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BEHAVIOURAL DETERMINANTS OF HUMAN AND PLANETARY HEALTH: THE ROLE OF NATURE CONTACT AND NATURE CONNECTEDNESS.

by

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Authors' Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee. Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment.

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Scientific seminars and conferences were regularly attended at which work was often presented. A six month (0.5FTE) placement at Natural England was undertaken during the course of this PhD (co-funded by the ESRC and the University of Plymouth). Relevant courses were attended to develop specific skills and several papers have been submitted or prepared for publication.

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Abstract

Behavioural determinants of human and planetary health: the role of nature contact and nature connectedness.

Leanne Martin

The benefits of natural environments for health and wellbeing are well-established, but less is known about their links human behaviour. This thesis presents a conceptual model proposing that increased contact with - and psychological connection to – nature will be associated with: a) a lower prevalence of health risk behaviours, and b) greater engagement with pro-environmental behaviours, via positive affect, negative affect, community cohesion and temporal discounting. Studies 1-3 used representative cross-sectional datasets to systematically investigate the associations between different types of nature contact, nature connectedness and behavioural outcomes. Study 4 used a bespoke cross-sectional survey to test the full conceptual model, including the proposed mediators. It was found that nature-behaviour associations differ, in both direction and strength, as a function of: a) the type of nature contact, and b) behavioural outcome. Specifically, after accounting for a range of covariates, residential nature contact (greenspace, green views) was associated with a lower prevalence of health risk behaviours (current smoking, exceeding alcohol guidelines, poor diets), as well as greater engagement household pro-environmental behaviours. Intentional nature contact (nature visits) was linked to a lower prevalence of poor diets and greater engagement in household pro-environmental behaviours. Indirect nature contact (watching/listening to nature media) was associated with a higher prevalence of current smoking and exceeding alcohol guidelines, as well as a lower prevalence of poor diets and more sustainable behaviours across domains (household, nature conservation). Nature

connectedness was most consistently related to a lower prevalence of poor diets and greater engagement in pro-environmental behaviours (household, nature conservation). There was evidence that, under some circumstances, nature connectedness moderated nature-behaviour associations. Additionally, associations between nature contact/connectedness and behavioural outcomes were mediated by somewhat different combinations of positive affect, negative affect, community cohesion and temporal discounting. The complexity of the findings indicates that a more nuanced approach to the study of human-nature interactions is likely to be necessary to inform integrated environmental policies that are beneficial to both human and planetary health.

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Introduction, Literature Review & Conceptual Model

1.1 Introduction: Human and Planetary Health

Public health and environmental sustainability present two of most significant global challenges of the 21st century (United Nations Environment Programme, 2016; WHO, 2013). With environmental degradation posing serious consequences to human health (WHO, 2018a) and human activity further compromising environmental quality (United Nations, 2018), there is increasing recognition that these two challenges are inter-connected (Nisbet & Gick, 2008; Graham & White, 2016; Whitmee, et al., 2015). A major determinant of both public and planetary health is human behaviour. Just as individual health risk behaviours contribute to illness (e.g. smoking and cardiovascular disease, WHO, 2018b), environmental issues are exacerbated by unsustainable human behaviours (e.g. driving and air pollution, Energy Information Administration, 2015; Barnes et al., 2019). With both public and planetary health under increasing pressure, there are growing calls to explore the integration of public health and environmental research agendas (Graham & White, 2016; Watts et al., 2015; Reis et al., 2015; Depledge et al., 2019).

Whilst public and planetary health constitute two distinct interdisciplinary fields, this thesis examines both issues from an environmental psychology perspective. Focusing on the interplay between people and their physical environments (van den Berg & Staats, 2018), current theories and research within environmental psychology are intrinsically linked to both human and planetary health. Particularly relevant to this thesis is the nature restoration literature, which examines the potential salutogenic - or health creating - effects of natural environments on human and environmental health

(Hartig et al., 2014; Hartig et al., 2007). Extending this line of enquiry further, a potential area of overlap between health risk and pro-environmental behaviours are individuals' physical and psychological experiences of the natural world. Consequently, this thesis investigates the links between nature contact, nature connectedness, and behavioural determinants of public and planetary health (i.e. health risk behaviours and pro-environmental behaviours). This chapter outlines how human behaviour influences both public health and planetary health, as well as considering the commonalities and differences between the two behavioural domains (Section 1.2). The current nature restoration literature on the roles of nature contact and nature connectedness in health risk and pro-environmental behaviours are then reviewed (Section 1.3). Finally, Section 1.4 provides an overview of this thesis.

1.2 Behavioural Determinants of Human and Planetary Health

1.2.1 Behavioural Determinants of Human Health

Modifiable consumption behaviours such as smoking, alcohol misuse and poor diet are widely recognised as major determinants of morbidity and mortality worldwide (WHO, 2013). Smoking increases the risk of cardiovascular disease, cancer and chronic respiratory disease (WHO, 2018b), even amongst occasional smokers (Schane et al., 2010). Exceeding recommended alcohol limits can adversely affect neurologic, cardiac, and gastrointestinal health (Rehm et al., 2017; WHO, 2020); and nutritionally poor diets, specifically those high in sodium, sugar and fat, are associated with obesity, diabetes, hyper-tension and cardiovascular disease (WHO, 2013; Popkin et al., 2001). Additionally, smoking, alcohol misuse and poor diet are associated with increased disease burden measured by disability-adjusted life years (May et al., 2015), as well as pressures on economic productivity and health systems (Bloom et al., 2011; Scarborough et al., 2011).

Given their substantial personal and economic costs, these three consumption behaviours constitute significant public health issues. Accordingly, identifying correlates and strategies to reduce them is pivotal to the World Health Organization's Global Action Plan for the Prevention and Control of Non-Communicable Diseases (WHO, 2013). Concerted efforts to reduce health risk behaviours through public health campaigns and individual-level interventions have been associated with increased awareness of their risks amongst the general public (Spronk et al., 2014), and a rise in individuals' intentions to reduce target behaviours (Shaikh et al., 2008; Robertson, 2008), yet actual consumption rates remain high. For instance, whilst there has been a consistent reduction in the prevalence of smoking and harmful alcohol use over the last decade, in 2019 5.7 million people (13.9%) in England were current smokers (Office for National Statistics, 2020a), and 21% of adults exceeded current alcohol guidelines of 14 units of alcohol a week (NHS Digital, 2020a). Similarly, mean intakes of saturated fat, sugar and salt in continue to exceed dietary recommendations (Public Health England, 2020a), and around two thirds of adults in England were obese or overweight in 2019 (NHS Digital, 2020b). These behavioural trends are consistent with cross-sectional data observing weak and sometimes inconsistent associations between risk perception, behavioural intentions and health behaviours (Sheeran et al., 2014; Hollands et al., 2016). Indeed, meta-analyses indicate that medium-to-large changes in health-related behavioural intentions, are associated with just small-to-medium changes in health behaviour (Webb & Sheeran, 2006). Collectively, these findings indicate that despite substantial investment into public health campaigns and intervention strategies, the prevalence of modifiable health risk behaviours remains high.

Smoking, alcohol misuse, and unhealthy diets tend to cluster together or co-occur (Nobel et al. 2015; Uddin et al., 2020), with individuals who smoke, also more likely to drink heavily and have nutritionally poor diets (Berrigan et al., 2003, Poortinga, 2007, De Vries et al., 2008). Evidence that combinations of health risk behaviours are more detrimental to health than their cumulative individual effects (Berrigan et al., 2003, French et al., 2008, Poortinga, 2007), implicates commonalities in the mechanisms underlying health risk behaviours, as well as the potential utility of strategies targeting multiple behaviours. However, although there is evidence that multi-behavioural interventions result in higher abstinence rates (Prochaska et al., 2010) and better health outcomes than single-target interventions (Sweet & Fortier, 2010; Minian et al., 2020), identifying appropriate, accessible, and cost-effective solutions remains a challenge (Atkins & Clancy, 2004; Goldstein et al., 2004; Minian et al., 2020).

This is particularly pertinent given that clusters of health risk behaviours are not randomly distributed amongst the population, but influenced by an individual's social, economic and environmental circumstances. Socioeconomic status, for instance, whether measured by income, education or occupational status, is among the most robust determinants of variations in clusters of health risk behaviours (Williams et al., 2016), with co-occurring health risk behaviours disproportionately higher amongst lower socio-economic groups (Noble et al., 2015; Meader et al., 2016). Similarly, neighbourhood characteristics, including area-deprivation, population density and urban/rural status are also positively associated with the prevalence of health risk behaviour clusters (Cerdá et al., 2010; Halonen et al., 2012; Lakshman et al., 2011). Research agendas and strategies to reduce health risk behaviours may therefore need to account for such social-contextual factors, in order to achieve discernible improvements to public health.

1.2.2 Behavioural Determinants of Planetary Health

Numerous environmental issues pose serious threats to the sustainability of the planet, including: global warming, resource depletion, air pollution and loss of biodiversity

(United Nations, 2018). Environmental sustainability depends strongly on human behaviour (Vlek & Steg, 2007). Human activities are estimated to have caused approximately 1.0°C of global warming (IPCC, 2018) and are the primary source of air pollution (European Environment Agency, 2020). Furthermore, approximately three-quarters of the land-based environment and 66% of the marine environment have been altered by human actions, resulting in a substantial decline in biodiversity (IPBES, 2019). With evidence that anthropogenic activities exacerbate environmental issues, identifying effective strategies that promote sustainable behaviours are fundamental to achieving current sustainability goals (Department of Environment, Food & Rural Affairs, 2018; United Nations, 2018).

Traditional strategies to encourage sustainable behaviours primarily involve conveying information about environmental issues, in addition to the potential harms and benefits of different behaviours. Whilst public information campaigns have been associated with increased public acceptance of environmental issues (Fernandez et al., 2017; Anable, 2006) and a rise in pro-environmental attitudes (Thomas et al., 2019; Howarth et al., 2010), they do not consistently translate to greater participation in sustainable behaviours (Howarth et al., 2010; Fernandez et al., 2017). Meta-analyses indicate that pro-environmental intentions explain approximately one quarter of the variance of pro-environmental behaviours (Bamberg & Möser, 2007; Morren & Grinstein, 2016). These findings are consistent with behavioural trends. For instance, despite a rise in public knowledge regarding energy consumption, in 2017 temperature-adjusted domestic energy consumption in the UK rose for the second consecutive year since 2015 and remained at this level in 2018 (Department for Business, Energy and Industrial Strategy, 2020). Travel habits remain particularly resistant to change: with 68% of workers in Great Britain commuting to work by car, and the number of terminal passengers at UK airports increasing for the eight consecutive year in 2018 (Department for Transport, 2019). Despite wide-spread public support for the single-use plastic bag charge in the United Kingdom leading to a substantial reduction in consumption rates since 2015 (Poortinga et al., 2016), large retailers alone reported selling 1.05 billion single-use bags between 2017 and 2018 (Department of Environment, Food & Rural Affairs, 2020). Taken together, these findings suggest that the current scale of behavioral change is insufficient to make the discernable environmental impacts needed.

Analogous with health behaviours, there is evidence that different types of sustainable behaviour cluster together and co-occur. For instance, a survey of 1600 households in the United Kingdom found that sustainable consumption behaviours (e.g. buying organic food) exhibited positive relationships to a variety of household (e.g. energy consumption and water-saving measures) and recycling behaviours (Barr et al., 2005). Similarly, Thøgersen & Ölander (2006) observed positive associations between recycling, buying organic food products, and sustainable transportation use (public transport/cycling). However inconsistent findings between studies should be noted. Using two large scale datasets from the United Kingdom, Alcock et al. (2017) found that engagement in household pro-environmental behaviours was unrelated to discretionary flight behaviour (e.g. air travel for leisure purposes rather than work). This finding is consistent with meta-analyses demonstrating that interventions targeting a specific sustainable behaviour are more likely to engage in other forms of sustainable behaviours (i.e positive spillover effects), when the two behavioural domains are perceived to be similar (Maki et al., 2019). Therefore, for perceptually similar behaviours at least, individuals who behave sustainably in one domain are more likely to exhibit pro-environmental behaviours in other domains.

Also consistent with health behaviour research, pro-environmental attitudes and behaviours are influenced by marked socio-contextual gradients. Whilst socio-economic status is positively related to the endorsement of pro-environmental attitudes (Franzen, 2003; Kemmelmeier et al., 2002; Milfont et al., 2015; Hornsey et al., 2016), its associations with pro-environmental behaviours are more complex. Individuals from higher socio-economic groups tend to behave more sustainably in terms of everyday behaviours (*Recycling*, Owens et al., 2000; *Sustainable purchases*, McEachern & Mcclean, 2002) and report more activism behaviours (Pisano & Lubell, 2017), yet use less sustainable modes of transport (*Car use*; Johansson-Stenman, 2002; *Discretionary flights,* Alcock et al., 2018). Collectively, these findings suggest that the associations between socio-economic status and pro-environmental behaviours, vary as a function of behavioural domain. Congruent with health risk behaviours, pro-environmental behaviours are also influenced by neighbourhood characteristics. Notably, individuals living in more deprived, densely populated and urban areas exhibit less engagement in pro-environmental behaviours (Laidley, 2013; Hinds & Sparks, 2008). Thus, the influence of both social and contextual factors needs to be accounted for in research and strategies targeting pro-environmental outcomes.

1.2.3 Commonalities and Differences between Behavioural Domains

Although current challenges to public health and environmental sustainability are inter-connected, they have traditionally formed two distinct fields of research. Nonetheless, a number of parallels exist between the two domains. Firstly, human behaviour is a major determinant of both public and planetary health. Individual health behaviours contribute to illness and environmental issues are exacerbated by unsustainable human behaviours. Consequently, the risks to both public health and environmental degradation can be reduced, at least in part, through changes to individual behaviour. Secondly, despite substantial investments into public information campaigns promoting healthier and more sustainable behaviours, evident intention-behaviour gaps exist in each domain.

Thirdly, both health risk behaviours and pro-environmental behaviours tend to cluster together or co-occur. For instance, individuals who smoke are more likely to engage in other health risk behaviours (e.g. exceeding recommended alcohol limits). Similarly, individuals who behave sustainably in one domain (e.g. buying organic food) are more likely to exhibit sustainable behaviours in other domains (e.g. energy conversation). Whilst recognising that these findings are less consistent amongst sustainable behaviours, evidence of co-occurrence indicates that there may be common mechanisms underlying health and sustainability behaviours, respectively. Consequently, there may be greater utility in strategies that influence multiple, rather than single behaviours. Finally, health behaviours and sustainability behaviours are similarly affected by socio-environmental gradients. Inconsistencies regarding transport use notwithstanding, individuals in higher socio-economic groups, are not only more likely to engage in healthy behaviours, but also more likely to behave sustainably. Similarly, adverse behavioural outcomes are associated with neighbourhood deprivation, population density and urbanicity across both domains. Thus, strategies accounting for these social-contextual factors, may be necessary to improve health and sustainability outcomes.

A noteworthy potential area of divergence between health and sustainability behaviours is their motivational benefits (Nisbet & Gick, 2008; De Groot & Steg, 2010), specifically whether the behaviour is driven by egoism (increasing one’s own welfare) and altruism (increasing the welfare of others, Tamborini et al., 2016). Health behaviours (e.g. smoking cessation) can be somewhat considered egoistic, typically benefiting individuals directly (e.g. improved health) and society indirectly (e.g. reduced use of health services). Conversely, the egoistic motives of some sustainable behaviours (e.g. driving less) are perhaps less apparent, with the effects most likely to be benefit to future generations (e.g. less air pollution) rather than the individual performing them.

Nevertheless, as many sustainability behaviours have economic (e.g. reduced energy consumption) and so called “warm glow” benefits (e.g. conservation volunteering) they cannot be considered to be without egoistic motives entirely. Moreover, many behaviours are mutually beneficial to both human and planetary health (Geiger et al., 2018). For example, cycling rather than driving and eating unprocessed foods benefits individual health and environmental sustainability. Conversely, smoking is not only detrimental to human health, it also negatively impacts the environment (e.g. air pollution, littering). Additionally, there is some evidence health behaviours and sustainable behaviours co-occur. Kim (2017) found that individual health behaviours were positively correlated with sustainable behaviours across a variety of domains (e.g. consumption behaviours, conservation behaviours). These findings have been replicated across a number of studies (Suki, 2013; Geiger et al., 2018).

To summarise, whilst some health and sustainability behaviours may differ somewhat in their intrinsic motivations, many have co-benefits and individuals who have a propensity to engage in healthy behaviours also tend to engage in at least some kinds of sustainable behaviours. In conjunction with evident commonalities between health behaviours and sustainability behaviours, these findings suggest that integrated strategies across these domains may play a part in achieving synergistic improvements in public health and environmental sustainability.

1.3 Literature Review: Natural Environments and Human Behaviour

An important emerging correlate that could meet these requirements involves greater contact with - and psychological connection to - natural environments. The nature restoration literature concerning the potential salutogenic effects of natural environments on human and planetary health (Hartig et al., 2014; Hartig et al., 2007) is well-established. There is now a considerable body of evidence demonstrating: a) the benefits of natural environments to broader human health and wellbeing outcomes (Lovell et al., 2018), and b) the ecological, or planetary health, benefits of greenspace (e.g. reduced carbon emissions, Beatley, 2000; Yang et al., 2005). However, fewer studies have explored whether natural environments may also promote *behaviours* which are beneficial to human and planetary health. Nonetheless, several strands of evidence support further investigation into this area. The following sections of this chapter reviews this evidence in relation to health risk behaviours (Section 1.3.1) and pro-environmental behaviours (Section 1.3.2), as well as considering common mechanisms, from existing psychological theories of nature restoration, which may underlie associations between nature contact/connectedness and both behavioural domains (Section 1.3.3).

1.3.1 Health Risk Behaviours

Nature contact refers to any interaction with a biophysical system, including flora, fauna, and geological landforms (Zylstra et al., 2014; Hartig et al., 2014). Existing theory within the nature restoration literature tends to be underpinned by the assumption that interactions with the natural world are beneficial, regardless of the type of nature contact (c.f. Wheeler et al., 2015; Bell et al., 2014). Nonetheless, research has typically focused on three distinct types of nature contact: residential (e.g. the availability of greenspace within an individual's neighbourhood), intentional (e.g. visits to natural spaces) and indirect (e.g. simulated exposure to natural environments via photos/videos).

These diverse interactions with the natural world have been associated with improvements to health and wellbeing. After controlling for a range of socio-demographics, greater proportions of greenspace within an individual's residential environment (i.e. residential nature contact) are associated with better perceived general health (Van den Berg et al., 2010; Twohig-Bennett & Jones, 2018), lower physician-assessed morbidity (Maas et al., 2009), and lower mortality rates (Mitchell & Popham; 2008; Villeneuve et al., 2012; Kondo et al, 2018). The odds of chronic diseases such as diabetes (Astell-Burt, Feng & Kolt, 2014; Bodicoat et al., 2014; Dalton et al., 2016; Muller et al., 2018), cardiovascular and respiratory disease are also lower in high greenspace neighbourhoods (Xu et al., 2017; Richardson & Mitchell, 2010; Twohig-Bennett & Jones, 2018; Dalton & Jones, 2020), even after individual and area-level covariates have been accounted for. Further, there is evidence that residential nature contact may also reduce socio-economic health inequalities. For instance, Maas et al. (2006) observed that the positive association between neighbourhood greenspace and perceived health was stronger for lower socio-economic groups. Similarly, income deprivation related health inequalities in all-cause mortality, circulatory diseases mortality (Mitchell & Popham, 2008) cardiovascular disease and diabetes (Xu et al., 2017), are less pronounced amongst individuals residing in greener neighbourhoods.

Whilst prior research has predominantly focused on residential nature contact, visits to natural spaces (intentional contact) are associated with congruent benefits to health and wellbeing. Notably, visits to natural spaces are linked to reduced stress (Razani et al., 2018; Marselle et al., 2014; 2019), blood pressure (Hartig et al., 2003; Shanahan et al., 2016), and better general health and wellbeing (White et al.,2017; White et al., 2019; Martin et al., 2020). Similarly, experimental studies have found reduced stress (Ulrich et al., 1991W; Brown et al., 2013), as well as improved cognition and mood (Valtchanov & Ellard, 2015; Anderson et al., 2017; Browning et al., 2020) amongst participants who experience nature indirectly, for instance by viewing photos/videos of natural (*vs.* urban) scenes. Moreover, studies examining multiple types of nature contact simultaneously suggest that distinct forms of interaction with the natural world often have additive effects on broader health and wellbeing outcomes (Shanahan et al., 2016; White et al., 2017; Martin et al., 2020).

Taken together, there is converging evidence that diverse forms of nature contact are associated with numerous public health and wellbeing benefits, and that residential nature contact at least, has the potential to reduce socio-contextual health disparities. Whilst some theories focus exclusively on the affective (e.g. Stress Reduction Theory; Ulrich et al., 1991) or cognitive benefits of natural environments (Attention Restoration Theory; Kaplan, 1995); others propose several interconnected pathways through which nature contact may benefit human health and wellbeing, including: lowered pollution; increased physical activity and greater opportunities for social contact (Hartig et al., 2014; Markevych et al., 2017). However, the evidence base for these mechanisms is far from conclusive. Despite a number of studies supporting these relationships (*Physical activity*, Giles-Corti, et al., 2005; Coombes et al., 2010; *Air pollution*, Davand et al., 2012; *Social contact*, Maas et al., 2009) associations are often weak, and are contradicted by studies failing to find an effect (Maas et al., 2008; Mytton, et al., 2012; Witten et al., 2008; Giles-Corti et al., 2005; Hillsdon et al., 2006).

Equivocal evidence for proposed mediators indicates that there may be additional pathways though which contact with the natural world benefits health, one such mechanisms may be reduced health risk behaviours. Several strands of evidence provide incidental support for this proposition. Cross-sectional work has demonstrated that the prevalence of a range of health risk behaviours differs as a function of urban/rural status. For instance, Idris et al. (2007) examined smoking rates between 1985-2000 across six European countries. Collapsing the data across years, they found that smoking prevalence was significantly higher in urban, relative to non-urban regions, and this effect was consistent between countries. These findings replicate prior work, and, again, the effects remain after controlling for a range of socio-demographic covariates (Völzke et al., 2006; Martinez et al., 2006). Similarly, urban inhabitants have a higher prevalence of unhealthy dietary behaviours (Peer et al., 2013) and higher odds of exceeding weekly alcohol limits (Borders & Booth, 2007), although for the latter there are some inconsistencies in the direction of the association between studies (Eberhardt et al., 2001). Moreover, for smoking at least, there is evidence that the prevalence of health risk behaviours increases incrementally with the degree of urbanisation (Pearce & Boyle, 2005; Idris et al., 2007).

A key feature of increasing urbanisation is the loss of natural spaces (Pauleit et al., 2005), which reduces opportunities to interact with the natural world (Soga & Gaston, 2016). Given the strong negative correlation between urbanisation and neighbourhood greenspace (Maas et al., 2006), urban-rural differences in health risk behaviours may, at least in part, be explained by the availability of residential greenspace. Preliminary support comes from inverse bivariate associations between neighbourhood greenspace and smoking, alcohol misuse and the high-fat diets observed in large scale cross-sectional surveys [1](Astell-Burt, Feng & Kolt, 2014; Van Herzele & de Vries, 2012; Wang et al., 2017). Nevertheless, further investigation controlling for potential individual and area-level covariates is required, to establish whether the observed associations are related to increased residential nature contact, or merely reduced urbanisation.

Further, evidence that participation in nature-based programmes is associated with higher fruit and vegetable consumption (Alaimo et al., 2008), as well as lower relapse rates for drug and alcohol addiction (Bennett et al., 1998) suggests that

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[1] These studies examine the associations between neighbourhood greenspace and health outcomes (e.g. diabetes) and include health risk behaviours (e.g. current smoking) as control variables. Whilst the bivariate associations between greenspace and health risk behaviours are reported in preliminary/descriptive analyses, they are not formally examined at the multivariate level.

intentional nature contact (nature visits) may also inversely associated with a range of health risk behaviours. Similarly, experimental findings that participants smoke less (Wu & Chiou, 2019) and make healthier dietary choices (Kao et al., 2019) after viewing media of natural (*vs.* urban) scenes, indicate that: a) similar benefits may occur from more indirect forms of nature contact and, b) associations between nature contact and health risk behaviours may be causal. Nonetheless, with little research formally investigating the links between different types of nature contact and health risk behaviours outside of the laboratory, it is unclear from the current literature whether the associations between nature contact and health risk behaviour are demonstrable within the general population, after relevant socio-demographics known to influence health risk behaviours (Section 1.2.1) have been accounted for. Moreover, the literature on health risk behaviours pertains to the links between singular types of nature contact and behavioural outcomes, thus the relative influences of different types of nature contact are unclear. This is important for two reasons. First, this type of comparison enables policy makers and practitioners to determine the focus of public health strategies and interventions. Second, with evidence of additive effects of multiple types of nature contact on broader health and wellbeing outcomes, (Shanahan et al., 2016; White et al., 2017; Martin et al., 2020), it is conceivable that multiple types of nature contact may also be simultaneously associated with positive behavioural outcomes.

In addition to nature contact, the personality construct of nature connectedness, an individual's subjective sense of their relationship with the natural world (Martin & Czellar, 2016), may also be relevant to health risk behaviours. Consistent with the broader benefits of contact with nature, trait nature connectedness is positively associated with subjective wellbeing (Zelenski & Nisbet, 2014), perceived vitality (Cervinka et al., 2011) and general health (Dean et al., 2018). Moreover, nature connectedness positively predicts fruit and vegetable consumption in children (Sobko, et al., 2020), indicating that the benefits of feeling more connected to the natural world may also extend to health behaviours. Indeed, whilst examining the unrelated topic of sun-exposure, Haluza et al. (2014) controlled for smoking status within their analysis and noted that participants with distinct smoking habits differed in their connection to nature. Specifically, the odds of being highly connected to nature were significantly higher for non-smokers, relative to both current smokers and former smokers. However, this finding has not be replicated between studies, with Forstmann & Sagioglou (2017) finding positive associations between nature connectedness and the use of psychoactive substances, including nicotine. Inconsistencies for smoking behaviours notwithstanding, given that nature contact and nature connectedness appear to have analogous associations to both health outcomes and dietary behaviours, future research might usefully examine these associations across a range of health-behaviours.

To summarise, contact with – and psychological connection to – nature are associated with public health benefits across numerous domains, and residential nature contact at least has the potential to reduce health disparities between socio-economic groups. Inconsistent findings regarding the purposed mechanisms underlying the relationships between nature contact and health outcomes, indicate that there may be additional pathways by which nature benefits health. With evidence of relationships between urbanicity, greenspace and health risk behaviours, it is conceivable that residential nature contact may be inversely related to the prevalence of a variety of health risk behaviours. Further, there is some evidence that other types of nature contact (intentional, indirect), as well as trait nature connectedness, may also be inversely associated with health risk behaviours. With little prior research directly examining these propositions, further work is required to establish: 1) whether the associations between greenspace and health risk behaviours are upheld once relevant socio-demographics are accounted for; 2) whether other types of nature contact (intentional and indirect), as well as nature connectedness, exhibit similar inverse associations to health risk behaviours within the general population after controlling for a range of socio-demographics. Additionally, it is unclear from the current literature whether specific types of nature contact, or indeed nature connectedness, may be more relevant to health risk behaviours than others, or whether they are simultaneously associated with lower engagement in health risk behaviours (i.e. additive effects).

1.3.2 Pro-Environmental Behaviours

The ecological benefits of natural environments are well established, with evidence that greenspaces reduce carbon emissions and air pollution (Beatley, 2000; Yang et al., 2005), conserve water and soil (Pauleit & Duhme, 2000), adjust microclimates and moderate temperatures (Shin & Lee, 2005) and stabilise ecological systems (Whitford, Ennos, Handley, 2001). However, far fewer studies have examined the associations between nature contact and human behaviours which may promote planetary health (i.e. pro-environmental behaviours). Nonetheless, there is some evidence from the nature restoration literature that different types of nature contact exhibit positive associations with pro-environmental behaviours. Notably, Whitburn et al. (2019) conducted a cross-sectional study of 423 residents of an urban city in New Zealand. They found that greenspace in adjoining streets positively predicted pro-environmental behaviours including: consumerism, energy consumption, mobility and transport, waste avoidance, recycling, and conservation behaviour. However, this finding has not be replicated between studies. In a large nationally representative sample from the United Kingdom, Alcock et al., (2020) found that residential nature contact did not significantly predict pro-environmental behaviours in urban subsamples after accounting for a range of socio-demographics, but was associated with greater sustainability behaviours in rural subsamples. Further, the authors found that recreational visits to natural spaces were a robust positive predictor of pro-environmental behaviours, across urban/rural subsamples, and a range of sociodemographic subpopulations (e.g. gender, age, socioeconomic status). This suggests that intentional nature contact may be a more consistent predictor of pro-environmental behaviours, compared to residential nature contact. Indeed, the findings regarding nature visits are in line with research and theory suggesting that positive experiences within natural spaces promotes ecological attitudes and behaviours (Hartig et al., 2001; Hartig et al., 2007; Lawrence, 2012; Coldwell & Evans, 2017).

Moreover, experimental studies have demonstrated that participants experiencing nature indirectly (e.g. viewing brief videos of natural scenes) report more pro-environmental intentions (Yang et al., 2018) and behave more sustainably within laboratory tasks (Zelenski et al., 2015) compared to those who view urban scenes. However, despite high profile nature series such as the BBC's Blue Planet being credited with transforming political and societal attitudes to the natural world (Rawlinson, 2017), the influence of indirect, technologically mediated, nature contact (e.g. watching/listening to nature programmes) on population level pro-environmental behaviours has received little empirical attention to date.

Collectively, these findings suggest that diverse forms of nature contact may exhibit similar positive associations to pro-environmental behaviours. Nonetheless, with inconsistences in the strength of the association for residential nature contact, and prior studies focusing predominantly on the impact of a singular form of interaction, establishing which *types* of nature contact are most relevant to sustainability outcomes is difficult. For instance, it is unclear from the current literature whether residential nature contact is sufficient to enable positive outcomes, in the absence of intentional visits, or indeed whether experimental findings of a greater propensity to behave sustainability following indirect contact might extend to the general population.

Nonetheless, incidental evidence of the additive benefits of multiple types of nature contact comes from Weinstein et al.'s (2015) nationally representative survey across the United Kingdom. Using a structural equation modelling approach, they found that contact with nature (natural views, perceived quality and visiting hours) and neighbourhood greenspace were positively related to environmental concern. These findings suggest that multiple types of nature contact may be important for sustainable attitudes. Yet with a focus on environmental attitudes and with nature contact specified as a latent variable, the relative importance of each type of nature contact, and indeed whether these associations extend to actual behaviour remains unclear.

A complementary body of research suggests that the trait nature connectedness may have similar associations to pro-environmentalism as does nature contact. Recent meta-analyses indicate that nature connectedness is positively associated with pro-environmental behaviours (Mackay & Schmitt, 2019; Whitburn et al., 2020). Whilst encouraging, the studies included within such analyses predominantly use relatively small (N < 400), unrepresentative samples which are unable to adequately control for the range of socio-demographic covariates that are necessary to inform public policy (e.g. area-level deprivation, socio-economic status). Further investigation using population-based samples is therefore needed, to establish whether these associations remain after accounting for a more comprehensive range of covariates.

Moreover, despite recognition of the importance of both contact with – and connectedness to – nature, in supporting better pro-environmental outcomes, research into these two domains has been conducted largely in parallel. With moderate positive associations between nature contact and nature connectedness noted in the development of connectedness measures (Mayer and Frantz, 2004; Nisbet et al., 2009), it is unclear whether similar associations to outcome variables are an artifact of shared variance or whether they independently predict positive outcomes (i.e. additive effects). Further, it has been suggested that these two constructs may affect pro-environmental behaviours inter-dependently (Ojala et al., 2019; Whitburn et al., 2019).

Prior theory and research have typically considered *state* nature connectedness to mediate the relationships between nature contact and positive outcomes, i.e. more contact increases feelings of connectedness, which in turn leads to positive outcomes (Mayer et al., 2009). Experimental studies have supported this by demonstrating that increased contact with natural environments, heightens *state* nature connectedness (i.e. connectedness in the moment), which in turn increases pro-environmental behaviours (Whitburn et al., 2019). Although less well-researched, *trait* nature connectedness may moderate the associations between nature contact and pro-environmental behaviours (Rosa et al., 2018; Ojala et al., 2019). Specifically, contact with nature may only promote pro-environmental outcomes among individuals who are already highly connected with it.

I am aware of just two studies, to date, that have examined the potential moderating effects of trait nature connection on nature contact in the context of pro-environmental behaviours. The first found interaction effects between nature connectedness and nature-related activities on pro-environmental attitudes, with nature-related leisure activities positively predicting pro-environmental views for individuals with a high (*vs.* low) emotional connection to nature (Ojala, 2009). Similarly, Arendt & Matthes (2016) found that watching a nature documentary increased donations to environmental organisations, but only for participants who were already highly connected to nature. Consistent with person-environment fit theories (Caplan, 1987) postulating that optimal behavioural outcomes emerge when an individual's personal attributes are compatible with environmental attributes, these findings suggest that nature contact may promote the most beneficial outcomes among individuals who are already highly connected with it. Nonetheless, as with much nature connectedness research, neither study accounted for different types of nature contact, or a broad range of socio-demographic covariates within their models.

To summarise, contact with – and psychological connection to – nature have been independently associated with increased pro-environmental attitudes and behaviours. Although various types of nature contact exhibit positive associations to pro-environmental concern and behaviour, with studies predominantly exploring the impact of a singular form of interaction, it remains unclear which types of nature contact are most relevant to pro-environmental behaviours. Whilst there is evidence that nature connectedness is also positively related to pro-environmental outcomes, studies tend to be too small to adequately account for the kind of socio-demographic covariates that are necessary to inform public policy. Despite propositions that nature contact and connectedness may affect pro-environmental behaviours in an interdependent manner, the current evidence base is small, with little research examining these two constructs simultaneously. Thus, methodological limitations inherent in previous research make it difficult to ascertain the process by which nature contact and connectedness relate to pro-environmental outcomes. Consequently, further large-scale research, capable of accounting for a wide range of socio-demographics, is required to establish: 1) the relative associations between different types of nature contact (residential, intentional, indirect) and pro-environmental behaviour, and 2) what role the psychological construct of nature connectedness plays in these associations (i.e. additive effects or moderation effects).

1.3.3 Potential Mechanisms Underlying Nature – Behaviour Associations

As outlined in Section 1.2, there are a variety of mechanisms through which nature contact is purported to influence broader health and wellbeing outcomes, including the affective (e.g. Stress Reduction Theory; Ulrich et al., 1991), cognitive (Attention

Restoration Theory; Kaplan, 1995), and social (Hartig et al., 2014; Markevych et al., 2017) benefits of natural environments. Although little research has investigated the processes underlying nature-behaviour associations, the aforementioned theories are nonetheless informative in identifying potential psychological mechanisms that are empirically linked to *both* health-risk and pro-environmental behaviours. These theories, as well as how they guided mediator selection are outlined briefly below.

1.3.3.1 Positive and Negative Affect

Stress Reduction Theory (Ulrich, 1991) posits that non-threatening natural environments supported evolutionary survival by reducing chronic physiological arousal which can lead to a range of negative health outcomes. In line with this theory, there is now a substantial body of empirical work indicating reduced stress levels and improved affect amongst individuals exposed to natural (*vs.* urban) environments (Gidlow et al., 2016; Bowler et al., 2010; Yao, Zhang & Gong, 2020; McMahan & Estes, 2015; Browning et al., 2020) Although heightened stress is associated with increases in health-risk behaviours (Suvarna et al., 2020), I identified little research examining stress and pro-environmental behaviours. Conversely, as outlined below, affect has been extensively linked to both behavioural domains.

Affective experience is widely conceptualised by two dominant dimensions: positive affect and negative affect (Díaz-García et al., 2020; Fredrickson, 2001). Differing in valence, positive affect includes feelings of happiness, joy and contentment, whereas negative affect comprises of emotions such as anger, sadness and fear (Diener et al., 2010). Whilst inversely related, positive and negative affect have distinct neural underpinnings (Grant & Harford, 2007), and psychological correlates (Watson et al., 1988), thus are typically considered to be functionally independent, rather than opposites on the same continuum (Russell & Carroll, 1999).

Individuals who experience higher positive affect are less likely to engage in a variety of health risk behaviours on the one hand (*Smoking:* Mojs et al., 2009; *Alcohol misuse:* Graham et al., 2004; *Poor diet*: Peltzer et al., 2017), and more likely to behave sustainably on the other (Ibanez et al., 2017; Chatelain et al., 2018; Bissing-Olson et al., 2013). Conversely, even brief periods of negative affect are associated with increased consumption of nicotine (Ng & Jeffery, 2003; Todd, 2004), alcohol (Cole et al. 1990; King et al. 2003), and high fat snacks and fast food (Ng & Jeffery, 2003; Pak et al., 2000; Epel et al., 2001). For sustainability outcomes, this pattern reverses, with lower negative affect predicting greater engagement with pro-environmental behaviours, even after controlling for positive affect (Coelh et al., 2017).

The affective benefits of greater contact with - and psychological connection to - the natural world are well established. Meta-analyses indicate that contact with nature results in moderate statistically significant increases in positive affect, and smaller, but still statistically significant, decreases in negative affect (McMahan & Estes, 2015; Browning et al., 2020). Similarly, individuals who feel more connected to nature tend to experience more positive affect (Capaldi et al., 2014; Lawton et al., 2017; Martyn & Brymer, 2016). Consequently, higher positive affect and lower negative affect have the potential to mediate the associations between nature contact/connectedness and behavioural outcomes.

1.3.3.2 Community cohesion

A number of theories within the nature restoration literature indicate increased social contact as a potential mechanism underlying associations between nature and broader health and wellbeing outcomes (Hartig et al., 2014; Markevych et al., 2017).

Specifically, greenspaces are considered to provide settings for social contact with family, friends and neighbours, which is likely to increase feelings of community cohesion - a sense of solidarity and harmony between members of a given neighbourhood (Maas et al., 2009). Consistent with these theories, a number of studies have found that individuals living in greener neighbourhoods report greater levels of community cohesion (Jennings & Bamkole, 2019; Liu et al., 2020; Moreton et al., 2019).

Crucially for this thesis, community cohesion has also been linked to both health risk and pro-environmental behaviours. Individuals living in more cohesive communities are less likely to engage in health risk behaviours (*Smoking*, Patterson et al., 2004; *Alcohol misuse*, Duncan et al., 2002), and report more pro-environmental attitudes (Weinstein et al., 2015) and behaviours (Uzzell et al., 2002), than those who live in less cohesive communities. Given that nature contact and nature connectedness are positively associated with perceived community cohesion (Jennings & Bamkole, 2019; Liu et al., 2020; Moreton et al., 2019; Dean et al., 2018), increased community cohesion may be another mechanism through which contact with, and psychological connection to nature, influences behavioural outcomes. Support for this proposition comes from Weinstein et al.'s (2015) nationally representative survey across the United Kingdom. Using a structural equation modelling approach, they found that contact with nature (natural views, perceived quality and visiting hours), was associated with higher perceived community cohesion, which in turn predicted greater environmental concern. Whilst promising, it remains to be established whether this pattern of associations extends to more sustainable behaviours, or indeed simultaneous benefits to health risk behaviours.

1.3.3.3 Temporal Discounting

Attention Restoration Theory (ART; Kaplan & Kaplan, 1989; Kaplan & Berman, 2010) concerns the impact of natural environments on our cognitive capacities, proposing that the inherently fascinating natural stimuli capture involuntary (or indirect attention), enabling individuals voluntary (or directed) attention capacities to recover and restore. Whilst traditionally focusing on directed attention, ART was subsequently expanded to incorporate nature's potential restoration of executive functions (i.e. higher order cognitive processes Kaplan & Berman, 2010). In line with this theory, numerous studies have found improvements on a variety cognitive tasks following exposure to natural environments, (Berman, Jonides & Kaplan, 2008, Berto, 2005, Stevenson, Schilhab Bentsen; 2018). Crucially for this thesis, these cognitive improvements also include reduced temporal discounting (Van der Wal et al., 2013; Berry et al., 2014, 2015, 2019).

Temporal discounting is a dimension of intertemporal decision making, that refers to a preference for smaller immediate rewards over larger rewards available after a delay (e.g. £10 today, rather than £20 next week; Frederick et al., 2002). Whilst most individuals exhibit some degree of temporal discounting, the rate at which people discount future rewards varies considerably (Seaman et al., 2020). A heightened propensity towards discounting future outcomes (i.e. less future-orientated decision making) has been linked to a variety of problematic behaviours, including engaging in unhealthy and unsustainable behaviours (Berry et al., 2020). Notably, higher discount rates predict current smoking (Barlow et al., 2017), alcohol misuse (Bjork et al. 2004; Bobova et al. 2009), and poor diet (Rollins et al., 2010; Dassen et al., 2015). Similarly, individuals who perceive climate change to be a distant event are less inclined to act to prevent it (Spence et al., 2012).

Several experimental studies have found lower discounting rates amongst participants who view natural (*vs.* urban) scenes (Van der Wal et al., 2013; Berry et al., 2014, 2015, 2019). Further, cross-sectional work indicates that feeling more psychologically connected to nature is also associated with lower future discounting (Iwaki, 2011). Taken together, these findings suggest that lower temporal discounting could be an additional mechanism through which contact with - and psychological connection to – nature influences behavioural outcomes. Indeed, two small-scale laboratory studies have found that lower discount rates mediate the beneficial effects of viewing photographs of natural environments on smoking rates (Wu & Chiou, 2019) and dietary choices (Kao et al., 2019). Nevertheless, further research is needed to establish whether these benefits generalise to pro-environmental behaviours, and indeed to the general population after relevant socio-demographics have been accounted for.

1.3.4 Overall Summary

Human behaviour is a major determinant of both public and planetary health. Consequently, current challenges to health and environmental sustainability, can be, at least in part, addressed through changes to individual behaviour. Evident inter-dependencies and commonalities between health behaviours and pro-environmental behaviours suggests that integrated strategies may be key to achieving synergistic improvements to human and planetary health. A potential area of overlap between health risk and pro-environmental behaviours are people’s physical and psychological experiences of the natural world. However, to date, research into these two behavioural domains, as well as work pertaining nature contact and nature connectedness, has been conducted largely in parallel. Nonetheless, several strands of evidence indicate that increased contact with – and psychological connection to – nature, could play an important role in both behavioural domains. First, both health risk and sustainability behaviours are affected by marked social gradients. There is evidence that associations between nature contact and broader health outcomes remain after controlling for a range of socio-demographics, and that increased contact with natural environments has the potential to reduce social-contextual disparities in this domain. Second, there is evidence that different types of nature contact, as well as trait nature connectedness, are associated with: a) reduced health risk behaviours and, b) increased engagement in pro-environmental behaviours. Third, there are a number of common mechanisms that may underlie associations between nature contact/connectedness and both behavioural domains, including: positive affect, negative affect, community cohesion and temporal discounting. However, evident gaps in the literature and methodological limitations inherent in prior research, discussed throughout this chapter, warrant further investigation into the links between nature contact, nature connectedness and health risk and pro-environmental behaviours. Specifically, the current evidence base is fragmented, and rarely accounts for: a) different types of nature contact, b) shared variance, or potential interactions between nature contact and nature connectedness, or c) socio-demographics known to be important to health risk and pro-environmental behaviours. Further, little research has explored potential mechanisms underlying associations between nature contact/connectedness and behavioural outcomes outside of highly controlled laboratory settings.

1.4 Thesis Overview

1.4.1 Research Questions

In reviewing the literatures above, three key research questions emerged:

RQ1. What are the associations between different types of nature contact and: a) health risk behaviours; and b) pro-environmental behaviours, after accounting for a range of socio-demographics?

RQ2. What role does trait nature connectedness play in these associations?

RQ3. What are the mechanisms underlying associations between nature contact/connectedness and behavioural outcomes?

1.4.2 Conceptual Model

Figure 1.1 presents a conceptual model depicting the hypothesised links between nature contact, nature connectedness, and behavioural determinants of public and planetary health (i.e. health risk behaviours and pro-environmental behaviours). The model is an interpretation of the overarching trends in the literature reviewed in Section 1.3 and provides a heuristic framework for the studies in this thesis.

In relation to research question one, with evidence that different types of nature contact may promote healthier behaviours on the one hand (e.g. Astell-Burt, Feng & Kolt, 2014; Bennett et al.,, 1998; Kao et al., 2019), and greater engagement in pro-environmental behaviours on the other (e.g. Whitburn et al., 2019; Hartig et al., 2007; Zelenski et al., 2015), it is predicted that increased nature contact will be inversely associated with health risk behaviours and positively associated with pro-environmental behaviours. Consistent with prior research on broader health outcomes (Shanahan et al., 2016; White et al., 2017; Martin et al., 2020) and environmental concern (Weinstein et al., 2015), the contributions of different types of nature contact are expected to be additive.

Regarding research question two, it is unclear from prior work whether trait nature connectedness independently predicts positive behavioural outcomes (i.e. additive effects), or influences the way in which individuals respond to the natural world (i.e. moderation effects). This thesis aims to explore these two competing hypotheses. Whilst it is expected that, consistent with prior work, nature connectedness

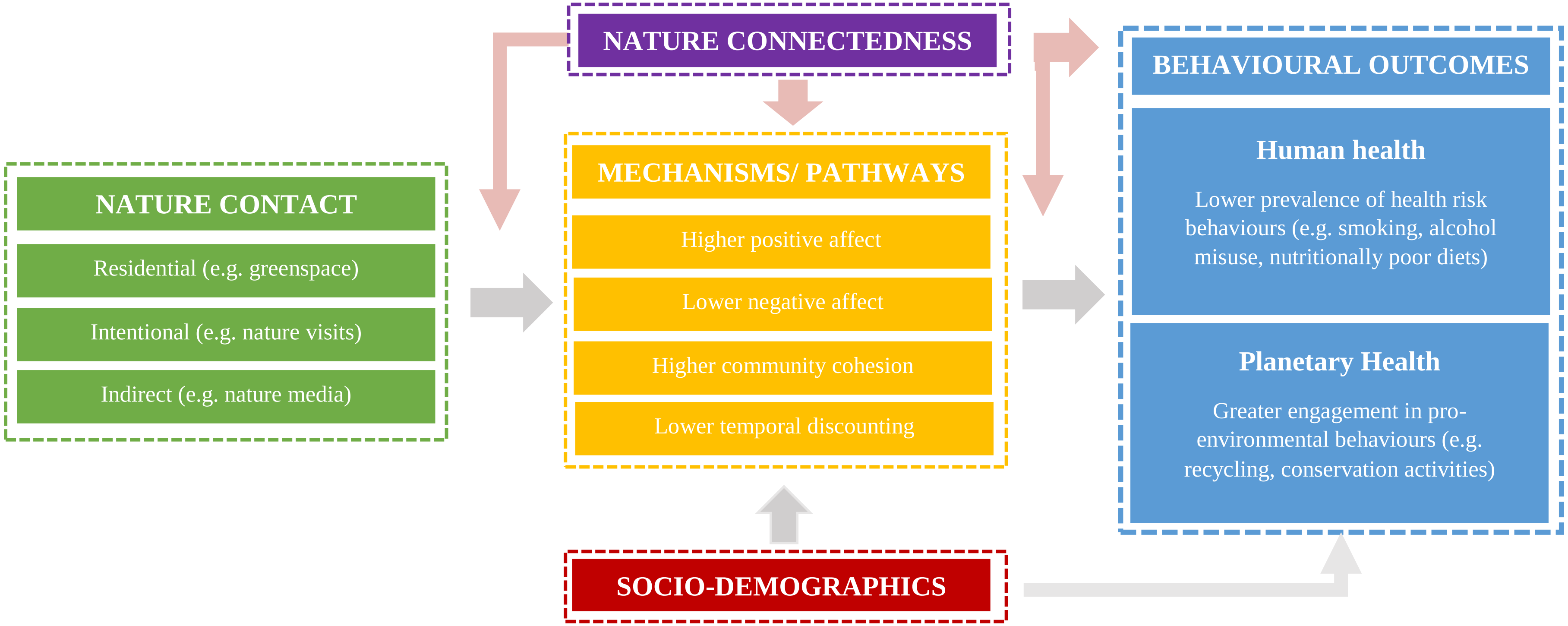

Figure 1.1 Conceptual model of the expected relationships between nature contact, nature connectedness and behavioural outcomes

Note. Red arrows depict the two competing processes by which trait nature connectedness may influence behavioural outcomes (additive effects *vs.* moderation).

will be inversely associated with health risk behaviours (e.g. Sobko et al., 2020), and positively associated with pro-environmental behaviours (Mackay & Schmitt, 2019; Whitburn et al., 2020), the associations between nature contact and beneficial outcomes (i.e. healthier and more sustainable behaviours) may be stronger amongst individuals who feel more connected to the natural world (Ojala, 2009; Arendt & Matthes, 2016; Caplan, 1987).

For research question three, prior theory and research suggests that increased contact with - and psychological connectedness to – nature are associated with better positive and negative affect, greater community cohesion and lower temporal discounting (Browning et al., 2020; Capaldi et al., 2014; Weinstein et al., 2015; Dean et al., 2018; Berry et al., 2014, 2015, 2019; Ulrich et al., 1991; Hartig et al., 2014; Markevych et al., 2017). As these constructs independently predict lower engagement in health risk behaviours on the one hand (e.g. Peltzer et al., 2017; Duncan et al., 2002; Kao et al., 2019), and a greater propensity to behave sustainably on the other (e.g. Chatelain et al., 2018; Weinstein et al., 2015; Spence et al., 2012), they have the potential to mediate associations between nature contact/connectedness and behavioural outcomes.

1.4.3 Methodological Approach

Given the importance of accounting for a range of individual and area-level socio-demographics, observational studies (a methodological approach widely adopted within the nature restoration literature; De Vries et al., 2003; Pearce et al., 2018) were used to examine the links between nature contact/connectedness and behavioural outcomes within the general population

1.4.3.1 Dataset selection

Datasets were carefully selected to address the specific research questions of this thesis. Longitudinal studies, such as the UK Household Longitudinal Survey (Institute for Social and Economic Research, 2021) include data on outcome variables of interest (health risk and pro-environmental behaviours), and have the advantage of allowing evaluation of key relationships over the life course/time (Caruana et al., 2015). Whilst it is possible, by application to the UK Data Service, to link survey data to environmental data, including residential greenspace metrics, existing longitudinal studies do not collect data on other types of nature contact (e.g. intentional nature visits), or psychological connectedness to nature. Thus, use of existing longitudinal datasets would preclude an examination of the associations between different types of nature contact and behavioural outcomes, and would be unsuitable for addressing research questions 1-2 (i.e. different types of nature contact and the role of nature connectedness in nature-behaviour associations).

Nevertheless, there were a number of secondary cross-sectional datasets available to me, through affiliations and data sharing agreements with the European Centre for Environment and Human Health (University of Exeter) and Natural England (DEFRA), which were: a) of high quality and b) well-suited to addressing Research Questions 1-2. These data sets had a range of characteristics that made them eminently suitable for studying the key research questions of the present thesis. First, the Health Survey for England, a nationally representative survey conducted annually on behalf of the UK Office for National Statistics, contains data on a range of health and lifestyle factors, with existing links to environmental datasets made by the European Centre for Environment and Human Health. Second, the Monitor of Engagement with the Natural Environment survey (MENE, Natural England, 2018), commissioned by Natural England as part of the Department of Environment, Food & Rural Affairs' social science research programme, focuses exclusively on respondents' interactions with nature and is, as far as I am aware, the world's largest and most comprehensive dataset on these issues. Consequently, the MENE datasets include a comprehensive range of nature contact, nature connectedness and pro-environmental variables from a nationally representative sample in England. Third, building on the MENE survey the BlueHealth International Survey (BIS, Grellier et al., 2017) was developed by an inter-disciplinary team with expertise in the field of environments and human health. It therefore contains a variety of validated measures of nature contact, nature connectedness and health outcomes for representative samples from 18 different countries.

Finally, to my knowledge there are no existing observational datasets including measures of the four proposed mediators (positive affect, negative affect, community cohesion and temporal discounting) of nature- behaviour associations. Therefore, a bespoke cross-sectional survey was designed to include measures of nature contact/connectedness, behavioural outcomes and proposed mediators that have been widely used in prior research.

In sum, although the cross-sectional approach employed throughout this thesis precludes causal inferences, as well as analyses of nature-behaviour associations over time, the selected datasets had a range of characteristics that made them eminently suitable for studying the key research questions of this thesis. Specifically, they were appropriate for examining: a) the links between *different types* of nature contact and key behavioural outcomes; b) the role of trait *nature connectedness* in nature-behaviour associations. Additionally, a bespoke survey was considered most suitable for conducting an initial exploration of proposed mediators, in advance of a more robust assessments using longitudinal cohort studies incorporating appropriate measures.

1.4.3.2 Residential Greenspace Measures

Existing measures of residential greenspace can be broadly categorised as either: 1) subjective self-reports of natural features within respondents' immediate neighbourhood (e.g. green views from home) and, 2) objective indices of residential greenspace within a defined geographical boundary, either from cartographical land use databases (e.g. LSOA greenspace from the English Generalised Land Use Database), or satellite imagery (e.g. Normalised Difference Vegetation Index, NDVI).

Circumventing the need to collect personally identifiable data (i.e. respondent postcode) and requiring no linkage to environmental data, self-reported measures of residential greenspace are widely used with prior work, particularly within smaller scale studies (e.g. Kaplan, 2001). Nevertheless, there is increasing recognition that individuals' perceptions of natural features do not always correspond to objective greenspace measures (Barlow, Lyons & Nolan, 2021). Furthermore, as visibility across terrains is determined not only by distance, but also the vertical dimension of a given viewpoint (Nutsford et al., 2015), greenery in respondents' view from home may capture different spatial aspects of residential nature contact than objective greenspace measures, which have well-defined geographical boundaries. For instance, even in neighbourhoods with limited greenspace, individuals residing in the upper levels of a building are more likely to have greater visual access to greenery, than those living on lower levels of the same building (Yu et al., 2016).

Despite requiring collection of, or access to, potentially identifiable information (i.e. details about respondents' home location), objective measures provide an estimation of greenspace characteristics within well-defined geographical areas. For instance, survey data can be readily linked to existing environmental datasets derived from the Generalised Land Use Database, in order to obtain the proportion of greenspace within pre-defined radial buffers (e.g. 300 meters) or administrative boundaries (e.g. in the UK Lower-layer Super Output Areas, LSOAs). LSOA greenspace is one of the most widely used greenspace measurements in England (Houlden et al, 2019), yet with a focus on administrative boundaries, rather than the area directly around an individual's home, there remains the potential for misclassifications of greenspace exposure. First, individuals living in the centre of a LSOA may differ in their access to nearby greenspaces compared to those who live close to border of another administrative area with a different proportion of greenspace (Houlden et al., 2017). Second, LSOA greenspace measurements correspond to census dates, and therefore are not always temporally consistent with survey data collection. Consequently, it may be that levels of neighbourhood greenspace actually experienced at the time of data collection differ from the estimated greenspace values.

Studies using objective greenspace measurements centred on each respondent's place of residence go some way towards addressing these two issues. For example, Moderate Resolution Imaging Spectroradiometer (MODIS) terra satellite imagery can be used to determine the Normalised Difference Vegetation Index (NDVI), an indicator of the density of green vegetation within a radial buffer around each respondents' home location, during a timeframe consistent with survey data collection. Nonetheless, calculation of NDVI is a time-intensive process requiring access to the latitude and longitude co-ordinates of each respondent, as well as specialist knowledge of Geographic Information Systems. Additionally, as generation of sufficient quality NDVI data is largely dependent on cloud cover during the sampling timeframe, use of this greenspace metric can lead to the exclusion of large number of cases (i.e. all respondents with high cloud cover in pixels surrounding their residential address, which is especially problematic outside of summer months in northern latitudes; Tang & Oki, 2007). Therefore, although NDVI mitigates some of the limitations associated with subjective and administrative boundary (e.g. LSOA) greenspace measurements, practical issues and potential data loss mean that this approach is not perfect either.

Considering the relative strengths and limitations of each residential greenspace indicator, the studies in this thesis use: 1) NDVI in a buffer around respondents' address wherein this measure was already included within a given dataset (Study 2); 2) LSOA greenspace when NDVI was not available (Studies 1 & 3); and 3) self-reported greenery in the view from home, when an issue with postcode data collection prevented linkage to objective greenspace measurements (Study 4).

Although each measure has been widely used in prior research to estimate residential nature contact (Kaplan, 2001, Pereira et al., 2012; White et al., 2017), it should be noted that the differences in the measures outlined above may affect: a) the interpretation of the findings, and b) links to the mechanisms proposed to underlie nature-behaviour associations. For instance, the differing geographical scales of the measures may lead to different implications/recommendations between studies regarding greenspace directly visible from home (i.e. green views), within respondent's immediate residential location (i.e. NDVI), and within their wider neighbourhood (i.e. LSOA greenspace). Moreover, with evidence that greenery directly around the home operates as a micro-restorative setting, with immediate visual access providing more regular restorative opportunities (Hartig et al., 2014; Kaplan, 2001), it is feasible that the use of green views from home in Study 4 may lead to stronger associations to positive affect, negative affect and temporal discounting than may have been observed if wider neighbourhood measures had been used (i.e. LSOA or NDVI greenspace). Conversely, NDVI and LSOA greenspace measures may be more adept at capturing use of greenspaces as settings for social contact with family, friends and neighbours, thus use of green views within the Study 4 may underestimate the association between residential nature contact and community cohesion.

