolutionary theory (Plutchik, 1980a, Plutchik, 1980b), suggests that, based on historical human-environment interactions and relationships, when there is an absence of threat, nature environments invoke positive primary emotional responses, which promote recovery from stress (Ulrich, 1981, Ulrich, 1984, Ulrich et al., 1991, Herzog and Strevey, 2008, Ewert et al., 2011). This is important for wellbeing as primary emotions are related to secondary and tertiary emotions (Plutchik, 1980a), which can also be termed 'affect'. As previously outlined within this chapter, affective state is an important component of wellbeing. Natural environments provide positive distractions from daily stresses and invoke feelings of interest, pleasantness and calm, thereby reducing stress symptoms and promoting positive affect (Ulrich, 1981, Ulrich, 1984, Ulrich et al., 1991, Herzog and Strevey, 2008, Ewert et al., 2011). Studies supporting this theory report reductions in stress measures, such as blood pressure, heart rate and stress hormones, following exposure to nature (Ulrich et al., 1991, Hartig et al., 2003, Laumann et al., 2003, Herzog and Strevey, 2008). The sympatho-adrenal medullary axis and the hypothalamic-pituitary-adrenal axis function as a psychophysiological pathway by which emotional responses influence physiological stress indicators (Cannon, 1935, Selye, 1956). In line with stress reduction theory, influences of nature on psychological stress can be measured in terms of its influence on the autonomic function and other physiological indicators of stress, such as skin conductance. Whereas the sympathetic nervous system is involved mainly in activation, such as in response to stressors, the parasympathetic system functions to restore the body to a state of relaxation (Andreassi and Filipovic, 2001). After viewing a psychologically stressful video, viewing scenes of nature improves recovery of parasympathetic activity, compared to viewing urban scenes (Ulrich et al., 1991). Similarly, viewing nature scenes prior to a stressor also improves autonomic recovery (Brown et al., 2013). Viewing still images of natural scenes elicits lower heart rate compared to a baseline measure, than do urban scenes (Laumann et al., 2003). Concurrent with these shorter-term influences, quantities of living-area greenspace predict differences in the circadian cycle of the stress hormone cortisol, in a manner consistent with the notion of nature functioning to reduce stress (Thompson et al., 2012). Furthermore, compared to classrooms without windows or with windows that offer views of built space, classroom views to green landscapes increase students' recovery from stressful experiences (Li and Sullivan, 2016).

1.5.3 Attention Restoration Theory

Directed attention is the effortful cognitive ability to avoid being distracted by competing stimuli (Itti et al., 2005, Kaplan and Berman, 2010). Brain regions associated with processes of mental effort, attention and mediation of cognitive control can fatigue over time (Kaplan and Berman, 2010). This depletion of directed attention is termed 'directed attention fatigue'.

Building on James' notion of effortful, voluntary attention (1892), attention restoration theory proposes that urban environments are filled with stimuli that demand relatively great dorsal- anterior-, dorsal-frontal- and parietal cortical structure-mediated top-down attentional processing (Corbetta and Shulman, 2002, Fan et al., 2005, Kaplan and Berman, 2010), therefore drawing on and gradually depleting the resource of directed attention (Kaplan, 1992, Kaplan, 1995, Berman et al., 2008). Attention restoration theory further suggests that particular environmental characteristics that are often prevalent in nature environments promote use of another mode of attention, namely 'involuntary attention', sometimes termed 'effortless attention'. Using involuntary attention – which does not involve mental effort and which is associated with ventral frontal-, temporal cortex- and subcortical structures-mediated bottom-up processing (Kaplan, 1995, Corbetta and Shulman, 2002, Fan et al., 2005, Berman et al., 2008, Kaplan and Berman, 2010) – decreases use of directed attention. This provides opportunity for restoration of depleted attentional resources (Kaplan and Berman, 2010, Rogerson and Barton, 2015).

The restorative characteristics described by attention restoration theory to be prevalent in many nature environments are those of 'being away' (being in an environment that does not require use of brain structures fatigued via overuse), 'extent' (being rich enough to constitute being an environment and engage an individual's mind, thus allowing psychological distance from tasks requiring directed attention), 'fascination' (containing features of 'soft fascination' which hold attention with little effort, freeing this capacity for other cognition), and 'compatibility' (how compatible an environment is with an individual's inclinations, and the ease of functioning) (Kaplan, 1995).

Attention restoration theory suggests that affective improvements occur in conjunction with attention restoration, whereby attentional fatigue increases the likelihood of and manifests in the form of negative affective states, for example, heightened negative emotions, irritability, impatience and worsened task performance (Kaplan and Kaplan, 1989, Hartig et al., 1991, Kaplan, 1993, Kaplan, 1995, Berto, 2014).

Influences of nature environments on affective state and psychological wellbeing have been outlined already within this chapter. Additionally, to a significantly greater extent than viewing urban environments, viewing nature environments improves performance on measures of directed attention, namely the Digit Span Backwards test and attention networking task (Berto, 2005, Berman et al., 2008). Concurrently, Ottosson and Grahn (2005) reported that in elderly individuals, compared to time spent resting indoors in their favourite room, spending time in a garden outside the geriatric home in which they live leads to improved Digit Span Backwards task performance. Nature views or the presence of plants within the workplace have been demonstrated to reduce mental fatigue (Kaplan, 1993, Berto, 2005, Raanaas et al., 2011). Complementing the reported acute influences of nature environments on attention (Berto, 2014), longer-term, more general associations between nature environments and attention-related outcomes have also been reported. Compared to classrooms without windows or with windows that offer views of built space, classroom views to green landscapes promote significantly better performance on tests of attention (Li and Sullivan, 2016). When controlling for student socio-economic status, ethnicity, building age, and enrolment size, views from school classroom and cafeteria windows which contain greater quantities of natural features were associated with better standardized test scores, higher graduation rates, higher percentages of students planning to attend college, and lower occurrences of criminal behaviour (Matsuoka, 2010). Here, it might be proposed that the increased directed attentional capacity resulting from nature exposure might allow for learning experiences in higher frequencies and of greater quality. Affective restoration has been shown to account for a substantial proportion of the preference for natural over built environments (Van den Berg et al., 2003). However, it is notable that restoration of attention has not yet been shown to mediate improvements in affective state.

Research findings that evidence the relationship between exposure to nature environments and recovery from physiological stress and mental fatigue are consistent with both Stress Recovery Theory and Attention Restoration Theory (Berto, 2014). Indeed, it is notable that across the literature, the terms ‘restorative’ and ‘restoration’ are often used in reference to overall affective state of psychological wellbeing, as well as in reference to restoration of attention fatigue. As Berto (2014) explains, Attention Restoration Theory and Stress Reduction Theory complement one another. The elevated physiological arousal and negative affect characteristic of stress (as outlined by Stress Reduction Theory) can occur in the absence of mental fatigue. Conversely elevated arousal or negative affect do not always accompany attentional fatigue (as outlined by Attention Restoration Theory), therefore attentional fatigue can be considered a stress aftereffect and treated as a condition that increases vulnerability to stress (Berto, 2014).

Individual differences in responses to environmental settings pervade this research area. Large variations in both subjective connectedness to nature and likelihood of perceiving natural beauty have been reported, and together, these correlate with measures of wellbeing (Zhang et al., 2014). Indeed, rather than uniformity in response to nature experiences, research has demonstrated only tendencies. Where biophilia hypothesis, Attention Restoration Theory and Stress Reduction Theory describe psycho-evolutionary mechanisms, such variation in responses suggests that lived experiences and social influences may function to attenuate aspects of individuals' environmental preferences and affective responses to environmental experiences.

It is also notable that both Stress Reduction Theory and Attention Restoration Theory focus mainly on discussion of the visual perceived environment. However, it is important to recognise that engagement with nature environments is most often a full sensory experience. Nature experiences are important in relation to sensory domains other than vision; urban greenspaces can function as a buffer from the negative influences of noise pollution (Dzhambov and Dimitrova, 2014).

1.5.4 Nature environments, physical activity and the ecological dynamics approach

Physical activity and environments independently influence wellbeing; however, research findings suggest a probable relationship between environment setting and physical activity participation (which mutually could effect wellbeing). Within urban areas, the most accessible nature-based environments, or 'greenspaces', are parks. A large number of studies have reported a relationship between proximity to park and physical activity levels, whereby individuals who have greater access to parks tend to be more active than those with less access (Roux et al., 2007, Wolch et al., 2014). For example, one study reported that each additional hectare of park area within 1 km from home increased the odds of individuals participating in at least 150 minutes (total) moderate-to-strenuous physical activity per week by 2%, and each additional park increased the likelihood of this total quantity of neighbourhood-based physical activity by 17% (Kaczynski et al., 2009). It is noteworthy, however, that positive association between greenspace and physical activity levels is not always unanimous. One systematic review found that evidence for an association between access to greenspace and physical activity was mixed, with 66% of identified studies finding evidence of a positive association (Lachowycz and Jones, 2011). That evidence in this area is mixed may be due partly to inter-study differences in definitions of and types of greenspaces examined, as well as potential cross-cultural differences. A study of New Zealand adolescents found nearby beach and park environments to be most frequently cited favourite places for participation in physical activity; ability to perform specific physical activities in these environments, having fun, and having friends to do an activity with were the most frequently cited reasons for liking these places (Rehrer et al., 2011). A UK-based study found that people who regularly used the natural environment for physical activity (defined as at least once per week) had about half the risk of poor mental health compared to those who did not do so (Mitchell, 2013). Additionally, each extra weekly use of the natural environment for physical activity was identified to reduce the risk of poor mental health by a further 6%. However, both of these studies used self-reported data, and were therefore vulnerable to the potential for measurement error that can lead to incorrect inferences and biased results, which are associated with use of this method for examining physical activity behaviours (Ainsworth et al., 2012).

As discussed earlier in this chapter, physical activity itself offers wellbeing benefits. Physical activity partially mediates the positive relationship between neighbourhood greenspace and mental health and wellbeing (Sugiyama et al., 2008, Richardson et al., 2013). For adults in middle-to-older age, greenspaces are not only important for promoting physical activity, but the mental health benefits of greener environments appear contingent upon those active lifestyles (Astell-Burt et al., 2013). In line with biophilia, the reported relationship between nature environments and physical activity levels suggest that individuals seek out nature environments, as they enable exercise behaviours which themselves are good for wellbeing. Outdoor settings are rated as more restorative than indoor settings, and restorative quality predicts the frequency of exercise in the past 30 days (Hug et al., 2009). Considered together with the previously cited notion that exposure to nature appears to be an important adaptive process aiding optimum functioning (Van den Berg et al., 2007), this positions nature environments as places which afford opportunities for wellbeing improvements via both direct (exposure to nature) and indirect (by facilitating physical activity participation) pathways.

Offering an approach to understanding relationships between the individual, the task, and the environment (social and physical) (Brymer and Davids, 2012), the ecological dynamics perspective views each of the individual, environment and exercise (task) as a system comprising a complex arrangement of factors (termed ‘constraints’); for example, within the individual system: cognitive, affective and physiological states, physical flexibility, limb length. It considers how the complex system formed by an individual, a task and the environment can constrain or afford processes relating to human wellbeing (Brymer et al., 2014). Ecological dynamics describes that constraints act as boundaries, within which behavioural invitations or possibilities (termed ‘affordances’) exist, thereby shaping behaviour (Figure 1.3)(Brymer and Davids, 2014, Yeh et al., 2015). Recounting the findings outlined within the current chapter, constraints associated with nature environments can promote affordances both for psychologically restorative experiences and for physical activity, that in turn promotes wellbeing improvements. Ecological dynamics forwards the notion that psychological wellbeing outcomes derived from physical activity participation might be greater when the physical activity is performed in nature environments, compared to other environments (Brymer et al., 2014, Yeh et al., 2015). Indeed, physical activity in natural environments is associated with a reduction in the risk of poor mental health to a greater extent than physical activity in other environments, and ‘activity in different types of environment may promote different kinds of positive psychological response’ (Mitchell, 2013). As outlined, as well as constraint characteristics of environments, individual differences contribute to the existence of behavioural affordances and the likelihood that behavioural affordances will be acted upon. Relating to the research outlined within this chapter, an individual with greater psychological connectedness to nature may be more likely to perceive and then behave in a way that acts upon the potentially restorative aspects of a nature experience. Indeed, it may also be that individuals with greater connectedness to nature have more potential benefit to gain from acting upon such affordances (Zhang et al., 2014).

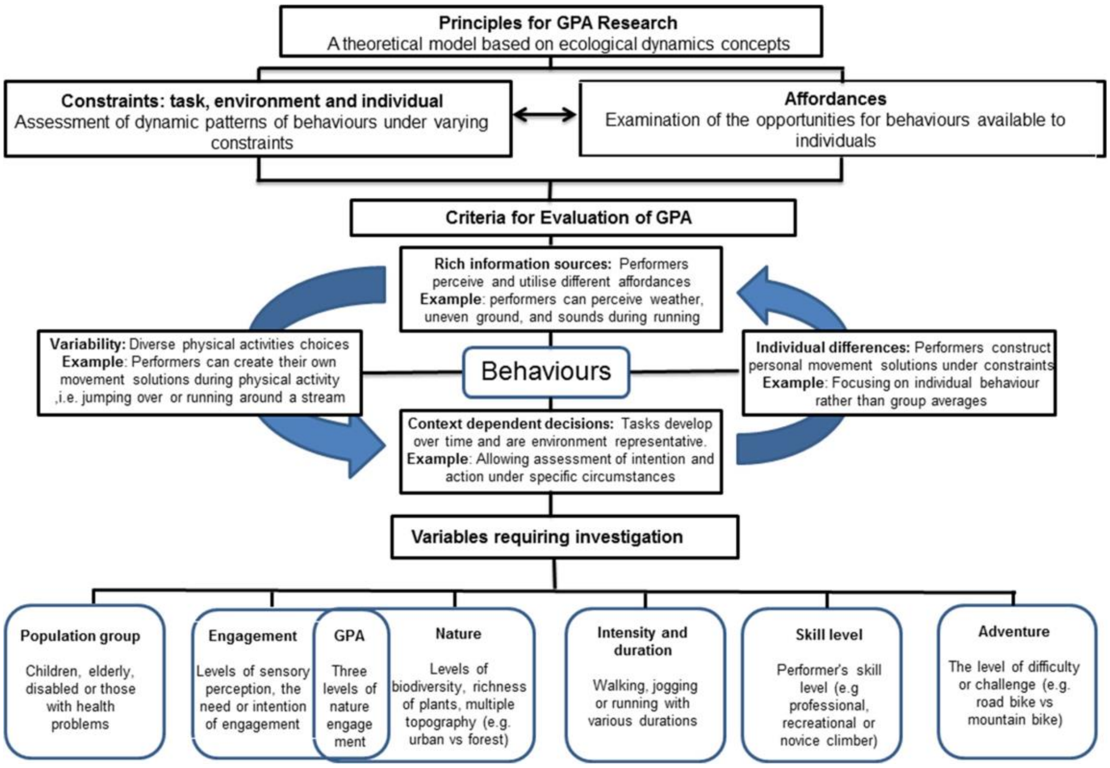


Figure 1.3 The theoretical model of principles for green physical activity research from an ecological dynamics perspective (Yeh et al., 2015)

1.6 GREEN EXERCISE

1.6.1 Defining green exercise: levels of engagement and immersion

Nature experiences can be described in terms of an individual's extent of engagement with nature (Pretty, 2004, Pretty et al., 2004). This extent of individuals' engagement with nature can be categorised into three levels (Pretty et al., 2003, Pretty et al., 2004):

(i) Viewing nature (such as through a window or in a printed or projected image)

(ii) Being in the presence of nature incidentally during another activity of focus (such as walking to work or talking with a friend)

(iii) Active involvement with nature (such as gardening, trekking or running)

'Green exercise' constitutes the third level of engagement, describing physical activity with simultaneous exposure to nature (Pretty et al., 2003, Pretty et al., 2005). It is important to note that this suggestion of categorisation was originally made in relation to individuals' decision-making processes and the physical description of human activity relative to an environment. This categorisation therefore does not necessarily reflect individuals' sensory environmental experiences or psychological engagement with an environment. However, the concept of engagement does resonate somewhat with the concept of immersion. Findings relating to immersion suggest that the extents and likelihoods of psychological effects of nature might partially depend on the extent of an individual's psychological immersion in that environmental experience (Weinstein et al., 2009). Via a series of studies, Weinstein et al. showed that greater psychological immersion in one's surrounding environment increased the effects of nature on measures of intrinsic and extrinsic aspirations. They suggest that individuals are more likely to fully attend to characteristics of their surrounding environment when psychologically immersed in it, than when not (Bystrom et al., 1999). Concurrently, in relation to the stress-reducing effects of natural environments, displaying images of nature on a highly-immersing larger-sized screen elicit greater reduction in physiological stress indicators (heart period and skin conductance level) over time, than displaying these images on a less-immersing, smaller screen (De Kort et al., 2006). Such a role of immersion suggests that in instances when psychological immersion is in line with physical engagement, green exercise might provide greater scope for psychological influence than either simply viewing or time spent at rest in nature environments. For example, the haptic aspect of green exercise participation may function to enhance individuals' psychological immersion in a given nature environment. Phenomenological research suggests that, alongside visual aspects, individuals' haptic lived experience is an important aspect of green exercise participation, whereby sensory experience creates an intense embodiment of heightened awareness (Owton and Allen-Collinson, 2014, Allen-Collinson and Leledaki, 2015). Additionally, the disparate influences of exercise and of nature environments may positively interact in a manner that further promotes psychological wellbeing improvements (Pretty et al., 2005).

1.6.2 Research findings to date

Green exercise research examines the possibility that environments in which individuals perform exercise may influence outcomes of that exercise participation. Both the overall thesis and this section of the current chapter focus on green exercise research relating to psychological outcomes. However, it is noteworthy that a number of physiological variables have also been examined in relation to green exercise participation. Compared to either exercising in or viewing built or urban scenes during exercise, exercising whilst being exposed to nature environments has significantly greater beneficial effects on blood pressure (Pretty et al., 2005, Li et al., 2011), other measures of cardiovascular and autonomic function (Brown et al., 2013, Gladwell et al., 2013, Brown et al., 2014, Gladwell et al., 2016), and endocrine and immune function (Li et al., 2007, Li et al., 2011, Lee et al., 2012). For example, compared to walks through a built setting, lunchtime walks through nature settings resulted in significantly greater overall heart rate variability and parasympathetic cardiac contribution during sleep later that night (Gladwell et al., 2016). Although this thesis focuses primarily on the non-elderly adult population (aged 18-65 years), there are also relevant green exercise research findings outside of this population, particularly in children and adolescents (Gladwell et al., 2013, Reed et al., 2013, Wood et al., 2013, Wood et al., 2014, Barton et al., 2015). Research focused on children or adolescents has reported that, beyond influences of physical activity itself, environmental settings do not significantly influence outcomes of self-esteem or mood (Reed et al., 2013, Wood et al., 2013, Wood et al., 2014).

Green exercise research has predominantly adopted four methodological approaches: (i) comparing outcomes of built- *versus* nature-based outdoor exercise (Hartig et al., 2003, Berman et al., 2008, Park et al., 2010, Lee et al., 2012, Brown et al., 2014); (ii) comparing outcomes of indoor exercise to those of outdoor exercise (Teas et al., 2007, Focht, 2009, Ryan et al., 2010b); (iii) employing ergometers within laboratory settings to rigorously control the exercise component and examine the importance of the visual exercise environment (Pretty et al., 2005, Akers et al., 2012, Wood et al., 2013, Rogerson and Barton, 2015); (iv) 'in the field' convenience sampling (Pretty et al., 2007, Barton et al., 2009, Barton and Pretty, 2010, Mackay and Neill, 2010). Research findings are discussed in relation to each of these four methodological approaches.

1.6.2.1 (i) Urban/built versus nature-based outdoor exercise

The main strength of this research approach is that it represents an ecologically valid comparison, in that individuals may often exercise in one of these two environments. Therefore such research findings can be understood in relation to, and can be applied to, real-world settings.

Using a mixed design (between variable - walk environment, built or nature) (within variable -time, pre-intervention and post-intervention) Brown et al. (2014) asked office workers to undertake two lunchtime walks per week for eight weeks using one of two routes. Whereas self-reported mental health significantly improved for individuals who completed the eight weeks of walking in a nature environment (centred around trees, maintained grass, and public footpaths), improvements were not reported by participants in the built condition (pavements around housing estates and industrial areas). Although walk distance was set by using specified routes, and walk duration was advised to be of 20 minutes, there were no rigorous controls for exercise intensity, and exercise intensity and duration were not measured objectively (exercise intensity is defined as the total or rate of energy expenditure during exercise (Macera et al., 2003, Thompson and Lim, 2003)). Indeed, the outcomes of this research were open to influences of confounding variables, such as weather and climate differences, and social influences, as the extent to which participants walked alone or in groups was not controlled. Berman et al., (2008) found that although walking in a downtown environment and a botanical garden both facilitated improvements in directed attention, the improvement after botanical garden walking was statistically significant, whereas the improvement associated with downtown walking was not; that is, improvement was greatest in the botanical garden condition. Measures of brain activity have also supported the role of environmental settings for psychological restoration. Electroencephalogram data showed that, in line with attention restoration theory, movement from an urban shopping street to a greenspace was associated with change in brain activity patterns indicative of reductions in arousal, frustration and engagement, and increased meditation (Aspinall et al., 2015).

Similarly to the findings of Berman et al. (2008), walking in oak-sycamore woodland nature settings increases positive affect and reduces anger, whereas urban walks in a city retail and office development promote opposite affective outcomes (Hartig et al., 2003). However, again, the variable of social presence of others was not controlled in either of these studies. Additionally, although Hartig et al. (2003) attempted to control exercise intensity (via researchers leading participants in order to maintain a slow walking pace with stops at specified locations on route), exercise intensity was not rigorously controlled in these studies. Additionally, this study did not account for differences in fitness between individuals. That is, what was perceived to be a slow walking pace for one participant might have been perceived as a moderate or fast pace by other participants. This is important because intensity influences psychological outcomes of exercise, including cognitive performance

(Tomporowski, 2003, Kilpatrick et al., 2007, Kashihara et al., 2009, Ekkekakis et al., 2011). Where exercise intensity, as measured by heart rate, has been comparable, beneficial influence of nature compared to urban settings has been reported for cognitive restoration but not for mood (Gidlow et al., 2016). This raises an important issue with existing research, of whether environmental influences on affective outcomes originate via perception of environmental settings, or via differences in exercise performed in the different environments.

Compared to guided walks in city centre environments, walks in urban park or woodland settings significantly reduced perceived stress (Tyrväinen et al., 2014). Other studies have also reported that walking in natural environments compared to environments lacking nature is associated with greater decreases in perceived stress and negative affect, and improvements in self-reported mental wellbeing (Roe and Aspinall, 2011, Marselle et al., 2013). Notably, the research of Roe and Aspinall was quasi-experimental in design and did not account for confounding factors such as prior knowledge of walking routes and climatic differences such as temperature. Social differences between environmental settings may also be important to exercise outcomes. Whereas a green park environment resulted in greater walking-associated increases in feelings of revitalisation than did street environments, even greater increases were associated with walks in a street setting when accompanied by a friend (Johansson et al., 2011). Marselle et al.'s research (2013) was cross-sectional across a 13-week period, and controlled for significant predictors of the outcome measures (e.g. duration of walks). Although it reported significant reductions in perceived stress and negative affect associated with green walks compared to urban walks, environmental setting did not significantly influence positive affect. As discussed by Marselle et al. (2013), these results indicate a need to control for physical activity-related and social setting-related variables when examining potential influences of exercise environments on outcome measures of psychological affect and wellbeing.

A systematic review by Bowler et al. (2010) summarising research findings indicated that exercise in natural compared to man-made environments was associated with lower negative emotions, such as anger and sadness, and greater levels of attention. Despite the merits of the 'built *versus* nature outdoor exercise' methodological approach, a main limitation is that it often lacks rigorous control of the exercise component, which is important, as exercise characteristics such as duration and intensity influence a number of outcomes themselves (Ekkekakis and Petruzzello, 1999, Ekkekakis et al., 2005, Ekkekakis et al., 2011).

1.6.2.2 (ii) Indoor versus outdoor exercise

As with urban/built *versus* nature-based exercise environment comparisons, a main strength of this research approach is that it represents an ecologically valid comparison. Again, however, a limitation of this approach is that it is difficult to ensure comparability of the exercise component; therefore it is challenging to infer the respective contributions to reported outcomes of environmental differences and exercise differences. In a systematic review of studies comparing indoor and outdoor physical activity, Thompson Coon et al. (2011) found that, compared to walking indoors, outdoor walking was associated with more positive mood, increased self-esteem, vitality, energy and pleasure, alongside reductions in frustration, worry, confusion, depression and tiredness. Running outside has also been associated with greater satisfaction and greater mood improvements than running indoors (Harte and Eifert, 1995, LaCaille et al., 2004). Another study found that including the measure of 'enjoyment' as a covariate within statistical analysis suggests that individuals' enjoyment of exercise may explain environment-associated differences in mood between these outdoor and indoor settings (Plante et al., 2007). However, this study focused on a female-only cohort, so it is unclear whether this is a generalisable occurrence.

Investigation of competitive runners failed to identify influences of exercise environments on affective outcomes (Kerr et al., 2006), possibly due to competitive exercisers focusing on internal cues to a greater extent, therefore reducing mindful engagement / immersion with environmental settings. Indeed, despite many findings to the contrary, Kerr et al. (2006) suggest that the importance of exercise-environment 'may be overstated' within the existing literature. Following two 5km runs, one in an outdoor natural environment and the other on a treadmill within a laboratory, although a range of affective measures were taken, only the measure of 'pride' was found to be significantly improved by exercise in nature compared to in the laboratory. Tension and effort stress scores were significantly higher with natural running than laboratory running. This study included recreational and competitive runners and controlled for both distance (5km) and exercise intensity in terms of percentage of heart rate reserve via use of a pacer watch. However, a methodological issue with this is that participants' focus on the wristwatch may have reduced mindful engagement with the exercise environment. In line with the concept of immersion and engagement, lower extent of immersion may reduce likelihood or extent of an environment's eliciting potential effects. Additionally, by fluctuating speed / velocity in order to remain within % heart rate reserve boundaries within each condition, duration of exercise and environmental exposure time is likely to have varied between trials. This is problematic, as duration and intensity themselves influence a number of affective outcomes of exercise (Ekkekakis and Petruzzello, 1999, Ekkekakis et al., 2011). The control of exercise duration at the expense of controlled intensity, or vice versa, is the main methodological issue that undermines much of the research outlined here, which examines differences between indoor and outdoor settings. Indeed another problem of Kerr et al.'s methodology and that of other outdoor *versus* indoor comparison studies, is that although attempts have been made to control exercise intensity, there are significant biomechanical differences between running over ground and on a treadmill (Nigg et al., 1995, Baur et al., 2007, Riley et al., 2008, Hong et al., 2012, Sinclair et al., 2013). Thus the mechanics of treadmill running cannot always be simply generalised to over-ground running (Sinclair et al., 2013), although this may be less of an issue for walking (Riley et al., 2007).

As well as affective outcomes, exercise environments may also influence social experiences of exercise sessions. Teas et al., (2007) noted that, in addition to promoting significantly greater improvements in mood compared to indoor exercise (in a sample of post-menopausal women), outdoor exercise also facilitated participants' engagement in verbal interaction during group exercise, suggesting that there may be additional social benefits to be gained from green exercise participation. However, suggesting at least partial independence of social and affective outcomes of exercise environments, Ryan et al. (2010b) controlled the speed of walking exercise and prohibited verbal social interaction during a comparison of indoor walks (whereby participants were led through a series of underground hallways and tunnels that were devoid of living things, although there were many objects, posters, physical changes, and colours present) *versus* outdoor walks (whereby participants were led along a largely tree-lined footpath beside a river). Greater improvements in feelings of vitality were reported in the outdoors condition. Focht (2009) showed that female participants experienced greater pleasant affective states after an outdoor walk, compared to an equivalent indoor walk. They also enjoyed the outdoor walks more and reported a greater intention to continue this behaviour in the future. Further to this, a randomised trial focusing on post-menopausal women reported that after 12 weeks of training, outdoor exercise was associated with enhanced affective responses and greater likelihood of adherence to the exercise programme when compared to indoor exercise (Lacharité-Lemieux et al., 2015). Such findings are of note for policymakers in the public health sphere, because this suggests a role for green exercise in increasing physical activity participation levels, in utilising links between affective responses to exercise, intentions, and future exercise behaviours (Williams et al., 2008, Kwan and Bryan, 2010a, Kwan and Bryan, 2010b, Ekkekakis et al., 2011).

Compared to individuals who report a tendency to only exercise indoors, greater exercise-related positive affect and wellbeing is associated with exercising both outdoors and indoors (Loureiro and Veloso, 2014). However, a methodological issue of this research was probable variation in the time at which participants completed questionnaires in relation to their acute exercise bout. It is not reported whether participants were sampled before exercise or after exercise sessions; therefore, it appears likely that this varied between participants. This is problematic as exercise per se is known to influence self-reported psychological wellbeing measures (McGowan et al., 1996, Yeung, 1996, Bartholomew et al., 2005).

Other research has focused on specific demographic samples and longer-term associations. For example. the role of environmental exercise setting has been investigated in relation to depressed individuals. Via a within-subjects design, compared to a sedentary control condition and 60-minute indoor exercise session, a single outdoor exercise session was associated with greater levels of self-reported affect and feelings of excitement and activation (Frühauf et al., 2016). In addition to the previously outlined findings regarding affect and adherence, a randomised trial reported that over a 12-week exercise programme, levels of depression decreased and physical activity levels increased in an outdoor exercise group, but did not in an indoor exercise group. The latter of these two findings suggests a role of environmental settings for influencing self-motivated exercise behaviours. In another study, when self-reported emotional wellbeing was statistically regressed onto weekly frequency of physical activity performed indoors, outdoors in nature and outdoors in built environments, national survey data from Finland indicated that outdoor nature settings were most positively associated with emotional wellbeing (Pasanen et al., 2014).

1.6.2.3 (iii) Urban/Built versus nature views in the laboratory

The strength of this approach is that the exercise component can be rigorously controlled. Its limitations are that it does not provide the full-sensory experience of green exercise participation, and that it lacks ecological validity; therefore, it requires further investigation in order to conclude whether laboratory-based findings are fully applicable to real-world scenarios.

Pretty et al. (2005) analysed the effect of exercising on a treadmill whilst viewing either rural pleasant, urban pleasant, rural unpleasant or urban unpleasant scenes on self-esteem and mood. There was also an exercise-only condition whereby participants exercised whilst viewing a blank screen. Whilst exercise alone resulted in improvements in self-esteem and mood, viewing urban and rural pleasant scenes during exercise produced greater effects. The unpleasant scenes had a depressive effect on both self-esteem and mood. However, the findings of this study allude that the variable of pleasantness (pleasant *versus* unpleasant) had a greater influence on the reported outcomes than did environment type (urban, rural). Therefore, the relative contributions to the reported effects cannot be confidently concluded in this case. Akers et al. (2012) similarly focused on the role of the visual exercise environment on the outcome of mood, during cycling exercise. After viewing colour-filtered scenes of a first-person movement through a woodland road environment (in a counter-balanced order) during moderate intensity cycling, participants reported greatest improvements in mood following the unedited ‘green’ video, compared to achromatic-filtered (grey) and red-filtered video. Participants’ perceived exertion was also lowest in the unedited video condition, suggesting that environmental colour may contribute to the reported psychological benefits of green exercise. However, this research was unable to discern whether reported outcome differences were due to colour perceptions per se (Wexner, 1954, Küller et al., 2006, Yildirim et al., 2007) or colours in relation to environment, or further, whether red and achromatic filters simply created cognitive dissonance by deviating from individuals’ regular association between environmental context and that context’s typical colour spectrum. Additionally, it is not known how perceived exertion varies with different visual exercise environment *types* during controlled exercise.

The question of what type of nature might be best for affective outcomes of exercise has received some initial investigation via the laboratory-based methodology. Compared to viewing a blank wall, both viewing simulated countryside environment and viewing simulated coastal environment on a screen during 15 minutes of cycling exercise resulted in significantly greater improvement in self-reported affect (White et al., 2015). However, as the sample of this research was that of post-menopausal females only, it is unclear as to the transferability of these findings to other populations. In an adolescent sample, Wood et al. (2013) found that manipulation of environmental scenes viewed during treadmill exercise did not significantly influence self-esteem and mood outcomes. This supports the notion that exercise environments may be of differing importance across age groups (Reed et al., 2013). Informed by these findings, the current thesis focuses on the general adult population.

1.6.2.4 (iv) 'In the field' convenience sampling

A number of studies have used opportunistic field sampling in order to examine green exercise participation. Although this research typically does not compare green exercise with equivalent 'non-green' exercise, its strengths are that (i) it has strong ecological validity, in that it accesses individuals who have self-selected their green exercise participation, and, although only examined by one study (Barton and Pretty, 2010), (ii) it enables 'within-green exercise' examination of and comparison between different environmental, exercise and individual variables. However, a limitation of this methodology is that self-selecting, often 'healthy' cohorts generally have good states of affect or mood, or high levels of self-esteem. This increases risk of ceiling effects across pre- to post-session data. Research of this kind has reported various green exercise activities such as horse riding and walking to improve self-esteem and mood (Pretty et al., 2007, Barton et al., 2009, Barton and Pretty, 2010). Barton and Pretty's meta-analysis of ten field sampling studies found that, similarly to exercise per se (Ekkekakis and Petruzzello, 1999, Ekkekakis et al., 2011), duration and intensity of exercise, as well as age, can influence green exercise outcomes (Barton and Pretty, 2010). Indeed, a five-minute bout of green exercise elicited greatest improvement in mood and self-esteem, with positive but diminishing returns for longer durations (Barton and Pretty, 2010). However, other factors such as climatic variables (e.g. temperature) and motivation for participation were not measured. As the studies included in this meta-analysis were convenience samples of self-selecting cohorts, it is likely that a number of participants were engaging in green exercise activities with the expectation that they would enjoy it, thus biasing results in a way that was not controlled for. Moreover, this study analysed data and drew conclusions across a range of activities without examining the role of activity type via subgroup analyses. Therefore, it is not necessarily possible to interpret the results with confidence regarding a specific green exercise activity. For example, for the activity of walking only, optimum activity duration is not reported. Another quasi-experimental study reported green exercise participation to result in short-term reductions in anxiety, with greatest reductions associated with greater perceived naturalness of the exercise environment (Mackay and Neill, 2010).

1.6.3 How green exercise improves health

Reviews and meta-analyses of green exercise research have evidenced the positive affective benefits of exercise in nature environments compared to urban or indoor environments (Bowler et al., 2010, Thompson Coon et al., 2011, Hartig et al., 2014). Hartig et al.'s (2014) model encapsulates how green exercise participation may elicit improvements in wellbeing (Figure 1.4).