1.4.3.3 Covariate Adjustment

As discussed in Section 1.2.1 and Section 1.2.2, there are a number of individual and area-level covariates with the potential to confound nature-behaviour associations. It is standard practice to statistically control for relevant covariates within environmental Psychology (e.g. Weinstein et al., 2015), as well as in other disciplines interested in the links between natural environments and health (i.e. human geography, Wheeler et al., 2015; environmental epidemiology; Pearce, et al., 2009). Nevertheless, caution is needed when selecting covariates, to avoid over adjustment bias (wherein inclusion of intermediate variables increases, rather than decrease bias) and unnecessary adjustment (in which control for a variable adversely affects model precision without introducing bias; Lu et al., 2021). To mitigate these issues, Schisterman et al (2009) recommends a cautious approach to covariate selection that is informed by substantive knowledge. To that end, Table 1.1 includes an overview of covariate selection, including prior literature indicating the potential for each factor to confound the associations between nature contact/connectedness and outcome variables.

1.4.4 Outline of Studies

The three research questions were systematically investigated using four large-scale, cross-sectional studies, capable of examining nature – behaviour associations with the general population, whilst accounting for a range of covariates known to influence health and sustainability behaviours (Section 1.2). Study 1 (Chapter 2, Section 2.2) used nationally representative data from the Health Survey for England to examine the associations between residential nature contact (neighbourhood greenspace) and two domains of health risk behaviours (smoking, alcohol). Study 2 (Chapter 2, Section 2.3)

Table 1.1 Summary of covariates for adjustment

Covariate	Justification for adjustment based on prior research
Gender	• Higher prevalence of health-risk behaviours in males (Waldron, 1991). • Lower engagement in pro-environmental behaviours amongst males (Scannell & Gifford, 2013). • Gender differences in the use of natural spaces (Elliott et al., 2018) and nature connectedness (Richardson et al., 2019).
Age	• Age differences in the prevalence of health-risk behaviours (WHO, 2013; Nobel et al., 2015) and pro-environmental behaviours (Scannell & Gifford, 2013). • Nature contact (Elliott et al., 2018) and nature connectedness (Richardson et al., 2019) vary as a function of age.
Marital status	• Higher prevalence of health-risk behaviours (Noble et al., 2015), as well as less engagement in pro-environmental behaviours (Alcock et al., 2020) amongst individuals who are single (*vs.* married/cohabiting). • Nature contact varies as a function of marital status (Astell-Burt et al., 2014).
Socio-economic status i.e. education, working status and income	• Health risk behaviours are more prevalent amongst lower socio-economic groups (Noble et al., 2015; Meader et al., 2016). • Higher socio-economic groups tend to behave more sustainably in terms of everyday behaviours (Owens et al., 2000; McEachern & Mcclean, 2002), but use less sustainable modes of transport (Johansson-Stenman, 2002 Alcock et al., 2018). • Better greenspace access amongst higher socio-economic groups (Boone et al., 2009; Iverson and Cook, 2000; Shanahan et al., 2014).
Disability	• Disability is positively associated with health-risk behaviours (WHO, 2013) and also influences people's propensity to visit natural spaces and engage in pro-environmental behaviours (Thøgersen and Ölander, 2006; Alcock et al., 2020).
Dog owner	• Higher prevalence of health risk behaviours amongst dog-owners (Maugeri et al., 2019). • Dog ownership is also linked to how often people visit natural spaces, as well as the types of activities they untaken within them (White et al., 2018)
Urban/rural status	• Higher prevalence of health-risk behaviours (Idris et al., 2007; Völzke et al., 2006; Martinez et al., 2006), as well as greater engagement in pro-environmental behaviours (Alcock et al., 2020) amongst individuals living in urban (*vs.* rural) areas. • There is evidence of a strong negative correlation between urbanisation and neighbourhood greenspace (Maas et al., 2006).
Area-level deprivation	• Area-level deprivation is positively associated with the prevalence of health risk behaviours (Cerdá et al., 2010; Halonen et al., 2012; Lakshman et al., 2011), and negatively associated with pro-environmental behaviours (Laidley, 2013; Hinds & Sparks, 2008). • There is evidence of differences in greenspace access and use as a function of neighbourhood deprivation (Jones, Hillsdon & Coombes, 2009).

extended this further, using an international sample (BlueHealth International Survey), to assess the relative associations between: two types of nature contact (residential, intentional), nature connectedness, and two domains of health risk behaviours (smoking alcohol). Study 3 (Chapter 3) focused on pro-environmental behaviours (household, nature conservation). Using nationally representative data from Natural England's Monitoring Engagement with Natural Environments (MENE) survey, Study 3 investigated the associations between three types of nature contact (residential, intentional, indirect), nature connectedness and two domains of pro-environmental behaviours (household, nature conservation). Study 4 (Chapter 4) used a bespoke survey of adults in Great Britain to test the full conceptual model, including the four potential mediators: positive affect, negative affect, community cohesion and temporal discounting. Finally, Chapter 5 of this thesis summarises and discusses the main findings of Studies 1-4, in relation to prior theory and research.

Chapter 2

Nature Contact, Connectedness and Health Risk Behaviours[2]

2.1 Chapter Overview

Within Chapter 1, several streams of evidence were reviewed to develop a conceptual model postulating that increased contact with – and psychological connection to – nature would be associated with behavioural determinants of public and planetary health (i.e. health risk behaviours and pro-environmental behaviours, Figure 1.1, Chapter 1). The present chapter presents two cross-sectional studies systematically investigating part of that model. Specifically, this chapter examines the associations between nature contact, nature connectedness and the prevalence of two domains of health risk behaviours (smoking and alcohol).

This chapter addresses two overarching research questions:

RQ1a. What are the associations between different types of nature contact and health risk behaviours, after accounting for a range of socio-demographics?

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[2] Abridged versions of Study 1 and Study 2 are currently published or under revision:

Martin, L., White, M.P., Pahl, S., May, J. & Wheeler, *B.* (2020). Neighbourhood greenspace and smoking prevalence: Results from a nationally representative survey in England. *Social Science & Medicine,* doi: 10.1016/j.socscimed.2020.113448.

Martin, L., White, M.P, Pahl, S., May, J, Newton, J.… (under minor revision). Nature contact and health risk behaviours: Prevalence, and population attributable fraction in a cross-sectional international sample. *Environment & Behavior*

RQ2. What role does trait nature connectedness play in these associations?

Specifically, Study 1 extends prior bivariate observations (Chapter 1, Section 1.3.1) by exploring the associations between residential nature contact (neighbourhood greenspace) and the prevalence of two domains of health risk behaviours (smoking and alcohol), whilst accounting for a range of individual and area-level covariates. As discussed in Chapter 1, Section 1.3.1) there is evidence that different types of nature contact, as well as nature connectedness, are associated with congruent benefits to broader health and wellbeing outcomes. Study 2 builds upon this work by examining the relative associations between two types of nature contact (residential- neighbourhood greenspace; intentional- nature visits), connectedness to nature, and the prevalence of two domains of health risk behaviours (smoking and alcohol) in an international sample. With evidence that nature connectedness moderates behavioural outcomes for pro-environmental behaviours (Chapter 1, Section 1.3.2), Study 2 also examines whether trait nature connectedness moderates the links between nature contact and health risk behaviours.

2.2 Study 1: Neighbourhood Greenspace and Health Risk Behaviours in England

2.2.1 Summary of Prior Research and Hypotheses

2.2.1.1 Neighbourhood Disparities in Health risk Behaviours

As discussed in Chapter 1 (Section 1.2.1), a number of neighbourhood characteristics have been positively associated with the prevalence of health risk behaviours, including: deprivation (Algren et al., 2015), crime (Caraballo et al., 2019) and, crucially for the current study, level of urbanisation (Pearce & Boyle, 2005). Several studies have now demonstrated that inhabitants of urban areas are more likely to engage in health risk behaviours (e.g. smoking, alcohol misuse), than those of rural areas (Völzke et al., 2006, Idris et al., 2007; Yaya & Bishwajit, 2019; Peer et al., 2013). Moreover, for smoking at least, prevalence increases with the degree of urbanisation (Pearce & Boyle, 2005; Idris et al., 2007), and these effects remain after controlling for a range of individual-level socio-demographics (Völzke et al., 2006; Martinez et al., 2006). Taken together, this suggests that area-level variations in health risk behaviours are not simply an artefact of varying socio-economic population compositions, but the result of contextual and environmental factors.

A key feature of increasing urbanisation is the loss of natural spaces (Pauleit et al., 2005) which reduces opportunities to interact with the natural world (Soga & Gaston, 2016). Given the strong negative correlation between urbanicity and neighbourhood greenspace (Maas et al., 2006), urban-rural differences in health risk behaviours may, at least in part, be explained by the availability of residential greenspace. Although I am unaware of any studies directly examining this proposition, several strands of evidence support further investigation into this area. For instance, using a nationally representative sample from the Netherlands, Maas et al. (2006) found that differences in general health between residents of urban and rural areas were largely explained by the proportion of neighbourhood greenspace, with the coefficients for urban/rural status reduced to non-significance once residential greenspace was entered into the models. Since health risk behaviours themselves predict health outcomes (Lopez et al., 2006; WHO, 2013), it follows that urban-rural disparities in the prevalence of health risk behaviours may also be due to variations in neighbourhood greenspace. Preliminary support for this idea comes from inverse bivariate associations between neighbourhood greenspace and health risk behaviours observed in large cross-sectional surveys (Astell-Burt, Feng & Kolt, 2014; Van Herzele & de Vries, 2012; Wang et al., 2017). Nevertheless, further studies are needed to ascertain whether the associations between greenspace and key policy outcomes (i.e. reduced health risk behaviours) are demonstrable at the population level, after relevant socio-demographic covariates have been accounted for.

To address this gap in the literature, Study 1 used data from a nationally representative survey of England to examine whether residential nature contact (neighbourhood greenspace) was related to two domains of health risk behaviours (smoking and alcohol), after controlling for a range of individual and area-level covariates. Based on the research reviewed above and in Chapter 1, hypotheses were as follows:

H_1. Residential nature contact will be inversely associated with the prevalence of current smoking, after accounting for a range of socio-demographics.

H_2. Residential nature contact will be inversely associated with the prevalence of exceeding alcohol guidelines, after accounting for a range of socio-demographics.

2.2.1.2 Distinguishing Between Ever Smoking and Smoking Cessation

The prevalence of current smokers within a particular sub-group of the population may be due to the likelihood of individuals starting smoking *and/or* cessation rates (Kuipers et al., 2013; DeCicca et al., 2008; Van Loon et al., 2005). Thus, distinguishing between ever-smoking and smoking cessation offers potential conceptual insights into the mechanisms by which area-level characteristics may influence smoking, and so helps to determine the focus of policy and interventions (Nagelhout, et al., 2012). In terms of neighbourhood greenspace, if the inverse bivariate association between neighbourhood greenspace and current smoking observed in prior research is generalisable once relevant socio-demographics are accounted for, then it is both conceptually and practically useful to establish whether this relationship is attributable to a lower prevalence of ever-smoking and/or a higher prevalence of smoking cessation. Hence, Study 1 examines the association between neighbourhood greenspace and three inter-related smoking outcomes (current smoking, ever-smoking and smoking cessation). Hypothesis 1 was extended as follows:

H_1. Residential nature contact will be inversely associated with the prevalence of current smoking, after accounting for a range of socio-demographics.

> **H_{1a}.** There will be an inverse association between residential nature contact and the prevalence of ever-smokers, after accounting for a range of socio-demographics.
>
> **H_{1b}.** There will be a positive association between residential nature contact and the prevalence of smoking cessation, after accounting for a range of socio-demographics.

2.2.2 Method

2.2.2.1 Participants and Procedure

The Health Survey for England (HSE) is conducted annually in England on behalf of the UK Office for National Statistics to provide information on health, lifestyle factors, and illnesses within the general population. Data is collected throughout the year by trained interviewers using a face-to-face interviewing protocol (NHS Digital, 2013). Participants were drawn from the 2012 wave of the HSE because this was the year for which updated measures of neighbourhood greenspace were available[3]. The sample consisted of 8,291 adults (4,601 females) aged ≥16 years. As part of England's official statistics, the HSE uses a multistage stratified design to achieve a sample representative of the population at both the national and regional level (NHS Digital, 2013). For current purposes, respondents with missing data for socio-demographic predictors (N = 156), or outcome variable of interest (smoking status: N = 76; alcohol consumption: N = 197) were excluded from the analyses, resulting in a reduced sample of 8,059 (4,462 females) for smoking models and 7,938 (4, 393 females) the alcohol models. There was little variation in the proportion (<1%) of respondents within each socio-demographic group as a function of the reduced sample (*vs.* the full sample), suggesting no systematic bias in the exclusion of cases as a function of socio-demographic variables.

2.2.2.2 Data Linkage

To preserve anonymity, standard licence versions of the HSE data include only large area geographical identifiers. Therefore, higher resolution measures of greenspace, urban-rural status and neighbourhood deprivation at the Lower-layer Super Output Area (LSOA) level were supplied to the data providers (NatCen Social Research) and linked anonymously to HSE data with agreement from the NHS Health and Social Care Information Centre (HSCIC, now NHS Digital). To prevent identification of any individual LSOAs, returned area-level variables were constrained to broad categories, with LSOA and regional identifiers removed from the dataset.

[3] Data from more recent waves of the Health Survey for England were not available to the European Centre for Environment and Human Health from whom access to the dataset was granted.

2.2.2.3 Measures

2.2.2.3.1 Outcome Variables

Smoking behaviours

Following Kuipers et al., (2013) three interrelated binary smoking indicators were derived from responses to a single item question pertaining to respondents' smoking status: current smoker, ever-smoker, smoking cessation. To examine the predictors of smoking prevalence, respondents' smoking status was dichotomised according to whether they were current smokers (N = 1,513) *vs.* non-smokers (N = 6,546), with the latter category aggregating former regular smokers and never regular smokers. To examine ever-smoking, respondents who currently smoked or were former regular smokers were classified as ever-smokers (N = 3,628) *vs.* never-smokers (N = 4,431). Finally, to assess predictors of smoking cessation, a binary variable was created categorising the subsample of ever- smokers as former (N = 2,115) *vs.* current smokers, with former smokers considered to have successfully given up smoking.

Exceeding alcohol guidelines (recommended units)

Alcohol consumption variables were derived from responses to a series of questions requiring respondents to indicate whether they drank alcohol and, if so, how much alcohol they had consumed during the last week. Respondents' drinking status was dichotomised according to whether respondents exceeded UK alcohol recommendations for 2012 (Science and Technology Committee, 2012) of 3-4 units of alcohol per day for men and 2-3 units per day for women. This equates to a maximum of 28 units per week for men and 21 units for women (exceeds alcohol limits: yes *vs.* no = reference). Analyses for this indicator excluded 197 respondents with missing consumption data, resulting in a reduced sample of 7,938 respondents for this variable. Sensitivity analyses comparing the inclusion *vs.* exclusion of respondents who did not drink alcohol (N=

1403) produced consistent results (Appendix 1). Therefore, the unconditional prevalence of exceeding alcohol limits (i.e. proportions within the entire sample, including non-drinkers) are reported here to maximize sample size.

2.2.2.3.2 Predictor Variables

Residential nature contact (neighbourhood greenspace)

Neighbourhood greenspace was based on the Lower-layer Super Output Area (LSOAs) in which respondents lived. LSOAs are produced by the Office for National Statistics and represent discrete geographic areas of similar population size. There are 32,484 LSOAs in England (2011 census), each containing approximately 1,500 residents. This information was added by the Health and Social Care Information Centre to the HSE dataset from other sources. Specifically, the percentage of land cover incorporating public greenspace and domestic gardens within each LSOA (at the resolution of $10m^2$) was derived from the Generalised Land Use Database. Sensitivity analyses with greenspace operationalised in quintiles, quartiles and as a binary variable (Appendix 2) produced largely consistent results[4].To ensure sufficient cases within groups, and enable comparability with previous epidemiological greenspace studies (e.g. Dalton et al., 2016; Liao et al., 2019), the final models expressed greenspace in quartiles, ranging from the lowest level of neighbourhood greenspace (M = 5%) to the highest (M = 86%).

[4] To ensure respondent anonymity, only categorical data for area level variables were made available to the European Centre for Environment and Human Health by the HSCIC/NHS Digital. For neighbourhood greenspace ten categories (0-10%, 11%-20%, 21-30%, 31%-40%, 41%-50%, 51%-60%, 61%-70%, 71%-80%, 81%-90, and 91%-100%) were provided, therefore operationalisation as a continuous variable was not possible.

2.2.2.3.3 Control Variables

Given that the outcome and predictor variables have been previously associated with a range of individual (e.g. socio-economic status, Allen et al., 2017) and area-level confounders (e.g. neighbourhood deprivation, Algren et al., 2015), control variables were created using available data from the HSE survey, as well as LSOA variables provided by the Health and Social Care Information Centre, and included within the multivariate analyses.

Individual-level control variables

Demographic controls included: gender (female, male = reference); age (16-34 = reference, 35-64, 65+); highest educational attainment (no formal education = reference, secondary, tertiary, higher, other); socio-economic classification (routine and manual occupations = reference, intermediate occupations, managerial and professional occupations, other); marital status (married/cohabiting, single/widowed/divorced = reference) and equivalised household income, a measure of income that takes into account the number of people living in the household (≤ £27, 624 = reference, >£27, 624). In order to keep those who preferred not to state their income in the analysis (N = 1,589) a third category of 'income undisclosed' was created for this variable.

Area-level control variables

Area level urbanicity and deprivation indicators, based on respondent LSOA codes, were added to the dataset by HSCIC/NHS Digital. Urbanicity was categorised as: urban *vs.* rural (hamlet/village/town-fringe). The Index of Multiple Deprivation (IMD), which provides a measure of relative disadvantage based on several domains, including: crime, income and employment (Department of Communities and Local Government, 2010), was provided in quintiles, ranging from the highest level of disadvantage (≥ 34.17= reference) to the lowest (≤8.49).

2.2.2.4 Analytical Approach

Without access to LSOA identifiers, multi-level modelling, with area modelled as a level one factor, was not possible. Nevertheless, similar studies have noted that due to their large number, many LSOAs contain only a single respondent, rendering multi-level modelling inappropriate (Boyd et al., 2018). Therefore, as recommended for prevalent binary outcomes (McNutt et al., 2003), modified Poisson regressions with robust standard errors were used to estimate prevalence ratios (*PR*) and corresponding 95% confidence intervals (*95% CIs*) for the associations between neighbourhood greenspace and health risk behaviours, whilst controlling for individual and area-level covariates. Unadjusted and partially adjusted models (examining area-level predictors only) are reported in Appendix 3. The direction of the associations between variables in these models were largely consistent with those observed in final models.

Additionally, to assess the magnitude of the effects of neighbourhood greenspace on the outcome variables, where appropriate, their prevalence ratios were compared to those of relevant control variables. Previous research has noted lower prevalence of smoking amongst individuals who live in the least disadvantaged neighbourhoods, are highly educated, from higher income households and higher socioeconomic groups (Laaksonen et al., 2005; Algren et al., 2015). Smoking cessation is also more prevalent within the aforementioned social groups (Chandola et al., 2004; Halonen et al., 2016). Accordingly, neighbourhood deprivation (5^{th} quintile, least disadvantaged *vs.* 1^{st} quintile, most disadvantaged) education (higher education *vs.* no formal education), socio-economic position (managerial/professional, highest *vs.* routine, lowest) and equivalised income (> £27,624 = reference *vs.* ≤ £27,624, lowest) were selected as comparator variables. Comparisons to these benchmarks connects the findings to other disciplines and helps researchers and policymakers assess their relative importance.

A series of robustness checks were conducted. Firstly, prior research observes better greenspace access among more educated and wealthier groups (Boone et al., 2009; Iverson and Cook, 2000; Shanahan et al., 2014). As these characteristics also influence health risk behaviours (Williams et al., 2016; Algren et al., 2015), it is possible that associations between greenspace and health risk behaviours could be due to social groups who are more or less likely to engage in these behaviours, simply residing in greener areas (i.e. multiplicative moderation effects). To test this possibility, where statistically significant associations between greenspace and health risk behaviours were observed, an additional series of Poisson regression models were conducted, estimating prevalence ratios for behavioural outcomes as a function of neighbourhood greenspace, individual (education, socio-economic group, income) and area-level characteristics (neighbourhood deprivation) and their interaction terms.

Secondly, prior research indicates that health risk behaviours cluster together or co-occur, with individuals who smoke also being more likely to engage in potentially harmful alcohol consumption (Berrigan et al., 2003, Poortinga, 2007). To account for this, additional models controlling for other domains of health risk behaviours (i.e. smoking, exceeding alcohol recommendations, lack of sufficient physical activity) were specified. Specifically, smoking models controlled for exceeding recommended alcohol limits; and alcohol models controlled for current smoking. With prior research indicating that individuals who engage in these two health risk behaviours are also less likely to meet recommended physical activity guidelines (Meader et al., 2016), whether or not respondents engaged in 30 minutes of moderate-intensity activity at least 5 times per week (Yes *vs.* No = reference) was also included within both models. Comparison of these models with the main models provides greater assurance that associations between greenspace and the outcome variables are not due to shared variance between different health risk behaviours.

2.2.3 Results

2.2.3.1 Descriptive Statistics

Descriptive data for the smoking and alcohol outcomes as a function of neighbourhood greenspace and covariates are presented in Table 2.1. Approximately one fifth of respondents (19%) were current smokers. Less than half of the sample (45%) reported ever having regularly smoked and of those respondents who had ever smoked, over half (58%) had given up smoking. Over a tenth (13%) of respondents exceeded the recommended units of alcohol per week. The prevalence of current smoking decreased incrementally with each quartile of neighbourhood greenspace (Q1 = 22%, Q2 = 20%, Q3 = 19%, Q4 = 14%). Conversely, smoking cessation rates increased as neighbourhood greenspace increased (Q1 = 53%, Q2 = 55%, Q3 = 60%, Q4 = 67%).

For ever smoking the trend was more nuanced: whilst the 4th (highest) quartile of neighbourhood greenspace had the lowest prevalence of ever smokers overall (Q4 = 42%), the highest rates were observed for respondents residing in the 3rd greenspace quartile (Q3 = 47%). Contrary to predictions, the proportion of individuals exceeding alcohol consumption guidelines was highest amongst those living in the highest greenspace quartile (Q1 =11%, Q2 = 13%, Q3 = 13%, Q4 = 15%).

Table 2.1 Individual and area-level characteristics by smoking and alcohol outcomes.

		Current Smoker		Ever Smoker		Smoking Cessation		Exceeds Alcohol Guidelines[b]	
		No	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
	Total N (%)[a]	6546 (81%)	1513 (19%)	4431 (54%)	3628 (45%)	1513 (41%)	2115 (58%)	6890 (87%)	1048 (13%)
Neighbourhood greenspace (%)									
1st quartile (*M*= 5.23, lowest)	2114 (26%)	1656 (78%)	458 (22%)	1135 (54%)	979 (46%)	458 (47%)	521 (53%)	1847 (89%)	237 (11%)
2nd quartile (*M*= 24.46)	1906 (24%)	1525 (80%)	381 (20%)	1068 (56%)	838 (44%)	381 (45%)	457 (55%)	1645 (87%)	236 (13%)
3rd quartile (*M*= 54.18)	2373 (29%)	1928 (81%)	445 (19%)	1264 (53%)	1109 (47%)	445 (40%)	664 (60%)	1997 (86%)	335 (13%)
4th quartile (*M*= 86.35, highest)	1666 (21%)	1437 (86%)	229 (14%)	964 (58%)	702 (42%)	229 (33%)	473 (67%)	1401 (85%)	240 (15%)
Gender									
Male	3597 (45%)	2866 (80%)	731 (20%)	1767 (49%)	1830 (51%)	731 (40%)	1099 (60%)	2997 (85%)	548 (15%)
Female	4462 (55%)	3680 (82%)	782 (18%)	2664 (60%)	1798 (40%)	782 (43%)	1016 (57%)	3893 (89%)	500 (11%)
Age									
16-34	1904 (24%)	1415 (74%)	489 (26%)	1153 (61%)	751 (39%)	489 (65%)	262 (35%)	1592 (88%)	216 (12%)
35-64	4031 (50%)	3199 (79%)	832 (21%)	2177 (54%)	1854 (46%)	832 (45%)	1022 (55%)	3403 (85%)	608 (15%)
65+	2124 (26%)	1932 (91%)	192 (09%)	1101 (52%)	1023 (48%)	192 (19%)	831 (81%)	1895 (89%)	224 (11%)
Education									
No formal education	1985 (25%)	1539 (78%)	446 (22%)	900 (45%)	1085 (55%)	446 (41%)	639 (59%)	1779 (91%)	179 (09%)
Secondary	1931 (24%)	1450 (75%)	481 (25%)	947 (49%)	984 (51%)	481 (49%)	503 (51%)	1636 (87%)	243 (13%)
Tertiary	1234 (15%)	988 (80%)	246 (20%)	707 (57%)	527 (43%)	246 (47%)	281 (53%)	1002 (83%)	209 (17%)
Higher	2909 (36%)	2569 (88%)	340 (12%)	1877 (65%)	1032 (35%)	340 (33%)	692 (67%)	2473 (86%)	417 (14%)
Socio-economic group									
Routine & manual	3036 (38%)	2207 (73%)	829 (27%)	1361 (45%)	1675 (55%)	829 (49%)	846 (51%)	2629 (88%)	347 (12%)
Intermediate	1993 (24%)	1649 (83%)	344 (17%)	1115 (56%)	878 (44%)	344 (39%)	534 (61%)	1708 (86%)	276 (14%)
Managerial & professional	2696 (34%)	2402 (89%)	294 (11%)	1682 (62%)	1014 (38%)	294 (29%)	720 (71%)	2278 (85%)	402 (15%)
Other	334 (04%)	288 (86%)	46 (14%)	273 (82%)	61 (18%)	46 (75%)	15 (25%)	275 (92%)	23 (08%)
Equivalised household income									
≤ £27, 624	3552 (44%)	2718 (77%)	834 (23%)	1728 (49%)	1824 (51%)	834 (46%)	990 (54%)	3095 (89%)	390 (11%)
> £27, 624	2918 (36%)	2554 (88%)	364 (12%)	1826 (63%)	1092 (37%)	364 (33%)	728 (67%)	2421 (84%)	467 (16%)
Undisclosed	1589 (20%)	1274 (80%)	315 (20%)	877 (55%)	712 (45%)	315 (44%)	397 (56%)	1374 (88%)	191 (12%)

Table 2.1 continued.

Marital Status									
Single/Separated/Divorced/Widowed	2874 (36%)	2185 (76%)	689 (24%)	1563 (54%)	1311 (46%)	689 (53%)	622 (47%)	2439 (88%)	338 (12%)
Married/Cohabiting	5185 (64%)	4361 (84%)	824 (16%)	2868 (55%)	2317 (45%)	824 (36%)	1493 (64%)	4451 (86%)	710 (14%)
Index of multiple deprivation (IMD)									
1st Quintile (most disadvantaged)	1788 (22%)	945 (69%)	434 (31%)	636 (46%)	743 (54%)	434 (58%)	309 (42%)	1196 (89%)	153 (11%)
2nd Quintile	1722 (22%)	1178 (76%)	364 (24%)	770 (50%)	772 (50%)	364 (47%)	408 (53%)	1333 (88%)	187 (12%)
3rd Quintile	1628 (20%)	1357 (83%)	271 (17%)	902 (55%)	726 (45%)	271 (37%)	455 (63%)	1409 (88%)	193 (12%)
4th Quintile	1542 (19%)	1447 (84%)	275 (16%)	1009 (59%)	713 (41%)	275 (39%)	438 (61%)	1440 (85%)	256 (15%)
5th Quintile (least disadvantaged)	1379 (17%)	1619 (91%)	169 (09%)	1114 (62%)	674 (38%)	169 (25%)	505 (75%)	1512 (85%)	259 (15%)
Urbanicity									
Rural	1809 (22%)	1538 (85%)	271 (15%)	1030 (57%)	779 (43%)	271 (35%)	508 (65%)	1524 (86%)	257 (14%)
Urban	6250 (78%)	5008 (80%)	1242 (20%)	3401 (54%)	2849 (46%)	1242 (44%)	1607 (56%)	5366 (87%)	791 (13%)

Notes: [a] percentages relate to total sample. All other percentages relate to % within each exposure category for each outcome. [b] Weekly limit of >28 units for men and >21 units for women

2.2.3.2 Main Findings

Fully-adjusted Poisson regression models estimating the prevalence ratios of behavioural outcomes, by quartile of neighbourhood greenspace and covariates, are reported in Table 2.2. Variance inflation factors (VIF) for the model parameters were < 2.46, indicating that multicollinearity was not an issue.

Smoking outcomes (Models 1-3)

In line with Hypothesis 1, the prevalence of current smoking was statistically significantly lower in the highest (*vs.* lowest) quartile of neighbourhood greenspace (*PR* = 0.80, *95 % CIs* = 0.67, 0.96, *p* = .017). Specifically, living in the highest greenspace quartile (4^{th}) was associated with a 20% lower prevalence of current smoking, compared to living in the lowest greenspace quartile (1^{st}). In contrast to Hypothesis 1a, there were no statistically significant associations between neighbourhood greenspace and the prevalence of ever-smokers (Q2: *PR* = 0.93, *95 % CIs* = 0.83, 1.04; Q3: *PR* = 1.00, *95 % CIs* = 0.94, 1.06; Q4: *PR* = 0.96, *95 % CIs* = 0.88, 1.06, all *ps >.05).* However, supporting Hypothesis 1b, amongst respondents who had ever smoked, residing in the 3^{rd} and 4^{th} greenspace quartiles (*vs.* 1^{st} quartile) was associated with a 10% and 12% higher prevalence of smoking cessation, respectively (Q3: *PR* = 1.10, *95 % CIs* = 1.02, 1.18, *p* = .012; Q4: *PR* = 1.12, *95 % CIs* = 1.02, 1.22, *p* = .016).

Exceeding Alcohol Guidelines (Model 4)

Contrary to Hypothesis 2, positive, but non-significant, associations emerged between neighbourhood greenspace and exceeding guideline weekly units (Q2: *PR* = 1.11, *95 % CIs* = 0.94, 1.31; Q3: *PR* = 1.18, *95 % CIs* = 0.96, 1.47; Q4: *PR* = 1.13, *95 % CIs* = 0.92, 1.38, all *p >.05).*

Table 2.2 Modified Poisson regression models estimating adjusted prevalence ratio of smoking outcomes for neighbourhood greenspace, controlling for individual and area level covariates.

	Model 1 Current Smoking			**Model 2 Ever Smoker**			**Model 3 Smoking Cessation**			**Model 4 Exceeds Alcohol Limits[a]**		
	PR	***(95% CIs)***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***
Neighbourhood greenspace (%)												
1st quartile (*M* = 5.23, lowest)												
2nd quartile (*M* = 24.46)	0.92	(0.82, 1.03)	.158	0.93	(0.83, 1.04)	.180	1.03	(0.95, 1.11)	.495	1.11	(0.94, 1.31)	.219
3rd quartile (*M* = 54.18)	0.91	(0.82, 1.02)	.121	1.00	(0.94, 1.06)	.922	1.10	(1.02, 1.18)	.012	1.18	(0.96, 1.47)	.120
4th quartile (*M* = 86.35, highest)	0.80	(0.67, 0.96)	.017	0.96	(0.88, 1.06)	.447	1.12	(1.02, 1.22)	.016	1.13	(0.92, 1.38)	.245
Individual-level controls												
Gender (female)	0.82	(0.75, 0.89)	<.001	0.78	(0.74, 0.82)	<.001	1.03	(0.98, 1.09)	.252	0.75	(0.67, 0.84)	<.001
Age												
16-34 (ref)												
35-64	0.85	(0.77, 0.94)	.002	1.11	(1.04, 1.19)	.001	1.41	(1.27, 1.56)	<.001	1.22	(1.05, 1.41)	.011
65+	0.29	(0.24, 0.34)	<.001	1.04	(0.97, 1.13)	.266	2.23	(2.01, 2.47)	<.001	0.98	(0.81, 1.19)	.840
Education												
No formal education (ref)												
Secondary	0.88	(0.79, 0.99)	.029	0.96	(0.91, 1.03)	.248	1.00	(0.93, 1.07)	.921	1.27	(1.04, 1.54)	.017
Tertiary	0.68	(0.59, 0.79)	<.001	0.86	(0.79, 0.93)	<.001	1.09	(0.99, 1.20)	.075	1.70	(1.38, 2.09)	<.001
Higher	0.54	(0.46, 0.63)	<.001	0.73	(0.68, 0.79)	<.001	1.13	(1.05, 1.22)	.002	1.29	(1.05, 1.58)	.016
Socio-economic group												
Routine & manual (ref)												
Intermediate	0.81	(0.72, 0.90)	<.001	0.90	(0.84, 0.95)	<.001	1.10	(1.03, 1.18)	.007	1.08	(0.93, 1.26)	.307
Managerial & professional	0.66	(0.57, 0.76)	<.001	0.87	(0.81, 0.93)	<.001	1.17	(1.09, 1.26)	<.001	1.03	(0.88, 1.21)	.713
Other	0.35	(0.27, 0.46)	<.001	0.35	(0.28, 0.45)	<.001	0.66	(0.45, 0.98)	<.001	0.67	(0.44, 1.02)	.059
Equivalised household income												
≤ £27, 624 (ref)												
> £27, 624	0.75	(0.66, 0.84)	<.001	0.85	(0.80, 0.90)	<.001	1.12	(1.06, 1.20)	<.001	1.27	(1.10, 1.46)	.001
Undisclosed	0.93	(0.83, 1.04)	.180	0.90	(0.85, 0.96)	.001	0.99	(0.92, 1.06)	.790	1.12	(0.95, 1.31)	.181

Table 2.2 continued.

Marital Status (Married/Cohabiting)	0.73	(0.67, 0.80)	<.001	0.98	(0.93, 1.03)	.378	1.26	(1.18, 1.34)	<.001	0.99	(0.88, 1.13)	.913
Area-level controls												
Index of multiple deprivation (IMD)												
1st Quintile (most disadvantaged, ref)												
2nd Quintile	0.88	(0.79, 0.99)	.034	0.95	(0.89, 1.02)	.182	1.14	(1.03, 1.26)	.015	1.01	(0.83, 1.24)	.918
3rd Quintile	0.71	(0.62, 0.81)	<.001	0.88	(0.82, 0.95)	.001	1.26	(1.14, 1.39)	<.001	0.93	(0.76, 1.14)	.486
4th Quintile	0.77	(0.67, 0.88)	<.001	0.84	(0.78, 0.91)	<.001	1.15	(1.04, 1.28)	.006	1.13	(0.92, 1.38)	.245
5th Quintile (least disadvantaged)	0.50	(0.42, 0.60)	<.001	0.80	(0.73, 0.87)	<.001	1.33	(1.21, 1.47)	<.001	1.05	(0.86, 1.28)	.640
Urbanicity (urban)	0.91	(0.78, 1.05)	.198	0.99	(0.92, 1.07)	.797	1.06	(0.98, 1.14)	.129	1.00	(0.84, 1.19)	.985
Constant	0.17	(0.12, 0.24)	<.001	0.22	(0.17, 0.28)	<.001	0.21	(0.18, 0.25)	<.001	0.08	(0.06, 0.11)	<.001
N	8,059			8,059			3628			7938		
Wald's χ^2	860***			596***			736***			114***		
Pearson goodness of fit χ^2	6557			4416			1481			6869		
Pseudo R^2	.09			.03			.05			.02		

Note. [a] Weekly alcohol limits of >28 units for men and >21 units for women

Control variables (Models 1-4)

Females (*vs.* males) had a lower prevalence of both current smoking (*PR* = 0.82, *95 % CIs* = 0.75, 0.89, *p* <.001) and exceeding alcohol guidelines (*PR* = 0.75, *95 % CIs* = 0.67, 0.84, *p* <.001). A lower prevalence of current smoking (*PR* = 0.85, *95 % CIs* = 0.77, 0.94), *p* = .002), but a higher prevalence of exceeding alcohol guidelines (*PR* = 1.22, *95 % CIs* = 1.05, 1.41, *p* = .011) was evident amongst older adults (35-64 *vs.* 16-34 years). The pattern of findings for socio-economic variables also differed across behavioural domains. Having a higher education (*vs.* no formal education: *PR* = 0.54, *95 % CIs* = 0.46, 0.63, *p* <.001), belonging to a managerial/professional socio-economic group (*vs.* routine/manual: *PR* = 0.66, *95 % CIs* = 0.57, 0.76, p <.001), and earning more than £27, 624 (*vs.* ≤ £27, 624: *PR* = 0.75, *95% CIs* = 0.66, 0.84, *p* <.001) were all associated with a lower prevalence of current smoking. Conversely, higher socio-economic status, measured by higher education (*PR* = 1.29, *95 % CIs* = 1.05, 1.58, *p* = *.016*) and earnings above £27, 624 (*PR* = 1.27, *95 % CIs* = 1.10, 1.46, *p* = .001) were associated with a higher prevalence of exceeding alcohol guidelines. Regarding area-level covariates, living in the least deprived neighbourhoods (5^{th} *vs.* 1^{st} quintile) was associated with a lower prevalence of current smoking (*PR* = 0.50, *95 % CIs* = 0.42, 0.60, *p* <.001) but unrelated to alcohol consumption (*PR* = 1.05, *95 % CIs* = 0.86, 1.28, *p* = .640). Living in an urban (*vs.* rural) area was unrelated to the prevalence of each health risk behaviour (current smoking: *PR* = 0.91, *95 % CIs* = 0.78, 1.05; ever smoking: *PR* = 0.99, *95 % CIs* = 0.92, 1.07; smoking cessation: *PR* = 1.06, *95 % CIs* = 0.98, 1.14; exceeding alcohol limits: *PR* = 1.00, *95 % CIs* = 0.84, 1.19, all *p* >*.05*).

2.2.3.3 Comparison with Socio-Demographics

Where statistically significant associations between greenspace and behavioural outcomes were observed (i.e. current smoking and smoking cessation) the prevalence ratio associated with residing in either the 3rd or 4th quartiles of neighbourhood greenspace (*vs.* 1st quartile) was compared to: a) living in the least *vs.* most disadvantaged neighbourhoods, *b*) having a higher *vs.* no formal education, c) holding a managerial/professional (highest) *vs.* routine (lowest) socio-economic position, and d) reporting an equivalised income of > £27, 624 (highest) *vs.* ≤ £27, 624 (lowest).

For current smoking, living in the highest greenspace quartile (4th) was associated with a 20% lower prevalence of current smoking, compared to living in the lowest (1st) greenspace quartile (*PR* = .80, *95 % CIs* = 0.67, 0.96, $p < .017$). This was less than half the size of the 50% lower prevalence associated with living in the least (*vs.* most) disadvantaged neighbourhoods (*PR* = .50, *95 % CIs* = 0.42, 0.60, $p < .001$). The prevalence ratio of being a current smoker for those residing in the 4th (*vs.* 1st) quartile of neighbourhood greenspace was also substantially smaller than that associated with having a higher education (*PR* = .54, *95 % CIs* = 0.79, 0.99, $p < .001$) and holding a managerial socioeconomic position (*PR* = 0.66, *95 % CIs* = 0.57, 0.76, p <.001); but comparable to the 25% lower prevalence associated with earning more than £27, 624 a year (*PR* = 0.75, *95 % CIs* = 0.66, 0.84, $p <.001$).

For smoking cessation, residing in the 3rd and 4th greenspace quartiles (*vs.* 1st quartile) was associated with a 10% and 12% higher prevalence of smoking cessation (*PR* = 1.10, *95 % CI*s = 1.02, 1.18, $p = .012$; *PR* = 1.12, *95 % CIs* = 1.02, 1.22, $p = .016$, respectively). These increases were approximately one third of the size of the 33% higher prevalence associated with living in the least (*vs.* most) disadvantaged neighbourhoods (*PR* = 1.33, *95 % CIs* = 1.21, 1.47, $p < .001$). Prevalence ratios for smoking cessation associated with living in the 3rd or 4th greenspace quartile (*vs.* 1st) quartile of neighbourhood greenspace were slighter smaller than those associated with holding a managerial socioeconomic position (*PR* = 1.17, *95 % CIs* = 1.09, 1.26, $p <$ .001); yet similar to the 13% and 12% increases in cessation prevalence associated with having a higher education (*PR* = 1.13, *95 % CIs* = 1.05, 1.22, *p* = .002) and earning more than £27, 624 a year (*PR* = 1.12, *95 % CIs* = 1.06, 1.20, *p* < .001). Overall, these comparisons suggest that for being a current smoker, the effects of neighbourhood greenspace are similar in magnitude to the existing socio-demographic benchmark of household income (i.e. earnings of £27, 624 a year). However, for smoking cessation the effects of greenspace are comparable to both having a higher education and earning more than £27,624 a year.

2.2.3.4 Robustness Checks

Moderation effects by socio-economic status (Appendix 4)

To ensure the observed associations between neighbourhood greenspace, current smoking and smoking cessation were not simply an artefact of socioeconomic groups that are less likely to smoke residing in greener areas, a series of additional models were conducted testing for potential moderation effects. Overall, there was no evidence of moderation effects by area or individual-level characteristics, in the 3rd and 4th quartiles of neighbourhood greenspace, where the differences in smoking behaviours as a function of neighbourhood greenspace were observed. Thus, associations between neighbourhood greenspace and smoking outcomes within these quartiles were not simply due to the composition of the population who resided in them.

Accounting for Co-occurrence of Health risk Behaviours (Appendix 5)

Adjustment for other health (risk) behaviours did little to alter the associations between neighbourhood greenspace, current smoking and smoking cessation observed within the main models. Thus, associations between greenspace, current smoking and smoking cessation are unlikely to be due to shared variance between different domains of health (risk) behaviours (i.e. exceeding alcohol limits, physical activity).

2.2.4 Discussion

Extending prior research into area-level characteristics and the prevalence of health risk behaviours, this study constitutes, as far as I am aware, the first formal investigation of the associations between residential nature contact (neighbourhood greenspace), smoking and alcohol behaviours. The aim of Study 1 was to establish whether neighbourhood greenspace was associated with the prevalence of two domains of health risk behaviours (smoking and alcohol), after controlling for a range of individual and area level covariates.

Neighbourhood greenspace was negatively associated with the prevalence of current smoking. Specifically, there was a lower prevalence of current smoking amongst individuals living in the highest greenspace quartile, relative to those who lived in the lowest quartile. The relationship between greenspace and smoking prevalence within the current study was upheld after adjusting for a range of covariates, extending previous bivariate observations (Astell-Burt, Feng & Kolt, 2014; Van Herzele & de Vries, 2012). This suggests that the relationship between greenspace and current smoking is not due to the socio-economic composition of the population at either the individual or area level. Further, the associations between greenspace and smoking prevalence were largely unmoderated by three measures of socio-economic status, indicating that the results are not simply due to socio-economic groups who are less likely to smoke residing in greener areas. Taken together, these findings strongly suggest that high greenspace neighbourhoods are independently associated with a lower prevalence of current smoking, irrespective of the socio-demographic characteristics of the individuals who reside in them. Although it is difficult to establish the mechanisms by which neighbourhood greenspace influences smoking behaviour using cross sectional data, the results obtained for ever smoking and smoking cessation are nonetheless informative.

Specifically, no association was found between neighbourhood greenspace and ever smoking. The null effects observed here may reflect aspects of the study design, specifically that the measurement of ever smoking was related to respondents' current area of residence. Given that smoking uptake typically occurs during adolescence (Wellman et al., 2016) individuals may have migrated to another neighbourhood since initiation, effectively weakening the relationship between ever-smoking and neighbourhood greenspace. Yet, the significance of other area-level characteristics (e.g. deprivation) within our ever-smoking models suggests that this was not the case here.

Conversely, neighbourhood greenspace was positively associated with smoking cessation. Notably, there was a higher prevalence of smoking cessation amongst respondents living in the 3rd and 4th quartiles of neighbourhood greenspace, compared to those who lived in the 1st quartile. Collectively, the results for smoking outcomes suggest that the lower prevalence of current smokers in high greenspace neighbourhoods may be attributable to higher prevalence of smoking cessation, rather than a lower prevalence of ever-smoking. In relative terms, neighbourhood deprivation, and socio-economic group were stronger predictors of these two smoking behaviours. Nevertheless, the associations between neighbourhood greenspace, current smoking and smoking cessation are likely to be practically meaningful, given that they were similar in magnitude to existing socio-demographic benchmarks which may be less amenable to change (i.e. education and income).

Contrary to prior bivariate observations of a lower frequency of alcohol consumption amongst individuals who live in greener neighbourhoods in Hong Kong (Wang et al., 2017), neighbourhood greenspace was unrelated to exceeding guideline weekly units within the current study conducted in England. With no clear trend towards a lower prevalence of exceeding alcohol limits as a function of greenspace observed at the bivariate level, this inconsistency is unlikely to be due the range of covariates accounted for within the multivariate analyses. The incongruent findings may instead relate to differences in alcohol consumption patterns between countries (WHO, 2020). Further work examining the association between greenspace and alcohol misuse, accounting for country variations in alcohol consumption is therefore needed.

The pattern of associations between socio-demographic covariates and outcome variables largely reflects well-established social gradients in the prevalence of health risk behaviours. The findings for current smoking are in line with prior studies indicating a lower prevalence of health risk behaviours amongst females (Waldron, 1991). The prevalence of current smoking and exceeding alcohol guidelines, as a function of age and measures of socio-economic status, also replicate prior work (WHO, 2013). Such consistency provides greater assurance in the robustness of the data. It was, however somewhat surprising that urban/rural residency did not statistically significantly predict smoking behaviours within the multivariate analyses, considering prior research demonstrating higher smoking prevalence in urban, relative to rural neighbourhoods (Völzke et al., 2006; Martinez et al., 2006). The divergent findings may relate to the inclusion of other area-level controls within the models, which were largely unaccounted for within prior studies. Indeed, additional analyses showed that urban/rural status statistically significantly predicted a higher prevalence of current smoking in the unadjusted models (Appendix 6), but this relationship was reduced to non-significance once neighbourhood greenspace and deprivation were entered into the partially adjusted models (see Appendix 3, Table 3b). Consistent with prior observations that urban-rural disparities in general health were largely explained by greenspace availability (Maas et al, 2006), this suggests that, in the current study at least, the prevalence of smoking outcomes as a function of urban/rural residency were due to variations in neighbourhood greenspace and neighbourhood deprivation.

Overall, the results of this study suggest that residential nature contact is differentially related to two domains of health risk behaviour. Specifically, high levels of neighbourhood greenspace are associated with a lower prevalence of current smoking, but unrelated to exceeding alcohol guidelines. Greenspace also exhibited divergent associations with smoking uptake and maintenance. Notably, neighbourhood greenspace was positively associated with smoking cessation prevalence, but unrelated to ever-smoking. This indicates that the association between greenspace and current smoking may be attributable to a higher prevalence of smoking cessation, rather than a lower prevalence of ever smoking. Nevertheless, the findings of the current study are based on data from 2012. Given the steady decline in smoking prevalence in the general population over the last decade (WHO, 2018b) and subsequent changes to UK alcohol consumption guidelines, it is unclear to what extent the associations observed here translate to present day trends in health risk behaviours. Thus, further studies utilising more recent datasets are needed to substitute these initial findings.

2.3 Study 2: Nature Contact, Nature Connectedness and Health Risk Behaviours in an International Sample

2.3.1 Overview and Hypotheses

Study 2 extended Study 1 in a several ways. Firstly, using an international cross-sectional dataset collected between 2017-2018, Study 2 allowed further investigation of the associations between greenspace and health risk behaviours, in a more recent dataset, capable of accounting for national differences in health risk behaviours.

Secondly, inclusion of both residential greenspace exposure and intentional nature visits into the same models allowed for an examination of the relative associations of two different types of nature contact and health risk behaviours. Third, as outlined in Chapter 1 (Section 1.3.1), nature contact and nature connectedness appear to have analogous associations to both health outcomes and health risk behaviours. Thus, Study 2 investigated how individual differences in trait nature connectedness relate to health risk behaviours.

2.3.1.1 Distinguishing Between Types of Nature Contact

Whilst Study 1 focused exclusively on the amount of neighbourhood greenspace near individuals' homes, this represents a largely incidental form of nature contact (Keniger, et al., 2013). However, as outlined in Chapter 1, there is growing awareness in the nature-health literature that time voluntarily engaging with nature (e.g. intentional nature visits) may be a more direct determinant of health and wellbeing outcomes (Shanahan et al., 2016; White et al., 2017). Given the strong relationship between general health and health-behaviours (WHO, 2013), it seems plausible to hypothesise that intentional nature contact may also be associated with a lower prevalence of health risk behaviours. Whilst I am aware of no prior research directly examining this, incidental evidence comes from two lines of research. First, both residential (neighbourhood greenspace) and intentional (visits to natural spaces) nature contact have been associated with congruent, often additive, benefits to broader health and wellbeing outcomes (White et al., 2017). Second, lower relapse rates have been observed amongst individuals undergoing drug and alcohol rehabilitation following nature-based treatment programmes involving time spent in natural spaces (Bennett et al., 1998). Thus, Study 2 included two types of nature contact within the same statistical analyses. By doing so, the relative associations of residential (neighbourhood greenspace) and intentional (nature visits) contact and health risk behaviours were explored, for the first time. This type of comparison may inform policy makers and practitioners where to focus public health strategies and interventions.

H_1. Residential contact (neighbourhood greenspace) will be inversely associated with the prevalence of current smoking, after accounting for a range of socio-demographics.

> **H_{1a}.** There will be an inverse association between residential contact and the prevalence of ever smokers, after accounting for a range of socio-demographics.

> **H_{1b}.** There will be a positive association between residential contact and the prevalence of smoking cessation, after accounting for a range of socio-demographics.

H_2. Intentional contact (nature visits) will be inversely associated with the prevalence of current smoking, after accounting for a range of socio-demographics.

> **H_{2a}.** There will be an inverse association between intentional contact and the prevalence of ever smokers, after accounting for a range of socio-demographics.

> **H_{2b}.** There will be a positive association between intentional contact and the prevalence of smoking cessation, after accounting for a range of socio-demographics.

Despite the null results observed in Study 1, prior work has found a lower frequency of alcohol consumption amongst individuals who live in greener neighbourhoods in Hong Kong (Wang et al., 2017). As this could potentially be due to increased neighbourhood greenspace and/or more visits to natural spaces, hypotheses for exceeding alcohol guidelines were as follows:

H_3. Increased nature contact (neighbourhood greenspace) will be inversely associated with the prevalence of exceeding alcohol guidelines, after accounting for a range of socio-demographics.

H_4. Increased nature contact (nature visits) will be inversely associated with the prevalence of exceeding alcohol guidelines, after accounting for a range of socio-demographics.

In line with prior research on the broader psychological benefits of nature (Shanahan et al., 2016; White et al., 2017) the contributions of different types of nature contact were expected to be additive.

2.3.1.2 The Role of Nature Connectedness

As outlined in Chapter 1 (Section 1.3.1), there is evidence that contact with – and psychological connection to – nature, exhibit analogous associations to both health outcomes, and health risk behaviour (Capaldi, et al., 2014; Pritchard et al., 2019; Haluza et al., 2014; Sobko et al., 2020). Nonetheless, prior research has typically examined nature contact and nature connectedness separately. With moderate positive associations between nature contact and nature connectedness noted in the development of connectedness measures (Mayer and Frantz, 2004; Nisbet et al., 2009), it is unclear whether similar associations to outcome variables are an artifact of shared variance or whether they independently predict positive outcomes (i.e. additive effects).

An alternative hypothesis, discussed in Chapter 1 (Section 1.3.2), is that trait individual differences in nature connectedness may moderate the associations between nature contact and behavioural outcomes. Whilst I am aware of no prior studies investigating this possibility in relation to health risk behaviours, research in the domain of pro-environmental behaviours is somewhat informative. Notably, contact with the natural world has been associated with greater endorsement of pro-environmental attitudes (Ojala, 2009) and increased engagement in pro-environmental behaviours (Arendt & Matthes, 2016), but only for individuals who are already highly connected to nature. Such findings are broadly consistent with person-environment fit theories, which posit that optimal behavioural outcomes emerge when an individual's personal attributes (e.g. their values) are compatible with environmental attributes (Caplan, 1987). With evident commonalities between health risk behaviours and pro-environmental behaviours (Chapter 1, Section 1.2.3), I hypothesise that associations between nature contact and health risk behaviours may also be moderated by trait nature connectedness. Based on person-environment fit theories (Caplan, 1987), a higher prevalence of health risk behaviours would be expected amongst individuals whose nature contact is incongruent with their psychological affinity to the natural world. Namely, those who are highly connected to nature, with limited access to the natural world; as well as those who are less psychologically connected, with high levels of nature contact. Therefore, a further aim of the Study 2 was to examine the role of nature connectedness in health risk behaviours. Specifically, two competing hypotheses were tested: whether nature connectedness operates in parallel with nature contact (i.e. additive main effects) or influences how nature contact affects health risk behaviours (i.e. moderation effects):

***H_4*.** Trait nature connectedness will inversely predict health risk behaviours independently of nature contact, after accounting for a range of socio-demographics.

***H_5*.** Trait nature connectedness will moderate the associations between nature contact and health risk behaviours, after accounting for a range of socio-demographics.

2.3.2 Method

2.3.2.1 Participants and Procedure

Data were drawn from the BlueHealth International Survey (BIS, Grellier et al., 2017), a cross-sectional survey of 18,838 adults (9,645 females) from 18 countries/regions (Bulgaria, California [USA], Canada, Czech Republic, Estonia, Finland, France, Germany, Greece, Hong Kong [China], Ireland, Italy, the Netherlands, Portugal, Queensland [Australia], Spain, Sweden, and the United Kingdom). Samples of approximately 1000 respondents, representative with respect to age, sex, and region, were obtained for each country/region by the international polling company YouGov using online survey panels, in four seasonal waves between June 2017 and April 2018. Full details are available in the technical report (https://doi.org/10.17605/OSF.IO/7AZU2). The current study used a sub-sample of the BIS dataset (N =14,359) for cases where: 1) residential greenspace data were available and of sufficient quality; and 2) there were no missing data for any other variables. Comparison of the proportion of respondents within each socio-demographic group, indicated little variation (<.05%) as a function of the reduced sample, suggesting that there were no systematic biases in the exclusion of cases.

2.3.2.2 Measures

2.3.2.2.1 Outcome Variables

Smoking outcomes

Using the same item as in the European Social Survey (2020), respondents were asked: “Which of these best describes your smoking behaviour? This includes rolled tobacco but not pipes, cigars or electronic cigarettes.” Response options were: 1) I have never smoked, 2) I have only smoked a few times, 3) I do not smoke now but I used to, 4) I smoke but not every day, 5) I smoke daily, and 6) Prefer not to answer. Consistent with Study 1, three interrelated binary smoking indicators were created: current smoker, ever-smoker, smoking cessation. To examine the predictors of current smoking, smoking status was dichotomised according to whether respondents were current smokers (N = 3,417; 4 & 5) *vs.* non-smokers (N = 10,942, 1-3), with the latter category aggregating former regular smokers and never regular smokers. For ever-smoking, respondents were classified as ever smokers (N = 7,074; 3-5) *vs.* never-smokers (N = 7,285, 1 & 2), with those who currently smoked or were former smokers aggregated as ever-smokers. Finally, to assess predictors of smoking cessation, a binary variable was created categorising the sub-sample of ever smokers as former (N= 3,657; 3) *vs.* current smokers, with formers smoker considered to have successfully given up smoking. Those who did not answer (N = 177) were excluded from the analyses.

Exceeding alcohol guidelines (daily drinking)

Consistent with the European Social Survey (2020), respondents were asked: "In the last 12 months, how often have you had a drink containing alcohol? This could be wine, beer, spirits, or other drinks containing alcohol" (1. Never, 2. Less than once a month, 3. Once a month, 4. 2-3 times a month, 5. Once a week, 6. Several times a week, 7. Every day, and 8. Prefer not to answer. Since data on units of alcohol consumed was not included in the survey, drinking status was dichotomised according to whether or not respondents reported drinking every day (yes, N = 1,004; no, N =11,191), thus exceeding UK Department of Health (2016) recommendations of at least two alcohol-free days a week. Sensitivity analyses comparing the inclusion *vs.* exclusion of respondents who selected 'Never' (N= 2,122) produced consistent results (Appendix 7). Therefore, consistent with Study 1, the unconditional prevalence of exceeding alcohol guidelines (i.e. proportions amongst the entire sample, including non-drinkers) are reported here to maximise sample size.

2.3.2.2.2 Predictor Variables

Nature contact

Following previous research (Weinstein et al., 2015) a range of nature contact metrics were operationalised. Residential contact (neighbourhood greenspace) was determined using Normalised Difference Vegetation Index (NDVI) values, derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) terra satellite imagery. NDVI data were at 250m resolution, with values ranging between -1.0 and 1.0 (with higher values indicating a higher density of green vegetation), assigned to each respondent based on the pixel value where their home geocode was located. Sensitivity analyses conducted on different categorisations of NDVI (high *vs.* low, tertiles, quartiles, continuous variable) yielded largely consistent findings (Appendix 8). To enable comparability with previous epidemiological studies operationalising NDVI as a categorical variable (Pereira et al., 2012, Study 1) while also ensuring there were sufficient observations within each country (Appendix 8), the final models expressed NDVI in tertiles, ranging from the lowest level of surrounding greenness (M =.31, SD = .08) to the highest (M = .70, SD = .06).

Intentional contact (nature visits) was based on responses to a single item derived from Natural England’s Monitor of Engagement with the Natural Environment Survey (2018), “In the last 12 months, how often, on average, have you spent your leisure time at green and blue spaces?” (1. More than once per day, 2. Every day, 3. Several times a week, 4. Once a week, 5. Once or twice a month, 6. Once every 2-3 months, 7. Once or twice and, 8. Never). Consistent with prior research (e.g. Shanahan et al., 2016), to aid interpretability for policy makers, the item was dichotomised according to whether respondents visited at least once a week (*vs.* less than weekly = reference).

Nature Connectedness

The Inclusion of Nature in Self Scale (INS; Schultz, 2001) is a concise measure of trait nature connectedness suitable for use within a large international survey. The INS consists of seven circle pairs, labelled 'Self' and 'Nature' that range from barely touching, to entirely overlapping. Respondents were required to select the pair that best represented their sense of connection with nature. Scores on the item range from 1-7 (*M* = 4.18, *SD* = 1.64), with higher scores indicating a greater sense of affinity with the natural world.

2.3.2.2.3 Control Variables

Given that the outcome and predictor variables have been previously associated with a range of socio-demographic covariates (e.g. socio-economic status, Allen et al., 2017) several control variables were included within the multivariate analyses. Demographic controls included: gender (female, male = reference); age (18-29 = reference, 30-39, 40-49, 50-59, 60+); long-term limiting illness or disability (no = reference, yes); completed higher education (yes, no = reference); working status (unemployed= reference, employed, in education, retired, other); marital status (married/cohabiting, single/widowed/divorced = reference, undisclosed); urbanicity (rural, urban = reference) and quintiles of household income, ranging from ranging from the lowest (1st = reference) to the highest (5th). In order to retain respondents who preferred not to state their income (N = 1,914), a sixth category of 'income undisclosed' was created for this variable. With prior research indicating that dog ownership may moderate the association between nature contact and broader health outcomes (White et al., 2018) whether respondents owned a dog (yes, no = reference) was included as a covariate. Country/region of residence (Queensland [Australia] = reference, Bulgaria, California [US], Canada, Czech Republic, Estonia, Finland, France, Germany, Greece, Hong Kong [China], Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom) was also controlled for.

2.3.2.3. Analytical Approach

A series of multilevel mixed-effects Poisson regressions with robust standard errors were used to examine the associations between nature contact, nature connectedness and health risk behaviours. Following best practice guidelines for modelling clustered data (Barr et al., 2013), country/region of residence was included as random intercept, with nature contact/connectedness variables specified as random slopes. This approach accounts for national-level respondent clustering, as well as cross-country variation in nature-behaviour associations. Survey weights were applied to ensure national representativeness with regards to the sampling strata within each country (sex, age, and region of residence). Unadjusted models are reported in Appendix 9. A series of initial models were specified to examine the relative associations between nature contact, nature connectedness and health risk behaviours. Consistent with Study 1, where statistically significant associations between nature contact and outcome variables were observed, I compare their prevalence ratios to those of relevant socio-demographics. Specifically, the prevalence ratio associated with increased nature contact (greenspace and nature visits) was compared to: a) having a higher *vs.* no higher education, and b) having an income in the 5^{th} quintile (highest) *vs.* the first quintile (lowest). A second series of models were then specified to examine whether trait nature connectedness moderated the associations between nature contact and the outcome variables. Finally, extending the approach used in Study 1, a series of robustness checks are reported, including models accounting for: 1) greenspace by socio-economic status interaction effects, and 2) co-occurrence between different health risk behaviours.

2.3.3 Results

2.3.3.1 Descriptive Statistics

Descriptive data for the smoking and alcohol outcomes as a function of nature contact and covariates are presented in Table 2.3. Approximately a quarter of respondents (24%) were current smokers. Less than half of the sample (49%) reported ever having smoked, and of those respondents who had smoked, just over half (52%) had given up smoking. Less than one tenth of the sample (7%) reported exceeding recommended alcohol guidelines by drinking every day. In line with predictions, there was a lower prevalence of current smokers in the two highest tertiles of neighbourhood greenspace (T2 = 24%, T3 = 21%), compared to the lowest tertile (T1 = 26%). The proportion of ever smokers was slightly lower in the highest two neighbourhood greenspace tertiles (T1 = 50%, T2 = 49%, T3 = 49%), and amongst ever-smokers, there was a higher prevalence of successful smoking cessation in greener neighbourhoods (T1 = 47%, T2 = 52%, T3 = 56%). The proportion of individuals who exceeded alcohol recommendations was lower in the two highest greenspace tertiles (T1 = 9%, T2 = 6%, T3 = 6%).

For intentional nature contact, there was no difference in the proportion of current smokers (24%), or ever smokers (49%) amongst individuals who visited natural spaces at least once a week (*vs.* less than weekly: 24% and 49%, respectively). However, there was a slightly higher prevalence of smoking cessation (52%) and exceeding alcohol guidelines (8%) amongst those who made weekly nature visits, compared to those who visited less often (51% and 6%, respectively). At the bivariate level, nature connectedness scores were slightly higher amongst current smokers, ever-smokers and those who drank alcohol every day, relative to those who did not engage in these behaviours.

2.3.3.2 Main Findings: Initial Models

Fully adjusted mixed-effects Poisson regression models with robust standard errors estimating the prevalence ratios of smoking and alcohol outcomes, by nature contact, nature connectedness and covariates are presented in Table 2.4. Country/region of residence was included as random intercept, with nature contact/connectedness variables specified as random slopes, to account for national-level respondent clustering, as well as cross-country variation in nature-behaviour associations. All variance inflation factors (VIF) for the model's parameters were < 3.34, again indicating that multicollinearity was not an issue.

Residential contact (neighbourhood greenspace)

Supporting Hypothesis 1a, living in the highest (3^{rd}) tertile of neighbourhood greenspace was associated with a 13% lower prevalence of current smoking, compared to living in the lowest greenspace tertile (*PR* = 0.87, *95% CIs* = 0.78, 0.96, *p* = .008). For ever-smoking, lower prevalence ratios were observed as neighbourhood greenspace increased, but these associations did not reach statistical significance (T1 *vs.* T2: *PR* = 0.97, *95% CIs* = 0.91, 1.03; T1 *vs.* T3: *PR* = 0.94, *95% CIs* = 0.87, 1.01, all *p* >.05). In line with Hypothesis 1b, amongst respondents who had ever smoked, there was a trend towards a higher prevalence of smoking cessation for those who lived in the 3^{rd} tertile of neighbourhood greenspace (*vs.* 1^{st} tertile; *PR* = 1.08, *95% CIs* = 0.98, 1.19, *p* = .104).

Table 2.3. Respondent characteristics according to health risk behaviour status.

			Current smoker (N =14,359)		**Ever Smoker** (N =14,359)		**Smoking Cessation** (N = 7,074)		**Exceeds Alcohol Guidelines**[a] (N = 14,317)	
	Total % Raw Data	**Total % Weighted**	**No**[b] (76%)	**Yes**[b] (24%)	**No**[b] (51%)	**Yes**[b] (49%)	**No**[b] (48%)	**Yes**[b] (52%)	**No**[b] (93%)	**Yes**[b] (7%)
Greenspace (NDVI)										
1st Tertile (M = .31)	34%	34%	74%	26%	50%	50%	53%	47%	91%	09%
2nd Tertile (M = .52)	33%	33%	76%	24%	51%	49%	48%	52%	94%	06%
3rd Tertile (M = .70)	33%	33%	79%	21%	51%	49%	44%	56%	94%	06%
Nature visits										
< once a week	42%	42%	76%	24%	51%	49%	49%	51%	94%	06%
≥ once a week	58%	58%	76%	24%	51%	49%	48%	52%	92%	08%
Nature Connectedness[c]	4.18 (1.64)	4.18 (1.64)	4.15 (1.63)	4.28 (1.68)	4.07 (1.62)	4.29 (1.66)	4.28 (1.68)	4.29 (1.63)	4.16 (1.63)	4.45 (1.74)
Gender										
Male	49%	49%	75%	25%	47%	53%	47%	53%	90%	10%
Female	51%	51%	77%	23%	54%	46%	49%	51%	95%	05%
Age										
18-29	18%	18%	79%	21%	69%	31%	65%	35%	97%	03%
30-39	18%	18%	73%	27%	55%	45%	59%	41%	95%	05%
40-49	19%	18%	73%	27%	50%	50%	55%	45%	94%	06%
50-59	18%	17%	72%	28%	43%	57%	49%	51%	92%	08%
60+	27%	29%	81%	19%	43%	57%	33%	67%	88%	12%
Marital status										
Single/widowed/divorced	36%	36%	74%	26%	54%	46%	56%	44%	94%	06%
Married/cohabiting	60%	60%	77%	23%	48%	52%	44%	56%	92%	08%
Undisclosed	04%	04%	79%	21%	63%	37%	56%	44%	96%	04%
Higher education										
No	49%	49%	73%	27%	45%	55%	50%	50%	93%	07%
Yes	51%	51%	79%	21%	56%	44%	47%	53%	93%	07%

Table 2.3 continued

Working status										
Unemployed	06%	06%	73%	27%	51%	49%	55%	45%	94%	06%
Employed	55%	55%	74%	26%	52%	48%	54%	46%	94%	06%
In education	07%	07%	85%	15%	74%	26%	57%	43%	98%	02%
Retired	20%	20%	83%	17%	43%	57%	29%	71%	87%	13%
Other	12%	12%	71%	29%	47%	53%	54%	46%	95%	05%
Household income										
1st quintile (lowest)	16%	16%	71%	29%	49%	51%	57%	43%	95%	05%
2nd quintile	15%	15%	74%	26%	46%	54%	49%	51%	94%	06%
3rd quintile	16%	16%	75%	25%	48%	52%	47%	53%	92%	08%
4th quintile	18%	18%	78%	22%	51%	49%	46%	54%	92%	08%
5th quintile (highest)	22%	22%	78%	22%	53%	47%	47%	53%	91%	09%
Undisclosed	13%	13%	82%	18%	58%	42%	43%	57%	95%	05%
Dog owner										
No	69%	69%	79%	21%	53%	47%	45%	55%	93%	07%
Yes	31%	31%	70%	30%	45%	55%	54%	46%	92%	08%
Disability										
No	63%	63%	77%	23%	54%	46%	49%	51%	93%	07%
Yes	37%	37%	74%	26%	44%	56%	47%	53%	92%	08%
Urbanicity										
Rural	34%	34%	75%	25%	48%	52%	47%	53%	93%	07%
Urban	66%	66%	77%	23%	52%	48%	49%	51%	93%	07%
Country/region										
Queensland (Australia)	05%	05%	75%	25%	48%	52%	48%	52%	87%	13%
Bulgaria	06%	06%	62%	38%	38%	62%	61%	39%	88%	12%
California (USA)	05%	05%	87%	13%	64%	36%	38%	62%	94%	06%
Canada	06%	05%	76%	24%	53%	47%	52%	48%	92%	08%
Czech Republic	06%	06%	71%	29%	50%	50%	58%	42%	94%	06%
Estonia	05%	05%	73%	27%	47%	53%	51%	49%	97%	03%
Finland	06%	06%	81%	19%	50%	50%	38%	62%	97%	03%
France	06%	06%	76%	24%	49%	51%	47%	53%	92%	08%
Germany	06%	06%	73%	27%	45%	55%	49%	51%	95%	05%

Table 2.3 continued

Greece	04%	05%	66%	34%	39%	61%	56%	44%	97%	03%
Hong Kong (China)	02%	03%	89%	11%	82%	18%	62%	38%	99%	01%
Ireland	06%	06%	78%	22%	51%	49%	45%	55%	96%	04%
Italy	06%	06%	70%	30%	50%	50%	60%	40%	91%	09%
Netherlands	06%	06%	80%	20%	51%	49%	41%	59%	90%	10%
Portugal	05%	06%	79%	21%	54%	46%	47%	53%	88%	12%
Spain	06%	06%	71%	29%	47%	53%	55%	45%	89%	11%
Sweden	06%	06%	86%	14%	56%	44%	31%	69%	98%	02%
United Kingdom	06%	06%	86%	14%	57%	43%	32%	68%	93%	07%

Note: First two column percentages relate to total sample. All other percentages relate to % within each exposure category across each domain of health risk behaviour. [a] Drinks every day [b]Using weighted data [c]Mean (Standard Deviation) reported for continuous variables.

Table 2.4. Fully adjusted mixed effects models, estimating the prevalence ratios (PR) and 95% CIs for the associations between nature contact, nature connectedness and health risk behaviours, controlling for covariates.

	Current Smoker			**Ever Smoker**			**Smoking Cessation**			**Exceeds Alcohol Guidelines**[a]		
	PR	***95% CIs***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***
Neighbourhood Greenspace (NDVI)												
1st Tertile (*M* = .31, least green, ref)												
2nd Tertile (*M* = .52)	0.94	(0.86, 1.02)	.150	0.97	(0.91, 1.03)	.309	1.06	(0.97, 1.16)	.170	0.75	(0.64, 0.88)	<.001
3rd Tertile (*M* = .70, most green)	0.87	(0.78, 0.96)	.008	0.94	(0.87, 1.01)	.093	1.08	(0.98, 1.19)	.104	0.79	(0.66, 0.96)	.016
Nature Visits												
<once a week (ref)												
≥ once a week	0.91	(0.83, 0.99)	.033	0.98	(0.93, 1.03)	.371	1.06	(0.99, 1.14)	.103	1.09	(0.90, 1.31)	.380
Nature Connectedness (INS)	1.02	(0.99, 1.04)	.157	1.01	(0.99, 1.02)	.319	0.99	(0.97, 1.01)	.379	1.03	(0.98, 1.07)	.265
Gender (female)	0.90	(0.84, 0.96)	.001	0.87	(0.83, 0.91)	<.001	0.98	(0.91, 1.04)	.489	0.49	(0.43, 0.56)	<.001
Age												
18-29 (ref)												
30-39	1.24	(1.10, 1.39)	<.001	1.33	(1.21, 1.46)	<.001	1.11	(0.96, 1.30)	.163	1.49	(1.09, 2.04)	.012
40-49	1.24	(1.11, 1.39)	<.001	1.43	(1.30, 1.57)	<.001	1.24	(1.07, 1.44)	.004	1.75	(1.29, 2.37)	<.001
50-59	1.25	(1.11, 1.40)	<.001	1.57	(1.43, 1.72)	<.001	1.40	(1.21, 1.62)	<.001	2.22	(1.65, 3.00)	<.001
60+	1.05	(0.92, 1.20)	.428	1.64	(1.48, 1.81)	<.001	1.62	(1.39, 1.89)	<.001	3.13	(2.30, 4.26)	<.001
Marital status												
Single/widowed/divorced (ref)												
Married/cohabiting	0.85	(0.79, 0.91)	<.001	1.06	(1.00, 1.12)	.055	1.23	(1.14, 1.34)	<.001	1.16	(0.99, 1.35)	.061
Undisclosed	0.88	(0.73, 1.05)	.145	0.94	(0.81, 1.08)	.353	1.16	(0.94, 1.42)	.157	1.22	(0.81, 1.84)	.336
Higher education (yes)	0.77	(0.72, 0.82)	<.001	0.80	(0.76, 0.84)	<.001	1.03	(0.96, 1.11)	.351	0.96	(0.84, 1.10)	.587
Working status												
Unemployed (ref)												
Employed	1.12	(0.98, 1.27)	.105	1.04	(0.93, 1.15)	.498	0.94	(0.81, 1.10)	.455	0.89	(0.66, 1.19)	.422
In education	0.65	(0.53, 0.80)	<.001	0.72	(0.61, 0.84)	<.001	1.09	(0.85, 1.40)	.479	0.55	(0.32, 0.94)	.030
Retired	0.75	(0.63, 0.89)	.001	1.01	(0.89, 1.14)	.892	1.15	(0.97, 1.35)	.115	1.20	(0.87, 1.65)	.262
Other	1.12	(0.96, 1.30)	.143	1.03	(0.92, 1.16)	.593	0.97	(0.82, 1.15)	.696	0.79	(0.56, 1.12)	.184

Table 2.4 continued

Household income												
1st quintile (lowest, ref)												
2nd quintile	0.94	(0.84, 1.05)	.277	1.01	(0.93, 1.10)	.758	1.07	(0.95, 1.21)	.254	0.95	(0.74, 1.24)	.725
3rd quintile	0.88	(0.79, 0.99)	.029	0.99	(0.91, 1.08)	.778	1.11	(0.98, 1.26)	.093	1.24	(0.97, 1.58)	.088
4th quintile	0.82	(0.73, 0.92)	.001	0.94	(0.86, 1.03)	.196	1.17	(1.03, 1.32)	.016	1.15	(0.89, 1.47)	.282
5th quintile (highest)	0.80	(0.71, 0.90)	<.001	0.94	(0.86, 1.03)	.172	1.17	(1.03, 1.33)	.019	1.31	(1.02, 1.69)	.033
Undisclosed	0.72	(0.63, 0.82)	<.001	0.88	(0.80, 0.97)	.009	1.22	(1.07, 1.39)	.003	0.98	(0.74, 1.30)	.879
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.18	(1.12, 1.24)	<.001	0.87	(0.81, 0.94)	<.001	1.22	(1.07, 1.40)	.004
Disability (yes)	1.15	(1.08, 1.24)	<.001	1.16	(1.10, 1.22)	<.001	1.01	(0.94, 1.08)	.741	1.18	(1.03, 1.34)	.018
Urban (yes)	0.96	(0.88, 1.03)	.256	0.99	(0.93, 1.04)	.635	1.02	(0.95, 1.10)	.595	0.89	(0.76, 1.03)	.115
Intercept	0.27	(0.22, 0.35)	<.001	0.37	(0.31, 0.44)	<.001	0.29	(0.23, 0.36)	<.001	0.03	(0.02, 0.05)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**		**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.03)		0.00	(0.00, 0.03)		0.00	(0.00, 0.02)	
Nature visits	0.01	(0.00, 0.04)		0.00	(0.00, 0.03)		0.00	(0.00, 0.03)		0.03	(0.02, 0.08)	
Nature connectedness	0.00	(0.00, 0.02)		0.00	(0.00, 0.04)		0.00	(0.00, 0.04)		0.01	(0.00, 0.02)	
Intercept	0.09	(0.04, 0.18)		0.20	(0.13, 0.40)		0.13	(0.08, 0.20)		0.02	(0.01, 0.04)	
χ^2 (df)	442.81 (24) ***				510.20(24)***		265.26(24)***			401.16(24)***		
Log likelihood	-8779.41				-11753.60		-5904.28			-3348.45		
Marginal R^2	.04				.08		.09			.04		
Conditional R^2	.16				.15		.30			.17		

Notes: All models use survey weights. *PR* = Prevalence Ratio. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** *p* <.001 [a] *Drinks every day;* Marginal R^2 includes only fixed effects and Conditional R^2 includes the random country effect.

However, perhaps due to the reduced sample size for this variable, these associations did not meet the threshold for statistical significance. In line with Hypothesis 3a, residing in the 2nd and 3rd greenspace tertiles (*vs.* 1st tertile) was associated with a 25% and 21% lower prevalence of exceeding alcohol guidelines (*PR* = 0.75, *95% CIs* = 0.64, 0.88, *p* <.001; *PR* = 0.79, *95% CIs* 0.66, 0.96, *p* = .016, respectively).

Intentional contact (nature visits)

Consistent with Hypothesis 2a, visiting natural spaces at least once a week (*vs.* < once a week) was associated with 9% lower prevalence of current smoking (*vs.* < once a week: *PR* = 0.91, *95% CIs* = 0.93, 1.03, *p* = .033). There was: a) a lower prevalence of ever-smokers (*PR* = 0.98, *95% CIs* = 0.93, 1.03, *p* = .371) and, *b*) a higher incidence of smoking cessation (*PR* = 1.06, *95% CIs* = 0.99, 1.14, *p* = .103) amongst respondents who visited natural spaces once a week (*vs.* < once a week), but again, these associations were not statistically significant. Regarding Hypothesis 3b, individuals who visited natural spaces at least once a week (*vs.* < once a week), had a higher prevalence of exceeding recommended alcohol limits, but with wide ranging confidence intervals this association was not statistically significant (*PR* = 1.09, *95% CIs* = 0.90 1.31, *p* = .380).

Nature connectedness

Contrary to Hypothesis 4, nature connectedness was not independently associated with any of the behavioural outcomes (current smoker: *PR* = 1.02, *95% CIs* = 0.99, 1.04, *p* = .157; ever smoker: *PR* = 1.01, *95% CIs* = 0.99, 1.02, *p* = .319; smoking cessation; *PR* = 0.99, *95% CIs* = 0.97, 1.01, *p* = .379; exceeding alcohol guidelines: *PR* = 1.03, *95% CIs* = 0.98, 1.07, *p* = .265).

Relative magnitude of nature-behaviour associations

Although widely used in environmental psychology, with recognition that p-values offer limited value in determining the magnitude of an effect and by implication its practical significance (Schober, Bossers & Schwarte, 2018), the prevalence ratios associated with statistically significant nature contact indices were compared to those that were non-significant. Although not statistically significant, a one scale increase in nature connectedness was associated with a 2% higher current smoking prevalence (*PR* = 1.02, *95% CIs* = 0.99, 1.04). In relative terms this was smaller in magnitude than the 13% and 9% lower prevalence associated with living in the 3rd (*vs.* 1st) greenspace tertile (*PR* = 0.87, *95% CIs* = 0.78, 0.96, p = .008) and weekly nature visits (*PR* = 0.91, *95% CIs* = 0.93, 1.03, p = .033), respectively. This remained the case even when considering a more substantial change in nature connectedness, for example, having a nature connectedness score one standard deviation above the mean (*vs.* one standard deviation below the mean; White et al., 2013) was associated with a 7% higher current smoking prevalence.

For drinking behaviour, residing in neighbourhoods in the 2nd and 3rd greenspace tertiles (*vs*. 1st tertile) was associated with a 25% and 21% lower prevalence of exceeding alcohol guidelines (P*R* = 0.75, *95% CIs* = 0.64, 0.88, p <.001; *PR* = 0.79, *95% CIs* 0.66, 0.96, p = .016, respectively). This was considerably larger in magnitude than the 9% and 3% higher prevalence associated with non-significant nature contact/connectedness indicators (nature visits: PR = 1.09, 95% CIs = 0.90 1.31, p = .380; nature connectedness: *PR* = 1.03, *95% CIs* = 0.98, 1.07, p= .265). Again, even when considering a more substantial change, the latter corresponds to a 10% higher prevalence associated with having a nature connectedness score one standard deviation above (*vs*. one standard deviation below the mean). Taken together, these comparisons indicate that the magnitude of statistically significant nature-behaviour associations exceeded those of non-significant nature-behaviour associations.

Covariates

Females (*vs.* males) had a lower prevalence of both current smoking (*PR* = 0.90, *95% CIs* = 0.84, 0.96, *p* = .001) and exceeding alcohol guidelines (*PR* = 0.49, *95% CIs* = 0.43, 0.56, *p* <.001). Younger adults (18-29 years) were less likely to be current smokers, or to exceed alcohol guidelines compared to older adults (e.g. 50- 59 years: *PR* = 1.25, *95% CIs* = 1.11, 1.40, p <.001 and *PR* = 2.22, *95% CIs* = 1.65, 3.00, *p* <.001, respectively). Having a higher education (*vs.* no higher education) was associated with a lower prevalence of current smoking (*PR* = 0.77, *95% CIs* = 0.72, 0.82, *p* <.001), but unrelated to exceeding alcohol guidelines (*PR* = 0.96, *95% CIs* = 0.84, 1.10, *p* = .587). As household income increased, the prevalence of current smoking decreased incrementally; for exceeding alcohol guidelines, however, prevalence was highest amongst those in the highest income quintile (*vs.* lowest: *PR* = 1.31, *95% CIs* = 1.02, 1.69, *p* = .033). Having a disability (*vs.* no disability) and owning a dog (*vs.* not owning a dog) were associated with higher rates of current smoking (*PR* = 1.15, *95% CIs* = 1.08, 1.24, *p* < .001; *PR* = 1.38, *95% CIs* = 1.29, 1.48, *p* <.001 respectively) and exceeding alcohol guidelines (*PR* = 1.18, *95% CIs* = 1.03, 1.34, *p* = .018; *PR* = 1.22, *95% CIs* = 1.07, 1.40, *p* = .004 respectively). Living in an urban (*vs.* rural) neighbourhood was unrelated to current smoking (*PR* = 0.96, *95% CIs* = 0.88, 1.03, *p* = .256) or exceeding alcohol guidelines (*PR* = 0.89, *95% CIs* = 0.76, 1.03, *p* = .115).

Variation in Nature-behaviour associations by country/region.

The random effect terms (bottom of Table 2.4) indicated a small degree of country/region variance in the associations between: a) neighbourhood greenspace and behavioural outcomes (current smoker: *95% CIs* = 0.00, 0.04; ever-smoker: *95% CIs* =

0.00, 0.03; smoking cessation: *95% CIs* = 0.00, 0.03; exceeds alcohol guidelines: *95% CIs* = 0.00, 0.02); and b) nature connectedness and behavioural outcomes (current smoker: *95% CIs* = 0.00, 0.02; ever-smoker: *95% CIs* = 0.00, 0.01; smoking cessation: *95% CIs* = 0.00, 0.04; exceeds alcohol guidelines: *95% CIs* = 0.00, 0.02). For nature visits, variance in health (risk) behaviours as a function of country/region was higher for exceeding alcohol guidelines (*95% CIs* = 0.02, 0.08), than current smoking (*95% CIs*= 0.00, 0.04), ever smoking (*95% CIs* 0.00, 0.03) and smoking cessation (*95% CIs* 0.00, 0.03).

Country/region heterogeneity in statistically significant nature-behaviour associations (i.e. greenspace- current smoking, greenspace-exceeding alcohol guidelines and nature visits- current smoking), is depicted in Figure 2.1 and Figure 2.2. For current smoking prevalence (Figure 2.1a), there was a trend towards a lower smoking prevalence amongst individuals who lived in the highest (3^{rd} *vs.* 1^{st}- lowest) greenspace tertile in 16/18 countries/regions. Exceptions were the Czech Republic and California (USA), in which there was little difference in smoking prevalence as a function of neighbourhood greenspace. As shown in Figure 2.1b, the trend towards a lower prevalence of exceeding alcohol guidelines amongst respondents who lived in the two highest greenspace tertiles (*vs.* the lowest) was remarkably consistent across countries/regions.

The predicted prevalence of current smoking for each country/region by frequency of nature visits are depicted in Figure 2.2. There was a general trend towards a lower smoking prevalence amongst individuals who visited nature at least once a week (*vs.* less than once a week) for 12/18 of the countries/regions. Exceptions to this were: Greece, Italy, France, Canada, California (USA) and Queensland (Australia), in which there was little difference in smoking prevalence between respondents who visited natural spaces weekly (*vs.* less than once a week). In sum, the pattern of nature-behaviour associations observed within the main models were largely consistent between countries/regions for: a) neighbourhood greenspace and both domains of health risk behaviour, but there was greater heterogeneity in the slopes for nature visits and current smoking.

2.3.3.3 Comparison to Socio-Demographics

Where statistically significant associations between greenspace and behavioural outcomes were observed (i.e. current smoking and exceeding alcohol guidelines), the prevalence ratio associated with increased nature contact (greenspace and nature visits) was compared to: a) having completed a higher education *vs.* not; and b) having an income in the 5th quintile (highest) *vs.* the first quintile (lowest).

For current smoking, living in the highest (3rd) tertile of neighbourhood greenspace was associated with a 13% lower prevalence of current smoking, compared to living in the lowest greenspace tertile (*PR = 0.87, 95% CIs = 0.78, 0.96, p = .008*). This was over half the size of the 23% and 20% lower prevalence associated with having a higher education (*vs.* not having a higher education; *PR = 0.77, 95% CIs = 0.72, 0.82, p <.001*) and having an income in the 5th quintile (*vs.* 1st quintile, *PR* = .80, (*95% CIs* = 0.71, 0.90, *p* < .001), respectively. Visiting natural spaces at least once a week was associated with 9% lower prevalence of current smoking (*vs.* < once a week: *PR* = 0.91, *95% CIs* = 0.93, 1.03, *p* = .033), which was smaller than the reductions associated with both residential greenspace and the two socio-demographic comparators.

Conversely, residing in the 2nd and 3rd greenspace tertiles (*vs.* 1st tertile) was associated with a 25% and 21% lower prevalence of exceeding alcohol guidelines (*PR* = 0.75, *95% CIs* = 0.64, 0.88, *p* <.001*; PR* = 0.79, *95% CIs* 0.66, 0.96, *p* = .016, respectively). This was greater in magnitude than those associated with having a higher

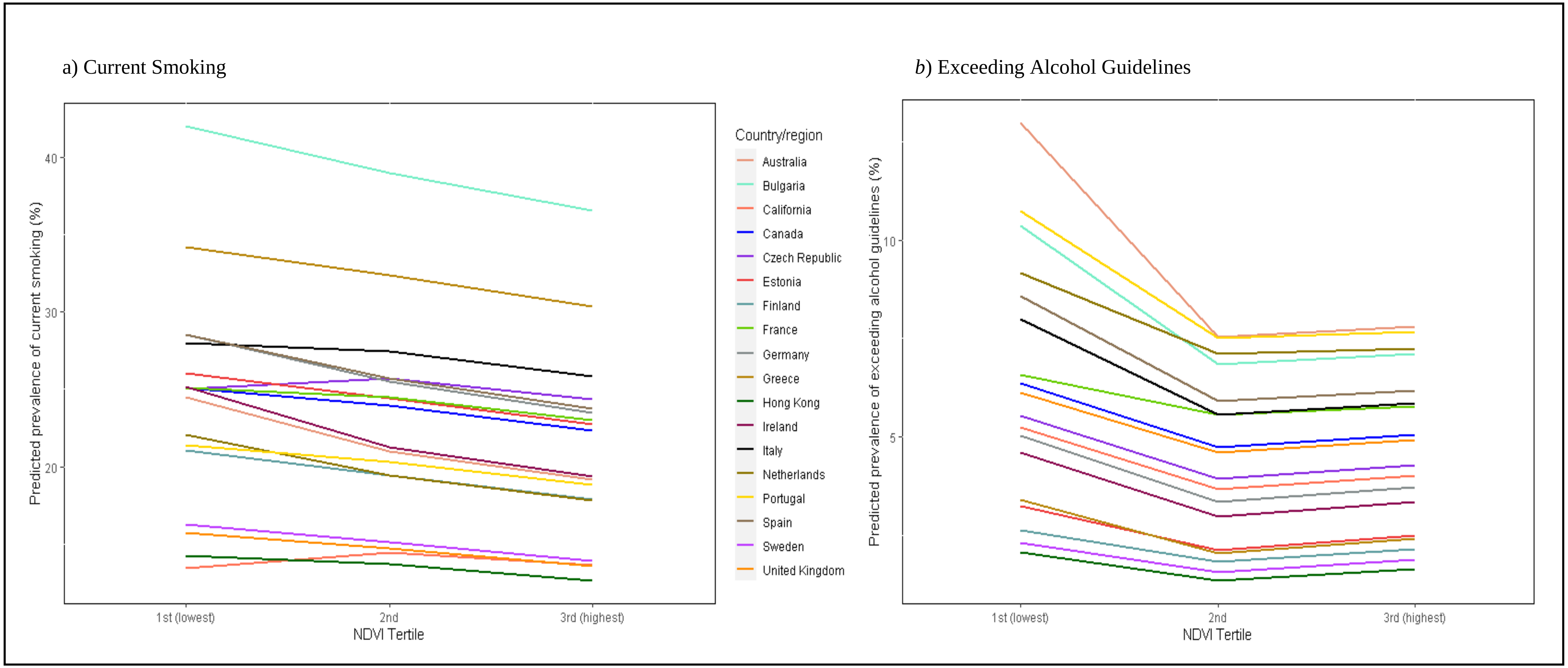

Figure 2.1 Predicted prevalence (%) of health risk behaviours for each county/region by tertile of neighbourhood greenspace (NDVI)

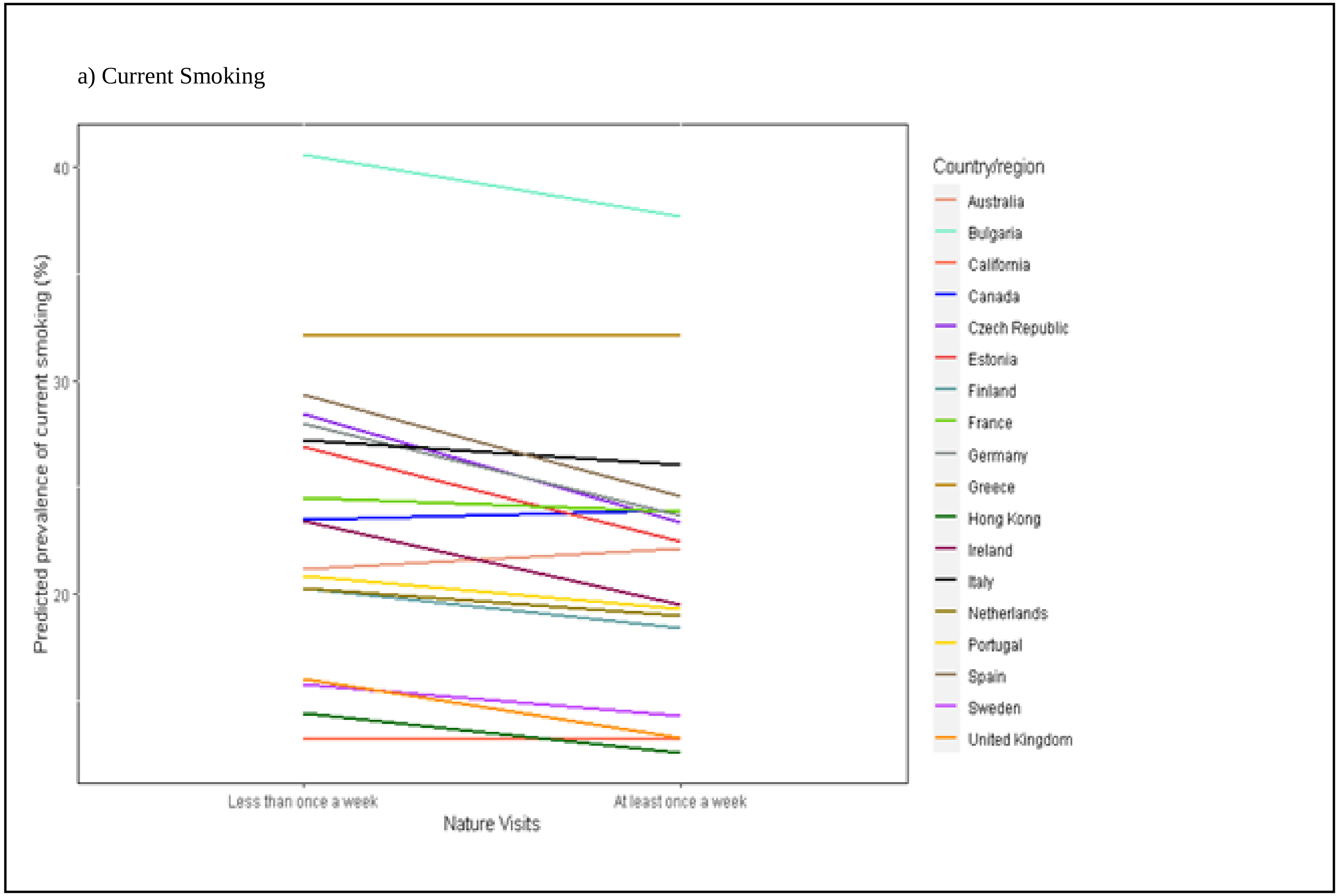

Figure 2.2 Predicted prevalence (%) of current smoking for each county/region by frequency of nature visit

education (*PR* = 0.96, *95% CIs* = 0.84, 1.10, *p* = .587), but smaller than the *higher* prevelance in exceeding alcohol guidleines associated with having an income in the 5th quintile (*PR* = 1.31, *95% CIs* = 1.02, 1.69, *p* = .033). Overall, these comparisons suggest that, in relative terms, for being a current smoker, the effects of neighbourhood greenspace are greater in magnitude than those of nature visits, but around half the size of those associated with benchmark socio-demographics. For exceeding alcohol guidelines, the effects of neighbourhood greenspace exceeded those of education, but were smaller in magnitude than the higher prevalence associated with income.

2.3.3.4 Main findings: Moderation Models

Fully adjusted mixed-effects Poisson regression models estimating the adjusted prevalence ratios of smoking and alcohol outcomes by nature contact, nature connectedness and their interactions terms are reported in Table 2.5.

Residential contact (neighbourhood greenspace)

There were no statistically significant greenspace by nature connectedness interaction effects for current smoking, ever-smoking or smoking cessation. Conversely, nature connectedness moderated the association between residential nature contact (neighbourhood greenspace) and exceeding recommended alcohol guidelines (3rd *vs.* 1st tertile: *PR* = .91, *95% CIs* = 0.83, 0.99, *p* = .036; Wald $\chi 2$ omnibus test: *F*(2, 1429) = 4.23, *p* = .039). As depicted in Figure 2.3, for individuals who felt less connected to nature, the amount of neighbourhood greenspace had little impact on exceeding alcohol guidelines. However, for individuals highly connected to nature, residing in the lowest greenspace neighbourhoods was associated with a higher probability of individuals exceeding alcohol guidelines.

Table 2.5. Fully adjusted mixed effect models, estimating the prevalence ratios (PR) and 95% CIs for the associations between nature contact, nature connectedness, health risk behaviours and their interaction terms, whilst controlling for covariates

	Current Smoker			Ever Smoker			Smoking Cessation			Exceeds Alcohol Guidelines[a]		
	PR	***95% CIs***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***
Fixed effects												
Neighbourhood Greenspace (NDVI)												
1st Tertile (*M* = .31, least green, ref)												
2nd Tertile (*M* = .52)	0.92	(0.74, 1.15)	.473	1.00	(0.85, 1.18)	.975	1.13	(0.90, 1.42)	.298	0.99	(0.64, 1.55)	.975
3rd Tertile (*M* = .70, most green)	1.01	(0.80, 1.28)	.935	1.08	(0.92, 1.28)	.337	1.08	(0.85, 1.36)	.525	1.24	(0.79, 1.94)	.356
Nature Visits												
<once a week (ref)												
≥ once a week	0.95	(0.78, 1.14)	.568	0.94	(0.82, 1.07)	.364	0.98	(0.81, 1.18)	.802	1.33	(0.90, 1.96)	.149
Nature Connectedness (INS)	1.03	(0.99, 1.08)	.128	1.02	(0.99, 1.05)	.285	0.98	(0.94, 1.03)	.462	1.11	(1.03, 1.19)	.009
Neighbourhood Greenspace X INS												
1st Tertile x INS (ref)												
2nd Tertile X INS	1.00	(0.96, 1.05)	.881	0.99	(0.96, 1.03)	.644	0.99	(0.94, 1.04)	.572	0.94	(0.85, 1.03)	.180
3rd Tertile X INS	0.96	(0.92, 1.01)	.159	0.97	(0.93, 1.00)	.058	1.00	(0.95, 1.05)	.976	0.91	(0.83, 0.99)	.036
Nature Visits X INS												
<once a week X INS (ref)												
≥ once a week X INS	0.99	(0.95, 1.03)	.654	1.01	(0.98, 1.04)	.531	1.02	(0.98, 1.06)	.354	0.95	(0.88, 1.03)	.255
Gender (female)	0.90	(0.84, 0.96)	.001	0.87	(0.83, 0.91)	<.001	0.98	(0.91, 1.04)	.493	0.49	(0.43, 0.56)	<.001
Age												
18-29 (ref)												
30-39	1.24	(1.10, 1.39)	<.001	1.33	(1.21, 1.46)	<.001	1.11	(0.96, 1.30)	.165	1.49	(1.09, 2.04)	.012
40=49	1.24	(1.10, 1.39)	<.001	1.42	(1.30, 1.56)	<.001	1.24	(1.07, 1.44)	.004	1.75	(1.29, 2.37)	<.001
50-59	1.25	(1.11, 1.40)	<.001	1.57	(1.43, 1.73)	<.001	1.40	(1.21, 1.62)	<.001	2.23	(1.65, 3.00)	<.001
60+	1.06	(0.93, 1.20)	.418	1.64	(1.48, 1.82)	<.001	1.62	(1.39, 1.89)	<.001	3.14	(2.30, 4.27)	<.001
Marital status												
Single/widowed/divorced (ref)												
Married/cohabiting	0.85	(0.79, 0.91)	<.001	1.05	(1.00, 1.11)	.057	1.23	(1.14, 1.33)	<.001	1.16	(0.99, 1.35)	.059
Undisclosed	0.88	(0.73, 1.04)	.141	0.94	(0.81, 1.07)	.346	1.16	(0.94, 1.42)	.157	1.21	(0.80, 1.82)	.362

Table 2.5 continued

Higher education (yes)	0.77	(0.72, 0.82)	<.001	0.80	(0.76, 0.84)	<.001	1.03	(0.96, 1.11)	.346	0.96	(0.84, 1.10)	.588
Working status												
Unemployed (ref)												
Employed	1.12	(0.98, 1.27)	.107	1.04	(0.93, 1.15)	.505	0.94	(0.81, 1.10)	.456	0.89	(0.66, 1.19)	.417
In education	0.65	(0.53, 0.80)	<.001	0.72	(0.61, 0.84)	<.001	1.09	(0.86, 1.40)	.476	0.55	(0.32, 0.95)	.032
Retired	0.75	(0.63, 0.89)	.001	1.01	(0.89, 1.14)	.910	1.15	(0.97, 1.36)	.115	1.20	(0.87, 1.65)	.265
Other	1.12	(0.96, 1.30)	.142	1.03	(0.92, 1.16)	.596	0.97	(0.82, 1.15)	.691	0.79	(0.56, 1.11)	.181
Household income												
1st quintile (lowest, ref)												
2nd quintile	0.94	(0.84, 1.05)	.288	1.01	(0.93, 1.10)	.746	1.07	(0.95, 1.21)	.251	0.96	(0.74, 1.24)	.753
3rd quintile	0.88	(0.79, 0.99)	.031	0.99	(0.91, 1.08)	.785	1.11	(0.98, 1.26)	.093	1.24	(0.97, 1.59)	.085
4th quintile	0.82	(0.73, 0.92)	.001	0.94	(0.87, 1.03)	.200	1.17	(1.03, 1.33)	.016	1.15	(0.90, 1.48)	.269
5th quintile (highest)	0.80	(0.71, 0.90)	<.001	0.94	(0.86, 1.03)	.170	1.17	(1.03, 1.33)	.019	1.32	(1.02, 1.69)	.032
Undisclosed	0.72	(0.63, 0.82)	<.001	0.88	(0.80, 0.97)	.009	1.22	(1.07, 1.39)	.003	0.98	(0.74, 1.30)	.888
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.16	(1.10, 1.22)	<.001	0.87	(0.81, 0.94)	<.001	1.22	(1.06, 1.40)	.004
Disability (yes)	1.15	(1.08, 1.24)	<.001	1.18	(1.12, 1.24)	<.001	1.01	(0.94, 1.08)	.739	1.17	(1.03, 1.34)	.018
Urban	0.96	(0.88, 1.03)	.259	0.99	(0.93, 1.04)	.620	1.02	(0.94, 1.10)	.619	0.88	(0.76, 1.03)	.109
Intercept	0.26	(0.20, 0.34)	<.001	0.35	(0.29, 0.43)	<.001	0.29	(0.22, 0.39)	<.001	0.02	(0.01, 0.04)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**		**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.03)		0.00	(0.00, 0.03)		0.00	(0.00, 0.07)	
Nature visits	0.01	(0.00, 0.08)		0.00	(0.00, 0.03)		0.00	(0.00, 0.02)		0.24	(0.11, 0.49)	
Nature connectedness	0.00	(0.00, 0.02)		0.00	(0.00, 0.01)		0.00	(0.00, 0.09)		0.00	(0.00, 0.05)	
Intercept	0.09	(0.04, 0.18)		0.20	(0.14, 0.31)		0.13	(0.08, 0.20)		0.53	(0.35, 0.80)	
χ^2 (df)	446.18(27)***			514.46(27)***			266.06(27)***			409.57(27)***		
Log likelihood	-8777.85			-11751.53			-5903.5821			-3345.3912		
Marginal R^2	.04			.08			.09			.04		
Conditional R^2	.16			.14			.30			.17		

Notes: All models use survey weights. *PR* = Prevalence Ratio. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** *p* <.001 [a] *Drinks every day;* Marginal R^2 includes only fixed effects and Conditional R^2 includes the random country effect.

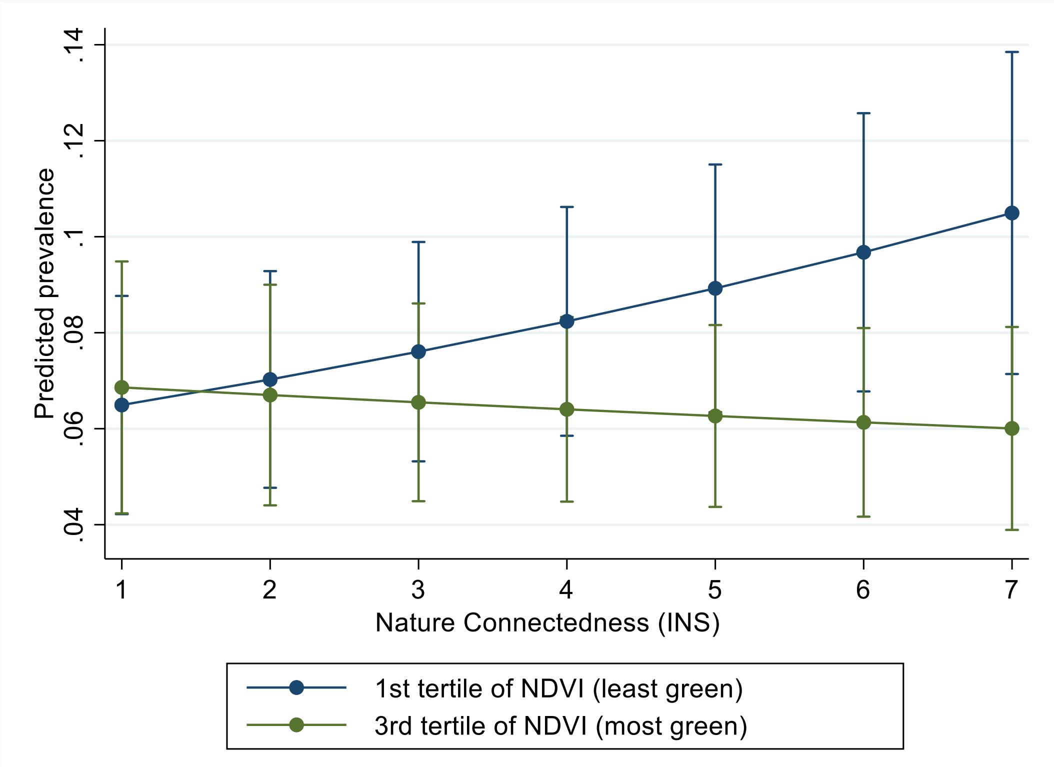

Figure 2.3 Predicted prevalence of exceeding alcohol guidelines, as a function of neighbourhood greenspace and nature connectedness.

2.3.3.4.2 Intentional contact (nature visits)

No additional moderation effects of nature connectedness were found for the associations between nature visits and any of the behavioural outcomes.

2.3.3.5 Robustness Checks

Moderation effects by socio-status (Appendix 10)

Overall, there was little evidence of moderation effects by socio-economic group in the greenspace tertiles where the differences in outcomes as a function of neighbourhood greenspace were most pronounced (i.e. between the 1st and 3rd greenspace tertiles for current smoking and between all tertiles for exceeding recommended alcohol guidelines). The only such effect was that individuals who were in the 3rd quintile of household income and lived in the 3rd tertile of neighbourhood greenspace (*vs.* those in the first income quintile, residing in the lowest greenspace tertile) were more likely to exceed recommended alcohol guidelines (*PR* = 1.88, *95% CIs* = 1.08, 3.30, *p* = .027). Overall, this suggests that the associations between neighbourhood greenspace, current smoking and exceeding alcohol guidelines were not simply an artefact of higher socio-economic groups residing in greener areas.

Accounting for Co-occurrence of Health risk Behaviours (Appendix 11)

Consistent with Study 1, adjustment for other health risk behaviours did little to alter the associations between nature contact and connectedness and behavioural outcomes observed within the main models. Thus, similar associations between nature contact, current smoking and exceeding alcohol guidelines are unlikely to be due to shared variance between different domains of health risk behaviours

2.3.4 Discussion of Main Findings

Study 2 investigated the associations between two types of nature contact, nature connectedness and the prevalence of two domains health risk behaviour using an international sample from 18 countries/regions. The study aims were two-fold: 1) to examine the relative associations between different types of nature contact and the prevalence of health risk behaviours and, 2) to explore what role nature connectedness played in these associations. Within this Section, the main findings of Study 2 are discussed and, where applicable, compared to those of Study 1.

There was evidence that residential nature contact (neighbourhood greenspace) was negatively related to both domains of health risk behaviours. These associations were upheld after adjusting for a broad range of covariates, including country/region, and other health (risk) behaviours. This suggests that the relationships between greenspace and health risk behaviours are not specific to current smoking prevalence in England (Study 1), but generalise across a wide range of countries and two domains of health risk behaviours. Further, these associations were robust to different operationalisations of greenspace, and largely unmoderated by two measures of socio-economic status. Taken together, these findings suggest that high greenspace neighbourhoods are independently associated with a lower prevalence of two distinct types of health risk behaviour, irrespective of the socio-demographic characteristics of the individuals who reside in them. For smoking behaviours, consistent with Study 1 and prior bivariate observations (Astell-Burt, Feng & Kolt ,2014; Van Herzele & de Vries, 2012) there was a lower prevalence of current smoking amongst individuals living in the highest (*vs.* lowest) greenspace neighbourhoods. Such consistency between studies situates neighbourhood greenspace as a robust and largely overlooked predictor of current smoking prevalence.

Nevertheless, evidence regarding the precise mechanism by which greenspace influences current smoking was less conclusive. Despite observing a lower prevalence of ever smokers and a higher prevalence of smoking cessation within high greenspace neighbourhoods, neither association reached statistical significance. Divergent findings between Study 1 and Study 2 in this respect may be due to the inclusion of country/region within the latter. With regional disparities in smoking uptake and maintenance (WHO, 2018b) it is possible that once these differences are accounted for, the influences of neighbourhood greenspace on ever smoking and smoking cessation become less pronounced. However, this seems unlikely, given the initial models showed lower county/regional level variances in ever-smoking and smoking cessation, compared to current smoking. An alternative explanation may be that these weaker associations (i.e. lower smoking uptake *and* higher cessation within high greenspace neighbourhoods), cumulatively lead to a statistically significantly lower prevalence of current smokers internationally.

Study 2 demonstrates for the first time beyond bivariate observations (Wang et al., 2017) an inverse association between greenspace and alcohol misuse, after controlling for a range of socio-demographics. Specifically, individuals living in the two highest (*vs.* lowest) greenspace tertiles had a lower incidence of exceeding alcohol guidelines. This contrasts with the findings of Study 1, in which neighbourhood greenspace was unrelated to exceeding alcohol guidelines. I had previously speculated that the inconsistent findings between Study 1 and Wang et al. (2017) might have been due to regional differences in alcohol consumption, however this appears not to be the case here. Despite substantial variation in exceeding alcohol guidelines between countries/regions, the trend towards a lower prevalence amongst individuals who lived in the two highest greenspace tertiles (*vs.* the lowest) was remarkably consistent across countries/regions. The inconsistent findings may relate to different operationalisations of exceeding alcohol guidelines between studies. Specifically, 2012 guidelines of (>28 units for men and >21 units for women, as per 2012 guidelines) used in Study 1 are less stringent than current alcohol guidelines. Equally, Study 1 assessed units of alcohol consumed per week, whereas both Study 2 and Wang et al., (2017) categorised respondents according to the frequency of their alcohol consumption. Although both are important predictors of health outcomes in their own right, the quantity of alcohol consumed and drinking frequency represent distinct components of drinking behaviour (Simpson et al., 2019; Oh et al., 2018). Taken together, these studies suggest that inverse associations between residential nature contact and alcohol health risk behaviours may be specific to the frequency with which individuals drink alcohol, rather than the number of units consumed. Given daily drinking is associated with an increase in all-cause mortality, even after controlling for alcohol units consumed (Hartz, et al., 2018), the results of Study 2 highlight the potential protective value of neighbourhood greenspace within this domain.

Regarding intentional contact (nature visits) the findings were mixed. Contrary to predictions, the frequency of nature visits exhibited an unexpected *positive,* but statistically non-significant association to exceeding alcohol guidelines. This finding is inconsistent with research demonstrating that intentional nature contact, in the form of nature-based treatment programmes, is associated with lower relapse rates for drug and alcohol addiction (Bennett et al., 1998). The incongruent findings may relate to differences in participant characteristics and the intensity of nature exposure between studies. Specifically, Bennett et al. (1998) examined the association between a three day nature programme within a sample of individuals who were already actively engaged in treatment for drug and alcohol misuse, whereas the current study focuses on more routine nature visits and exceeding recommended alcohol guidelines within the general population. Further, within the context of the current study, it is feasible that spontaneous nature visits within the context of individuals everyday lives may co-occur with activities that may also involve consuming alcohol (e.g. barbeques, camping, fishing trips), potentially confounding the association between visits and alcohol consumption. Therefore research might usefully explore whether activity type moderates the association between nature visits and alcohol consumption within the general population.

Conversely, after controlling for covariates, there was a lower prevalence of current smoking amongst individuals who visited natural spaces at least once a week (*vs.* < once a week). Whilst promising, it is noteworthy that there was variation in this association between countries, with little difference in smoking prevalence between respondents who visited natural spaces weekly (*vs.* less than once a week) in Greece, Italy, France, Canada, California (USA) and Queensland (Australia). Such findings are in line with country-level differences in nature-health associations observed elsewhere (White et al., 2021) and highlight potential societal/cultural differences in the way nature affects health outcomes. With cross-cultural examination of nature-health associations in its infancy, further research is required to explore potential reasons for such variations in more depth.

Country/region heterogeneity in this association notwithstanding, to my knowledge, this is the first study demonstrating that the benefits associated with visiting natural environments may extend beyond health and wellbeing outcomes (White et al., 2017; Cox et al., 2018), to lower rates of current smoking. That both greenspace and nature visits remained statistically significant within the same models suggests that the benefits of these two types of nature contact may be cumulative for current smoking. This finding is consistent with additive effects of different types of nature contact observed for health and wellbeing outcomes (Shanahan et al., 2016; White et al., 2017).

Nevertheless, it is noteworthy that, at the descriptive level, there was no difference in the proportion of current smoking amongst individuals who visited natural spaces once a week (*vs.* < once a week). Additional analyses (Appendix 12) revealed that the association between nature visits and current smoking only became apparent in the multivariate models once dog ownership was included as a covariate. With prior research indicating that dog ownership moderates the association between nature contact and health outcomes (White et al., 2018), its influence upon the association between nature visits and current smoking is potentially telling here. Whilst speculative, dog ownership may determine not only the activity undertaken whilst visiting natural spaces, but the quality of human-nature interactions. For example, although someone may visit nature frequently to walk their dog, this contact may occur in ecologically impoverished urban parks, and engagement in the activity of dog walking itself may result in diminished awareness of their surroundings. This is important for two reasons.

Firstly, recent research suggests higher subjective wellbeing is associated with visits to higher quality nature settings (Wyles et al., 2019). Secondly, the quality of the interaction is also determined by the activity, for example interventions to notice the ‘good things’ in nature have been found to increase psychological well-being (Richardson & Sheffield, 2017). Consequently, further research is needed to disentangle the influences of activity type and environment quality on the associations between nature visits and health risk behaviours.

Regarding the psychological trait of nature connectedness, Study 2 tested two competing hypotheses: whether nature connectedness operates in parallel with nature contact or influences how nature contact affects health risk behaviours. Nature connectedness was unrelated to any of the behavioural outcomes. This is perhaps surprising considering prior work observing contact with - and psychological connection to - nature, exhibit analogous associations to wellbeing outcomes (Capaldi, et al., 2014; Pritchard et al., 2019). With a higher likelihood of being highly connected to nature amongst non-smokers noted elsewhere (Haluza et al., 2014), these findings are unlikely to reflect differential relationships between connectedness across outcome domains (i.e. wellbeing outcomes in prior work and health risk behaviours here). Instead, the findings may relate to the range of covariates included within the present study, which were unaccounted for elsewhere. In particular, Study 2 examined two types of nature contact and connectedness simultaneously, for the first time. Given moderate relationships between contact and connectedness (Mayer and Frantz, 2004; Nisbet et al., 2009), associations between nature connectedness and smoking observed by Haluza et al. (2014) may have been the result of shared variance between these indicators.

Extending prior work in other domains (e.g. pro-environmental behaviours; Arendt & Matthes, 2016; Ojala, 2009), there was, however, some evidence that individual differences in nature connectedness moderated associations between neighbourhood greenspace and health risk behaviours. Specifically, for individuals who felt highly connected to nature, living in the lowest (*vs.* highest) greenspace areas were more likely to exceed alcohol guidelines. Consistent with person-environment fit theories (Caplan, 1987) individuals who had strong preferences for the natural world, but limited access to neighbourhood greenspace, were more likely to engage in this domain of health risk behaviour. The broader literature of person-environment fit is potentially informative here. With a large body of evidence demonstrating that incompatibilities between person-environment attributes are associated with negative emotions (e.g. frustration, stress) and counterproductive behaviours (Harold et al., 2016; Yu et al., 2019), further research might usefully explore whether this association represents these findings may reflect a negative emotional-behavioural response to limited greenspace amongst individuals who have a strong affinity towards nature.