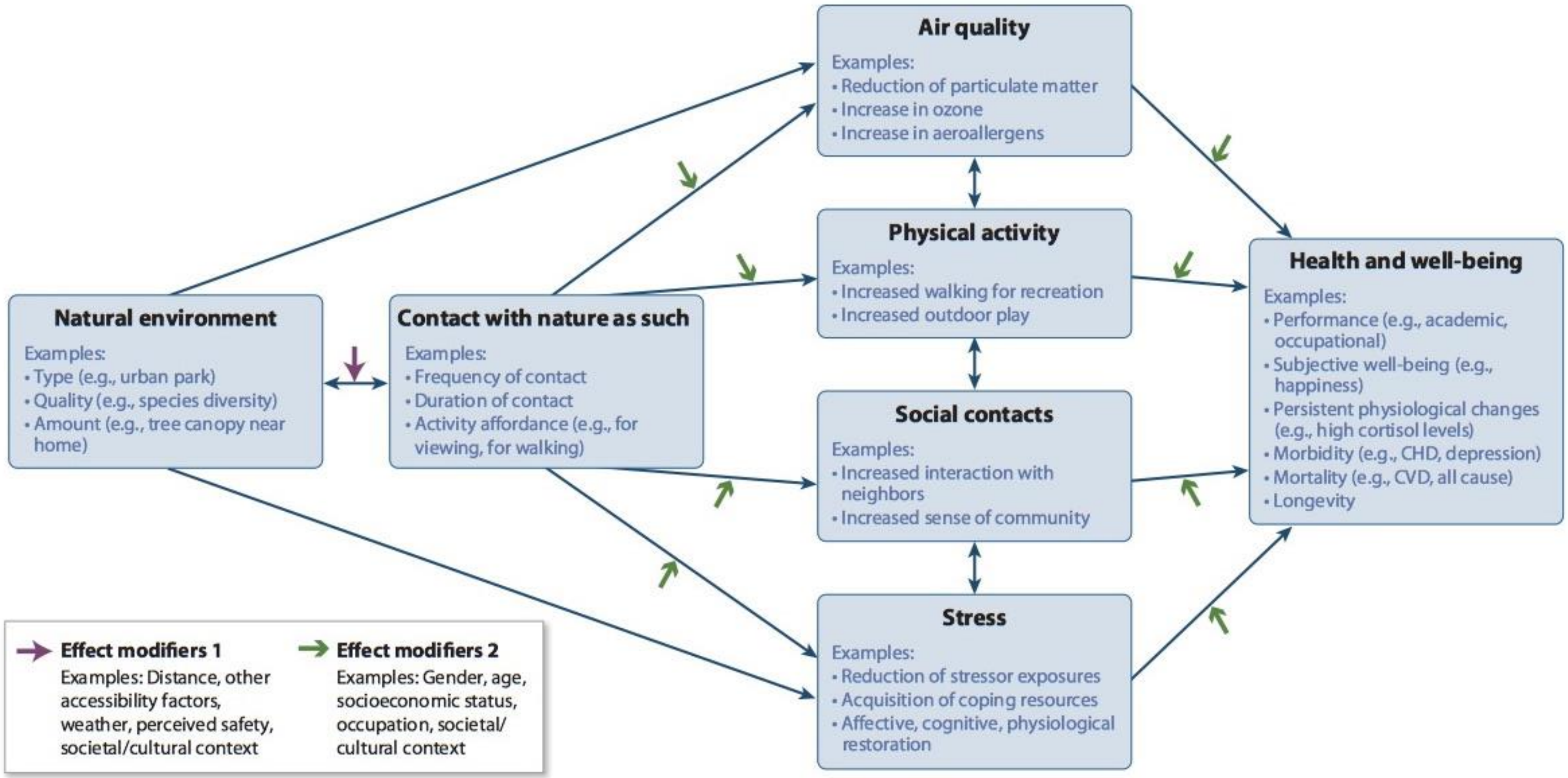


Figure 1.4 Hartig et al.'s (2014) Model of how nature environments affect human health and wellbeing

Drawing on many of the findings described in the current chapter, Hartig et al. (2014) suggest that additionally to nature environments promoting physical activity, green exercise offers reductions in psychological stress, and exposes individuals to increased social interaction. This model is in line with findings of the systematic review of Bowler et al. (2010), which also described that nature environments improve wellbeing via increased opportunity for stress reduction, physical activity and social interaction. Physical activity and social experiences can contribute to satisfaction of the three domains of basic psychological needs that self-determination theory suggests underpin individuals' psychological wellbeing: competency, autonomy and relatedness (Deci and Ryan, 2000). More specifically, the ecological dynamics perspective suggests that, amongst other factors, physical activity in nature environments (compared to synthetic environments) offers individuals a greater richness of environmental information to be perceived and utilised (such as features of soft fascination that can be utilised for attention restoration), and greater environmental variability, allowing for more diverse movements and experiences (which may satisfy individuals' basic psychological needs to a greater extent) (Yeh et al., 2015).

1.7 SUMMARY, GAPS IN THE LITERATURE, AND CONCLUSION

The UK is currently in the midst of simultaneous physical inactivity and mental health crises, with clear links existing between the two. The concept of green exercise was born from existing literature reporting benefits to psychological wellbeing, each from physical activity and from exposure to nature environments. The past 10-15 years of research has reported influences of environmental exercise settings on mental wellbeing and other related psychological outcomes. The findings suggest that nature environments may provide additional psychological benefits from exercise participation, compared to synthetic environments.

Gaps in the literature currently include:

- As in many experimental studies, participants perform exercise in a randomised order of environmental conditions; it could be argued that this removal of individual choice might remove associations with leisure and enjoyment of the environment (Bowler et al., 2010). It is therefore important for future research of this kind to be complemented with more ecologically valid, 'in the field' sampling research. However, where some such previous research has compared *between* individuals' pre- *versus* post-green exercise participation (Barton et al., 2009), further research should seek to maintain research design strength of within-participant comparisons.

- Whereas much research has compared outcomes of green exercise with those of exercise in built, urban and indoor environmental settings, little research has compared outcomes of green exercise in different types of nature (White et al., 2015), and this research used visually-simulated environments rather than real environments. Therefore, it is not yet clear whether there is an optimal 'type' of nature environment for maximising the reported psychological outcomes of green exercise participation.

- In studies comparing affective outcomes of exercise between environments, the exercise component has often not been controlled, and in instances that it has been controlled, findings have been mixed. Additionally, within laboratory paradigms, intended control of exercise has not been measured. As physical characteristics of exercise influence psychological outcomes, future research should ensure comparability of exercise between experimental conditions, so that differences in outcomes can more confidently be attributed to environmental settings.

- Although there is some evidence of greater attention after exposure to a natural environment compared to synthetic environments, this is severely weakened when adjusting effect sizes for pretest differences (Bowler et al., 2010). This highlights the methodological issue of measuring changes relative to baseline, or pre-intervention values, which should be addressed in future research.

- Although highlighted by Hartig et al.'s (2014) model as an influence of nature environments, potential influences of environmental exercise settings on social experience are yet to be examined.

- Acute affective exercise outcomes influence longer-term motivation for and adherence to exercise behaviours (Williams et al., 2008, Kwan and Bryan, 2010a, Kwan and Bryan, 2010b). Given the reported influences of environmental settings on affective exercise outcomes, nature-based environmental settings might function as a tool for maintenance of exercise behaviours (Thompson Coon et al., 2011). However, little research has addressed this possibility. Given the current mental wellbeing and physical inactivity crises in the UK, and the associations between these issues, research should examine the efficacy of using green exercise participation to promote on-going wellbeing and physical activity participation.

In order to maximise benefits to wellbeing, greater understanding of what might constitute optimal green exercise settings, and of the underpinning mechanisms of reported green exercise effects, are required. Additionally, environmental exercise settings might influence other psychological outcomes of relevance to wellbeing and physical activity behaviours, such as social interaction. Increased knowledge in this area can come from further comparison research, specifically that which both addresses gaps in, and builds upon, the existing literature.

1.8 AIMS OF THE CURRENT THESIS

The overall aim of this thesis is to rigorously test the influence of environmental setting on exercise-related wellbeing outcomes. The experimental chapters of this thesis will use and progress existing research paradigms, via different design, different equipment and different analytical approach. Yeh et al. (2015) suggest that the variables of type of nature, and exercise intensity and duration, require investigation. These are key variables that will be addressed within the experimental chapters of this thesis, and the following overarching research questions will guide the research conducted:

1. Is there an optimal green exercise environment for promoting wellbeing?
2. When exercise is controlled, are findings consistent with previously reported psychological outcomes?
3. Do environmental settings influence social outcomes of exercise or intentions to repeat exercise behaviours?

The specific aims of the experimental chapters, and how these map on to identified gaps in the literature, are outlined in Table 1.1.

Table 1.1. Mapping identified gaps in the literature onto chapter aims

Chapter	Gap in the literature to be addressed	Chapter aims
3	• It is not yet clear whether there is an optimal ‘type’ of nature environment for maximising the reported psychological outcomes of green exercise participation • ‘In the field’ research should seek to maintain research design strength of within-participant comparisons	• To investigate potential differences in affective outcomes of running between different typical green exercise environments • To examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes
4	• Within laboratory paradigms, intended control of exercise has not been measured	• To examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component
5	• The exercise component has often not been controlled or measured within comparisons of outdoor *versus* indoor exercise	• To identify a method for ensuring consistency of the exercise component between indoor (treadmill) and outdoor (over ground) exercise • To compare psychological outcomes of outdoor *versus* indoor exercise
6	• Potential influences of environmental exercise settings on social experience are yet to be examined • Little research has addressed the possibility that nature-based environmental settings might function as a tool for maintenance of exercise behaviours	• To compare psychological, social and behavioural intention outcomes of exercise in green outdoors *versus* indoors settings, whilst controlling the exercise component

Chapter Two: Theoretical Constructs, Measures and Methods Used in the Experimental Chapters

2.1 INTRODUCTION

All of the research presented in this thesis was conducted in accordance with the Declaration of Helsinki. In all instances, ethical consideration and risk assessment documentation was provided to and approved by the University of Essex Ethics Committee. All participants were fully informed of procedures before providing their written consent.

All data collected and analysed within the experimental chapters (Chapters 3 – 6) was numerical quantitative data. All psychological measures used were theoretical constructs (all those except for heart, energy expenditure, step count, and time spent socially interacting during exercise). That is, these constructed measurable variables are intended to be representative of the non-directly unobservable phenomena upon which they are theoretically based.

As one of the aims of this thesis was to build on existing research findings, a number of the measures used in the following experimental chapters were initially selected in line with their employment in previous research. There is some reoccurrence of measures used throughout the experimental chapters as the thesis continues to follow particular lines of enquiry. These are outlined within the current chapter. Other non-reoccurring measures are introduced and outlined within the experimental chapters in which they are used. Table 2.1 shows the overarching research question addressed in each experimental chapter and the research designs used.

Table 2.1. Paradigm, design and research questions addressed, by experimental chapter

Experimental chapter	Paradigm	Aim of chapter	Design
Chapter 3	In the field, convenience sample	• To investigate potential differences in affective outcomes of running between different typical green exercise environments • To examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes	• Mixed - 2 X 4 within (pre-, post-exercise) – between (four typical green exercise environments) • Regression analyses to examine importance of individual, environment, and exercise related variables
Chapter 4	Laboratory-based manipulation of visual environment	• To examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component	• 2 X 3 within design (time: pre-, post-exercise) (condition: built, nature and control)
Chapter 5	Indoor *versus* outdoor (running / walking exercise)	• To identify a method for ensuring consistency of the exercise component between indoor (treadmill) and outdoor (over ground) exercise • To compare psychological outcomes of outdoor *versus* indoor exercise	• 2 X 2 within design (time: pre-, post-exercise) (condition: outdoors, indoors)
Chapter 6	Indoor *versus* outdoor (cycling ergometers)	• To compare psychological, social and behavioural intention outcomes of exercise in green outdoors *versus* indoors settings, whilst controlling the exercise component	• 2 X 2 within design (time: pre-, post-exercise) (condition: outdoors, indoors)

2.2 REOCCURRING MEASURES

As discussed in Chapter 1, a number of important, potentially beneficial outcomes of green exercise participation relate to psychological wellbeing. Therefore, combinations of the measures of mood, self-esteem and perceived stress were selected throughout the experimental chapters in order to give an overview of psychological wellbeing. Another dependant variable of interest is that of directed attention, for which the experimental work of this thesis used the measure of Digit Span Backwards test. Although this measure appears in three experimental chapters, precise details of the administration and scoring of the test vary slightly throughout the thesis. Therefore, although an overview of this measure is given in the current chapter, greater detail is described in each respective experimental chapter.

Table 2.2 indicates the measures included in each experimental chapter, and Table 2.3 outlines key features of the reoccurring measures. The reoccurring measures (those which appear in two or more experimental chapters) are discussed in the paragraphs that follow.

Table 2.2. Measures administered in each experimental chapter

Measure	Chapter					
			5			
	3	4	A	B	C	6
Rosenberg Self-Esteem scale (Rosenberg, 1965)	■		■	■	■	
Profile Of Mood States (McNair et al., 1992)	■		■	■	■	■
Perceived Stress Scale (Cohen et al., 1983)	■		■	■	■	
Backwards Digit Span test		■			■	■
Nature Relatedness (Nisbet et al., 2009)	■					■
Enjoyment of exercise	■				■	■
Rated Perceived Exertion (Borg, 1998)		■			■	■
Heart rate		■				
Energy expenditure		■	■			
Step count			■	■		
Time spent socially interacting during exercise						■
Enjoyment of social interaction						■
Intention for future exercise behaviour						■

Table 2.3. Reoccurring measures within the experimental chapters

Measure	Items	Instruction	Method	Scoring
Rosenberg Self-Esteem scale	10 statements	Here is a list of statements about your feelings about yourself RIGHT NOW. Please tick the relevant box to answer the questions.	Sum scores for all items (some items are reverse scored)	Minimum = 0, maximum = 30 (higher values indicate better self-esteem)
Profile Of Mood States	30 emotion descriptor words	Below is a list of words that describe feelings people have. Please read each one carefully. Then fill in ONE circle under the answer to the right which best describes how you FEEL RIGHT NOW.	Sum scores for each subscale (Tension, Depression, Anger, Vigour, Fatigue, Confusion). Only item reverse score is 'Efficiency'. Raw scores are then converted to T-scores (in line with McNair et al., 1992). Total mood disturbance calculated by subtracting Vigour score from all other summed subscales.	Total mood disturbance: minimum = 112; maximum = 282; greater score indicates worse mood
Perceived Stress Scale	10 statements	A number of statements which people use to describe themselves are given below. Read each statement and then tick the appropriate box to the right of the statement to indicate "how you feel right now, at this moment".	Sum scores for all items (some items are reverse scored)	Minimum = 0, maximum = 40 (higher score indicates an individual perceiving themselves to be more stressed)

Backwards Digit Span test	Strings of numbers	Do not write anything down until prompted to by the screen. When you are writing down your answer, you must physically write in the direction from left to right. Do not mouth the numbers at all, at any time. If you cannot remember, please make the best guess that you can. When you hear the chime sound, stop and look at the screen. Your answer is the reverse of the numbers that you saw, e.g. if you see '1,2,3', the answer is '3,2,1'.	Participants view each number string displayed on the laptop screen, before attempting to write the reverse of this string on an answer sheet	Minimum = 0, maximum = 9 (higher values indicate greater level of directed attention) Chapter 5: minimum = 0, maximum = 14
Nature Relatedness (NR-6)	6 statements	Please rate the extent to which you agree with each statement by writing one of the numbers below in each box. You can use each number as many times as you like. Please respond with how you really feel, rather than how you think 'most people' feel.	Sum item scores and calculate mean score	Minimum = 1, maximum = 5 (higher values indicate having a closer relationship to nature and identifying as being more 'nature-related')
Enjoyment of exercise	100 mm line	Put a mark on the line to indicate how much you enjoyed the exercise session.	Measure distance from zero to point line was marked	Minimum = 0 (not at all), maximum = 100 (very much)
Rated Perceived Exertion	Numbered scale with descriptor words	Please point to a number to indicate how hard you feel like you are working right now (Chapter 5: Please point to a number to indicate how hard you feel like you were working overall during the exercise that you just completed)		Minimum = 6 (minimal exertion), maximum = 20 (maximal exertion)

2.2.2 Self-esteem

Self-esteem is the overall affective evaluation of one's own worth, value or importance (Blascovich and Tomaka, 1993). Although self-esteem can be considered as a multidimensional construct comprising academic, physical, social, athletic, and behavioural and other dimensions, with perceived importance influencing the impact of each dimension on global self-esteem (Harter, 1993), the Rosenberg Global Self-Esteem scale (RSE) (Rosenberg, 1965, Rosenberg, 1989) is the most common measure of a global conceptualisation of self-esteem (Lowry et al., 2007). Whereas specific self-esteem may be more relevant to behaviour, global self-esteem is more relevant to psychological wellbeing (Rosenberg et al., 1995).

Previous research has reported positive influences of green exercise on self-esteem in both adult and adolescent samples (Barton and Pretty, 2010, Thompson Coon et al., 2011, Barton et al., 2012a, Gladwell et al., 2013, Wood et al., 2013). The inclusion of the RSE within the current work was in line with its inclusion in this previous green exercise research.

The RSE scale is a widely used ten-item measure of psychological wellbeing within physical activity research (Biddle et al., 2002, Day et al., 2004, Scherr et al., 2013). Of the ten items, five are worded positively, with the other five being negatively worded. Respondents indicate the extent to which they agree with each statement item, by ticking one of four boxes along a Likert scale from 'strongly agree', to 'strongly disagree'. The system of attributing points for scoring these items has encountered variation in usage, with some research scoring 1 to 4 points per statement (creating an overall score of 10-40) (Gumley et al., 2006, Lee et al., 2006, Barton et al., 2012a), despite its intended scoring of each item being from 0 to 3 (creating an overall score of 0-30) (Rosenberg, 1989). Other research has used Likert scales with more than four points, for example to enable 'neutral' responses (Mustian et al., 2004). For the purposes of the current thesis, the four-point Likert scale method was used, with scoring from 0 to 3 per item. Higher score values indicate better states of self-esteem (Table 2.4).

Table 2.4 Scoring method for the Rosenberg Global Self-Esteem Scale (*Adapted from source: (Rosenberg, 1989))*

Item number	**Scoring Method**
1,3,4,7,10	Strongly agree=3; Agree=2; Disagree=1; Strongly Disagree=0.
2,5,6,8,9	Strongly agree=0 Agree=1; Disagree=2; Strongly Disagree=3.
Overall range	0 - 30

Although normative data for specific populations has been reported (Bagley et al., 1997, Bagley and Mallick, 2001), there are currently no widely accepted universal normative means for this measure. However, the RSE can be used to identify intervention-related self-esteem changes within research samples (Lee et al., 2006, Huang et al., 2007). RSE has been tested for cross-cultural universality (Schmitt and Allik, 2005). With reported Cronbach's alpha coefficients ranging from 0.77 to 0.88 (Rosenberg, 1986, Blascovich and Tomaka, 1993), validity of the RSE scale is widely acknowledged (Fox, 2000).

A number of the experimental studies of this thesis use the RSE scale to examine changes in reported self-esteem from pre- to post-exercise. For the purpose of examining subtle short-term changes in self-esteem, the instructional wording of the questionnaire was changed from 'Below is a list of statements dealing with your general feelings about yourself. Please indicate how strongly you agree or disagree with each statement', to 'Here is a list of statements dealing with how you feel about yourself RIGHT NOW (at the moment). Please tick the relevant box to answer the questions.'.

2.2.3 Mood

Mood is a hypothetical, relatively global unfocused and diffused construct of affect, which is somewhat related to the more focused array of emotions being experienced by an individual at a given time (Luomala and Laaksonen, 2000, Martin, 2003, Schucman and Thetford, 1975). The inclusion of a measure of mood within the current work was in line with consistent examination of mood and affect within green exercise research (Kerr et al., 2006, Plante et al., 2007, Teas et al., 2007, Barton and Pretty, 2010, Akers et al., 2012, Barton et al., 2012b, Wood et al., 2013). Mood is an important component of psychological wellbeing. One measure of mood is the Profile of Mood States (POMS) (McNair et al., 1971, McNair et al., 1992), which has been used in this context by previous research (Barton et al., 2012a, Chen et al., 2014). The POMS measure comprises six subscales: Tension, Depression, Anger, Vigour, Fatigue and Confusion. Individuals complete the POMS by describing how they feel 'right now' via responses to 60 single-word mood descriptor items, along a five-point Likert-type scale. Each mood descriptor's score ranges from 0 ('Not at all') to 4 ('Extremely'). For comparability with previous green exercise research of this type (Pretty et al., 2005, Barton and Pretty, 2010, Akers et al., 2012, Barton et al., 2012a, Wood et al., 2013), and to enable adherence to shorter protocol completion times, the current research used the shortened, 30-item version of the POMS, whereby each mood subscale comprises five mood descriptor items. Raw scores are converted to 'T scores' as per McNair et al. (1992). Although individual subscales can be analysed alone, all subscales are interrelated, and an overall mood score that accommodates this can be calculated by summing the negative subscale scores (Tension, Depression, Anger, Fatigue and Confusion) and subtracting the subscale score for vigour. This overall score is termed 'Total Mood Disturbance' (TMD), with a greater score indicating worse mood (minimum = 112, maximum = 282). Given the neuroendocrinological foundation of psychological mood, it is unsurprising that the 'depression' subscale of POMS has been linked to, and even used, as a screening measure to identify individuals with depression (Wilkins et al., 1995, Patterson et al., 2006). POMS has been shown to have acceptable internal consistency with Chronback's alpha values of 0.67 – 0.93 and 0.84 – 0.95 reported (McNair et al., 1992, Hansen et al., 2001). Validity and reliability tests show that a shortened version of the POMS is suitable for use in exercise contexts (Grove and Prapavessis, 1992, McNair et al., 2003).

For the purpose of identifying acute influences of exercise bouts, the POMS questionnaire was administered both pre- and post-exercise. In order to detect short-term changes in mood, the 'RIGHT NOW' version of the 30-item questionnaire was used. Participants were instructed for each item to 'Fill in one circle under the answer to the right which best describes how you feel right now.'.

The measure of POMS was selected in line with much of the previous green exercise research on which the current thesis builds (Barton et al., 2009, Barton and Pretty, 2010, Barton et al., 2012a, Gladwell et al., 2013). The following experimental chapters examined the construct of mood via the POMS measure (Chapters 3, 5 and 6). This was to enable comparisons to be made between existing research findings and those of the current research.

2.2.4 Perceived Stress

The Perceived Stress Scale (PSS) was used to capture perceived stress (Cohen et al., 1983, Cohen, 1988, Roberti et al., 2006, Cohen and Janicki - Deverts, 2012). The PSS consists of 10-statement items that measure an individual's appraisal of potentially stressful life situations, and has coefficient alpha reliability of 0.78 – 0.91 in US samples reported in 2006 and 2009 (Cohen and Janicki - Deverts, 2012). The PSS has been validated in many samples, as it is considered to be a global measure of stress (Haim et al., 2015). Self-reported measures of stress have not been used in green exercise research before. Rationale for use of the PSS in the current work was that, together with measures of self-esteem and mood, this addressed another element of state psychological wellbeing. To adhere to the short-term nature of the current study, a modified version of the PSS was employed. Items were adjusted from statements such as 'In the last month, how often have you felt nervous and "stressed"?' to 'I feel nervous and "stressed"', with an accompanying instruction telling participants to 'Indicate how you feel right now, at the moment.'. Responses on the original PSS are made via Likert-type scales from '0-Never' to '4-Very Often'. The modified PSS for this study replaced this scale with descriptors of '0-Strongly Disagree' to '4-Strongly Agree'. Higher scores indicate a greater level of stress (maximum score = 40, minimum score = 0).

2.2.1 Directed Attention and the Backwards Digit Span test

Directed attention is the effortful cognitive ability to avoid being distracted by competing stimuli (Itti et al., 2005, Kaplan and Berman, 2010). Because the Backwards Digit Span test (Wechsler, 1955) requires attentional effort to mentally track, hold and rearrange items within the short-term memory (Cowan, 2001, Berman et al., 2008), it has often been used as a measure of directed attention (Tennessen and Cimprich, 1995, Taylor et al., 2002, Stark, 2006, Berman et al., 2008, Taylor and Kuo, 2009, Kaplan and Berman, 2010). In many of these instances, the Digit Span Backwards test has been used successfully for detecting subtle short-term changes, as directed attentional state is temporally changeable and influenced by the perceptual interaction between individual and environmental surroundings (Kaplan, 1995).

Normally, the Backwards Digit Span test requires participants to listen to strings of numbers before attempting to verbally recite them in reverse order (Tennessen and Cimprich, 1995, Berman et al., 2008). Whereas computer programmes are sometimes used, in other research, experimenters verbally read number strings to participants (Kuo and Sullivan, 2001). In the event that participants recite the order correctly, they then attempt another string, increased in length by one additional digit. Participants are given two attempts at each digit string length (for example, five digits long). When participants fail their second attempt to correctly recite a string of particular length, this signals the end of the test. The participant's score represents the longest string length that they successfully recited. Greater score values indicate a better level of directed attention.

The Digit Span Backwards test has been used to examine environmental influences on directed attention associated with time at rest or low-level physical activity (Tennessen and Cimprich, 1995, Berto, 2005, Berman et al., 2008), but rarely with considerable focus on the exercise component (Bodin and Hartig, 2003, Hartig et al., 2003).

In the experimental chapters of this thesis, an alternative approach to the Backwards Digit Span test was taken. Participants viewed a set number of strings displayed on a computer screen before writing their answers by hand when prompted. For each string, numbers were presented serially on the screen, for one second each. Rules were instructed to the participants both on the screen and verbally by the experimenter, at the start of each test. These were: ‘Do not write anything down until prompted to by the screen’; ‘When you are writing down your answer, you must physically write in the direction of from left to right’; ‘Do not mouth the numbers at all, at any time’; ‘If you cannot remember, please make the best guess that you can’. The experimenter was positioned in order to view the screen, the participant and the answer sheet, to ensure that participants adhered to the given rules. All participants attempted all digit strings, with tests then scored out of a maximum potential score. This approach was taken as it enabled control of the duration and manner of the test on each occasion, which was important for (i) controlling recovery time following exercise bouts (Chapter 1), and (ii) ensuring consistency in the administration of the test both between participants and between conditions, including minimising potential influences of the experimenter delivery, such as tone of voice.

2.2.1.1 Directed Attention-Reducing Battery

Two tasks (Subtraction of Serial Sevens Test and spelling words backwards) modified from the Mini-Mental State Examination (Folstein et al., 1975) were completed to utilise and deplete participants' directed attention. Multiple variations were used in order to comprise a five-minute Directed Attention-Reducing Battery. This was used in Chapters 4 and 5. For Subtraction of Serial Sevens Test, participants were asked to verbally subtract seven from a randomly generated number between 100 and 999. They continued verbally counting down until reaching six or less before restarting with another number, for 2:30mins. For spelling words backwards, participants were instructed to listen to the experimenter read and then spell (forwards) an 8-letter word, before attempting to verbally spell that word in reverse. Each word was used only once, to avoid learning effects. This process continued for 2:30mins.

2.2.5 Nature Relatedness

As a potentially useful measure for investigating human-nature relationships, the construct of nature relatedness is considered a relatively temporally stable measure of an individual's cognitive, affective and experiential connection to nature (Nisbet et al., 2009, Nisbet et al., 2011). The standard nature relatedness scale comprises 21 statement items, with which participants are asked to rate the extent to which they agree. Responses are recorded via a five-point Likert type scale, ranging from '1 - disagree strongly', to '5 - agree strongly'. Nature relatedness comprises three dimensions, which form distinct subscales within the nature relatedness scale: self;

perspective; experience. A number of items are reverse-scored. Averaging scores for all items calculates an overall nature relatedness score.

The current research used a shortened version of the nature relatedness scale, the NR-6 (Nisbet et al., 2009, Nisbet and Zelenski, 2013). The NR-6 comprises six items from the full questionnaire, that is, two items from each subscale. In line with Nisbet et al. (Nisbet et al., 2009), items are averaged to create a NR-6 score. A higher score indicates a greater level of nature relatedness (maximum = 5, minimum = 0). The NR-6 strongly correlates with the full scale (r = 0.91) and has good one-month test retest reliability in college (0.83) and community (0.84) samples (Nisbet and Zelenski, 2013).

Nature relatedness has been shown to correlate with environmental scales, behaviour, and frequency of time in nature (Nisbet et al., 2009), and significantly predicts happiness (Zelenski and Nisbet, 2014). The measure of nature relatedness has yet to be used within green exercise research. It was included in a number of the experimental chapters in order to enable exploratory investigation of its potential importance in explaining both outcomes of green exercise participation and psychological and behavioural influences of different types of exercise environment.

2.2.6 Enjoyment

Although there is no widely accepted standardised measure of enjoyment, the parameter of enjoyment has received some attention from previous green exercise research (Plante et al., 2007, Focht, 2009). Within Focht's research, enjoyment was self-reported via a ten point scale from 1-10, with verbal anchors of '1 – not at all', '5 – moderately enjoyable', '10 – 'extremely enjoyable'. Plante et al. used the physical activity enjoyment scale. Although this is a validated scale (Kendzierski and DeCarlo, 1991, Motl et al., 2001), it was not selected for use here as it contains numerous items, and the research of the current experimental chapters required measures to be as brief as possible. More similar to the measure used by Focht, within the current experimental chapters, enjoyment of exercise was measured via a single 100 mm continuum, with a written anchor at one end of 'not at all', and at the opposite end 'very much' (see Table 2.3).

2.2.7 Rated Perceived Exertion

Rating of perceived exertion is a method by which individuals can describe the physiological intensity at which they perceive themselves to be working at a given moment. The most widely-used measure for reporting this information is the Rated Perceived Exertion (RPE) scale (Borg, 1982, Borg, 1998). The scale comprises a fifteen-point vertical list of numbers, some of which are accompanied by a descriptor word, from '6 – no exertion' to '20 – maximal exertion'. Weighted mean validity coefficients of physiological measures have been reported for RPE scores: heart rate (0.62); blood lactate concentration (0.57); % VO_2max (0.64); VO_2 (0.63) and respiration rate (0.72) (Chen et al., 2002). It has been shown that RPE is strongly correlated with heart rate and blood lactate concentration, irrespective of gender, age, coronary artery disease, physical activity status and exercise testing modality (Coutts et al., 2009, Scherr et al., 2013).

Previous research has reported effects of exercise environments on RPE (Focht, 2009, Akers et al., 2012), and via its relationship with affect, exercise-associated RPE is important to exercise maintenance (Williams et al., 2008, Dasilva et al., 2011, Ekkekakis et al., 2011). In order to address methodological issues and to further investigate its relationship to exercise outcomes in different environmental settings, the measure of RPE was included as a focus of the research presented in Chapters 4, 5 and 6.

2.3 STATISTICAL ANALYSES

IBM SPSS Version 19 software was used for all presented statistical analyses (IBM Corp. Released 2010. IBM SPSS Statistics for Windows). Throughout the experimental chapters, preliminary analysis of the data was performed to assess normality, heteroscedasticity and sphericity. For testing normality, the power of the Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests are too low for sample sizes of 30 and below (Razali and Wah, 2011). Although the sample size for Chapter 3 was 331, sample sizes in all other experimental chapters were between 12 and 35. Although typically of insufficient power, the Shapiro-Wilk test is the most appropriate for testing normality of these small sample sizes (Razali and Wah, 2011), therefore for consistency, the Shapiro-Wilk test was used to assess normality of the data throughout this thesis. Of additional note however, so long as ANOVA research designs are balanced, repeated measures ANOVAs are robust to violations of the normal distribution assumption. That is, for sample sizes over 10 to

20, the normality assumption is unnecessary (Norman and Streiner, 2008). Indeed, research designs of Chapters 4, 5 and 6 were each equally balanced and of sufficient sample size to ensure robustness of design.

Repeated measures ANOVAs were used in every experimental chapter. In each instance of repeated measures ANOVA, sphericity of the data was assessed using Mauchley's test of sphericity. Where one-way ANOVAs or t-tests were used, heterogeneity of the data was assessed using Levene's test for homogeneity of variances.

Regression analyses were used in Chapter 3 and Chapter 6. In Chapter 3, stepwise multiple regression analyses were used to examine the extent that secondary variables predicted pre- to post-exercise changes in the primary measures of interest. These analyses adhered to Tabachnick and Fidell's (2007) guideline that a cases-to independent variable (IV) ratio of 40 to 1 is reasonable for stepwise multiple regression analyses. All models presented were examined for instances of significant multicollinearity. In Chapter 6, simple linear regressions were conducted in order to examine the relationships between social interaction time and the measure of intention for each environmental condition.

An alpha level of 0.05 was chosen for indication of statistical significance throughout all of the experimental chapters. In addition to the use of p values, where appropriate, partial eta squared effect size and confidence interval statistics were considered in order to offer greater detail of the magnitude of effects in a manner compatible with the data.

Chapter Three: A Comparison of Four Typical Green Exercise Environments and Prediction of Psychological Health Outcomes

* *

A version of this chapter has been published as a research article. The reference for this is:

Rogerson, M., Brown, D.K., Sandercock, G., Wooller, J.J. and Barton, J., 2015. A comparison of four typical green exercise environments and prediction of psychological health outcomes. *Perspectives in public health*, p.1757913915589845. DOI: 10.1177/1757913915589845

* *

Table 3.1 Thesis map outlining study aims of the experimental chapters

Chapter	Aims
3	• To investigate potential differences in affective outcomes of running between different typical green exercise environments • To examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes
4	• To examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component
5	• To identify a method for ensuring consistency of the exercise component between indoor (treadmill) and outdoor (over ground) exercise • To compare psychological outcomes of outdoor *versus* indoor exercise
6	• To compare psychological, social and behavioural intention outcomes of exercise in green outdoors *versus* indoors settings, whilst controlling the exercise component

3.1 INTRODUCTION

The literature discussed in Chapter 1 suggests that, compared to built or indoor settings, nature environments can enhance wellbeing-related outcomes of exercise. However, it remains less clear as to whether different types of nature environment may be optimal for these effects, as little research has compared how exercising in different outdoor environmental settings influences psychological wellbeing. Barton and Pretty (2010) reported that affective benefits of green exercise activity were enhanced for waterside settings. However, the exercise mode was not consistent between the compared environments, which may have also contributed to the reported findings. Chapter 3 sought to inform the remaining experimental chapters regarding the most appropriate kinds of typical green exercise setting to compare with equivalent built / urban or indoor exercise. It examined different green exercise settings whilst maintaining consistency of exercise mode.

A typical example of green exercise participation is that of running in a park. Acute bouts of exercise facilitate affective improvements (Yeung, 1996, Reed and Ones, 2006) such as mood (Lane and Lovejoy, 2001, Bartholomew et al., 2005) and self-esteem (Ekeland et al., 2005). As outlined in Chapter 1, research articles and systematic reviews report that, compared to exercising either indoors (Teas et al., 2007, Focht, 2009) or in built outdoor environments (Bodin and Hartig, 2003), exercise in nature-based environments can lead to greater psychological benefits (Bowler et al., 2010, Thompson Coon et al., 2011).