It is interesting, however, that the amount of neighbourhood greenspace had little influence on the incidence of exceeding alcohol guidelines, when individuals were less connected. Put differently, high levels of neighbourhood greenspace did not have a similar antagonistic influence on individuals who felt less connected to the natural world. This may reflect, that unlike nature lovers residing in less green neighbourhoods, those who feel less connected to nature living greener areas still have their preferences for less contact with nature available to them. In this regard, the absence of similar moderation effects between intentional nature contact and nature connectedness are somewhat intuitive, considering that spending time in nature is likely to be largely within an individual’s control. Indeed, individuals who feel more connected to nature tend to visit natural spaces more frequently than do those who feel less connected (Mayer and Frantz, 2004; Nisbet et al., 2009).

As with Study 1, the pattern of associations between socio-demographic covariates and outcome variables reflect well-established social gradients in the prevalence of health risk behaviours. The findings are in line with prior studies indicating a higher prevalence of health risk behaviours in males (*vs.* females), individuals with disabilities (*vs.* no disability), and dog-owners (*vs.* not owning a dog), (WHO, 2013; Maugeri et al., 2019). The prevalence of smoking and exceeding alcohol guidelines as a function of age and socio-economic status also replicates prior work (WHO, 2013; Nobel et al., 2015). Such consistency provides greater assurance in the robustness of the nature-behaviour associations observed here.

2.4. General Discussion

This chapter outlined two studies that were undertaken to investigate the associations between nature contact, nature connectedness and health risk behaviours. Study 1 examined the relationship between neighbourhood greenspace and two domains of health risk behaviours in England. Study 2 extended this by exploring the relative associations between two types of nature contact and health (risk) behaviours, as well as the role of nature connectedness in these relationships, using an international sample. The remainder of this chapter provides a summative discussion of the results in relation to research questions 1a and 2, as well as a consideration of cross-study limitations.

2.4.1 RQ1a. How are Different Types of Nature Contact Related to Health Risk Behaviours?

Across studies, residential nature contact exhibited an inverse association to current smoking, with a lower prevalence of current smokers found in the most (*vs.* least) green neighbourhoods. Such consistency between studies indicates that neighbourhood greenspace is a robust, and largely overlooked, predictor of current smoking. Nevertheless, the findings regarding the mechanisms underlying this association between studies (i.e. ever smoking and smoking cessation) were less conclusive. Findings regarding residential nature contact and exceeding alcohol guidelines were also mixed: neighbourhood greenspace was unrelated to exceeding recommended units in Study 1, but emerged as a negative predictor of drinking every day in Study 2. Taken together, these findings indicate the potential protective value of neighbourhood greenspace for two distinct types of health risk behaviour: current smoking and daily alcohol consumption.

Regarding the influence of intentional nature contact, Study 2 indicated that visiting natural spaces at least once a week (*vs.* < once a week) was associated with a lower prevalence of current smoking. Not only did residential and intentional nature contact exhibit similar associations to current smoking, but these effects appeared to be additive. However, contrary to expectations, weekly nature visits were unrelated to exceeding alcohol guidelines. As previously discussed, it is possible that this association was confounded by many activities that take place in natural spaces also providing opportunities to consume alcohol. Further research accounting for activity type(s) is therefore needed to disentangle these influences.

Differential patterns of associations within and between studies notwithstanding, it is noteworthy that when statistically significant associations between greenspace and health risk behaviours were observed, they were robust to different operationalisations of greenspace, and unaffected by adjustment for: a) a range of covariates and, b) socio-economic interactions. This strongly suggest that these associations are not due to compositional effects, rather that high greenspace neighbourhoods may be beneficial to these behaviours, irrespective of the socio-demographic characteristics of the individuals who reside in them. Within both studies, the magnitude of the nature-behaviour associations, in comparison to benchmark socio-demographics that may be less amenable to change, indicated that they may be practically meaningful for potential public health intervention. For example, the association between greenspace and current smoking was comparable to that of earning more than £27,624 a year in England (Study 1) and over half the size of earnings in the highest income quintile internationally (Study 2). Similarly, the influence of neighbourhood greenspace on smoking cessation (Study 1) and exceeding alcohol guidelines (Study 2) was larger in magnitude to having a higher education (*vs.* < higher education). Overall, these comparisons identify limited nature contact as an overlooked environmental risk factor for engagement in health risk behaviours and highlight the potential protective value of natural environments within this domain.

Both studies adjusted for co-current health risk behaviours. Thus, similar associations between greenspace, current smoking and exceeding alcohol guidelines observed in Study 2 are unlikely to be due to shared variance between different domains of health risk behaviours. Further, as the inclusion of physical activity within the models did not alter the relationships between nature contact and health risk behaviours, statistically significant nature contact effects are unlikely to be due to increased physical activity associated with living near (Study 1 & 2) or visiting natural spaces (Study 2). As outlined in Chapter 1 (Section 1.3.3), there are several inter-connected mechanisms through which increased nature contact may influence health risk behaviours. Notably, natural environments have been associated with improved affect (Neill et al., 2019) and social cohesion (Weinstein, et al., 2015), as well reduced temporal discounting (Berry et al., 2014). Given that these constructs independently predict lower engagement in health risk behaviours (Romain et al., 2018; Stein, et al., 2016; Jennings & Bamkole, 2019) further research might usefully explore these potential mediating pathways.

2.4.2 RQ2. What Role does Trait Nature Connectedness Play in these Associations?

Nature connectedness was not independently associated with any of four behavioural outcomes. However, for exceeding alcohol guidelines at least, trait nature connectedness appears to modify the way in which individuals respond to residential contact with the natural world. Specifically, individuals who had strong preferences for the natural world, but limited access to neighbourhood greenspace, were more likely to be daily drinkers. Given the broad range of health and wellbeing benefits associated with heightened nature connectedness (Capaldi et al., 2014; Pritchard et al., 2019), policies that increase access to greenspace *and* encourage a greater a greater sense of connection to the natural world may be complementary in achieving synergistic improvements to public health.

2.4.3 Limitations

Whilst providing unique insights into the relationships between nature contact, nature connectedness and health risk behaviours, Studies 1 and 2 are not without limitations. First, the cross-sectional approach limits the ability to make causal inferences. Despite experimental evidence demonstrating improvements in health risk behaviours following exposure to natural environments (Kao et al., 2019; Wu & Chiou, 2019), it cannot be ruled out that individuals already exhibiting healthier lifestyles selectively migrate towards more natural settings. Second, despite having controlled for a range of possible confounds, there remains the possibility of residual confounding, or unmeasured confounding across studies (Villeneuve et al., 2012; Pearce et al., 2016). Third, results are based on self-report data. Whilst self-reported health risk behaviours correlate strongly with objective indices (Vartiainen et al., 2002), due to well-known negative health consequences of smoking and alcohol misuse, we cannot rule out possible misclassifications in outcome variables due to social desirability bias. Fourth, as already noted, ever-smoking and smoking were measured retrospectively and related to the respondents' current place of residence. As individuals may have migrated to another neighbourhood since uptake, migration effects have the potential to confound their associations to neighbourhood greenspace. Fifth, as recognised previously, these measures tell us little about the quality of nature contact, or indeed the how specific activities in natural environments may influence associations between nature contact and health risk behaviours.

2.4.4 Conclusion

As major determinants of morbidity and mortality worldwide, smoking and alcohol misuse constitute significant public health issues. Studies 1 and 2 contribute to a greater understanding of how nature contact and nature connectedness are associated with the prevalence of these two domains of health risk behaviour. After accounting for a range of covariates, greenspace near one's home was associated with a lower prevalence of current smoking and drinking alcohol every day. Further, limited access to greenspace amongst individuals who were highly connected to nature was associated with a higher prevalence of daily alcohol consumption. Visiting natural spaces at least once a week was associated with a lower prevalence of current smoking, but unrelated to exceeding alcohol guidelines. Recognition of these associations supports the need to safeguard greenspaces, in order to optimise their potential benefits to public health. If further evidence can corroborate that these associations are causal, then increased nature contact, particularly by means of increasing neighbourhood greenspace, may offer a viable strategy of reducing multiple health risk behaviours at the population-level. Further, targeted nature-based interventions encouraging more visits may be particularly useful for assisting individuals attempting to give up smoking. Despite providing valuable insights into nature-behaviour associations, Study 1 and 2 examined just one part of a larger conceptual model postulating that increased contact with, and psychological connection to, nature, would be associated with behavioural determinants of public and planetary health, via positive affect, negative affect, community cohesion and temporal discounting. Chapter 3, therefore, focuses on another part of that model: the associations between nature contact, nature connectedness and pro-environmental behaviours

Chapter 3

Nature Contact, Connectedness and Pro-environmental Behaviours[5]

3.1 Chapter Overview

Chapter 2 provided a partial investigation of a conceptual model postulating that increased contact with - and psychological connection to - nature would be associated with behavioural determinants of public and planetary health via positive affect, negative affect, community cohesion and temporal discounting (i.e., health risk behaviours and pro-environmental behaviours, Figure 1.1, Chapter 1). The current chapter presents a cross-sectional study examining another part of that model: the associations between nature contact, connectedness and pro-environmental behaviours.

This chapter addresses two overarching research questions:

RQ1b. How are different types of nature contact related to pro-environmental behaviours?

RQ2. What role does the psychological construct of nature connectedness play in these associations?

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[5] An extended version of Study 3 was published in the Journal of Environmental Psychology. As this study was completed during a placement with Natural England, the published paper includes health and wellbeing outcomes in addition to the pro-environmental outcomes reported within this chapter.

Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., & Burt, J. (2020). Nature contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours. *Journal of Environmental Psychology, 68*, 101389.

3.2 Study 3: Nature Contact, Connectedness and Pro-Environmental Behaviours

3.2.1 Summary of Prior Research and Hypotheses

3.2.1.1 The Relative Importance of Different Types of Nature Contact

As discussed in Chapter 1 (Section 1.3.2), both residential (neighbourhood greenspace) and intentional (nature visits) nature contact have been independently associated with a heighted propensity to behave sustainably (Whitburn et al., 2019; Alcock et al., 2020; Hartig et al., 2001; Hartig et al., 2007; Lawrence, 2012; Coldwell & Evans, 2017), and there is incidental evidence, for pro-environmental concern at least, that these effects may be cumulative (Weinstein et al., 2015). Nevertheless, with inconsistences in the strength of the association between studies for residential nature contact (Chapter 1, Section 1.3.2), and prior studies predominantly focusing on the impact of a singular form of interaction, it is difficult to establish which *type(s)* of nature contact are most relevant to pro-environmental behaviours.

Furthermore, time outdoors is not the only way nature contact can be established, or indeed influence an individual's propensity to engage in pro-environmental behaviours. Laboratory studies have demonstrated that participants experiencing nature indirectly (e.g. viewing brief videos of natural scenes) report more pro-environmental intentions (Yang et al., 2018) and behave more sustainably within laboratory tasks (Zelenski et al., 2015) compared to those who view urban scenes. Yet, despite high profile nature documentaries (e.g. the BBC's Blue Planet) considered to have transformed political and societal attitudes towards the natural world (Rawlinson, 2017; Schnurr et al., 2018), the influence of indirect, technologically mediated, nature contact (e.g. watching/listening to nature media) on population level pro-environmental behaviours has received little empirical attention.

This is particularly surprising, given that individuals are, on average, spending more recreational time indoors (Office for National Statistics, 2017). In the UK for instance, people spend approximately 15 hours per week watching/listening to digital media, compared to just 2 hours a week engaged in outdoor activities (ONS, 2017). Moreover, the benefits of virtual reality nature may be particularly relevant to people with limited access to natural places, for example individuals in health and social care settings (Tanja-Dijkstra et al. 2018; White et al., 2018; Yeo et al., 2020). Consequently, establishing the association between indirect nature contact (watching/listening to nature media) and pro-environmental behaviours not only holds practical significance for the general population, but also subpopulations who are less able to access to natural spaces.

To address these gaps in the literature, Study 3 included three types of nature contact within the same study. By doing so, the relative associations between three types of nature contact (residential, intentional, indirect) and pro-environmental behaviours were explored for the first time. This type of comparison enables policy makers and practitioners to consider the focus of sustainability strategies and interventions. Based on the aforementioned research, hypotheses were as follows:

H_1. Increased nature contact (a. residential [neighbourhood greenspace], b. intentional [nature visits], c. indirect [watching/listening to nature media]) will be positively associated with pro-environmental behaviours, after accounting for a range of socio-demographics.

In line with prior work on environmental concern (Weinstein et al., 2015), the associations between different types of nature contact and pro-environmental behaviours were expected to be cumulative.

3.2.1.2 The Role of Nature Connectedness

As outlined in Chapter 1 (Section 1.3.2), there is evidence that contact with - and psychological connection to – nature exhibit analogous positive associations to pro-environmental behaviours (Mackay & Schmitt, 2019; Whitburn et al., 2020). Nonetheless, such research has typically examined nature contact and nature connectedness separately. With moderate positive associations between nature contact and nature connectedness (Mayer and Frantz, 2004; Nisbet et al., 2009; Noble 2009), it is unclear whether similar associations with outcome variables are an artifact of shared variance or whether they independently predict positive outcomes (i.e. additive effects).

An alternative hypothesis, discussed in Chapters 1 and 2, is that associations between nature contact and pro-environmental behaviours may be moderated by trait nature connectedness. Just two studies, to date, have examined this possibility, finding that contact with the natural world was associated with greater endorsement of pro-environmental attitudes (Ojala, 2009) and increased engagement in pro-environmental behaviours (Arendt & Matthes, 2016), but only for individuals who are already highly connected to nature. Consistent with person-environment fit theories (Caplan, 1987), these findings suggest that, for pro-environmental behaviours, contact with nature may promote the most beneficial outcomes among individuals who are already highly connected with it. Nevertheless, as with the majority of research into nature connectedness, neither study accounted for socio-demographic covariates that have previously been shown to be important for pro-environmental behaviours, including area-level deprivation and socio-economic status (Alcock et al., 2020; Meyer et al., 2014). Thus, it is unclear both how generalisable these associations are beyond the specific samples used, or whether they are demonstrable at the population level, after relevant socio-demographic covariates have been accounted for.

Therefore, a further aim of Study 3 was to examine the role of nature connectedness in pro-environmental behaviours whilst controlling for relevant socio-demographics. Specifically, I tested two competing hypotheses: whether nature connectedness operates in parallel with nature contact (i.e. additive main effects) or influences how nature contact affects pro-environmental behaviours (i.e. moderation effects):

H_2. Trait nature connectedness will positively predict pro-environmental behaviours independently of nature contact, after accounting for a range of socio-demographics.

H_3. Trait nature connectedness will moderate the associations between nature contact and pro-environmental behaviours, after accounting for a range of socio-demographics.

3.3 Method

3.3.1 MENE Survey Overview

The Monitor of Engagement with the Natural Environment (MENE) survey is commissioned by Natural England, a part of the Department of Environment, Food & Rural Affairs' (DEFRA) social science research programme. It is part of a face-to-face in-home omnibus survey conducted by trained interviewers using computer-assisted personal interviewing (Natural England, 2018). Data are collected across the whole of England, and throughout the year, in order to reduce potential geographical and seasonal biases (Natural England, 2018). As part of the United Kingdom's official statistics, substantial effort is made to ensure sampling is as representative of the adult English population as possible. Key features include: 1) a computerised sampling system which integrates the Post Office Address with the 2001 Census small area data at output area level to produce replicated waves of multi-stage stratified samples; 2) areas within each Standard Regions are stratified into population density bands and within band, in descending order by percentage of the population in socio-economic Grade I and II and 3) quotas set by sex, presence of children and working status to ensure a balanced sample of adults (Natural England, 2018).

3.3.2 Participants

Participants were drawn from eight waves of the MENE survey that contained the Nature Connection Index (NCI, Hunt et al., 2017). Data were collected on a quarterly basis between May 2015- February 2018, during the months of May, August, November and February. The sample comprised of a total 4,960 adults (2,550 females) aged between 16 and 95 years.

3.3.3 Measures

3.3.3.1 Outcome Variables

Pro-environmental Behaviours

Respondents were required to indicate which environment-related activities (see Table 3.1) they had undertaken during the previous 12 months. Each of the items was binary coded to represent engagement in that specific behaviour and the items were subjected to a principal components analysis with an orthogonal varimax rotation (*KMO* =.75; Bartlett's test of sphericity, χ^2 (36) = 5339, $p < .001$). The model yielded a two-factor solution, with Factor 1 and Factor 2 accounting for 28.09% and 14.95% of the variance, respectively (Table 3.1). These factors formed the basis of the two pro-environmental behaviour indicators which were labelled: 'household' and 'nature conservation' pro-environmental behaviours, respectively. Whilst these two factors have similarities to the distinction between private and public spheres (Stern, 2000), they are not identical, therefore factor labels highlight the fact that the second dimension is focused on nature conservation issues in particular (as opposed to other environmental topics e.g. transport/energy etc.).The number of behaviours reported for each factor were totalled to yield scores of 0-5 for household behaviours (*M* = 2.07, *SD* = 1.44) and 0-4 for nature conservation behaviours (*M* = .23, *SD* = .62) with higher scores on each item indicating a greater propensity to act sustainably.

3.3.3.2 Predictor Variables

Nature Contact

Following previous research (e.g. Weinstein et al., 2015), a range of nature contact metrics were operationalised.

Residential contact (neighbourhood greenspace) was determined using information about the Lower-layer Super Output Area (LSOAs) in which respondents lived. As outlined in Chapter 2 (Section 2.2.2.3), LSOAs represent discrete geographic areas of similar population size. I added this information to the MENE survey using LSOA datasets. Specifically, the percentage of land cover incorporating public greenspace and domestic gardens within each LSOA (at the resolution of $10m^2$) was derived from the Generalised Land Use Database (Office of the Deputy Prime Minister, 2005). As this data was only available for 4,875 participants, analyses including this variable exclude 85 participants. The mean proportion of neighbourhood greenspace within the current study was 64.38% (*SD* = 18.70). As with Studies 1 and 2, the main findings were robust to different operationalisations of greenspace (Appendix 13) and there was very little change (<0.05%) in the proportion of individuals within each social-demographic group as a function of the reduced sample.

Table 3.1. Factor Loadings for Pro-Environmental Behaviour Items

	Factor 1 Household PEB	**Factor 2** Nature conservation PEB
I usually recycle items rather than throw them away	**.60**	-.07
I usually buy eco-friendly products and brands	**.65**	.20
I usually buy seasonal or locally grown food	**.68**	.10
I choose to walk or cycle instead of using my car when I can	**.57**	.04
I encourage other people to protect the environment;	**.60**	.30
I am a member of an environmental or conservation organisation	.14	**.68**
I volunteer to help care for the environment;	.07	**.66**
I donate money at least once every three months to support an environmental or conservation organisation	.18	**.61**
I donate my time at least once every three months to an environmental or conservation organisation	-.03	**.70**

Note. PEB = Pro-environmental behaviour

Intentional contact (nature visits) was based on a single item assessing respondents' average visit frequency over the last twelve months ('More than once per day', 'Every day', 'Several times a week', 'Once a week', 'Once or twice a month', 'Once every 2-3 months', 'Once or twice', 'Never'; Natural England, 2018). To enable comparability across studies (e.g. Shanahan et al., 2016, Study 2), the item was dichotomised according to whether respondents visited natural spaces at least once a week (*vs.* less than weekly = reference).

Indirect contact (nature media) was operationalised according to whether respondents reported 'watching or listening to nature programmes on the TV or radio, either regularly or occasionally' (Yes *vs.* No = reference). This item was included as a relatively novel measure of indirect contact, which may have relevance when considering policy and practice implications for people with limited access to natural places.

Nature Connectedness

The Nature Connection Index (NCI, Hunt et al, 2017) was developed by Natural England as a concise measure of nature connectedness suitable for use within a nationally representative UK based survey. The NCI has favourable psychometric properties, with good levels of internal reliability (α = .92 in the current study) and convergent validity with US developed scales such as the Nature Relatedness Scale and the Inclusion of Nature in the Self measure (Richardson et al., 2019). The scale consists of six items scored on a 7-point Likert scale (1, "Completely disagree" - 7, "Completely agree") pertaining to an individual's trait sense of their general emotional relationship with the natural world (e.g. 'I feel part of nature'). Items are scored according to a weighted points index (Hunt et al., 2017) resulting in scores from 0 to 100, with higher scores indicating a stronger sense of connection (M = 60.12, SD = 28.27).

3.3.3.3 Control Variables

With outcome and predictor variables previously shown to be associated with a range of covariates (e.g. socio-economic status, Meyer et al., 2014; neighbourhood deprivation, Jokela, 2015) control variables were created using available data from the MENE survey, as well as additional LSOA datasets and included within the multivariate analyses.

Area-level control variables

Respondent LSOA codes were used to derive area-level urbanicity and deprivation indicators. Urbanicity was categorised as: rural (hamlet/village/town-fringe) *vs.* urban (= reference) and included 14% and 86% of the sample, respectively. Quintiles of the Index of Multiple Deprivation (IMD) scores were also calculated, ranging from the lowest level of deprivation (M = 7.00, SD = 2.47 = reference) to the highest (M = 50.20, SD = 9.30).

Individual-level control variables

Demographic controls included: gender (female, male = reference); age (16-34 = reference, 35-64, 65+); ethnicity (White British, *vs.* Other = reference); working status (unemployed = reference, full-time employed, part-time employed, in education, retired); marital status (married/cohabiting, single/widowed/divorced= reference); household composition (living alone = reference, with adults, with children, with adults and children); and socio-economic group based on occupation (AB (highest), C1, C2, DE (lowest) = reference). The year in which respondents completed the MENE survey was also included as a covariate (2015/16 = reference, 2017/18).

Related outcome control variables

With moderate positive correlations between outcome variables (see Table 3.2), I controlled for related outcome variables within the multivariate models, to better understand the unique contributions of predictor variables on each outcome variable separately. Specifically, each model controlled for the remaining pro-environmental behaviour.

3.3.4 Analytical Approach

An initial series of linear regression models were fitted to examine the relative contributions of different types of nature contact and nature connectedness to each domain of pro-environmental behavior. For the two continuous variables (greenspace and nature connectedness), coefficients were small and therefore difficult to interpret when reported to two decimal places (e.g. *B* = .00). As rescaling these variables would have caused difficulty interpreting interaction terms and comparison of standardised regression coefficients or their effect sizes is discouraged in the case of categorical variables (Pek & Flora, 2018), consistent with White et al. (2013), coefficients are instead reported to four decimal places (e.g. *B* =.0021).

To assess the magnitude of the effects of nature contact and connection on the outcome variables, where appropriate, the effects of a change in the predictor variable on the unstandardised coefficients for each outcome measure were compared to those of relevant control variables. For continuous variables (greenspace and nature connectedness), unstandardised coefficients relate to the change in scores on the outcome measure for a 1% increase in the predictor variable. A useful way of interpreting this relationship is to consider the effect of a more substantial change. Thus, following White et al., (2013) the difference in scores on outcome measures, between greenspace/nature connectedness scores of 1 standard deviation below the mean were compared to those of scores of 1 standard deviation above the mean. Prior research suggests that females (*vs.* males) and individuals from higher (*vs.* lower) socio-economic groups, on average, report more pro-environmental behaviours (Scannell & Gifford, 2013). Accordingly, gender (female *vs.* male) and belonging to socio-economic group AB (highest *vs.* DE, lowest) were selected as comparator variables.

A second series of linear regression models were specified to examine whether trait nature connectedness moderated the associations between nature contact and the outcome variables. All models presented in the main text are adjusted for individual and area-level control variables, plus related outcome controls. Unadjusted and partially-adjusted models (accounting for individual and area-level covariates, but not related outcomes) are reported in Appendix 14. The direction of the associations between variables was largely consistent with those observed in final models.

3.4 Results

3.4.1 Descriptive Data

Descriptive statistics and bivariate associations between nature contact/connectedness indicators and pro-environmental behaviours are presented in Table 3.2. On average, individuals reported performing more household pro-environmental behaviours (M = 2.07, SD = 1.44), than nature-conservation activities (M = .23, SD =.62). In line with hypotheses 1 and 2, increased contact with, and connection to, nature were positively associated with both domains of pro-environmental behaviours.

3.4.2 Main findings: Initial Models

Fully adjusted regression models of nature exposure, nature connected and the two domains of pro-environmental behaviour, controlling for covariates, are reported

Table 3.2. Bivariate relationships between nature contact, nature connectedness and outcome variables

	1	2	3	4	5	6
1. Neighbourhood greenspace	**64.38 (18.70)**					
2. Nature visits (≥ once a week)	.10***	**N=2954 (60%)**				
3. Nature media (yes)	.10***	--	**N=2503 (50%)**			
4. Nature Connectedness	.04**	.12***	.21***	**60.12 (28.27)**		
5. Household PEB	.12***	.22***	.34***	.34***	**2.07 (1.44)**	
6. Nature conservation PEB	.07***	.09***	.18***	.19***	.31***	***.23 (.62*)**

Note: *** p <.001; ** p <.01; * p <.05. PEB = Pro-environmental behaviours. Figures below the diagonal derived from Pearson coefficients for continuous data and point bi-serial correlations for binary variables. Figures in bold along the diagonal express the Mean (Standard Deviation) of continuous variables and Numbers (%) for binary variables.

in Table 3.3. Variance inflation factors (VIF) for the models were < 3.83, indicating that multicollinearity was not an issue. The predictors accounted for 29% and 13% of the variance in household and nature conservation behaviours, respectively.

Residential contact (neighbourhood greenspace)

Contrary to hypothesis 1a, there was no statistically significant associations between neighbourhood greenspace and pro-environmental behaviours (household behaviours *b* = .0012, *95% CIs* = -.0012, .0036, *p* = .320; conservation behaviours *b* = -.0008, *95% CIs* = -.0020, .0003, *p* = .165).

Intentional contact (nature visits)

There was mixed support for hypothesis 1b, visiting nature ≥ once a week (*vs.* < once a week) was positively related to household pro-environmental behaviours (*b* = .3412, *95% CIs* = .2689, .4136, *p* < .001), but not statistically significantly associated with conservation behaviours (*b* = -.0148, *95% CIs* = -.0205, .0501, *p* = .411).

Indirect contact (nature media)

In line with hypothesis 1c, watching/listening to nature media was associated with higher levels of both types of pro- environmental behaviour (household behaviours *b* = .6779, *95% CIs* = .6057, .7501, *p* < .001; conservation behaviours *b* =.0706, *95% CIs* = .0345, .1067, *p* < .001.

Nature connectedness

In line with hypothesis 2, Nature connectedness was positively related to household pro-environmental behaviours (*b* =.0110, *95% CIs* = .0097, .0123, *p* < .001) and nature conservation behaviours (*b* =.0020, *95% CIs* = .0013, .0026, *p* < .001).

Table 3.3. Fully adjusted linear regression models predicting pro-environmental behaviours, as a function of nature contact, nature connectedness, controlling for individual, area and related-outcome covariates.

	Household PEB				Nature Conservation PEB			
	b	***95% CIs b***	***β***	***p***	***b***	***95% CIs b***	***β***	***p***
Neighbourhood greenspace (%)	.0012	(-.0012, .0036)	.0157	.320	-.0008	(-.0020, .0003)	-.0243	.165
Nature visits (≥ once a week)	.3412	(.2689, .4136)	.1164	<.001	.0148	(-.0205, .0501)	.0116	.411
Nature media (yes)	.6779	(.6057, .7501)	.2356	<.001	.0706	(.0345, .1067)	.0563	<.001
Nature connectedness (%)	.0110	(.0097, .0123)	.2158	<.001	.0020	(.0013, .0026)	.0882	<.001
Individual-level controls								
Gender (female)	.1447	(.0728, .2166)	.0503	<.001	-.0276	(-.0625, .0072)	-.0220	.120
Age								
16-34 (ref)								
35-64	-.0131	(-.1057, .0796)	-.0045	.782	.0413	(-.0035, .0862)	.0325	.071
65+	-.1445	(-.3177, .0287)	-.0453	.102	.0195	(-.0643, .1034)	.0141	.648
Ethnicity (White British)	.1208	(.0331, .2085)	.0357	.007	-.0085	(-.0510, .0339)	.0058	.693
Working Status								
Unemployed (ref)								
Full-time Employment	.1236	(.0119, .2352)	.0405	.030	-.0515	(-.1055, .0026)	-.0387	.062
Part-time Employment	.1415	(.0111, .2719)	.0333	.033	-.0264	(-.0896, .0367)	-.0143	.412
In Education	.3040	(.1242, .4838)	.0530	.001	-.0348	(-.1219, .0523)	-.0139	.433
Retired	-.0231	(-.1932, .1469)	-.0074	.790	.0593	(-.0230, .1415)	.0436	.158
Marital Status								
(Married/Cohabiting)	.1198	(.0181, .2216)	.0414	.021	-.0061	(-.0554, .0431)	.0049	.807
Household composition								
Alone (ref)								
With adults	-.0576	(-.1726, .0573)	-.0200	.326	-.0096	(-.0652, .0461)	-.0076	.736
With children	-.1319	(-.3225, .0588)	-.0186	.175	.0639	(-.0283, .1562)	.0207	.174
With adults and children	-.1525	(-.2979, -.0071)	-.0449	.040	-.0404	(-.1108, .0300)	-.0273	.260

Table 3.3 continued.

Social Grade								
DE (ref)								
C2	.1649	(.0636, .2663)	.0460	.001	.0221	(-.0270, .0712)	.0142	.378
C1	.2930	(.1964, .3897)	.0901	<.001	.0683	(.0214, .1152)	.0482	.004
AB	.5255	(.4158, .6352)	.1396	<.001	.2068	(.1535, .2599)	.1260	<.001
Survey year (2017/18)	-.0798	(-.1577, -.0020)	-.0244	.044	.0132	(-.0245, .0509)	.0093	.491
Area-level controls								
Deprivation Index								
1st Quintile (Least deprived, ref)								
2nd Quintile	-.1579	(-.2669, -.0489)	-.0434	.005	-.0077	(-.0605, .0451)	-.0049	.775
3rd Quintile	-.0948	(-.2063, .0166)	-.0264	.095	-.0258	(-.0797, .0282)	-.0164	.349
4th Quintile	-.1500	(-.2666, -.0334)	-.0417	.012	-.0291	(-.0855, .0274)	-.0186	.313
5th Quintile (Most deprived)	-.3003	(-.4244, -.1761)	-.0835	<.001	-.0171	(-.0773, .0431)	-.0109	.578
Urbanicity (Rural)	.0369	(-.0786, .1525)	.0090	.531	.1028	(.0470, .1587)	.0573	<.001
Related outcome controls								
Household PEB	--	--	--	--	.1005	(.0872, .1139)	.2307	<.001
Nature Cons. PEB	.4292	(.3723, .4861)	.1870	<.001	--	--	--	--
Constant	1.01	(.7433, 1.2827)		<.001	.0723	(-.0590, .2035)		.281
N	4874				4874			
Adjusted R^2	.29				.13			

Relative magnitude of nature-behaviour associations

Comparison of the standardised regression coefficients indicated that the magnitude of the associations between statistically significant nature variables and pro-environmental outcomes (e.g. nature visits and household behaviours: β = .1164), exceeded those associated with each nature variable that did not reach statistical significance (e.g. nature visits and nature conservation behaviours: β = .0116).

Covariates

Being female (*vs.* male: *b* =.1447, *95% CIs* = .0728, .2166, *p* < .001), being married/or cohabiting (*vs.* single/widowed/divorced: *b* =.1198, *95% CIs* = .0181, .2216, *p* = .021), and working full-time *(vs.* unemployed*: b* =.1236, *95% CIs* = .0119, .2352, *p* = .030) were all positively associated with household pro-environmental behaviours, but unrelated to nature conservation behaviours (female: *b* = - .0276, *95% CIs* = .0625, .0072, *p* = .120; married/cohabiting: *b* = -.0061 , *95% CIs* = -.0554, .0431, *p* = .807; working full time: *b* = -.0515, *95% CIs* = -.1055, .0026, *p* = .062). Age was unrelated to the propensity to engage in both domains of pro-environmental behaviours (all *ps* >.05). Having a high (AB) *vs.* low (DE) socio-economic status was associated with greater engagement in both behavioural domains (household: *b* =.5255, *95% CIs* = .4158, .6352, *p* < .001; conservation: *b* =.2068, *95% CIs* = .1535, .2599, *p* < .001). Area-level characteristics were differentially related to the two domains of pro-environmental behaviours. Living in the most (*vs.* least deprived) neighbourhoods was negatively associated with household behaviours (*b* = -.3003, *95% CIs* = -.4244, -.1761, *p* < .001), but unrelated to nature conservation behaviours (*b* = -.0171, *95% CIs* = -.0773, .0431, *p* = .578). Conversely, living in a rural (*vs.* urban) neighbourhoods was associated with greater engagement in conservation behaviours (*b* = .1028, *95% CIs* = .0470, .1587, *p* < .001), but did not statistically significantly predict household behaviours (*b* = .0369, *95% CIs* =

-.0786, .1525, p = .531). Greater engagement in one domain of pro-environmental behaviour positively predicted engagement in the other domain (conservation on household: b = .4292, *95% CIs* = .3723, .4861; household on conservation: b = .1005, *95% CIs* = .0872, .1139, both $ps < .001$).

3.4.3 Comparison to Socio-Demographics

Estimated marginal means for outcome variables as a function of environmental indicators and selected socio-demographic comparators (gender: female *vs.* male; social grade: AB *vs.* DE) are presented in Table 3.4. The increase in household behaviours associated with visiting nature ≥ once a week (17%), watching/listening to nature media (33%) and having a nature connectedness score of one standard deviation above the mean (30%) were substantially larger than the increase associated with being female *vs.* male (7%). Watching/listening to nature media and having a nature connectedness score of 1 standard deviation above the mean also exceeded the increase in household behaviours associated with having a high *vs.* low socio-economic status (24%). For nature conservation behaviours, the increase associated with watching/listening to nature media (30%) was under half the size of the increase associated with having higher *vs.* lower socio-economic status (76%). Having a nature connectedness score of one standard deviation above the mean was associated with an increase in nature conservation behaviours roughly one third (47%) smaller than the increase associated with having higher *vs.* lower socio-economic status.

Table 3.4. Estimated Marginal Means and Percentage Difference in outcome variables as a function of nature contact, nature connectedness and socio-demographic comparators.

	Household PEB		**Nature Conservation PEB**	
	EMM	**% difference**	**EMM**	**% difference**
Neighbourhood greenspace				
1 *SD* below Mean (45.68%)	2.05	-	.25	-
1 *SD* above Mean (83.08%)	2.10	2.41%	.22	-12.77%
Nature visits				
< once a week	1.87	-	.22	-
≥ once a week	2.22	17.11%	.24	8.70%
Nature media				
No	1.73	-	.20	-
Yes	2.41	32.85%	.27	29.79%
Nature connectedness				
1 *SD* below mean (31.85)	1.76	-	.18	-
1 *SD* above mean (88.39)	2.38	29.95%	.29	46.81%
Gender				
Male	2.00	-	.25	-
Female	2.14	6.76%	.22	-12.77%
Social grade				
DE	1.87	-	.17	-
AB	2.39	24.41%	.38	76.36%

Note: EMM = Estimated marginal means derived from the fully adjusted regression models. PEB = Pro-environmental behaviour

3.4.4 Main findings: Moderation models

Fully-adjusted regression models predicting pro-environmental behaviours as a function of nature contact, nature connectedness and their interaction terms, are reported in Table 3.5. Variance inflation factors (VIF) for the models were < 3.82, again indicating that multicollinearity was not an issue. The predictors accounted for 29% and 9% of the variance in household and nature conservation behaviours, respectively. There was a differential pattern of moderation effects for distinct types of nature contact, providing inconsistent support for hypothesis 3.

Residential contact (neighbourhood greenspace)

No moderation effects of nature connectedness were found for the associations between living near greenspace and pro-environmental behaviour outcomes.

Intentional contact (nature visits)

For nature visits a statistically significant interaction was only observed for nature conservation behaviours (*b* = .0013, *95% CIs* = .0001, .0024, *p* = .040; Wald $\chi 2$ omnibus test: F(1, 4844) = 4.23, p = .039). As shown in Figure 3.1, the association between nature connectedness and these behaviours was stronger for those who visited at least weekly.

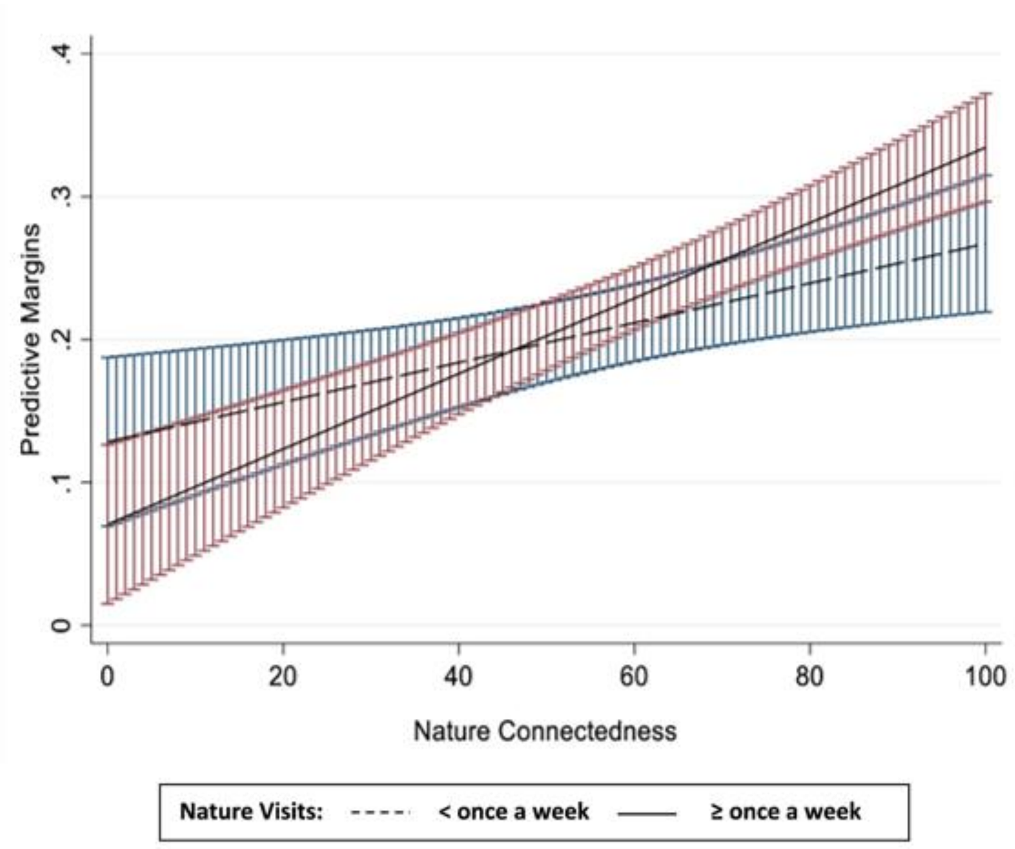

Figure 3.1. Estimated marginal means for nature conservation behaviours, as a function of nature visits and nature connectedness

Table 3.5. Fully-adjusted linear regression models predicting pro-environmental behaviours as a function of nature contact, nature connectedness and their interaction terms, controlling for individual, area and related-outcome covariates.

	Household PEB				**Nature Conservation PEB**			
	b	***95% CIs b***	***β***	***p***	***b***	***95% CIs b***	***β***	***p***
Neighbourhood greenspace (%)	-.0006	(-.0052, .0040)	-.0077	.800	-.0012	(-.0035, .0010)	-.0366	.280
Nature visits (≥ once a week)	.2682	(.1050, .4314)	.0915	.001	-.0578	(-.1366, .0210)	-.0452	.151
Nature media. TV/radio (Yes)	.4981	(.3323, .6640)	.1731	<.001	-.1192	(-.1994, -.0389)	-.0951	.004
Nature connectedness (%, NC)	.0070	(.0025, .0115)	.1374	.002	-.0006	(-.0028, .0015)	-.0288	.564
Greenspace x NC	.0000	(.0000, .0001)	.0460	.378	.0000	(.0000, .0000)	-.0230	.690
Visits x NC	.0013	(-.0012, .0037)	.0327	.319	.0013	(.0001, .0024)	.0747	.040
Nature media. x NC	.0030	(.0005, .0055)	.0792	.019	.0032	(.0020, .0044)	.1930	<.001
Individual-level controls								
Gender (female)	.1420	(.0701, .2140)	.0493	<.001	-.0300	(-.0648, .0048)	-.0239	.091
Age								
16-34 (ref)								
35-64	-.0149	(-.1075, .0777)	-.0051	.752	.0393	(-.0054, .0840)	.0309	.085
65+	-.1487	(-.3218, .0245)	-.0466	.092	.0152	(-.0684, .0988)	.0109	.722
Ethnicity (White British)	.1205	(.0328, .2083)	.0356	.007	-.0100	(-.0524, .0324)	-.0068	.644
Working Status								
Unemployed (ref)								
Full-time Employment	.1227	(.0111, .2343)	.0402	.031	-.0517	(-.1055, .0022)	-.0388	.060
Part-time Employment	.1428	(.0124, .2731)	.0336	.032	-.0241	(-.0870, .0389)	-.0130	.453
In Education	.3004	(.1206, .4801)	.0524	.001	-.0360	(-.1228, .0509)	-.0144	.417
Retired	-.0254	(-.1954, .1445)	-.0081	.769	.0575	(-.0245, .1395)	.0423	.169
Marital Status (Married/Cohabiting)	.1199	(.0182, .2217)	.0414	.021	-.0057	(-.0549, .0434)	-.0045	.819
Household composition								
Alone (ref)								
With adults	-.0560	(-.1710, .0591)	-.0194	.340	-.0076	(-.0631, .0480)	-.0060	.790
With children	-.1334	(-.3241, .0573)	-.0188	.170	.0622	(-.0298, .1542)	.0202	.185
With adults and children	-.1507	(-.2962, -.0051)	-.0444	.042	-.0387	(-.1090, .0315)	-.0262	.280

Table 3.5 continued

Social Grade								
DE (ref)								
C2	.1665	(.0652, .2679)	.0465	.001	.0235	(-.0255, .0724)	.0150	.347
C1	.2938	(.1971, .3904)	.0903	<.001	.0694	(.0226, .1162)	.0490	.004
AB	.5294	(.4197, .6390)	.1406	<.001	.2103	(.1572, .2634)	.1282	<.001
Survey year (2017/18)	-.0810	(-.1588, -.0031)	-.0247	.041	.0124	(-.0252, .0500)	.0087	.518
Area-level controls								
Deprivation Index								
1st Quintile (Least deprived, ref)								
2nd Quintile	-.1595	(-.2684, -.0505)	-.0438	.004	-.0103	(-.0629, .0424)	-.0065	.702
3rd Quintile	-.0956	(-.2071, .0159)	-.0266	.093	-.0278	(-.0816, .0260)	-.0178	.311
4th Quintile	-.1526	(-.2693, -.0358)	-.0425	.010	-.0333	(-.0896, .0231)	-.0212	.248
5th Quintile (Most deprived)	-.3060	(-.4301, -.1818)	-.0851	<.001	-.0229	(-.0830, .0372)	-.0146	.455
Urbanicity (Rural)	.0342	(-.0813, .1498)	.0083	.561	.1007	(.0450, .1564)	.0562	<.001
Related outcome controls								
Household PEB	--	--	--	--	.0982	(.0849, .1115)	.2254	<.001
Nature Cons. PEB	.4215	(.3643, .4786)	.1836	<.001	--	--	--	--
Constant	1.2523	(.8806, 1.6240)		<.001	.2300	(.0498, .4101)		.012
N	4874				4874			
Adjusted R^2	.29				.13			

Indirect contact (nature media)

The clearest moderation patterns emerged between nature connectedness and the propensity to watch/listen to nature media. Firstly, a statistically significant interaction between nature connectedness and nature media observed for household pro-environmental behaviours *(b* = .0030, *95% CIs* = .0005, .0055, *p* = .019; Wald $\chi 2$ omnibus test: $F(1, 4844) = 5.55$, $p = .018$). As shown in Figure 3.2a, individuals who watched nature media reported more household pro-environmental behaviours than those who did not, and this pattern became more marked as nature connectedness increased. Secondly, there was a statistically significant interaction between nature connectedness and nature media on nature conservation behaviours (*b* = .0032, *95% CIs* = .0020, .0044, $p < .001$; Wald $\chi 2$ omnibus test: $F(1, 4844) = 26.98$, $p < .001$). Notably, for individuals who did not watch nature media, nature connectedness had little impact upon conservation behaviours (Figure 3.2b). Conversely, amongst those that watched nature media, conservation behaviours increased as nature connectedness increased in a similar fashion (i.e. slope) to household behaviours. In sum, there were positive synergistic effects of nature connectedness and watching/listening to nature media.

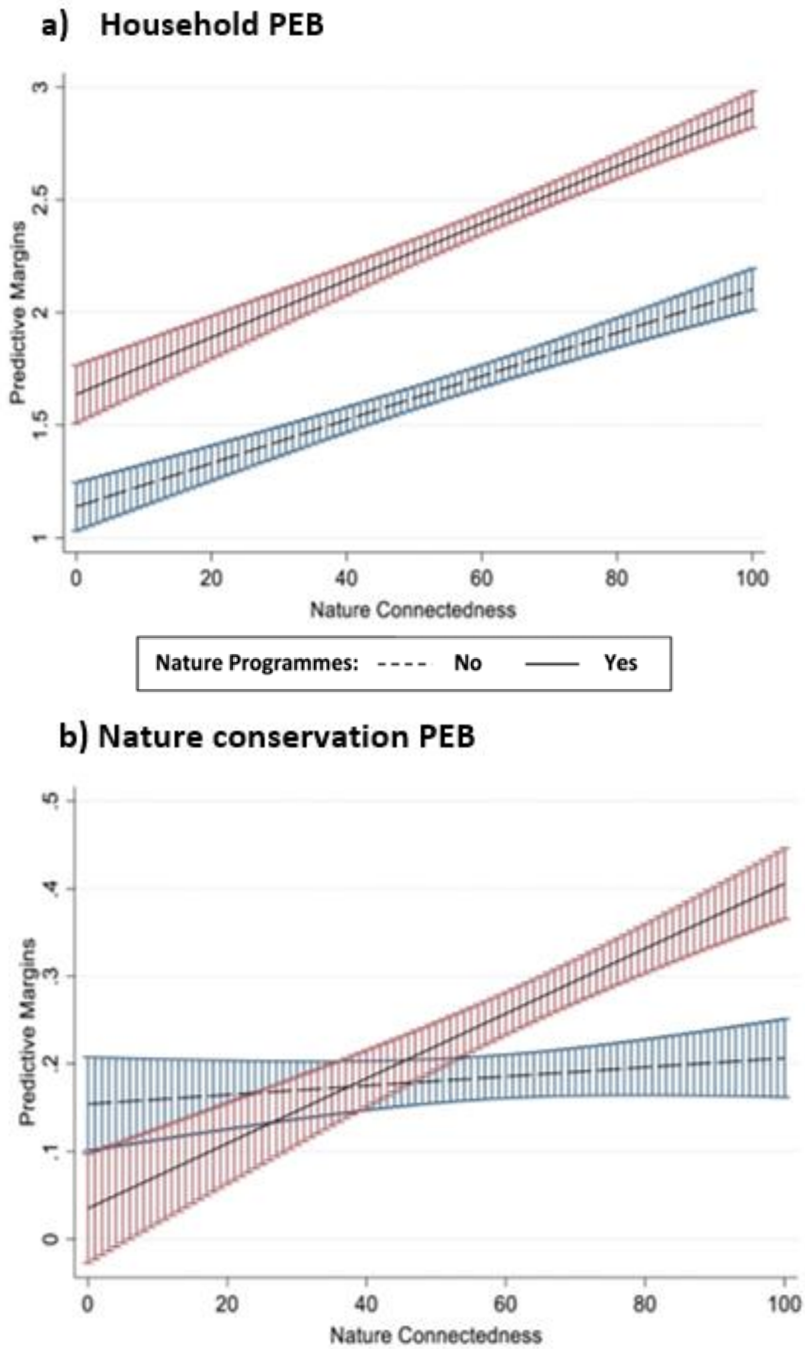

Figure 3.2. Predictive margins for pro-environmental outcomes as a function of nature media and nature connectedness.

3.5 Discussion

Study 3 investigated the associations between three types of nature contact (*residential*- neighbourhood greenspace, *intentional*- nature visits, *indirect*- nature media), nature connectedness and two domains of pro-environmental behaviour (household, nature conservation) using a representative sample of the adult population of England. The aims of the study were two-fold: 1) to examine the relative associations between different types of nature contact and the pro-environmental behaviours and, 2) to explore what role nature connectedness played in these associations. Within this Section, the main findings of Study 3 are outlined, in relation to research questions 1b and 2. The study limitations and directions for future research are also considered.

3.5.1 RQ1b. How are Different Types of Nature Contact Related to Pro-Environmental Behaviours?

Contrary to predictions and prior work (Whitburn et al., 2019; Alcock et al., 2020), neighbourhood greenspace was unrelated to both domains of pro-environmental behaviour, and this finding was robust to different operationalisations of greenspace. It is noteworthy that Alcock et al. (2020) found a positive relationship between high (*vs.* low) neighbourhood greenspace and pro-environmental behaviours in rural, but not urban neighbourhoods. Although it was not possible to conduct a similar analysis in Study 3, due to limited sample size (rural sub-sample N = 695), the null effects may be due to the predominantly urban sample used here. Equally, given that the benefits of greenspace increase with biodiversity (Fuller et al., 2007; Wood et al., 2018), and that biodiversity itself predicts more sustainable behaviour (Cazalis & Prévot, 2019), the lack of an association may reflect that the metric used in Study 3 focused on the quantity rather than the quality of greenspace (Van Dillen et al., 2012; Francis et al., 2012).

Nevertheless, it is also possible that the mere presence of greenspace is simply not an important determinant of pro-environmental behaviours, compared to other forms of nature contact. Indeed, contrary to common assumptions about residing in greener areas facilitating more time in nature, previous analysis of a different subsample of MENE data observed that people in England living in the least green areas spend significantly more time visiting nature than those living in the greenest areas, (White et al., 2019; Alcock et al., 2020). It has been suggested that individuals living in less green areas may make more intentional nature visits to compensate for the lack of greenery within their immediate neighbourhood (Sijtsma et al., 2012). Taken together with the weak correlation between neighbourhood greenspace and nature visits observed within the current study, such findings further highlight the importance of distinguishing between the presence and use of greenspace.

Consistent with both evidence and theory suggesting that direct contact with nature promotes ecological attitudes and behaviours (Hartig et al., 2001; Lawrence, 2012; Coldwell & Evans, 2017), individuals who visited natural spaces at least once a week (*vs.* less than weekly) were more likely to engage in household pro-environmental behaviours, such as recycling and buying ecological products. Moreover, the increase in household behaviours associated with weekly nature visits was substantially higher than that associated with being female (*vs.* male), although it did not exceed that of belonging to a higher (*vs.* lower) social group. Conversely, nature visits were unrelated to nature conservation behaviours. Thus, the benefits of weekly nature visits did not appear to extend to pro-environmental behaviours involving greater personal investment in environmental issues (e.g. volunteering). This finding is in line with prior work observing differences in the strength of the associations between nature contact and distinct types of pro-environmental behaviours (Alcock et al., 2017).

The lower frequency with which individuals reported conservation behaviours, as well as the moderate bivariate association between household and nature conservation pro-environmental behaviours, are potentially telling in this respect. They suggest that even for those individuals who engage in household pro-environmental behaviours, this does not always correspond with a higher propensity to perform conservations behaviours. With evidence that perceived similarity predicts behavioural spill-over effects between distinct pro-environmental domains (Thøgersen, 2004), the divergent findings may reflect a lack of recognition that household and conservation behaviours are intrinsically linked to a common goal. Additionally, perceived difficulty is an important determinant of sustainable behaviours (Rosentrater et al., 2013, Fujii, 2006), and there are evident differences in the ease of performing more routine household activities such as recycling, compared to conservation behaviours, that often require more commitment and personal investment (Bamberg & Moser, 2007; Steg and Vlek, 2009). Equally, the discrepancy may reflect the role of habit formation in directing sustainable behaviours (Steg and Vlek, 2009; Miller et al., 2015). Specifically, the regularity with which household behaviours, such as recycling, are performed, allows for the development of automatic responses to contextual cues; whereas less commonplace conservation behaviours are likely to require more conscious decision making (Alcock et al., 2020). With the fully-adjusted models explaining a relatively low level of the variance in nature conservation (9%), it is evident that there is still much to learn about the factors influencing this more challenging behavioural domain.

Considering these disparities, it is therefore encouraging that watching/listening to nature media was positively associated with both household and nature conservation pro-environmental behaviours. Extending experimental work (Zelenski et al., 2015), by using a more naturalistic measure of indirect nature contact, these findings suggest nature media has the potential to simultaneously influence two domains of pro-environmental behaviours within the general population. For household pro-environmental behaviours, these findings are likely to be practically meaningful, given the strength of this association was considerably greater than that of visiting natural spaces, as well as benchmark socio-demographics (gender and social grade) that are less amenable to change.

Watching/listening to nature media was the only nature contact variable to predict nature conservation behaviours. The magnitude of the association exceeded that associated with being female (*vs.* male) but was substantially smaller than that of belonging to a higher (*vs.* lower) social group. This likely reflects the broader challenges of motivating individuals to perform pro-environmental behaviours that involve greater personal investment (Bamberg & Moser, 2007; Steg and Vlek, 2009). Nevertheless, the positive association found here is somewhat intuitive, when one considers that such programmes typically feature high quality environments (e.g., rainforests) that are likely to be richer in biodiversity than many individual's local nature experiences. Indeed, watching biodiverse nature media can promote a sense of awe (an emotional response to perceptually vast stimuli that transcend current frames; Young-Mason 2020), which has been shown to motivate individuals to make personal sacrifices for the environment (Zhao et al., 2018). Moreover, in addition to providing many of the sensory aspects of real nature contact (e.g., visual /audio nature material), nature media often contain sustainability narratives. For instance, a recent content analysis of the scripts from the Netflix's Our Planet series found frequent mentions of anthropogenic activities and conservation successes embedded within each episode (Jones et al., 2019). With the presentation of such information linked to a rise in conservation intentions (Hofman & Hughes, 2018), further research is required to establish whether the positive association observed here is due to virtual contact with nature itself, and/or exposure to sustainability narratives.

Additionally, causal directionality within the current study is unclear. It may also be the case that people who begin to engage in more pro-environmental behaviours, for instance, due to external circumstances such as the introduction of a new doorstep recycling scheme, may start to become more interested in nature-related programmes. Nonetheless, with individuals spending increasing amounts of their recreational time indoors, watching/listening to digital media (Office for National Statistics, 2017), alongside difficulty accessing nature amongst vulnerable groups, these initial findings are encouraging. If substantiated by further work, then nature media may constitute a viable method of encouraging two domains of sustainable behaviour within the general population, as well as in sub-populations who are less able to visit natural spaces.

The pattern of associations between socio-demographic covariates and outcome variables reflect well-established social gradients in sustainability behaviours. The findings are in line with prior studies indicating that females (*vs.* males) and individuals who are married/cohabiting (*vs.* single/widowed/divorced) perform more commonplace pro-environmental behaviours (Patel et al., 2017; Scannell & Gifford, 2013). Associations to socio-economic indicators (education, income and social grade) also replicate prior work showing that individuals from higher socio-economic groups tend to behave more sustainably (Owens et al., 2000; McEachern & Mcclean, 2002; Pisano & Lubell, 2017). Such consistency provides greater assurance in the robustness of the data.

Overall, Study 3 indicated that specific types of nature contact are differentially associated with pro-environmental behaviours. Whilst residential nature contact (neighbourhood greenspace) was unrelated to behaviours in both pro-environmental domains, voluntarily engaging with nature, either directly (by visiting natural spaces), or indirectly (through nature media), predicted an increased propensity to behave sustainably. For household pro-environmental behaviours, both visiting natural spaces at least once a week and watching/listening to nature media were associated with more sustainable behaviours. That both indicators remained statistically significant within the same models suggests that the benefits of these two types of nature contact may be cumulative for household pro-environmental behaviours. Conversely, of the nature contact variables, only watching/listening to nature media predicted greater engagement in nature conservation behaviours. As these associations remained after accounting for a range of socio-demographics known to influence sustainability outcomes, Study 3 situates intentional and indirect nature contact as important predictors of pro-environmental behaviour in their own rights. Although the effect sizes for both variables were small, where statistically significant nature-behaviour associations were observed, they were often larger in magnitude than those associated with benchmark socio-demographics of gender, and, albeit to a lesser extent, social grade. Thus, if further evidence can corroborate that these associations are causal, policies encouraging contact with the natural world, through more nature visits and nature media, may constitute a viable strategy of promoting sustainable behaviours.

***3.5.2 RQ2*. What Role does Trait Nature Connectedness Play in these Associations?** Regarding the psychological trait of nature connectedness, Study 3 tested two competing hypotheses: whether nature connectedness operates in parallel with nature contact or influences how nature contact affects pro-environmental behaviours. Extending prior work (Mackay & Schmitt, 2019; Whitburn et al., 2020), the positive associations between nature connectedness and both domains of pro-environmental behaviours remained after accounting for: a) various types of nature contact, and b) a comprehensive range of socio-demographics. This indicates that the sustainability benefits associated with feeling more connected to the natural world are not simply an artifact of shared variance with nature contact measures, or the result of socio-demographic confounding. Rather, trait nature connectedness appears to be an independent and robust predictor of both household and nature conservation behaviours. For household behaviours, this association is likely to be practically meaningful, given the magnitude exceeded that of bench-mark socio-demographics (i.e., gender and social grade). In relative terms, nature connectedness was a stronger predictor of conservation behaviours than nature media and gender, but exerted a substantially smaller influence than social grade. Again, this may reflect the broader challenges of encouraging individuals to perform pro-environmental behaviours that involve greater personal effort (Bamberg & Moser, 2007; Steg and Vlek, 2009).