The ecological dynamics approach offers explanation for how green exercise improves psychological wellbeing. Compared to synthetic environments, nature environments provide more challenging, complex, varied, and intense affordances (invitations or possibilities) (Brymer and Davids, 2012, Brymer and Davids, 2014), whereby individuals can experience a broad range of emotions and other psychological feelings such as mindfulness, peace, and calm (Brymer and Davids, 2014). This approach suggests that because laboratories contribute to promoting different affordances than do natural environments, where possible, green exercise research should employ designs which prioritise use of natural environments (Brymer and Davids, 2014). A number of studies have used opportunistic field sampling in order to examine green exercise participation via ecologically valid samples, reporting benefits to self-esteem and mood, across various green exercise activities such as horse riding and walking (Pretty et al., 2007, Barton et al., 2009, Barton and Pretty, 2010). Barton and Pretty's (2010) meta-analysis of ten field sampling studies found that similarly to exercise per se (Ekkekakis and Petruzzello, 1999, Ekkekakis et al., 2011), duration and intensity of exercise, as well as age, can influence green exercise outcomes. However, other variables such as temperature and motivation for participation were not measured. Improvements in self-esteem (d= 0.46, 95% CI [0.34, 0.59]) and mood (d= 0.54, 95% CI [0.38, 0.69]) resulting from acute bouts of green exercise are significant (Barton and Pretty, 2010). However, it is important to understand how to maximise these benefits in order to better direct the adoption of green exercise activities for psychological health in the wider public domain.

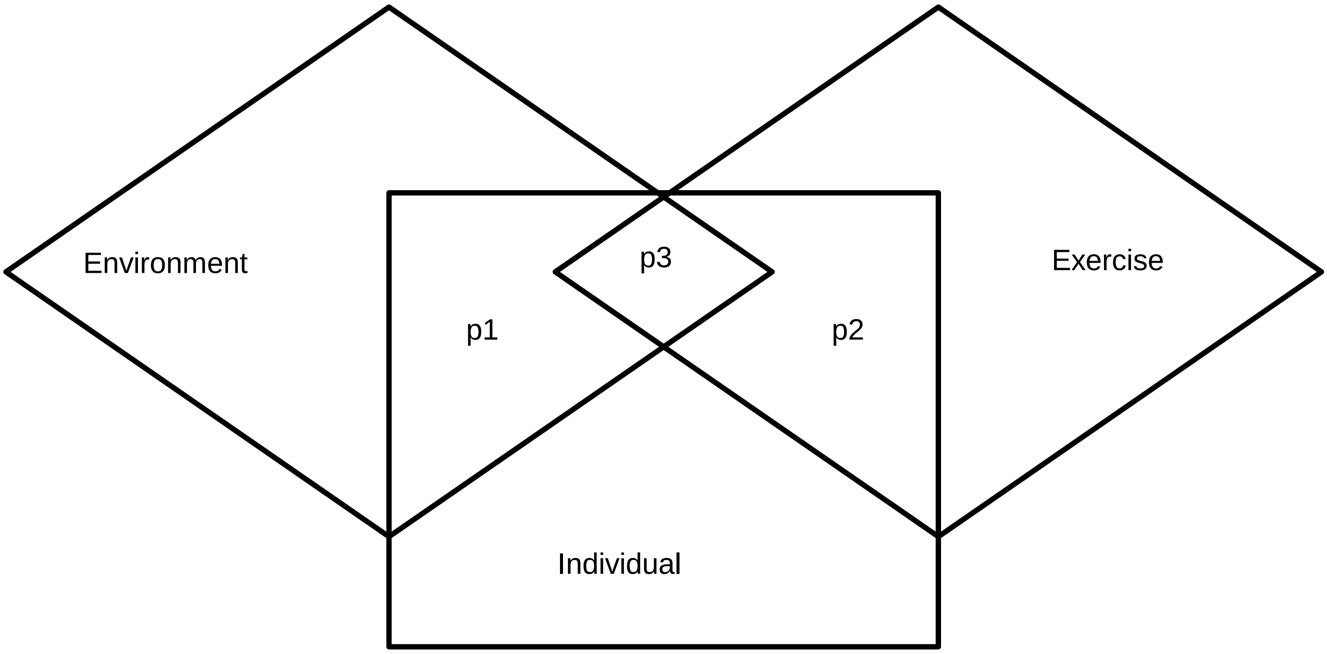


Figure 3.1 The Four Components (Categories of Variables) of Green Exercise: The Three Physical Components, and the Processes Component (p1 - p3)

A framework for categorising and considering variables in relation to green exercise can be derived from Bandura's triadic model of reciprocal determinism and the ecological dynamics approach (Bandura, 1986a, Brymer and Davids, 2014). Figure 3.1 shows that green exercise has three physical components (categories of variables): individual, exercise and environment, and a fourth interactive processes component. The processes component comprises psychological and physiological processes within the individual, in relation to the environment or the exercise, or both. Some stimuli and accompanying processes are mutually environment- and exercise-related (p3 area of Figure 3.1). For example, when running in nature, the stimulus of visual optic flow, as perceived by the individual, is a product of exercise-related motion through the environment (Gibson, 1954, Assaiante et al., 1989) (Gibson, 1954, Assaiante et al., 1989). The ecological dynamics approach views each of the individual, environment and exercise (task) as a system comprising a complex arrangement of factors (e.g. within the individual system: cognitive, affective and physiological states, physical flexibility, limb length). These interacting constraints act as boundaries, within which, behavioural invitations or possibilities (termed 'affordances') exist. In this way, the component-related variables referred to within the current study might also be thought of in terms of being constraints.

Exploration of phenomenological experiences of green exercise activities (Brymer and Gray, 2009) and the underpinning cognitive processes of green exercise effects (Harte and Eifert, 1995, Berman et al., 2008, Akers et al., 2012) has provided an initial insight into the processes component. Age and gender appear to influence psychological outcomes, addressing the individual component (Barton and Pretty, 2010). Regarding the exercise component, intensity and duration of green exercise can influence affective outcomes (Barton and Pretty, 2010, Thompson Coon et al., 2011). Examining the environment component, perceived colour of the visual exercise environment effects mood and perceived exertion (Akers et al., 2012). Climatic conditions influence mood and cognition (Keller et al., 2005) but such temporary variables are often not well-accounted for. Furthermore, few research studies have compared exercise outcomes between different nature environments, despite suggestions that the presence of water features within nature-based environments can enhance the effects of green exercise (Barton and Pretty, 2010, White et al., 2010). To better understand green exercise outcomes, the four green exercise components should be studied simultaneously.

3.1.1 Chapter Aims and the Current Study

The modern function of parks often includes usage by organised running groups who participate in set distance runs. This provides an ecologically valid opportunity to control or record relevant variables whilst measuring outcomes of green exercise participation. The current chapter had two aims: to investigate potential differences in affective outcomes of running between different typical green exercise environments; and to examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes. The hypotheses were (i) that environments with greater presence of visible water features would facilitate greatest improvements in affective states via green exercise participation; and (ii) that a number of other measured individual factors, and those related to the environment, the exercise undertaken, and the processes component, would significantly predict psychological improvements.

3.2 METHODS

3.2.1 Participants

A convenience sample of 331 participants was recruited for this study (180 males, 151 females; age 40.8 ± 12.0 years). Participants were attendees at four UK parkrun event locations: Gorleston Cliffs (‘beach’): N = 67; Nowton Park, Bury St Edmunds (‘grasslands’): N = 83; Central Park, Chelmsford (‘riverside’): N = 100; Castle Park, Colchester (‘heritage’): N = 81. In order to produce variance in the environmental-component related measures of interest, data was collected on four separate dates at each event location, during September and November 2013. Adhering to Tabachnick and Fidell’s (2007) guideline that a cases-to-independent variable (IV) ratio of 40 to 1 is reasonable for stepwise multiple regression analysis (SMR), a minimum sample size of N=300 was sought in order to allow for a maximum of six IVs to be entered into each SMR.

3.2.2 ‘parkrun’ and event locations

‘parkrun’ is a weekly, timed, 5km run which takes place in public spaces across multiple locations, both within the UK and internationally. It is branded as ‘not about racing, it’s about running’, in order to encourage individuals of wide-ranging fitness to participate (parkrun, 2015). During the first six months of 2014, a mean of 243 ± 16 events were held in the UK each Saturday. The average combined weekly attendance to UK parkrun events for this period was 42,966 ± 6,006 individuals.

Event locations were selected to enable comparisons between different typical green exercise environments. As outlined previously, event locations were those of: beach, grasslands, riverside, heritage. Two criterion measures were used: (i) average number of attendees per week (selection criteria was a minimum average of 80 attendees); (ii) environmental characteristics of 5km run route, in particular, the quantity of water content.

The environmental characteristics of each location were as follows. The beach route (Gorleston Cliffs) was along a pathway which tracks both along the top of cliffs (with views of beach and sea to one side, and a road and buildings to the other) and along the beach pathway below. The grasslands route (Nowton Park, Bury St Edmunds) was within a park, with the majority of the route comprising grassland that bordered areas of woodland and was interspersed with trees; there was no view of water on this route. The riverside route (Central Park, Chelmsford) tracked along pathways within an urban park. The majority of the route closely followed a river and, although had frequent views of buildings, was predominantly maintained grass areas interspersed with trees. The heritage route (Castle Park, Colchester) tracked along pathways within a heritage park. The route in part tracked along a river and, although in parts had views of buildings (including a castle), was predominantly maintained grass areas interspersed with trees and maintained flowerbeds. A greater proportion of the riverside route was in visible proximity to river than was the heritage route.

3.2.3 Design and Procedure

At one of four locations, participants completed questionnaires immediately pre- and post-run, creating a mixed between-within design. On arrival, attendees were approached at random by a researcher and asked whether they would be willing to complete the two questionnaires; this was 5 - 35 minutes before the run commenced. Participants completed their post-run questionnaire within 10 minutes of crossing the finish line. It was estimated that approximately 35% of approached attendees declined to participate.

Questionnaires were composite, comprising standard international measures of self-esteem (RSE), perceived stress (PSS), mood (POMS) and nature-relatedness (NR-6). Questionnaires also included bespoke menu-based questions regarding participants' primary motivation for attendance (the available options for this were: 'improving your fitness'; 'improving your performance time'; 'the social aspects of attending'; 'getting outdoors for a while'; 'other'), membership of a running club (the options for this were: 'yes'; 'no'), and run performance in relation to their expectation (measured in the post-run questionnaire, the options for this were: 'I did better than I had expected'; 'I did worse than I had expected'; 'I did equally as well as to how I had expected'; 'I did not have an expectation today'). Participants' enjoyment of the run was measured in the post-run questionnaire using a 100 mm visual analogue scale as a continuum from '0 - not at all' to '100 - very much'.

Collection of data on four dates at each location produced variance measures of the climatic environmental factors (temperature, cloud cover, rain). On each data collection date, new participants were sought. Where participants completed questionnaires on more than one date, only data from their first date was included in the analysis.

3.2.4 Measures

The measures of RSE, PSS, NR-6 and POMS TMD are outlined in Chapter 2. Other factors relating to the climate, individual, and the exercise performed were also measured via questionnaire and collected from the parkrun website (Table 3.2). Participants' performance time (time taken to complete the run) and an age-adjusted performance level were obtained from the parkrun organisation's database. Age-adjusted performance was calculated by the parkrun organisation as an expression of participants' run completion time in relation to the 5km world record for their sex and age. Temperature and cloud cover percentage at 09:00am, and rainfall during the run were also recorded (Table 3.2).

Table 3.2 Descriptive Statistics for Environment-, Exercise- and Individual-Related Variables

Individual-related Variables	**Mean ± SD**	**Frequency**	
Age (yrs)	40.8 ± 12.00		
Sex		Male -54.4% (n= 180)	Female – 45.6% (n= 151)
Motivation for Attendance		Improving fitness – 67% (n= 208)	Other – 33.3% (n= 104)
Club Runner		Club-runners – 33.8% (n= 112)	Non club-runners – 66.2% (n= 219)
Performance Expectation		Did better than expected – 40.2% (n= 132)	Other – 59.8% (n= 196)
Nature Relatedness	3.71 ± 0.78		
Exercise-related Variables			
Performance time (seconds)	1642.15 ± 341.84		
Age-adjusted performance (%)	56.11 ± 9.60		
Environment-related Variables			
Temperature (° C)	12.21 ± 4.00		
Cloud cover (%)	58.16 ± 30.11		
Rain during run (yes or no)		Rain:- 2 events	No rain – 14 events
Processes-related Variable			
Enjoyment Rating (mm)	80.5 ± 19.3		

Age-adjusted performance: calculated by parkrun as a comparison of participants' run completion time against the 5 km world record for the participant's sex and age (greater score % = better relative performance). Primary motivation for attendance: options for this were 'improving your fitness'; 'improving your performance time'; 'the social aspects of attending'; 'getting outdoors for a while'; 'other'. Enjoyment rating: visual analogue scale continuum form 0 mm –not at all to 100 mm – very much. Performance expectation: how well participants felt that they performed in the run in relation to how they had expected to do – options for this were: 'I did better than I had expected'; I did worse than I had expected'; 'I did equally as well as to how I had expected'; 'I did not have an expectation today'. Nature Relatedness: ranging from 0-5, higher scores indicate greater level of nature relatedness.

3.2.5 Data Treatment

For SMR analyses, the variable of 'primary motivation' was dichotomised into two categories: 'improving fitness' (the most frequent response); and 'other reasons' (created by collapsing all other options: 'improving your performance time'; 'the social aspects of attending'; 'getting outdoors for a while'; 'other'). The variable of 'expectation' was also dichotomised into two categories: 'I did better than I had expected' (most frequent response); and 'other' (created by collapsing all other options: 'I did worse than I had expected'; 'I did equally as well as to how I had expected'; 'I did not have an expectation today').

3.2.6 Statistical Analysis

For the primary hypothesis, mixed 4 (between (event location: beach, grasslands, riverside, heritage)) x 2 (within (time: pre-exercise, post-exercise)) ANOVAs compared change in the measures of RSE, PSS, and TMD, according to location. Locations were ordinally ranked in terms of the proportion of the 5km route from which water was visible. A one-way within-subjects MANOVA analysed changes in subscale mood factors from pre- to post-run. For the secondary hypothesis, SMRs examined the extent that individual-, environment-, and exercise-component-related IVs were associated with the selected outcomes (RSE, PSS, TMD). Predictors were selected based on their strength of association with the pre- to post-exercise change in that measure. For each outcome, only statistically significant predictors were entered into a SMR. For the continuous-data variables, strengths of associations were indicated by beta values, calculated via simple linear regressions with the delta value for each selected measure (Table 3.3). For the dichotomised, categorical-data variables, strength of association was indicated by Cohen's d, obtained via independent samples t-tests on the delta values of each measure (Table 3.4).

3.3 RESULTS

Table 3.3 Standardized beta coefficient from simple linear regressions to select continuous-data variables to enter the SMR for each measure

Scale Variable	Measure		
	Δ RSE	**Δ PSS**	**Δ TMD**
Age (years)	B= -0.066 p= 0.23	B= 0.067 p= 0.23	B= 0.025 p= 0.68
Temperature (°C)	B= 0.060 p= 0.28	B= 0.042 p= 0.45	B= 0.060 p= 0.32
Cloud Cover %	B= 0.041 p= 0.47	B= 0.016 p= 0.77	B= -0.013 p= 0.83
Performance Time (secs)	B= 0.065 p= 0.26	B= -0.102 p= 0.08	B= -0.069 p= 0.27
Age Adjusted performance (%)	B= -0.058 p= 0.31	B= 0.126* p= 0.03	B= 0.029 p= 0.64
Enjoyment Rating	B= 0.289* p= 0.00	B= -0.078 p= 0.18	B= -0.251* p= 0.00
Nature Relatedness	B= -0.064 p= 0.26	B= -0.026 p= 0.65	B= -0.154* p= 0.01

* = selected for stepwise multiple regression

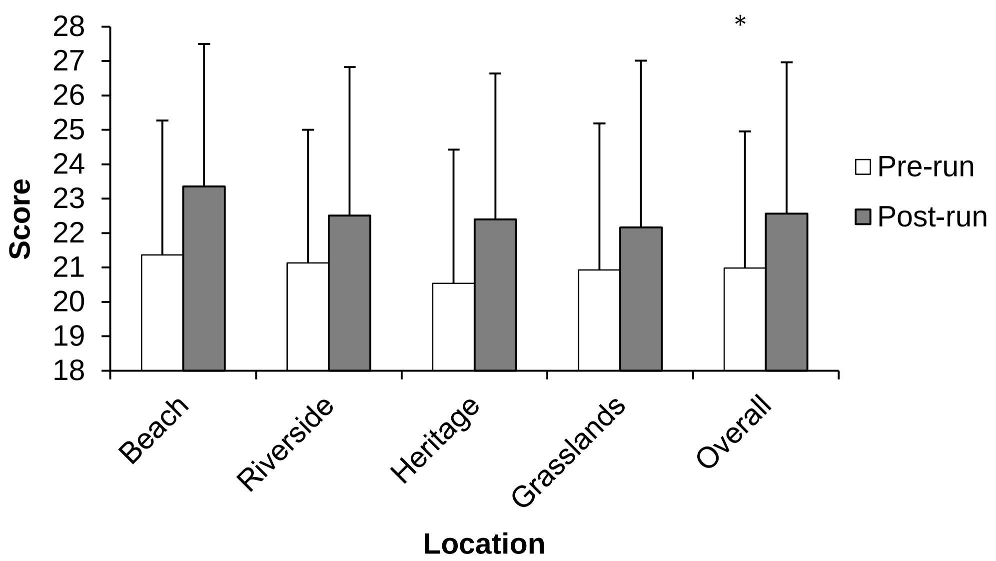
Table 3.4 Independent t-tests to select categorical variables to enter the stepwise multiple regression for each measure

Dichotomous Variable	Measure		
	Δ RSE	Δ PSS	Δ TMD
Sex	t= -1.48 p= 0.139 *d*= 0.164 r= 0.082	t= 1.03 p= 0.305 *d*= 0.121 r= 0.060	t= 2.38 p=0.018 *d*= 0.285* r= 0.141
Rain	t= -0.35 p= 0.729 *d*= -0.038 r= 0.019	t= -0.74 p= 0.461 *d*= -0.083 r= 0.041	t= 0.49 p= 0.625 *d*= 0.059 r= 0.029
Performance Expectation	t= -2.52 p= 0.012 *d*= -0.281* r= 0.139	t= 1.39 p= 0.166 *d*= 0.157 r= 0.078	t= 1.37 p= 0.173 *d*= 0.164 r= 0.082
Primary Motivation	t= -1.18 p= 0.24 *d*= -0.134 r= 0.067	t= 0.59 p= 0.559 *d*= 0.068 r= 0.034	t= 0.30 p= 0.769 *d*= 0.036 r= 0.018
Club Runner	t= -0.23 p= 0.818 *d*= -0.026 r= 0.013	t= -0.38 p= 0.703 *d*= -0.043 r= 0.021	t= 1.25 p= 0.212 *d*= 0.150 r= 0.075

* = selected for stepwise multiple regression

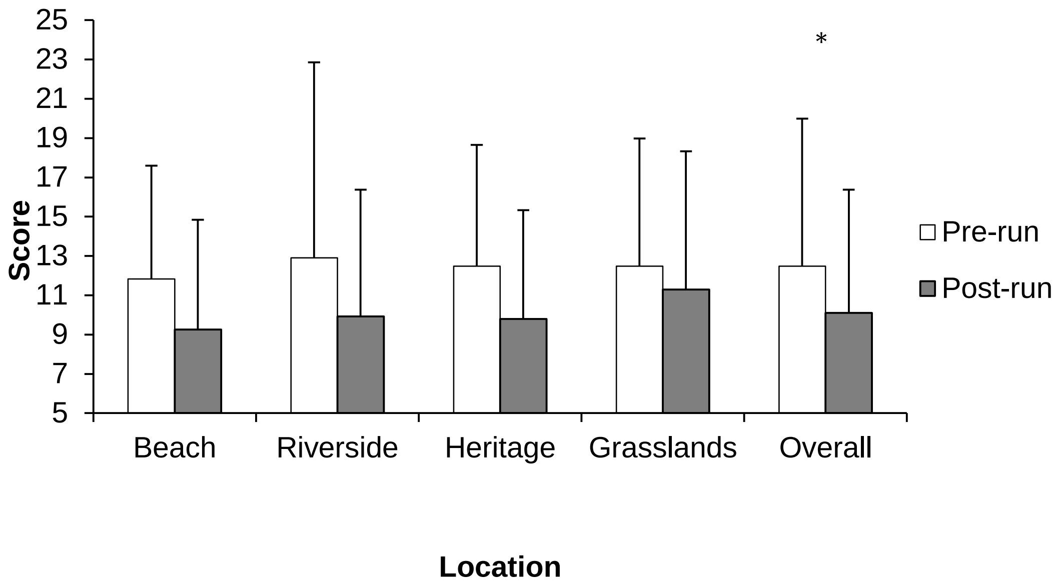
3.3.1 Analysis of means

Mixed ANOVAs showed that there were no significant time by location interaction effects ($p > 0.05$) and no main effects for location ($p > 0.05$) for any of the main measures. However, there were significant ($p < 0.001$) improvements from pre- to post-exercise for RSE (7.7% improvement; $F_{1,324} = 100.58$, $\eta p^2 = 0.24$; Figure 3.2), PSS (18.4% improvement; $F_{1,315} = 50.78$, $\eta p^2 = 0.139$; Figure 3.3) and TMD (14.2% improvement; $F_{1,278} = 22.15$, $\eta p^2 = 0.07$; Figure 3.4).



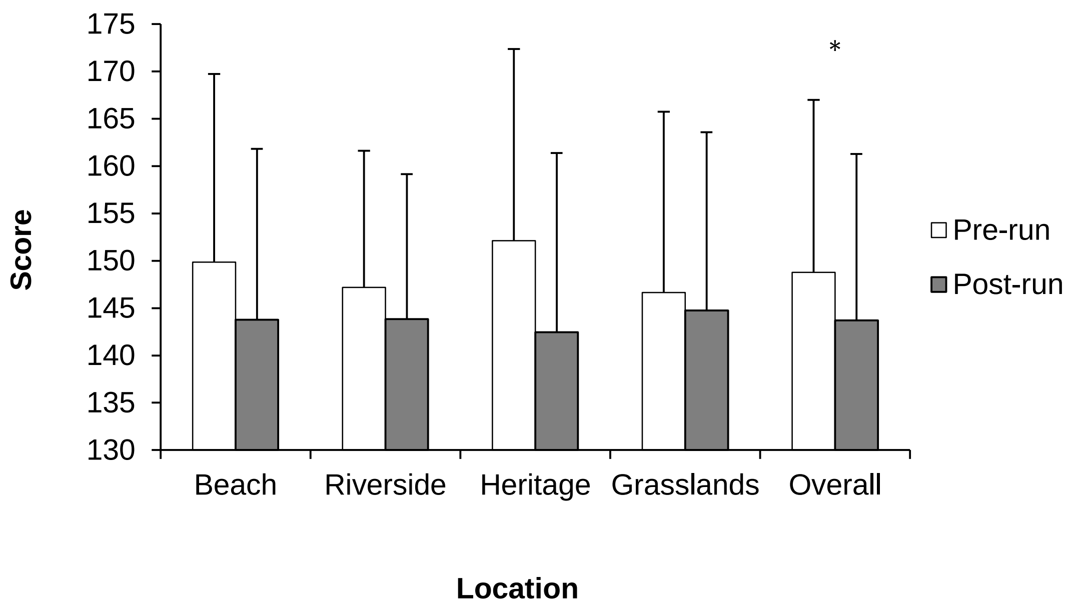
* indicates significant pre- to post-run improvement at alpha level of 0.05; higher score indicates greater self-esteem

Figure 3.2 Pre- and post-run scores for RSE



* indicates significant pre- to post-run improvement at alpha level of 0.05; higher score indicates greater stress

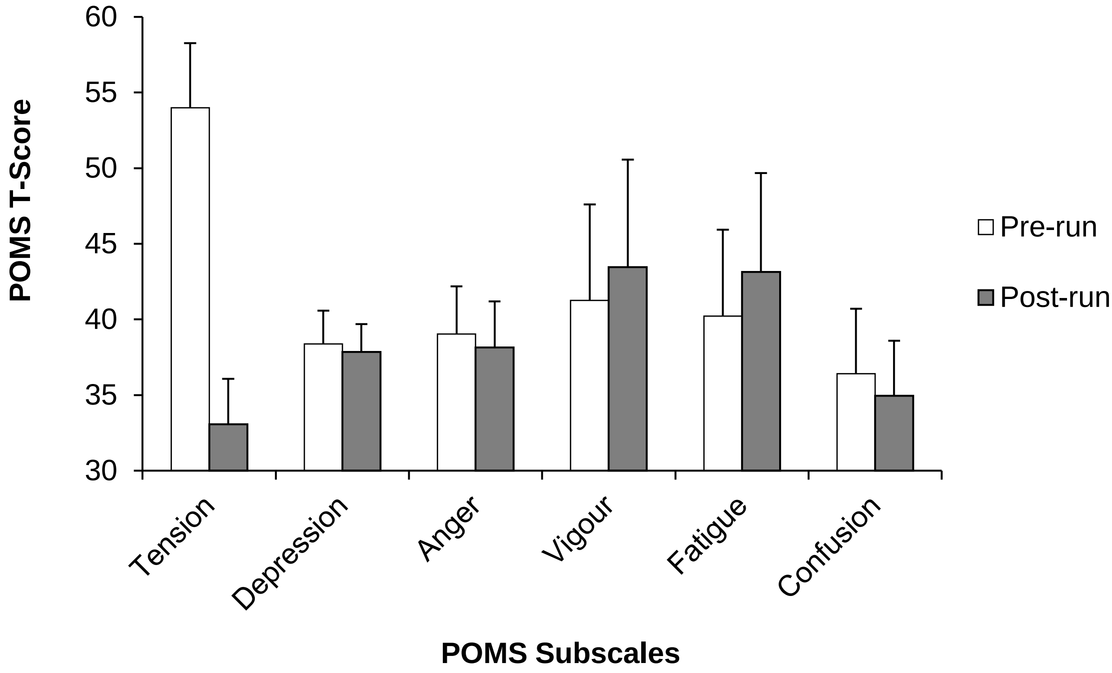
Figure 3.3 Pre- and post-run scores for PSS



* indicates significant pre- to post-run improvement at alpha level of 0.05; lower score indicates better mood

Figure 3.4 Pre and post-run scores for POMS TMD

A one-way within-subjects MANOVA found that there was not a significant time by condition interaction for the POMS subscale scores. Neither was there a main effect for condition. However, there was a significant ($p < 0.001$) main effect for time ($F_{6,276} = 51.13$, $\eta p^2 = 0.526$). Univariate analyses showed that tension, depression, anger and confusion all significantly ($p < 0.001$) decreased from pre- to post-run. Vigour and fatigue significantly ($p < 0.001$) increased (Figure 3.5).



Higher score indicates greater level of subscale mood state

Figure 3.5 Pre and post-run differences in scores for POMS subscales

3.3.2 Prediction of outcomes

SMR showed that RSE improvement was predicted by enjoyment rating and performance in relation to expectation. Enjoyment rating was the primary predictor of ΔRSE, whereby each percent of greater enjoyment of the run explained 0.26% (B= 0.03, 95% CI [0.02, 0.05]) of the improvement in self-esteem. Reporting 'better than expected' performance in relation to expectation was associated with greater RSE improvement (B= 0.86, 95% CI [0.22, 1.50]) than was reporting one of the other collapsed options for this measure. This model accounted for 9.0% of the variance of RSE improvement. That is, participants who reported greatest enjoyment of the run and reported feeling that they performed 'better than expected' obtained 9% more benefit from their participation in terms of RSE than those who reported least enjoyment and reported feeling that they either performed worse than expected, performed equally as well as expected, or did not have an expectation.

Only age-adjusted performance level predicted ΔPSS. Each percent lower of age-adjusted performance level was associated with 0.08% (95% CI [0.01, 0.15]) of the reported improvement in PSS. This model accounted for 1.6% of variance in PSS improvement.

Nature relatedness, sex and enjoyment independently predicted improvement in TMD. Each percent of greater nature relatedness was associated with 3.68% (B= -3.68, 95% CI [-6.40, -1.0]) of the reported improvement in TMD (as indicated by greater negative Δ value). Greater enjoyment of the run was associated with greater improvement in TMD (B= -0.15, 95% CI [-0.24, -0.06]), and females reported greater improvement in TMD than males (B= -6.82, 95% CI [-11.12, -2.51]). This model accounted for 9.5% of the variance of TMD improvement. That is, females who reported greatest levels of nature relatedness and greatest enjoyment obtained 9.5% more improvement in mood than did males who reported lowest nature relatedness and enjoyment.

All tolerance values were greater than 0.9, indicating that there were no cases of significant multicollinearity for any of the multiple regression models (Tabachnick and Fidell, 2007). Summary of regression models can be seen in Table 3.5.

Table 3.5 Summary of stepwise multiple regression models for each measure

		Coefficient Values and Collinearity Statistic					Model Values				
Measure	Model	Coefficient	Unstandardized Beta	Standardised Beta	p	Tolerance	r	R^2	Adjusted R^2	R^2 change	Durbin Watson
RSE	1	Constant	-1.72		0.018		0.26	0.07	0.07	0.07	2.09
		Enjoyment	0.03	0.26	<0.001	1.0					
	2	Constant	-1.99		0.007		0.3	0.09	0.08	0.02	
		Enjoyment	0.03	0.26	<0.001	0.998					
		Expectation	0.86	0.15	0.008	0.998					
PSS	1	Constant	-6.86		0.001		0.13	0.02	0.01	0.02	1.88
		Age-adjusted performance	0.08	0.13	0.029	1.0					
TMD	1	Constant	8.80		0.069		0.19	0.04	0.03	0.04	1.81
		Enjoyment	-0.14	-0.19	0.003	1.0					
	2	Constant	13.14		0.008		0.26	0.07	0.06	0.04	
		Enjoyment	-0.16	-0.20	0.001	0.992					
		Sex	-6.79	-0.19	0.002	0.992					
	3	Constant	26.54		<0.001		0.31	0.10	0.08	0.03	
		Enjoyment	-0.15	-0.20	0.001	0.992					
		Sex	-6.82	-0.19	0.002	0.992					
		Nature relatedness	-3.68	-0.16	0.008	0.999					

3.4 DISCUSSION

Chapter 1 discussed that green exercise participation promotes affective wellbeing. The current study aimed to determine potential sources of variation in these changes. The aims of the study were twofold: (i) to investigate whether psychological green exercise effects might differ according to the type of green setting (e.g. quantity of water), and (ii) to investigate which individual-, environment-, exercise- and processes-related factors might predict green exercise health outcomes.

Consistent with previous research, a single bout of green exercise improved self-esteem and mood (Barton et al., 2009, Barton and Pretty, 2010). It also improved perceived stress. That green exercise improved TMD, tension, depression, anger, vigour and confusion, is consistent with previous research (Barton et al., 2009). Although these measures cannot indicate either the real term benefit to participants or the potential clinical significance, the findings demonstrate significant improvements in acute psychological wellbeing nonetheless, which in the short term may be used by health promotion initiatives (Barton et al., 2012a). Acute affective exercise outcomes influence longer-term motivation for and adherence to exercise behaviours (Williams et al., 2008, Kwan and Bryan, 2010a, Kwan and Bryan, 2010b). Here, green exercise participation might function as a tool for maintenance of exercise behaviours (Thompson Coon et al., 2011). This possibility will be examined in comparison to indoor exercise in a later experimental chapter. The worsening of POMS fatigue contradicts previous work. Timed 5km runs are likely to be more strenuous than the exercise of previous green exercise studies (Pretty et al., 2005, Focht, 2009, Barton and Pretty, 2010, Akers et al., 2012). Greater exercise intensity may increase likelihood of participants interpreting items of the fatigue subscale (‘fatigued, worn out, exhausted, sluggish, weary’) as referring to physiological senses of these words, rather than the intended psychological sense.

Although exercise may have been more strenuous than that examined in previous green exercise studies, it seems likely that the intensity of exercise tended to be below ventilatory or lactate thresholds. Whereas intensities below these thresholds are associated with positive affective responses, for most recreational exercisers, intensities above these are associated with affective displeasure (Ekkekakis et al., 2011). However, self-pacing of exercise facilitates greater tolerance of high intensities than does imposed pacing (Ekkekakis et al., 2011). For some individuals this may have buffered their overall affect from detrimental influences of high intensities.

Global self-esteem is typically considered to be a stable construct. However, acute effects of exercising in different environments on self-esteem have been reported (Barton and Pretty, 2010, Thompson Coon et al., 2011). As suggested by Fox’s hierarchical model of physical self-perceptions in the physical domain (Fox, 1990), the acute impact reported for global self-esteem in the current study was likely to have been contributed to by underpinning perceptual domains of sports competence and physical self-worth (Fox, 1990). A limitation of the current study was that it did not additionally use the physical self-perception profile or a similar inventory to enable these domain and sub-domains to be fully considered (Fox and Corbin, 1989).

Hypothesis (i), that event locations with greatest presence of water features would facilitate greatest psychological improvements, was not supported. Event location was not shown to influence the extent of the psychological improvements, despite differences in environmental characteristics. This is in contrast to previous evidence that the presence of water might enhance psychological effects of green exercise (Barton and Pretty, 2010, White et al., 2010). Considering these previous and current findings together alludes to the possibility that in previous research, such as that of Barton and Pretty (2010), differences in outcomes between green exercise environments might have been significantly contributed to by other factors which vary between settings, such as exercise type, duration, and intensity. Another possibility is that, although the beach route incorporated mostly water (with the sea visible along the entire route), buildings were also visible along much of the route, which may have been detrimental to affect (Pretty et al., 2005). The possibility that timed parkrun 5km exercise may have been more strenuous than previous green exercise studies is also important (Pretty et al., 2005, Focht, 2009, Barton and Pretty, 2010, Akers et al., 2012). Environmental characteristics might be less influential at greater exercise intensities, as attention is focused more internally (LaCaille et al., 2004, Hutchinson and Tenenbaum, 2007).

The finding that outcomes were not different between typical green exercise environments can be interpreted in different ways. Considered in relation to previous research reporting green exercise to elicit comparatively greater psychological benefits than exercising either indoors (Teas et al., 2007, Focht, 2009) or in built outdoor environments (Bodin and Hartig, 2003, Bowler et al., 2010, Thompson Coon et al., 2011), this finding suggests that additional affective benefits may be universally obtainable across a range of green exercise environments. However, the current study did not include a non-nature based comparison exercise-environment. Here, as acute affective benefits of single exercise bouts have been consistently reported (Yeung, 1996, Lane and Lovejoy, 2001, Bartholomew et al., 2005, Reed and Ones, 2006, Ellis et al., 2013, Guszkowska et al., 2013), it is not possible for the current study to decipher between the respective contributions of the 'greenness' of the exercise-environments and the exercise per se. That is, similar affective benefits might have been gained by 'non-green' exercise. Given that the current findings failed to support hypothesis (i), and that a non-green comparison is required in order to examine benefits of green *versus* non-green environmental settings; the remaining experimental chapters of this thesis will therefore include non-green environmental comparison conditions. The findings for hypothesis (i) also indicate that a grassland park is an appropriate outdoor green exercise environment for outdoors *versus* indoor comparisons. This will be used in later experimental chapters.

A main strength of this study was its ecological validity. The results represent improvements in psychological wellbeing as observed from real-world agency of individuals, rather than of a designed and instructed intervention. Another strength of this study was that it controlled exercise type and accounted for component-related variables – a first within green exercise research using field sampling. Previous research of this kind has not examined whether type of green environmental setting still influences psychological outcomes after controlling exercise type and/or differences in exercise performed (such as duration) (Pretty et al., 2007, Barton et al., 2009, Barton and Pretty, 2010).

Hypothesis (ii), that a number of such variables would predict psychological outcomes, was supported. Run enjoyment and performance in relation to expectation accounted for 9.0% of the variance in RSE improvement. Further, age-adjusted performance level accounted for 1.6% of the variance in improved stress. Individuals' nature relatedness, sex and enjoyment accounted for 9.5% of the variance in improved overall mood. The positive correlation of enjoyment with affective state outcomes from green exercise participation is consistent with the findings of Focht (2009). Enjoyment significantly predicting mood was anticipated, as enjoyment has been categorised as a tertiary emotion (Plutchik, 1980a, Shaver et al., 1987) and describes self-appraisals of emotional responses to an event.

As the individual system comprises personal characteristics which influence relationships with the environment, identification of the most relevant characteristics to beneficial outcomes of green exercise is important (Brymer and Davids, 2014). There was positive association between the individual component-related variable of nature-relatedness and improvement in mood. As psychological wellbeing has been associated with individuals' relationship with nature (Wilson, 1984, Howell et al., 2011, Nisbet et al., 2011), it might also be expected that individuals who have the greatest level of nature relatedness would respond most positively to green exercise (Martyn and Brymer, 2014). This was the first study to measure nature relatedness within green exercise research. That it accounted for a proportion of the improvement in mood suggests that this variable warrants inclusion in future examinations of green exercise. Therefore the NR-6 measure will be included in later experimental chapters of this thesis.

Explanation of the negative association between age-adjusted performance level and perceived stress improvement is unclear. To speculate, higher age-adjusted performance level might be indicative of greater focus on exercise cues and therefore less psychological engagement with the environment, which may limit affective benefits from environment-related semantic and episodic memory recall.

Less than 10% of the variance in the health measure improvements was predicted by the independent variables, alluding to the importance of processes component-related factors such as individuals' phenomenological experiences of both exercise and environment. The lived experience of exercise can be complex and difficult to measure (Crocitto, 1982). Methods more complex than the quantitative approach of this study may offer greater scope for understanding and assigning meaning to occurrences within the 'black box' of the processes component, which underpin the reported outcomes. Phenomenological methodologies of interviews, written reports and auto-ethnography may be of use here.

The demonstrated inclusiveness of affective improvements is consistent with psycho-evolutionary perspectives discussed in Chapter 1, which suggest that, via the evolutionary history of human experiences within nature environments, today's individuals are pre-disposed to positive psychological responses to nature environments, given an absence of perceived threat (Wilson, 1984, Kaplan and Kaplan, 1989, Ulrich et al., 1991, Kaplan, 1995).

This was the first study to rigorously examine the importance of a range of factors relating to the individual, exercise, environmental and processes components to green exercise health outcomes. Green exercise improves self-esteem and mood and reduces feelings of stress, irrespective of the type of green setting. Considered together with the research outlined in Chapter 1, the implication of this finding is that, whereas overall type (i.e. nature, urban) of environmental exercise may be important for wellbeing outcomes, specific exemplars of environment type may be less important.

The findings also advance the previous limited understanding of the importance to outcomes, of specific individual-, environment-, and exercise-related variables (constraints). Although a range of component-related variables can influence the attainment of green exercise benefits, much of the variance in the data was not explained by these. This suggests that large proportions of the psychological benefits of green exercise are universally obtainable, independent of demographic, performance-level, climatic and other environmental characteristics. This finding alludes that further examination of the processes component of green exercise is warranted. The field methodology of the current chapter does not enable controlled manipulations; therefore, for examination of mechanisms that might comprise the processes component of green exercise participation, the remaining experimental chapters will instead use laboratory-based methods, as outlined in Chapter 1.

Chapter Four: Effects of the Visual Exercise Environments on Cognitive Directed Attention, Energy Expenditure and Perceived Exertion

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A version of this chapter has been published as a research article. The reference for this is:

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Table 4.1 Thesis Map outlining Chapter aims and key findings

Chapter	Aims	Key Findings
3	• To investigate potential differences in affective outcomes of running between different typical green exercise environments • To examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes	• Affective wellbeing improved from pre- to post-green exercise participation • No significant effect of green exercise environment type was identified • RSE improvement was predicted by enjoyment, and performance in relation to expectation; PSS improvement was predicted by age-adjusted performance; TMD improvement was predicted by nature relatedness, sex and enjoyment • Large proportions of the psychological benefits of green exercise are universally obtainable independent of a range of exercise-, individual-, environment-related variables
4	• To examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component	
5	• To identify a method for ensuring consistency of the exercise component between indoor (treadmill) and outdoor (over ground) exercise • To compare psychological outcomes of outdoor *versus* indoor exercise	
6	• To compare a psychological, social and behavioural intention outcomes of exercise in green outdoors *versus* indoors settings, whilst controlling the exercise component	

4.1. INTRODUCTION

In Chapter 3, a between-participant design was used, whereby each participant only completed exercise in only one of the four environmental conditions. Potentially confounding influences of individual differences can be negated, and environmental influences on exercise outcomes better isolated by within-participant design can be used. As the study of Chapter 3 did not include a non-green comparison environment, it was not possible to determine whether or not any, or all, of the four examined typical green exercise environments would enhance psychological exercise outcomes compared to built or indoor environments. Its discussion section highlighted the importance of including a non-green comparison condition. Chapter 4 therefore compares nature environmental setting with a built setting, and includes an additional control condition.

Chapter 1 discussed that green exercise environments can promote restoration of fatigued attentional resources, which may in turn function to improve affective states. In order to understand specific facets of how wellbeing-related psychological outcomes of green exercise participation occur, elements of the green exercise experience must be examined in isolation. Although in Chapter 3 the type of exercise performed was consistent (running), the exercise intensity varied between participants due to factors such as fitness and motivation. The laboratory-based paradigm outlined in Chapter 1 enables control of the exercise component, which allows for human-environment interactions during exercise to be examined. For these reasons, Chapter 4 uses a laboratory-based methodology.

As well as the affective measures that were the focus of Chapter 3, 'directed attention' is another psychological outcome that can be influenced by exercise-environments (Hartig et al., 2003, Berman et al., 2008). As outlined in Chapter 1, directed attention is the effortful cognitive ability to avoid being distracted by competing stimuli (Itti et al., 2005, Kaplan and Berman, 2010). Brain regions associated with processes of mental effort, attention and mediation of cognitive control can fatigue over time (Kaplan and Berman, 2010). This depletion of directed attention is termed 'directed attention fatigue'. Using involuntary attention - that which does not involve mental effort (Kaplan, 1995, Berman et al., 2008) – decreases use of directed attention. This provides opportunity for restoration of depleted attentional resources (Kaplan and Berman, 2010).

Transient hypofrontality (Dietrich, 2003, Dietrich and Sparling, 2004, Dietrich, 2006) posits a pathway linking exercise with attention restoration. Prefrontal cortex activation is associated with processes of directed attention (Daffner et al., 2000, Milham et al., 2001, Miller and Cohen, 2001, Gailliot and Baumeister, 2007). Exercise facilitates prefrontal cortex restoration via transient hypofrontality (Dietrich, 2003, Dietrich and Sparling, 2004, Dietrich, 2006), that is, decreases in prefrontal cortex activity that occur in conjunction with increased motor cortex activity. *During* exercise, this decreased prefrontal cortex activity may be detrimental to cognitive performance (Dietrich and Sparling, 2004, Labelle et al., 2013). However, *following* prolonged opportunity for prefrontal cortex restoration, transient hypofrontality improves post-exercise executive functioning and cognitive performance (Yanagisawa et al., 2010, Byun et al., 2014).

Disparate to exercise-related mechanisms, attention restoration theory proposes that visual characteristics of natural environments promote involuntary attention and facilitate restoration of directed attention capacity and affective states (Kaplan and Kaplan, 1989, Kaplan, 1995, Kaplan, 2001). Spending an hour at rest in an outdoor garden facilitates directed attention improvements in elderly individuals, compared to equivalent rest in a favourite indoor room (Ottosson and Grahn, 2005). Viewing photographs of nature environments improves directed attention-related task performance, whereas viewing urban environments does not (Berto, 2005). Within workplace settings, 'micro-restorative experiences' provided by views of nature through a window or the presence of plants indoors can reduce directed attention fatigue (Kaplan, 1993, Raanaas et al., 2011).

Green exercise promotes a greater psychological engagement with nature than does viewing nature (Pretty, 2004). Greater immersion may elicit a fuller experience and greater responses to nature environments (Weinstein et al., 2009). Such a role of immersion suggests that green exercise might provide greater scope for attention restoration than either micro-restorative experiences or time spent at rest in nature environments. Additionally, the disparate influences of exercise and of nature environments may positively interact in a manner that further promotes attention restoration. It has been suggested that attention restoration might partly underpin the influence of exercise-environments on affective states (Barton et al., 2009, Barton and Pretty, 2010, Bowler et al., 2010). Directed attention improves following a walk in nature environments but not after an equivalent walk around more built routes (Hartig et al., 2003, Berman et al., 2008). However, the variable of social presence of others was not controlled in this research. Additionally, although Hartig et al. (Hartig et al., 2003) attempted to control exercise intensity, via researchers leading participants in order to maintain a slow walking pace with stops at specified locations on route, exercise intensity (defined as the total or rate of energy expenditure during exercise (Macera et al., 2003, Thompson and Lim, 2003)) was not rigorously controlled in these studies. This is important because intensity influences psychological outcomes of exercise, including cognitive performance

(Tomporowski, 2003, Kilpatrick et al., 2007, Kashihara et al., 2009, Ekkekakis et al., 2011). Chapter 1 identified that future research should ensure comparability of exercise between experimental conditions, so that differences in outcomes can more confidently be attributed to environmental settings.

Exercise environment also influences perceived exertion (how hard one feels that they are physically working during activity; measured by Rated Perceived Exertion scale (Borg, 1970, Borg, 1982, Borg, 1998)). This is one possible pathway via which a lack of control of the exercise component can promote problematic differences in exercise intensity between experimental conditions. When exercising at an instructed perceived exertion, individuals work harder (measured by speed, heart rate and blood lactate concentration) during outdoor exercise than during indoor treadmill exercise (Ceci and Hassmén, 1991). Concurrently, during self-paced exercise, individuals walk faster and work harder (measured by heart rate), yet report lower perceived exertion during outdoor walking compared to indoor treadmill walking (Focht, 2009). These findings are concurrent with the notion that synthetic environments demand greater directed attention processing (Kaplan and Kaplan, 1989, Ulrich et al., 1991, Kaplan, 1995, Kaplan, 2001), as cognitive fatigue promotes greater perceived exertion and impairs performance of exhaustive exercise (Marcora et al., 2009). However, biomechanical and climatic differences between indoor and outdoor exercise are not controlled within these research designs; therefore, origins of reported effects are unclear (Ceci and Hassmén, 1991, Focht, 2009). The colour of visual environment is important to perceived exertion during exercise. Individuals report significantly lower perceived exertion during cycling exercise whilst viewing a nature-scene video, compared to cycling whilst viewing either achromatic- or red-filter versions of the same video (Akers et al., 2012). However, it is not known how perceived exertion varies with different visual exercise environment *types* during controlled exercise.

Lacking control of the exercise component in these studies is also problematic for understanding the origins of reported influences on *physiological* outcomes. It is reported that walking in nature environments promotes lower post-exercise heart rate, greater heart rate variability, lower blood pressure and lower sympathetic nerve activity than equivalent walks in built environments (Tsunetsugu et al., 2007, Park et al., 2008, Park et al., 2010). Environment-associated differences in physiology, as measured during exposure, have also been reported (Park et al., 2010). However, uncontrolled exercise intensity means that findings from these studies cannot be confidently attributed to environment alone. Physiological effects of environment are yet to be demonstrated during controlled exercise. Heart rate, VO_2 and respiratory exchange ratio are not significantly influenced by colour properties of visual exercise environment during controlled cycling exercise (Akers et al., 2012). However, influences of holistic visual exercise environments on directed attention have not been examined during controlled exercise.

The design of the current study enables examination of the reported influence of exercise-environment on perceived exertion (Ceci and Hassmén, 1991, Focht, 2009, Akers et al., 2012). Biological links between subjective sensations of effort and exercise-related physiology comprise a mechanism by which perceived exertion contributes to limiting of exercise performance (Hampson et al., 2001, Tucker, 2009). Perceived exertion is strongly related to individuals' time to exhaustion during high-intensity exercise (Reilly and Baxter, 1983). The current study examines whether visual exercise environment influences perceived exertion and time to voluntary exhaustion during high-intensity exercise.

4.1.1 Chapter Aims and the Current Study

The aim of the current chapter was to examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component.

The current study measured pre- to post-exercise changes in directed attention in three conditions: a nature condition, a built condition and a control condition. Energy expenditure, respiratory exchange ratio and heart rate were measured to ensure: (i) comparability of the exercise component between conditions; (ii) identification of physiological effects of visual environments *during* exercise, and (iii) impacts of physiological differences on changes in cognitive function. The primary hypothesis is that (i) directed attention will improve more after a 15-minute exercise bout whilst viewing video footage of a nature environment, compared to footage of a built environment or viewing a blank screen (control). Secondary hypotheses include (ii) during a steady-state 15-minute exercise bout there will be no significant differences in participants' energy expenditure, respiratory exchange ratio and heart rate between conditions; (iii) perceived exertion will be lower and time to exhaustion will be longer in the nature condition than in a built condition or control condition.

4.2. METHODS

4.2.1. Participants

Twelve healthy adult participants (6 male, 6 female; age 27.8 ± 5.5 years; stature 173.4 ± 11.9 cm; mass 65.4 ± 10.5 kg) were recruited via oral and written advertisements, from student and staff populations at the University of Essex. Participants were instructed to avoid alcohol, caffeine and strenuous exercise within 24-hours prior to each test occasion, and to maintain usual lifestyle and exercise routines throughout their participation.

4.2.2. Design

A within-subjects design was used. Participants completed a Bruce treadmill protocol (Bruce et al., 1963, Bruce et al., 2004) on the first of four test occasions. Participants then completed three experimental test occasions in a randomised, counter-balanced order. Time of day was consistent between occasions (within two hours) and occasions were a minimum of seven days apart, to avoid fatigue effects. Average time between conditions was 13 days. Maximum time between conditions was 25 days.

Experimental test occasions differed only by the video footage displayed on a screen during exercise. In the nature condition, the video consisted of scenes extracted from 'Evening Run Through Endless Forest'. In the built condition, the video consisted of scenes extracted from the 'Boston Marathon Route' (this footage follows the marathon route but is not filmed in the context of the Boston marathon; both videos produced by Outside Interactive, Hopkinton, MA, USA). The speed of movement was consistent (9.62 km/hr) between videos, to avoid confounding variations in pacing-deception and optic flow. To ensure that participants' semantic associations with the city of Boston or the Boston marathon were not a confounding influence, participants were asked whether they recognised the place in the footage. No participants recognised the place. In order to reduce potential social influences, footage was edited to minimise presence of others. For the video footage of the built condition, scenes from the 'Boston Marathon Route' video during which the route moves through areas outside of the city centre (which are of greater greenery) were not included in the footage used. However, some elements of greenery were present in the footage used, for example, trees lining pavements in the city area. The footage used both provided contrast between built and nature conditions and avoided potential confounding influences of large quantities of greenery in both the built condition and the nature condition. The presence of some but little greenery is typical of modern urbanised city areas, thus maintaining the ecological validity of the current study. In the control condition, no video footage was displayed on the screen. That is, participants viewed a blank white screen. The video footage did not include auditory sound, so as to isolate the independent variable of visual environmental stimuli.

4.2.3 Procedures

4.2.3.1 First Test Occasion

Participants completed a Physical Activity Readiness Questionnaire and Informed Consent documents and were briefed on the session's content. Resting blood pressure was then measured in the seated position (using an automatic blood pressure unit; MX3 Plus; Omron, Illinois, USA). Participants were then familiarised and fitted with a heart rate monitor (FR-70 Garmin, Olathe, USA) and portable gas analyser ($K4b^2$: Cosmed, Rome, Italy).

Participants completed a five-minute warm-up which consisted of a 2:30mins treadmill walk (JW200 Powerjog, Sport Engineering Ltd, Birmingham, UK) at a self-selected speed to reflect 50% of perceived maximum effort, followed by a set of stretching exercises as directed by computer presentation (participants were instructed to stretch to an extent that they felt to be at '8 out of 10' in relation to their maximum).

Participants then performed a Bruce treadmill protocol to exhaustion. This was to identify an intensity (speed and gradient) that elicited participants' VO_2peak (VO_2peakInt) for application in the experimental protocols. The treadmill's display screen was covered throughout the study, in order to prevent subjects from viewing intensity, distance and time information.

4.2.3.2. Experimental Conditions

Participants' blood pressure was measured; they were briefed regarding the session's content, and fitted with heart rate and portable gas analysis equipment. Next, participants performed a set five-minute warm-up consisting of a 2:30mins treadmill exercise at 50% VO_2peakInt, followed by the same set of stretching exercises as in the first test occasion.

Participants sat at a desk and completed a Directed Attention-Reducing Battery (as outlined in Chapter 2) in order to utilise and thereby reduce their remaining directed attentional capacity, followed by a Backwards Digit Span test. (Details of the Backwards Digit Span test used were outlined in Chapter 2. Participants attempted to recite nine number strings that were 3-11 digits in length, increasing with order, via a programmed computer-based presentation. The set duration of each Backwards Digit Span test ensured consistency of time between Exercise 1 and Exercise 2, between participants and conditions). During both the Directed Attention-Reducing Battery and the Backwards Digit Span test, the mask of the portable gas analyser was worn loosely around the neck.

Participants then completed a 15-min bout of exercise on the treadmill, at 60% VO_2peakInt (Exercise 1). Participants were instructed to engage with the content of the videos during the exercise. Perceived exertion was measured at 4:30, 9:30, and 14:30mins.

Participants then completed a second Backwards Digit Span test. The warm-up was completed before the Directed Attention-Reducing Battery in order to enable the pre- and post-Exercise 1 Backwards Digit Span tests to occur directly before and after the main manipulation of the study – viewing different environmental scenes during a 15-minute exercise bout. This was to ensure that differences between conditions in participants' lived experiences of the warm-up did not influence performance on post-Exercise 1 Backwards Digit Span tests.

Participants then returned to the treadmill to complete a second exercise bout (Exercise 2). Intensity of Exercise 2 was 85% VO_2peakInt and participants were instructed to run to voluntary exhaustion. Perceived exertion was measured at two-minute intervals. Time to exhaustion for Exercise 2 was also recorded. As variation in participants' time to exhaustion may have served as a confounding influence between conditions, no Backwards Digit Span tests were completed following Exercise 2.

4.2.5. Data Treatment

Respiratory exchange ratio is calculated as = VCO_2 / VO_2 and gives an indication of the energy source being utilised by the working tissues of the body. Respiratory exchange ratio values above 1.1 can be used as an endpoint criterion during VO_2max and VO_2peak tests (Goyal, 2014).

The shortest recorded time to exhaustion for Exercise 2 was 4:47mins. Therefore, to ensure comparability of data both between participants and between conditions, for Exercise 2, only the initial 4:47mins of physiology data (energy expenditure, respiratory exchange ratio, heart rate) were analysed. Heart rate data for two participants was excluded from analysis due to equipment failure.

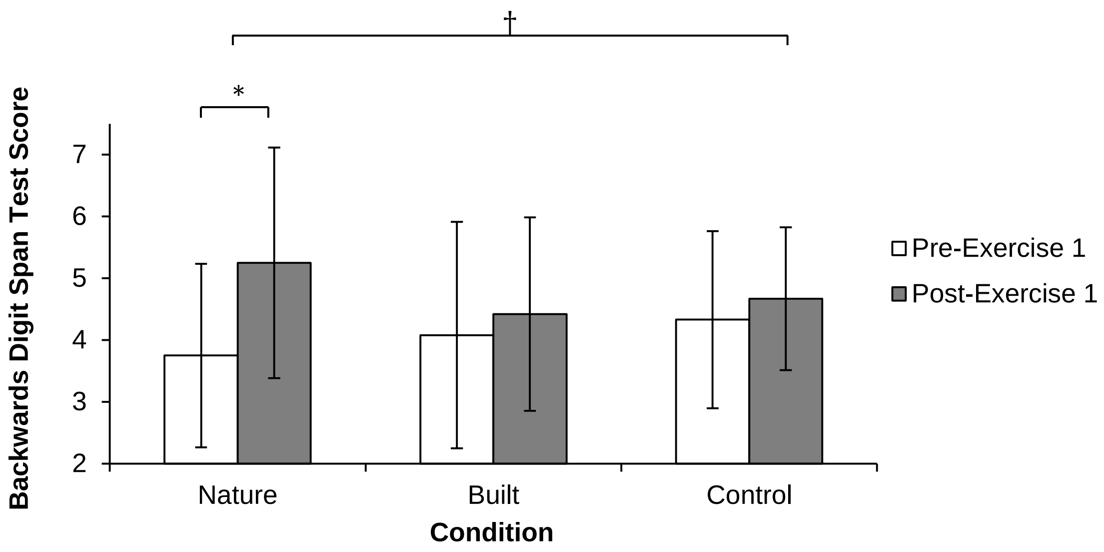
4.2.6. Statistical Analysis

One-way repeated-measures ANOVAs were performed to check for differences in (i) pre-exercise Backwards Digit Span test scores between conditions; (ii) mean heart rate values between conditions during Exercise 1 and Exercise 2; (iii) perceived exertion at each of three time points (4:30mins, 9:30mins, 14:30mins); and (iv) time to exhaustion during Exercise 2. A two-way repeated measures ANOVA was performed on Backwards Digit Span test scores in order to identify any time by condition interaction effect. As energy expenditure and respiratory exchange ratio are directly related variables, one-way repeated measures MANOVAs were used to analyse these variables for each of Exercise 1 and Exercise 2. Although heart rate is also a related physiological variable, this was analysed separately in order to maintain a sample of 12 for the variables of energy expenditure and respiratory exchange ratio. An alpha level of 0.05 was used to indicate statistical significance.

4.3. RESULTS

4.3.1. Backwards Digit Span test scores

Results of a one-way repeated measures ANOVA indicated no significant effect for condition on pre-exercise Backwards Digit Span test scores ($p = 0.290$). A two-way repeated measures ANOVA indicated a significant interaction effect for time by condition ($F_{2,22} = 6.267$, $p = 0.007$, $\eta p^2 = 0.363$; Figure 4.1). Pairwise comparisons showed Backwards Digit Span improvements were significantly greater in the nature condition ($p < 0.001$, 95% CI [0.87, 2.14]), compared to the built condition ($p = 0.266$) and control condition ($p = 0.166$).

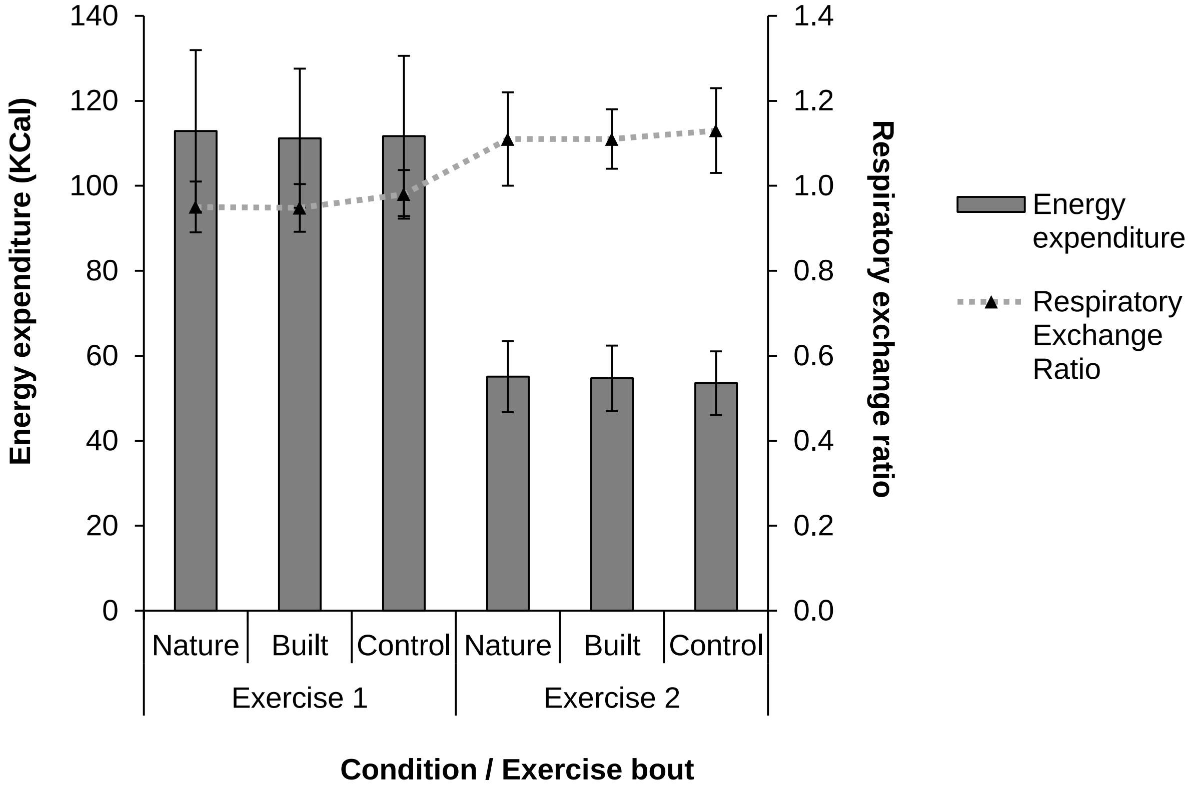


Higher score represents greater level of directed attention; *, pre- and post- Exercise 1 values significantly differ ($p = 0.001$); †, significant time by condition interaction ($p = 0.007$).

Figure 4.1. Mean (±SD) pre- and post-Exercise 1 Backwards Digit Span test scores by condition

4.3.2. Physiological measures

One-way repeated measures MANOVAs indicated that there was no significant effect of condition on energy expenditure and respiratory exchange ratio for either Exercise 1 (p= 0.34) or Exercise 2 (p= 0.63). Energy expenditure and respiratory exchange ratio values are shown in Figure 4.2. One-way repeated measured ANOVAs indicated no statistically significant effect of condition on mean heart rate values in either Exercise 1 (p= 0.36) or Exercise 2 (p= 0.88; Table 4.2).



Exercise 1 duration was 15mins, Exercise 2 values each represent 4:47mins of data.

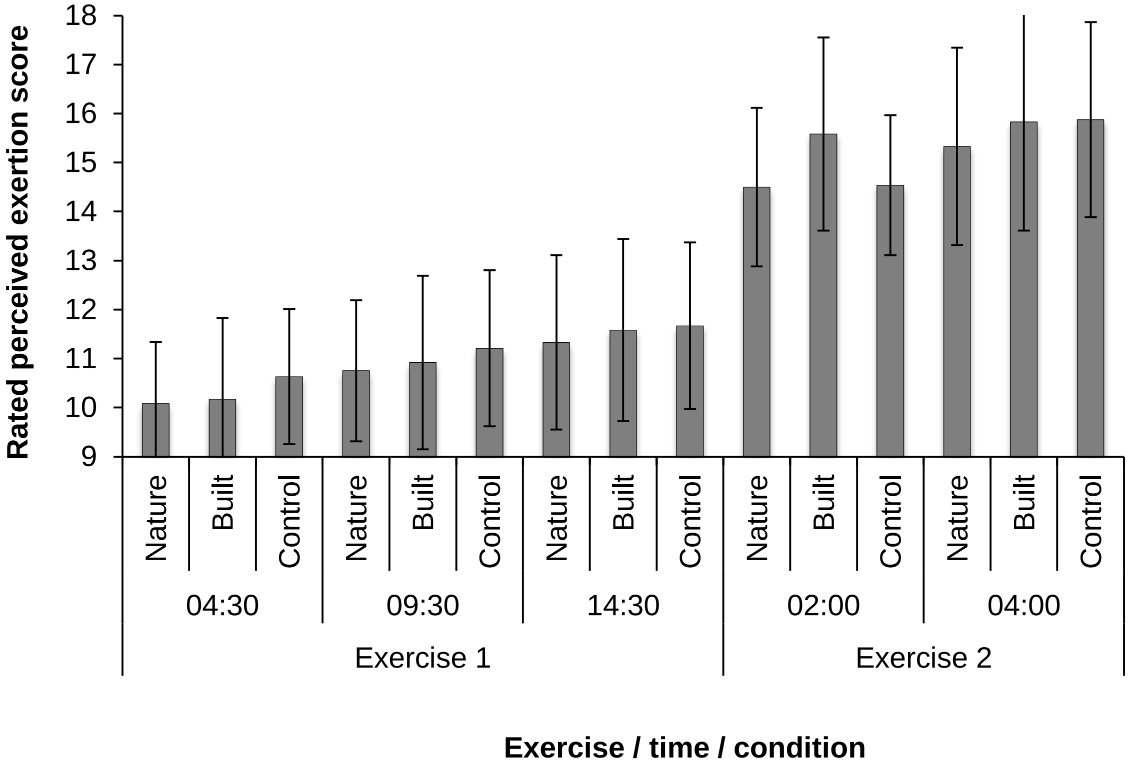
Figure 4.2 Mean (±SD) energy expenditure and respiratory exchange ratio by condition for Exercise 1 and Exercise 2.

Table 4.2 Mean (± SD) results for heart rate and time to exhaustion by condition

Measure	Exercise Bout	Condition		
		Nature	Built	Control
Heart Rate (bpm)	Exercise 1	108.8 ± 9.2	109.9 ± 11.2	107.5 ± 12.0
	Exercise 2	145.7 ± 7.9	145.1 ± 11.0	144.1 ± 9.5
Time to exhaustion (secs)	Exercise 2	824.1 ± 336.3	726.0 ± 269.8	769.17 ± 292.2

4.3.3. Perceived exertion and time to exhaustion

One-way repeated measures ANOVAs indicated that there were no significant differences in perceived exertion scores between conditions during Exercise 1 at either 4:30mins ($p = 0.389$), 9:30mins ($p = 0.509$) or 14:30mins ($p = 0.655$), or during Exercise 2 at either 2mins ($p = 0.947$) or 4mins (0.302). Perceived exertion values are presented in Figure 4.3. Although time to exhaustion was longest in the nature condition, results of a one-way repeated-measures ANOVA indicated no statistically significant main effect for condition ($p = 0.203$; Table 4.2).



Rated perceived exertion: minimum value = 6 (no exertion at all), maximum value = 20 (maximal exertion).

Figure 4.3 Perceived exertion scores by exercise bout, time and condition

4.4. DISCUSSION

The aim of the current chapter was to examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component.

4.4.1. Directed Attention

This was the first study to demonstrate an effect of visual environment on directed attention whilst controlling exercise. Concurrent with previous findings relating to transient hypofrontality, directed attention improved from pre- to post-exercise in all conditions (Dietrich, 2003, Dietrich and Sparling, 2004, Dietrich, 2006). However, it is not possible within the current study to confirm this mechanism. Without inclusion of a non-exercise control condition, these acute improvements might also be considered to be short-term learning or motivational effects. The primary hypothesis, that directed attention would improve more after a 15-minute exercise bout whilst viewing video footage of a nature environment, compared to footage of a built environment or viewing a blank screen (control), was supported. Significant improvements in directed attention were observed in the nature condition but not in the built or control conditions. This finding is concurrent with that of Berman et al. (Berman et al., 2008). One possible explanation for this finding is that the nature video reduced the need for directed attentional processes, maximising attention restoration during the opportunity afforded by Exercise 1 (Kaplan, 1995, Kaplan, 2001, Kaplan and Berman, 2010). This is also the first study to combine measures of attention following steady state exercise with measures of perceived exertion and time to exhaustion during vigorous exercise. A strength of this study was that it rigorously controlled exercise between conditions. Exercise intensities (speed / gradient) of Exercise 1 and Exercise 2 were replicated via programming of a treadmill, to ensure that the independent variable of visual environment was isolated. Unlike previous research (Hartig et al., 2003, Berman et al., 2008, Taylor and Kuo, 2009), it is possible to conclude that visual nature facilitates attention restoration during exercise independently from influences of exercise.

As discussed in Chapter 1, attention restoration theory postulates that restoration in turn promotes improvements in affective states (Kaplan, 1995). The results of the current study support the possibility that attention restoration might partly underpin the influence of exercise environments on affective states (Barton et al., 2009, Barton and Pretty, 2010, Bowler et al., 2010). Later experimental chapters within the current thesis (Chapters 5 and 6) will investigate this possibility further via paradigms that include pre- and post-exercise measures both of directed attention and affect whilst controlling or measuring the exercise component.

4.4.2. Physiological measures

All participants' respiratory exchange ratio values for the final minute of the Bruce protocol were above 1.1, indicating that identified VO_2peaks likely represented maximal effort (Goyal, 2014). Greater respiratory exchange ratio values for Exercise 2 than for Exercise 1 are a product of the exercise intensities performed by participants during the respective exercise bouts.

The secondary hypothesis, that during a steady-state 15-min exercise bout there would be no significant differences in participants' energy expenditure, respiratory exchange ratio and heart rate between conditions, was supported. Previously reported physiological differences during exercise in different environments may have been due to differences in exercise (Park et al., 2010). Considered together with previously reported effects of exercise environments on post-exercise physiology, the results suggest that physiological effects of perceived exercise environments may occur primarily during recovery from exercise (Tsunetsugu et al., 2007, Park et al., 2008, Park et al., 2010, Li et al., 2011). If physiological effects of exercise-environments occur during exercise, this result alludes to two further possibilities: (i) that physiological responses to visual environments were *overridden* by exercise-related physiology; (ii) that physiological responses to visual environments were *masked* by exercise-related physiology. A limitation of the current study is that its results do not indicate whether either of these possibilities is true, or occurred.