Stable individual differences in trait nature connectedness also moderated the associations between specific types of nature contact and pro-environmental outcomes. Therefore, the findings extend prior theory and research that focused on the mediating role of state connectedness (Mayer et al., 2009; Whitburn et al., 2019), demonstrating that *trait* nature connectedness appears to modify the way in which individuals respond to contact with the natural world (Arendt & Matthes, 2016; Ojala, 2009). Specifically, for intentional nature contact, weekly visits alone were not sufficient to encourage conservation behaviours, individuals also needed to feel an affinity towards nature, in order to act to protect it. This suggests that efforts to build nature connectedness may be particularly important for these more challenging behaviours. Congruent with prior research (Arendt & Matthes, 2016), the moderation effects observed suggested that the associations between watching/listening to nature media and both domains of pro-environmental outcomes were stronger for individuals who were most highly connected to nature. These findings are broadly consistent with person-environment fit theories postulating that optimal behavioural outcomes emerge when an individual's personal attributes (e.g. their values) are compatible with environmental attributes (Caplan, 1987). Taken together, the findings of Study 3 suggest that efforts to build trait nature connectedness may be particularly important for influencing household and nature conservation behaviours.

3.5.3 Limitations

The results of Study 3 should be considered within the context of several limitations. First, despite experimental evidence demonstrating more pro-environmental behaviours following nature contact (Zelenski et al., 2015), use of cross-sectional data limits causal inferences. This is particularly the case, since pro-environmental behaviour, nature contact and nature connectedness are likely to be self-reinforcing and bidirectional (Wyles et al. 2019). For instance, positive experiences in nature, over a sustained period of time, may strengthen trait connectedness; and their influences on pro-environmental behaviours could further reinforce a sense of connection and a desire to for contact with nature. Second, results are based on self-report data. Whilst self-reported pro-environmental behaviours are good predictors of actual behaviour (Fujii et al., 1985, Warriner et al., 1984), possible misclassifications in outcome variables due to social desirability bias cannot be ruled out. Third, survey data were collected several years after the neighbourhood greenspace data which was assigned to individuals based on the LSOA of their current residence. Consequently, it may be that levels of neighbourhood greenspace actually experienced at the time of self-reported outcomes differed from the values used here, which may have added error to the models. Future work using temporally consistent exposure and outcome metrics would be useful, although this is not always easy to establish at the national scale. Fourth, the results are based on the covariates available in the waves of the MENE dataset that included the NCI. Unfortunately, variables including the amount of physical activity undertaken per week, and the existence of a long-term limiting illness/disability were not available in these waves. Thus, unlike previous MENE studies that have controlled for these factors, I was unable to do so here. Fifth, Study 3 tells us little about the mechanisms underlying these nature-behaviour associations. As outlined in Chapter 1 (Section 1.3.3), there are a number of mechanisms through which increased nature contact may influence sustainability behaviours. Notably, natural environments have been associated with improved affect (McMahan & Estes, 2015) and social cohesion (Jennings & Bamkole, 2019; Liu et al., 2020), as well reduced temporal discounting (Berry et al., 2014). Given that these constructs independently predict better engagement in pro-environmental behaviours (Coelh et al., 2017; Spence et al., 2012; Weinstein et al., 2015), further research might usefully explore these potential mediating pathways.

3.4.4 Conclusion

Environmental sustainability presents one of most significant global challenges of the 21st century (United Nations Environment Programme, 2016; World Health, 2015). With evidence that anthropogenic activities exacerbate environmental issues, identifying effective strategies that promote sustainable behaviours is fundamental to achieving current sustainability goals (Department of Environment, Food & Rural Affairs, 2018; United Nations Sustainable Development Goals, 2018). Study 3 contributes to a greater understanding of the links between nature contact, nature connectedness and two domains of pro-environmental behaviour. After controlling for a range of covariates, neighbourhood greenspace had little influence on household behaviours. Voluntary engagement with the natural world, either directly (through nature visits), or indirectly (via nature media), however, were both associated with a heightened propensity to behave sustainably. For household pro-environmental behaviours, the benefits of visiting natural spaces at least once a week and watching/listening to nature media appear to be cumulative. Conversely, of the nature contact variables, only watching/listening to nature media predicted greater engagement in nature conservation behaviours. Recognition of these associations supports the need to protect natural spaces, in order to optimise their potential benefits for planetary health. Furthermore, where statistically significant nature-behaviour associations were found, many were moderated by psychological connectedness with nature. This suggests that nature contact may be more effective when accompanied by a positive disposition towards natural environments. If substantiated by further work, then policies encouraging more voluntary nature contact, in addition to greater sense of connection to nature, may constitute a viable strategy of promoting sustainable behaviours across domains.

The studies presented so far constitute a partial investigation of a larger conceptual model (Figure 1.1, Chapter 1) proposing that that increased contact with - and psychological connection to - nature, would be associated with behavioural determinants of public and planetary health (i.e., health risk behaviours and pro-environmental behaviours), via positive affect, negative affect, community cohesion and temporal discounting. Examination of health risk and pro-environmental behaviours in parallel, rather than within the same sample, makes it difficult to ascertain whether contact with, and psychological connection to nature, are simultaneously associated with behaviours across the two domains. Uncertainty also remains over the mechanisms underlying nature-behaviour associations. Thus, Chapter 4 presents a final study addressing these issues in full, by investigating: 1) a range of health risk and pro-environmental outcomes, simultaneously, within the same sample; and 2) multiple mediating pathways (positive affect, negative affect, social cohesion and temporal discounting) between nature contact/connectedness and these two behavioural domains.

Chapter 4

Nature - behaviour associations: a multiple mediation model.[6]

4.1 Chapter Overview

Chapters 2 and 3 provided partial investigations of a conceptual model proposing that increased contact with – and psychological connection to – nature would be associated with behavioural determinants of public and planetary health (i.e., health risk behaviours and pro-environmental behaviours) via positive affect, negative affect, community cohesion and temporal discounting. The current chapter presents a cross-sectional study investigating the full conceptual model. Specifically, Study 4 examines the associations between different types of nature contact, nature connectedness and a range of: a) health risk behaviours; and b) pro-environmental behaviours. In addition, Study 4 provides an initial exploration of whether the relationships between nature contact/connectedness and behavioural outcomes are mediated by: positive affect, negative affect, community cohesion and temporal discounting. This chapter addresses three overarching research questions:

RQ1: What are the associations between different types of nature contact and a) health risk behaviours and b) pro-environmental behaviours, after accounting for a range of socio-demographics?

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[6] An abridged version of Study 4 is in preparation for submission to Environment & Behavior:

Martin, L., Pahl, S., White, M.P. & May, J. (*In prep*). Types of nature contact: a multiple mediation model of their relative influences on health risk and pro-environmental behaviours.

RQ2. What role does trait nature connectedness play in these associations?

RQ3. What are the mechanisms underlying associations between nature contact/connectedness and behavioural outcomes?

4.2 Study 4. Nature-Behaviour Associations: a Multiple Mediation Model

4.2.1 Summary of Studies 1-3

Prior studies in this thesis broadly supported the original conceptual model proposing that increased contact with – and psychological connection to – nature would be associated with behavioural determinants of public and planetary health (i.e. health risk behaviours and pro-environmental behaviours). Increased nature contact was associated with: a) a lower prevalence of health risk behaviours, and *b*) a greater propensity to engage in pro-environmental behaviours (Study 3). Further, for both health risk and pro-environmental behaviours there was some evidence that nature connectedness moderated the associations between nature contact variables and behavioural outcomes (Studies 2 & 3).

Nevertheless, systematic differences in the strength of the nature-behaviour associations indicated that different types of nature contact may be more relevant to specific behavioural outcomes. Notably, residential nature contact (neighbourhood greenspace) emerged as a fairly consistent inverse predictor of health risk behaviours (Studies 1 & 2), but was unrelated to pro-environmental behaviours (Study 3). Whilst intentional nature contact (nature visits) predicted a lower prevalence of current smoking, visiting natural spaces at least once a week was unrelated to the prevalence of exceeding alcohol guidelines (Study 2). Likewise, weekly nature visits predicted a greater propensity to engage in household pro-environmental behaviours, but were unrelated to conservation behaviours (Study 3). Nature connectedness did not independently predict health risk behaviours (Study 2), yet was associated with greater engagement in pro-environmental behaviours across domains (Study 3). Nonetheless, assessments of health risk and pro-environmental behaviours within the same sample are required to ascertain whether increased nature contact, or indeed nature connectedness, are simultaneously associated with these behavioural outcomes. To address this, Study 4 includes a range of health risk and pro-environmental behavioural outcomes within the same study, and indeed applies the same statistical analyses to both behavioural domains. In addition, Study 4 incorporates a broader range of health risk behaviours and types of nature contact than previous studies.

First, Studies 1 and 2 focused exclusively on health risk behaviour involving potentially addictive, psychoactive substances (i.e. nicotine and alcohol). Nevertheless, there is evidence that increased nature contact may also be beneficial to other health risk behaviours. Notably, greener views have been associated with reduced cravings for a range of addictive and non-addictive substances, including food (Martin et al., 2019). Indeed, as outlined in Chapter 1 (Section 1.3.1), inverse bivariate relationships between neighbourhood greenspace and high fat diets have been observed in large scale cross-sectional research (Astell-Burt, Feng & Kolt, 2014), indicating that the benefits of residential nature contact may extend beyond subjective experiences of cravings to healthier dietary behaviours. With participation in community gardening schemes associated with higher fruit and vegetable intake (Alaimo et al., 2008), and brief exposures to nature posters linked to healthier snack choices (Stöckli et al., 2016), intentional and indirect nature contact may also be beneficial to diet quality. Although I know of no prior work examining the link between nature connectedness and diet quality, evidence that nature connectedness positively predicts fruit and vegetable consumption in children (Sobko et al., 2020) indicates its potential predictive value.

Second, Studies 1 & 2 focused exclusively on residential and intentional nature contact. Therefore, it is currently unclear whether the potential benefits of nature media (e.g. watching/listening to nature media) observed for pro-environmental behaviours (Study 3), might also extend to a lower prevalence of health risk behaviours. The broader negative impacts of increased media use on smoking, alcohol consumption and dietary intake are well documented (Grant et al., 2019; Dong et al., 2020; Niermann et al., 2018). However, experimental findings that participants smoke less (Wu & Chiou, 2019) and make healthier dietary choices (Kao et al., 2019) after viewing media of natural (*vs.* urban) scenes indicate that watching/listening to nature media may be inversely associated with health risk behaviours.

To address these gaps in the literature, Study 4 examines the associations between three types of nature contact (residential, intentional and indirect), nature connectedness and a broad range of health risk (current smoking, exceeding alcohol guidelines, poor diet) and pro-environmental (household, nature conservation) behavioural outcomes. Hypotheses, drawing on the studies reviewed above, were as follows:

H_1. Residential nature contact (green views from home)[7] will be negatively associated with health risk behaviours (a. current smoking, b. exceeding alcohol guidelines, c. poor diet), after accounting for a range of socio-demographics.

[7] I had intended to collect all but the last digit of participants' postcodes- the minimum information required to derive percentage greenspace by LSOA- without requesting personally identifiable data. However, an error with the postcode survey item validation in Qualtrics resulted in respondents providing varying amounts of postcode data. With the majority of respondents providing all but the last two digits of their postcode, it was possible to include some existing area-level covariates at the postcode-sector level (i.e. population density, deprivation) into the analyses, however there are no publically available measures of neighbourhood greenspace at this scale. Whilst neighbourhood greenspace by postcode-sector could have been calculated using Geographic Information Systems (GIS), given the relatively short time-frame to complete the analysis due to the Covid-19 pandemic, coupled with my unfamiliarity mapping geographical data, self-reported green views from home (an additional variable collected in the survey) was used as an alternative measure of residential nature contact in this study.

Based on the non-significant associations between neighbourhood greenspace and pro-environmental behaviours observed in Study 3, it is expected that green views from home will be unrelated to household and nature conservation pro-environmental behaviours.

H_2. Intentional nature contact (nature visits) will be negatively associated with: a) current smoking and b) poor diet; and positively associated with: c) household pro-environmental behaviours, after accounting for a range of socio-demographics.

Consistent with non-significant associations in Study 2 and Study 3, nature visits were expected to be unrelated to exceeding alcohol guidelines and nature conservation behaviours.

H_3. Indirect nature contact (nature media) will be negatively associated with health risk behaviours (a. current smoking, b. exceeding alcohol guidelines, c. poor diet); and positively associated with pro-environmental behaviours (d. household, e. nature conservation), after accounting for a range of socio-demographics.

H_4. Trait nature connectedness will negatively predict a. poor diet and positively predict pro-environmental behaviours (b. household, c. nature conservation) after accounting for nature contact and a range of socio-demographics.

In line with Study 2, I expected nature connectedness to be unrelated to health risk behaviours involving the consumption of psychoactive substances (current smoking, exceeding alcohol guidelines), after controlling for covariates.

H$_5$. Nature connectedness will moderate the associations between nature contact and: a) health risk behaviours and pro-environmental behaviours, after accounting a range of socio-demographics. Specifically, better behavioural outcomes (i.e. a lower prevalence of health risk behaviours and greater engagement in pro-environmental behaviours) will occur amongst individuals whose level of nature contact is consistent with their psychological affinity to the natural world.

4.2.2 Potential Mediators of Nature-Behaviour Associations

As outlined in Chapter 1 (Section 1.3.3), greater contact with – and psychological connection to – nature are associated with higher positive affect, lower negative affect, greater community cohesion and reduced temporal discounting (e.g. Browning et al., 2020; Capaldi et al., 2014; Jennings & Bamkole, 2019; Dean et al., 2018; Berry et al., 2014, 2015, 2019). As these constructs are independently associated with lower engagement in health risk behaviours on the one hand (e.g. Peltzer et al., 2017; Ng & Jeffery, 2003; Patterson et al., 2004; Dassen et al., 2015), and a greater propensity to behave pro-environmentally on the other (Chatelain et al., 2018; Coelh et al., 2017; Uzzell et al., 2002; Spence et al., 2012), each has the potential to mediate associations between nature contact/connectedness and behavioural outcomes. However, although a small number of experimental studies have found some of these constructs mediate nature-behaviour associations (i.e. temporal discounting; Wu & Chiou, 2019; Kao et al., 2019), little work has explored multiple mediators within the general population. Based on the research outlined above, the hypotheses were:

H$_6$. Nature-behaviour associations will be mediated by: a) higher positive affect; b) lower negative affect; c) higher community cohesion; and d) lower temporal discounting, after controlling for socio-demographics and other proposed mediators.

4.3 Method

4.3.1 Participants

Data were collected during September 2020 using an online survey administered to 4,151 adults from Great Britain using CINT research panels[8]. To minimise potential confounding due to the Covid-19 pandemic, individuals who had been self-isolating or shielding at any time in the four weeks prior to data collection were excluded from participating. The survey took approximately 10 minutes to complete and comprised of a series of measures presented to participants in five sections: aspects of their local home environment (including community cohesion), sustainable behaviours, health (including positive and negative affect), monetary choices (the temporal discounting measure) and demographics. Demographic information, including partial-postcode, was obtained last, with the remaining sections counterbalanced between participants to mitigate potential order effects. Where possible, measures addressed the same temporal frame (i.e. four weeks prior to survey completion). The current study used a sub-sample of the dataset (N = 3, 811) for cases where: 1) respondents provided a valid partial-postcode or sufficient length to determine post-code sector and, 2) there were no missing data for any other variables. As with studies 1-3, comparison of the proportion of individuals within each socio-demographic group did not vary greatly between the full and reduced sample (<1%), indicating no systematic biases in the exclusion of missing data.

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[8] This study was pre-registered on Open Science Framework:

Martin, L., Pahl, S., White, M.P & May, J. (2020). Mechanisms underlying associations between nature contact, nature connectedness and behavioural determinants of human/planetary health (health risk behaviours, pro-environmental behaviours). *Open Science Framework*. DOI 10.17605/OSF.IO/VJSHA

4.3.2 Measures

4.3.2.1 Outcome Variables

Health risk behaviours[9]

Smoking

Using an item from the European Social Survey (2020), respondents were asked: "Which of these best describes your smoking behaviour? This includes rolled tobacco but not pipes, cigars or electronic cigarettes". Response options were: 1) I have never smoked, 2) I have only smoked a few times, 3) I do not smoke now but I used to, 4) I smoke but not every day, 5) I smoke daily, and 6) Prefer not to answer. Respondents' smoking status was dichotomised according to whether they were current smokers (N = 944; 4 & 5) *vs.* non-smokers (N = 2867, 1-3), with the latter category aggregating former regular smokers and never regular smokers. Those who did not answer (N = 44) were excluded from the analyses.

Exceeding alcohol guidelines

Two single item questions were used to assess respondents' alcohol consumption over the last four weeks. Firstly, consistent with the European Social Survey (2020) respondents were asked "how often have you had a drink containing alcohol? This could be wine, beer, spirits, or other drinks containing alcohol" (1. Not at all, 2. Once or twice in the last four weeks, 3. Once a week, 4. Several times a week, 5. Every day). Additionally, using an adaptation of the single-item question developed by Smith (2009) respondents indicated "over the last four weeks, how often have you consumed more than 14 units of alcohol in a week" (1. 14 units or less each week, 2. More than 14

[9] Attempts to create a composite health risk behaviour scale were unsuccessful (see Appendix 15 for details), therefore in line with studies 1 and 2, health risk behaviours were operationalised as binary variables.

units occasionally, 3. More than 14 units most weeks, 4. More than 14 units every week). The two items were highly correlated ($r = .66$, $p < .001$), loaded onto the same factor (Appendix 15), and contrary to the findings of Studies 1 and 2, exhibited similar associations to predictor variables (Appendix 16). Therefore, to avoid issues with multicollinearity in the multivariate models, a composite binary indicator of exceeding alcohol guidelines was created (No, N = 3113 *vs.* Yes, N = 698). Specifically, consistent with Department of Health (2016) recommendations, respondents were considered to have exceeded guidelines if they drank everyday (No, N =3575; Yes, N = 236); *and/or* they reported regularly consuming more than14 units of alcohol a week (> more than 14 units most weeks, N =634 *vs.* ≤ more than 14 units occasionally; N = 3177). A sensitivity analysis comparing the inclusion *vs.* exclusion of respondents who indicated that they had not consumed any alcohol during the last four weeks ('Not at all', N= 906), yielded largely consistent results (Appendix 17). Therefore, the unconditional prevalence of exceeding alcohol guidelines (i.e., proportions amongst the entire sample, including non-drinkers) is reported here to maximise sample size.

Diet quality

Following Loftfield et al., (2015) respondents were required to indicate "In general, how healthy was your overall diet in the last four weeks?" (1. Excellent, 2. Very Good, 3. Good, 4. Fair, 5. Poor). As only 179 respondents reported having a poor diet, a binary indicator was created, dichotomising respondents according to whether they reported a poor or fair diet (N = 1082, 4 & 5) *vs.* good-excellent (N= 2,729).

Pro-environmental Behaviours

Adapting the timeframe of the MENE item (Natural England, 2018) used in Study 3 (Chapter 3, Section 3.3.3), respondents were required to indicate which environment-related activities they had undertaken during the last four weeks (Table 4.1). Each of the items was binary coded (yes = 1, no = 0) to represent engagement in that specific behaviour. A principal components analysis with an orthogonal varimax rotation (*KMO* =.74; Bartlett's test of sphericity: $\chi 2$ (45) = 3501.88., $p < .001$), yielded a two-factor solution, with Factor 1 and Factor 2 accounting for 45.80% and 54.20% of the variance, respectively. Consistent with Study 3, these factors were labelled: household, and nature conservation behaviours. The number of behaviours reported for each factor were totalled to yield scores of 0-5 (household: *M* = 2.72, *SD* = 1.43; nature conservation: *M* = .47, *SD* = .85), with higher scores on each factor indicating a greater propensity to act sustainably.

4.3.2.2 Predictor Variables

Nature contact

Consistent with Studies 2 and 3, a range of nature contact metrics were operationalised.

Residential (green view from home): As outlined in Section 4.2.1, technical issues resulting in truncated post-code data, meant I was unable to assign respondents greenspace values by LSOA. With no existing neighbourhood greenspace measures available at the postcode-sector level (for which there was sufficient data for the majority of respondents), green views from home provided an alternative measure of residential nature contact. Consistent with prior research (Taylor et al., 2002; Martin et al., 2019) respondents were required to estimate the proportion of the view from their home comprising of greenspace (*M* = 25.83, *SD* = 12.10). Despite positive skews in the distribution, multivariate analysis was considered appropriate given the large sample size (Lumley et al., 2002). Sensitivity analyses conducted using binary (high *vs.* low) and quartiles of green view yielded largely consistent findings, indicating that the distributions were not affecting the reliability of our results (Appendix 18).

Table 4.1. Factor Loadings for Pro-Environmental Behaviour Items

	Factor 1 Household Behaviours	**Factor 2** Nature conservation behaviours
Purchased eco-friendly products and brands	**.38**	.27
Brought seasonal or locally grown food	**.39**	.14
Recycled items rather than throw them away	**.49**	-.05
Chosen to walk/ cycle or instead of using my car	**.37**	.03
Conserved water or energy in my home	**.56**	-.03
Encouraged other people to protect the environment	.31	**.33**
Been a member of an environmental/conservation organisation	.01	**.51**
Volunteered to help care for the environment	.00	**.59**
Donated money to support an environmental/conservation organisation	.14	**.40**
Donated my time to an environmental /conservation organisation	.01	**.58**

Intentional contact (nature visits): an item from the MENE survey (Natural England, 2018) was adapted to fit the temporal frame of current study (i.e. last four weeks). Respondents were required to indicate the frequency of 'their leisure visits to natural space over the last four weeks'. Response options were: 1. Not at all in the last four weeks; 2. Once or twice in the last four weeks; 3. Once a week and 4. Several times a week. To enable comparability across studies (e.g. Shanahan et al., 2016, Study 2 & 3), the item was dichotomised according to whether respondents visited natural spaces at least once a week (*vs.* less than weekly).

Indirect contact (nature media): Adapting the timeframe of the MENE item (Natural England, 2018) used in Study 3 (Chapter 3, Section 3.3.3), respondents reported the frequency with which they had 'watched or listened to nature programmes on the TV or radio in the last four weeks' (Not at all in the last four weeks; Once or twice in the last four weeks; Once a week; Several times a week.). As with intentional contact, nature media was dichotomised according to whether respondents reported engaging in this behaviour at least once a week (*vs.* less than weekly).

Nature Connectedness

The Inclusion of Nature in Self Scale (INS; Schultz, 2001) was used as a concise measure of trait nature connectedness. The INS consists of seven circle pairs, labelled 'Self' and 'Nature' that range from barely touching, to entirely overlapping. Respondents were required to select the pair that best represented their sense of connection with nature. Scores on the item range from 1-7 (M = 4.24, SD = 1.69), with higher scores indicating a greater sense of affinity with the natural world.

4.2.2.3 Proposed Mediators

Positive and Negative Affect

With favourable psychometric properties and high levels of reliability, the Scale of Positive And Negative Experience (SPANE, Diener et al., 2010) was used to measure affect. The SPANE was preferable to the Positive And Negative Affect Scale (PANAS, Watson et al., 1988) as it captures a more balanced range of emotions in terms of arousal (Diener et al., 2010). The measure consists of 12 items describing possible affective states, corresponding to the two subscales: positive affect (e.g. pleasant, joyful) and negative affect (e.g. sad, afraid). Participants were required to indicate on a 5-point response scale the extent to which each statement applied to them over the last four weeks (‘Never/very rarely’ to ‘Very often/always’). Aggregate mean positive (M = 20.09, SD = 4.56) and negative affect (M = 15.83, SD = 5.14) scores were calculated for the purpose of bivariate analysis, but individual items were used to construct two latent factors for SEM.

Community Cohesion

Following Weinstein et al. (2015) community cohesion was assessed using four items (“I care about other people in my neighbourhood”, “I feel connected to other people in my neighbourhood”, “I feel that people within my neighbourhood are on the 'same team'”, and “I would help my neighbours if they required 1 hour of my time”). Each item was measured on a 5-point response scale (1, not at all true to 5, very much true). Aggregate mean scores were calculated for the purpose of bi-variate analysis (M = 10.19, SD = 3.25), whilst individual items were used to construct a latent social cohesion factor for SEM.

Temporal Discounting

The Monetary-Choice Questionnaire (MCQ; Kirby & Maraković, 1996) is a brief, reliable measure of temporal discounting (Epstein et al., 2003) suitable for use within a large scale survey. The MCQ comprises of 27 items presenting hypothetical monetary choices between: a) a smaller, immediate monetary reward, or *b*) a larger, delayed reward. Each item choice corresponds to a k value, representing the amount of discounting of the later reward that renders it equal to the smaller reward. The MCQ -27 automated scorer (Kaplan et al., 2016) was used to derive the geometric mean of all item-level k values. The geometric mean *k* represents the overall degree of discounting, with a possible range of .00016 and .25 (Kirby & Maraković, 1996), and higher values indicating a preference for smaller, immediate rewards (*M* = .03, *SD* = .05).

4.2.2.3 Control Variables

Given that the outcome and predictor variables have been previously associated with a range of individual (e.g. socio-economic status, Allen et al., 2017) and area-level confounders (e.g. neighbourhood deprivation, Algren et al., 2015) several control variables were included within the multivariate analyses.

Individual level covariates

Demographic controls included: gender (female, male = reference); age (18-29 = reference, 30-39, 40=49, 50-59, 60+); long-term limiting illness or disability (no = reference, yes); completed higher education (yes, no = reference); working status (unemployed= reference, employed, in education, retired, other); marital status (married/cohabiting, single/widowed/divorced = reference, undisclosed); dog ownership (yes, no = reference); whether or not respondents engaged in 30 minutes of moderate-intensity activity at least 5 days per week (yes, no = reference) and quintiles of household income, ranging from the lowest (1st = reference) to the highest (5th). In order to retain respondents who preferred not to state their income (N = 1,914), a sixth category of 'income undisclosed' was created for this variable. As data were collected during the Covid-19 pandemic, analyses also controlled for whether respondents lived in an area that had been subject to local government restrictions during the four weeks prior to survey completion (yes, no = reference).[10]

Area-level control variables

Partial postcodes (i.e. all but the last two digits) were used to derive area-level covariates at the postcode sector level (detailed characteristic postcode sectors for Scottish respondents). There are 9046 postcode sectors in Great Britain, containing an average of 6,784 residents (ONS, 2011). Using 2011 census data (see Appendix 19 for further details), I calculated population density (*M* = 34.53, *SD* = 34.41) and quintiles of Carstairs deprivation score (1st quintile, most disadvantaged, ≤ 12.10; 5th quintile, least disadvantaged, ≥ - 4.71, *M* = .76, *SD* = 2.97).

4.2.3 Analytical Approach

Analyses were conducted using STATA 16 (StataCorp, College Station, TX). Due to their large number, many postcode sectors contained only a single respondent, rendering multi-level modelling with area modelled as a level one factor inappropriate (Boyd, et al., 2018). To enable comparability with Studies 1-3, a series of multiple regression models were fitted to examine the relative contribution of environmental indicators to each outcome measure, as well as the nature contact x connectedness moderation

[10] During the period of data collection, several areas in Great Britain were subject to enhanced government Covid-19 restrictions, however these did not, at the time data were collected, place any restrictions on time spent outdoors.

effects. Specifically, consistent with Studies 1 and 2, modified Poisson regressions with robust standard errors were used to estimate prevalence ratios for the associations between nature contact, nature connectedness and health risk behaviours. In line with Study 3, linear regressions were used to estimate the associations between nature contact, nature connectedness and pro-environmental behaviours. As with Study 3 rescaling continuous variables would have caused difficulty interpreting interaction terms, thus in line with prior work (White et al., 2013) coefficients are reported to four decimal places (e.g. PR = 1.0011, B =.0021). All regression analyses presented here were adjusted for individual and area-level confounders. Unadjusted and partially adjusted models (accounting for individual level covariates only) are reported in Appendix 20.

A series of robustness checks and exploratory analyses were also conducted using multiple regressions, including: 1) green view by socio-economic interaction effects; 2) associations between nature contact, ever-smoking and smoking cessation; and 3) an assessment of whether the tendency to consume alcohol on visits to natural spaces moderates the associations between visit frequency and exceeding alcohol guidelines.

Finally, the mediation effects depicted in the schematic conceptual model (Figure 1.1, Chapter 1) and alternative causal models were tested using structural equation modelling (SEM). Allowing for the estimation of all indirect and direct effects within a single model, SEM has several advantages over traditional tests of mediation (MacKinnon, 2008). Specifically, multiple mediation models are able to show the unique mediating effects controlling for the presence of other variables, whilst reducing the likelihood of parameter bias associated with omitted variables (Preacher and Hayes, 2008). This was particularly pertinent within the current study, as there were not only multiple mediators, but co-occurrence between behavioural outcomes (see Table 4.1).

With categorical outcomes variables assumptions of linearity and normality were not met, however to better accommodate these indicators, parameters were estimated using the maximum likelihood method with a bootstrap resample of 1000. Goodness of fit indices included: the comparative fit index (CFI) > .95; Tucker-Lewis Index (TLI) >.95; standardized root mean square residual (SRMSR) <.08; and the root-mean-square error of approximation (RMSEA) <.06 (Schreiber, 2008). Chi-square goodness of fit values were not used to assess fit, because this index is less informative with larger samples (Schermelleh-Engel et al., 2003).

4.4 Results

4.4.1 Preliminary Analysis

Descriptive statistics and bivariate analyses are presented in Table 4.2. Approximately a quarter of respondents (25%) were current smokers and almost one fifth exceeded alcohol consumption guidelines (18%). Under a third of the sample reported having a poor diet (28%). On average, individuals engaged in fewer nature conservation behaviours, relative to household pro-environmental behaviours (*M* = .47 *vs*. 2.72). Bivariate associations were generally consistent with predictions that increased contact with – and psychological connection to – nature would be inversely associated with health risk behaviours and positively associated with pro-environmental behaviours, via higher positive affect, lower negative affect, higher social cohesion and lower temporal discounting. Exceptions were: a) watching/listening to nature media at least once a week was positively associated with current smoking (r = .11, p <.001) and exceeding alcohol guidelines (r = .08, p <.001); b) nature connectedness was positively related to current smoking (r = .04, p = .008); c) watching/listening to nature media at least once a week was positively associated with temporal discounting (r = .07, p = .011); and

Table 4.2. Bivariate correlations between nature contact, nature connectedness, behavioural outcomes and proposed mediators

	1	2	3	4	5	6	7
1. Green view (%)	**25.83 (12.10)**						
2. Nature visits (≥ once a week)	.06***	**2,028 (53.21)**					
3. Nature media (≥ once a week)	-.01	.18***	**1,118 (29.34)**				
4. Nature connectedness (INS)	.07***	.26***	.20***	**4.24 (1.69)**			
5. Current smoker (yes)	-.07***	.01	.11***	.04*	**944 (24.77)**		
6. Exceeds alcohol guidelines (yes)	-.05**	.04*	.08***	-.01	.15***	**698 (18.32)**	
7. Poor diet (yes)	-.06***	-.11***	-.08***	-.13***	.03	-.02	**1,082 (28.39)**
8. Household PEB	.08***	.25***	.12***	.31***	-.05**	-.02	-.11***
9. Nature conservation PEB	-.01	.11***	.21***	.20***	.05**	.09***	-.08***
10. Positive affect (SPANE)	.07***	.18***	.07***	.21***	-.04*	-.01	-.28***
11. Negative affect (SPANE)	-.06***	-.06**	.03	-.12***	.09***	.09***	.20***
12. Community cohesion	.02	.17***	.17***	.22***	.08***	.04*	-.19***
13. Temporal discounting (MCQ)	-.07***	-.03	.07***	.03	.15***	.05**	.04*

Table 4.2 continued.

	8	9	10	11	12	13
1. Green view (%)						
2. Nature visits (≥ once a week)						
3. Nature media (≥ once a week)						
4. Nature connectedness (INS)						
5. Current smoker (yes)						
6. Exceeds alcohol guidelines (yes)						
7. Poor diet (yes)						
8. Household PEB	**2.72 (1.43)**					
9. Nature conservation PEB	.24***	**.47 (.85)**				
10. Positive affect (SPANE)	.15***	.07***	**20.09 (4.56)**			
11. Negative affect (SPANE)	-.07***	.08***	-.56***	**15.83 (5.14)**		
12. Community cohesion	.14***	.17***	.38***	-.21***	**10.19 (3.24)**	
13. Temporal discounting (MCQ)	-.10***	.00	.00	.05**	.04*	**.03 (.05)**

Note: * *p* <.05, ** *P*<.01 *** *p*<.001; PEB = Pro-environmental behaviours. Figures below the diagonal derived from Pearson coefficients for continuous data and point bi-serial correlations for binary variables. Where both variables were binary, Pearson coefficients were used to estimate relationships for conciseness. Figures in bold along the diagonal express the Mean (Standard Deviation) of continuous variables and Numbers (%) for binary variables. INS = Inclusion of Nature in Self Scale; PEB = Pro-environmental behaviour; SPANE = Scale of Positive And Negative Experience; MCQ = Monetary Choices Questionnaire

d) community cohesion was positively related to current smoking (r = .08, p < .001) and exceeding alcohol guidelines (r = .04, p = .016).

4.4.2 Regression Models

Fully-adjusted regression models of nature contact, nature connectedness and behavioural outcomes, controlling for covariates, are summarised in Tables 4.3 and 4.4. Full models, including covariates, are outlined in Appendix 21. Specifically, Table 4.3 presents the results of the modified Poisson regressions models, estimating the prevalence ratios (*PR*) for the associations between nature contact, nature connectedness and health risk behaviours. Table 4.4 presents the results of the linear regressions estimating the associations between nature contact, nature connectedness and pro-environmental behaviours. All variance inflation factors (VIF) for model parameters were <3.40, indicating that multicollinearity was not an issue.

4.4.2.1 Initial Models (upper half of Table 4.3 & Table 4.4)

Residential contact (green view)

Controlling for all covariates, consistent with Hypotheses 1a-1c, green view was negatively associated with the prevalence of each health risk behaviour (current smoker: *PR* = 0.9925, *95% CI* = 0.9873, 0.9977, p = .005; exceeds recommend alcohol guidelines: *PR* = 0.9936, *95% CI* = 0.9876, 0.9997, p = .040; poor diet: *PR* = 0.9946, *95% CI* = 0.9896, 0.9997, p = .037, Table 4.3). In line with predictions, green view was unrelated related to nature conservation behaviours (b = -.0005, 95% *CI* = -.0026, .0016, p = .641, Table 4.4), but exhibited an unexpected positive association with household PEBs (b = .0046, 95% *CI* = .0012, .0081, p = .009, Table 4.4)

Table 4.3. Summary of fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of nature contact, nature connectedness (and their interaction terms), whilst controlling for covariates.

	Current Smoker			**Exceeds Alcohol Guidelines**			**Poor Diet**		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Initial Models									
Green view (%)	0.9925	(0.9873, 0.9977)	.005	0.9936	(0.9876, 0.9997)	.040	0.9946	(0.9896, 0.9997)	.037
Nature visits (≥ once a week)	0.9583	(0.8336, 1.1017)	.550	1.1184	(0.9489, 1.3181)	.182	0.9074	(0.7968, 1.0334)	.143
Nature media. (≥ once a week)	1.3179	(1.1467, 1.5146)	<.001	1.2240	(1.0394, 1.4413)	.015	0.8562	(0.7405, 0.9898)	.036
Nature connectedness (INS)	1.0519	(1.0109, 1.0946)	.013	0.9648	(0.9206, 1.0111)	.135	0.9182	(0.8843, 0.9533)	<.001
Constant	0.2632	(0.1814, 0.3818)	<.001	0.1898	(0.1206, 0.2987)	<.001	0.7773	(0.5504, 1.0976)	.152
Pseudo R^2	.06			.04			.04		
Moderation Models									
Green view (%)	0.9952	(0.9817, 1.0088)	.486	0.9920	(0.9770, 1.0072)	.301	1.0074	(0.9955, 1.0195)	.225
Nature visits (≥ once a week)	1.2070	(0.8343, 1.7463)	.318	1.3852	(0.9129, 2.1018)	.126	0.9423	(0.6778, 1.3101)	.724
Nature media (≥ once a week)	1.5766	(1.0777, 2.3064)	.019	1.1987	(0.7722, 1.8607)	.419	0.7773	(0.5346, 1.1300)	.187
Nature connectedness (INS)	1.1144	(1.0200, 1.2174)	.016	0.9819	(0.8827, 1.0923)	.737	0.9929	(0.9127, 1.0801)	.868
Green view x INS	0.9993	(0.9965, 1.0022)	.642	1.0004	(0.9970, 1.0037)	.834	0.9967	(0.9939, 0.9995)	.021
Nature Visits x INS	0.9478	(0.8758, 1.0258)	.184	0.9491	(0.8644, 1.0421)	.273	0.9903	(0.9180, 1.0682)	.800
Nature media x INS	0.9620	(0.8888, 1.0413)	.338	1.0057	(0.9158, 1.1044)	.906	1.0223	(0.9423, 1.1091)	.595
Constant	0.2093	(0.1272, 0.3443)	<.001	0.1781	(0.0987, 0.3213)	<.001	0.5821	(0.3740, 0.9060)	<.001
Pseudo R^2	.06			.04			.05		
Delta R^2	.00			.00			.01		

Table 4.4. Summary of fully adjusted linear regression models predicting pro-environmental behaviours as a function of nature contact, nature connectedness (and their interaction terms) whilst controlling for covariates.

	Household PEB				Nature Conservation PEB			
	b	**95% *CI b***	***β***	***p***	***b***	**95% *CI b***	***β***	***p***
Initial models								
Green view (%)	.0046	(.0012, .0081)	.0391	.009	-.0005	(-.0026, .0016)	-.0072	.641
Nature visits (≥ once a week)	.3876	(.2982, .4769)	.1354	<.001	.0268	(-.0279, .0815)	.0158	.337
Nature media. (≥ once a week)	.1553	(.0605, .2501)	.0495	.001	.2665	(.2085, .3246)	.1433	<.001
Nature connectedness (INS)	.1906	(.1643, .2168)	.2252	<.001	.0870	(.0709, .1031)	.1733	<.001
Constant	.8355	(.5824, 1.0887)	.	<.001	-.1185	(-.2735, .0365)	.	.134
Pseudo R^2	.18				.12			
Moderation models								
Green view (%)	.0041	(-.0048, .0129)	.0344	.367	-.0035	(-.0089, .0019)	-.0503	.202
Nature visits (≥ once a week)	.1816	(-.0560, .4191)	.0635	.134	-.1309	(-.2763, .0144)	-.0772	.077
Nature media (≥ once a week)	.3107	(.0453, .5761)	.0991	.022	.1677	(.0053, .3302)	.0902	.043
Nature connectedness (INS)	.1753	(.1151, .2354)	.2071	.000	.0435	(.0067, .0803)	.0866	.021
Green view x INS	.0001	(-.0017, .0020)	.0067	.891	.0007	(-.0004, .0019)	.0627	.215
Nature Visits x INS	.0487	(-.0035, .1008)	.0881	.067	.0378	(.0059, .0697)	.1154	.020
Nature media X INS	-.0353	(-.0901, .0196)	-.0585	.207	.0211	(-.0125, .0546)	.0589	.218
Constant	.8930	(.5580, 1.2280)	.	<.001	.0531	(-.1519, .2581)	.	.612
Pseudo R^2	.18				.12			
Delta R^2	.00				.00			

Note. PEB = pro-environmental behaviours

Intentional contact (nature visits)

Contrary to Hypotheses 2a-b, visiting natural spaces at least once a week was unrelated to current smoking (*PR* = 0.9583, *95% CI* = 0.8336, 1.1017, *p* = .550, Table 4.3) and poor diet (*PR* = 0.9074, *95% CI* = 0.7968, 1.0334, *p* = .147, Table 4.3), yet as predicted were unrelated to exceeding alcohol guidelines (PR = 1.1184, 95% CI = 0.9489, 1.3181, p = .182, , Table 4.3). However, in line Hypothesis 2c, weekly visits to natural spaces were positively associated with household pro-environmental behaviours (*b* = .3876, 95% *CI* = .2982, .4769, *p* < .001, Table 4.4), and unrelated to nature conservation behaviours, as expected (*b* = .0268, 95% *CI* = -.0279, .0815, *p* = .337, Table 4.4).

Indirect contact (nature media)

Contrary to Hypotheses 3a-*b*, watching/listening to nature media at least once a week was positively associated with the prevalence of smoking (*PR* = 1.3179, *95% CI* = 1.1467, 1.5146, *p* < .001, Table 4.3) and exceeding alcohol guidelines (*PR* = 1.2240, *95% CI* = 1.0394, 1.4413, *p* = .115, Table 4.3). In line with Hypothesis 3c, nature media was associated with a lower prevalence of poor diets (poor diet: *PR* = 0.8562, *95% CI* = 0.7405, 0.9898, *p* = .036, Table 4.3). As predicted (Hypotheses 3d-e) nature media positively predicted both domains of pro-environmental behaviour (household: *b* = .1553, 95% *CI* = .0605, .2501, *p* = .001; nature conservation: *b* = .2665, 95% *CI* = .2085, .3246, *p* <.001, Table 4.4).

Nature connectedness

Contrary to predictions, nature connectedness was associated with a higher prevalence of current smoking (current smoker: *PR* = 1.0519, *95% CI* = 1.0109, 1.0946, *p* = .013, Table 3), but was unrelated to exceeding alcohol guidelines, as expected (*PR* = 0.9648, *95% CI* = 0.9206, 1.0111, *p* = .135, Table 3). Consistent with Hypothesis 4a, nature connectedness exhibited an inverse association to poor diet (*PR* = 0.9182, *95% CI* = 0.8843, 0.9533, *p* <. 001, Table 4.3). Supporting Hypotheses 4c-d, nature connectedness positively predicted household (*b* = .1906, *95% CI* = .1643, .2168, *p* <.001) and nature conservation pro-environmental behaviours (*b* = .0870, *95% CI* = .0709, .1031, *p* <.001, Table 4.4).

Relative magnitude of nature-behaviour associations

For health risk behaviours, (Table 4.3) as with Study 2, the magnitude of statistically significant nature-behaviour associations exceeded those of non-significant nature-behaviour associations. For instance, the 1% lower prevalence of current smoking associated with one unit change in green view (*PR* = 0.9925, *95% CI* = 0.9873, 0.9977, *p* = .005), corresponds to 24% lower current smoking prevalence for individuals reporting green views one standard deviation above the mean (*vs.* one standard deviation below the mean). Similarly, the 5% higher current smoking prevalence associated with a one unit change in nature connectedness (*PR* = 1.0519, *95% CI* = 1.0109, 1.0946, *p* = .013), represents an 18% higher prevalence for individuals one standard deviation above the mean (*vs.* one standard deviation below the mean). These associations were considerably larger in magnitude than the, non-significant, 4% lower current smoking prevalence associated with visiting natural spaces once a week (*vs.* less than once a week; *PR* = 0.9583, *95% CI* = 0.8336, 1.1017, *p* = .550).

Similarly, for pro-environmental behaviours (Table 4.4) comparison of the standardised regression coefficients indicated that the magnitude of the associations between statistically significant nature variables and behavioural outcomes (e.g. nature visits and household behaviours: β = .1354), exceeded those associated with each nature variable that did not reach statistical significance (e.g. nature visits and nature conservation behaviours: β = .0158).

4.4.2.2 Robustness Checks

There was little evidence of moderation by either of the three measures of socio-economic status (higher education, quintiles of income, neighbourhood deprivation) as a function of green view (Appendix 22). Attempts to uncover whether the associations between nature contact and current smoking were attributable to a lower prevalence of ever smoking and/or a higher prevalence of smoking cessation (Appendix 23) did not replicate Study 1's finding of a higher prevalence of smoking cessation in greener neighbourhoods (*PR* = 1.0012, *95% CI* = 0.9978, 1.0046, *p* = .484). However, green view was inversely associated with the prevalence of ever-smoking (*PR* = 0.9938, *95% CI* = 0.9911, 0.9965, *p* <.001); and watching/listening to nature programmes at least once a week was associated with a higher prevalence of ever-smoking (*PR* = 1.0933, *95% CI* = 1.0209, 1.1707, *p* = .011) and a lower prevalence of smoking cessation (*PR* = 0.8194, *95% CI* = 0.7345, 0.9141, *p* <. 001). Nature connectedness was also associated with a higher prevalence of ever-smoking (*PR* = 1.0460, *95% CI* = 1.0258, 1.0666, *p* <. 001).

As nature visits may co-occur with activities that also involve consuming alcohol (e.g. barbeques, fishing, camping trips), I examined potential moderation effects between the frequency of visits to natural spaces (at least once a week *vs.* less than weekly) and the tendency to consume alcohol during nature visits (alcohol on nature visits *vs.* no alcohol on some nature visits) on the prevalence of exceeding alcohol guidelines (Appendix 24). Amongst the sub-sample of individuals who had visited nature at least once in the last month (N =3,160), visiting natural spaces at least once a week was only associated with a higher prevalence exceeding alcohol guidelines, when nature visits involved the consumption of alcohol (*PR* = 2.2533, *95% CI* = 1.1039, 4.5995, 1.12, *p* = .026).

4.4.2.3 Moderation effects (lower half of Tables 4.3 & 4.4)

Overall, there was little evidence that nature connectedness moderated the effects of nature contact on behavioural outcomes. Exceptions to this were: a) a statistically significant interaction with green view was observed for poor diet (*PR* = 0.9967, *95% CI* = 0.9939, 0.9995, *p* = .021, Table 4.3) and *b*) a statistically significant interaction with nature visits was observed for nature conservation behaviours (*b* = .0378, *95% CI* = .0059, .0697, *p* = .020, Table 4.4; Wald $\chi 2$ omnibus test: $F(1, 3776) = 5.39$, *p* = .020). As depicted in Figure 4.1, for individuals with no greenery in the view from home (0%) nature connectedness was unrelated to the prevalence of poor diets, however as the proportion of greenery increased, the prevalence of poor diets decreased incrementally for those who felt more connected to nature. Similarly, the relationship between nature connectedness and nature conservation behaviours was stronger for those that visited natural spaces at least once a week than those that did not (Figure 4.2).

4.4.3 Structural Equation Models: Mediation Analysis

SEM was used to test the conceptual model depicted in Figure 1.1 (Chapter 1). However, with few statistically significant nature contact x nature connectedness interactions observed, and no change to the Delta R^2 between the initial and moderation regression models (Tables 4.3 & 4.4), to reduce model complexity, these moderation effects were not specified in the SEM.

4.4.3.1 Measurement Model

CFA was used to define three latent (positive affect, negative affect, community cohesion) and one observed variable (temporal discounting), (Appendix 25). As the mediating

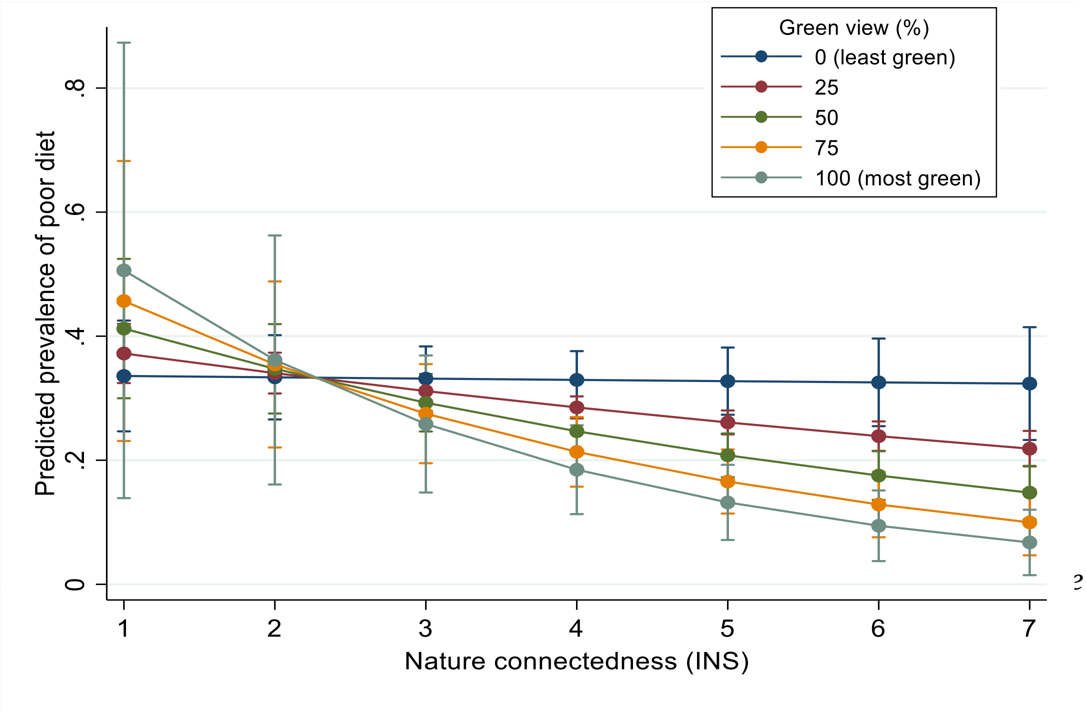

Figure 4.1. Predicted prevalence of poor diet as a function of green view and nature connectedness.

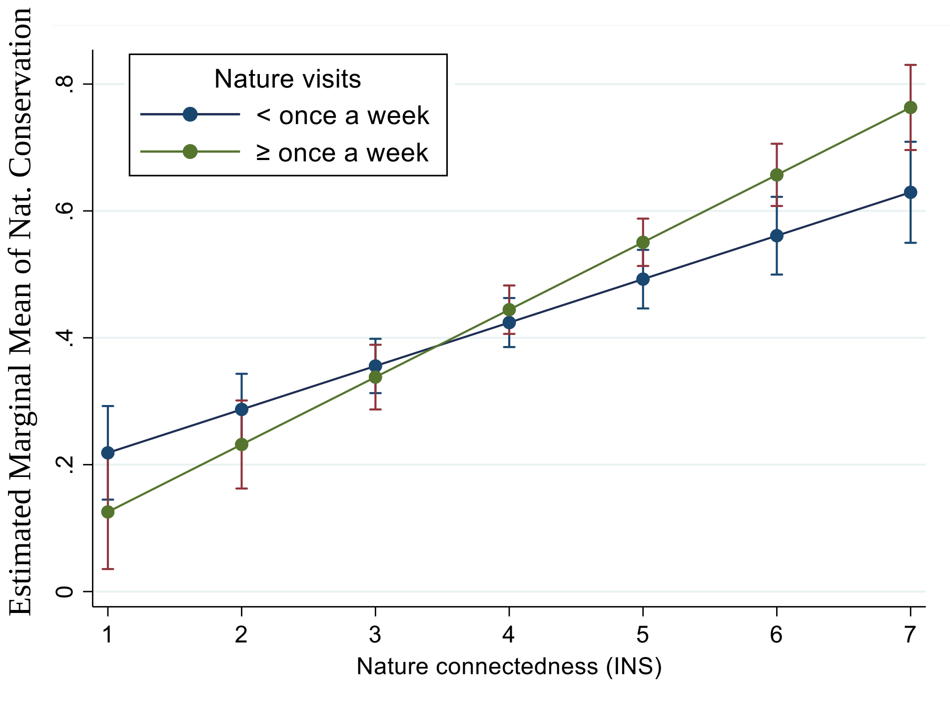

Figure 4.2. Estimated marginal means for nature conservation behaviours as a function of nature visits and nature connectedness.

variables represent conceptually related processes, their residual terms were allowed to covary. All standardised factor loadings were statistically significant and exceeded recommended thresholds for inclusion (>.50 >.70; Gaskin & Happell, 2014). The initial measurement model provided an excellent fit to the data (*CFI* = .99, *TLI* = .98, *SRMR* = .03, *RMSEA* = .04). Based on these results, the measurement model was retained without modification.

4.4.3.2 Structural Model

The observed variables: green view, nature visits, nature media and nature connectedness, plus dummy control variables (see Appendix 26 for details), were regressed onto the five observed outcomes (current smoker, exceeds alcohol guidelines, poor diet, household PEB, nature conservation PEB). Green view, nature visits, nature media, nature connectedness and control variables were also regressed onto the four mediator variables (positive affect, negative affect, community cohesion, temporal discounting). Finally, the latent (positive affect, negative affect, community cohesion) and observed (temporal discounting) mediator variables were regressed onto each outcome variable (current smoker, exceeds alcohol guidelines, poor diet, household PEB, nature conservation PEB). The residual terms of each behavioural outcome were allowed to covary with one another. The model exhibited an excellent fit to the data (*CFI* = .97, *TLI* = .96, *SRMR* = .02, *RMSEA* = .03). The largest normalised residuals, 1.88 and -1.56, were within acceptable limits (Kline, 2016). The modification indices suggested no additional structural pathways, therefore the initial model was retained without modification. Figure 4.3 depicts all statistically significant direct paths between variables of interest (full models are outlined in Appendix 26). The model accounted for 9%, 6%

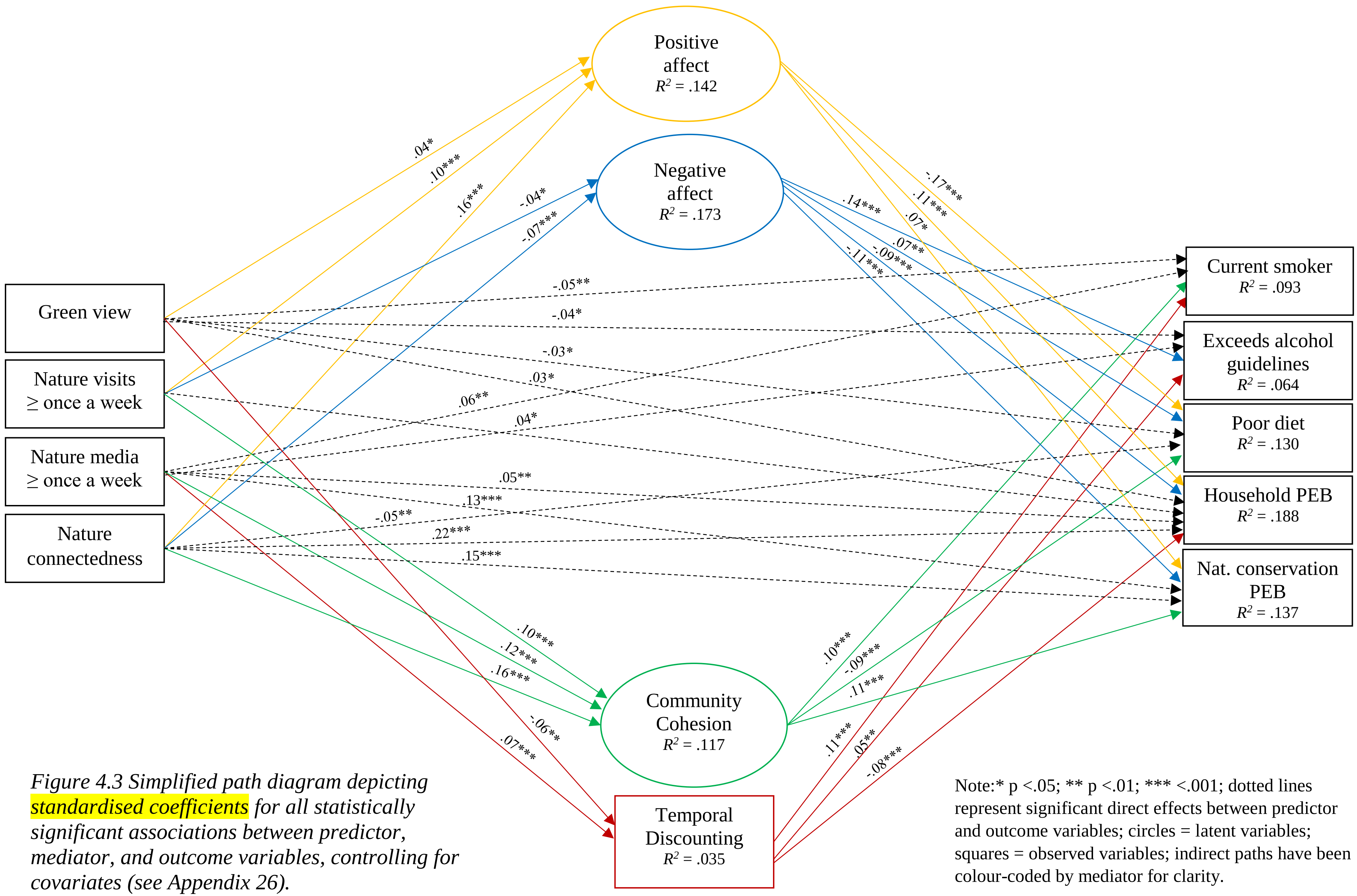

Figure 4.3 Simplified path diagram depicting standardised coefficients for all statistically significant associations between predictor, mediator, and outcome variables, controlling for covariates (see Appendix 26).

Note:* p <.05; ** p <.01; *** <.001; dotted lines represent significant direct effects between predictor and outcome variables; circles = latent variables; squares = observed variables; indirect paths have been colour-coded by mediator for clarity.

and 13% of the variance in current smoking, exceeding alcohol guidelines and poor diets, respectively, but explained a larger share of variation in household (19%) and nature conservation behaviours (14%) overall. In terms of the proposed mediators, the model accounted for a substantial share of the variation in positive affect (14%), negative affect (17%) and community cohesion (12%), compared to a much smaller variation in temporal discounting (4%; Ferguson, 2006). Table 4.5 presents a decomposition of the standardised total, direct and indirect effects of nature contact/connectedness indicators on behavioural outcomes, as well as the specific indirect effects through each mediator. Where statistically significant total effects were observed, specific indirect effects were examined in both the presence/absence of non-significant total indirect effects, as suppression effects have the potential to obscure the impact of individual mediators (MacKinnon et al., 2000).