The current study's design controlled individual-, exercise- and environment-related variables except for visual stimuli. Psychological effects of visual exercise environments reported by both the current study and previous laboratory-based research likely resulted via psychological mechanisms alone (Pretty et al., 2005, Akers et al., 2012). Mechanisms of this kind, such as attention restoration theory and stress reduction theory have been theorised (Kaplan and Kaplan, 1989, Ulrich et al., 1991, Kaplan, 1995, Kaplan and Berman, 2010). Furthering understanding of perceptual and cognitive interactions with environments during exercise can support maximisation of mental and physical health outcomes from exercise participation, such as lowering blood pressure (Pretty et al., 2005, Brown et al., 2014), and improving mood (Rogerson et al., 2015) and perceived mental health (Brown et al., 2014).

4.4.3. Perceived Exertion

This was the first study to examine the role of different visual environmental types on exercise-related time to exhaustion. The results did not support the secondary hypothesis that perceived exertion would be lower and time to exhaustion would be longer in the nature condition than in a built condition or control condition. The current study failed to support previously reported findings that exercise environments influence perceived exertion, although it is notable that different exercise modes (walking, cycling) and exercise intensities were used in these previous studies (Focht, 2009, Akers et al., 2012). Large standard deviations indicate that statistical under-powering of this study was the likely reason that, despite time to exhaustion in nature condition being 12.7% greater than in the built condition and 6.9% greater than in the control condition, differences were not statistically significant. Indeed a major limitation of the current study was its small sample size, which may have served to increase type I and type II statistical errors in the analyses of each of the reported dependent variables. The results indicate that future research should investigate these variables using designs that are sufficiently powered following sample-size calculations.

Visual exercise environment influenced one psychological measure of this study (Backwards Digit Span score) but not the other (perceived exertion). To speculate here, one possible explanation of this might be related to the face mask worn during the exercise (as part of the portable gas analyser). Amplified sounds of breathing may have facilitated internal focus on physiological sensations, aiding consistency in perceived exertion (Fillingim and Fine, 1986, Lohse and Sherwood, 2011). This may have reduced opportunity for visual exercise environment to influence participants' appraisal and reporting of exertion. Although mask-related cognitions may have also functioned to reduce opportunity for environment-related cognitions, as many aspects of restoration-related processes occur subconsciously (Kaplan, 1995), attention restoration via visual exercise environment may have therefore remained unhindered.

In order to examine influences of visual environmental stimuli, no auditory stimuli were included in the video footage of the nature and built conditions. This may have caused confounding dissonance within each of the nature and built conditions, in that such visual stimuli would normally be accompanied by appropriate auditory stimuli. It is not known in which condition dissonance may have been greatest; however, it seems likely that the control condition would elicit least dissonance due to its lack of visual cues. Future work might examine the importance of different sensory modalities to influences of exercise environments of this kind. Additionally, whereas nature and built conditions included video content, the control condition did not include such visual cues. Providing neutral stimuli for participants to visually attend to would have avoided this potential confound. However, the control condition served as a comparison to enable influences of treadmill exercise alone to be examined.

4.4.4. Application

The findings further previous research which has examined the notion that green exercise might promote outcomes beneficial to workplace contexts (Brown et al., 2014). Acute bouts of green exercise promote restoration from directed attention fatigue, thus replenishing an important resource for performance of cognitively-demanding workplace tasks. The current findings are also relevant to educational contexts. Attention restoration via green exercise environments can aid children's concentration in school and ameliorate symptoms of ADHD (Kuo and Taylor, 2004, Taylor and Kuo, 2009). Results of the current study suggest that the visual element of real green exercise environments may play an important role in obtaining these benefits.

4.4.5. Conclusions

This was the first study to demonstrate effects of controlled exercise conducted in different visual environments on post-exercise directed attention. Visually perceived nature promotes attention restoration during moderate intensity exercise, independent of physiological influence. Additionally to physiological and other psychological outcomes (Pretty et al., 2005, Barton et al., 2009, Barton and Pretty, 2010, Bowler et al., 2010, Park et al., 2010, Li et al., 2011, Thompson Coon et al., 2011, Barton et al., 2012b, Lee et al., 2012), acute green exercise participation benefits cognitive functioning (Hartig et al., 2003, Berman et al., 2008). Such improvements are relevant for workplace and educational performance. Equipment-related cognitions may have limited potential influences of visual exercise-environments on perceived exertion, and in turn, time to exhaustion.

Although the laboratory-based paradigm used in this chapter ensured comparability and isolated potential roles of visual environments, it lacks ecological validity; video scenes projected onto a screen are not an accurate representation of exercise in the simulated environments. Therefore, Chapters 5 and 6 also compare outcomes of green exercise *versus* equivalent non-green exercise, however do so by examining exercise performed indoors *versus* outdoors whilst controlling the exercise component, in order to isolate potential environmental effects.

Chapter Five: Controlling the exercise intensity within the indoor *versus* outdoor paradigm

Table 5.1 Thesis Map outlining Chapter aims and key findings

Chapter	Aims	Key Findings
3	• To investigate potential differences in affective outcomes of running between different typical green exercise environments • To examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes	• Affective wellbeing improved from pre- to post-green exercise participation • No significant effect of green exercise environment type was identified • RSE improvement was predicted by enjoyment, and performance in relation to expectation; PSS improvement was predicted by age-adjusted performance; TMD improvement was predicted by nature relatedness, sex and enjoyment • Large proportions of the psychological benefits of green exercise are universally obtainable independent of a range of exercise-, individual-, environment-related variables
4	• To examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component	• Visual nature can facilitate attention restoration during moderate-intensity exercise via psychological mechanisms alone • Previous findings regarding influence of visual environments on perceived exertion were not replicated • Visual environment did not significantly influence energy expenditure during exercise
5	• To identify a method for ensuring consistency of the exercise component between indoor (treadmill) and outdoor (over ground) exercise • To compare psychological outcomes of outdoor *versus* indoor exercise	
6	• To compare a psychological, social and behavioural intention outcomes of exercise in green outdoors *versus* indoors settings, whilst controlling the exercise component	

5.1 INTRODUCTION

As outlined in Chapter 4's conclusions, although its laboratory-based paradigm ensured comparability and isolated potential roles of visual environments, it lacked ecological validity. Chapter 1 outlined that previous green exercise research has compared perceptual and affective outcomes of self-paced indoor (ergometer-based) *versus* over-ground outdoor walking or running (Harte and Eifert, 1995, Bodin and Hartig, 2003, Marsh et al., 2006, Teas et al., 2007, Focht, 2009, Dasilva et al., 2011). Other studies have compared efficacy of treadmill *versus* over-ground walking interventions (Polese et al., 2013). However, many of these studies have been employed with surprisingly little consideration of potential differences in the physiological qualities of these exercises. For example, Teas et al. (2007) noted a difference in distance walked of 0.8km, during 1 hour of walking outdoors compared to indoors; however, did not account for this difference in their analysis of other dependant variables such as mood. Another study prescribed a 10-minute walking duration; however, did not record either exact return times in an outdoor condition or total distance walked in either outdoor or indoor conditions (Focht, 2009). Dasilva et al. (2011) examined influences of exercise environments on self-selected exercise intensity, and reported faster walking speeds for an over-ground condition compared to a treadmill condition. They also reported that a less positive affective response occurred during treadmill walking than during over-ground walking. However the authors did not consider a potentially causal role of physiological differences on the psychological outcomes. Further, the changeable gradient of outdoor running is often not adequately accounted for during an 'equivalent' treadmill running condition. For example, Focht et al. (2009) allowed participants to self-select and alter gradient during the treadmill run, where this was not possible for the outdoor walk. Exercise intensity is itself associated with affective exercise outcomes (Ekkekakis et al., 2011). This alludes that in previous studies, unaccounted-for differences in physiological properties of indoor *versus* outdoor exercise, as well as other variables such as wind resistance, may have contributed to outdoor exercise demanding different total work than the indoor 'equivalent' exercise. For this reason, Chapter 3 examined influences of exercise-related parameters; although age-adjusted performance value explained a small proportion of improvements in PSS, performance time (run completion time) did not feature in any of the predictive models. However, Chapter 3 did not compare green exercise participation with non-green exercise. One study that did make this comparison allowed participants to freely pace their walking exercise within all experimental conditions (urban – quiet residential streets with low levels of traffic; green – country park within the city; blue – footpath beside a canal with a range of natural vegetation) and checked comparability of exercise intensity by analysing heart rate data from during the walks (Gidlow et al., 2016). With comparability of exercise intensity confirmed, analysis of mood data failed to find a significant time by condition interaction effect, thus failing to support the notion that nature environments promote relatively greater exercise-related affective improvements than synthetic environments.

Another variable that has received attention from outdoor over-ground *versus* indoor treadmill walking or running comparisons is perceived exertion (measured by the RPE scale (Borg, 1970, Borg, 1982, Borg, 1998)). Via its relationship with affect, exercise-associated RPE is important to exercise maintenance (Williams et al., 2008, Dasilva et al., 2011, Ekkekakis et al., 2011). When exercising at an instructed constant RPE, individuals work harder (measured by speed, heart rate and blood lactate concentration) during outdoor over-ground walking than during indoor treadmill walking (Ceci and Hassmén, 1991). Concurrently, during self-paced exercise, individuals walk faster and work harder, yet report lower RPE during outdoor walking compared to indoor treadmill walking (Marsh et al., 2006, Focht, 2009, Dasilva et al., 2011).

What is not currently known is whether influences of exercise environments on affective measures and perceived exertion occur via psychological pathways alone, or whether physiological differences between outdoor over-ground and treadmill exercise have significantly contributed to these findings. This is because studies have not rigorously controlled both exercise duration and intensity, which is important as exercise intensity and duration influence affective outcomes and perceived exertion (Wenos et al., 1996, Kennedy and Newton, 1997, Arent et al., 2000, Little and Williams, 2007, Ekkekakis et al., 2011, Thompson Coon et al., 2011, Haddad et al., 2014).

Reliable methods for controlling intensity and duration are therefore needed when comparing outcomes of treadmill *versus* over-ground walking or running exercises. Two such studies have attempted to control exercise intensity and duration by fitting participants with a heart rate monitor and wristwatch, and instructing them to adjust their speed in order to remain within a given range (Kerr et al., 2006, Plante et al., 2007). However, the reactive nature of this method suggests that rigorous control may be difficult to replicate, with high likelihood of inconsistencies in exercise duration. Furthermore, in research where individuals' mindful engagement with the environment is of importance, focussing on a wristwatch detracts from this.

5.1.2 Biomechanical differences

A simple averaging of speed may not provide an effective solution to controlling exercise intensity for fair comparisons of over-ground *versus* treadmill exercise outcomes. Additionally to the lived experience of constant paced exercise differing from that of free pacing, both biomechanical and energy expenditure differences between over-ground and treadmill running, and physiological differences associated with self-paced *versus* enforced-paced exercise, add to this methodological problem. Although there are general similarities between over-ground and treadmill running gaits (Riley et al., 2008, Fellin et al., 2010), there are significant biomechanical and neuromuscular differences. Compared to over-ground running, treadmill running is associated with flatter foot landing, 12 degrees lesser hip flexion at foot-strike, 6 degrees lesser ankle excursion to peak angle, 6.3 degrees greater peak ankle eversion, and both lower magnitude of maximal plantar pressure and a lower maximum plantar force at the plantar areas (Nigg et al., 1995, Hong et al., 2012, Sinclair et al., 2013). There are also significant differences in knee kinematics, peak ground reaction forces, joint movements and joint power trajectories (Riley et al., 2008). Further, treadmill running elicits weaker amplitudes of soleus neuromuscular activity during the push-off phase of running than does over-ground running (Baur et al., 2007). Thus, the mechanics of treadmill running cannot always be simply generalised to over-ground running (Sinclair et al., 2013). Addressing these disparities however, over durations of approximately five minutes for velocities of 2.92 – 5.0 $m \cdot s^{-1}$, energy expenditure of over-ground running at a level gradient (0%) can be most accurately replicated on a treadmill via application of a 1% gradient (Jones and Doust, 1996). However, as the exercise of Jones and Doust's research was of constant speed for short durations, it is not known whether the 1% gradient amendment holds true for runs that are of longer duration and comprise pacing fluctuations. Additionally, the over-ground running examined by this research was on a hard-surfaced road, and little is known regarding the transferability of this finding to other over-ground surfaces, such as grass-field terrain.

5.1.2 Comparing self-paced with enforced paced exercise

Without effortful control of pacing, non-conscious mechanisms regulate and promote exercise-pacing fluctuations in line with maintaining homeostasis (Gibson and Noakes, 2004, Lambert et al., 2005, Billat et al., 2006, Tucker et al., 2006, Noakes, 2008). Consistent with this, compared to self-paced 10,000m running, completing this distance at the same overall average speed via enforced pacing elicits greater physiological strain as measured by mean oxygen consumption, heart rate and blood lactate concentration (Billat et al., 2006).

Despite the complexities of this problem, there are merits to comparing outcomes of self-paced over-ground exercise *versus* enforced-pace treadmill exercise, as this is representative of a common exercise choice of individuals (for example, running outdoors compared to in a gym). When making ecologically valid comparisons between outcomes of outdoor *versus* treadmill walking or running, in order to correctly attribute the causes of possible differences, it is important that exercise-pacing fluctuations are replicated across both conditions. Using Jones and Doust's (1996) approach as a method for ensuring comparability of such exercises would require that the pacing be controlled accurately at a constant speed, which is particularly uncommon during outdoor running. Since the 1% gradient was proposed, technology is now commonly available that enables accurate measurement of outdoor pacing fluctuations via foot-pods. Further, treadmills can be programmed to replicate the outdoor pacing fluctuations.

5.2 CHAPTER AIMS AND THE CURRENT STUDIES

The aim of this chapter was to address the previously used indoor *versus* outdoor walking / running paradigm, with an alternative research design. The current chapter explores methodological and statistical approaches for controlling (or controlling *for*) the exercise performed when comparing outcomes of indoor *versus* outdoor exercise. The current chapter comprises three experimental studies: Study A, Study B and Study C. Across these, one method used seeks to physically control the exercise component (Studies A and B), and another seeks to control *for* the exercise component statistically within statistical analyses of the outcome variables (Study C). This is in order to enable greater certainty in the identification of mechanisms that may underpin previously reported outcome differences between indoor and outdoor exercise.

5.3 STUDY A

Study A employed Jones and Doust's (1996) recommended 1% gradient on a treadmill to match energy expenditure of level over-ground running, and additionally, accurately replicated pacing fluctuations of individuals' self-paced exercise. It was intended that accurately replicating pacing fluctuations of the self-paced over-ground exercise may reduce potential impacts that are typically associated with enforced pacing (Gibson and Noakes, 2004, Lambert et al., 2005, Billat et al., 2006, Tucker et al., 2006, Noakes, 2008). Study A compared measures of energy expenditure and step count between outdoor *versus* treadmill running exercise in order to assess the reliability of the method used for controlling the exercise component. Affective measures of self-esteem, mood and perceived stress were also included, in line with previous studies that have reported influences of environmental settings on affective outcomes of exercise.

Hypothesis (i) was that energy expenditure and step count values would be consistently similar between conditions. Hypotheses (ii) – (iv) were that for the measures of (ii) self-esteem, (iii) perceived stress and (iv) mood, greater post-exercise values would be associated with the OUTDOOR condition compared to the INDOOR condition.

5.3.1 Methods

5.3.1.1 Participants

21 healthy adult participants (15 male, 6 female; age 25.8 ± 8.0 years; stature 172 ± 7.0 cm; mass 71.0 ± 13.0 kg) were recruited via oral and written advertisements, from student and staff populations at the University of Essex and the general population of Colchester, UK. Participants received a Participants' Information document via email prior to their first test occasion, which instructed them to avoid alcohol, caffeine and strenuous exercise within 24 hours prior to each test occasion, and to refrain from alternating from their usual lifestyle and exercise routines for the duration of their participation in the study. Testing occurred between the months of August and October 2013.

5.3.1.2 Design

A within-participants design was used. All participants completed two test occasions, which varied only by the exercise environment. Exercise was performed outdoors (OUTDOOR). The OUTDOOR condition was only completed if the route surface was largely dry. Exercise was also performed indoors (INDOOR) on a treadmill in a laboratory. Conditions were completed on different days to avoid fatigue effects. Although some measures were recorded during exercise, the majority were completed both pre-and post-exercise in the laboratory. Participants completed the OUTDOOR condition first, followed by the INDOOR condition, in order to control pacing profiles. Treadmill exercise was pre-programmed using data obtained from the OUTDOOR condition in order to replicate pacing fluctuations.

5.3.1.3 Protocols

A summary of Study A protocols is shown by Figure 5.2.

OUTDOOR Condition

On arrival, participants' resting blood pressure was taken after a minute of rest in the seated position, using an Omron Digital Automatic Blood Pressure Monitor MX3 Plus (Omron MX3; Omron Healthcare UK Ltd, Milton Keynes, UK). This was taken as a screening measure to ensure that participants were in a physiologically suitable condition to exercise. A cut-off point of 140/90 mmHg was used to indicate hypertension. No participants were excluded from the study based on this criterion. Remaining seated at the table, the experimenter then asked participants to complete the pre-exercise questionnaire, comprising RSE, PSS and POMS. Participants were fitted with the FR-70 Garmin foot-pod (Garmin, Olathe, USA) to record pacing data and step count. They were also fitted with the Cosmed K4B^2 portable gas analyser (K4B^2, Cosmed, Rome, Italy) to record energy expenditure (Eisenmann et al., 2003). They then walked from the laboratory to the start of the route, accompanied by the experimenter. This walk was audibly referred to by the experimenter as 'serving as a warm-up walk'. On arrival at the route's start, the experimenter spent up to 90 seconds verbally describing and showing participants a map of the route (see Figure 5.1).

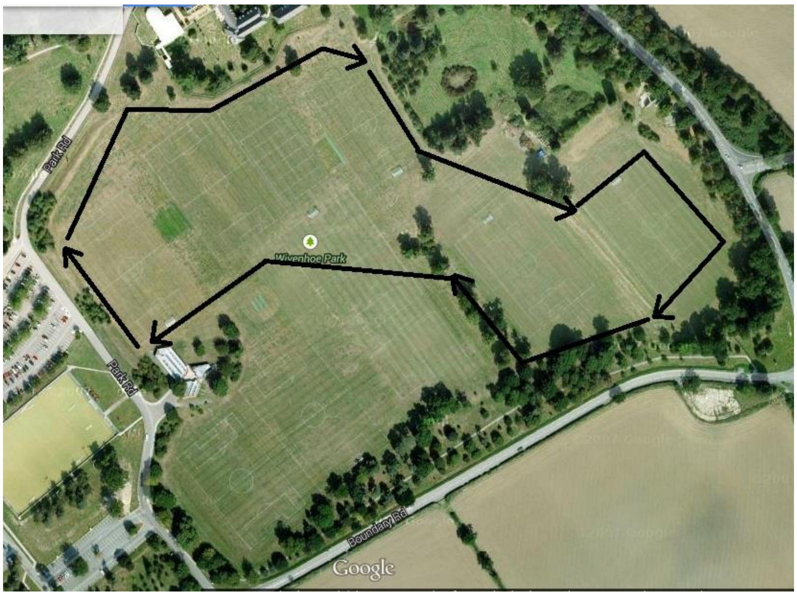


Figure 5.1 Route for the outdoors condition

The route distance was 1367m, and was marked with cones around the largely level-gradient University of Essex sports fields - a flat, maintained grass-field area, surrounded by and interspersed with trees. Approximately one third of the route was located audibly close to a minor road. A manor house was visible for approximately half of the route (see Figure 5.1). Participants were then asked to 'go for a light run or jog around this route, at a pace of your own choosing'. The entire route was in visual range of the experimenter, in order to ensure compliance to the route and as a safety precaution. On completion of the main exercise, the experimenter accompanied the participant back to the laboratory. This walk was audibly referred to by the experimenter as 'serving as a cool-down walk'. On arrival at the laboratory, participants were seated at the table. The $K4B^2$ mask was removed from the participant's face, and participants completed the post-exercise questionnaire, comprising RSE, PSS and POMS. FR-70 and $K4B^2$ equipment was then removed entirely. Participants were then thanked for their participation, signalling the end of the experimental occasion (see Figure 5.2).

INDOOR Condition

The INDOOR condition differed from the OUTDOOR condition only by the environment in which the exercise was performed. Whereas the main running exercise (around the set route), warm-up walk and cool-down walk (walking to and from the set route) were performed outdoors in the OUTDOOR condition, in the INDOOR condition each of these three exercises was performed on a treadmill in a laboratory (Ergo ELG55, Woodway, Weil am Rhein, Germany). In the INDOOR condition, respective exercises were referred to as the ‘warm-up’, ‘run’ and ‘cool-down’. For each exercise, the treadmill was pre-programmed to replicate the respective exercise from the outdoors condition, via application of a constant 1% gradient and based on pacing data collected from the FR-70 equipment. Data was averaged to calculate 15-second intervals because (i) this was a duration greater than the sample rate of the FR-70 equipment (sample rate was 5 seconds); and (ii) preliminary data indicated that 15-second intervals were sufficient for identification of frequent but non-extreme pacing fluctuations of a magnitude relevant to the treadmill’s programming sensitivity (minimum change of 0.1 $km \cdot h^{-1}$). This ensured that each exercise was of identical duration and distance to the outdoors condition, and followed similar pacing fluctuations. Participants were not made aware that pacing fluctuations on the treadmill replicated their outdoor equivalent exercise. The experimenter told participants that the ‘warm-up’ and ‘cool-down’ exercises were “pre-set standard warm-up / cool-down walks”, and for the ‘run’, that “the treadmill is pre-programmed for an exercise of 1367m at a difficulty relative to your level of fitness, attained from the previous test occasion”. In order to provide distance information similar to that available to participants via visual cues during the outdoor condition, participants were told distance remaining every 200m, by the researcher.

Temperature in the laboratory was set to replicate the OUTDOOR condition temperature, which was obtained from records of a nearby weather station. In order to ensure minimal crossover of environmental characteristics between the two environmental contexts of the study, in the indoor condition, artificial lighting was used and blinds were drawn to ensure no outside light entered the laboratory.

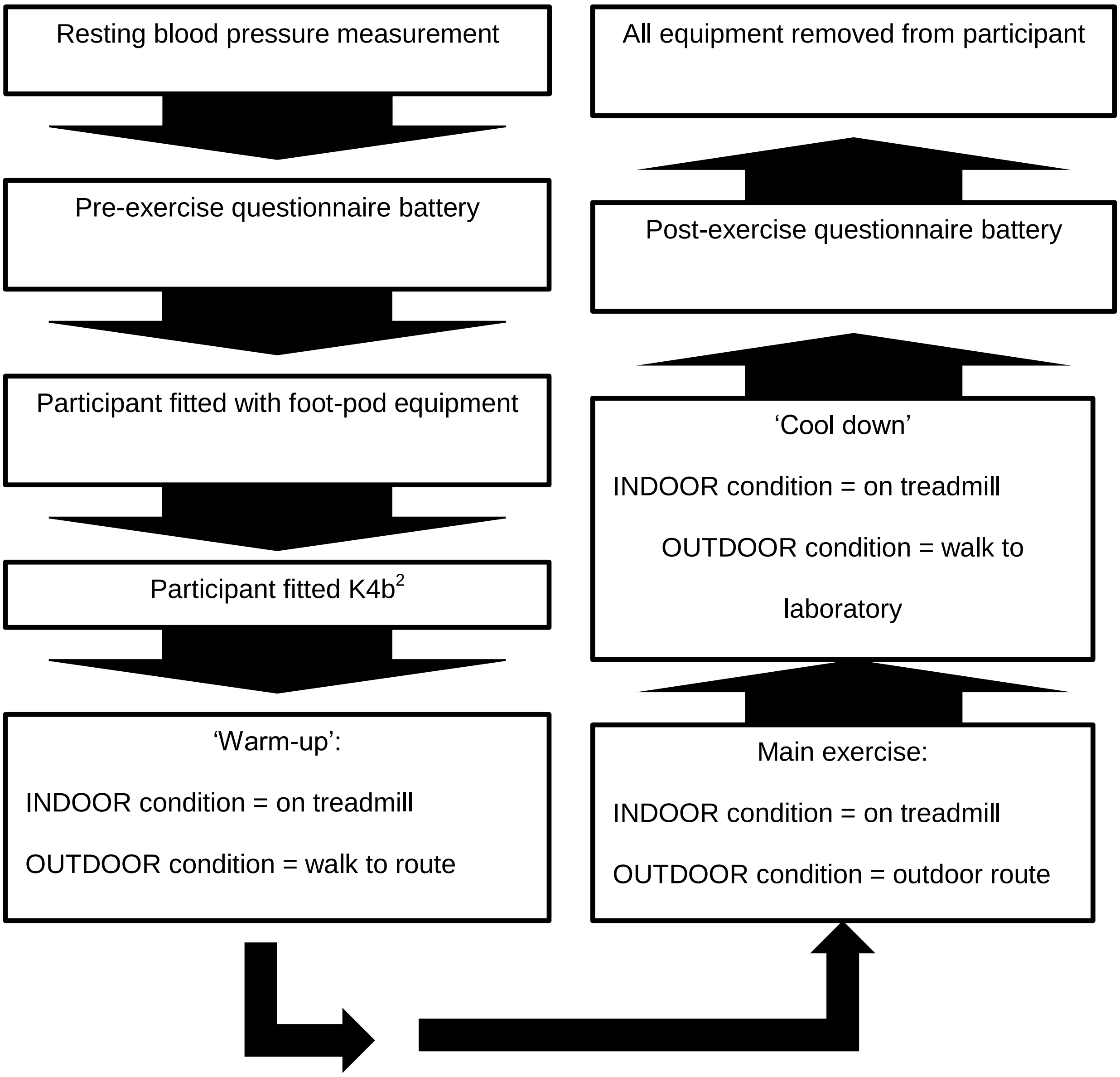


Figure 5.2 Study A Protocol

5.3.1.4 Statistical Analysis

Paired samples t-tests for the primary measures of energy expenditure and step count were accompanied by calculations of intra-class correlation coefficients (ICCs) in order to assess the reliability of the method used for replicating outdoor over-ground running exercise using a treadmill. Only data of the main 'run' exercise was analysed; i.e. not the warm-up and cool down.

For the measures of RSE, PSS and POMS TMD, although post-exercise values are those of greatest importance, given that conditions were not of randomised order and that baseline (pre-exercise) measures were recorded within each condition, post-exercise values should be considered in relation to individuals' pre-exercise status. In relation to clinical trials, mean baseline values offer an appropriate value from which to consider treatment effects (Frison and Pocock, 1992). Therefore, mean pre-exercise values were entered as covariate variables within a series of one-way repeated measures ANCOVAs in order to examine post-exercise values between conditions. For each measure, data underwent preliminary analyses. Data was checked for homogeneity of regression slopes to ensure that pre-exercise values were related to post-exercise values similarly between conditions. As pre-exercise values are controlled for as covariate variables, differences in pre-exercise values between conditions were not checked for.

5.3.2 Results

Mean run duration was 441.0 ± 85.5 seconds. Mean running speed was 3.1 ± 0.5 $m \cdot s^{-1}$. The maximum running speed attained across all participants was 5.4 $m \cdot s^{-1}$. The minimum running speed attained was 0.7 $m \cdot s^{-1}$, although this included data both of accelerations when exercise commenced and of decelerations towards route completion. The mean distance covered by participants was 1391.0 ± 75.8 metres, demonstrating good adherence to the route.

Energy expenditure and step count

For energy expenditure, a paired-samples t-test showed that OUTDOOR *versus* INDOOR values were not significantly different ($t_{20} = 0.3$, $p > 0.05$; 95% CI of the difference [-1.7, 2.2 kcal]). Mixed model absolute agreement ICC showed highly reliable absolute reproducibility of exercise between conditions as measured by energy expenditure. The average measures ICC (3, k) was 0.97 (95% CI [0.95, 0.99], $F_{20, 20} = 42.9$, $p < 0.05$)(Figure 5.3).

For the measure of step count, a paired-samples t-test showed that OUTDOOR *versus* INDOOR values were not significantly different ($t_{20} = 0.65$, $p > 0.05$; 95% CI of the difference [-15.9, 30.3 steps]). Mixed model absolute agreement ICC showed highly reliable absolute reproducibility of exercise between conditions for step count. The average measures ICC (3, k) was 0.98 (95% CI [0.95, 0.99], $F_{20, 20} = 47.0$, $p < 0.05$)(Figure 5.3).

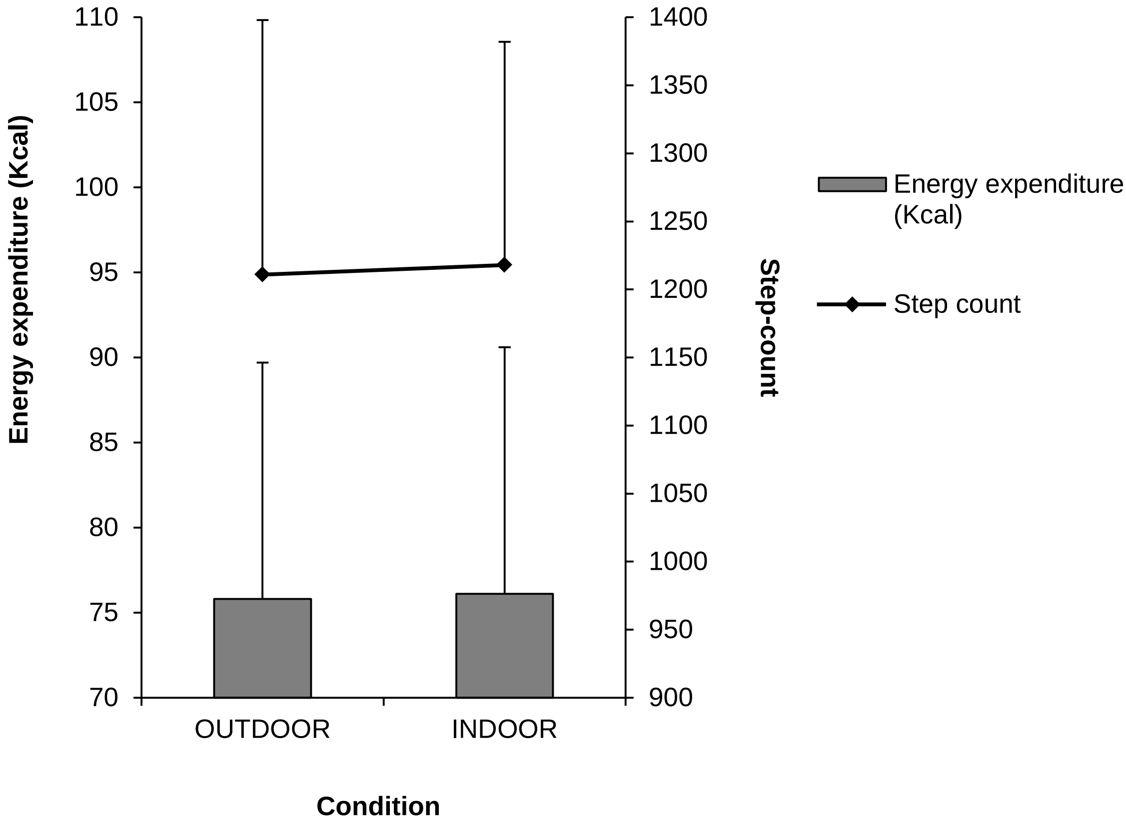


Figure 5.3 Study A mean (+ 1 SD) energy expenditure and step count values by condition

Affective measures

For RSE, the covariate, mean pre-exercise RSE, was significantly related to post-exercise RSE ($F_{1,19}$= 91.7, p<0.05, η_p^2= 0.83). For PSS, the covariate, mean pre-exercise PSS, was significantly related to post-exercise PSS ($F_{1,19}$= 23.4, p<0.05, η_p^2= 0.55). For TMD, the covariate, mean pre-exercise TMD, was not significantly related to post-exercise TMD ($F_{1,19}$= 3.55, p>0.05, η_p^2= 0.16). Repeated measures ANCOVAs showed that, after controlling for respective mean baseline values (pre-exercise measures), there were no statistically significant main effects of condition for post-exercise values of RSE, PSS, and POMS TMD (p<0.05; Table 5.2).

Table 5.2 Study A mean and standard deviation values for affective measures by condition and time

Measure	Outdoor Values by Time (*M* ± 1SD)		Indoor Values by Time (*M* ± 1SD)	
	Pre	**Post**	**Pre**	**Post**
RSE	20.8 ± 4.4	22.9 ± 5.0	21.3 ± 4.9	22.6 ± 5.0
PSS	10.8 ± 5.2	8.1 ± 4.3	11.3 ± 6.1	8.0 ± 5.3
POMS TMD	145.6 ± 15.0	137.5 ± 11.8	144.3 ± 16.8	140 ± 16.2

5.3.3 Discussion

Energy expenditure and step count

The measure of step count was exploratory and was not selected in line with its use in previous research. The findings for the measures of energy expenditure and step count supported hypothesis (i). The results showed that this method accurately and reliably replicated step count and exercise intensity in terms of total energy expenditure. This is consistent with the findings of Jones and Doust (1996), and offers a potentially more reliable and accurate method for controlling exercise intensity and duration than has been used by previous research comparing outcomes of over-ground *versus* treadmill exercise (Harte and Eifert, 1995, Bodin and Hartig, 2003, Milgrom et al., 2003, Marsh et al., 2006, Focht, 2009, Dasilva et al., 2011). In contrast to the findings of Billat et al., (2006) the enforcement of pacing associated with treadmill exercise did not lead to greater physiological strain in terms of energy expenditure. In the current study, rather than enforcing pacing at the average speed of the entire exercise period, replication of pacing fluctuations may have functioned to reduce disparity in physiological strain between self-paced and enforced-paced exercise. The strength of the ICCs suggest that this method could be used for longer exercise durations, with reduced risk of differences in physiological strain (Jones and Doust, 1996, Billat et al., 2006). Indeed, the foremost practical application of the findings regarding energy expenditure and step count is confidence in the use of this method in future research. Although non-randomisation of OUTDOOR *versus* INDOOR conditions remains problematic here, as used in Study A and as suggested in relation to clinical trials, variations in baseline (pre-exercise) measurements can be statistically accounted for (Frison and Pocock, 1992).

Although Study A trialled this methodology only in relation to level maintained grass terrain, taken together with Jones and Doust's (1996) findings in relation to road terrain, the results suggest that this method may be transferable to other over-ground surfaces. However, when over-ground running is not at a level gradient, further knowledge of specific energy expenditure comparisons is required for a fair comparison, or for full understanding of, the causes of exercise outcomes. It is not currently known whether the 1% gradient treadmill exercise applies similarly to other over-ground gradients (e.g. if it is a 2% gradient outdoors, should gradient be 3% on a treadmill?).