Residential contact (green view)

Green view had statistically significant negative total effects on current smoking (β = -.0555, *95% CIs* = -.0876, -.0234, p = .001), exceeding alcohol guidelines (β = -.0418. *95% CIs* = -.0765, -.0072, p = .018), and poor diet (β = -.0436, *95% CIs* = -.0751, -.0121, p = .007), as well as statistically significant positive total effects on household pro-environmental behaviours (β = .0373. *95% CIs* = .0084, .0663, p = .011). Green view exhibited negative direct paths to current smoking (β = -.0475. *95% CIs* = -.0790, -.0160, p = .003), exceeding alcohol guidelines (β = -.0279, *95% CIs* = -.0716, -.0042, p = .027) and poor diet (β = -.0329, *95% CIs* = -.0636, -.0022, p = .036), as well a positive direct path to household pro-environmental behaviours (β = .0298 *95% CIs* = .0009, .0588, p = .043). Statistically significant direct and indirect paths between green view and each of these behavioural outcomes suggests partial mediation of these associations. Examination of the specific indirect

Table 4.5. Summary of total, direct and indirect effects of nature contact/connectedness and behavioural outcomes

	Green view			**Nature visits (≥ once a week)**			**Nature media (≥ once a week)**			**Nature connectedness**		
	β	***95% CIs***	***p***	***β***	***95% CIs***	***p***	***β***	***95% CIs***	***p***	***β***	***95% CIs***	***p***
Current smoker												
Total effect	**-.0555**	**(-.0876, -.0234)**	**.001**	-.0108	(-.0440, .0224)	.524	**.0782**	**(.0446, .1118)**	**<.001**	**.0449**	**(.0104, .0794)**	**.011**
Direct effect	**-.0475**	**(-.0790, -.0160)**	**.003**	-.0126	(-.0457, .0204)	.453	**.0590**	**(.0254, .0927)**	**.001**	.0339	(-.0012, .0690)	.059
Indirect effect (total)	**-.0080**	**(-.0136, -.0025)**	**.004**	.0018	(-.0050, .0087)	.596	**.0192**	**(.0119, .0264)**	**<.001**	**.0110**	**(.0019, .0201)**	**.018**
via positive affect	-.0015	(-.0040, .0009)	.226	-	-	-	-.0004	(-.0017, .0009)	.569	-.0058	(-.0140, .0025)	.169
via negative affect	-.0008	(-.0024, .0008)	.344	-	-	-	.0008	(-.0009, .0024)	.348	-.0023	(-.0060, .0015)	.233
via community cohesion	.0007	(-.0025, .0039)	.661	-	-	-	**.0114**	**(.0058, .0169)**	**<.001**	**.0155**	**(.0084, .0227)**	**<.001**
via temporal discounting	**-.0064**	**(-.0105, -.0024)**	**.002**	-	-	-	**.0074**	**(.0029, .0119)**	**.001**	.0035	(-.0008, .0078)	.112
Exc. alcohol guidelines												
Total effect	**-.0418**	**(-.0765, -.0072)**	**.018**	.0302	(-.0033, .0637)	.077	**.0515**	**(.0182, .0847)**	**.002**	-.0285	(-.0620, .0051)	.096
Direct effect	**-.0279**	**(-.0716, -.0042)**	**.027**	.0289	(-.0049, .0627)	.094	**.0408**	**(.0074, .0743)**	**.017**	-.0328	(-.0667, .0012)	.058
Indirect effect (total)	**-.0139**	**(-.0095, -.0016)**	**.050**	.0013	(-.0050, .0076)	.689	**.0106**	**(.0041, .0171)**	**.001**	.0043	(-.0044, .0130)	.331
via positive affect	.0018	(-.0009, .0046)	.196	-	-	-	.0005	(-.0011, .0020)	.568	-	-	-
via negative affect	-.0033	(-.0080, .0015)	.183	-	-	-	.0033	(-.0014, .0079)	.166	-	-	-
via community cohesion	.0002	(-.0009, .0013)	.671	-	-	-	.0037	(-.0009, .0084)	.113	-	-	-
via temporal discounting	**-.0027**	**(-.0054, -.0001)**	**.039**	-	-	-	**.0031**	**(.0003, .0059)**	**.028**	-	-	-
Poor Diet												
Total effect	**-.0436**	**(-.0751, -.0121)**	**.007**	**-.0368**	**(-.0701, -.0036)**	**.030**	**-.0372**	**(-.0683, -.0060)**	**.019**	**-.0959**	**(-.1286, -.0632)**	**<.001**
Direct effect	**-.0329**	**(-.0636, -.0022)**	**.036**	-.0087	(-.0414, .0241)	.605	-.0286	(-.0591, .0019)	.066	**-.0513**	**(-.0836, .0191)**	**.002**
Indirect effect (total)	**-.0107**	**(-.0196, -.0018)**	**.018**	**-.0282**	**(-.0378, -.0185)**	**<.001**	-.0086	(-.0182, .0011)	.081	**-.0445**	**(-.0557, -.0334)**	**<.001**
via positive affect	**-.0068**	**(-.0127, -.0009)**	**.023**	**-.0163**	**(-.0238, -.0089)**	**<.001**	-.0017	(-.0071, .0037)	.534	**-.0262**	**(-.0355, -.0168)**	**<.001**
via negative affect	-.0018	(-.0044, .0009)	.200	-.0027	(-.0056, .0002)	.065	.0018	(-.0008, .0043)	.170	-.0050	(-.0089, .0011)	.069
via community cohesion	-.0007	(-.0036, .0023)	.661	**-.0085**	**(-.0131, -.0039)**	**<.001**	**-.0104**	**(-.0156, -.0051)**	**<.001**	**-.0142**	**(-.0210, -.0073)**	**<.001**
via temporal discounting	-.0015	(-.0036, .0006)	.165	-.0006	(-.0017, .0005)	.281	.0017	(-.0005, .0040)	.136	.0008	(-.0006, .0022)	.254
Household PEB												
Total effect	**.0373**	**(.0084, .0663)**	**.011**	**.1386**	**(.1071, .1701)**	**<.001**	**.0508**	**(.0204, .0812)**	**.001**	**.2242**	**(.1921, .2564)**	**<.001**
Direct effect	**.0298**	**(.0009, .0588)**	**.043**	**.1277**	**(.0963, .1590)**	**<.001**	**.0501**	**(.0199, .0803)**	**.001**	**.2137**	**(.1813, .2460)**	**<.001**
Indirect effect (total)	**.0075**	**(.0024, .0126)**	**.004**	**.0109**	**(.0050, .0168)**	**<.001**	-.0007	(-.0071, .0058)	.843	**.0106**	**(.0026, .0186)**	**.009**
via positive affect	**.0043**	**(.0002, .0085)**	**.040**	**.0104**	**(.0044, .0164)**	**.001**	.0011	(-.0024, .0045)	.535	**.0167**	**(.0082, .0251)**	**<.001**
via negative affect	-.0021	(-.0053, .0011)	.197	-.0033	(-.0067, .0001)	.061	.0021	(-.0009, .0051)	.167	**-.0060**	**(-.0107, -.0014)**	**.011**
via community cohesion	.0001	(-.0005, .0007)	.691	.0016	(-.0019, .0051)	.365	.0020	(-.0023, .0063)	.366	.0027	(-.0031, .0085)	.358
via temporal discounting	**.0051**	**(.0016, .0086)**	**.004**	.0021	(-.0009, .0050)	.167	**-.0058**	**(-.0094, -.0023)**	**.001**	-.0028	(-.0063, .0008)	.126

Table 4.5 continued

Nat. Conservation PEB												
Total effect	-.0079	(-.0387, .0228)	.614	.0188	(-.0123, .0499)	.237	**.1438**	**(.1085, .1792)**	**<.001**	**.1736**	**(.1391, .2081)**	**<.001**
Direct effect	-.0103	(-.0410, .0205)	.513	.0046	(-.0263, .0356)	.769	**.1286**	**(.0946, .1626)**	**<.001**	**.1528**	**(.1184, .1873)**	**<.001**
Indirect effect (total)	.0023	(-.0035, .0082)	.434	**.0142**	**(.0073, .0210)**	**<.001**	**.0152**	**(.0079, .0225)**	**<.001**	**.0208**	**(.0115, .0301)**	**<.001**
via positive affect	-	-	-	**.0069**	**(.0009, .0128)**	**.023**	.0007	(-.0016, .0030)	.546	**.0110**	**(.0020, .0200)**	**.017**
via negative affect	-	-	-	**-.0042**	**(-.0083, .0000)**	**.049**	.0027	(-.0011, .0065)	.164	**-.0077**	**(-.0131, -.0023)**	**.005**
via community cohesion	-	-	-	**.0109**	**(.0056, .0162)**	**<.001**	**.0133**	**(.0075, .0191)**	**<.001**	**.0182**	**(.0109, .0255)**	**<.001**
via temporal discounting	-	-	-	.0005	(-.0005, .0016)	.332	-.0015	(-.0038, .0008)	.202	-.0007	(-.0021, .0007)	.310

Notes. Exc. alcohol guidelines = exceeding alcohol guideline; household PEB = household pro-environmental behaviours; Nat. conservation PEB = nature conservation PEB effects indicates that green views influenced health risk behaviours and more routine household pro-environmental behaviours, through higher positive affect and/or lower temporal discounting. Specifically, having a greener view was associated with lower temporal discounting (β = -.0606, *95% CIs* = -.0955, -.0257, *p* = .001, Appendix 26), which in turn negatively predicted current smoking (β = -.0064, *95% CIs* = -.0105, -.0024, *p* = .002), and exceeding alcohol guidelines (β = -.0027, *95% CIs* = -.0054, -.0001, *p* = .039). Greener views were also associated with higher positive affect (β = .0411, *95% CIs* = .0074, .0747, *p* = .017, Appendix 26), which in turn, inversely predicted having a poor diet (β = -.0068, *95% CIs* = -.0127, -.0009, *p* = .023). For household pro-environmental behaviours, green view had statistically significant indirect effects via both higher positive affect (β = .0043, *95% CIs* = .0002, .0085, *p* = .040) and lower temporal discounting (β = .0051, *95% CIs* = .0016, .0086, *p* = .004). For each of these behavioural outcomes, the statistically significant specific indirect effects of green view accounted for a substantially smaller proportion of the total effects, than the direct effects (Smoking: 12% *vs.* 86%; Alcohol: 6% *vs.* 67%; Diet: 16% *vs.* 75%; Household PEB: 25% *vs.* 80%)[11].

Intentional nature contact (nature visits)

Consistent with the results of the multiple regression models, the total effects of nature visits on current smoking (β = -.0108, *95% CIs* = -.0440, .0224, *p* = .524), exceeding alcohol limits (β = .0302, *95% CIs* = -.0033, .0637, *p* = .077) were non-significant. However, nature visits had statistically significant negative total effects on poor diet (β = -.0368, *95% CIs* = -.0701, -.0036, *p* = .030), with the non-significant direct effect (β = -.0087, *95% CIs* = -.0414, .0241, *p* = .605) and statistically significant total indirect

[11] With differences in the directions of indirect pathways, the proportion of the mediated effect do not always equate to 100 percent.

effect (β = -.0282, *95% CIs* = -.0378, -.0185, p < .001), indicating complete meditation of this association. Nature visits were associated with higher positive affect (β = .0986, *95% CIs* = .0647, .1324, p < .001, Appendix 26), and higher social cohesion (β = .0964, *95% CIs* = .0622, .1307, p < .001, Appendix 26), which in turn negatively predicted poor diet (β = -.0163, *95% CIs* = -.0238, -.0089, p < .001 and β = -.0085, *95% CIs* = -.0131, -.0039, p < .001, respectively).

Regarding pro-environmental behaviours, consistent with the regression models nature visits had positive total effects on household pro-environmental behaviours (β = .1386, *95% CIs* = .1071, .1701, p <.001) but non-significant total effects on nature conservation behaviours (β = .0188, *95% CIs* = -.0123, .0499, p = .237). For household pro-environmental behaviours statistically significant direct (β = .1277, *95% CIs* = .0963, .1590, p < .001) and total indirect paths (β = .0109, *95% CIs* = .0050, .0168, p < .001) indicated that higher positive affect (β = .0104, *95% CIs* = .0044, .0164, p = .001) mediated around 8% of the total effect. For nature conservation behaviours, despite the non-significant total effects, non-significant direct (β = .0046, *95% CIs* = -.0263, .0356, p = .769) and statistically significant total indirect effects (β = .0142, *95% CIs* = .0073, .0210, p < .001). Specific indirect effects were calculated to investigate this further: the association between nature visits and nature conservation behaviours was completely mediated by higher positive affect (β = .0069, *95% CIs* = 0009, .0128, p = .023), lower negative affect (β = -.0042, *95% CIs* = -.0083, .0000, p = .049), and higher community cohesion (β = .0109, *95% CIs* = .0056, .0162, p < .001).

Indirect Nature Contact (nature media)

Consistent with results of the multiple regression models, nature media had unexpected positive total effects on current smoking (β = .0782, *95% CIs = .0446, .1118*, p <.001) and exceeding alcohol guidelines (β = *.0515*, *95% CIs = .0182, .0847*, p = .002), but negative total effects on poor diet (β = -.0372, *95% CIs* = -.0683, -.0060, *p* = .019). Watching/listening to nature media was associated with higher social cohesion (β = .1176, *95% CIs* = .0843, .1508, *p* < .001, Appendix 26), and higher temporal discounting (β = .0693, *95% CIs* = .0353, .1032, *p* < .001, Appendix 26), which, in turn, had divergent influences on the three health risk behaviours. Specifically, 15% of the positive total effect of nature media on current smoking was mediated by higher social cohesion (β = *.0114*, *95% CIs* = .0058, .0169, *p* <.001) and a further 9% by higher temporal discounting (β = *.0074*, *95% CIs =.0029, .0119*, *p* = .001). Conversely, higher temporal discounting alone mediated just 6% of the positive total effect of watching/listening to nature media on exceeding alcohol guidelines (β = .0031, *95% CIs* = .0003, .0059, *p* =.028). With a non-significant direct effect (β = -.0286, *95% CIs* = -.0591, .0019, *p* = .066), the inverse total effect of nature media on poor diet was completely mediated by higher social cohesion (β = -.0104, *95% CIs* = -.0156, -.0051, *p* <.001).

For sustainability outcomes, nature media had positive total effects on household behaviours (β = .0508, *95% CIs* = .0204, .0812, *p* = .001) and nature conservation behaviours (β = .1438, *95% CIs* = .1085, .1792, *p* <. 001). Whilst the positive direct effects of nature media on these two behavioural outcomes (household: β = .0501, *95% CIs* = .0199, .0803, *p* = .001; nature conservation: β = .1286, *95% CIs* = .0946, .1626, *p* <. 001) accounted for a substantial proportion of the total effects. Nonetheless statistically significant specific indirect effects emerged for both outcomes, indicating partial mediation. Notably, and at odds with the positive total effect, watching/listening to nature media was associated with higher temporal discounting, which was, in turn, associated with *lower* engagement with household pro-environmental behaviours (β =

-.0058, *95% CIs* = -.0094, -.0023, *p* = .001). In contrast, the association between nature media and nature conservation behaviours was partially mediated by higher community cohesion *(β* = .0133, *95% CIs* - .0075, .0191, *p* <.001).

Nature connectedness

Consistent with the results of the multiple regression models, nature connectedness had statistically significant positive total effects on current smoking (*β* = .0449, *95% CIs* = .0104, .0794, *p* = .011), non-significant total effects on exceeding alcohol guidelines (*β* = -.0285, *95% CIs* = -.0620, .0051, *p* = .096) and statistically significant negative total effects on poor diet (*β* = -.0959, *95% CIs* = -.1286, -.0632, *p* <.001). Feeling more connected to the nature was associated with higher positive affect (*β* = .1577, *95% CIs* = .1221, .1933, *p* < .001, Appendix 26), lower negative affect (*β* = -.0687, *95% CIs* = -.1036, -.0339, *p* < .001, Appendix 26), and higher community cohesion which (*β* = .1608, *95% CIs* = .1247, .1970, *p* < .001, Appendix 26), in turn, had divergent influences on the three current smoking and poor diet. Specifically, with a non-significant direct effect (*β* = .0339, *95% CIs* = -.0012, .0690, *p* = .059), the positive total effect of nature connectedness on current smoking was completely mediated higher social cohesion (*β* = .0155, *95% CIs* = .0084, .0227, *p* <.001). Conversely, with statistically significant direct (*β* = -.0513, *95% CIs* = -.0836, -.0191, *p* =.002) and indirect paths (*β* = -.0445, *95% CIs* = -.0557, -.0334, *p* <.001), the association between nature connectedness and poor diet was partially mediated by higher positive affect and higher social cohesion (*β* = -.0262, *95% CIs* = -.0355, -.0168, *p* <.001 and *β* = -.0142, *95% CIs* = -.0210, -.0073, *p* <.001, respectively).

Nature connectedness had statistically significant positive total effects on household (*β* = .2242, *95% CIs* = .1921, .2564, *p* <.001) and nature conservation behaviours (*β* =.2242, *95% CIs* = 1921, .2564, *p* <.001). For each of these behaviours, the direct effects of nature connectedness accounted for a large proportion of the total effects (household: β =.2137, *95% CIs* = .1813, .2460, p <.001; nature conservation: (β =.1528, *95% CIs* = .1184, .1873, p <.001). Nonetheless, statistically significant indirect effects for each behaviour, indicated partial mediation via affective and/or social pathways. Specifically, for household pro-environmental behaviours, nature connectedness had statistically significant indirect effects via both higher positive affect (β = .0167, *95% CIs* = .0082, .0251, p <.001) and lower negative affect (β = -.0060, *95% CIs* = -.0107, -.0014, p = .011). Similarly, for nature conservation behaviours, feeling more connected to nature was associated with higher positive affect, lower negative affect and higher social cohesion, which in turn predicted a greater propensity to engage in conservation activities (β = .0110, *95% CIs* = .0020, .0200, p = .017; β = -.0077, *95% CIs* = -.0131, -.0023, p = .005; β = .0182, *95% CIs* = .0109, .0255, p <.001, respectively).

4.4.3.3 Alternative Structural Models

Three alternative directional models were specified (see Appendix 27 for details). First, the reverse causal pathway (health risk and pro-environmental behaviours > mediators > nature contact/connectedness) was tested. Second, with evidence that: 1) better affect predicts lower temporal discounting (Lockenhoff, et al., 2011; Augustine & Larsen, 2011), and 2) increased social cohesion predicts better affect (Ruiz et al., 2018; 2019), two further models tested for serial mediation. The alternative models either failed to converge or exhibited a poor fit to the data. Refinements made to the alternative models based on examination of the modification indices (where possible) did not sufficiently improve the models' fit. The original model alone successfully converged and exhibited an acceptable fit to the data.

4.5 Discussion

Using cross-sectional data from adults in Great Britain, Study 4 examined the associations between three types of nature contact (residential, intentional and indirect), nature connectedness, potential mediators (positive affect, negative affect, community cohesion, temporal discounting), and a range of health risk and pro-environmental behaviours. The aims of the study were three-fold: 1) to examine the relative associations between different types of nature contact and behavioural outcomes; 2) to establish what role nature connectedness played in these associations; and 3) to explore whether nature-behaviour associations are mediated by: positive affect, negative affect, community cohesion and temporal discounting. Within this Section, the main findings of Study 4 are discussed, with reference to prior research.

4.5.1 Summary of Main Findings

4.5.1.1 Residential contact (green view).

Extending Studies 1-3, residential nature contact simultaneously predicted three types of health risk behaviour and household pro-environmental behaviours, even after accounting for a range of covariates. Specifically, having a greener view from home was associated with a lower prevalence of current smoking, exceeding alcohol guidelines and poor diets, as well as greater engagement in more routine household pro-environmental behaviours. Consistent with Studies 1-3, these associations were robust to different operationalisations of green view (i.e. low *vs.* high, quartiles of green view, Appendix 18) and largely unmoderated by three measures of socio-economic status (i.e. education, income, neighbourhood deprivation, Appendix 22). Thus, residential nature contact appears to be a robust predictor of a range of behavioural outcomes, irrespective of the socio-demographic characteristics of the individuals who reported greener views from home. Further, path analyses indicated that green views predicted these behavioural outcomes both directly, and indirectly, through higher positive affect and/or lower temporal discounting.

Extending the findings of Study 1 and 2, associations between green view, current smoking and exceeding alcohol guidelines were partially mediated by lower temporal discounting. To date, prior work demonstrating that reduced temporal discounting following nature contact (Van der Wal et al., 2013; Berry et al., 2014, 2015, 2019) leads to healthier behaviours (Wu & Chiou, 2019; Kao et al., 2019) has been conducted under laboratory conditions with small samples. Therefore, these findings contribute to a much smaller literature on the cognitive benefits of nearby nature observed outside of a laboratory setting (de Keijzer et al., 2016; Berry et al., 2020). Taken together, they suggest that visual exposure to greenspace from the home, or what this represents in terms of residential proximity to nature, is associated with more future-orientated decision making within the general population, and this, in part, predicts a lower prevalence of the unhealthy use of two types of psychoactive substances (i.e. nicotine and alcohol).

Substantiating prior bivariate observations (Astell-Burt, Feng & Kolt, 2014), greener views were also associated with a lower prevalence of poor diets, even after controlling for a range of socio-demographics. Whilst greenery around the home exhibits similar negative associations to a range of health risk behaviours, the path analyses indicate that these associations may be driven by somewhat different mechanisms. Notably, consistent with the affective benefits of nearby nature noted elsewhere (Kwon et al., 2021; Soga et al., 2020), the association between green view and poor diet was partially mediated by higher positive affect. The non-significant indirect effect via temporal discounting, is, however, at odds with the findings for current smoking and exceeding alcohol guidelines. This is surprising, given prior work demonstrating that reduced temporal discounting mediates the effect of nature contact on healthier snack choices (Kao et al., 2019). The null results may relate to inclusion of multiple mediators within the current study, as opposed to the single mediator used by Kao et al., (2019). It may be that temporal discounting is simply a less important determinant of poor diet, once positive affect is accounted for. Certainly, whilst the influence of positive affect on dietary choices is well established (Peltzer et al., 2017), meta-analyses indicate that associations between temporal discounting and diet are less consistent between studies, relative to those observed for psychoactive substances (e.g. smoking, alcohol, illicit drugs; Story et al., 2014; Barlow et al., 2016).

Regarding sustainability behaviours, the positive association between green views and household pro-environmental behaviours observed here is inconsistent with the null findings of Study 3, yet in line with prior cross-sectional work finding individuals living in greener areas tend to behave more sustainably (Whitburn et al., 2019). As discussed in Chapters 1 and 3, the discrepant findings may relate to different operationalisations of residential nature contact between studies. Specifically, the LSOA greenspace metric used in Study 3 covers a substantially larger geographically area than greenery directly visible from the home used here, as well as vegetation cover for households in adjoining streets measured by Whitburn et al., (2019). It may be that visible greenery directly around the home may be a more important determinant of household pro-environmental behaviours, compared to more distal greenspace measured at the neighbourhood level. Equally, as visibility across terrains is determined not only by distance, but also the vertical dimension of a given viewpoint (Nutsford et al., 2015), greenery in respondents' view from home may capture different spatial aspects of residential nature contact than neighbourhood measures. For instance, even in neighbourhoods with limited greenspace, individuals residing in the upper levels of a building are more likely to have greater visual access to greenery, than those living on lower levels of the same building (Yu et al., 2016).

These uncertainties notwithstanding, the cognitive and affective benefits of green views from home have been demonstrated elsewhere (Ward-Thompson et al., 2016; Lee et al., 2015a; Soga et al., 2020). Such findings are of particular relevance here, given path analyses indicating that green views influenced household pro-environmental behaviours, in part, through higher positive affect and lower temporal discounting. These findings support and expand upon prior theory and research proposing that improved affective experiences (Chatelain et al., 2018) and more future-orientated decision making (Berry et al., 2020) promote more ecological behaviour.

4.5.1.2 Intentional contact (nature visits)

Results for intentional nature contact were more mixed. Visiting natural spaces at least once a week (*vs.* < once a week) was unrelated to current smoking and exceeding alcohol guidelines, but was simultaneously associated with better diet quality and greater engagement in pro-environmental behaviours.

The null findings for current smoking are inconsistent with those of Study 2, in which individuals who visited natural spaces at least once a week had a lower prevalence of current smoking. It is noteworthy however, that this associations was consistent in direction to those observed in Study 2. Thus, the inconsistent findings may reflect the smaller sample size used in the current study, relative to that of Study 2 (N= 3,811 *vs.* N =14,359). Equally, unlike previous studies, data for the current study were collected during the Covid-19 pandemic. Despite efforts to mitigate potential confounding, an ongoing pandemic has the potential to influence individuals' willingness to visit natural spaces, as well as their psychological experiences within them. Analyses of individuals use of natural spaces over the course of the pandemic have observed diverse alterations in behaviour, with some individuals increasing their nature visits in response to a limited range of other recreational activities, and others visiting less often than usual to minimise their risks of exposure to the virus (Ugolini et al., 2020; Day, 2020). Further, restrictions on freedom and social interactions, coupled with concerns about the virus itself, have been linked to heightened stress, anxiety, and perhaps most importantly in the context of the current study, fear of infection itself (Kontoangelos et al., 2020; Pakpour & Griffiths, 2020). Prior research has demonstrated that concerns for personal safety constitute a barrier to the use of natural spaces (Cho et al., 2005) and can substantially reduce the psychological benefits of contact with the natural world (Fleming et al., 2016). Therefore, changes to the frequency of visits to natural spaces, as well as reduced psychological restoration whilst visiting, in response to the pandemic, may have effectively reduced the strength of the association between visits and current smoking.

Similarly, for exceeding alcohol guidelines, I had previously speculated that the non-significant positive association between nature visits and daily drinking observed in Study 2 might, in part, be due to nature visits co-occurring with activities that may also involve consuming alcohol (e.g. trips to country pubs, barbeques, camping). It is therefore interesting, that in the context of the pandemic, wherein many of these activities were either prohibited (e.g. drinking venues closed in some parts of the country and had reduced trading hours in others), or restricted in scale (e.g. outdoor social gatherings of no more than six people), the association between nature visits and exceeding alcohol guidelines was not significant. Further, for the current study, robustness checks indicated that visiting natural spaces at least once a week (*vs.* less than once a week) was only associated with a higher prevalence of exceeding alcohol guidelines amongst those who regularly consumed alcohol whilst on nature visits. Taken together, these results indicate that nature visits in themselves may not constitute a risk factor for exceeding alcohol guidelines, but may nonetheless provide opportunities for those wishing to consume alcohol to do so.

Given the pandemic-related behavioural changes discussed so far, it is therefore encouraging that, consistent with prior work (Alaimo et al., 2008), visits to natural spaces at least once a week were associated with a lower prevalence of poor diets. In line with evidence linking affective disturbances (Ingram et al., 2020), and lack of social support (Balanzá-Martínez, et al., 2020) to poorer dietary habits over the course of the pandemic, path analyses indicated that nature visits influenced diet quality entirely indirectly, through higher positive affect and higher community cohesion. Thus, building upon prior work demonstrating that spending time in nature enhances positive mood (McMahan & Estes, 2015; Browning et al., 2020) and facilitates social connections (Jennings & Bamkole, 2019; Liu et al., 2020; Moreton et al., 2019), the current study indicates that the affective and social benefits of nature visits may also extend to better quality diets.

Consistent with Study 3 and prior work suggesting that direct contact with nature promotes ecological attitudes and behaviours (Hartig et al., 2001; Lawrence, 2012; Coldwell & Evans, 2017), visiting natural spaces at least once a week was associated with a greater propensity to engage in household pro-environmental behaviours. Over 90% of the total effect of nature visits on household pro-environmental behaviours was explained by the direct effect. Yet, consistent with evidence that positive emotions promote more pro-social and sustainable behaviour (Ibanez et al., 2017; Chatelain et al., 2018; Bissing-Olson et al., 2013), nature visits also influenced household behaviours indirectly, via higher positive affect. Conversely, congruent with the findings of Study 3, nature visits were not significantly associated with nature conservation behaviours within the regression models. Nonetheless, when entered into the SEM with the proposed mediators, path analyses indicated statistically significant indirect effects through higher positive affect, lower negative affect and higher community cohesion. This suggests that, although weekly recreational visits to natural spaces may not directly encourage more conservation behaviours, the affective and social benefits derived from such visits may nevertheless lead to greater engagement with conservation activities.

4.5.1.3 Indirect Contact (Nature Media)

Indirect nature contact was differentially associated with behavioural outcomes. Notably, watching/listening to nature media at least once a week was unexpectedly associated with a higher prevalence of current smoking and exceeding alcohol guidelines, but, in line with predictions, was also linked to better quality diets and greater engagement with pro-environmental behaviours.

The findings for current smoking and exceeding alcohol guidelines are inconsistent with experimental findings that participants engage in healthier behaviours after viewing media featuring natural (*vs.* urban) scenes (Wu & Chiou, 2019; Kao et al., 2019). Nevertheless, the negative impacts of increased media use in general on smoking and alcohol consumption are well documented (Grant et al., 2019; Dong et al., 2020; Niermann et al., 2018), thus these findings may reflect that individuals who watch/listen to nature media at least once a week simply engage in more media-based activities in general. Certainly, media consumption of terrestrial and on demand digital content rose considerably during the April Covid-19 lockdown, and continued to be higher than 2019 monthly averages even after national lockdown measures had eased (OFCOM, 2020).

The indirect paths through which nature media influenced these behavioural outcomes are somewhat informative in this respect. Firstly, path analyses indicate that the adverse influence of nature media on current smoking and exceeding alcohol guidelines, was, in part, due to higher temporal-discounting. This finding is in line with evidence that media use activates reward-related regions (Kuhn et al., 2011), and predicts higher temporal discounting, as well as engagement in risky behaviours (Schulz van Endert & Mohr, 2020). Nonetheless, as it is not possible to disaggregate watching/listening to nature media from general media use within the current study, further work needed to ascertain whether these associations are due exposure to nature media in itself, or simply consuming more media in general.

Secondly, for current smoking, there was further mediation through higher community cohesion. Since exposure to local digital media (i.e. regional television and radio broadcasts), and social media platforms constitute tools for social participation (Marlowe et al., 2016), these findings may again reflect that respondents who watched/listened to nature media weekly simply engaged in more media-based activities in general. Indeed, there is evidence that digital technologies and social media platforms can help facilitate and strengthen connections within communities (Craig & Williams, 2011; Gifford & Wilding, 2013), especially in the context of a pandemic where in person social opportunities are restricted (Brandtzaeg, 2020). It is, however, unclear why higher social cohesion would positively predict current smoking, given prior work observing lower smoking prevalence in more cohesive communities (Patterson et al., 2004).

Whilst speculative, given that the measure of community cohesion focuses exclusively on the social relationships at the neighbourhood-level, a potential explanation for this finding relates to the influence of collective norms on smoking behaviour (Pearce et al., 2012). Specifically, where social cohesion is high and smoking norms are permissive there is potential for unhealthy behavioural norms to be reinforced (Portes, 1998; Stead et al, 2001). Indeed, Ahern et al. (2009) found that individuals living in more cohesive communities with permissive smoking norms were more likely to be current smokers, relative to those living in highly cohesive communities with anti-smoking norms. Permissive smoking norms tend to be more prevalent within disadvantaged communities (Stead et al., 2001), and as noted in Appendix 19, mean deprivation scores for the current sample were higher than the national average. Thus, over-representation of individuals residing in more deprived communities, who are perhaps more likely to be exposed to permissive smoking norms, may contribute to this unexpected finding. Further, there is evidence that greater media use is associated with heightened perceptions of permissive smoking norms (i.e. believing that others hold more favourable attitudes towards smoking; Zhu, 2017). Hence, if watching/listening to nature at least once a week does coincide with greater media use in general, then this may constitute an additional means through which smoking behaviour could be normalised. Although investigation of these issues is beyond the scope of the current study, further research might usefully account for general media use, as well as the influence of perceived smoking norms, within the local community and the media, on the association between nature media and current smoking.

Contrary to the findings for other health risk behaviours, watching/listening to nature media at least once a week was associated with a lower prevalence of poor diets. This finding is in line with experimental work demonstrating that participants make healthier dietary choices (Kao et al., 2019) after viewing photographs of natural (*vs.* urban) scenes. Building on prior work linking higher social capital to higher fruit and vegetable consumption (Poortinga, 2006; Johnson et al., 2010), path analyses revealed that this association was completely mediated by higher social cohesion. It is interesting, however, that the very mechanism that had an adverse influence on current smoking was simultaneously associated with better quality diets. I had speculated that the results for current smoking may relate to over-representation of individuals residing in more deprived neighbourhoods, which tend to have more permissive smoking norms (Stead et al., 2001). With meta-analyses indicating that robust positive associations between neighbourhood deprivation and smoking do not extend to dietary behaviours (Algren et al., 2015), the composition of the current sample has the potential to influence these two health risk behaviours in the divergent manner observed here. Moreover, research on dietary norms at the neighbourhood level is scarce (Carroll et al., 2018), but experimental studies suggest that proximal norms (i.e. those reinforced by friends/family) exert a greater influence on dietary intentions than more distal community norms (Yun & Silk, 2011). Thus, whilst greater levels of community cohesion may be beneficial to diet, for instance due to enhanced social support (Poortinga, 2006), the role of community social norms may be less relevant than those endorsed by close friends and family.

In line with Study 3, watching/listening to nature media at least once a week was associated with greater engagement in both household and nature conservation pro-environmental behaviours. For both types of behaviour, a large proportion of the total effect of nature media was explained by the direct effects. Nevertheless, watching/listening to nature media at least once a week had a small negative indirect effect on household behaviours, via higher temporal discounting. This suggests that, despite the overall positive total effect of weekly nature media on household pro-environmental behaviours, consistent with the findings for smoking and alcohol outcomes, this type of nature contact might promote less future-orientated decision making. Conversely, the association between nature media and nature conservation behaviours was partially mediated by higher community cohesion. This finding extends prior work linking community cohesion to greater environmental concern (Weinstein et al., 2015; Uzzell, et al., 2002), to greater engagement in conservation behaviours.

4.5.1.4 Nature connectedness

Main effects

Nature connectedness exhibited divergent relationships with behavioural outcomes. Feeling more connected to nature was, perhaps surprisingly, associated with a higher prevalence of current smoking, but unrelated to exceeding alcohol guidelines. Conversely, and more in line with expectations, heightened nature connectedness was associated with better diet and greater engagement in both domains of pro-environmental behaviour. Where statistically significant associations were observed, nature connectedness influenced behavioural outcomes, at least in part, indirectly, through affective improvement and/or higher social cohesion.

That nature connectedness was associated with higher smoking prevalence is inconsistent with the non-significant (albeit positive) associations observed in Study 2, but in line with prior work demonstrating that individuals who use a range of psychoactive substances, including nicotine, tend to feel more connected to the natural world (Forstmann & Sagioglou, 2017). Consistent with evidence that individuals who are more connected to nature also tend to feel more socially connected to others (Lee, et al., 2015b; Moreton et al., 2019), path analyses indicated that the association was completely mediated by higher social cohesion. As previously noted, the positive association between social cohesion and current smoking, however, is somewhat inconsistent with prior work observing lower smoking prevalence in more cohesive communities (Patterson et al., 2004). Although speculative, the conceptual similarities between nature connectedness and social connectedness are potentially telling here. As both constructs involve inclusion of the other (i.e. the natural world or other people) in the self-concept (Schultz, 2002), it may be that these findings reflect the influence of broader personality traits, on collective norms pertaining to smoking behaviour. Specifically, both nature connectedness and social connectedness have been linked to the personality trait of openness to experience (Lee et al., 2015b), the propensity to be amenable to new ideas, experiences and unconventional perspectives (George & Zhou, 2001). As openness to experience itself predicts a lower adherence to collective norms (Packer, 2010), and higher odds of lifetime smoking (Zvolensky et al., 2015), it may, at least in part, account for the positive associations between the two connectedness measures and current smoking within the current study. Equally, the possibility of reverse causality cannot be ruled out here. Notably, use of psychoactive substances themselves may promote experiences of unity and interconnectedness (Griffiths et al., 2008) and greater openness to experience (MacLean et al., 2011), which in turn, could lead to a heightened sense of connection, both with nature and to other human beings (Forstmann & Sagioglou, 2017). Consequently, further research is needed to disentangle the influences of broader personality types and social norms on measures of connectedness and smoking outcomes.

Regarding diet, feeling more connected to the natural world was associated with a lower prevalence of poor diets. These findings support and build upon prior research linking nature connectedness to the adoption of more sustainable dietary behaviour (Weber et al., 2020; Molinario et al., 2020), suggesting that the benefits of feeling more connected to the natural world may also benefit overall diet quality. Consistent with the affective (Capaldi et al., 2014), and social benefits (Dean et al., 2018) of nature connectedness noted elsewhere, path analyses revealed that this association was partially mediated by higher positive affect and higher community cohesion. It is again interesting that nature connectedness was associated with a higher prevalence of current smoking, but a lower prevalence of poor diets. I had previously speculated that the results for current smoking may relate to the influence of broader personality constructs (i.e. openness to experience) on measures of connectedness. Evidence that openness to experience is associated with higher odds of lifetime smoking on the one hand (Zvolensky et al., 2015), and healthier diets on the other hand (Raynor & Levine, 2009; Keller & Siegrist) might also account for the divergent influences of nature connectedness and community cohesion, within the current study.

Consistent with Study 3, and prior work suggesting individuals who feel more connected to the natural world are more inclined to act to protect it (Schultz, 2002; Mackay & Schmitt, 2019), nature connectedness was associated with a greater propensity to engage in household pro-environmental and conservation behaviours. Extending the affective benefits of nature connectedness noted elsewhere (Capaldi et al., 2014; Lawton et al., 2017; Martyn & Brymer, 2016), higher positive affect and, to a lesser extent, lower negative affect mediated the associations between nature connectedness and both domains of pro-environmental behaviour. For nature conservation behaviours, there was further mediation through higher community cohesion. This finding builds upon prior work demonstrating positive associations between nature connectedness and social cohesion (Dean et al., 2018), suggesting that this in turn may extend to greater engagement in conservation activities.

Moderation effects

For the vast majority of variables there was limited evidence that trait nature connectedness moderated the associations between nature contact and behavioural outcomes. However, for poor diet at least, trait nature connectedness appears to modify the way in which individuals respond to residential contact with the natural world. Specifically, for individuals with strong preferences for the natural world, the prevalence of poor diets decreased incrementally as the proportion of greenery in the view from home increased. Further, replicating the findings of Study 3 for intentional nature contact, weekly visits alone were not sufficient to encourage conservation behaviours, individuals also needed to feel an affinity towards nature, in order to act to protect it. These findings are broadly consistent with person-environment fit theories postulating that optimal behavioural outcomes emerge when an individual's personal attributes (e.g. their values) are compatible with environmental attributes (Caplan, 1987). Nonetheless, these results should perhaps be treated with caution, as inclusion of these interaction terms in the regression models explained no further variance in behavioural outcomes than the main effects alone.

4.5.2 Summative Discussion

At the beginning of this chapter, I outlined three research questions, pertaining to a conceptual model of the associations between nature contact, nature connectedness and behavioural determinants of public and planetary health (i.e., health risk behaviours and pro-environmental behaviours) via positive affect, negative affect, community cohesion and temporal discounting. The remainder of this chapter provides a summative discussion of the results in relation to research questions 1-3, as well as a consideration of methodological limitations.

4.5.2.1 RQ1. What are the Associations between Different Types of Nature Contact and, a) Health Risk Behaviours and b) Pro-Environmental Behaviours?

Consistent with the conceptual model, there was evidence that increased nature contact was simultaneously associated with a range of health risk and pro-environmental behaviours. Notably, greater residential nature contact (green views from home) was associated with a lower prevalence of each health risk behaviour, as well as a greater propensity to engage in more routine household pro-environmental behaviours. Similarly, greater intentional contact (nature visits) and indirect contact (nature media) were associated with better quality diets and greater engagement in pro-environmental behaviours. Moreover, for diet and both domains of pro-environmental behaviours, multiple types of nature contact remained statistically significant with the same models, suggesting that the benefits of these distinct types of nature contact may be additive.

These findings are consistent with additive effects of different types of nature contact observed for health and wellbeing outcomes (Shanahan et al., 2016; White et al., 2017) and pro-environmental concern (Weinstein et al., 2015).

Nevertheless, specific types of nature contact exhibited divergent, and sometimes adverse associations, with current smoking and exceeding alcohol guidelines. Whilst residential nature contact (greener views from home) was associated with a lower prevalence of each behaviour, intentional nature contact (nature visits) was unrelated to either outcome. Further, contrary to predictions, indirect nature contact (nature media) was associated with a higher prevalence of both behaviours. Thus, whilst greater residential nature contact was associated with healthier and more sustainable behaviours, the potential benefits of intentional and indirect nature contact appear to be specific to diet quality and pro-environmental behaviours. Such findings highlight the importance of distinguishing between different types of nature contact.

The contrast between the findings for smoking and alcohol outcomes, relative to those for poor diet, are particularly striking. As previously discussed the inconsistent findings may relate to the former two behaviours involving the consumption of potentially addictive psychoactive substances, and/or the divergent influences of neighbourhood deprivation and community social norms on different health risk behaviours (Algren et al., 2015; Yun & Silk, 2011; Ahern et al., 2009). It is noteworthy however, that poor diet was not associated with current smoking, or exceeding alcohol guidelines in the bivariate analyses, yet exhibited statistically significant negative associations with the two domains of pro-environmental behaviour. That the SEM results for poor diet were more comparable to those observed for pro-environmental behaviours is potentially telling. Whilst speculative, consistent with propositions that increased nature contact may promote more sustainable food choices (Cassus et al., 2018), with a single-item measure of overall diet quality, the results of the current study may reflect an increased propensity to eat more sustainably. Certainly, the overlap between healthier and more sustainable diets (i.e. less animal produce and processed foods) have been noted elsewhere (Steenson & Buttriss, 2020). Moreover, additional analyses (Appendix 28) indicated that of the pro-environmental items, poor diet exhibited stronger inverse associations to buying 'seasonal and locally grown food' and 'eco-friendly products and brands', compared to items less relevant to dietary choices (e.g. recycling, energy conservation). Further research distinguishing between healthy and sustainable dietary choices is therefore needed to ascertain whether the findings of the current study reflect a lower prevalence of unhealthy diets, and/or a greater propensity to eat sustainably.

These differences notwithstanding, where beneficial associations between nature contact and behavioural outcomes were observed, they were unaffected by adjustments for: a) a range of covariates, *b*) socio-economic interactions and, c) covariance between behavioural outcomes. This strongly suggests that these associations are not due to compositional effects, or shared variance between behavioural domains, rather that increased nature contact may be beneficial to a range a of behavioural outcomes. This is especially the case for diet and pro-environmental behaviours, with comparison of the unadjusted (Appendix 21) and adjusted regression models (Tables 4.2 and 4.3, Section 4.4.2.1), indicating that over half of the variance in these behavioural outcomes was explained by the nature contact/connectedness indicators alone. This is a striking finding, given the range of individual and area-level control variables known to influence these behavioural outcomes also included in the study. Taken together, these comparisons highlight the potential protective value of nature contact for healthier and more sustainable behaviours.

4.5.2.2 RQ2. What role does trait nature connectedness play in these associations?

Study 4 tested two competing hypotheses: whether nature connectedness operates in parallel with nature contact (i.e. additive effects), or influences how nature contact affects pro-environmental behaviours (i.e. moderation effects). As noted above (Section 4.5.1), there was limited evidence overall that nature connectedness moderated the associations between nature contact and behavioural outcomes. Rather, despite its somewhat divergent associations to specific behaviours, nature connectedness emerged as a largely independent predictor of a range of behavioural outcomes. Notably, feeling more connected to the natural world was associated with a higher prevalence of current smoking, as well as with better quality diets and greater engagement in pro-environmental behaviours. Extending prior work on nature connectedness (Mackay & Schmitt, 2019; Whitburn et al., 2020), these associations remained after accounting for: a) various types of nature contact, and b) a comprehensive range of socio-demographics. This indicates that behavioural outcomes associated with feeling more connected to the natural world, are not due to shared variance with nature contact measures, or the result of socio-demographic confounding.

Nevertheless, there is an evident disconnect between the findings for current smoking and poor diets. As previously discussed, the inconsistent findings may relate to the divergent influences of broader personality traits on smoking and diet quality (Zvolensky et al., 2015; Keller & Siegrist, 2015). Equally, there is evidence that individuals who feel more connected to nature are more likely to make sustainable food choices (Weber et al., 2020; Molinario et al., 2020). Hence, congruent with my speculations regarding nature contact, the findings for diet may also reflect more sustainable eating habits amongst those who feel more connected to nature, rather than better quality diets per se. Further work distinguishing between healthy and sustainable dietary choices, and their relative associations to nature connectedness, would therefore be informative in this respect.

4.5.2.3 RQ3. What Mechanisms Underlie Nature – Behaviour Associations?

Whilst the affective, social and cognitive benefits of greater contact with, and psychological connectedness to nature, have been noted elsewhere (Browning et al., 2020; Capaldi et al., 2014; Berry et al., 2020; Weinstein et al. 2015), prior work has tended to focus on a single mediator. Therefore, this study constitutes, to my knowledge, the first empirical investigation of the relative influences of multiple mediators underlying a range of nature-behaviour associations. Path analyses indicated that specific types of nature contact were associated with behavioural outcomes via somewhat different mechanisms. Notably, green views from home were linked to behavioural outcomes, in part, through higher positive affect and/or lower temporal discounting; whereas associations between nature visits and behavioural outcomes, were mediated, to varying degrees, by affective improvement (higher positive affect/lower negative affect) and/or higher community cohesion. The divergent associations between nature media and behavioural outcomes were, at least in part, mediated by higher community cohesion and/or higher temporal discounting. Similarly, affective improvement (higher positive affect, lower negative affect) and/or higher community cohesion mediated the associations between connectedness and behavioural outcomes, irrespective of their direction.

The current study contributes to a more nuanced understanding of the varied pathways linking nature contact, nature connectedness and behavioural outcomes. Specifically, although different types of nature contact, as well as nature connectedness, often exhibited similar relationships with behavioural outcomes, these associations appeared to be driven by different mechanisms. Conversely, wherein nature media and nature connectedness had divergent associations to behavioural outcomes, path analyses indicated that they did so through broadly similar mechanisms. For instance, nature media was associated with higher community cohesion which was, in turn was related to better quality diets and pro-environmental behaviours, but positively associated with current smoking. Nevertheless, with many remaining statistically significant direct paths, and the mediators often accounting for a small proportion of the total effects, it is evident that there is still much to learn about the mechanisms underlying nature-behaviour associations.

4.5.2.4 Limitations

Despite providing unique insights into the links between nature contact, nature connectedness and a range of behavioural outcomes, Study 4 has several limitations. Firstly, although my results are broadly consistent with experimental work suggesting nature contact promotes healthier and more sustainable behaviours (Wu & Chiou, 2019; Kao et al., 2019; Zelenski et al., 2015), the cross-sectional data precludes causal inferences. Whilst alternative path models tested either failed to converge or exhibited a poor fit to the data, thereby supporting the conceptual model, further work in the form of longitudinal studies, or interventions studies manipulating nature contact, are required to substantiate these findings. Second, the unrepresentative sample and data collection during the Covid-19 somewhat limits the generalisability of the findings to other populations and time-points. Third, although there is evidence that self-reported health risk and pro-environmental behaviours correlate strongly with objective measures of behaviour (Vartiainen et al., 2002; Fujii et al., 1985, Warriner et al., 1984), possible misclassifications in outcome variables due to social desirability bias cannot be ruled out. Fourth, as noted in Section 4.2.3 the SEMs did not meet assumptions of normality or linearity, thus these results should perhaps be treated with caution, unless substantiated by further work operationalising health risk behaviours on a continuous scale. Fifth, survey data were collected several years after the area-level data which was assigned to individuals based on their post-code sector. Consequently, it may be that levels of deprivation and population density actually experienced differed from the values used here, which may have added error to the models. Future work using temporally consistent exposure and outcome metrics would be useful, although this is not always easy to establish in large-scale work.

Finally, as discussed in Chapter 1 (Section 1.4.3.1) the use of a subjective measure of residential greenspace within the current study (*vs*. objective measures of residential greenspace within Studies 1-3) somewhat limit the generalisability of the findings. Firstly, green views from home are likely to capture a different spatial area than LSOA and NDVI within the wider neighbourhood. Second, individuals' perceptions of natural features do not always correspond to objective greenspace measures (Barlow, Lyons & Nolan, 2021). Thus, despite being largely consistent with the findings of Studies 1-3, the extent to which the findings of the current study might generalise to greenspace within the wider neighbourhood is unclear. This is particularly the case for the mechanisms included within this study, which were unexamined in Studies 1-3. Notably, with evidence that greenery directly around the home operates as a micro-restorative setting, with immediate visual access providing more regular restorative opportunities (Hartig et al., 2014; Kaplan, 1995), it is conceivable that use of green views from home in Study 4 may have stronger associations to positive affect, negative affect and temporal discounting than may have been observed if LSOA or NDVI greenspace were used. Conversely, NDVI and LSOA greenspace measures may be more adept for capturing use of greenspaces as settings for social contact with family, friends and neighbours, thus use of green views within the Study 4 may underestimate the association between residential nature contact and community cohesion. Further research comparing subjective and objective greenspace measures in terms of their relative associations to behavioural outcomes would therefore be useful in this respect.

4.5.2.5 Conclusion

Public health and environmental sustainability present two of the most significant global challenges of the 21st century (United Nations Environment Programme, 2016; WHO, 2013). Study 4 contributes to a nuanced understanding of pathways linking nature contact and nature connectedness to healthier, more sustainable behaviours. After accounting for a range of covariates, I found that having a greener view from home was associated with a lower prevalence of a range of health risk behaviours (current smoking, exceeding alcohol guidelines and poor diet), as well as greater engagement in household pro-environmental behaviours. Visiting natural spaces at least once a week (*vs.* < once a week) was unrelated to current smoking, exceeding alcohol guidelines, yet associated with better diet and more pro-environmental behaviours. Both watching/listening to nature media at least once a week (*vs.* < once a week) and nature connectedness exhibited somewhat divergent associations to behavioural outcomes. Specifically, both predictors were associated with better diet and pro-environmental behaviours, yet positively predicted health risk behaviours involving psychoactive substances (i.e. current smoking and/or exceeding alcohol guidelines). Path analyses indicated that specific types of nature contact/connectedness predict behavioural outcomes via unique combinations of positive affect, negative affect, community cohesion and temporal discounting. If further evidence can corroborate that these associations are causal, then increasing visible greenery around the home may offer a viable strategy of reducing multiple health risk behaviours, whilst simultaneously promoting more routine forms of pro-environmental behaviour (e.g. recycling, energy conservation). Additionally, policies encouraging more voluntary nature contact (i.e. nature visits, nature media), in addition to a greater psychological connection with nature, may also facilitate healthier diets and more sustainable behaviour.

Chapter 5

Overall Findings, Implications and Future Research

5.1 Thesis Overview

A major determinant of both public and planetary health is human behaviour. Just as human behaviour contributes to illness (e.g. smoking and cardiovascular disease, WHO, 2018b), anthropogenic activity exacerbates environmental degradation (e.g. driving and air pollution, Energy Information Administration, 2015). A potential area of overlap between health risk and pro-environmental behaviours are people's physical and psychological experiences of the natural world (Berry et al., 2020). However, to date, research into these two behavioural domains, as well as work pertaining to nature contact and nature connectedness, has been conducted largely in parallel.

To overcome the fragmentation in these literatures, this thesis presented a conceptual model proposing that increased contact with - and psychological connection to – nature would be associated with benefits to health risk and pro-environmental behaviours via positive affect, negative affect, community cohesion and temporal discounting (Figure 1.1, Chapter 1). The aims of the thesis were threefold. The first aim was to investigate how different types of nature contact (residential, intentional, indirect) were associated with a range of health risk and pro-environmental behaviours, after accounting for a range of socio-demographics. The second aim was to examine whether trait nature connectedness operates in parallel with nature contact (i.e. additive effects), or influences the way in which individuals respond to contact with the natural world (i.e. moderation effects). The third aim was to explore potential mechanisms (positive affect, negative affect, community cohesion, temporal discounting) underlying the associations between nature contact/connectedness and behavioural outcomes.

These issues were systematically investigated using four cross-sectional studies, capable of accounting for a range of covariates known to influence health and sustainability behaviours (e.g. socio-economic status, neighbourhood deprivation, Noble et al., 2015; Völzke et al., 2006; Hornsey et al., 2016; Laidley, 2013). This chapter discusses the overall findings of this thesis in relation to prior theory and research. The methodological limitations of this research will then be considered, along with suggestions for future research. The thesis will then be concluded with some practical implications of this programme of research.

5.2 Summary of Results

Within this Section the main findings of Studies 1-4 are discussed, both in relation to one another, as well as to prior theory and research. For clarity, this Section is structured around the three research questions. A summary of the associations between different types of nature contact, nature connectedness and behavioural outcomes across studies is presented in Table 5.1.

5.2.1 RQ1. How are different types of nature contact associated with health risk and pro-environmental behaviours?

5.2.1.1 Residential contact: greenspace (Column 1, Table 5.1)

Extending prior research into area-level characteristics and the prevalence of health risk behaviours (Pearce & Boyle, 2005; Völzke et al., 2006), Studies 1, 2 and 4 constitute, to my knowledge, the first formal investigations of the links between residential nature contact and health risk behaviours. These studies demonstrated, for the first time beyond bivariate observations (Astell-Burt, Feng & Kolt, 2014; Van Herzele & de

Table 5.1. Summary of nature-behaviour associations from Studies 1-4

		1. Residential (greenspace)	2. Intentional (visits)	3. Indirect (media)	4. Nature connectedness	5. Residential x connectedness	6. Intentional x connectedness	7. Indirect x connectedness
Health (risk) behaviours:-								
Current smoking	Study 1	LOWER	-	-	-	-	-	-
	Study 2	LOWER	LOWER	-	*ns*	*ns*	*ns*	-
	Study 4	LOWER	*ns*	HIGHER	HIGHER	*ns*	*ns*	*ns*
Ever smoker	Study 1	*ns*	-	-	-	-	-	-
	Study 2	*ns*	*ns*	-	*ns*	*ns*	*ns*	-
	Study 4	LOWER	*ns*	HIGHER	HIGHER	*ns*	*ns*	*ns*
Smoking cessation	Study 1	HIGHER	-	-	-	-	-	-
	Study 2	*ns*	*ns*	-	*ns*	*ns*	*ns*	-
	Study 4	*ns*	*ns*	LOWER	*ns*	*ns*	*ns*	*ns*
Exceeds alcohol guidelines	Study 1	*ns*	-	-	-			
	Study 2	LOWER	*ns*	-	*ns*	✓	*ns*	-
	Study 4	LOWER	*ns*	HIGHER	*ns*	*ns*	*ns*	*ns*
Poor diet	Study 4	LOWER	LOWER	LOWER	LOWER	✓	*ns*	*ns*
Pro-environmental behaviour:-								
Household PEB	Study 3	*ns*	HIGHER	HIGHER	HIGHER	ns	*ns*	✓
	Study 4	HIGHER	HIGHER	HIGHER	HIGHER	ns	*ns*	*ns*
Nat. conservation PEB	Study 3	*ns*	*ns*	HIGHER	HIGHER	ns	✓	✓
	Study 4	*ns*	HIGHER†	HIGHER	HIGHER	ns	✓	*ns*

Note. PEB= Pro-environmental behaviours; columns 1-4 present the main effects whilst columns 5-7 present nature contact by nature connectedness interactions, green font = statistically significant association consistent with predictions; red font = statistically significant association in opposite direction to predictions; ✓ = statistically significant interaction effect; *ns* = non-significant association; - = variable not examined; † association was non-significant in the regression model, but there was evidence of statistically significant indirect effects in the SEM.

Vries, 2012; Astell-Burt, Mitchell & Hartig, 2014), inverse associations between residential nature contact and a range of health risk behaviours, after controlling for a range of individual and area-level covariates. Specifically, residing in a greener neighbourhood (Study 1 & 2), or having greener views from home (Study 4), were associated with a lower prevalence of: current smoking (Study 1, Study 2, Study 4), exceeding alcohol guidelines (Study 2, Study 4), and poor diets (Study 4).

Nonetheless, with evident differences in the strength of the associations between studies (as denoted by the non-significant findings in column 1, Table 5.1), attempts to assess whether the associations between greenspace and current smoking were attributable to a lower prevalence ever-smoking and/or a higher prevalence of smoking cessation were less conclusive. Study 1 found a higher prevalence of smoking cessation amongst individuals living in greener neighbourhoods, whereas Study 4 found having greener views from home was associated with a lower prevalence of ever smoking. However, these findings were not replicated between studies. As noted in Chapter 2 (Section 2.3.1), these inconsistencies may reflect the cross-sectional approach. Briefly, in contrast to current smoking, ever-smoking and smoking cessation were measured retrospectively and related to greenspace in the respondent's current place of residence. As individuals may have relocated since uptake or cessation, migration effects have the potential to confound the associations between residential nature contact and these two outcome measures.

These disparities notwithstanding, for the three main health risk behaviours examined within this thesis (current smoking, exceeding alcohol guideline, poor diet), where statistically significant associations were observed, the findings were upheld after adjustment for other health risk behaviours, and were largely unmoderated by measures of socio-economic status. This indicates that the results are unlikely to be due to: a) shared variance between health risk behaviours, or b) individuals from socio-economic groups that are less likely engage in health risk behaviours, simply residing in greener areas. Further, the magnitude of these associations in comparison to benchmark socio-demographics in Studies 1-2 indicated that they may be practically meaningful for potential public health intervention. For example, the association between greenspace and current smoking was comparable to that of earning more than £27,624 (*vs.* < £27, 624) a year in England (Study 1), and over half the size of that associated with earnings in the highest income quintile (*vs.* lowest income quintile) internationally (Study 2). Similarly, the association between neighbourhood greenspace and exceeding alcohol guidelines (Study 2) was similar in magnitude to having a higher education (*vs.* < higher education) and having a high (*vs.* low) household income. Overall, these studies have demonstrated that greenspace, both within the wider neighbourhood and directly around the home, is a robust predictor of a lower prevalence of a range of health risk behaviours that may be at least as important as some life circumstances.

Conversely, and somewhat inconsistent with prior work observing positive associations between greenspace and pro-environmental behaviours (Whitburn et al., 2019; Alcock et al., 2020), I found limited evidence that residential nature contact predicted pro-environmental behaviours, after accounting for: a) different types of nature contact; and b) a range of socio-demographics. This was especially the case for nature conservation behaviours, which were unrelated to residential nature contact across studies (Study 3-4). As discussed in Chapter 3 (Section 3.5.1), the incongruent findings here may be related to different operationalisations of greenspace and pro-environmental behaviours between studies, or simply the wider range of nature contact types included within the models here. Equally, these findings may reflect that residential nature contact alone is insufficient to motivate individuals to perform pro-environmental behaviours that involve greater personal investment (Bamberg & Moser, 2007; Steg and Vlek, 2009).

Household pro-environmental behaviours were unrelated to neighbourhood greenspace (Study 3), but positively associated with greener views from home (Study 4). As discussed in Chapter 4 (Section 4.5.1), these findings may be due to different operationalisations of residential nature contact between studies. Briefly, the LSOA greenspace metric used in Study 3, covers a substantially larger geographical area than greenery directly visible from the home used in Study 4, as well as vegetation cover for households in adjoining streets measured by Whitburn et al., (2019). Equally, Alcock et al. (2020) only found a positive relationship between neighbourhood greenspace and pro-environmental behaviours in a rural sub-sample, who are conceivably more likely to have greener views from home, than their urban counterparts. Alternatively, greenery in the view from home may capture different spatial aspects of residential nature contact than neighbourhood measures (i.e. aspect and slope, Yu et al., 2016). Taken together, these findings are indicative that visible greenery directly from the home may be more relevant to household pro-environmental behaviours, than greenspace within the wider neighbourhood.

5.2.1.2 Intentional Contact: Nature Visits (Column 2, Table 5.1)

Prior to this thesis, participation in nature-based programmes had been associated with higher fruit and vegetable consumption (Alaimo et al., 2008), as well lower relapse rates for drug and alcohol addiction (Bennett et al., 1998), yet little work had directly examined the links between nature visits and health risk behaviours within the general population. Developing this limited literature further, this thesis demonstrated that visiting natural spaces at least once a week (*vs.* less than weekly) was associated with a lower prevalence of poor diets (Study 4), but unrelated to exceeding alcohol guidelines (Study 2, Study 4). However, the links between intentional nature contact current smoking were somewhat inconsistent between studies. Notably, visiting natural spaces at least once a week (*vs.* < once a week) as associated with a lower prevalence of current smoking in Study 2, but these findings were not replicated in Study 4. As discussed in Chapter 4 (Section 4.5.1), the non-significant findings for current smoking and exceeding alcohol guidelines in Study 4 may be due to data collection during the Covid-19 pandemic. Thus, whilst the studies in this thesis show that weekly nature visits are associated with a lower prevalence of poor diets, more research is needed to establish their links to current smoking.

In contrast, the associations between intentional nature contact and specific types of pro-environmental behaviours were replicated between studies. Consistent with research and theory suggesting direct contact with nature promotes ecological attitudes and behaviours (Hartig et al., 2001; Lawrence, 2012; Coldwell & Evans, 2017), I found that individuals who visited natural spaces at least once a week (*vs.* less than weekly), were more likely to engage in more routine household pro-environmental behaviours (Studies 3-4). However, non-significant associations in the regression analyses of Studies 3 & 4 indicated that the benefits of weekly nature visits may not extend to pro-environmental behaviours involving greater personal investment in environmental issues (e.g. volunteering). Nevertheless, statistically significant indirect paths between nature visits and conservation behaviours observed in the structural equation model (Study 4) suggest that the affective and social benefits derived from such visits were indirectly associated with greater engagement with conservation activities.

5.2.1.3 Indirect Contact: Nature Media (Column 3, Table 5.1)

Experimental work has demonstrated that participants experiencing nature indirectly (e.g. viewing nature videos/photos) make healthier (Wu & Chiou, 2019; Kao et al., 2019) and more sustainable choices (Zelenski et al., 2015), yet, to my knowledge, the association between indirect nature contact and these behavioural outcomes within the general population had not been empirically tested. For health risk behaviours, Study 4 demonstrated that watching/listening to nature media at least once a week was associated with a lower prevalence of poor diets, and, unexpectedly, a *higher* prevalence of current smoking and exceeding alcohol guidelines. The findings for the latter two behaviours are inconsistent with experimental work (Wu & Chiou, 2019; Kao et al., 2019), yet in line with the broader literature on the negative impacts of general media use on smoking and alcohol consumption (Grant, et al., 2019; Dong et al., 2020; Niermann et al., 2018). Thus, as discussed in Chapter 4 (Section 4.5.1) the unexpected findings may reflect that individuals who watch/listen to nature media at least once a week simply engage in more media-based activities across genres, or more specifically may relate to data collection during the Covid-19 pandemic wherein hours of media use rose (OFCOM, 2020).

Regarding pro-environmental behaviours, consistent with experimental work (Zelenski et al., 2015), watching/listening to nature media was associated with a greater propensity to engage in household and nature conservation behaviours within the general population (Study 3, Study 4). The magnitude of these associations in comparison to benchmark socio-demographics indicated that they may be practically meaningful. This is especially the case for household pro-environmental behaviours, where the strength of this association was considerably larger than that of visiting natural spaces, as well as benchmark socio-demographics (gender and social grade, Study 3). Therefore, whilst the studies in this thesis demonstrate that watching/listening to nature media is associated with a lower prevalence of poor diets, as well as greater engagement in two domains of pro-environmental behaviour within the general population, it positively predicts health risk behaviours involving the consumption of psychoactive substances (nicotine, alcohol).

5.2.1.4 Summative Discussion

Consistent with conceptual model, there was some evidence that increased nature contact was simultaneously associated with healthier and more sustainable behaviours. Notably, greater residential nature contact (greenspace, green views from home) was associated with a lower prevalence of three types of health risk behaviour, as well as a greater propensity to engage in household pro-environmental behaviours. Increased intentional contact (nature visits) was associated with better diet quality and more pro-environmental behaviours. Similarly, increased indirect contact (nature media) was linked a lower prevalence of poor diets and a greater engagement in pro-environmental behaviours. Moreover, consistent with the additive effects of different types of nature contact observed for broader health and wellbeing outcomes (Shanahan et al., 2016; White et al., 2017) and pro-environmental concern (Weinstein et al., 2015), for poor diet and household pro-environmental behaviours, multiple types of nature contact remained statistically significant within the same models, suggesting that the potential benefits of distinct types of nature contact could be cumulative.

Nevertheless, systematic differences in the strength and direction of the associations, within and between studies (as denoted by red font and non-significant findings in columns 1-3, Table 5.1), highlighted complexities beyond those envisioned in the conceptual model. Firstly, specific types of nature contact exhibited divergent, and sometimes adverse associations to current smoking and exceeding alcohol guidelines. For instance, there was some evidence that increased indirect nature contact was associated with a higher prevalence of current smoking and exceeding alcohol limits. Further work is therefore needed to ascertain whether these types of nature contact in themselves, or co-occurring activities (i.e. greater media use across genres), constitute a risk factor for these two behavioural outcomes.

Second, the findings of Studies 1-4 indicated that specific types of nature contact may be more relevant to particular behavioural domains. Compared to other forms of nature contact, residential nature contact (greenspace, green views) was most consistently associated with a lower prevalence of health risk behaviours. This is perhaps surprising, given prior work demonstrating that intentional nature visits are stronger determinant of broader health and wellbeing outcomes (Shanahan et al., 2016; White et al., 2017). Whilst recognising the possibility of residual confounding, a potential explanation is that greenery around the home and within the wider neighbourhood environment operates as a micro-restorative setting, with immediate visual access providing more regular restorative opportunities (Hartig et al., 2014; Kaplan, 1995), than those afforded by nature visits and nature media. Certainly, the cognitive and affective benefits of greenspace close to the home have also been demonstrated elsewhere (Cox et al., 2017; Ward-Thompson et al., 2016; Kaplan, 2001; De Vries et al., 2013; Sop Shin, 2007), with even forty second micro-exposures to greenery found to benefit attention (Lee et al., 2015a). Moreover, visual assess to greenery, but not the frequency of nature visits, predicts lower cravings for a range of substances, including nicotine, alcohol and food (Martin, et al., 2019). Given that smoking, drinking and unhealthy eating patterns often constitute habitual responses (Gardener, 2015) to everyday stressors (Ng & Jeffery, 2003) and cravings (Hofmann et al., 2012), greenspace characteristics that are visually accessible may conceivably be most beneficial for attenuating these kinds of behaviours.

In contrast, voluntary engagement with nature, either directly (by visiting natural spaces), or indirectly (through nature media), was a more consistent predictor of pro-environmental behaviour than residential nature contact (neighbourhood greenspace, green views). These findings extend prior theory and research suggesting that direct contact with nature promotes ecological attitudes and behaviours (Hartig et al., 2001;

Lawrence, 2012; Coldwell & Evans, 2017) in two ways. Firstly, they indicate the whilst intentional contact with the natural world is associated with greater engagement in routine household behaviours, such as recycling or making eco-friendly purchases, nature visits alone may not be sufficient to encourage conservation behaviours involving greater personal commitment to environmental issues (e.g. volunteering). Second, they suggest that more indirect forms of nature contact that are embedded with individuals' everyday lives (i.e. watch/listening to nature media) may also encourage pro-environmental behaviours across domains.

Whilst speculative, nature visits and nature media may afford more conscious appraisals of environment quality than residential experiences which often occur whilst individuals are engaged in other activities (e.g. commuting to work). For instance, salient cues pertaining to environmental degradation featured on nature programmes (Jones et al., Rust & Veríssimo, 2019), or experienced first-hand during recreational nature visits (e.g. visible signs of littering; Wyles et al., 2016), may promote greater awareness of environmental issues, and thus facilitate behaviours to avoid them. Equally, salient positive nature experiences, such as a sense of awe when watching nature media (Young-Mason 2020), or feelings of restoration after visiting natural spaces (White et al., 2013), may motivate individuals to engage in ecological behaviours to maintain such desirable environmental conditions (Hartig et al., 2001). These explanations are of course tentative and, as discussed in Chapter 3 (Section 3.5.1), further work is required to establish the precise components of nature media (e.g. sensory nature experiences, biodiversity and/or sustainability narrative) that are most beneficial to pro-environmental behaviours.

Overall, whilst it is evident that there is still much to learn about nature-behaviour associations, the studies in this thesis contribute to a more nuanced understanding of how specific types of nature contact are associated with a range of health risk and sustainability behaviours. In particular, existing theory and research tends to be underpinned by the assumption that interactions with the natural world are beneficial, regardless of the type of contact (c.f. Wheeler et al., 2015; Bell et al., 2014). This programme of research has demonstrated empirically that nature-behaviour associations differ, in both direction and strength, as a function of: a) the type of nature contact, and b) specific behavioural outcomes.

5.2.2 RQ2. What is the role of nature connectedness in nature-behaviour associations?

As outlined in Chapter 1 (Section 1.3), there is evidence that contact with - and psychological connection to – nature exhibit analogous negative associations with health risk behaviours on the one hand (Haluza et al., 2014), and positive associations with pro-environmental behaviours on the other (Mackay & Schmitt, 2019; Whitburn et al., 2020). However, it was unclear from prior work whether trait nature connectedness independently predicts positive outcomes (i.e. additive effects), or influences the way in which individuals respond to the natural world (i.e. moderation effects). This thesis examined these two competing hypotheses, whilst controlling for a range of socio-demographic covariates that are known to influence behavioural outcomes (e.g. socio-economic status, neighbourhood deprivation, Noble et al., 2015; Völzke et al., 2006; Hornsey et al., 2016; Laidley, 2013), but have been largely unaccounted for within prior connectedness research.

5.2.2.1 Main Effects (Column 4, Table 5.1)

Evidence for the role of trait nature connectedness in health risk behaviours involving the consumption of psychoactive substances (i.e. smoking and alcohol) was inconclusive, with inconsistent associations emerging between studies (Study 2, Study 4). Notably, nature connectedness was unrelated to current smoking and exceeding alcohol guidelines in Study 2, but was associated with a higher prevalence of each behaviour in Study 4. Similar inconsistencies for health risk behaviours involving psychoactive substances have been noted elsewhere, with some studies observing inverse associations (Haluza et al., 2014), and others positive associations (Forstmann & Sagioglou, 2017).

Nonetheless, extending prior work (Mayer et al., 2009; Whitburn et al., 2019), and in line with the conceptual model, trait nature connectedness predicted both a lower prevalence of poor diets (Study 4) and greater engagement in household and nature conservation pro-environmental behaviours (Study 3, Study 4). These associations remained after accounting for: a) various types of nature contact, and b) a comprehensive range of socio-demographics, indicating that the behavioural outcomes associated with feeling more connected to the natural world are not simply an artifact of shared variance with measures of nature contact, or the result of socio-demographic confounding. For household behaviours in particular, the association is likely to be practically meaningful, given that its magnitude exceeded that of bench-mark socio-demographics (i.e., gender and social grade, Study 3). Therefore, the studies in this thesis support the predictive value of trait nature connectedness in terms of diet quality and pro-environmental behaviours, but its role in health risk behaviours involving psychoactive substances requires further investigation.

5.2.2.2 Moderation Effects (Columns 5-7, Table 5.1)

Across studies in this thesis, there was some evidence that stable individual differences in trait nature connectedness moderated the associations between specific types of nature contact and particular behavioural outcomes. First, consistent with person-environment fit theories (Caplan, 1987), individuals who felt highly connected to nature, residing in areas with less greenspace, were more likely to exceed alcohol guidelines (Study 2). As discussed in Chapter 2 (Section 2.3.4), with evidence that incompatibilities between person-environment attributes are associated with negative emotions (e.g. frustration, stress) and counterproductive behaviours (Harold et al.,2016; Yu et al., 2019), this finding may reflect a negative emotional-behavioural response to limited greenspace in people high in trait connectedness. However, for diet quality, as the proportion of greenery in the view from home increased, the prevalence of poor diets decreased incrementally for those who felt more connected to nature (Study 4). Taken together, these findings suggest that better behavioural outcomes (i.e. healthier behaviours) are most likely among individuals who felt highly connected to the natural world when they also have higher levels residential nature contact. Nevertheless, as the interaction effect for exceeding alcohol guidelines was not replicated between studies (Study 4) and no interaction effects were observed for the remaining health risk behaviours, these findings should perhaps be treated with caution.

Second, whilst trait nature connectedness influenced household pro-environmental behaviours independently of nature visits (i.e. additive effects), the positive association between nature visits and nature conservation behaviours were stronger for individuals who were highly connected to nature (Study 2, Study 4). This suggest that weekly visits alone may not be sufficient to encourage nature conservation behaviours, rather individuals also need to feel an affinity towards nature, in order to act to protect it. This finding builds on prior work showing that trait connectedness moderates the association between nature-based activities and pro-environmental attitudes (Ojala, 2009).

The precise role of nature connectedness in the associations between nature media and pro-environmental behaviours, however, was less conclusive between studies. Consistent with experimental work (Arendt & Matthes, 2016), Study 3 found that the positive associations between nature media and both domains of pro-environmental behaviour were stronger for individuals who were more connected to nature. However, these moderation effects were not replicated in Study 4, with connectedness and nature media independently predicting greater engagement with household and nature conservation behaviours. The differential findings may reflect the smaller sample used in Study 4, which may have lacked the statistical power to detect smaller interaction effects. These inconsistencies notwithstanding, the findings of Studies 2-4 broadly support the contention that efforts to build trait nature connectedness *and* nature contact may be complementary in promoting healthier diets and more sustainable behaviour.

5.2.2.3 Brief Summary

Overall, the studies in this thesis highlight the relevance of person-specific factors in human-nature interactions, particularly in regards to diet quality and pro-environmental behaviours. My findings extend prior theory and research that focused on the mediating role of state connectedness (Mayer et al., 2009; Whitburn et al., 2019), demonstrating that, under some circumstances, *trait* nature connectedness appears to modify the way in which individuals respond to contact with the natural world (Arendt & Matthes, 2016; Ojala, 2009). Going forward, a more nuanced approach to the study of human-nature interactions is likely to be necessary to understand these complexities better, and subsequently inform policies that are beneficial to both human and planetary health.

5.2.3 RQ3. What are the mechanisms underlying associations between nature contact/connectedness and behavioural outcomes?

As outlined in Chapter 1 (Section 1.3.3), prior theory and research suggests that increased contact with - and psychological connectedness to - nature, benefits affect and cognition, and promotes social interaction (Browning et al., 2020; Capaldi et al., 2014; Weinstein et al., 2015; Dean et al., 2018; Berry et al., 2014, 2015, 2019; Ulrich et al., 1991; Hartig et al., 2014; Markevych et al., 2017). A small number of experimental studies have found some of these psychological benefits, mediate nature-behaviour associations (i.e. temporal discounting; Wu & Chiou, 2019; Kao et al., 2019), but little work has explored multiple mediators within the general population. Developing this limited literature further, Study 4 used a bespoke cross-sectional survey of adults in Great Britain to test the full conceptual model proposing that associations between nature contact/connectedness and behavioural outcomes would be mediated by: positive affect, negative affect, community cohesion and temporal discounting.

5.2.3.1 Nature Contact: Main Findings

Residential contact (green views)

After accounting for a range of socio-demographics, I found that the associations between residential nature contact and: a) health risk behaviours, and b) household pro-environmental behaviours were partially mediated by cognitive and/or affective constructs. First, extending experimental findings that nature contact reduces temporal discounting (Van der Wal et al., 2013; Berry et al., 2014, 2015, 2019; Wu & Chiou, 2019; Kao et al., 2019), I found that the negative associations between green view, current smoking and exceeding alcohol guidelines were partially mediated by lower temporal discounting. Second, consistent with the affective benefits of nearby nature noted elsewhere (Kwon et al., 2021; Soga et al., 2020), the association between green view and poor diet was partially mediated by higher positive affect. Third, in line with prior research that improved affective experiences (Chatelain et al., 2018) and more future-orientated decision making (Berry et al., 2020) promote more ecological behaviour, the positive association between green views and household pro-environmental behaviours was partially mediated by higher positive affect and higher temporal discounting. Taken together, these findings suggest that visual access to greenspace from the home may promote a range of healthier and more sustainable behaviours within the general population, in part, by facilitating more future-orientated decision making and/or positive moods.

Intentional contact (nature visits)

This thesis demonstrated that the associations between nature visits and: a) poor diets, and b) pro-environmental behaviours were mediated, at least in part, by affective and/or social constructs. Notably, consistent with evidence linking affective disturbances (Ingram et al., 2020), and lack of social support (Balanzá-Martínez, et al., 2020) to poor dietary habits, the negative association between nature visits and poor diet was completely mediated by higher positive affect and higher community cohesion. That is, the reason why visiting nature seems to have been associated with better diet was because people who visited nature at least once a week tended to report better positive moods and greater social cohesion. Similarly, congruent with propositions that positive emotions elicit more sustainable behaviour (Ibanez et al., 2017; Chatelain et al., 2018; Bissing-Olson, et al., 2013), the association between nature visits and household behaviours was partially mediated by higher positive affect, whereas the association between nature visits and conservation behaviours was completely mediated by higher positive affect, lower negative affect and higher community cohesion. Collectively, these findings suggest that the affective (McMahan & Estes, 2015; Browning et al., 2020), and/or social benefits (Weinstein et al., 2015) of nature visits noted elsewhere, may play a part in promoting healthier diets and more pro-environmental behaviour.

Indirect contact (nature media)

Study 4 demonstrated that the associations between nature media and behavioural outcomes were mediated, in part, by cognitive and/or social constructs. Specifically, the unexpected positive associations between nature media, current smoking and exceeding alcohol guideline, were partially mediated by higher temporal discounting. Similarly, although watching/listening to nature media was associated with greater engagement in household behaviours overall, it also had a small negative indirect effect on household behaviours, via higher temporal discounting. These findings are incongruent with previous theory and research suggesting that viewing images of natural scenes reduces temporal discounting (Van der Wal et al., 2013; Berry et al., 2014, 2015, 2019), but consistent with evidence that media use activates reward-related regions (Kuhn et al., 2011) and predicts higher temporal discounting (Schulz van Endert & Mohr, 2020). As discussed in Chapter 4 (Section 4.5.1), these findings may reflect that individuals who watch/listen to nature media at least once a week simply engage in more media-based activities in general.

Consistent with evidence that digital media constitute a tool for social participation (Marlowe et al., 2016), I found that watching/listening to nature programmes at least once a week was associated with higher perceived community cohesion, which in turn predicted better quality diets and more nature conservation behaviours, as well as a higher prevalence of current smoking. The findings of diet and pro-environmental behaviours support prior work demonstrating the importance of community cohesion to these two behavioural domains (Poortinga, 2006; Johnson et al., 2010; Weinstein et al., 2015). However, with evidence of lower smoking prevalence in more cohesive communities (Patterson, 2004), the results of current smoking were unexpected. As discussed in Chapter 4 (Section 4.4.1.3), future work is required to establish whether the divergent findings for smoking and dietary behaviours, reflect the differential role of community norms in guiding these behaviours (Algren et al., 2015).

Overall, my findings suggest that although different types of nature contact oftentimes exhibited similar associations to behavioural outcomes, these associations may be driven by somewhat different mechanisms. As discussed in Chapter 1 (Section 1.3.1), there are theories pertaining to the affective (e.g. stress reduction theory; Ulrich et al., 1991), cognitive (e.g. attention restoration theory; Kaplan, 1995) and social benefits (e.g. Hartig et al., 2014; Markevych et al., 2017) of nature experiences on broader health and wellbeing outcomes. My findings indicate that, for specific types of nature contact at least, the psychological benefits proposed by current theories may also extend to a number of socially relevant behaviours.

Further, as current theory rarely distinguishes between the psychological benefits of different types of nature contact, this thesis offers unique insights into the kinds of interactions with nature that may potentially ‘activate’ specific pathways. First, consistent with stress reduction theories (Ulrich et al., 1991), for green views and nature visits, associations to behavioural outcomes were often mediated by affective pathways. However, this was not the case for nature media, which was unrelated to either positive or negative affect. These findings are in line with meta-analyses indicating actual contact with the natural world has a larger effect on affect than simulated nature contact (McMahan & Estes, 2015; Browning et al., 2020), and suggests that nature media embedded within individuals’ everyday lives may not be sufficient to improve mood. Second, building on the proposed cognitive benefits of attention restoration theory (Kaplan, 1995), green views from home, but not nature visits, were associated with lower temporal discounting. This suggests that regular visual access to greenspace characteristics could be more beneficial to this particular aspect of cognition, than presumably less regular visits to natural spaces. Additionally, my findings suggest that watching/listening to nature media weekly is associated with higher temporal discounting, although as noted above, this may be due to greater media use in general. Third, building on theories postulating increased social contact as a means through which visits to natural spaces facilitate better health and wellbeing (Hartig et al., 2014; Markevych et al., 2017), my findings suggest that indirect nature contact also positively predicts perceived community cohesion, although this in turn may have divergent influences on behavioural outcomes. Thus, the studies in this thesis contribute to a more comprehensive understanding of the mechanisms through which specific types of nature contact are linked to human behaviour, as well how different types of interactions could potentially support, or undermine, broader psychological processes.

5.2.3.2 Nature Connectedness

Despite evidence that individuals who feel more connected to nature tend to experience more positive affect (Capaldi et al., 2014) and feel more socially connected to others (Lee et al., 2015b; Moreton et al., 2019), the mechanisms through which nature connectedness influences behavioural outcomes has received little theoretical or empirical attention. Building on this limited literature, Study 4 demonstrated that the associations between trait nature connection and behavioural outcomes are mediated, to varied degrees, by affective and/or social constructs. Firstly, the unexpected positive association between nature connectedness and current smoking was completely mediated by higher community cohesion. As noted in Chapter 4 (Section 4.5.1), these findings may reflect the influence of broader personality traits (i.e. openness to experience) on perceptions of connectedness (Lee et al., 2015b) and adherence to social norms (Packer, 2010). Equally, with evidence that use of psychoactive substances themselves may promote a sense of unity and interconnectedness (Griffiths et al., 2008), the possibility of reverse causality cannot be ruled out here. Secondly, the inverse association between nature connectedness and poor diet was partially mediated by higher positive affect and higher social cohesion. Thirdly, for both domains of pro-environmental behaviour, positive associations with nature connectedness were partially mediated by higher positive affect, and to a lesser extent lower negative affect. For nature conservation behaviours, there was further mediation through higher community cohesion. Collectively, these findings indicate that the affective (Capaldi et al., 2014; Lawton et al., 2017; Martyn & Brymer, 2016), and/or social benefits (Dean et al., 2018) of nature connectedness noted elsewhere may also extend to better quality diets and more sustainable behaviours.

5.5.3.3 Brief Summary

Overall, Study 4 contributes to a more nuanced understanding of the varied pathways linking nature contact, nature connectedness and behavioural outcomes. Although different types of nature contact, as well as nature connectedness, often exhibited similar associations to behavioural outcomes, these relationships appeared to be driven by somewhat different mechanisms. Conversely, wherein nature media and nature connectedness were linked to divergent behavioural outcomes (i.e. a higher prevalence of health risk behaviours involving the consumption of psychoactive substances, but better diet quality and more pro-environmental behaviours), my findings indicated that these associations were mediated by broadly similar mechanisms. Thus, this research highlights not only the mechanisms by which nature contact/connectedness may promote healthier and more sustainable behaviours, but also those which could potentially undermine them. Nevertheless, with many remaining statistically significant direct paths, and the mediators often accounting for only a small proportion of the total effects, it is evident that there is still much to learn about the mechanisms underlying associations between nature contact/connected and behavioural outcomes.

5.3 Limitations

The findings of this thesis should be considered in the light of several limitations. First, although the results are consistent with experimental findings that contact with nature promotes healthier (Wu & Chiou, 2019; Kao et al., 2019) and more sustainable decisions (Zelenski et al., 2015; Janpol & Dilts, 2016), reliance on cross-sectional datasets precludes the ability to make causal inferences. Therefore, despite evidence that residential selections are not primarily determined by the availability of natural spaces (Schirmer et al., 2014; Gehrke et al., 2019), reverse causality cannot be ruled out. Specifically, individuals already exhibiting healthier and more sustainable lifestyles may selectively migrate towards more natural settings, or simply choose to spend more time in them.

Second, despite having controlled for a range of possible confounds, there remains the possibility of residual confounding, or unmeasured confounding across studies (Villeneuve et al., 2012; Pearce et al., 2016). As noted throughout this thesis, co-occurring activities (i.e. opportunities to consume alcohol on nature visits, greater media use across genres) have the potential to confound nature-behaviour associations. Additionally, as noted in Chapter 4 (Section 4.5.1), normative processes that have been recognised as important drivers of health risk and sustainability behaviours (Pearce et al., 2012; Bamberg & Schmidt, 2001; Lindenberg & Steg, 2007) were unaccounted for within the current research.

Third, as noted in Chapter 1 (Section 1.4.3.3), many studies statistically control for relevant covariates within environmental psychology, however many scholars advocate caution in the selection of control variables, due to the risk of over-adjustment bias (Lu et al., 2021; Schisterman et al., 2009). Thus, although the covariates selected for inclusion within this thesis were based upon prior literature (Table 1.1), directed acyclic graphs (DAGs) may have offered a more structured and explicit approach to identifying sources of confounding (Suttorp, 2015; Schisterman et al., 2009). Equally, although covariates were operationalised consistently with prior research within the field (e.g. Weinstein et al., 2015; Alcock et al., 2020), the potential pitfalls of using categorical covariates ought to be noted. Specifically, categorical covariates, especially those with less than five categories may be less effective than continuous variables, and in some cases their inclusion may inflate the type one error rate (Brenner et al., 1998; Austin & Brunner, 2004). Thus, future research within environmental psychology might usefully consider instrumental variables analysis, or matching approaches to negate these issues (Stuart, 2010; Johnston et al., 2008).

Fourth, the results presented herein are based largely on self-report data. There is little research on the accuracy of self-reported nature contact measures (i.e. visit frequency, exposure to nature media, or estimations of greenery around the home), so it is unclear whether there are any biases inherent within these measures. Whilst self-reported health risk and pro-environmental behaviours are good predictors of actual behaviour (Fujii et al., 1985, Warriner et al., 1984; Vartiainen et al., 2002), and are widely used in the context of cross-sectional research, possible misclassifications in outcome variables due to social desirability bias cannot be ruled out. Further, use of categorical measures (e.g. ratings of overall diet quality on a five point scale), may over simplify complex realities. Indeed, as noted in Chapter 4 (Section 4.5.2.1), it is unclear whether the findings for diet represent healthier eating per se, or simply adopting a more sustainable diet. Equally, with a focus on whether respondents exceeded recommended alcohol guidelines throughout this thesis, it is unclear whether observed nature-behaviour associations might extend to risker drinking behaviours that have a greater impact upon health (i.e. binge drinking, alcohol use disorders; Tetrault & O'Connor, 2017). Nonetheless, with meta-analyses reporting little change in risky drinking behaviour following non-pharmacological intervenions (Scott et al., 2018) it seems appropriate to speculate that greenspace access likely constitutes a relatively minor influence on these kinds of behaviours, compared to other fundamental social and individual circumstances (Härkönen et al., 2017). Conversely, prior work demonstrating lower relapse rates for drug and alcohol addiction (Bennett et al., 1998) following nature-based treatment programmes, indicates that more direct form of nature contact could potentially be beneficial for riskier drinking behaviours when embedded into a wider therapeutic programme.

Fifth, there is evidence that quality of natural spaces, as well as activities undertaken in them, are important predictors of broader health and wellbeing outcomes (Van Dillen, 2012; Wyles et al., 2019). As recognised previously, the measures used in the current research tell us little about the quality of nature contact, or indeed the how specific activities in natural environments may influence associations between nature contact and behavioural outcomes. Moreover, as with much previous nature restoration research, the studies within this thesis focused exclusively on residence-based measures of greenspace. Consequently, other potentially important green space exposures, for instance greenspace around workplace, schools or indeed within commuting routes were unaccounted for here.

Sixth, there is increasing recognition that the researcher degrees of freedom – flexibility in collecting and analysing data – may bias studies and increase the Type I error rate (Gelman & Loken, 2013). One way to counteract such bias is to preregister studies with precise and detailed protocols that allow researchers little room for arbitrary decision making (Wicherts et al., 2016). Whilst other steps were taken to minimise researcher degrees of freedom (i.e. decision making informed by existing research; relevance of variable operationalisation and inclusion criteria demonstrated through sensitivity analyses), only Study 4 was pre-registered.

Finally, with several statistical tests performed within each study, potential inflation of the Type I error rate (i.e. false positives) as a result of multiple testing ought to be considered. Although a number of statistical procedures have been developed to deal with multiplicity, including False Discovery Rate (FDR) adjustments (Streiner, & Norman, 2011), there remains controversy as to whether, and under which conditions they should be applied (Cf. Rothman, 1990; Savitz & Olshan, 1995; Moyé et al., 1998; Andrade, 2019). False Discovery Rate (FDR) adjustments were not reported within the main results section of this thesis for two reasons. First, although widely used in the fields of genomics, ecology and economics (Korthaue et al., 2019), FDR adjustments are not standard practice within environmental psychology, or behavioural epidemiology (Sjölander & Vansteelandt, 2019; Catelan & Biggeri, 2010). Thus, the statistical approach taken within this thesis is consistent with many published works pertaining the benefits of natural environments (e.g. Pearce et al., 2011; Alcock et al., 2020) as well as studies on the prevalence of health-risk behaviours (Pearce & Boyle, 2005; Idris et al., 2007). Second, given the trade-off between Type I and Type II errors, the utility of FDR adjustments varies according to a study's purpose (Chen, Feng & Yi, 2017). Notably, where interpretation of a finding has clinical consequences (i.e. the efficacy of a new medication) Type I errors ought to be rigorously controlled for. Conversely, in studies aiming to obtain candidates for further investigation, it may be better to tolerate some false positives, rather than to prematurely discard potentially useful observations (Rothman, 1990). Given the novelty of the nature-behaviour associations examined herein and the correlational approach, I consider the studies within this thesis fall into the latter category.

Nonetheless, to assess the degree to which the inferences within this thesis reflect a reliance on unadjusted p-values, adjusted p-values for the hypotheses tested within each study are summarised in Appendix 29. Of the 73 unadjusted statistically significant associations ($p < .05$) observed within this thesis, 54 remained statistically significant with a FDR <.05, 63 with a FDR <.10, and 68 with a FDR < .25 (See Appendix 29 for future details). Thus, were a very conservative FDR of <.05 applied, the number of statistically significant nature-behaviour associations would have been reduced by 26%. Conversely, were a less stringent, yet widely used FDR of <.25 (e.g. Billatos et al., 2018), my interpretations of the unadjusted p-values would have been largely upheld.

5.4 Future Research

The findings of Studies 1-4, as well as their methodological limitations, highlight a number of potential avenues of further research. These are outlined briefly below.

5.4.1 Types of nature contact: establishing temporal sequence and accounting for confounds

5.4.1.1 Residential Contact (Greenspace)

With the studies in this thesis indicating that greater residential nature contact is associated with a higher prevalence of a range of health risk behaviours and greater engagement in household pro-environmental behaviours, a logical extension to this programme of research would be longitudinal and intervention studies to confirm causal direction. For example, cohort studies examining the impact of relocation to a greener (or less green) neighbourhoods on health risk behaviours would help to establish whether changes in residential nature contact are associated with improvements (or deteriorations) in respondents' health risk and sustainability behaviours over time. This kind of study would be particularly useful to ascertain whether any changes in the prevalence of current smoking are attributable to a lower prevalence of ever-smoking and/or higher prevalence of smoking cessation. Intervention studies comparing residents' health risk and sustainability behaviours, before and after the introduction of urban greening initiatives, would also be informative in this respect.

Although the studies in this thesis controlled for a broad range of individual and area-level covariates, there may be other neighbourhood characteristics that coincide with living in greener areas, which may account for the associations observed. For example, factors such as the availability of tobacco/alcohol retailers, or fast food outlets have been shown to influence health risk behaviors (Pearce et al., 2012; Pearce et al., 2009). Additionally, social norms are considered important determinants of health risk and sustainability behaviours (Pearce et al., 2012; Bamberg & Schmidt, 2001; Lindenberg, & Steg, 2007) and as discussed in Chapter 4 (Section 4.5.1) may modify the social benefits that are associated with greater contact with the natural world. Therefore, it would be useful for future research to account for these potential confounds, in addition to range of covariates included with studies 1-4.

5.4.1.2 Intentional contact (nature visits)

Experimental field studies have been widely used to investigate the effects of nature walks (*vs.* those in urban settings) on cognition and affect (Faber Taylor & Kuo, 2009; Pasanen et al., 2018). This methodology could usefully be extended to incorporate more objective measures of human behaviour, to establish whether the pattern of associations observed are causal, and indeed whether they extend beyond self-reported behaviour. For instance, commons dilemma tasks have been adapted to measure sustainable behaviour (Zelenski et al., 2015), thus differences in performance on this measure before and after walks in different environments may be informative. Similarly, for health risk behaviours, the nutritional value of participants' snack choices (i.e. sugar, fat, calorie content), or the amount of alcohol consumed during tasks, might be compared pre and post intervention. This type of experimental design would be particularly useful for establishing the effect of nature visits on alcohol consumption, without the potential confounds of co-occurring activities that may also involve consuming alcohol (e.g. barbeques, camping, fishing trips).

5.4.1.3 Indirect contact (nature media)

The studies in this thesis demonstrated that watching/listening to nature media was associated with better quality diets and greater engagement in pro-environmental behaviours, as well as a higher prevalence of current smoking and exceeding alcohol guidelines. As already noted, further work is needed to establish: a) whether the positive association between nature media and health risk behaviours involving psychoactive substances are due to greater media use across genres; b) whether this was merely a confound of the research having been conducted during the Covid 19 pandemic where media consumption in general rose (OFCOM, 2020); and c) which components of nature media are most relevant for positive behavioural outcomes. To this end, experimental work demonstrating that participants who view natural (*vs.* urban) scenes make healthier and more sustainable decisions (Wu & Chiou, 2019; Kao et al., 2019; Zelenski et al., 2015) could be extended by using actual footage of nature documentaries. This would be particularly useful for establishing the effects of nature media on health risk behaviours involving the consumption of psychoactive substances (i.e. nicotine, alcohol) without the potential confound of greater general media use. Further, experimental work manipulating biodiversity and sustainability narratives with nature documentaries between conditions, would be useful to determine which components of nature media promote healthier dietary choices and more sustainable behaviours.

5.4.2 Nature Connectedness: Trait and State

With little prior work explicitly distinguishing between trait and state nature connectedness (Chapter 1, Section 1.3.2), this thesis aimed to develop a deeper understanding of the role of trait connectedness in health risk and pro-environmental behaviours. However, an interesting line of future research might be to explore the inter-play between trait and state nature connectedness, and their links to behavioural outcomes. With evidence that positive experiences in nature heighten state nature connectedness (Wyles et al., 2019), it is conceivable that regular contact with the natural world might, over time, increase baseline levels of trait nature connectedness, and thus potentially promote better quality diets and greater engagement in pro-environmental behaviours.

5.4.3 Possible Extensions of the Current Work

5.4.3.1 Further Distinguishing between the Type and Quality of Nature Contact

With systematic differences arising in the associations between different types of nature contact and behavioural outcomes, future research might develop these distinctions further. Firstly, greenspaces beyond residential location (i.e. schools, workplaces and travel routes; Dadvand et al., 2015), as well as local blue spaces (lakes, coasts, rivers) are increasing recognised for their potential to support public health and sustainability agendas (Pasanen et al., 2019; Britton et al., 2020; Vert, et al., 2020; Gunawardena et al., 2017). Therefore, examining the links between a greater variety of nature exposures and behavioural outcomes would be an interesting next step. To this end, future research might better capture the totality of green/blue space exposure by establishing the geolocations of workplaces/schools and frequent travel routes, in addition to participants place of residence. Equally, Global Positioning Systems (GPS) from mobile phones offer a promising means of tracking which parts of the natural environment people experience within their day-to-day lives.

Second, whilst the focus of this thesis has been on the quantity of nature contact, the quality of human-nature interactions may also be relevant to behavioural outcomes. Thus, future work might examine whether the broader health and wellbeing benefits associated with high quality natural environments (i.e. natural areas with protected status, higher biodiversity, or better facilities Wyles et al., 2019; Van Dillen et al., 2012), extend to healthier and more sustainable behaviours.

5.4.3.2 Nature-Behaviour Associations in Sub-Groups of the Population

The current programme of research focused exclusively on nature-behaviour associations within general adult populations, predominantly in within nations of the United Kingdom (Study 1, 3 and 4). Future research could benefit from examining these associations within specific sectors of the population in more detail. Firstly, late childhood and adolescence are formative periods for the development of attitudes and behaviours pertaining to one's own health (Spring et al., 2012; Sawyer et al., 2012), as well as the health of the planet (Grønhøj & Thøgersen, 2017). Despite evidence that greater contact with the natural world during childhood predicts better health and wellbeing (Bezold et al., 2018) and fosters a greater desire to protect the environment (Glettler & Rauch, 2020), it is unclear from the current literature whether these benefits might extend to healthier and more sustainable behaviours during childhood and adolescence. Moreover, longitudinal studies might usefully explore whether there are cumulative effects of nature contact over the life course, or indeed whether there are critical periods in people's lives where natural spaces are particularly important to health-risk and pro-environmental behaviours (Pearce et al., 2016).

Second, with the studies in this thesis demonstrating a lower prevalence of health risk behaviours amongst individuals living in greener areas and previous work demonstrating lower relapse rates for drug and alcohol addiction (Bennett et al., 1998) following nature-based treatment programmes, future work might investigate these associations in clinical samples (i.e. individuals struggling with addiction/substance abuse).

5.4.3.3 Distinguishing between sustainable and healthy diets

As discussed in Chapter 4 (Section 4.5.2.1), there were evident similarities in the findings of Study 4 for poor diet and the two pro-environmental behaviours. With evidence that nature contact and nature connectedness promote more sustainable food choices (Cassus et al., 2018; Weber et al., 2020; Molinario et al., 2020), these findings may reflect an increased propensity to eat more sustainably. Certainly, the overlap between healthier and more sustainable diets (i.e. less animal produce and processed foods) has been noted elsewhere (Steenson & Buttriss, 2020). Further research distinguishing between healthy and sustainable dietary choices is therefore needed to ascertain whether the findings of the Study 4 reflect a lower prevalence of unhealthy diets, and/or a greater propensity to eat sustainably.

5.4.3.4 Additional Mechanisms Underlying Nature-Behaviour Associations

Study 4 demonstrated that specific types of nature contact/connectedness influenced behavioural outcomes via somewhat different combinations of positive affect, negative affect, community cohesion and temporal discounting. Nonetheless, with many remaining statistically significant direct paths, and the mediators often accounting for only a small proportion of the total effects, future work might usefully explore additional mediating pathways. For example, increased nature contact is associated with reduced stress, impulsivity and cravings (Thompson et al., 2012; Repke et al., 2018; Martin et al., 2019). As these factors independently predict greater engagement in a variety of health risk behaviours (Algren et al., 2018; Granö et al., 2004; Cosci et al., 2016; Richard et al., 2017; Rosenberg & Mazzola, 2007), future research could explore these potential mediating pathways. Additionally, greater contact with the natural world promotes greater mindfulness (Dzhambov et al., 2019; Hamann & Ivtzan, 2016), which may be beneficial to both health risk (Sala et al., 2020) and pro-environmental behaviours (Barbaro & Pickett, 2016). With prior work indicating that aforementioned constructs and the mediators examined in Study 4 may are conceptually related (Peters et al., 2011; Ashe et al., 2015; Martin et al., 2019), further work attempting to disentangle these potentially inter-connected pathways may be especially useful.

5.5 Practical Applications

The findings of this thesis are particularly relevant to practitioners and policy makers because of the representative nature of Studies 1-3, as well as the realistic and diverse types of nature contact respondents reported on across studies. Overall, the range of behavioural benefits associated with residential greenspace and intentional nature visits highlighted throughout this thesis advocate a need to protect and invest in natural resources that are already under pressure, in order to maximise the health and sustainability benefits that they may afford. Whilst recognising the correlational nature of the datasets, I outline below potential practical implications of this work, should further research confirm that the associations observed are causal.

5.5.1 Improving Greenspace Provision

Given the personal and economic costs associated with health risk behaviours (Chapter 1, Section 1.2.1), there is growing interest in place-based health promotion strategies, that can be used alongside individual health care interventions (Fielding et al., 2013; McGinnis et al., 2002). The findings of this thesis situate residential nature contact as a potential protective factor for a range of health risk behaviours. If further research can corroborate that these links are causal, then improvements to the provision and maintenance of public greenspace, for instance through greener infrastructure or urban greening strategies, represents a promising place-based strategy for reducing multiple health risk behaviours at the population-level. With competing demands for land use and widespread budgetary constraints (Public Health England, 2020b), local authorities should consider the prioritisation of greenspaces within communities with a higher prevalence of health risk behaviours, as part of the wider plan to reduce local health inequalities. Further, Study 4 highlighted the potential benefits of visible greenery from the home to health risk behaviours, as well as more routine pro-environmental behaviours. If substantiated by further work, then 'streetscape' greenery currently being implemented with urban cities to mitigate flood risks and urban heat island effects (Mayor of London, 2019) might usefully be extended to urban residential areas to promote healthier and more sustainable behaviours.

5.5.2 Nature-Based Interventions

As highlighted by this programme of research, weekly nature visits are associated with a lower prevalence of poor diets, as well as with greater engagement in more routine household pro-environmental behaviours. If further work confirms that these associations are causal, then efforts to encourage more frequent nature visits (i.e.by improving access to natural spaces in urban settings or enhancing motivations to visit), may play a part in encouraging better diets, and more sustainable behaviours. Further, current green prescribing initiatives aimed at improving mental health and physical activity (Robinson et al., 2020), might be extended to support individuals with unhealthy dietary habits. Given that association between nature visits and poor diets was completely mediated by positive affect and community cohesion, this type of intervention may be particularly beneficial for individuals for whom emotional eating is a problem, or those with low social support.

5.5.3 Harnessing the Benefits of Indirect Nature Contact

Assessments of the mental health benefits of technology mediated nature experiences for individuals with limited access to natural spaces (i.e. in health and social care settings) are already underway (Tanja-Dijkstra et al. 2018; White et al., 2018; Yeo et al., 2020; Browning et al., 2020). Given that indirect nature contact was associated with benefits to diet quality and perceptions of community cohesion (Study 4), this type of intervention might be particularly useful for individuals with poor diets, or low social support. Nonetheless, if further work substantiates that the unexpected positive relationships between indirect nature contact and health risk behaviours involving the consumption of psychoactive substances are causal, then practitioners should be cautious about implementing these interventions amongst smokers, or those with a history of alcohol misuse. Additionally, this programme of research demonstrated that indirect nature contact is a robust predictor of pro-environmental behaviours across domains. As watching/listening to nature media is already a prevalent leisure activity within many individuals' lives (Jones et al., 2019), there is scope to harness their potential sustainability benefits further. For instance, embedding information about local conservation activities, or appeals for monetary donations, within nature programmes themselves, may encourage greater uptake of these behaviours.

5.5.4 Building Nature Connectedness

The findings presented in this thesis suggest that trait psychological connectedness to nature may be a key factor for: a) better quality diets and *b*) sustainable behaviours, not just in terms of its direct associations with these behaviours, but also through its moderating effects on specific types of nature contact. For instance, for nature conservation behaviours, visit frequency and nature connectedness interacted, suggesting optimal visits may be those that activate the pathways to nature connectedness (Lumber et al., 2017). Interventions could be designed to encourage this process, by, for instance, embedding efforts to stimulate nature connectedness within nature-based activities. At the very least, the findings of the current work support the value of collecting information on nature connectedness at the national-level and encouraging interventions that increase it among the population (Richardson et al, 2015; 2018).

5.5.5 Integrated Strategies to Human and Planetary Health

The findings of this thesis highlight nature contact and nature connectedness with the natural world as an area of potential overlap between health risk and pro-environmental behaviours. If further research can corroborate that these links are causal, then it is conceivable that nature-based interventions currently in place to encourage positive behaviours in one domain (e.g. more sustainable behaviours), could have unexpected co-benefits to other domains (e.g. reduced health risk behaviours). Further, given the budgetary challenges facing local councils (Public Health England, 2020), there may be utility in pursuing more integrated approaches to public and planetary health.

5.6 Conclusion

The overarching aim of this thesis was to examine the links between nature contact, nature connectedness, and behavioural determinants of public and planetary health (i.e.

health risk behaviours and pro-environmental behaviours). These relationships were systematically investigated using four large scale cross-sectional datasets. After accounting for a range of socio-demographics, it was found that nature-behaviour associations differ, in both direction and strength, as a function of: a) the type of nature contact, and b) specific behavioural outcomes. Residential nature contact (greenspace, green views) was associated with a lower prevalence of three domains of health risk behaviours (current smoking, exceeding alcohol guidelines, poor diets), as well as greater engagement in household pro-environmental behaviours. These associations were partially mediated by higher positive affect and/or lower temporal discounting. Visiting natural spaces at least once a week (*vs.* < once a week) was associated with better quality diets and greater engagement with pro-environmental behaviours, via affective improvement (higher positive affect/lower negative affect) and/or higher community cohesion. Watching/listening to nature media was associated with a higher prevalence of current smoking and exceeding alcohol guidelines, as well as better quality diets and greater engagement in pro-environmental behaviours across domains. Irrespective of their direction, these associations were mediated, to varying degrees, by higher community cohesion and/or higher temporal discounting. Trait nature connectedness was most consistently associated with better quality diets and a heightened propensity to behave sustainably across domains, via affective improvement (higher positive affect/lower negative affect) and/or higher community cohesion. Further, there was evidence that, under some circumstances, trait nature connectedness moderated nature-behaviour associations, with better behavioural outcomes (i.e. healthier and more sustainable behaviours) most likely amongst individuals who felt highly connected to the natural world, when they also had higher levels of nature contact. This thesis situates people's physical and psychological experiences with the natural world, as a largely overlooked area of overlap between health risk and pro-environmental behaviours. The complexity of the findings indicates that a more nuanced approach to the study of human-nature interactions is likely to be necessary to inform integrated environmental policies that are beneficial to both human and planetary health.

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Appendices

Appendix 1. Study 1: sensitivity analysis comparing the inclusion *vs.* exclusion of non- drinkers

A sensitivity analysis was carried out to ensure that excluding non-drinkers from our main models did not bias the results. Table 1 presents fully adjusted Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for the associations between greenspace and exceeding recommended alcohol guidelines (model 1: including non-drinkers *vs*. model 2: excluding non-drinkers). There was little difference in the direction and strength of associations between nature contact and exceeding alcohol guidelines between to the two models.

Table 1. Sensitivity analysis: comparison of the association between nature contact and exceeding recommended alcohol guidelines, including/excluding non-drinkers

	Model 1 Including non-drinkers			**Model 2 Excluding non-drinkers**		
	PR	**95% CIs**	***p***	***PR***	**95% CIs**	***p***
Neighbourhood greenspace (%)						
1st quartile (M= 5.23, lowest)						
2nd quartile (M= 24.46)	1.11	(0.94, 1.31)	.219	1.12	(0.93, 1.34)	.234
3rd quartile (M= 54.18)	1.18	(0.96, 1.47)	.120	1.18	(0.94, 1.44)	.132
4th quartile (M= 86.35, highest)	1.13	(0.92, 1.38)	.245	1.16	(0.92, 1.46)	.212
Gender (female)	0.75	(0.67, 0.84)	<.001	0.80	(0.70, 0.90)	<.001
Age						
16-34 (ref)						
35-64	1.22	(1.05, 1.41)	.011	1.26	(1.07, 1.49)	.006
65+	0.98	(0.81, 1.19)	.840	1.06	(0.86, 1.30)	.617
Education						
No formal education (ref)						
Secondary	1.27	(1.04, 1.54)	.017	1.13	(0.92, 1.38)	.247
Tertiary	1.70	(1.38, 2.09)	<.001	1.53	(1.23, 1.91)	<.001
Higher	1.29	(1.05, 1.58)	.016	1.17	(0.95, 1.44)	.144
Socio-economic group						
Routine & manual (ref)						
Intermediate	1.08	(0.93, 1.26)	.307	1.08	(0.91, 1.27)	.369
Managerial & professional	1.03	(0.88, 1.21)	.713	1.00	(0.84, 1.18)	.969
Other	0.67	(0.44, 1.02)	.059	1.03	(0.67, 1.59)	.889

Table 1 continued

Equivalised household income						
≤ £27, 624 (ref)						
> £27, 624	1.27	(1.10, 1.46)	.001	1.17	(1.01, 1.36)	.036
Undisclosed	1.12	(0.95, 1.31)	.181	1.17	(0.98, 1.39)	.080
Marital Status (Married/Cohabiting)	0.99	(0.88, 1.13)	.913	0.99	(0.86, 1.13)	.832
Area-level controls						
Index of multiple deprivation (IMD)						
1st Quintile (most disadvantaged, ref)						
2nd Quintile	1.01	(0.83, 1.24)	.918	0.93	(0.75, 1.15)	.483
3rd Quintile	0.93	(0.76, 1.14)	.486	0.85	(0.68, 1.06)	.145
4th Quintile	1.13	(0.92, 1.38)	.245	0.98	(0.79, 1.21)	.833
5th Quintile (least disadvantaged)	1.05	(0.86, 1.28)	.640	0.92	(0.74, 1.14)	.431
Urbanicity (urban)	1.00	(0.84, 1.19)	.985	1.04	(0.86, 1.26)	.674
Constant	0.08	(0.06, 0.11)	<.001	0.11	(0.08, 0.16)	<.001
N	7938			6535		
Wald's χ^2	114***			60.84***		
Pearson goodness of fit χ^2	6869			5486		
Pseudo R^2	.02			.01		

Note. *** = p <.001

Appendix 2. Study 1: sensitivity analyses comparing greenspace operationalisations

A sensitivity analysis was conducted on three different operationalisations of neighbourhood greenspace (high *vs*. low, quartiles, quintiles). Tables 2a-2b present fully-adjusted Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for the associations between greenspace and behavioural outcomes with greenspace included as a binary variable (Table 2a) and in quintiles (Table 2b). Results for greenspace expressed in quartiles are as reported in Table 2.2 within the main manuscript (Chapter 2, section 2.2.3.2). The direction of associations between greenspace and health (risk) behaviours was consistent between models. Quartiles of greenspace were used in the main analysis, for two reasons. Firstly, to avoid a reduction in sensitivity and power associated with the use of binary variables. Secondly, quartiles were preferable to maximise statistical power, since operationalisation in quintiles resulted in substantially fewer cases in the highest (*vs*. lowest, Table 2b) greenspace quintiles (where hypothesised greenspace were likely to be most pronounced). This was particularly important given planned robustness checks, examining greenspace by socio-economic variable interaction effects (i.e. moderation effects with other categorical variables).

Table 2a: Sensitivity analysis: the association between greenspace and health risk behaviours, specifying greenspace as a binary variable (High vs. Low) using a median split.

	Model 1 Current Smoking			**Model 2 Ever Smoker**			**Model 3 Smoking Cessation**			**Model 4 Exceeds Alcohol Limits[a]**		
	PR	**(95% CIs)**	***p***	**PR**	**95% CIs**	***p***	**PR**	**95% CIs**	***p***	***PR***	**95% CIs**	***p***
Neighbourhood greenspace												
Low (<40%, N = 4020)												
High (≥40%, N = 2029)	0.93	(0.83, 1.05)	.228	0.99	(0.96, 1.11)	.458	1.09	(0.98, 1.20)	.100	1.16	(0.96, 1.34)	.071
Gender (female)	0.82	(0.74, 0.90)	<.001	0.78	(0.73, 0.83)	<.001	1.03	(0.94, 1.12)	.496	0.75	(0.66, 0.84)	<.001
Age												
16-34 (ref)												
35-64	0.85	(0.76, 0.96)	.008	1.11	(1.02, 1.22)	.019	1.41	(1.23, 1.62)	<.001	1.22	(1.03, 1.44)	.020
65+	0.29	(0.24, 0.35)	<.001	1.04	(0.94, 1.16)	.438	2.23	(1.92, 2.59)	<.001	0.98	(0.80, 1.21)	.861
Education												
No formal education (ref)												
Secondary	0.88	(0.77, 1.01)	.070	0.96	(0.88, 1.06)	.427	1.00	(0.88, 1.13)	.960	1.27	(1.03, 1.55)	.024
Tertiary	0.68	(0.57, 0.80)	<.001	0.86	(0.76, 0.96)	.009	1.09	(0.94, 1.27)	.264	1.70	(1.36, 2.12)	<.001
Higher	0.54	(0.46, 0.64)	<.001	0.73	(0.66, 0.82)	<.001	1.13	(0.99, 1.29)	.072	1.28	(1.04, 1.58)	.022
Socio-economic group												
Routine & manual (ref)												
Intermediate	0.81	(0.71, 0.92)	.001	0.89	(0.82, 0.97)	.010	1.10	(0.98, 1.23)	.101	1.08	(0.92, 1.27)	.355
Managerial & professional	0.66	(0.56, 0.77)	<.001	0.87	(0.79, 0.95)	.003	1.17	(1.04, 1.32)	.009	1.03	(0.87, 1.22)	.751
Other	0.35	(0.26, 0.48)	<.001	0.35	(0.27, 0.46)	<.001	0.66	(0.40, 1.11)	.117	0.67	(0.43, 1.03)	.069
Equivalised household income												
≤ £27, 624 (ref)												
> £27, 624	0.75	(0.65, 0.85)	<.001	0.85	(0.78, 0.92)	<.001	1.12	(1.01, 1.25)	.031	1.27	(1.09, 1.47)	.002
Undisclosed	0.93	(0.82, 1.06)	.273	0.91	(0.83, 0.99)	.026	0.99	(0.88, 1.11)	.862	1.11	(0.94, 1.33)	.224

Table 2a continued

Marital Status -Married/Cohabiting	0.73	(0.66, 0.81)	<.001	0.98	(0.91, 1.05)	.524	1.26	(1.14, 1.39)	<.001	0.99	(0.87, 1.14)	.939
Index of multiple deprivation												
1st quintile (ref)												
2nd Quintile	0.88	(0.77, 1.02)	.083	0.96	(0.86, 1.06)	.382	1.13	(0.98, 1.32)	.099	1.01	(0.81, 1.25)	.932
3rd Quintile	0.71	(0.60, 0.83)	<.001	0.88	(0.79, 0.98)	.016	1.26	(1.09, 1.47)	.002	0.93	(0.74, 1.16)	.515
4th Quintile	0.76	(0.65, 0.90)	.001	0.84	(0.75, 0.94)	.002	1.16	(0.99, 1.35)	.069	1.12	(0.91, 1.39)	.293
5th Quintile (least disadvantaged)	0.50	(0.41, 0.60)	<.001	0.79	(0.71, 0.89)	<.001	1.33	(1.14, 1.55)	<.001	1.05	(0.85, 1.31)	.653
Urbanicity (urban)	0.97	(0.83, 1.13)	.672	1.01	(0.92, 1.10)	.875	1.05	(0.93, 1.18)	.426	1.02	(0.87, 1.20)	.776
Constant	0.85	(0.67, 1.08)	.193	0.73	(0.62, 0.86)	<.001	0.21	(0.17, 0.27)	<.001	0.08	(0.06, 0.12)	<.001
N	8059			8059			3628			7938		
Wald's χ^2	684***			333***			286***			113***		
Pearson goodness of fit χ^2	6553			4415			1481			6862		
Pseudo R^2	.09			.03			.04			.02		

Note. [a] Weekly alcohol limits of >28 units for men and >21 units for women; *** = p <.001

Table 2b: Sensitivity analysis: the association between greenspace and health risk behaviours, specifying greenspace in quintiles.