Affective measures

Support for hypothesis (i) suggests that findings relating to the remaining hypotheses could be attributed to differences in the lived experiences of the exercise performed in either condition. Conversely to previous research, hypotheses (ii) – (iv) were not supported; Study A did not find a significant influence of environmental setting on affective outcomes (RSE, PSS, POMS TMD). This finding is in contrast to previous research that has made similar environmental comparisons (Teas et al., 2007, Focht, 2009, Dasilva et al., 2011). A possible reason for this was that participants were wearing a mask over their face as part of the $K4B^2$ equipment. As discussed in Chapter 4, amplified sounds of breathing may have facilitated internal focus on physiological sensations. This may have reduced participants' mindful engagement with the environmental surroundings, which may in turn have functioned to reduce influence of the environmental manipulation. Of further note, the statistical analyses used to compensate for non-randomisation of conditions (namely the use of mean pre-exercise values as covariates) is different to that used within this comparable previous research. For these reasons, Study B repeats the methodology of Study A, without use of $K4B^2$ equipment. Study C then makes the same environmental comparison using an alternative study design and statistical approach. Findings for affective measures are then discussed, informed by all of studies A, B and C.

5.4 STUDY B

Study B repeated the methodology of Study A in order to physiologically control the exercise component, but did so without the potentially confounding use of gas analysis equipment (as was required in Study A for measuring energy expenditure). Previous research of this kind has examined indoor *versus* outdoor comparisons for both walking (Plante et al., 2007, Teas et al., 2007, Focht, 2009) and running exercise (Harte and Eifert, 1995, LaCaille et al., 2004, Kerr et al., 2006). As exercise intensity is suggested to influence affective outcomes of green exercise participation (Barton and Pretty, 2010), and Study A did not find an effect of environmental setting on affective outcomes, an additional intention of Study B's design was to enable outcomes of walking and running exercises to be compared.

Hypothesis (i) was that step count values would be consistently similar between conditions. ***Hypotheses (ii) – (iv)*** were that for the measures of ***(ii)*** self-esteem, ***(iii)*** perceived stress and ***(iv)*** mood, greater post-exercise values would be associated with the OUTDOOR condition compared to the INDOOR condition.

5.4.1 Methods

5.4.1.1 Participants

Participants were recruited as per Study A. Thirty-five healthy adult participants were recruited (19 male; age 26.1 ± 9.1 years; stature 172.6 ± 8.7 cm; mass 67.3 ± 13.8 kg). Testing occurred between the months of June and September 2014.

5.4.1.2 Design

Participants were entered into one of two sub-groups: 'WALKING' (17 participants); and 'RUNNING' (18 participants). For the WALKING group, the main exercise of the study was walking. For the RUNNING group, the main exercise of the study was running. The remainder of the design was identical to that of Study A.

5.4.1.3 Protocols

OUTDOOR and INDOOR protocols were identical to those of Study A, with two exceptions: firstly, that $K4B^2$ equipment was not used in Study B (see Figure 5.4), and secondly, in the WALKING group, instructions from the experimenter were tailored to be consistent with the exercise type. For example, in the OUTDOOR condition, the experimenter asked participants to 'go for a ***walk*** around this route, at a pace of your own choosing', rather than the '***light run or jog***' that was requested within Study A and within the RUNNING GROUP of Study B.

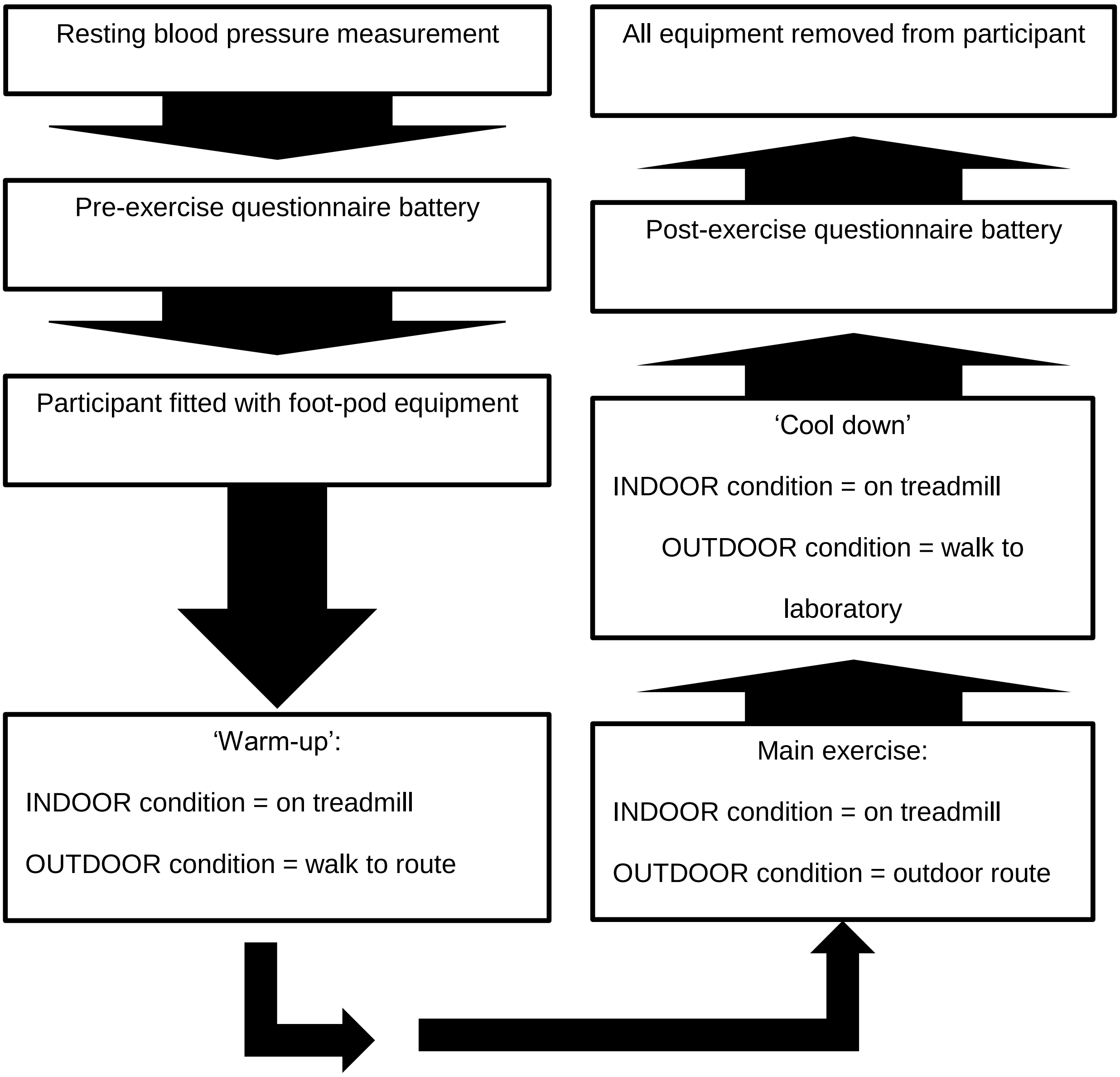


Figure 5.4. Study B protocol

5.4.1.4 Statistical Analysis

The measures of RSE, PSS and POMS TMD were analysed using mixed repeated measures ANCOVAs (within: condition (OUTDOOR, INDOOR); between: study group (WALKING, RUNNING); covariate: mean pre-exercise value). As pre-exercise values are controlled for as covariate variables, differences in pre-exercise values between conditions were not checked for.

Step count was recorded via FR-70 equipment, in order to ensure that exercise was comparable between conditions. Due to technical problems, step count data was not recorded for four participants; therefore, statistical analysis for this measure was performed on 31 participants' data only. The measure of step count was analysed using a paired samples t-test and an ICC in order to ensure comparability of exercise between conditions.

5.4.2 Results

Step count

There was no statistically significant difference in step count between OUTDOOR (1407.9 ± 305.8 steps) and INDOOR (1413.6 ± 286.2 steps) conditions (t_{30}= 0.60, p>0.05). Mixed model absolute agreement intra-class coefficients showed high similarity of exercise between conditions in terms of step count. The average measures ICC (3, k) was 0.99 (95% CI [0.98, 1.00], $F_{30, 30}$= 124.39, p<0.05).

Affective measures

The covariate, pre-exercise baseline RSE, was significantly related to post-exercise RSE ($F_{1,32}$= 170.29, p<0.05, η_p^2= 0.84). A mixed repeated measures ANCOVA showed that, after controlling for mean pre-exercise RSE, there was no significant effect of condition on post-exercise values (p>0.05), and no significant condition by exercise group interaction (p>0.05; Table 5.2).

The covariate, mean pre-exercise PSS, was significantly related to post-exercise PSS ($F_{1,32}$= 143.59, p<0.05, η_p^2= 082). A mixed repeated measures ANCOVA showed that, after controlling for mean pre-exercise PSS, there was no significant effect of condition on post-exercise values ($p>0.05$), and no significant condition by exercise group interaction ($p>0.05$; Table 5.2).

The covariate, mean pre-exercise POMS TMD, was significantly related to post-exercise TMD ($F_{1,32}= 59.02$, $p<0.05$, $\eta_p^2= 0.65$). A mixed repeated measures ANCOVA showed that, after controlling for mean pre-exercise POMS TMD, there was no significant effect of condition on post-exercise values ($p>0.05$), and no significant condition by exercise group interaction ($p>0.05$; Table 5.3).

Table 5.3 Study B mean and standard deviation values for affective measures by condition and time

Measure	**Outdoor Values by Time** (*M* ± 1SD)		**Indoor Values by Time** (*M* ± 1SD)	
	Pre	**Post**	**Pre**	**Post**
RSE	20.4 ± 4.7	22.6 ± 4.3	21.9 ± 4.2	22.8 ± 4.4
PSS	12.7 ± 6.4	9.5 ± 6.2	11.5 ± 5.8	10.3 ± 6.2
POMS TMD	150.2 ± 16.3	140.5 ± 12.6	149.4 ± 19.0	148.37 ± 16.7

5.4.3 Discussion

Study B did not find a significant influence of environmental setting on affective outcomes of exercise. These findings are consistent with Study A, despite the fact that a gas analysis mask was not worn by participants in Study B. A remaining possible reason for this, and a limitation of both Studies A and B, was the non-randomisation of condition order and the statistical method used to compensate for this. For this reason, Study C examined the same INDOOR *versus* OUTDOOR environmental comparison, but controlled for differences in exercise performed, within statistical analyses of the data.

5.5 STUDY C

Study C examined the same environmental exercise settings as Studies A and B, however used an alternative methodology in order (i) to enable condition order to be randomised, and (ii) to avoid the discussed issues associated with comparing self-paced *versus* enforced-paced exercise. In Study C, participants were free to self-select run pacing both outdoors and on the treadmill indoors. Additionally to the affective outcomes of interest in Studies A and B, Study C includes measures of directed attention and perceived exertion and enjoyment. Study C instead controlled *for* measured differences in the exercise component, that is, exercise duration, within statistical analysis of the data.

Consistent with Studies A and B, ***hypotheses (i) – (iii)*** were that, for the measures of ***(i)*** self-esteem, ***(ii)*** perceived stress and ***(iii)*** mood, greater improvement would occur in the OUTDOOR condition compared to the INDOOR condition. ***Hypotheses (iv) – (vi)*** were that, compared to INDOOR condition, ***(iv)*** greater enjoyment would be reported following exercise in the OUTDOOR condition, ***(v)*** lower RPE values would be reported in the OUTDOOR condition, and ***(vi)*** greater improvement in directed attention would occur in the OUTDOOR condition;

5.5.1 Methods

5.5.1.1 Participants

Nineteen healthy adult participants were recruited (11 male; age 23.3 ± 7.7 years; stature 175.9 ± 8.7 cm; mass 72.3 ± 13.3 kg). Testing occurred between the months of June and September 2014.

5.5.1.2 Design

In Study C, condition order was randomised, with participants free to self-pace exercise in both conditions. All participants completed running exercise; that is, unlike Study B, there was no comparison between different exercise types. Duration of exercise performed was recorded.

5.5.1.3 Protocols

Study C OUTDOOR and INDOOR protocols were identical to those of Study B, with the exception of the following details (also see Figure 5.5):

(i) In Study C, participants completed Informed Consent and Par-Q documentation, as well as stature and mass measurements, at the start of whichever experimental condition occasion was their first. Additionally, on participants' first experimental condition occasion only, participants completed a short familiarisation Backwards Digit Span task (see Figure 5.5).

(ii) In the INDOOR condition participants were free to self-pace their exercise (in Studies A and B exercise speed and gradient were pre-programmed); although gradient remained constant at 1%, participants controlled the speed of the treadmill using buttons on the treadmill. Immediately prior to the 'warm-up' and 'cool-down' exercises, the experimenter instructed participants that 'I would like you to perform five minutes of walking exercise as a warm-up / cool-down - please select a walking pace using the buttons, and you are free to change the speed using these buttons whenever you like'. For the main run exercise, the experimenter instructed participants that 'I would like for you to now complete a 1367 m run at a pace of your own choosing - use the buttons on the treadmill to control your pace, and feel free to change the pace however you like, whenever you like, and as frequently as you like'. As in Studies A and B, in order to provide distance information similar to that available to participants via visual cues during the OUTDOOR condition, participants were told distance remaining every 200 m. At these times, the experimenter additionally stated 'Also, just to remind you that you are free to change your pacing as much or as little as you like, using the buttons'.

(iii) Additionally to measures of RSE, PSS and POMS, both the pre- and post-exercise questionnaires included the measure of enjoyment of the exercise performed. This measure was identical to that outlined in Chapter 2 and used in Chapter 3.

(iv) Immediately before completing the pre-exercise questionnaire, participants were familiarised with the RPE scale before completing a Directed Attention-Reducing Battery, followed by a Backwards Digit Span test (each of these measures is outlined in Chapter 2). On cessation of the main exercise, the experimenter asked participants to report their RPE in relation to the exercise overall, before walking back to the laboratory. Participants then completed the post-exercise questionnaire, followed by another Backwards Digit Span test (Figure 5.5). The method by which the Backwards Digit Span test was presented and completed was highly similar to that in Chapter 4. However, rather than strings of 3-11 digits, giving a maximum score of 9 as in Chapter 4, in the current chapter, a total of 14 strings were presented (maximum score of 14), comprising two strings of each length, ranging from 3-9 digits. Digit string lengths were again presented in increasing length, that is, the two 3-digit strings preceded the two 4-digit strings, and so forth. This change from Chapter 4 was made in an attempt to increase sensitivity of the measure. For example, rather than a participant consistently failing at a single attempt at a string length of 5 digits (two possibilities: correct, not correct), having two strings of 5 digits in length enables three possibilities: to get both correct, one correct, or none correct.

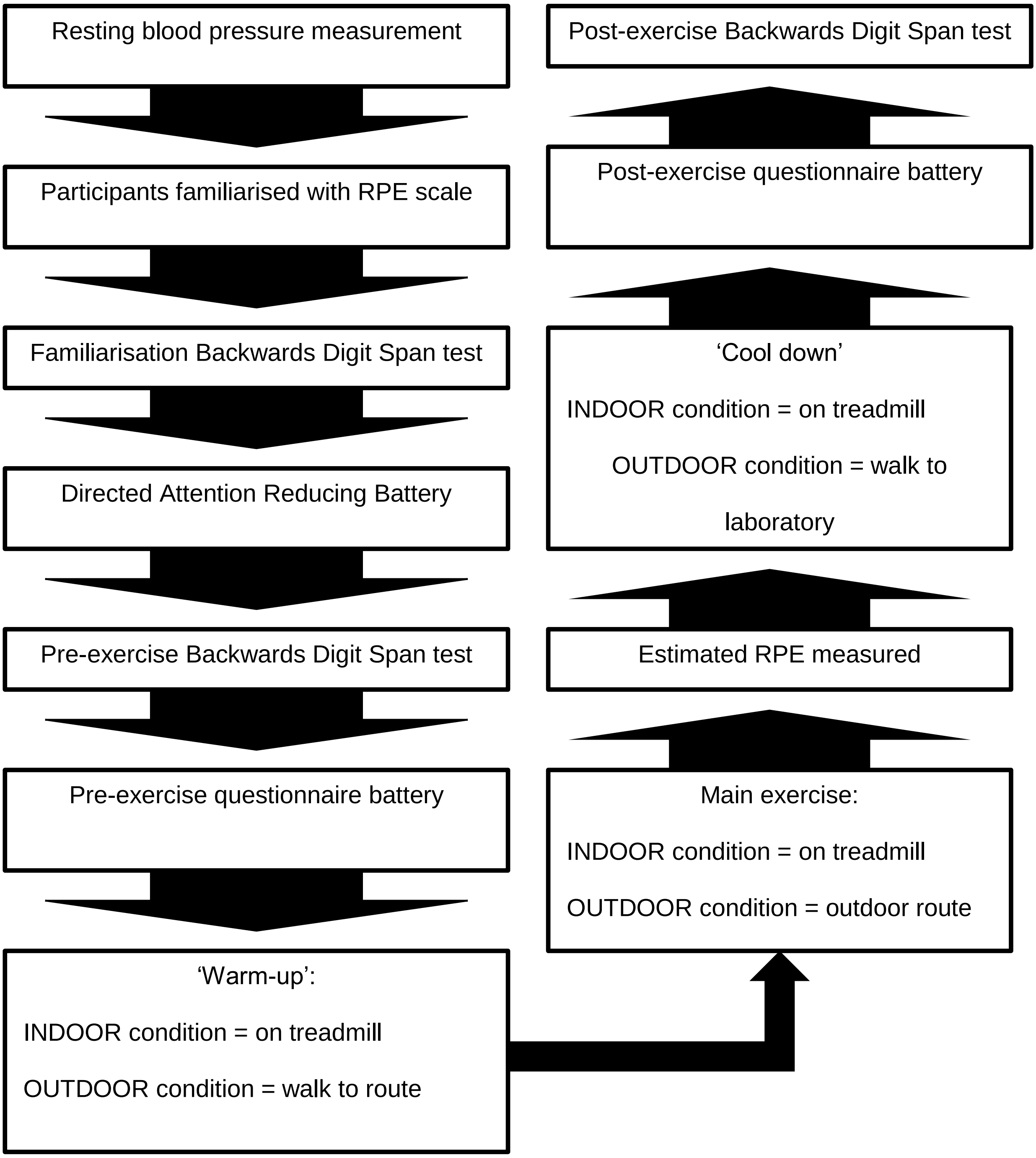


Figure 5.5. Study C protocol

5.5.1.4 Statistical Analysis

For the measures of RSE, PSS, POMS TMD and Backwards Digit Span score, a series of paired-samples t-tests were used to identify significant differences in pre-exercise values between conditions. A paired samples t-test was used to compare run completion time. Two sets of analyses were then performed. Whereas one set of analyses did not account for differences in the exercise component (in this instance, the variable of run completion time, i.e. exercise duration, calculated as OUTDOOR minus INDOOR), the other set of analyses did. It was hoped that performing both sets of analyses would enable comment on the importance of controlling for exercise differences between INDOOR *versus* OUTDOOR settings.

The measures of POMS TMD, RSE, PSS and Backwards Digit Span test score were first analysed using a series of two-way repeated measures ANOVAs (time: pre-exercise, post-exercise; condition: OUTDOOR, INDOOR); and were secondly analysed using a series of two-way repeated measures ANCOVAs in order to control for differences in run completion time between conditions. Similarly, POMS subscales were first analysed using a two-way repeated measures MANOVA; and were secondly analysed using a two-way repeated measures MANCOVA.

The measures of RPE and enjoyment were first analysed using paired samples t-tests, and secondly analysed using one-way repeated measures ANCOVAs, in order to control for the differences in run completion times between conditions.

5.5.2 Results

A series of paired-samples t-tests found that there were no statistically significant differences in pre-exercise values between conditions for the measures of RSE, PSS, POMS TMD and Backwards Digit Span score ($p > 0.05$). OUTDOOR run completion time was significantly quicker than in the INDOOR condition ($t_{18} = 7.50$, 95% CI [-207.5, -116.7], $p < 0.001$)(Table 5.4).

Table 5.4 Study C mean and standard deviation values by condition and time

Measure	**Outdoor Values by Time** (*M* ± 1SD)		**Indoor Values by Time** (*M* ± 1SD)	
	Pre-exercise	**Post-exercise**	**Pre-exercise**	**Post-exercise**
RSE	19.7 ± 3.4	*21.5* ± 3.7	19.6 ± 4.1	21.5 ± 4.2
PSS	11.5 ± 4.3	*9.1* ± 3.4	12.1 ± 4.1	10.0 ± 3.9
POMS TMD	143.63 ± 9.1	139.4 ± 12.7	145.9 ± 11.6	138.1 ± 6.8
POMS Tension	33.7 ± 2.1	31.9 ± 1.4	35.2 ± 3.0	31.8 ± 1.3
POMS Depression	37.3 ± 0.7	37.1 ± 0.3	37.5 ± 1.2	37.2 ± 0.5
POMS Anger	37.6 ± 1.3	37.1 ± 0.5	38.0 ± 2.4	37.2 ± 0.7
POMS Vigour	38.3 ± 5.3	40.0 ± 7.3	39.3 ± 6.1	40.6 ± 5.8
POMS Fatigue	37.7 ± 3.5	39.4 ± 5.1	37.2 ± 4.0	38.0 ± 3.4
POMS Confusion	35.6 ± 2.4	33.8 ± 2.1	37.3 ± 5.0	34.5 ± 1.9
Backwards Digit Span score (0-14)	8.1 ± 2.9	8.4 ± 3.7	8.3 ± 2.7	9.3 ± 3.0

Affective measures

A series of two-way repeated measures ANOVAs found that there were no statistically significant time by condition interactions for the measures of RSE and PSS ($p > 0.05$). Similarly, a series of two-way repeated measures ANCOVAs found that, after controlling for difference in run completion time, there were no statistically significant time by condition interactions for these measures (RSE: $p > 0.05$, $\eta_p^2 < 0.01$; PSS: $p > 0.05$, $\eta_p^2 < 0.001$). The ANCOVA for the measure of RSE showed that there was a main effect for time, whereby RSE improved from pre- to post-exercise ($F_{1,17} = 15.97$, 95% CI of difference [1.17, 2.47], $p < 0.01$, $\eta_p^2 = 0.48$). There was also a main effect for condition, whereby higher RSE scores were reported in the OUTDOOR condition ($F_{1,17} = 7.24$, 95% CI [-0.79, 0.74], $p < 0.05$, $\eta_p^2 = 0.30$). The ANCOVA for the measure of PSS additionally showed that there was a significant main effect for time, whereby participants' scores improved from pre- to post-exercise ($F_{1,17} = 8.59$, 95% CI [0.80, 3.73], $p < 0.01$, $\eta_p^2 = 0.34$). There was no significant main effect for condition ($p > 0.05$).

For the measure of POMS TMD, a two-way repeated measures ANOVA found that there was no statistically significant time by condition interaction ($F_{1,18} = 1.72$, $p > 0.05$, $\eta_p^2 = 0.09$). There was a significant main effect for time, whereby mood improved from pre- to post-exercise ($F_{1,18} = 7.44$, 95% CI [-10.7, -1.4], $p < 0.05$, $\eta_p^2 = 0.29$). There was no significant main effect for condition ($p > 0.05$). Similarly, for POMS TMD, a two-way repeated measures ANCOVA showed that, when controlling for difference in run completion time, there was no statistically significant time by condition interaction ($F_{1,17} = 0.99$, $p > 0.05$, $\eta_p^2 = 0.06$). However, there was a statistically significant main effect for time, whereby mood improved from pre- to post-exercise ($F_{1,17} = 10.50$, 95% CI [-10.4, -1.7], $p < 0.01$, $\eta_p^2 = 0.38$). There was also a marginally significant time by difference in run completion time interaction ($F_{1,17} =$

4.19, $p < 0.06$, $\eta_p^2 = 0.20$). When condition was collapsed, simple linear regression showed that longer run completion time predicted greater improvement in TMD ($F_{1,36} = 7.13$, $r = 0.41$, $B = -0.02$, 95% CI [-0.43, -0.01], $p < 0.05$). There was also a statistically significant main effect for condition, whereby mood was better in OUTDOOR condition ($F_{1,17} = 20.47$, 95% CI [-2.2, 3.2], $p < 0.001$, $\eta_p^2 = 0.55$).

For the POMS subscales, a two-way repeated measures MANOVA showed that there was no significant time by condition interaction for POMS ($F_{6,13} = 1.84$, $p > 0.05$, $\eta_p^2 = 0.46$). This MANOVA found a significant main effect for time ($F_{6,13} = 7.76$, $p < 0.01$, $\eta_p^2 = 0.78$). Univariate analyses showed that scores improved from pre- to post-exercise for the subscales of tension ($F_{1,18} = 27.70$, 95% CI [-3.65, -1.57], $p < 0.001$, $\eta_p^2 = 0.61$), anger ($F_{1,18} = 4.84$, 95% CI [-1.234, -0.03], $p < 0.05$, $\eta_p^2 = 0.21$), and confusion ($F_{1,18} = 17.79$, 95% CI [-3.35, -1.12], $p = 0.001$, $\eta_p^2 = 0.50$). There was no significant main effect for condition ($p > 0.05$). Similarly, a two-way repeated measures MANCOVA showed that, after controlling for difference in run completion time, there was no significant time by condition interaction for the POMS ($F_{6,12} = 2.32$, $p > 0.05$, $\eta_p^2 = 0.54$). This MANCOVA found a significant main effect for time ($F_{6,12} = 3.06$, $p < 0.05$, $\eta_p^2 = 0.61$). Univariate analyses showed that values for the subscales of anger ($F_{1,17} = 8.86$, 95% CI [-1.29, -0.08], $p = 0.01$, $\eta_p^2 = 0.33$) and confusion ($F_{1,17} = 15.18$, 95% CI [-3.28, -1.19], $p = 0.001$, $\eta_p^2 = 0.47$), significantly improved from pre- to post-exercise. There was no significant main effect for condition ($p > 0.05$).

Enjoyment and RPE

Paired samples t-tests showed that there were no statistically significant differences between the outdoor and indoor conditions for the post-exercise measures of enjoyment ($p > 0.05$; Figure 5.6) and RPE ($p > 0.05$; Figure 5.7.). Further, one-way repeated measures ANCOVAs found that, after controlling for difference in run completion time, there were no statistically significant effects for condition for either of these measures (p> 0.05).

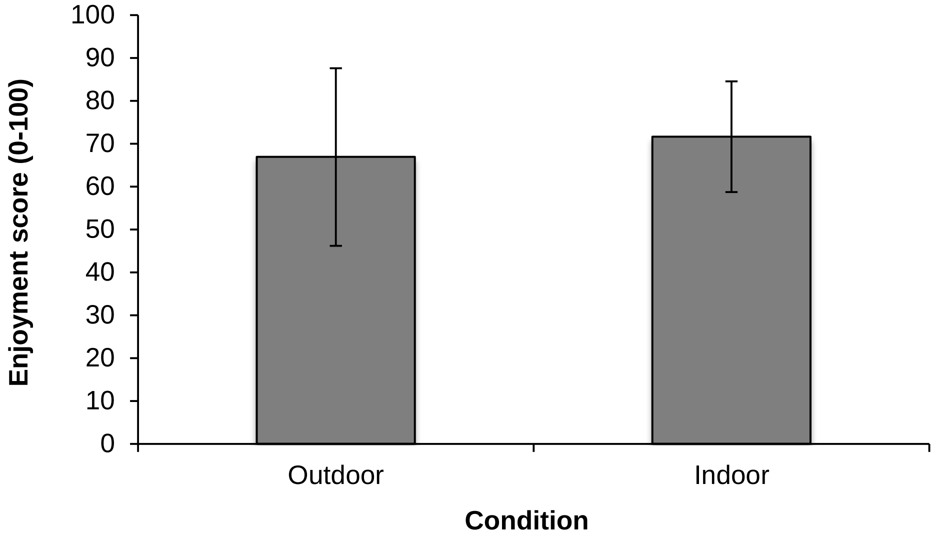


Figure 5.6. Study C enjoyment scores by condition

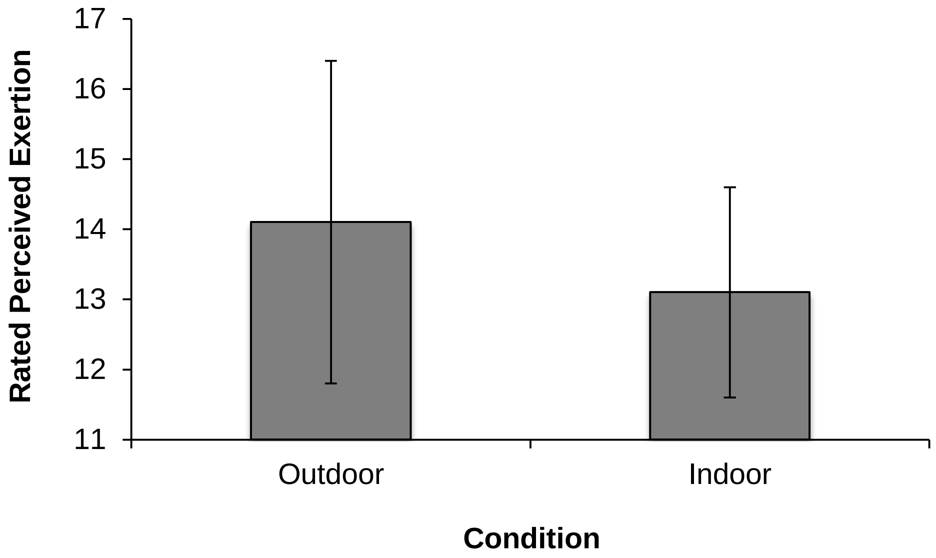


Figure 5.7. Study C Rated Perceived Exertion scores by condition

Directed attention

A two-way repeated measures ANOVA found that there was no statistically significant time by condition interaction for Backwards Digit Span test score ($p > 0.05$). Similarly, a two-way repeated measures ANCOVA found that, after controlling for difference in run completion time, there was no statistically significant time by condition interaction ($p > 0.05$, $\eta_p^2 = 0.03$) and no significant main effects for either time or condition ($p > 0.05$).

5.5.3 Discussion

As the parameters of perceived exertion and directed attention featured only in Study C, these are now discussed. Findings for the affective measures are discussed within the overall chapter discussion that follows (see 5.6).

Perceived exertion

Hypothesis (v) was not supported, as perceived exertion was not significantly different between conditions. This was true both when differences in the exercise component (run completion time) were controlled for and when they were not. This finding is consistent with that of Chapter 4 (Rogerson and Barton, 2015). When difference in run completion time was not statistically controlled for, that participants completed the OUTDOOR exercise in a significantly quicker time than INDOOR but did not perceive it to be more physically exertive is of interest. This finding does not support, but is also not entirely inconsistent with, previously reported findings: that compared to treadmill-based indoor exercise, individuals work harder but report lower perceived exertion outdoors (Ceci and Hassmén, 1991, LaCaille et al., 2004, Marsh et al., 2006, Focht, 2009, Dasilva et al., 2011). However, when difference in run completion time *was* controlled for, that there was no effect of environmental setting is inconsistent with the findings of these cited studies, although it is noteworthy that the current study took a different statistical approach to these previous studies.

Directed attention

The current research was the first of this kind to examine acute influences on directed attention of running in different environments. Hypothesis (vi) (that compared to the INDOOR condition, greater improvement in directed attention would occur in the OUTDOOR condition) was not supported. This finding is in contrast to those of previous research that has compared influences of time spent either resting or walking within different environment types, or viewing different environmental scenes either at rest or whilst exercising (Hartig et al., 2003, Berto, 2005, Ottosson and Grahn, 2005, Berman et al., 2008, Rogerson and Barton, 2015, Gidlow et al., 2016). The running exercise of the current study was likely to have been of a greater relative intensity than the exercise of previous research, whereby participants walked in the different environments (Hartig et al., 2003, Pretty et al., 2005, Teas et al., 2007, Berman et al., 2008, Focht, 2009, Dasilva et al., 2011). As internalisation of focus is greater at higher exercise intensities (Hutchinson and Tenenbaum, 2007), this may have led to the current participants being less mindful of their exercise environment than participants were in the previous studies. The implication of this suggestion is that, in order to best gain the reported psychological benefits of 'green exercise' environments, internalisation of focus should be avoided in order to maintain higher levels of mindfulness and awareness of the environmental settings. However, attention restoration is suggested to occur without conscious effort (Kaplan, 1995), suggesting that such explanation may not be fitting for the measure of directed attention.

As a disparate suggestion, in Chapter 4, although the screen viewed by participants during laboratory-based treadmill exercise was large, participants still had large relative quantities of laboratory space within their visual field. Compared to the extent of optic flow experiences whilst running outside (as in the current chapter), the optic flow associated with those laboratory views would have been less. The neurological visual system comprises two visual routes: a dorsal stream, progressing from the striate cortex to the posterior parietal cortex, which is involved with perception of movement and spatial location; and a ventral stream, progressing from the striate cortex to the inferior temporal cortex, which is associated with the perception of form and object recognition (Goodale and Milner, 1992, Milner and Goodale, 2008). As the two routes are likely to interact to a significant extent (Milner and Goodale, 2008, McIntosh and Schenk, 2009), it may be possible that when a greater extent of movement is perceived via the dorsal stream (as with outdoor running compared to treadmill running whilst viewing a video, as in Chapter 4), less conscious mindfulness is afforded for the semantic association of recognised objects. However, it is important to qualify here that this is merely offered speculation, and currently, research to date has not suggested any such inhibitive role of one stream upon the other. Further, that there was no significant main effect for time fails to support the notion discussed in Chapter 4 that exercise-associated transient hypofrontality might promote attention restoration (Dietrich, 2003, Dietrich and Sparling, 2004, Dietrich, 2006, Rogerson and Barton, 2015).

5.6 CHAPTER FIVE OVERALL DISCUSSION

The purpose of this chapter was to examine the outcomes of interest via the previously used 'indoor *versus* outdoor exercise' paradigm. It used new approaches for controlling the exercise component when making comparisons between these environmental settings. Studies A and B sought to physically control the exercise component, and Study C sought to control for the exercise component statistically within analyses of the outcome variables.

Hypotheses for measures of RSE, PSS, POMS and enjoyment were not supported in any of the three studies. In Studies A and B, there were no statistically significant differences in post-exercise values after controlling for mean baseline values. Similarly, in Study C, after controlling for differences in the run completion time, there were no significant time by condition interactions for these measures. Considered together with the suggested relationship between exercise intensity and affective responses to exercise (Ekkekakis et al., 2011), the current findings support the suggestion that, in previous studies of this kind, differences in the exercise component may have contributed to the influences of environmental settings on affective outcomes of exercise (Teas et al., 2007, Focht, 2009, Dasilva et al., 2011). However, this interpretation of the results is challenged by the additional finding that there were no significant time by condition interactions for POMS, PSS and RSE, even when differences in the run completion time ***were not*** controlled for within Study C. Indeed, compared to not controlling for differences in run completion time between conditions, controlling for this made little difference to statistical values reported for the time by condition interactions, for example, the measure of POMS TMD: effect size when not controlling for differences in run completion time was η_p^2= 0.09; effect size *when controlling* for differences in run completion time was η_p^2=

0.06. This suggests that, rather than the case that affective outcome differences between conditions should be attributed to differences in the exercise performed, this study simply failed to identify differences in affective outcomes per se. This finding is consistent with that of Gidlow et al. (2016), but in contrast with previous research that has reported greater affective outcomes following outdoor exercise compared to indoor exercise (Teas et al., 2007, Focht, 2009, Dasilva et al., 2011).

To speculate further here regarding the findings for affective measures of self-esteem, perceived stress and mood for Studies A and B, a reason for these may be the difference in the statistical analysis used compared to the aforementioned research. Whereas previous studies comparing indoor *versus* outdoor exercise have examined time (either pre-exercise - post-exercise or at multiple time-points during exercise) by condition (indoor, outdoor) interactions (Focht, 2009, Dasilva et al., 2011), or compared only post-exercise values without controlling for pre-exercise status (Teas et al., 2007), Studies A and B of the current chapter compared post-exercise values after statistically controlling for differences in pre-exercise values between conditions. Another possible reason, which encompasses the findings across all of Studies A, B and C, is that the environmental settings compared in the current studies were simply not compatible with promoting differences in these affective outcomes. This point raises an important issue for this research area: that comparisons of exercise in indoors *versus* 'green' or outdoor environments rarely provide detailed information describing those environments (Thompson Coon et al., 2011). 'Indoor *versus* outdoor exercise' research is often considered under one umbrella, with findings cross-referenced despite potentially large inter-study differences between each of the 'indoor' and the 'outdoor' environmental settings. For example, in the current studies, the green outdoor environment was that of maintained grassland interspersed with trees, whereas in the research by Focht

(2009) the outdoor environment is simply described as that of ‘an outdoor setting’. Whereas Chapter 3 identified that affective benefits gained from exercise did not differ between a range of typical green environments, it did not examine a non-green comparison environment (Rogerson et al., 2015). Future research should seek to further identify which types of ‘green outdoor’ environments might best promote the previously reported affective benefits compared to built or indoor environments (Teas et al., 2007, Focht, 2009, Dasilva et al., 2011). In Study C, main effects for time were reported for the affective measures of RSE, PSS and POMS (specifically, the negative mood states of anger and confusion were ameliorated). This finding is in line with the suggestion that exercise per se can improve psychological affective state (Yeung, 1996, Arent et al., 2000, Reed and Ones, 2006).

5.6.1 Strengths and limitations

The strength of these studies was that, in aggregate, they accounted for the exercise component to a greater extent than previous studies of this kind. These studies maintained ecologically valid representations of both outdoor and indoor treadmill exercise, whist physically or statistically ensuring that outcomes were not influenced by differences in the exercise performed.

A limitation of the method used in Studies A and B was that, as well as the independent variable of interest - environmental setting, the two conditions also varied in that, whereas exercise outdoors was self-paced, indoor treadmill exercise was of enforced pacing. It was intended that, compared to a simple averaging of pacing speed across the entire run, replicating outdoor pacing fluctuations would at least mirror fluctuations that occurred under conditions of high agency. Pacing fluctuations within the indoor condition may have served a physiological function to a level between those of a simple averaging of pacing speed across the entire run, and free pacing. However, as pacing fluctuations were not of participants' own agency within the INDOOR condition, Studies A and B are likely to have fostered differences in participants' sense of agency between conditions. This again highlights the importance of considering Studies A, B and C together, as in Study C, exercise was self-paced in both conditions. Nevertheless, despite the control of pacing afforded to participants in Study C, a large proportion of pacing fluctuations occur via non-conscious mechanisms in line with maintaining homeostasis (Gibson and Noakes, 2004, Lambert et al., 2005, Billat et al., 2006, Tucker et al., 2006, Noakes, 2008). Therefore, any treadmill-based exercise is likely to prevent these fluctuations from occurring. This occurrence may itself in turn promote notably different lived experiences compared to freely paced outdoor exercise. Enforcing a constant-pace has profound implications for the perceptual experience of exercise, as it prevents the normal homeostatic control of exercise, and as such interferes with the unconscious estimation of maximally tolerable intensity and/or duration. Since perception of effort is anchored to this estimate, individuals find any sub-maximal exercise intensity harder when it is enforced, rather than self-paced (Gibson and Noakes, 2004, Hu et al., 2004, Lambert et al., 2005, Billat et al., 2006, Tucker et al., 2006, Noakes, 2008, Tucker and Noakes, 2009, Parry et al., 2012). This is an issue that should be noted for all treadmill *versus* non-treadmill exercise comparisons. Non-motorised, self-powered curve treadmills may offer a solution to this issue, although running exercise on this type of treadmill requires greater energy expenditure than that on traditional, electronically powered treadmills (Snyder et al., 2011), and this would need to be accounted for. Alternatively, ergometers that passively control exercise intensity, for example, cycle ergometers that amend resistance relative to pedal cadence, may offer methods by which to examine outcomes of exercise environments while controlling the exercise component.

The methods section for Study C described the change made to the Backwards Digit Span test from Chapter 4 in an attempt to increase sensitivity of the measure. As the current chapter failed to find significant environment-associated influence on scores for this measure, Chapter 6 will return to the version used within Chapter 4.

5.6.2 Conclusions and future research recommendations

The current chapter represents novel attempts to approach the indoor *versus* outdoor exercise comparison paradigm. Statistical and prescriptive control was used to address the exercise component, rather than a reactive physical control or no control at all. The current chapter failed to support the previously reported affective influences of outdoor *versus* indoor exercise environments. However, the results also do not support the notion that differences in the exercise component were underlying causes of those previously reported effects. This notion may have been argued if both of the following had occurred: (i) in Studies A and B, when controlling for mean baseline values, significant main effects for condition had been reported for self-esteem, perceived stress and mood; (ii) in Study C, significant time by condition interaction effects were found for self-esteem, perceived stress, mood and enjoyment when not controlling for exercise differences, but this statistical significance had been lost when exercise differences ***were*** statistically controlled for.

An implication of the current findings is that, in order to best gain the reported psychological benefits of ‘green exercise’ environments, internalisation of focus should be avoided in order to maintain higher levels of mindfulness and awareness of the environmental settings. In addition, study findings highlight the need for future outdoor *versus* indoor exercise comparisons to be designed to avoid the problematic issues of enforced pacing *versus* freely paced exercise. Although Chapter 3 identified that affective benefits can be gained from exercise in a range of different green exercise environments, (Rogerson et al., 2015), in order to enhance understanding of which types of 'green outdoor' environments might best promote the reported affective benefits compared to indoor environments, future research should be clear in describing the exercise environments being examined.

Chapter 5 encountered methodological issues across Studies A, B and C. Studies A and B highlighted problematic issues associated with free-paced and enforced-pace exercise and needed to use statistical methods to account for issues with non-randomisation of conditions. Study C randomised condition order but did not control the exercise performed. Chapter 6 examines the same environmental comparison, but uses cycle ergometers in both green outdoor and laboratory indoor settings in order to physically control the exercise performed and avoid biomechanical variation associated with terrain differences.

Chapter Six: Influences of Green Outdoors *versus* Indoors Environmental Settings on Psychological and Social Outcomes of Controlled Exercise

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A version of this chapter has been published as a research article. The reference for this is:

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Table 6.1 Thesis Map outlining Chapter aims and key findings

Chapter	Aims	Key Findings
3	• To investigate potential differences in affective outcomes of running between different typical green exercise environments • To examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes	• Affective wellbeing improved from pre- to post-green exercise participation • No significant effect of green exercise environment type was identified • RSE improvement was predicted by enjoyment, and performance in relation to expectation; PSS improvement was predicted by age-adjusted performance; TMD improvement was predicted by nature relatedness, sex and enjoyment • Large proportions of the psychological benefits of green exercise are universally obtainable independent of a range of exercise-, individual-, environment-related variables
4	• To examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component	• Visual nature can facilitate attention restoration during moderate-intensity exercise via psychological mechanisms alone • Previous findings regarding influence of visual environments on perceived exertion were not replicated • Visual environment did not significantly influence energy expenditure during exercise
5	• To identify a method for ensuring consistency of the exercise component between indoor (treadmill) and outdoor (over ground) exercise • To compare psychological outcomes of outdoor *versus* indoor exercise	• The exercise component was successfully controlled physically (as measured physiologically) and controlled for statistically (as measured by time), across Studies A-C • Findings failed to replicate previously reported affective influences of outdoor *versus* indoor exercise environments • It was not possible to indicate whether or not differences in the exercise component might have been underlying causes of previously reported effects • Important methodological limitations and issues were identified, namely those of enforced pace *versus* self-paced exercise, and non-randomisation of condition order
6	• To compare a psychological, social and behavioural intention outcomes of exercise in green outdoors *versus* indoors settings, whilst controlling the exercise component	

6.1 INTRODUCTION

Beyond the knowledge that regular exercise is associated with better physical and mental health (Warburton et al., 2006, Reed and Buck, 2009, Pasco et al., 2011), evidence outlined in Chapter 1 suggests that, compared to other environments, acute bouts of exercise in nature-based spaces promote greater attentional and affective wellbeing benefits and might better enable mechanisms that foster future adherence to exercise behaviours (Bodin and Hartig, 2003, Pretty et al., 2005, Teas et al., 2007, Focht, 2009, Bowler et al., 2010, Thompson Coon et al., 2011). The findings of Chapter 4 were consistent with previously reported attentional outcomes; however, the findings of Chapter 5 (Study C) were not. The findings for affective measures within Chapter 5 were not consistent with previously reported influences of environment; however, its discussion section highlighted that methodological issues such as enforced pacing *versus* self-paced exercise may have been important.

During exercise, nature environments best promote restoration of fatigued cognitive directed attention, which is beneficial to workplace task performance and may be an underpinning mechanism by which acute bouts of nature-based exercise improve affective states (Kaplan, 1993, Kaplan, 1995, Berman et al., 2008, Raanaas et al., 2011, Rogerson and Barton, 2015). As discussed within both Chapter 3 and Chapter 4, environmental settings also influence perceived exertion during exercise (measured by the RPE scale). During self-paced walking exercise outdoors, individuals walk faster and work harder, but report lower perceived exertion compared to indoors treadmill-based walking (Marsh et al., 2006, Focht, 2009, Dasilva et al., 2011). When asked to adhere to a given perceived exertion, individuals exercise at greater speed, heart rate and blood lactate concentration during outdoors exercise than during indoors exercise (Ceci and Hassmén, 1991).

However, in many of these studies, whereas indoors exercise is performed on static ergometers, outdoors exercise constitutes physical movement through an environment. Therefore, the respective extents to which influences on perceived exertion originate from environmental characteristics, such as colour (Akers et al., 2012) or from differences in optic flow, are unknown (Parry et al., 2012). Optic flow is defined as the expanding flow on the retina caused by moving through an environment that forms the representational basis of egomotion (estimating motion relative to a rigid or static scene) (Gibson, 1950, Gibson, 1954, Warren and Rushton, 2009, Parry et al., 2012). Slower optic flow has been associated with lower RPE during cycling exercise (Parry et al., 2012). It is proposed that, alongside other factors such as prior experience, optic flow functions as an important cue for an individual's internal "performance template" (Tucker and Noakes, 2009), which is used to assess fatigue and exertion in relation to performance expectations. Restrictions of this cue associated with ergometer-based exercise may therefore influence perceived exertion. In the presence of a possible causal pathway linking exercise intensity and perceived exertion to future exercise behaviours via affective responses (Williams et al., 2008, Dasilva et al., 2011, Ekkekakis et al., 2011), environmental settings may provide a mode of manipulation by which adherence to exercise behaviours may be influenced. Indeed, in a comparison of outcomes of outdoors walks *versus* laboratory-based treadmill walks, individuals reported significantly greater intention to engage in future exercise behaviours following outdoors walking (Focht, 2009). Another study, which focused on postmenopausal women, found that, following a 12-week exercise programme, outdoor exercise led to both significantly greater affective responses and significantly greater adherence compared to indoor exercise (97% *versus* 91% respectively) (Lacharité-Lemieux et al., 2015). However, it is unclear whether such findings might also be true across the general population. Additionally, as the sample size was small (n= 23) within this randomised between-subjects design, further examination with greater sample size is required.

Social experience may provide an additional pathway by which green exercise might promote future exercise behaviours. Nature-based environments facilitate social interactions within communities, and social cohesion can function as a mediator by which greenspaces can influence health (Coley et al., 1997, Peters et al., 2010, de Vries et al., 2013). Indeed, social support can indirectly influence exercise through self-efficacy and outcome expectations and should therefore be included in interventions targeting exercise behaviours (Resnick et al., 2002). Social expectations of exercise participation significantly contribute to the prediction of exercise frequency in different environmental settings (Hug et al., 2009). Although previous research has reported a sample of individuals to have greater social expectations of indoors as compared to outdoors exercise, this may have been influenced by the season being winter when the data was collected (Hug et al., 2009). Teas et al. (2007) noted that, during group walking exercise, individuals tended to fall into conversation during outdoors walking, but did not do so during an equivalent indoors condition. Differences in social experiences between exercise environments are important; individuals are more successfully persuaded to partake in physical activity by potential social opportunities associated with exercise sessions than by health benefits (Schasberger et al., 2009). Therefore, green exercise might promote future exercise behaviour by facilitating social interaction and increasing enjoyment of participation (Hug et al., 2009, Gladwell et al., 2013).

Of particular relevance to affective and attentional outcomes, green exercise research is yet to transcend a problematic gap between research paradigms. Some research compares outcomes of exercise either in “built” *versus* nature-based environments (Hartig et al., 2003, Berman et al., 2008, Park et al., 2010, Lee et al., 2012, Brown et al., 2014). Other research, such as that of Chapter 5, compares outcomes of exercise performed indoors *versus* outdoors (Teas et al., 2007, Focht, 2009, Ryan et al., 2010b). However, as identified within Chapter 1 and discussed further in both Chapter 4 and Chapter 5, a methodological issue with this paradigm is that research of this kind has often not rigorously controlled the exercise component. This lack of rigorous control is problematic, as exercise intensity and duration influence psychological outcomes (Ekkekakis et al., 2011, Thompson Coon et al., 2011), including perceived exertion (Haddad et al., 2014). An alternative approach, as employed within Chapter 4, uses ergometers within laboratory settings to control the exercise performed and to examine the importance of the visual exercise environment (Pretty et al., 2005, Akers et al., 2012, Wood et al., 2013). However, this methodology lacks ecological validity, in that viewing environmental scenes alone does not provide the full sensory experience of being present in those environments. An example of this methodological gap is the outcome of directed attention. Improvements in directed attention during exercise have been reported to be facilitated by nature-based settings, both via nature *versus* built outdoors comparisons (Hartig et al., 2003, Berman et al., 2008) and disparately via the laboratory ergometer-based paradigm (Rogerson and Barton, 2015). However, research is yet to compare this outcome between indoors and green outdoors environmental settings while controlling for duration and level of intensity of the exercise.

6.1.1 Chapter aims and the current study

The current study was informed by the preceding experimental chapters and by the wider literature. It sought to draw upon the learning from each of the previous chapters in order to address the methodological gap in existing research of this kind, by comparing a range of previously reported psychological outcomes of exercise in green outdoors *versus* indoors settings whilst rigorously controlling the exercise component. Participants took part in pairs in order to investigate how environmental setting might influence social experiences of exercise. The hypotheses were that: (i) outdoors exercise would facilitate improvements in directed attention from pre- to post-exercise to a greater extent than indoors exercise (Berman et al., 2008, Raanaas et al., 2011, Rogerson and Barton, 2015); (ii) outdoors exercise would facilitate improvements in mood from pre- to post-exercise to a greater extent than indoors exercise (Pretty et al., 2005, Teas et al., 2007, Focht, 2009, Thompson Coon et al., 2011); (iii) perceived exertion would be lower during outdoors exercise compared to indoors exercise (Ceci and Hassmén, 1991, Marsh et al., 2006, Focht, 2009, Dasilva et al., 2011); (iv) accumulative time spent socially interacting during the exercise session would be greater during outdoors exercise compared to indoors exercise (Teas et al., 2007); (v) greater intention for a future exercise behaviour would be reported following outdoors exercise compared to indoors exercise (Focht, 2009); (vi) social interaction time would predict intention for future exercise behaviour (Resnick et al., 2002, Teas et al., 2007, Hug et al., 2009, Schasberger et al., 2009); and (vii) greater enjoyment of the exercise session would be reported following outdoors exercise compared to indoors exercise (Focht, 2009).

6.2 METHODS

6.2.1. Participants

24 participants (19 females, 5 males; age range 18–73 years (*M* = 35.1 ± 20.1 years); stature = 166.8 ± 8.0 cm; mass = 70.2 ± 15 kg) were recruited in pairs from staff (1 participant) and student (10 participants) populations at the University of Essex, as well as from the general public in Essex (13 participants). Each pair of participants knew each other prior to their participation. Participants responded to written and verbal advertisements in which they were asked to sign up as a pair, alongside a friend, family member or romantic partner. Self-pairing of participants was used in order to maintain ecological validity; that is, individuals typically exercise with a partner who they know and with whom they choose to exercise. All participants stated that they were familiar with cycle ergometer-based exercise, except for one participant, who stated that she had never previously experienced using cycle ergometers. Beyond this, participants' exercise backgrounds were not attained.

6.2.2 Design and Procedure

A within-participants design was used, whereby all participants completed each of three conditions: baseline, outdoors, and indoors (Figure 6.1). For each pair of the participants, conditions were completed on separate days at the same time of day (±1 h). All participants completed the baseline condition first. The mean number of days between participants' baseline occasion and first experimental occasion was 5.6 ± 3.4 days. The mean number of days between experimental occasions was 9.4 ± 7.8 days.

Paired participants completed experimental conditions (outdoors; indoors) in a randomised, counter-balanced order; that is, 12 pairs of participants were randomly assigned to complete the outdoors condition before the indoors condition, with the remaining 12 pairs completing the experimental conditions in the opposite order. The baseline condition was used in order to familiarise participants with each of the experimental measures, equipment and routine, and to obtain physiological data that enabled the calculation of each participant's 50% HRR for use in the experimental conditions. Experimental conditions differed only by the environment in which the exercise of the session was performed.

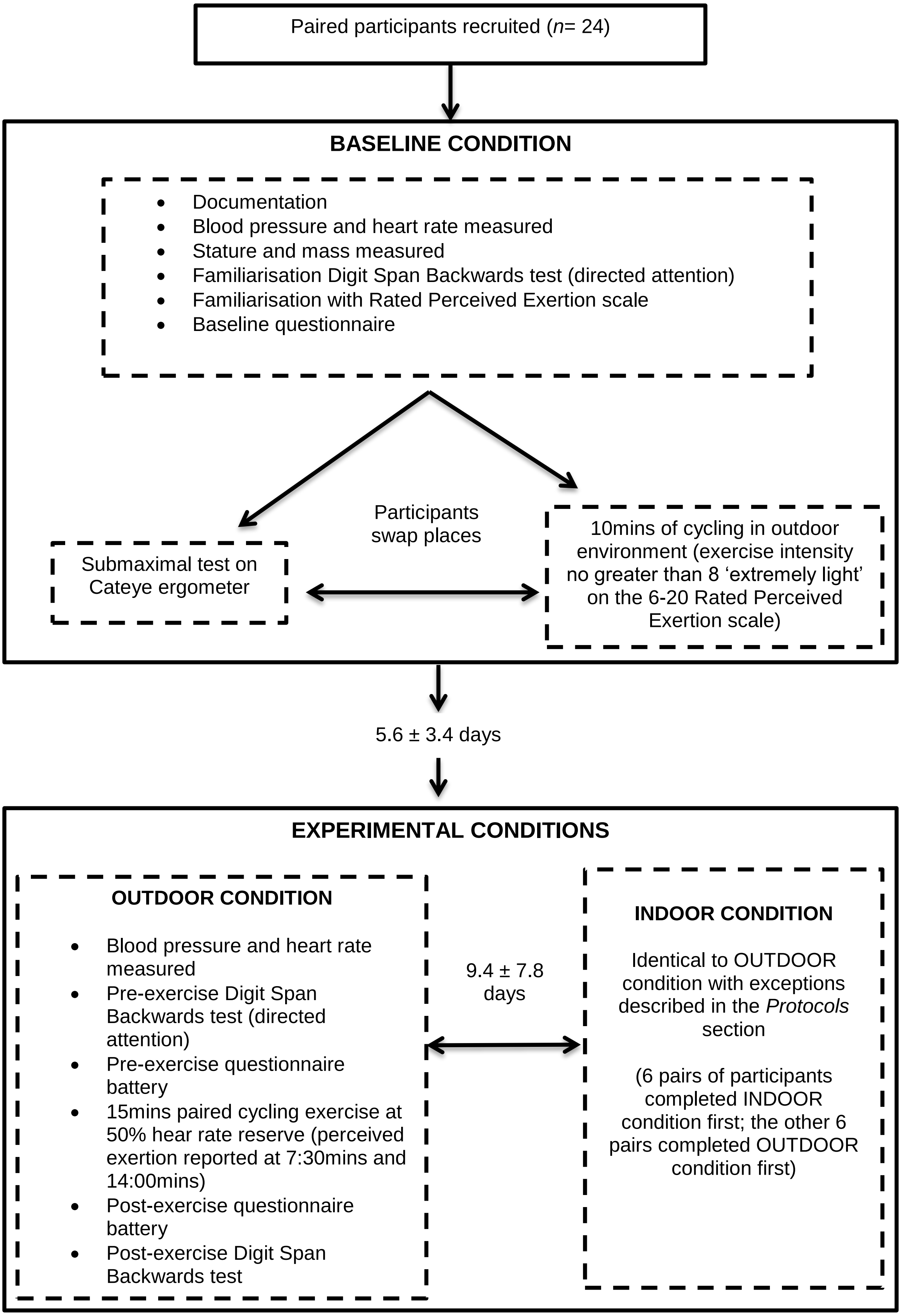

Figure 6.1 Overview of sessions

6.2.3 Description of Environmental Settings

In the outdoors condition, exercise was performed outside on the University of Essex sports fields, which is a large area of largely level gradient, maintained grassland, lined and partly interspersed with trees (see Figure 6.2). This was the same green OUTDOOR environment used within Chapter 5. In the indoor condition, exercise was performed indoors in a laboratory setting, whereby participants' view was of a white painted brick wall (Figure 6.3). This was the same laboratory setting as used for the INDOOR conditions of Chapter 5. The dimensions of the laboratory were 8.3 m × 4.9 m. The experimenters were based at desks placed in one corner of the laboratory. Cycle ergometers were placed approximately in the centre of the laboratory, with participants' table and chairs positioned between the ergometers and the experimenters' desks. The laboratory was set out consistently between conditions and between participants.

To ensure consistency between conditions in both environmental settings, the researchers were based at a desk positioned 2 metres diagonally behind the cycle ergometers. It was intended that the sound of the fan/air-conditioning unit in the laboratory of the indoors condition would replicate, to some extent, breeze-related sound in the outdoors condition, in an attempt to prevent participants from feeling that their interactions were more observed or listened to in one condition compared to the other.

Figure 6.2 View from the cycle ergometer within the baseline and outdoors conditions.

Figure 6.3 View from the cycle ergometer within the baseline and indoors conditions.

6.2.4 Equipment

CatEye ergociser (EC-1600, CatEye Co. Ltd., Osaka, Japan) ergometers were used in all conditions. In the baseline condition, an in-built submaximal fitness “test” mode within the ergometer was used (derived from the YMCA bicycle submaximal fitness test (Golding et al., 1989)). In the experimental conditions, the CatEye ergociser enabled rigorous control of exercise intensity. Intensity was set using the CatEye’s “constant” mode, whereby resistance is continually automatically adjusted in response to fluctuations in pedal cadence, in order to maintain constant intensity wattage.

6.2.5 Measures

The pre-exercise questionnaire of the experimental conditions consisted only of the selected measure for mood. Baseline and post-exercise questionnaires were composite, comprising measures of mood, enjoyment of the exercise session and intention for a future exercise behaviour. The measures of POMS, RPE and directed attention are outlined in Chapter 2.

6.2.5.1 Social Interaction Time

Social interaction time was measured using a stopwatch during the main exercise of each condition. One of the two experimenters was positioned behind the participants and continually visually and audibly observed for visual and verbal interaction between the participants. Social interaction periods were timed accumulatively to give the social interaction time value.

6.2.5.2 Intention for a Future Exercise Behaviour and Enjoyment of Exercise Session

A 100mm line was used to measure each of the participants' enjoyment of the exercise and their intention for a future exercise behaviour. The measure of enjoyment was as described in Chapter 2. Similarly, for the measure of intention, participants responded to the question: "Would you attend a free exercise session in the same place that you did your cycling exercise today? Mark the line to indicate your intention". The continuum ranged from 'I definitely will not attend (0)' to 'I will definitely attend (100)'. For each measure, participants were required to draw a mark somewhere along the respective 100mm continuum line. Both of these items were included in the post-exercise questionnaire only.

6.2.6 Procedures

Two experimenters were present during all sessions. This enabled simultaneous supervision of participants in different places within the baseline session, as well as simultaneous taking of measurements (e.g. blood pressure, perceived exertion) in the experimental sessions.

6.2.6.1 Baseline Condition

On arrival at the laboratory, participants sat on a chair at the table whilst the experimenter provided a verbal overview of the content of the study, before participants read a Participant's Information document and then completed a Physical Activity Readiness Questionnaire (PAR-Q) and informed consent documentation. Participants' blood pressure was then measured in the seated position, using an Omron MX3 blood pressure monitor (Omron Healthcare UK Ltd., Milton Keynes, UK). Together with the PAR-Q, this served as a screening measure for participants' suitability for the exercise of the session. Answers on the PAR-Q that suggested exercise-related physiological risk that were not then elaborated on satisfactorily (e.g. reporting experiencing back pain, but elaborating that their doctor had confirmed that they were still safe to perform exercise) would result in exclusion from participation. Participation was only allowed when participants' blood pressure values were less than 200 (systolic)/100 (diastolic) mmHg. No participants were excluded from the study. Participants' stature and mass were then measured. Participants returned to sit at the table and completed a familiarisation Digit Span Backwards task (directed attention), before being familiarised with the RPE scale and completing a baseline questionnaire (these measures are not reported here).

Participants were then split in order to complete the remainder of the baseline session separate from their paired participant. One participant remained in the laboratory with one experimenter and was fitted with a heart rate monitor, before completing a submaximal fitness test on a CatEye cycle ergometer. The test lasted for 10mins in total, comprising a 1 min rest period and three 3 min exercise stages, whereby resistance was informed by participants' resting heart rate and heart rate in previous stages. This was completed in order to identify an exercise intensity of 50% heart rate reserve for use in the experimental sessions. Meanwhile, the remaining experimenter walked the remaining participant to the University's sports fields, where the participant completed 10mins of cycling on a cycle ergometer (see Figure 2). The experimenter instructed this participant to cycle at a RPE intensity of "8, extremely light". The purpose of this exercise was to familiarise participants with using the ergometer in the field environment in order to minimise novelty effects during the experimental sessions. Upon completion, the participants (with experimenters) then swapped and completed the remaining task. Upon completion of the second task, both participants and experimenters assembled in the laboratory, where participants were debriefed, marking the end of the test occasion.

6.2.6.2 Outdoors Condition

Upon arrival at the laboratory, participants were sat at the table, given a verbal briefing by the experimenter and re-familiarised with the RPE scale, after which blood pressure was taken. Participants then completed the pre-exercise Digit Span Backwards task (directed attention), followed by the pre-exercise questionnaire battery. Experimenters then led the participants to the university sports fields (the same location as used in the baseline condition), where two CatEye cycling ergometers were placed next to each other, one meter apart, with a vista of the sports fields. Upon ensuring that the seat and handlebar heights were comfortable and appropriate, the experimenters instructed participants: “We would now like you to complete 15 min of cycling exercise. The bikes have been programmed for you and we will ask you to report your Rated Perceived Exertion at a couple of points during the exercise. Please report this to us by pointing to the number rather than saying it verbally. Although this is research, please feel free to talk as much or as little as you like”. Participants then completed 15mins of cycling at an intensity of 50% heart rate reserve. At 7:30mins and at 14mins into the exercise, the experimenters simultaneously asked participants to report their perceived exertion using the RPE. For this, the experimenters stood on the outer side of the pair of ergometers, so that participants turned away from each other when reporting perceived exertion, so as to avoid awareness of and therefore influence upon each other’s answers.

Upon cessation of exercise, the experimenters led participants back to the laboratory. Participants then sat at the table and completed the post-exercise questionnaire followed by the post-exercise Digit Span Backwards task (directed attention). Participants were debriefed and thanked for their participation.

For health and safety reasons regarding the electricity-powered CatEye cycle ergometers, the outdoor condition was completed only if it was not raining at the time of testing. However, there were no instances of the outdoors condition cancellation due to this reason.

6.2.6.3 Indoors Condition

The indoors condition was identical to the outdoors condition with a couple of exceptions. Regarding where the exercise of the session was performed, in the indoors condition, the 15mins cycling exercise was performed in the laboratory. Whereas in the outdoors condition, participants walked to and from the sports fields, in the indoors condition, the experimenter led participants on 4mins, entirely indoors walks around the laboratory building and sports centre buildings, both immediately prior to and following the main cycling exercise.

6.2.7 Statistical Analysis

For the measures of social interaction time, intention for a future exercise behaviour, enjoyment of the exercise session and perceived exertion, a series of mixed within (condition: outdoor, indoor) — between (condition order: outdoor first, indoor first)

ANOVAs were used to compare values reported in outdoor and indoor conditions. Regressions were also conducted in order to further examine the relationships between social interaction time and the outcome of intention for each environmental condition. For the measures of directed attention and POMS, mixed within (condition: outdoor, indoor; time: pre-exercise, post-exercise) - between (condition order: outdoor first, indoor first) repeated measures ANOVA and mixed repeated measures MANOVA were used where appropriate in order to identify potential time by condition interactions. An alpha level of 0.05 was used to indicate statistical significance, with partial eta squared effect sizes and confidence intervals included in order to indicate the magnitude of the effects.

6.3 RESULTS

For all measures, mean and standard deviation values are reported in Table 6.2.

Table 6.2 Mean pre- and post-exercise (±1 SD) values by condition

Measure	Pre-Exercise Values by Condition		Post-Exercise Values by Condition	
	Outdoors	Indoors	Outdoors	Indoors
Intention for future exercise behaviour			68.3 ± 22.0	69.7 ± 25.4
Enjoyment of exercise session			65.9 ± 23.5	64.2 ± 23.4
RPE at 7:30mins			11.9 ± 2.5	12.2 ± 2.5
RPE at 14:00mins			12.9 ± 2.2	13.5 ± 2.2
Social interaction time (seconds)			613.6 ± 222.2	415.8 ± 263.9
Directed attention (number of strings successfully recited backwards)	3.2 ± 1.7	3.5 ± 1.4	3.5 ± 1.7	3.0 ± 1.6

6.3.1 Directed Attention

For Hypothesis (i), a paired samples t-test showed that outdoors and indoors pre-exercise directed attention did not significantly differ (t_{23} = −1.37, 95% CI (−0.73, 0.15), p > 0.05). A within (condition: outdoor, indoor; time: pre-exercise, post-exercise) - between (condition order: outdoor first, indoor first) repeated measures ANOVA found that there was a statistically significant condition by time interaction effect ($F_{1,22}$ = 6.21, p = 0.02, η_p^2 = 0.22). Pairwise comparisons showed that whereas directed attention worsened in the indoors condition (M Δ = −0.4, 95% CI for difference (−0.11, 0.94), p > 0.05), it improved in the outdoors condition (M Δ = 0.3, 95% CI for difference (−0.01, 0.68), p > 0.05; Figure 6.4). There was no significant condition order × condition × time interaction effect (p > 0.05).

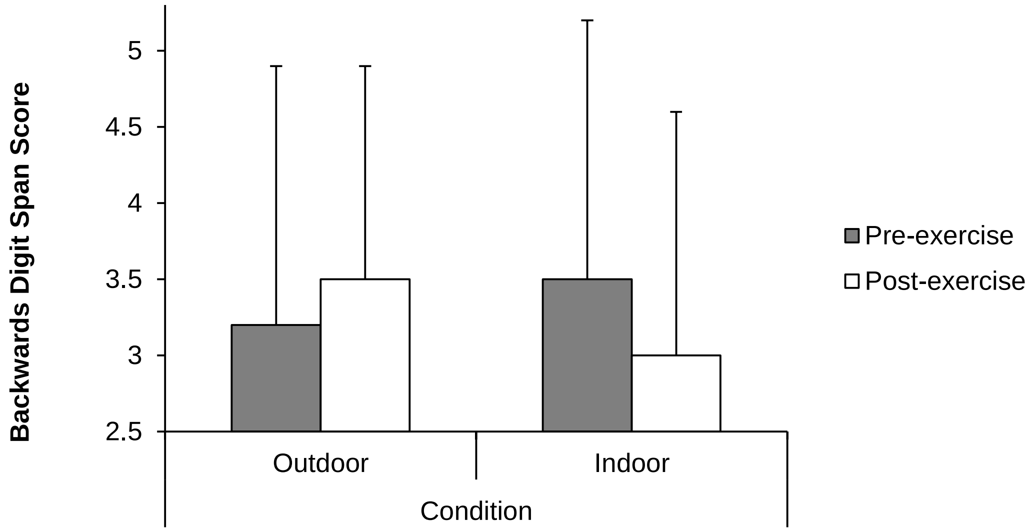

Figure 6.4 Mean (±1 SD) pre- and post-exercise directed attention scores by condition

6.3.2 Mood

For Hypothesis (ii), a mixed measures MANOVA indicated that there was no statistically significant time by condition interaction for POMS ($F_{6,17}$ = 1.70, p > 0.05, η_p^2 = 0.38) and no significant main effect for either condition ($F_{6,17}$ = 1.27, p > 0.05, η_p^2 = 0.31) or time ($F_{6,17}$ = 2.33, p > 0.05, η_p^2 = 0.45; Table 6.3). There was no significant condition order × condition × time interaction effect ($F_{6,17}$ = 1.02, p > 0.05, η_p^2 = 0.26).

Table 6.3 Mean pre- and post-exercise (±1 SD) POMS subscale values by condition

Mood Subscale	Pre-Exercise Values by Condition		Post-Exercise Values by Condition	
	Outdoors	Indoors	Outdoors	Indoors
Tension	32.6 ± 2.9	32.5 ± 2.0	32.4 ± 2.1	32.2 ± 1.6
Depression	37.5 ± 1.1	37.6 ± 1.1	37.3 ± 0.8	37.2 ± 0.5
Anger	38.0 ± 1.8	38.0 ± 1.4	37.4 ± 1.7	37.3 ± 1.0
Vigour	35.9 ± 8.6	37.1 ± 7.2	37.2 ± 8.4	38.6 ± 8.6
Fatigue	40.0 ± 7.9	38.8 ± 6.6	39.3 ± 5.1	39.4 ± 4.7
Confusion	36.5 ± 4.1	36.1 ± 3.5	36.3 ± 3.5	34.6 ± 2.9

6.3.3. Perceived Exertion, Enjoyment, Social Interaction and Intention

A series of within-between ANOVAs found that there were no significant effects for condition for the measures of RPE (Hypothesis (iii)) at 7:30mins and 14:00mins, intention for future exercise behaviour (Hypothesis (v)) and enjoyment of the exercise session (Hypothesis (vii)) (all p-values > 0.05). For each of these measures, there were also no significant condition order × condition × time interaction effects (all p-values > 0.05).

For the measure of social interaction time (Hypothesis (iv)), a within-between ANOVA found a statistically-significant effect for condition ($F_{1,22} = 44.79$, $p > 0.001$, $\eta_p^2 = 0.67$), whereby social interaction time was greater in the outdoors condition compared to the indoors condition.

For Hypothesis (vi), for the outdoors condition, a simple linear regression found that intention for future exercise behaviour was significantly positively predicted by social interaction time ($F_{1,22} = 12.23$, b = 0.06, $p < 0.01$). For the indoors condition, no statistically significant equation was found ($p > 0.05$).

6.4 DISCUSSION

The current study drew upon knowledge gained from the laboratory-based paradigm of Chapter 4 and the indoors *versus* outdoors comparison paradigm of Chapter 5, regarding ecological validity and the use of ergometers for controlling the exercise component. It aimed to merge these approaches in order to transcend the methodological issues encountered within those previous experimental chapters. The current study examined a range of psychological outcomes that were investigated by the previous experimental chapters (POMS, directed attention, enjoyment, RPE). It compared these outcomes (and others) between exercise performed in green outdoors *versus* indoors environments, whilst controlling the exercise component.

In addition to the control of the exercise component, another strength of the current study was its robust within-subjects, randomised and counter-balanced condition order design. This improved on the methodology of Chapter 5 in that both condition order randomisation and control of the exercise component were achieved, whilst avoiding methodological issues of enforced-paced *versus* self-paced exercise. Another strength of this study was its use of a social exercise setting (coupled with the control of the exercise component), transcending the previously existing gap in research regarding the influences of exercise environments, which have either controlled the exercise component or used a social setting.

6.4.1 Directed attention

Hypothesis (i) (that the outdoors condition would best promote improvements in directed attention) was supported. This is consistent with both attention restoration theory (Kaplan, 1995, Kaplan, 2001, Berman et al., 2008) and previous findings such as those of Chapter 4, supporting the suggestion that, compared to “built” indoors or outdoors environments, nature environments facilitate attention restoration during medium intensity exercise (Berman et al., 2008, Rogerson and Barton, 2015). Whereas previous studies reported such findings in relation to walking or running exercise whereby individuals exercised alone, the current study employed cycling exercise using ergometers and examined individuals exercising in pairs. Thus, considered together with previous research, the results allude to the idea that attention restoration can be facilitated by environmental settings during exercise of different modes, in different social settings, and without actual or simulated movement through the environment. That directed attention worsened in the indoors condition is in contrast to previous research and fails to support the suggestion that exercise, in general, promotes directed attention improvements (Dietrich, 2003, Dietrich and Sparling, 2004, Dietrich, 2006, Rogerson and Barton, 2015). However, this finding should be considered with caution as, although the difference in pre-exercise directed attention was not statistically significant, the direction of the difference in these values did contribute to the reported significant time by condition interaction for this measure. Indeed, there was less scope for improvement following the pre-exercise Digit Span Backwards task in the indoors condition.

6.4.2 Mood, enjoyment and intention

The results failed to support Hypotheses (v) (intention), (ii) (mood) and (vii) (enjoyment), that participants would report greater values for these measures in the outdoors compared to the indoor condition. This finding for POMS (mood) was consistent with the findings of Chapter 5. Together, these findings of Chapters 5 and 6 for POMS are in contrast to previous research of this kind (Pretty et al., 2005, Teas et al., 2007, Focht, 2009, Bowler et al., 2010, Thompson Coon et al., 2011). As exercise was controlled in Chapters 5 and 6 but was not within the cited previous research, this alludes that environmental influences on affective outcomes are likely to be contributed to by differences in the exercise performed. Additionally, the current findings are not inconsistent with the suggested pathway linking exercise intensity and perceived exertion to future exercise behaviours via affective responses (Williams et al., 2008, Dasilva et al., 2011, Ekkekakis et al., 2011). As enjoyment is a tertiary emotion (Plutchik, 1980a, Shaver et al., 1987), the lack of significant difference in the measure of enjoyment between conditions was consistent with the lack of time by condition interaction for the measure of POMS. This combination of results is in line with previous research including that of Chapter 3, which reported the outcome of POMS to correlate with, and be predicted by, enjoyment of participation in a bout of green exercise (Focht, 2009, Rogerson et al., 2015). When the exercise performed is comparable, environmental settings appear not to directly influence intentions to repeat exercise behaviour. As exercise intensity and duration influence psychological outcomes of exercise (Ekkekakis et al., 2011, Thompson Coon et al., 2011, Haddad et al., 2014), a possible explanation for the results' unexpected lack of support for hypotheses (v) (intention), (ii) (mood) and (vii) (enjoyment) is that, in previous research, outdoors *versus* indoors differences in the exercise performed may have contributed to the reported outcome differences (Ceci and Hassmén, 1991, Marsh et al., 2006, Focht, 2009, Dasilva et al., 2011). For example, whereas the current study controlled exercise intensity, Focht (2009) reported participants' self-selected intensities of 57% and 59% heart rate reserve indoors and outdoors respectively, although this difference was not accounted for in the analysis of the measure of intention. Additionally, the current finding for POMS was consistent with the findings of Chapter 5, which did control for differences in exercise performed. The theoretical and practical implication of these findings is that differences in physiological qualities of exercise, associated with different environmental settings, may be the greatest contributor to previously reported, practically attainable environment-related differences in affective outcomes of exercise.

The lack of a significant main effect for time on POMS was in contrast to the findings of Chapter 5 and was unexpected, given that exercise per se is frequently suggested to improve affective state (Yeung, 1996, Kopp et al., 2012). Dual-mode theory proposes that the interplay between, and shifting relative importance of collections of cognitive (e.g. self-efficacy, self-presentational concerns) and physiological elements (e.g. acidosis, core temperature) of exercise experiences, influence the exercise-affect relationship (Ekkekakis, 2009). It is plausible that the context (i.e. social setting, in a research context) and settings (e.g. of a duration great enough to promote fatigue in some participants) of the exercise performed in the current study may have predisposed characteristics of, and the relative importance of, particular cognitive and physiological elements, which may in turn not have been conducive to promoting a positive exercise-affect relationship. To speculate, aside from a possible pathway involving attention restoration, as the social setting of the exercise in the current study was different from that of previous research, affect associated with social interactions during the exercise might have functioned to distract from or override other pathways, via which both exercise and environments influence affect. However, the data generated by the current study does not enable investigation of this speculation. Indeed, as previous research of this kind has most frequently focused on affective outcomes of individuals exercising alone, a theoretical and practical implication of the current findings is that potential enhancement of affective exercise outcomes via environment settings may not be generalisable across different social settings.

Considering the findings for Hypothesis (i) (directed attention), together with the findings for Hypothesis (ii) (mood), fails to support the suggestion that attention restoration theory might partly underpin previously reported affective benefits of green exercise; that is, that positive affective valence may occur as a side effect of attention restoration (Kaplan, 1993, Kaplan, 1995, Berman et al., 2008, Raanaas et al., 2011, Rogerson and Barton, 2015). Phenomenological and ecological dynamics approaches offer alternative methodologies for elucidating the underpinning mechanisms of previously reported affective outcomes of green exercise (that is, examination of how characteristics of nature environments might promote greater extent of affordances for affect-influencing individual-environment interactions than do characteristics of indoors environments) and understanding the individual's lived experience of these interactions (Brymer and Davids, 2012, Brymer and Davids, 2014, Brymer et al., 2014).

6.4.3 Social interaction

Hypothesis (iv) (that accumulative time spent interacting socially during the exercise session would be greater during outdoors exercise compared to indoors exercise) was supported. This is consistent with the findings of Teas et al. (2007). Although the results did not directly support Hypothesis (v) (intention), Hypothesis (vi) (social interaction time predicting intention) was partially supported. As intention can in part influence behaviour (Fishbein and Ajzen, 1975, Ajzen and Fishbein, 1980, Ajzen, 1991), the finding that intention for future exercise behaviour was positively predicted by social interaction time in the outdoors condition, but not in the indoors condition, both suggests that green exercise settings may facilitate more meaningful social interaction during exercise and supports the notion that environmental exercise settings might influence behavioural choices via a pathway involving social experience (Resnick et al., 2002, Hug et al., 2009). A practical implication of this finding is that, for exercise contexts in which social experience is deemed important, the environment in which the exercise is performed should be considered. However, future study of, and potential future application of, an exercise environment-social experience-intentions-behaviour pathway should incorporate consideration of a range of other conceptual (e.g. existing habits of an individual) and measure-related factors that influence the intention-behaviour relationship (Webb and Sheeran, 2006).

6.4.4 Perceived exertion

The results did not support Hypothesis (iii) that RPE would be lower during outdoors exercise compared to indoors exercise. This is inconsistent with previous research making such comparisons (Ceci and Hassmén, 1991, Marsh et al., 2006, Focht, 2009, Dasilva et al., 2011). Although it is plausible that this result occurred because participants effectively expended more perceived effort socially interacting during outdoors exercise (therefore offsetting against differences in perceived exertion that might otherwise have been reported), this possibility cannot be elucidated within the current data, and the current results support the assertion that optic flow at least partially underpins the influences of the environment on perceived exertion during exercise (Parry et al., 2012). However, the current findings for RPE are in line with the findings of Chapters 4 and 5. Considered together, that optic flow varied between OUTDOOR and INDOOR conditions within Chapter 5 fails to support this assertion.

6.4.5 Limitations and future research recommendations

It was beyond the scope of the current research to relate reported exercise intention to actual future exercise behaviours. Future research would benefit from longitudinal designs in this way. In order to better inform designs of therapeutic applications of green exercise, future research should also consider designs that enable relationships and possible interactions between environment and social exercise settings to be elucidated and the roles of exercise mode and social settings to be examined. Such research would clarify remaining caveats, such as: whether reported environmental influences occur when exercise groups are greater in number; when exercise mode is different from those already investigated (e.g. resistance exercise); or when required focus on the exercise component is greater, for example during games or sports.

In the baseline condition, half of the participants completed the submaximal cycling test shortly after ten minutes of "extremely light" intensity cycling outside, and this may have biased the results of the submaximal test. That is, particularly for participants who exercise less frequently, even "extremely light" intensity exercise may effect the heart rate response of a subsequent bout, thereby biasing the estimated 50% HRR intensity levels used for the experimental conditions. To help guard against this potential bias, resting heart rate values were obtained at a prior stage of the baseline condition session, and participants undertook a two-minute rest period immediately prior to completing the submaximal test.

A further limitation of the current study was that neither participants' exercise background, nor their relationship with their exercise partner, was controlled for. It is possible that some participants were more experienced and comfortable cycling at 50% HRR intensity than other participants. Additionally, day of the week was not consistent between test occasions and was not controlled for within analyses of the data. This was a limitation of the study, as day of the week has been shown to influence affective state (Ryan et al., 2010a).

It should be noted that, where the current study compared a laboratory to a "green", nature-based outdoors environment, this represents only one specific environmental comparison. Although the findings have been discussed in relation to previous research of this kind, the current results may have been different if the environments compared were different examples of 'green' outdoors or laboratory environments.

This denotes a need for further research to examine alternative examples of indoors and outdoors environments, such as gymnasium (indoors) and forest or beach environments (outdoors).

6.4.6 Conclusions

Restoration of directed attention can be facilitated by environmental settings during exercise of different modes, in different social settings and without actual or simulated movement through the environment. However, the results fail to support the suggestion that attention restoration theory may partly explain previously reported affective benefits of green exercise. The findings of the current study allude to the idea that previously reported influences of environmental exercise settings on affective exercise outcomes may have been significantly contributed to by differences in the exercise performed. However, environmental settings might influence behavioural choices via a pathway involving social experience. The marriage of current quantitative methods with phenomenological and ecological dynamics approaches may aid in the understanding of how and why environmental settings of exercise might influence selected outcomes.

Chapter Seven: Discussion

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Elements of this chapter are published as a chapter within a book:

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Table 7.1 Thesis Map outlining Chapter aims and key findings

Chapter	Aims	Key Findings
3	• To investigate potential differences in affective outcomes of running between different typical green exercise environments • To examine the importance of exercise-, individual- and environment-related variables in relation to these outcomes	• Affective wellbeing improved from pre- to post-green exercise participation • No significant effect of green exercise environment type was identified • RSE improvement was predicted by enjoyment, and performance in relation to expectation; PSS improvement was predicted by age-adjusted performance; TMD improvement was predicted by nature relatedness, sex and enjoyment • Large proportions of the psychological benefits of green exercise are universally obtainable independent of a range of exercise-, individual-, environment-related variables
4	• To examine influences of visual exercise environments on directed attention, perceived exertion and time to exhaustion, whilst measuring and controlling the exercise component	• Visual nature can facilitate attention restoration during moderate-intensity exercise via psychological mechanisms alone • Previous findings regarding influence of visual environments on perceived exertion were not replicated • Visual environment did not significantly influence energy expenditure during exercise
5	• To identify a method for ensuring consistency of the exercise component between indoor (treadmill) and outdoor (over ground) exercise • To compare psychological outcomes of outdoor *versus* indoor exercise	• The exercise component was successfully controlled physically (as measured physiologically) and controlled for statistically (as measured by time), across studies A-C • Findings failed to replicate previously reported affective influences of outdoor *versus* indoor exercise environments • It was not possible to indicate whether or not differences in the exercise component might have been underlying causes of previously reported effects • Important methodological limitations and issues were identified; namely those of enforced pace *versus* self-paced exercise, and non-randomisation of condition order
6	• To compare a psychological, social and behavioural intention outcomes of exercise in green outdoors *versus* indoors settings, whilst controlling the exercise component	• Environmental exercise settings might influence behavioural choices via a pathway involving social experience • Compared to indoors, the green outdoor setting significantly promoted attention restoration • No significant influence of environmental setting on mood or perceived exertion • Findings fail to support the suggestion that attention restoration may explain previously reported affective benefits of green exercise

7.1 SUMMARY

The overall aim of this thesis was to rigorously test the influence of environmental settings on exercise-related wellbeing outcomes. The literature review of Chapter 1 identified this as an important current requirement of the green exercise research area, given the discussed findings and limitations of previous research. The experimental chapters addressed three overarching research questions. Question (i) was ‘Is there an optimal green exercise environment that promotes wellbeing?’ This is an important research question because Chapter 1 identified that, from existing literature, it is not yet clear whether there is an optimal ‘type’ of nature environment for maximising the reported psychological outcomes of green exercise participation. Greater understanding in this area might enable finer tailoring of exercise experiences for wellbeing outcomes. Question (ii) was ‘When exercise is controlled, are findings consistent with previously reported psychological outcomes?’ This is an important research question because Chapter 1 identified that exercise component has often not been controlled, and in instances that it has been controlled, findings have been mixed. Question (iii) was ‘Do environmental settings influence social outcomes of exercise or intentions to repeat exercise behaviours?’ This is an important research question because Chapter 1 identified that, although exercise is often a social event, influences of environmental exercise settings on social experience were yet to be rigorously examined. Additionally, Chapter 1 identified that, although links between affective outcomes and exercise intentions have been outlined, little research has addressed the possibility that nature-based environmental settings might function as a tool for maintenance of exercise behaviours.

Chapter 3 addressed the question of whether there is an optimal green exercise environment. Examining measures of mood, perceived stress and self-esteem, it found that a large proportion of the reported affective benefits were universally obtainable across four typical green exercise environments (namely, three urban parks and a coastal route), and across a number of exercise-, environment- and exercise-component-related characteristics. This advances green exercise field research: (i) as it furthers the efforts of Barton and Pretty (2010) in examining the importance of a range of factors such as age and gender in relation to wellbeing outcomes of green exercise; and (ii) as it was the first study to compare outcomes of one consistent activity across different typical green exercise environments. It was a significant study for this research area because it addressed the potential importance of variation in what have been defined and tested as 'green' exercise environments – an issue that pervades the existing green exercise research literature. Chapter 3 advanced understanding of the green exercise research field by suggesting, via quantitative data, the importance of the processes component of green exercise. However, examination of this requires greater control of other influential variables in order to isolate manipulations of interest. As the field paradigm does not allow for this, the remaining experimental chapters used laboratory-based methodologies.

Chapters 4, 5 and 6 addressed the question of whether, when exercise is controlled, findings are consistent with previously reported psychological outcomes. For these chapters, laboratory-based methodologies were used in order to control the exercise component and isolate potential influences of either visual environments or experiential aspects of exercise environments. Within a laboratory, Chapter 4 isolated the role of visual-environments during exercise and found that, consistent with both theory and previous research, nature environments facilitated restoration from directed attention fatigue. This is important as an outcome both in itself and because Chapter 1 found that attention restoration may promote wellbeing-related affective improvements. However, as laboratory-isolated visual environments are not representative of real green exercise participation, Chapters 5 and 6 made more ecologically valid comparisons between indoor and outdoor exercise. Chapter 5 trialled new methodologies for controlling (or controlling for) the exercise component and compared outcomes of indoor and outdoor exercise. However, its findings did not offer strong conclusions regarding the role of differences in the exercise component. Further, the studies of Chapter 5 highlighted methodological issues of the indoor *versus* outdoor exercise comparison paradigm, perhaps most importantly those of phenomenological and psychological issues associated with comparing self-paced *versus* enforced-paced exercise. This issue was dealt with in Chapter 6 via use of cycle ergometers within the same environmental settings. Chapter 6 additionally addressed the questions of whether environmental settings influence social outcomes of exercise or intentions to repeat exercise behaviours. This was important in relation to the current state of physical inactivity within the UK outlined in Chapter 1, and because in real-world practice exercise is often a social event, and previous research had offered only initial investigations of environmental influences on both social experience and intentions to repeat exercise behaviours (Teas et al., 2007, Focht, 2009). It merged laboratory ergometer methods with the indoor *versus* outdoor exercise paradigm. This was in order to enable control of the exercise performed whilst comparing real environments. It discussed relevant issues in relation to its findings for the measures of RPE and POMS, contrasting with those of previous research. Whereas environmental setting did not influence RPE and POMS, green settings facilitated improvements in directed attention. Additionally, from the findings of Chapter 6, it is now known that environmental settings can influence social experiences of exercise, and that for green exercise participation (but not for indoor exercise), social experience may play an important role in adherence-related intentions to repeat exercise behaviour.

7.2 KEY FINDINGS

- Green exercise offers accessible provision for improving acute psychological wellbeing.
- Characteristics of the individual, exercise and environment can significantly influence affective outcomes of green exercise participation; however, large proportions of the affective outcomes are universally obtainable.
- The processes component (psychological and physiological processes within the individual, in relation to the environment or the exercise, or both) may explain reported influence of environment type on exercise-associated affect.
- Compared to indoor or built environmental settings, nature environments promote increases in directed attention from pre- to post-exercise. This environmental influence can occur subconsciously via psychological pathways alone, in different social settings.
- For measures of affect, when the exercise component was either physically or statistically controlled, previously reported influences of outdoor *versus* indoor exercise environments were not replicated.
- The findings highlighted phenomenological and psychological issues associated with comparisons of self-paced *versus* enforced-paced exercise.
- The findings failed to support the suggestion that attention restoration theory may partly explain previously reported affective benefits of green exercise.
- Compared to exercising alone, exercising in a social setting may detract from environmental influences on consciously reported psychological measures; however, these social influences may impact on adherence to future green exercise behaviours.

7.3 DISCUSSION

Overall, the findings of this thesis fail to support suggestions that, compared to indoor exercise, green exercise participation has positive impacts on wellbeing measures. As discussed in Chapters 5 and 6, this may have been due to methodological advancements of the current thesis studies in controlling the exercise component between conditions. That these chapters failed to find statistically significant main effects for time is suggestive of other potential occurrences. For example, participants may have relatively (for them as individuals) reported highly on wellbeing measures at the pre-exercise time-point, leaving little room for exercise-associated improvement. However, examination of pre-exercise POMS TMD values across the thesis does not support this particular suggestion; Chapter 3 reported a main effect for time from a mean pre-exercise value of 148.8, which was highly similar to mean pre-exercise values from Chapters 5 and 6 (Chapter 5 Study A OUTDOOR = 145.6; Chapter 5 Study A INDOOR = 144.3; Chapter 5 Study B OUTDOOR = 150.2; Chapter 5 Study B INDOOR = 149.4; Chapter 5 Study C OUTDOOR; 143.63; Chapter 5 Study C INDOOR = 145.9; Study 6 outdoors = 148.8; Chapter 6 indoors = 145.9). Almost all mean pre-exercise POMS TMD values within each study of Chapter 5 (A, B and C) and Chapter 6 were also within one standard deviation of pre-intervention values reported by previous green exercise research, such as that of Barton et al. (2009) (M= 147.5 ± 22.0) and Wooller et al. (2015) (M= 139 ± 10; M= 144 ± 10; M= 139 ± 13).

In relation to Hartig et al.'s (2014) model of how nature environments can influence human health and wellbeing, findings of Chapter 3 for the measures of perceived stress, mood and self-esteem were consistent with the suggested pathway that contact with nature environments promotes stress reduction, which in turn improves wellbeing. However, findings of Chapters 5 and 6 were not consistent with such environmental influences. Both Hartig et al.'s model and the findings of Bowler et al. (2010) also suggest a social pathway from contact with nature to improved health and wellbeing. Relating to the ecological dynamics perspective on green exercise, beyond the notion that nature environments promote affordances for increased social contact and sense of community, the findings of Chapter 6 suggest that the nature environments may promote affordances for social interaction during exercise to a greater extent than indoor environments.

The findings of Chapters 5 and 6 failed to support the possibility that affective benefits of green exercise follow in a causal manner from attention restoration (represented in Figure 7.1 by dashed arrow from point 7). Environmental influences on directed attention were not accompanied by significant environmental influences on measures of affect. These findings allude that it may be more likely that affective influences can occur alongside, but independent of, attention restoration, rather than as a causal result of it (Kaplan, 1995, Barton et al., 2009, Barton and Pretty, 2010, Kaplan and Berman, 2010).

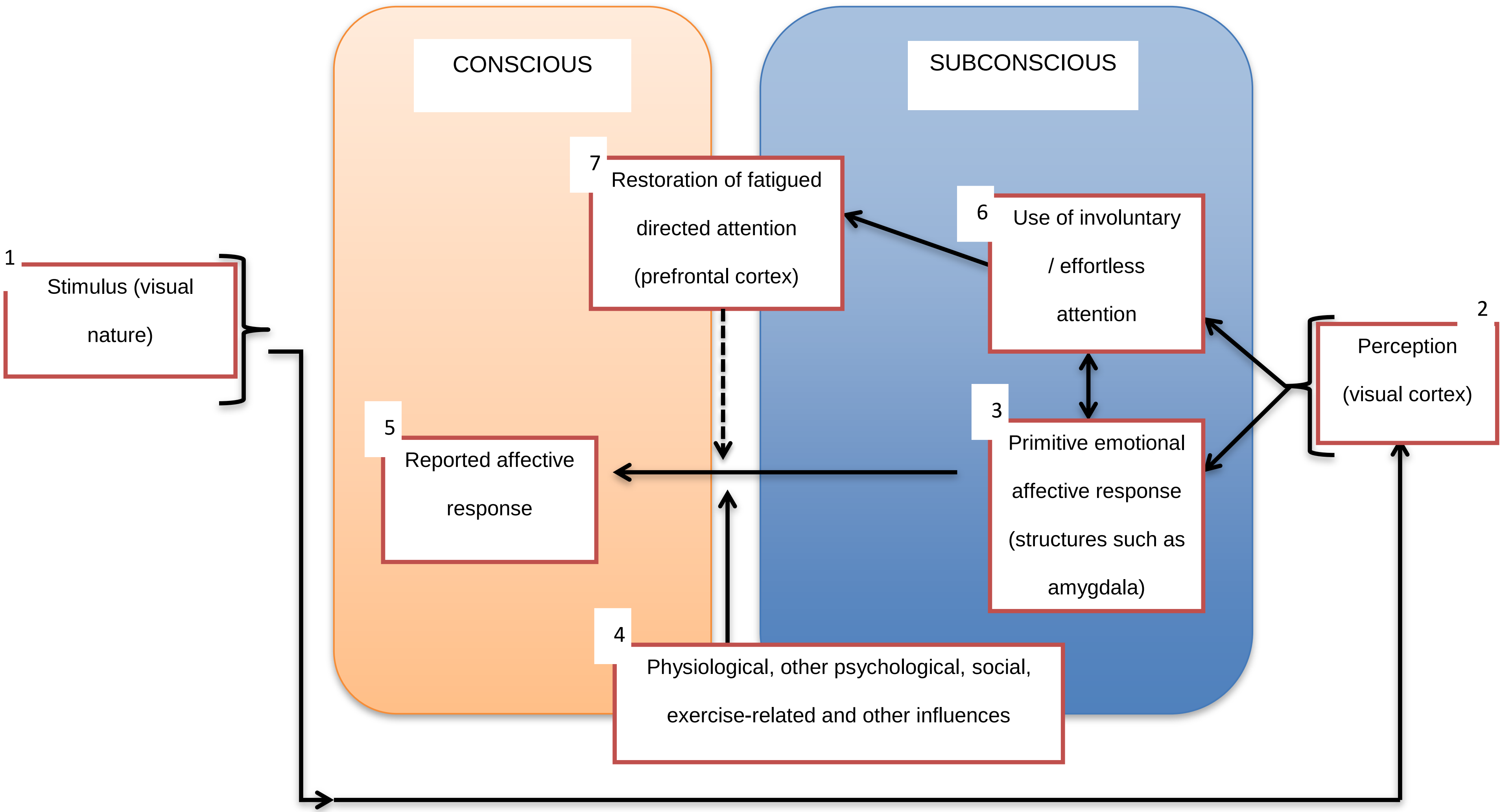

Figure 7.1 Theoretical diagram of how visual nature environments might influence affective and directed attention outcomes of exercise

In relation to Figure 7.1, at points 1 and 2 the visual environment is captured by the eyes and coded for within the visual cortex. In the current thesis, Chapter 3 examined different types of typical green exercise environments, Chapter 4 compared built *versus* nature visual environments, and Chapters 5 and 6 compared indoor laboratory *versus* outdoor 'green' environments. At points 3 and 6, Chapter 1 outlined that stress reduction theory suggests that a positive, subconscious emotional response occurs (Ulrich et al., 1991), and this might in turn promote use of involuntary effortless attention; attention restoration theory suggests that the perceived environment is attended via effortless attention and that this ease of attention might prompt positive emotional response (Kaplan, 1995). The research of the current thesis did not enable investigation of the direction of this relationship. Regarding point 4, other physiological, psychological, social, exercise-related and other factors influence the individual's affective state. Chapter 6 discussed possible exercise-associated social influences. At point 5, consciously reported affect occurs. In the current thesis, these were measures of mood, self-esteem and perceived stress. Finally, at point 7, use of effortless attention promotes restoration of fatigued directed attention. In the current thesis, exercise-associated environmental influence on attention restoration was reported in Chapters 4, 5 and 6.

Resonating with the notion of levels of engagement (Pretty et al., 2003, Pretty et al., 2004), where most research has focused on comparisons of nature *versus* built, indoor or urban environments, it has not yet been clearly demonstrated as to whether green exercise results in relatively greater wellbeing benefits than simple exposure to nature whilst at rest. That is, the suggestion of synergy is unsupported. Like previous research, what has been found by the current thesis is that, for exercise participation, nature environments might enhance some beneficial outcomes. However, it is not yet clear how the psychological benefits of physical activity and nature exposure interact, and whether these benefits are sub-additive, additive or synergistic (Shanahan et al., 2016). Future research might examine this question via a design of two (environment: nature *versus* built) by two (activity: rest *versus* physically active) conditions, such as that used to examine physiological variables (Park et al., 2008, Park et al., 2010).

7.4 Wider implications of the current thesis findings

The implication of the research of the current thesis is that knowledge and understanding of environmental influences on wellbeing-related outcomes has been enhanced. Findings of this thesis enhance understanding of ***how*** and ***why*** environmental settings influence a range of psychological outcomes, for example, the aforementioned discussion of processes as outlined by Figure 7.1. As well as informing ***how*** and ***why*** environmental settings influence a range of psychological outcomes, findings of this thesis can be applied to real-world contexts in order to assist individuals in maximising the psychological benefits attained from exercise participation. For example, the findings of Chapter 3 imply that an individual can gain the majority of the potential wellbeing outcomes of green exercise participation, regardless of the environmental content of the park or coastal route where they exercise. Chapter 4 implies that choosing to exercise in greenspaces offers greater attention restoration benefits than exercise indoors in a built environment. That is, the current findings serve to inform ***that*** environmental settings influence a range of psychological outcomes. A philosophical point here is whether it matters ***how*** and ***why*** it works, or only ***that*** it works. The question raised is whether it is worth further investment in unpicking the mechanisms that underpin green exercise effects, or whether it is more important to invest in real-world applications of green exercise.

Whereas the current state of mental wellbeing and physical inactivity in the UK (outlined in Chapter 1) might suggest that application is of greatest importance, there remains merit to better understanding potential underpinning mechanisms, as this understanding can be used to maximise efficacies of such application. The green exercise research area should consider directing its future research along these two distinct agendas. It is clear that green exercise participation offers health and wellbeing benefits, in some cases to a greater extent than equivalent non-green exercise; green exercise can function as an upstream preventative mental health promotion intervention (Maller et al., 2006, Rogerson et al., 2015). Therefore, one agenda of research should investigate potential benefits of green exercise in relation to a range of previously unexplored measures of interest, so as to consider how wide ranging the benefits of participation are. For example, a range of social outcomes, such as social cohesion, are yet to receive attention. The complementary line of research should comprise detailed examination of the mechanisms that underpin the reported beneficial outcomes, for example, in considering which elements of the sensory experience of green exercise may be most important for different specific outcomes. That is, if green exercise were considered as a drug for mental health and wellbeing, more detailed understanding of its mechanisms can lead to optimal dosage, and knowledge of when and for whom it might work best.

7.5 Taking the current thesis findings forwards

Chapter 5 was not able to make strong conclusions regarding the possibility that differences in exercise intensity may have contributed to previously reported influences of environments on affective outcomes of exercise (Ekkekakis et al., 2011); and Chapter 6 discussed that social influences may have functioned to reduce mindful engagement. An indication from the findings of this thesis is that future research that compares physical activity between environmental settings should either physically or statistically control the exercise component, or discuss the possibility that proportions of some outcome differences may be attributed to differences in the physical activity performed.

Like much of the literature, the current thesis has contributed empirical evidence to current understanding of the role of environments for exercise-associated wellbeing outcomes, and it is intended that this evidence will contribute to the ongoing development of theoretical frameworks for understanding how green exercise can promote wellbeing (Yeh et al., 2015). Furthermore, like most research in this area, the current thesis has focused on acute bouts of green exercise. To enhance real-world application of research findings, future work should examine such environmental influences in relation to repeated physical activity behaviour. For example, are there environmental influences on sustained or long-term wellbeing improvements when physical activity is performed at a dose-frequency of three times per week?

Further, in order to maximise potential benefits from green exercise participation, it is necessary to know the optimal 'dose' of this experience. This applies equally for either particular outcome measures *alone*, or for combined outcomes *overall*. Dose–response modelling – an analytical technique often used for informing guidelines for health interventions – may be of great use here (Shanahan et al., 2015). However, beyond the work of Chapter 3, very few papers to date have directly sought to identify optimal characteristics for maximising desired outcomes of green exercise participation (Barton and Pretty, 2010, Rogerson et al., 2015).

As outlined in Chapter 3, green exercise participation comprises interactions between numerous environmental, exercise and individual-related variables (Brymer et al., 2014, Rogerson et al., 2015). Therefore, knowledge of optimal doses of exercise per se and of nature exposure per se might also be considered together with green exercise research findings when attempting to identify an optimal dose of green exercise for health benefits. The three dose-response components for both nature and exercise would include: (i) intensity of exposure [i.e. quality (species richness, biodiversity, habitats, vegetation structure etc.) and quantity (extent and type of vegetation) of nature. The quantity and quality of available greenspace close to the home is correlated with longevity and a decreased risk of mental ill health (Maas et al., 2006, 2009; Ward Thompson et al., 2012; White et al., 2013). Individual preferences and perceptions may also influence the dose response. This would also relate to the intensity of the exercise; for example, as discussed within Chapters 1, 3, 4, 5 and 6, there is a relationship between exercise intensity and affective outcomes (Ekkekakis et al., 2011)]; (ii) frequency of exposure [how often you exercise or experience nature in a defined timeframe. This may also be influenced by the pattern of exposure (e.g. intermittent, random, cumulative etc.) and the outcomes measured (e.g. psychological or physiological health - frequent short bouts of nature exposure could cumulatively negate mental fatigue but have minimal impact on physiological health, whereas participating in repeated bouts of exercise over a longer time period might enhance cardiovascular health)]; (iii) duration of exposure [length of time of exercise bout and/or nature exposure].

7.6 Additional future research suggestions

Chapter 3 examined potential influences on wellbeing outcomes of individuals' motivations for their green exercise participation. The role of individuals' beliefs about green exercise participation might also be important to wellbeing outcomes. Beliefs about physical activity are powerful enough to improve physiological health measures of waist-to-hip ratio and blood pressure simply via the placebo effect, compared to a control group (Crum and Langer, 2007). This highlights the possibility that, within research that compares environmental settings for exercise outcomes (such as that of the current thesis), reported influences of environments on psychological variables might be partly explained by individual differences in beliefs. Marriage of quantitative methods (such as those of the current thesis) with phenomenological research approaches may be of particular use for investigations of this important issue.

Where Chapter 6 highlighted the potential importance of optic flow for environmental influences on perceived exertion, both for this and wellbeing variables, it is not yet known to what extent environmental influences occur similarly across different exercise modes. That is, whether reported outcomes would differ between static resistance exercises compared to aerobic exercise that entails movement through the environment. This represents another important future avenue for research in order to better inform use of green exercise participation for public health benefits.

7.7 Conclusions

The work of this thesis has addressed and highlighted methodological issues around green exercise research, and has added to current knowledge of the influences of environmental settings on a range of psychological outcomes of acute exercise participation. The findings presented suggest that when comparing indoor *versus* green outdoor exercise settings, some differences in psychological outcomes may be attributed to differences in the physical activity performed. However, for public wellbeing benefits, the maximisation of such benefits is important, regardless of the origin of these effects. A key aspect of this thesis has been its use, and latterly its merging, of a range of research methodologies to further understanding of previously reported outcomes, such as directed attention. Independent of exercise differences, green environments enhance exercise-related attention restoration. This work also positions green environmental settings as potentially useful for enhancing social exercise experience, which may be harnessed to influence intentions for future adherence to physical activity behaviours. This thesis attests that green exercise participation can facilitate enhancements in wellbeing-related parameters, and that access to natural environments for physical activity should be protected and promoted as a vehicle for improving population mental health (Mitchell, 2013).

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