	Model 1 Current Smoking			Model 2 Ever Smoker			Model 3 Smoking Cessation			Model 4 Exceeds Alcohol Limits[a]		
	PR	**(95% CIs)**	***p***	**PR**	**95% CIs**	***p***	**PR**	**95% CIs**	***p***	***PR***	**95% CIs**	***p***
Neighbourhood greenspace (%)												
1st quintile (*M* = 5.24, N = 2114)												
2nd quintile (*M* =20.00, N =1057)	0.92	(0.80, 1.06)	.238	0.93	(0.84, 1.02)	.104	1.03	(0.91, 1.17)	.671	1.11	(0.93, 1.33)	.252
3rd quintile (*M* = 38.74, N = 2107)	0.90	(0.77, 1.05)	.188	0.99	(0.90, 1.10)	.883	1.10	(0.96, 1.26)	.158	1.13	(0.92, 1.38)	.243
4th quintile (*M* = 70.28, N = 1722)	0.90	(0.76, 1.06)	.189	0.99	(0.89, 1.10)	.848	1.10	(0.96, 1.25)	.184	1.13	(0.99 1.29)	.070
5^{th} quintile (*M* = 90.00, N = 1059)	0.88	(0.79, 0.99)	.034	0.99	(0.85, 1.15)	.886	1.12	(1.01, 1.25)	.031	1.03	(0.79, 1.35)	.807
Gender (female)	0.82	(0.74, 0.90)	<.001	0.78	(0.73, 0.83)	<.001	1.03	(0.94, 1.12)	.496	0.75	(0.66, 0.84)	<.001
Age												
16-34 (ref)												
35-64	0.85	(0.76, 0.96)	.008	1.11	(1.02, 1.22)	.018	1.41	(1.23, 1.62)	<.001	1.22	(1.03, 1.43)	.021
65+	0.29	(0.24, 0.35)	<.001	1.04	(0.94, 1.16)	.425	2.23	(1.92, 2.60)	<.001	0.98	(0.80, 1.21)	.861
Education												
No formal education (ref)												
Secondary	0.88	(0.77, 1.01)	.072	0.96	(0.88, 1.06)	.432	1.00	(0.88, 1.13)	.962	1.27	(1.03, 1.56)	.022
Tertiary	0.68	(0.57, 0.80)	<.001	0.86	(0.76, 0.96)	.009	1.09	(0.94, 1.27)	.264	1.70	(1.36, 2.12)	<.001
Higher	0.54	(0.46, 0.64)	<.001	0.73	(0.66, 0.81)	<.001	1.13	(0.99, 1.29)	.070	1.28	(1.04, 1.59)	.021
Socio-economic group												
Routine & manual (ref)												
Intermediate	0.81	(0.71, 0.92)	.001	0.89	(0.82, 0.97)	.010	1.10	(0.98, 1.23)	.101	1.08	(0.92, 1.28)	.341
Managerial & professional	0.66	(0.56, 0.77)	<.001	0.87	(0.79, 0.95)	.003	1.17	(1.04, 1.32)	.009	1.03	(0.87, 1.23)	.718
Other	0.35	(0.26, 0.48)	<.001	0.35	(0.27, 0.46)	<.001	0.66	(0.40, 1.11)	.119	0.67	(0.43, 1.03)	.066
Equivalised household income												
≤ £27, 624 (ref)												
> £27, 624	0.75	(0.65, 0.85)	<.001	0.85	(0.78, 0.92)	<.001	1.12	(1.01, 1.25)	.031	1.27	(1.09, 1.48)	.002
Undisclosed	0.93	(0.81, 1.06)	.264	0.90	(0.83, 0.99)	.023	0.99	(0.88, 1.11)	.874	1.12	(0.94, 1.33)	.219

Table 2b continued.

Marital Status (Married/Cohabiting)	0.73	(0.66, 0.81)	<.001	0.98	(0.91, 1.05)	.535	1.26	(1.14, 1.38)	<.001	0.99	(0.87, 1.14)	.903
Index of multiple deprivation (IMD)												
1st Quintile (most disadvantaged, ref)												
2nd Quintile	0.88	(0.77, 1.02)	.082	0.95	(0.86, 1.06)	.372	1.14	(0.98, 1.32)	.095	1.01	(0.81, 1.25)	.959
3rd Quintile	0.71	(0.60, 0.83)	<.001	0.88	(0.79, 0.98)	.017	1.27	(1.09, 1.47)	.002	0.91	(0.73, 1.14)	.429
4th Quintile	0.76	(0.65, 0.90)	.001	0.84	(0.75, 0.94)	.002	1.16	(0.99, 1.36)	.069	1.11	(0.89, 1.38)	.338
5th Quintile (least disadvantaged)	0.50	(0.41, 0.61)	<.001	0.80	(0.71, 0.89)	<.001	1.33	(1.14, 1.56)	<.001	1.02	(0.82, 1.28)	.839
Urbanicity (urban)	0.95	(0.79, 1.14)	.580	1.01	(0.90, 1.12)	.927	1.05	(0.91, 1.20)	.500	0.96	(0.80, 1.16)	.688
Constant	0.90	(0.70, 1.17)	.443	0.76	(0.64, 0.91)	.002	0.21	(0.16, 0.27)	<.001	0.09	(0.06, 0.12)	<.001
N	8059			8059			3628			7,938		
Wald's χ^2	685***			336***			286***			121*		
Pearson goodness of fit χ^2	6558			4416			1481			6862		
Pseudo R^2	.09			.03			.04			.02		

Note. [a] Weekly alcohol limits of >28 units for men and >21 units for women; *** $p < .001$; * $p < .05$

Appendix 3. Study 1: unadjusted and partially-adjusted Poisson regression models

Unadjusted models (neighbourhood greenspace only) are presented in Table 3a and partially adjusted models (all area-level predictors) are presented in Table 3b.

Table 3a: unadjusted modified Poisson regression models estimating adjusted prevalence ratio of health (risk) behaviours by neighbourhood greenspace quartile.

	Model 1 Current Smoking			Model 2 Ever Smoker			Model 3 Smoking Cessation			Model 4 Exceeds Alcohol Limits[a]		
	PR	**(95% CIs)**	***p***	**PR**	**95% CIs**	***p***	**PR**	**95% CIs**	***p***	***PR***	**95% CIs**	***p***
Neighbourhood greenspace												
1st quartile (M= 5.23)												
2nd quartile (M= 24.46)	0.92	(0.82, 1.04)	.192	0.95	(0.89,1.02)	.137	1.02	(0.94, 1.12)	.574	1.10	(0.92, 1.32)	.285
3rd quartile (M= 54.18)	0.87	(0.77, 0.97)	.015	1.01	(0.95, 1.07)	.776	1.13	(1.04, 1.21)	.002	1.26	(1.07, 1.49)	.006
4th quartile (M= 86.35)	0.63	(0.55, 0.73)	<.001	0.91	(0.85, 0.98)	.011	1.27	(1.17, 1.37)	<.001	1.29	(1.07, 1.54)	.006
Constant	0.22	(0.20, 0.24)	<.001	0.46	(0.44, 0.48)	<.001	0.53	(0.50, 0.56)	<.001	0.11	(0.10, 0.13)	<.001
N	8059			8059			3628			7938		
Wald's χ^2	39.18***			10.49*			43.89***			10.92*		
Pearson goodness of fit χ^2	6546			4431			1513			6890		
Pseudo R^2	.004			.005			.003			.001		

Note. [a] Weekly alcohol limits of >28 units for men and >21 units for women. *** *p* <.001; * *p* <.05

Table 3b: partially-adjusted modified Poisson regression models estimating adjusted prevalence ratio of health (risk) behaviours by neighbourhood greenspace, controlling for area-level deprivation and urban/rural status.

	Model 1 Current Smoking			**Model 2 Ever Smoker**			**Model 3 Smoking Cessation**			**Model 4 Exceeds Alcohol Limits[a]**		
	PR	**(95% CIs)**	***p***	**PR**	**95% CIs**	***p***	**PR**	**95% CIs**	***p***	***PR***	**95% CIs**	***p***
Neighbourhood greenspace												
1st quartile (M= 5.23)												
2nd quartile (M= 24.46)	0.96	(0.85, 1.08)	.470	0.96	(0.90, 1.03)	.414	1.02	(0.94, 1.11)	.596	1.10	(0.92, 1.31)	.318
3rd quartile (M= 54.18)	0.96	(0.85, 1.08)	.453	1.05	(0.98, 1.12)	.313	1.09	(1.01, 1.17)	.029	1.24	(1.04, 1.46)	.015
4th quartile (M= 86.35)	0.81	(0.67, 0.98)	.033	1.00	(0.91, 1.10)	.964	1.15	(1.04, 1.26)	.006	1.22	(0.97, 1.53)	.097
IMD												
1st Quintile (ref)												
2nd Quintile	0.76	(0.67, 0.85)	<.001	0.92	(0.86, 1.00)	.131	1.26	(1.13, 1.41)	<.001	1.07	(0.86, 1.33)	.535
3rd Quintile	0.54	(0.47, 0.62)	<.001	0.82	(0.76, 0.89)	<.001	1.48	(1.34, 1.64)	<.001	1.03	(0.83, 1.28)	.792
4th Quintile	0.53	(0.46, 0.61)	<.001	0.76	(0.70, 0.82)	<.001	1.44	(1.29, 1.60)	<.001	1.28	(1.04, 1.57)	.022
5th Quintile	0.31	(0.26, 0.37)	<.001	0.69	(0.64, 0.75)	<.001	1.76	(1.59, 1.94)	<.001	1.23	(1.00, 1.51)	.047
Urbanicity (urban)	0.93	(0.79, 1.10)	.396	0.98	(0.90, 1.06)	.731	1.04	(0.96, 1.12)	.385	1.01	(0.84, 1.22)	.909
Constant	0.35	(0.29, 0.42)	<.001	0.55	(0.49, 0.61)	<.001	0.39	(0.34, 0.44)	<.001	0.10	(0.08, 0.13)	<.001
N	8059			8059			3628			7938		
Wald's χ^2	276.46***			116.26***			192.86***			20.43*		
Pearson goodness of fit χ^2	6541.30			4431.01			1512.38			6893		
Pseudo R^2	.03			.005			.012			.003		

Note. [a] Weekly alcohol limits of >28 units for men and >21 units for women. *** *p* <.001; * *p* <.05

Appendix 4. Study 1: robustness check – moderation by socio-economic status

Additional models were conducted testing for potential moderation effects between neighbourhood greenspace and socio-economic variables (i.e. education, socio-economic group [SEG], income, neighbourhood deprivation). These models are presented in Tables 4a-4d below. Overall, there was no evidence of moderation effects by area or individual-level characteristics, in the 3rd and 4th quartiles of neighbourhood greenspace, where the differences in smoking behaviours as a function of neighbourhood greenspace were observed.

Table 4a. Fully adjusted modified Poisson regression models estimating prevalence ratio of smoking outcomes for neighbourhood greenspace, education and their interaction terms, controlling for other individual and area-level covariates

	Current Smoking			Smoking Cessation		
	PR	***(95% CIs)***	***p***	***PR***	***95% CIs***	***p***
Neighbourhood greenspace (%)						
1st quartile (M= 5.23, lowest)						
2nd quartile (M= 24.46)	0.83	(0.68, 1.02)	.073	0.00	(0.97, 1.27)	.138
3rd quartile (M= 54.18)	0.83	(0.69, 1.01)	.058	1.12	(0.99, 1.27)	.069
4th quartile (M= 86.35, highest)	0.69	(0.51, 0.93)	.014	1.22	(1.06, 1.41)	.007
Education						
No formal education (ref)						
Secondary	0.83	(0.69, 1.00)	.051	0.98	(0.84, 1.15)	.816
Tertiary	0.58	(0.45, 0.74)	<.001	1.22	(1.01, 1.47)	.040
Higher	0.48	(0.39, 0.61)	<.001	1.24	(1.08, 1.42)	.002
Greenspace x Education						
Q1 x No formal education (ref)						
Q2 x Secondary	1.11	(0.84, 1.47)	.471	0.95	(0.76, 1.19)	.672
Q2 x Tertiary	1.15	(0.80, 1.65)	.449	0.87	(0.66, 1.13)	.284
Q2 x Higher	1.21	(0.87, 1.69)	.246	0.88	(0.72, 1.06)	.175
Q3 x Secondary	1.11	(0.85, 1.44)	.459	1.08	(0.88, 1.31)	.472
Q3 x Tertiary	1.20	(0.84, 1.70)	.312	0.90	(0.71, 1.15)	.402
Q3 x Higher	1.16	(0.85, 1.59)	.351	0.92	(0.78, 1.09)	.346
Q4 x Secondary	1.09	(0.76, 1.58)	.636	1.00	(0.81, 1.23)	.990
Q4 x Tertiary	1.16	(0.89, 1.52)	.281	0.82	(0.63, 1.06)	.125
Q4 x Higher	1.16	(0.77, 1.76)	.467	0.85	(0.71, 1.00)	.057
Gender (female)	0.81	(0.75, 0.89)	<.001	1.03	(0.98, 1.09)	.221

Table 4a continued

Age						
16-34 (ref)						
35-64	0.85	(0.77, 0.94)	.002	1.42	(1.28, 1.57)	<.001
65+	0.29	(0.24, 0.34)	<.001	2.24	(2.02, 2.49)	<.001
Socio-economic group (SEG)						
Routine & manual (ref)						
Intermediate	0.81	(0.72, 0.90)	<.001	1.10	(1.03, 1.18)	.007
Managerial & Professional	0.66	(0.57, 0.76)	<.001	1.17	(1.09, 1.25)	<.001
Other	0.35	(0.27, 0.46)	<.001	0.67	(0.45, 0.99)	.043
Equivalised household income						
≤ £27, 624 (ref)						
> £27, 624	0.75	(0.66, 0.84)	<.001	1.13	(1.06, 1.20)	<.001
Undisclosed	0.93	(0.83, 1.03)	.176	0.99	(0.93, 1.07)	.871
Marital Status (Married/Cohabiting)	0.73	(0.67, 0.80)	<.001	1.26	(1.19, 1.34)	<.001
Index of multiple deprivation (IMD)						
1st Quintile (most disadvantaged, ref)						
2nd Quintile	0.88	(0.78, 0.99)	.032	1.13	(1.02, 1.26)	.016
3rd Quintile	0.71	(0.62, 0.82)	<.001	1.26	(1.14, 1.39)	<.001
4th Quintile	0.77	(0.67, 0.89)	<.001	1.15	(1.04, 1.28)	.007
5th Quintile (least disadvantaged)	0.50	(0.42, 0.60)	<.001	1.33	(1.20, 1.47)	<.001
Urbanicity (urban)	0.90	(0.78, 1.05)	.189	1.06	(0.98, 1.14)	.126
Constant	1.02	(0.81, 1.28)	.892	0.20	(0.17, 0.24)	<.001
N	8059			3628		
Wald's χ^2	877.14***			747.29***		
Pearson goodness of fit χ^2	6551.31			1478.73		
Pseudo R^2	.09			.04		

Note: *** = p <.001

Table 4b. Fully adjusted modified Poisson regression models estimating prevalence ratio of smoking outcomes for neighbourhood greenspace, socio-economic group and their interaction terms, controlling for other individual and area-level covariates

	Current Smoking			**Smoking Cessation**		
	PR	***(95% CIs)***	***p***	***PR***	***95% CIs***	***p***
Neighbourhood greenspace (%)						
1st quartile (M= 5.23, lowest)						
2nd quartile (M= 24.46)	0.84	(0.72, 0.98)	.024	1.16	(1.02, 1.32)	.021
3rd quartile (M= 54.18)	0.96	(0.83, 1.10)	.527	1.13	(1.00, 1.28)	.048
4th quartile (M= 86.35, highest)	0.81	(0.65, 1.01)	.065	1.18	(1.02, 1.37)	.027
Socio-economic group (SEG)						
Routine & manual (ref)	0.84	(0.69, 1.02)	.079	1.16	(1.01, 1.34)	.040
Intermediate	0.63	(0.50, 0.79)	<.001	1.32	(1.16, 1.50)	<.001
Managerial & professional	0.29	(0.19, 0.47)	<.001	0.21	(0.03, 1.40)	.107
Other						
Greenspace x SEG						
Q1 x Routine/Manual (ref)						
Q2 x Intermediate	1.08	(0.81, 1.43)	.614	0.86	(0.70, 1.05)	.137
Q2 x Mang. & professional	1.39	(1.01, 1.89)	.041	0.76	(0.63, 0.91)	.003
Q2 x Other	1.24	(0.61, 2.53)	.555	2.31	(0.23, 22.79)	.473
Q3 x Intermediate	0.86	(0.65, 1.14)	.304	0.96	(0.79, 1.15)	.634
Q3 x Mang. & professional	0.87	(0.63, 1.20)	.407	0.93	(0.79, 1.09)	.352
Q3 x Other	1.25	(0.62, 2.54)	.539	4.29	(0.58, 31.49)	.152
Q4 x Intermediate	0.91	(0.65, 1.27)	.575	0.96	(0.80, 1.17)	.708
Q4 x Mang. & professional	0.98	(0.67, 1.42)	.899	0.86	(0.73, 1.02)	.093
Q4 x Other	1.88	(0.85, 4.17)	.118	4.27	(0.58, 31.18)	.153
Gender (female)	0.81	(0.75, 0.89)	<.001	1.03	(0.98, 1.09)	.250
Age						
16-34 (ref)						

Table 4b continued

35-64	0.86	(0.77, 0.95)	.002	1.40	(1.26, 1.55)	<.001
65+	0.29	(0.24, 0.34)	<.001	2.21	(1.99, 2.45)	<.001
Education						
No formal education (ref)						
Secondary	0.88	(0.79, 0.99)	.028	0.99	(0.92, 1.07)	.885
Tertiary	0.68	(0.59, 0.79)	<.001	1.09	(0.99, 1.20)	.085
Higher	0.54	(0.47, 0.63)	<.001	1.13	(1.04, 1.21)	.002
Equivalised household income						
≤ £27, 624 (ref)						
> £27, 624	0.75	(0.66, 0.84)	<.001	1.12	(1.05, 1.19)	<.001
Undisclosed	0.92	(0.83, 1.03)	.166	0.99	(0.92, 1.06)	.777
Marital Status (Married/Cohabiting)	0.74	(0.67, 0.80)	<.001	1.26	(1.18, 1.34)	<.001
Index of multiple deprivation (IMD)						
1st Quintile (most disadvantaged, ref)						
2nd Quintile	0.87	(0.78, 0.98)	.024	1.14	(1.02, 1.26)	.015
3rd Quintile	0.71	(0.62, 0.81)	<.001	1.26	(1.14, 1.40)	<.001
4th Quintile	0.76	(0.66, 0.88)	<.001	1.15	(1.04, 1.28)	.007
5th Quintile (least disadvantaged)	0.50	(0.42, 0.59)	<.001	1.33	(1.20, 1.47)	<.001
Urbanicity (urban)	0.90	(0.77, 1.05)	.176	1.06	(0.98, 1.14)	.124
Constant	0.95	(0.77, 1.18)	.665	0.20	(0.17, 0.24)	<.001
N	8059			3628		
Wald's χ^2	875.77***			740.70***		
Pearson goodness of fit χ^2	6536.02			1484.56		
Pseudo R^2	.09			.05		

*Note: *** = p <.001*

Table 4c: Fully adjusted modified Poisson regression models estimating prevalence ratio of smoking outcomes for neighbourhood greenspace, equalised household income and their interaction terms, controlling for other individual and area-level covariates

	Current Smoking			**Smoking Cessation**		
	PR	***95% CIs***	***p***	***PR***	***95% CIs***	***p***
Neighbourhood greenspace (%)						
1st quartile (M= 5.23, lowest)						
2nd quartile (M= 24.46)	0.95	(0.82, 1.10)	.471	1.02	(0.91, 1.15)	.695
3rd quartile (M= 54.18)	0.84	(0.73, 0.98)	.025	1.17	(1.06, 1.30)	.003
4th quartile (M= 86.35, highest)	0.88	(0.71, 1.09)	.256	1.09	(0.96, 1.24)	.201
Equivalised household income						
≤ £27, 624 (ref)						
> £27, 624	0.79	(0.64, 0.97)	.023	1.16	(1.03, 1.31)	.017
Undisclosed	0.86	(0.71, 1.05)	.140	1.01	(0.88, 1.17)	.852
Greenspace x Income						
Q1 x ≤ £27, 624 (ref)						
Q2 x >£27, 624	0.89	(0.65, 1.20)	.442	1.01	(0.85, 1.20)	.919
Q2 x Undisclosed	0.98	(0.73, 1.31)	.899	1.02	(0.82, 1.26)	.879
Q3 x >£27, 624	1.07	(0.81, 1.41)	.650	0.88	(0.76, 1.03)	.112
Q3 x Undisclosed	1.25	(0.62, 2.54)	.539	0.87	(0.72, 1.05)	.142
Q4 x>£27, 624	0.77	(0.55, 1.07)	.117	1.02	(0.87, 1.20)	.812
Q4 x Undisclosed	0.89	(0.61, 1.30)	.549	1.09	(0.90, 1.33)	.371
Gender (female)	0.81	(0.75, 0.89)	<.001	1.03	(0.98, 1.08)	.278
Age						
16-34 (ref)						
35-64	0.86	(0.78, 0.95)	.003	1.41	(1.27, 1.57)	<.001
65+	0.29	(0.24, 0.34)	<.001	2.22	(2.00, 2.47)	<.001

Table 4c continued

Education						
No formal education (ref)						
Secondary	0.88	(0.79, 0.99)	.032	0.99	(0.92, 1.07)	.853
Tertiary	0.68	(0.59, 0.79)	<.001	1.09	(0.99, 1.20)	.085
Higher	0.54	(0.47, 0.63)	<.001	1.13	(1.04, 1.21)	.002
Socio-economic group (SEG)						
Routine & manual (ref)						
Intermediate	0.81	(0.72, 0.90)	<.001	1.10	(1.03, 1.18)	.007
Managerial & professional	0.66	(0.57, 0.76)	<.001	1.17	(1.09, 1.26)	<.001
Other	0.36	(0.27, 0.47)	<.001	0.66	(0.45, 0.98)	.039
Marital Status (Married/Cohabiting)	0.73	(0.67, 0.80)	<.001	1.25	(1.18, 1.33)	<.001
Index of multiple deprivation (IMD)						
1st Quintile (most disadvantaged, ref)						
2nd Quintile	0.87	(0.78, 0.98)	.022	1.14	(1.03, 1.26)	.014
3rd Quintile	0.70	(0.61, 0.80)	<.001	1.27	(1.15, 1.40)	<.001
4th Quintile	0.76	(0.66, 0.88)	<.001	1.16	(1.04, 1.28)	.006
5th Quintile (least disadvantaged)	0.50	(0.42, 0.60)	<.001	1.33	(1.21, 1.47)	<.001
Urbanicity (urban)	0.90	(0.78, 1.05)	.192	1.06	(0.98, 1.14)	.134
Constant	0.95	(0.76, 1.18)	.616	0.21	(0.17, 0.24)	<.001
N	8059			3628		
Wald's χ^2	866.46***			745.13***		
Pearson goodness of fit χ^2	6550.21			1480.18		
Pseudo R^2	.09			.04		

Note: *** $p < .001$

Table 4d: Fully adjusted modified Poisson regression models estimating prevalence ratio of smoking outcomes for neighbourhood greenspace, neighbourhood deprivation and their interaction terms, controlling for other individual and area-level covariates

	Current Smoking			**Smoking Cessation**		
	PR	***95% CIs***	***p***	***PR***	***95% CIs***	***p***
Neighbourhood greenspace (%)						
1st quartile (M= 5.23, lowest)						
2nd quartile (M= 24.46)	1.06	(0.89, 1.27)	.503	1.02	(0.82, 1.26)	.880
3rd quartile (M= 54.18)	0.92	(0.76, 1.11)	.379	1.24	(1.02, 1.50)	.030
4th quartile (M= 86.35, highest)	0.71	(0.36, 1.42)	.336	1.36	(0.81, 2.30)	.246
Index of multiple deprivation (IMD)						
1st Quintile (most disadvantaged, ref)						
2nd Quintile	0.94	(0.77, 1.14)	.510	1.16	(0.96, 1.40)	
3rd Quintile	0.87	(0.70, 1.09)	.227	1.32	(1.10, 1.59)	.129
4th Quintile	0.75	(0.58, 0.97)	.031	1.26	(1.05, 1.53)	.003
5th Quintile (least disadvantaged)	0.50	(0.35, 0.70)	<.001	1.44	(1.19, 1.74)	.015
						<.001
Interaction terms						
Greenspace (quartile) x IMD (quintile)						
Q1 x Q1 (ref)						
Q2 x Q2	0.72	(0.53, 0.96)	.028	1.16	(0.89, 1.52)	.281
Q2 x Q3	0.59	(0.41, 0.84)	.003	1.10	(0.85, 1.43)	.464
Q2 x Q4	1.06	(0.73, 1.53)	.773	0.86	(0.64, 1.15)	.306
Q2 x Q5	1.13	(0.72, 1.79)	.589	0.92	(0.70, 1.19)	.514
Q3 x Q2	1.09	(0.82, 1.44)	.555	0.85	(0.66, 1.09)	.202
Q3 x Q3	0.77	(0.55, 1.08)	.125	0.87	(0.68, 1.11)	.267
Q3 x Q4	1.08	(0.76, 1.54)	.658	0.86	(0.67, 1.10)	.220
Q3 x Q5	1.07	(0.69, 1.67)	.761	0.85	(0.67, 1.07)	.170
Q4 x Q2	1.17	(0.55, 2.49)	.684	0.86	(0.49, 1.52)	.613
Q4 x Q3	1.10	(0.53, 2.30)	.795	0.77	(0.45, 1.34)	.358
Q4 x Q4	1.19	(0.56, 2.50)	.651	0.78	(0.45, 1.35)	.382
Q4 x Q5	1.02	(0.45, 2.30)	.971	0.80	(0.47, 1.38)	.429

Table 4d continued

Gender (female)	0.81	(0.75, 0.89)	<.001	1.03	(0.98, 1.09)	.241
Age						
16-34 (ref)						
35-64	0.85	(0.77, 0.94)	.002	1.41	(1.27, 1.56)	<.001
65+	0.29	(0.24, 0.34)	<.001	2.23	(2.01, 2.47)	<.001
Education						
No formal education (ref)						
Secondary	0.89	(0.79, 0.99)	.035	0.99	(0.92, 1.07)	.859
Tertiary	0.68	(0.59, 0.79)	<.001	1.09	(0.99, 1.20)	.079
Higher	0.54	(0.47, 0.63)	<.001	1.13	(1.05, 1.22)	.002
Socio-economic group (SEG)						
Routine & manual (ref)						
Intermediate	0.81	(0.72, 0.90)	<.001	1.10	(1.03, 1.18)	.007
Managerial & professional	0.66	(0.57, 0.76)	<.001	1.17	(1.09, 1.26)	<.001
Other	0.35	(0.27, 0.47)	<.001	0.66	(0.45, 0.98)	.041
Equivalised household income						
≤ £27, 624 (ref)						
> £27, 624	0.75	(0.66, 0.84)	<.001	1.12	(1.06, 1.20)	<.001
Undisclosed	0.93	(0.83, 1.03)	.169	0.99	(0.93, 1.07)	.858
Marital Status (Married/Cohabiting)	0.73	(0.66, 0.79)	<.001	1.27	(1.19, 1.34)	<.001
Urbanicity (urban)	0.91	(0.78, 1.06)	.242	1.05	(0.98, 1.14)	.172
Constant	0.90	(0.71, 1.12)	.339	0.20	(0.16, 0.24)	<.001
N	8059			3628		
Wald's χ^2	891.51***			755.51***		
Pearson goodness of fit χ^2	6546.82			1479.87		
Pseudo R^2	.09			.05		

Note: *** = p <.001

Appendix 5. Study 1: robustness check - co-occurrence between health (risk) behaviours

Prior research indicates that health risk behaviours cluster together or co-occur, with individuals who smoke also being more likely to engage in potentially harmful alcohol consumption. To account for this, Table 5 reports additional Poisson regression models, controlling for other domains of health risk behaviours (i.e. smoking, exceeding alcohol recommendations, lack of sufficient physical activity), as well as individual and area-level covariates. As expected, exceeding alcohol limits was a statistically significant positive predictor of smoking behaviours, and being a current smoker was associated with a statistically significantly higher prevalence of exceeding alcohol limits. Engaging in less than 30 minutes of physical activity at least 5 times a week was, however, unrelated to either behavioural outcome. Inclusion of these additional covariates led to slight reductions in the size of the associations between greenspace and health risk behaviours, compared to those observed in the main models. Nevertheless, statistically significant associations observed in the main models (i.e. for current smoking and smoking cessation), remained statistically significant in the adjusted models. This suggests that associations between greenspace, current smoking and smoking cessation, are unlikely to be due to shared variance between different domains of health risk behaviours.

Table 5: Modified Poisson regression models estimating adjusted prevalence ratio of smoking outcomes for neighbourhood greenspace, controlling for individual and area level covariates, plus related-outcome controls.

	Model 1 Current Smoking			**Model 2 Ever Smoker**			**Model 3 Smoking Cessation**			**Model 4 Exceeds Alcohol Limits[a]**		
	PR	**(95% CIs)**	***p***	**PR**	**95% CIs**	***p***	**PR**	**95% CIs**	***p***	***PR***	**95% CIs**	***p***
Neighbourhood greenspace (%)												
1st quartile (M= 5.23, lowest)												
2nd quartile (M= 24.46)	0.93	(0.81, 1.07)	.320	0.93	(0.85, 1.02)	.137	1.02	(0.90, 1.16)	.744	1.12	(0.93, 1.34)	.235
3rd quartile (M= 54.18)	0.90	(0.79, 1.04)	.146	0.99	(0.91, 1.08)	.836	1.10	(1.00, 1.20)	.049	1.12	(0.95, 1.33)	.162
4th quartile (M= 86.35, highest)	0.86	(0.75, 0.99)	.037	0.97	(0.85, 1.10)	.631	1.13	(1.02, 1.26)	.025	1.20	(0.95, 1.51)	.128
Gender (female)	0.84	(0.75, 0.93)	.001	0.79	(0.74, 0.84)	<.001	1.03	(0.94, 1.12)	.560	0.78	(0.69, 0.89)	<.001
Age												
16-34 (ref)												
35-64	0.84	(0.74, 0.95)	.006	1.10	(1.00, 1.20)	.049	1.38	(1.20, 1.59)	<.001	1.26	(1.07, 1.49)	.006
65+	0.30	(0.25, 0.36)	<.001	1.04	(0.93, 1.16)	.502	2.15	(1.84, 2.51)	<.001	1.17	(0.95, 1.45)	.146
Education												
No formal education (ref)												
Secondary	0.86	(0.75, 0.99)	.037	0.95	(0.86, 1.04)	.286	1.01	(0.89, 1.15)	.856	1.27	(1.04, 1.56)	.022
Tertiary	0.66	(0.55, 0.78)	<.001	0.84	(0.75, 0.95)	.004	1.10	(0.94, 1.29)	.217	1.77	(1.42, 2.21)	<.001
Higher	0.54	(0.45, 0.64)	<.001	0.73	(0.65, 0.81)	<.001	1.13	(0.99, 1.29)	.068	1.37	(1.11, 1.70)	.004
Socio-economic group												
Routine & manual (ref)												
Intermediate	0.81	(0.71, 0.93)	.002	0.89	(0.82, 0.97)	.010	1.09	(0.98, 1.23)	.120	1.12	(0.95, 1.33)	.162
Managerial & professional	0.66	(0.56, 0.77)	<.001	0.86	(0.78, 0.95)	.003	1.17	(1.04, 1.33)	.009	1.10	(0.93, 1.31)	.278
Other	0.34	(0.24, 0.48)	<.001	0.34	(0.26, 0.45)	<.001	0.74	(0.44, 1.23)	.248	0.76	(0.49, 1.18)	.227

Table 5 continued

Equivalised household income												
≤ £27, 624 (ref)												
> £27, 624	0.74	(0.64, 0.85)	<.001	0.85	(0.78, 0.92)	<.001	1.13	(1.02, 1.26)	.025	1.31	(1.13, 1.53)	<.001
Undisclosed	0.94	(0.82, 1.07)	.351	0.90	(0.83, 0.99)	.027	0.99	(0.88, 1.11)	.815	1.13	(0.95, 1.34)	.181
Marital Status (Married/Cohabiting)	0.75	(0.67, 0.83)	<.001	0.98	(0.91, 1.05)	.492	1.24	(1.13, 1.37)	<.001	1.05	(0.91, 1.20)	.510
Index of multiple deprivation (IMD)												
1st Quintile (most disadvantaged, ref)												
2nd Quintile	0.90	(0.78, 1.04)	.151	0.97	(0.88, 1.08)	.582	1.13	(0.97, 1.32)	.103	1.03	(0.83, 1.28)	.770
3rd Quintile	0.74	(0.63, 0.87)	<.001	0.89	(0.80, 1.00)	.044	1.25	(1.08, 1.46)	.004	0.98	(0.79, 1.23)	.894
4th Quintile	0.77	(0.65, 0.91)	.003	0.85	(0.76, 0.95)	.005	1.15	(0.98, 1.35)	.079	1.18	(0.95, 1.47)	.133
5th Quintile (least disadvantaged)	0.52	(0.43, 0.63)	<.001	0.81	(0.72, 0.91)	<.001	1.32	(1.13, 1.55)	<.001	1.15	(0.92, 1.43)	.222
Urbanicity (urban)	0.92	(0.76, 1.10)	.353	0.99	(0.89, 1.10)	.838	1.05	(0.92, 1.20)	.487	1.00	(0.83, 1.21)	.983
Current smoker (yes)										1.95	(1.69, 2.25)	<.001
Exceeds alcohol limits (yes)	1.68	(1.48, 1.91)	<.001	1.41	(1.29, 1.54)	<.001	0.86	(0.76, 0.97)	.012	-	-	-
Physical activity (≥30 mins, ≥5 days)	1.03	(0.92, 1.15)	.645	0.98	(0.91, 1.05)	.523	0.97	(0.88, 1.07)	.601	1.13	(0.99, 1.28)	.067
Constant	0.83	(0.63, 1.08)	.164	0.74	(0.62, 0.89)	.001	0.23	(0.17, 0.29)	<.001	0.05	(0.04, 0.07)	<.001
N	7871			7871			3553			7871		
Wald's χ^2	701***			377***			265***			194***		
Pearson goodness of fit χ^2	6336			4287			1432			6741		
Pseudo R^2	.09			.03			.04			.03		

Note. [a] Weekly alcohol limits of >28 units for men and >21 units for women. *** *p* <.001

Appendix 6. Study 1: additional analysis assessing the unadjusted influence of urbancity on health (risk) behaviours.

Prior work has found urban/rural status statistically significantly predicts health (risk) behaviours, but this predictor was non-significant in the fully adjusted models (Chapter 2, Table 2.2). Additional analyses (Table 6 below) that urbanicity was associated with a statistically significantly higher prevalence of current smoking, but unrelated to ever-smoking, smoking cessation or exceeding alcohol guidelines. As shown in Appendix 3 (Table 3b) the association between urbanicity and current smoking was reduced to non-significance once other area-level covariates were entered into the models.

Table 6: Unadjusted modified Poisson regression models estimating prevalence ratio of smoking outcomes for urbanicity.

	Current Smoking			**Ever Smoker**			**Smoking Cessation**			**Exceeds Alcohol Limits[a]**		
	PR	***95% CIs***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***	***PR***	***95% CIs***	***p***
Urbanicity (urban)	1.33	(1.18, 1.50)	<.001	1.06	(0.99, 1.12)	.061	1.03	(0.95, 1.11)	.525	0.89	(0.77, 1.03)	.116
Constant	0.15	(0.13, 0.17)	<.001	0.43	(0.41, 0.45)	<.001	1.10	(1.03, 1.19)	.008	0.14	(0.13, 0.16)	<.001
N	8059			8059			3628			7938		
Wald's χ^2	21.10***			3.51			22.01***			2.57		
Pearson goodness of fit χ^2	6546			4431			1513			6890		
Pseudo R^2	.002			.0002			.001			.0004		

Note: *** = p <.001

Appendix 7: Study 2: sensitivity analysis comparing the inclusion *vs.* exclusion of non- drinkers

A sensitivity analysis was carried out to ensure that excluding non-drinkers from our main models did not bias the results. Table 7 presents the fully adjusted multilevel mixed-effects Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for the associations between nature contact and exceeding recommended alcohol guidelines excluding non-drinkers. Compared to the main model including non-drinkers (Table 2.4, Chapter 2), there was little difference in the direction and strength of associations between nature contact and exceeding alcohol guidelines.

Table 7. Sensitivity analysis: comparison of the association between nature contact and exceeding recommended alcohol guidelines, including/excluding non-drinkers.

	Exceeds alcohol guidelines - excluding non-drinkers (N = 12,195)		
	PR	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI)			
1st Tertile (M = .31, ref)			
2nd Tertile (M = .52)	0.70	(0.60, 0.82)	<.001
3rd Tertile (M = .70, most green)	0.75	(0.62, 0.89)	.001
Nature Visits			
<once a week (ref)			
≥ once a week	1.12	(0.98, 1.27)	.093
Nature Connectedness (INS)	1.01	(0.97, 1.07)	.088
Gender (female)	0.51	(0.45, 0.59)	<.001
Age			
18-29 (ref)			
30-39	1.37	(1.03, 1.83)	.031
40=49	1.62	(1.23, 2.15)	.001
50-59	2.08	(1.58, 2.74)	<.001
60+	2.87	(2.17, 3.79)	<.001
Marital status			
Single/widowed/divorced (ref)			
Married/cohabiting	1.05	(0.91, 1.21)	.497
Undisclosed	1.17	(0.79, 1.73)	.426
Higher education (yes)	0.91	(0.80, 1.03)	.147

Table 7 continued			
Working status			
Unemployed (ref)			
Employed	0.87	(0.66, 1.15)	.317
In education	0.52	(0.31, 0.86)	.012
Retired	1.24	(0.92, 1.68)	.156
Other	0.81	(0.58, 1.12)	.195
Household income			
1st quintile (lowest, ref)			
2nd quintile	0.87	(0.68, 1.11)	.256
3rd quintile	1.12	(0.89, 1.42)	.323
4th quintile	1.10	(0.87, 1.39)	.420
5th quintile (highest)	1.23	(0.97, 1.56)	.089
Undisclosed	0.95	(0.73, 1.24)	.707
Dog owner (yes)	1.24	(1.09, 1.41)	.001
Disability (yes)	1.21	(1.07, 1.38)	.003
Urban (yes)	1.03	(0.99, 1.07)	.097
Intercept	0.04	(0.03, 0.07)	<.001
Random effects (country/region)	**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.02)	
Nature visits	0.03	(0.02, 0.08)	
Nature connectedness	0.01	(0.00, 0.02)	
Intercept	0.02	(0.01, 0.05)	
χ^2 (df)	430.06(24) ***		
Log likelihood	-3540.73		
Marginal R^2	.04		
Conditional R^2	.17		

Appendix 8. Study 2: sensitivity analyses comparing NDVI operationalisations

As outlined in section 2.3.2.2.2, a sensitivity analysis was on four different operationalisations of NDVI (high *vs*. low, tertiles, quartiles, continuous variable). Tables 8a-8c present fully-adjusted multilevel mixed-effects Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for the associations between nature contact and exceeding recommended alcohol guidelines with NDVI included as a binary variable (Table 8a), in quartiles (Table 8b) and as a continuous variable (Table 8c). Results for NDVI expressed in tertiles as reported in Table 2.2 within the main manuscript. The direction of associations between NDVI and health risk behaviours were consistent between models.

Table 8a: Sensitivity analysis: the association between nature contact and health risk behaviours, specifying NDVI as a binary variable (High vs. Low) using a median split.

	Current Smoking (N=14,359)			**Exceeding Recommended Alcohol Guidelines (N= 14, 317)**		
	PR	**95% CIs**	***p***	**PR**	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI)						
Low (<.52,N = 7332, ref)						
High *(>.52*, N =7027*)*	0.90	(0.83, 0.98)	.010	0.86	(0.74, 0.99)	.032
Nature Visits						
<once a week (ref)						
≥ once a week	0.91	(0.85, 0.98)	.010	1.05	(0.91, 1.18)	.491
Gender (female)	0.89	(0.84, 0.95)	.001	0.48	(0.42, 0.54)	<.001
Age						
18-29 (ref)						
30-39	1.23	(1.10, 1.39)	<.001	1.38	(1.03, 1.84)	.030
40=49	1.24	(1.10, 1.39)	<.001	1.60	(1.21, 2.12)	.001
50-59	1.24	(1.11, 1.39)	<.001	2.09	(1.59, 2.75)	<.001
60+	1.05	(0.92, 1.19)	.491	2.86	(2.16, 3.78)	<.001
Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	0.85	(0.79, 0.91)	<.001	1.08	(0.93, 1.24)	.310
Undisclosed	0.88	(0.74, 1.05)	.152	1.15	(0.78, 1.70)	.470
Higher education (yes)	0.77	(0.72, 0.82)	<.001	0.94	(0.83, 1.07)	.349
Working status						
Unemployed (ref)						
Employed	1.12	(0.98, 1.28)	.089	0.87	(0.66, 1.15)	.335

Table 8a continued

In education	0.65	(0.53, 0.80)	<.001	0.50	(0.30, 0.83)	.008
Retired	0.75	(0.64, 0.89)	.001	1.21	(0.89, 1.63)	.220
Other	1.12	(0.97, 1.30)	.128	0.76	(0.55, 1.05)	.095
Household income						
1st quintile (lowest, ref)						
2nd quintile	0.94	(0.84, 1.05)	.288	0.89	(0.70, 1.14)	.351
3rd quintile	0.88	(0.79, 0.99)	.031	1.21	(0.96, 1.53)	.104
4th quintile	0.82	(0.73, 0.92)	.001	1.18	(0.93, 1.49)	.167
5th quintile (highest)	0.80	(0.71, 0.90)	<.001	1.33	(1.05, 1.68)	.018
Undisclosed	0.72	(0.63, 0.82)	<.001	1.02	(0.78, 1.33)	.884
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.23	(1.08, 1.40)	.001
Disability (yes)	1.15	(1.08, 1.24)	<.001	1.17	(1.03, 1.32)	.017
Nature Connectedness (INS)	1.02	(1.00, 1.04)	.095	1.03	(0.99, 1.07)	.118
Urban (yes)	0.96	(0.89, 1.04)	.302	0.92	(0.80, 1.05)	.225
Intercept	0.27	(0.21, 0.34)	<.001	0.03	(0.02, 0.05)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.02)	
Nature visits	0.01	(0.00, 0.04)		0.03	(0.02, 0.08)	
Nature connectedness	0.00	(0.00, 0.02)		0.01	(0.00, 0.03)	
Intercept	0.09	(0.04, 0.18)		0.02	(0.01, 0.04)	
χ^2 (df)	445.46(23) ***			447.56(23) ***		
Log likelihood	-8781.58			-3706.03		
Marginal R^2	.04			.04		
Conditional R^2	.16			.17		

Notes: All models use survey weights. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** *p* <.001

Table 8b: Sensitivity analysis: the association between nature contact and health risk behaviours, specifying NDVI in quartiles.

	Current Smoking (N=14,359)			Exceeding Recommended Alcohol Guidelines (N= 14, 317)		
	PR	**95% CIs**	***p***	**PR**	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI)						
1st quartile (M = .28, N = 3594, ref)						
2nd quartile (M = .45, N = 3,593)	0.95	(0.86, 1.03)	.221	0.74	(0.63, 0.86)	<.001
3rd quartile (M = .58, N = 3,615)	0.89	(0.80, 0.98)	.018	0.72	(0.60, 0.86)	<.001
4th quartile (M = .73, N = 3, 553)	0.85	(0.76, 0.95)	.005	0.72	(0.59, 0.89)	.002
Nature Visits						
<once a week (ref)						
≥ once a week	0.91	(0.85, 0.98)	.010	1.03	(0.79, 1.34)	.182
Gender (female)	0.89	(0.84, 0.95)	.001	0.48	(0.42, 0.54)	<.001
Age						
18-29 (ref)						
30-39	1.24	(1.10, 1.39)	<.001	1.38	(1.04, 1.84)	.028
40-49	1.24	(1.10, 1.39)	<.001	1.61	(1.21, 2.13)	.001
50-59	1.24	(1.11, 1.40)	<.001	2.09	(1.59, 2.75)	<.001
60+	1.05	(0.92, 1.20)	.467	2.90	(2.19, 3.84)	<.001
Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	0.85	(0.79, 0.91)	<.001	1.08	(0.94, 1.25)	.280
Undisclosed	0.88	(0.74, 1.05)	.150	1.15	(0.78, 1.69)	.486
Higher education (yes)	0.77	(0.72, 0.82)	<.001	0.94	(0.83, 1.06)	.302

Table 8b continued						
Working status						
Unemployed (ref)						
Employed	1.12	(0.98, 1.28)	.097	0.87	(0.66, 1.14)	.318
In education	0.65	(0.53, 0.80)	<.001	0.50	(0.30, 0.84)	.008
Retired	0.75	(0.63, 0.89)	.001	1.20	(0.89, 1.63)	.224
Other	1.12	(0.97, 1.30)	.134	0.76	(0.55, 1.05)	.101
Household income						
1st quintile (lowest, ref)						
2nd quintile	0.94	(0.84, 1.05)	.291	0.90	(0.70, 1.14)	.378
3rd quintile	0.88	(0.79, 0.99)	.032	1.22	(0.97, 1.54)	.097
4th quintile	0.82	(0.73, 0.92)	.001	1.18	(0.93, 1.50)	.162
5th quintile (highest)	0.80	(0.71, 0.90)	<.001	1.33	(1.05, 1.69)	.018
Undisclosed	0.72	(0.63, 0.82)	<.001	1.03	(0.79, 1.34)	.812
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.23	(1.09, 1.40)	.001
Disability (yes)	1.15	(1.08, 1.24)	<.001	1.17	(1.03, 1.33)	.017
Nature Connectedness (INS)	1.02	(1.00, 1.04)	.090	1.03	(0.99, 1.07)	.108
Urban	0.95	(0.88, 1.03)	.192	0.90	(0.78, 1.03)	.136
Intercept	0.28	(0.22, 0.35)	<.001	0.04	(0.02, 0.06)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.02)	
Nature visits	0.01	(0.00, 0.04)		0.04	(0.02, 0.09)	
Nature connectedness	0.00	(0.00, 0.02)		0.01	(0.00, 0.02)	
Intercept	0.09	(0.04, 0.19)		0.02	(0.01, 0.04)	
χ^2 (df)	447.65(25) ***			461.51(25) ***		
Log likelihood	-8780.53			-3698.82		
Marginal R^2	.04			.04		
Conditional R^2	.16			.17		

Notes: All models use survey weights. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** p <.001

Table 8c: Sensitivity analysis: the association between nature contact and health risk behaviours, specifying NDVI as a continuous variable.

	Current Smoking (N=14,359)			**Exceeding Recommended Alcohol Guidelines (N= 14, 317)**		
	PR	**95% CIs**	***p***	**PR**	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI, M = .51)[a]	0.65	(0.51, 0.82)	<.001	0.40	(0.26, 0.61)	<.001
Nature Visits						
<once a week (ref)						
≥ once a week	0.91	(0.85, 0.98)	.011	1.16	(0.77, 1.71)	.462
Gender (female)	0.89	(0.84, 0.95)	.001	0.48	(0.42, 0.54)	<.001
Age						
18-29 (ref)						
30-39	1.24	(1.10, 1.39)	<.001	1.38	(1.04, 1.84)	.028
40=49	1.24	(1.10, 1.39)	<.001	1.61	(1.22, 2.14)	.001
50-59	1.24	(1.11, 1.40)	<.001	2.11	(1.60, 2.77)	<.001
60+	1.05	(0.92, 1.20)	.452	2.90	(2.20, 3.84)	<.001
Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	0.85	(0.79, 0.91)	<.001	1.08	(0.94, 1.25)	.275
Undisclosed	0.88	(0.74, 1.05)	.153	1.16	(0.78, 1.70)	.463
Higher education (yes)	0.77	(0.71, 0.82)	<.001	0.94	(0.83, 1.06)	.325
Working status						
Unemployed (ref)						
Employed	1.12	(0.98, 1.28)	.100	0.87	(0.66, 1.14)	.306
In education	0.65	(0.53, 0.80)	<.001	0.50	(0.30, 0.83)	.008

Retired	0.75	(0.63, 0.89)	.001	1.20	(0.89, 1.62)	.237

Table 8c continued

Other	1.12	(0.96, 1.30)	.138	0.76	(0.55, 1.04)	.090
Household income						
1st quintile (lowest, ref)						
2nd quintile	0.94	(0.85, 1.05)	.298	0.90	(0.70, 1.15)	.383
3rd quintile	0.88	(0.79, 0.99)	.031	1.21	(0.96, 1.53)	.102
4th quintile	0.82	(0.73, 0.92)	<.001	1.18	(0.94, 1.50)	.159
5th quintile (highest)	0.80	(0.71, 0.90)	<.001	1.34	(1.05, 1.69)	.016
Undisclosed	0.72	(0.63, 0.82)	<.001	1.03	(0.79, 1.34)	.830
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.23	(1.09, 1.40)	.001
Disability (yes)	1.16	(1.08, 1.24)	<.001	1.17	(1.03, 1.32)	.017
Nature Connectedness (INS)	1.02	(1.00, 1.04)	.086	1.03	(0.99, 1.07)	.107
Urban	0.94	(0.87, 1.02)	.118	0.87	(0.75, 1.00)	.045
Intercept	0.32	(0.24, 0.42)	<.001	0.05	(0.03, 0.08)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.02)	
Nature visits	0.01	(0.00, 0.04)		0.03	(0.02, 0.08)	
Nature connectedness	0.00	(0.00, 0.02)		0.01	(0.00, 0.02)	
Intercept	0.09	(0.04, 0.18)		0.02	(0.01, 0.04)	
χ^2 (df)	451.55(23) ***			460.58(23) ***		
Log likelihood	-8778.60			-3699.64		
Marginal R^2	.04			.04		
Conditional R^2	.16			.17		

Notes: All models use survey weights. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** *p* <.001; [a] not normally distributed, with skewness of -.18.03 and kurtosis of 2.20, p <.001

Appendix 9. Study 2: unadjusted models

Table 9a. unadjusted Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for the associations between nature contact and health risk behaviours.

	Current Smoking (N = 14,359)			**Exceeding Recommended Alcohol Guidelines** (N = 14, 317)		
	PR	**95% CIs**	***p***	**PR**	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI)						
1st Tertile (M = .31, ref)						
2nd Tertile (M = .52)	0.90	(0.83, 0.97)	.006	0.70	(0.60, 0.81)	<.001
3rd Tertile (M = .70)	0.81	(0.75, 0.87)	<.001	0.68	(0.59, 0.79)	<.001
Nature Visits						
<once a week (ref)						
≥ once a week	0.99	(0.92, 1.05)	.682	1.22	(1.08, 1.39)	.002
Intercept	0.26	(0.25, 0.28)	<.001	0.08	(0.07, 0.09)	<.001

Appendix 10: Study 2: robustness check – moderation by socio-economic status

Moderation models by education and income are presented in Tables 10a and 10b, respectively.

Table 10a. Multilevel mixed-effects Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for health risk behaviours as a function of neighbourhood greenspace, higher education and their interaction terms, whist controlling for covariates.

	Current Smoking (N=14,359)			**Exceeding Recommended Alcohol Guidelines (N= 14, 317)**		
	PR	**95% CIs**	***p***	**PR**	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI)						
1st Tertile (M = .31, least green, ref)						
2nd Tertile (M = .52)	0.94	(0.84, 1.05)	.285	0.62	(0.51, 0.76)	<.001
3rd Tertile (M = .70, most green)	0.91	(0.81, 1.03)	.127	0.64	(0.51, 0.80)	<.001
Higher education (yes)	0.79	(0.71, 0.88)	<.001	0.81	(0.68, 0.97)	.024
Greenspace X Education						
1st tertile x higher education (no), ref						
2nd tertile x higher education (yes)	1.00	(0.86, 1.17)	.989	1.24	(0.93, 1.65)	.140
3rd tertile x higher education (yes)	0.89	(0.75, 1.04)	.148	1.21	(0.96, 1.53)	.104
Nature Visits						
<once a week (ref)						
≥ once a week	0.91	(0.85, 0.98)	.010	1.15	(0.98, 1.28)	.099
Gender (female)	0.90	(0.84, 0.96)	.001	0.48	(0.42, 0.54)	<.001
Age						
18-29 (ref)						
30-39	1.24	(1.10, 1.39)	<.001	1.39	(1.04, 1.85)	.027
40=49	1.24	(1.10, 1.39)	<.001	1.61	(1.21, 2.13)	.001
50-59	1.25	(1.11, 1.40)	<.001	2.08	(1.58, 2.74)	<.001
Table 10a continued						
60+	1.05	(0.92, 1.20)	.441	2.88	(2.18, 3.81)	<.001

Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	0.85	(0.79, 0.91)	<.001	1.08	(0.94, 1.25)	.278
Undisclosed	0.88	(0.74, 1.05)	.152	1.15	(0.78, 1.69)	.487
Working status						
Unemployed (ref)						
Employed	1.12	(0.98, 1.28)	.099	0.87	(0.66, 1.15)	.341
In education	0.65	(0.53, 0.80)	<.001	0.50	(0.30, 0.83)	.008
Retired	0.75	(0.63, 0.89)	.001	1.21	(0.89, 1.63)	.218
Other	1.12	(0.96, 1.30)	.146	0.77	(0.56, 1.06)	.111
Household income						
1st quintile (lowest, ref)						
2nd quintile	0.94	(0.84, 1.05)	.292	0.89	(0.70, 1.14)	.375
3rd quintile	0.88	(0.79, 0.99)	.031	1.21	(0.96, 1.53)	.104
4th quintile	0.82	(0.73, 0.92)	.001	1.18	(0.94, 1.50)	.161
5th quintile (highest)	0.80	(0.71, 0.90)	<.001	1.33	(1.05, 1.68)	.018
Undisclosed	0.72	(0.63, 0.82)	<.001	1.02	(0.79, 1.33)	.869
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.23	(1.09, 1.40)	.001
Disability (yes)	1.16	(1.08, 1.24)	<.001	1.16	(1.02, 1.32)	.020
Nature Connectedness (INS)	1.02	(1.00, 1.04)	.091	1.03	(0.99, 1.07)	.108
Urban	0.95	(0.88, 1.03)	.194	0.89	(0.77, 1.03)	.108
Intercept	0.27	(0.21, 0.34)	<.001	0.04	(0.02, 0.06)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.02)	
Nature visits	0.01	(0.00, 0.04)		0.03	(0.02, 0.08)	
Nature connectedness	0.00	(0.00, 0.02)		0.01	(0.00, 0.02)	

Table 10a continued						
Intercept	0.09	(0.04, 0.18)		0.02	(0.01, 0.04)	
χ^2 (df)	447.90(26) ***			472.28(26) ***		
Log likelihood	-8779.79			-3694.02		
Marginal R^2	.05			.04		
Conditional R^2	.17			.17		

Notes: All models use survey weights. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** *p* <.001

Table 10b. Multilevel mixed-effects Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for health risk behaviours as a function of neighbourhood greenspace, household income and their interaction terms, whist controlling for covariates.

	Current Smoking (N=14,359)			**Exceeding Recommended Alcohol Guidelines (N= 14, 317)**		
	PR	**95% CIs**	***p***	**PR**	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI)						
1st Tertile (M = .31, least green, ref)						
2nd Tertile (M = .52)	1.10	(0.92, 1.31)	.307	0.74	(0.49, 1.10)	.137
3rd Tertile (M = .70, most green)	0.93	(0.76, 1.13)	.454	0.54	(0.34, 0.85)	.008
Household income						
1st quintile (lowest, ref)						
2nd quintile	0.94	(0.78, 1.14)	.517	0.76	(0.51, 1.11)	.155
3rd quintile	0.92	(0.77, 1.11)	.393	0.94	(0.66, 1.34)	.736
4th quintile	1.02	(0.85, 1.22)	.821	1.31	(0.94, 1.82)	.114
5th quintile (highest)	0.89	(0.75, 1.07)	.210	1.25	(0.91, 1.73)	.169
Undisclosed	0.76	(0.61, 0.95)	.014	0.93	(0.63, 1.39)	.734
Greenspace X Household income						
1st tertile x 1st quintile (ref)						
2nd tertile x 2nd quintile	0.94	(0.72, 1.22)	.617	0.97	(0.54, 1.74)	.923

Table 10b continued						
2nd tertile x 3rd quintile	0.86	(0.67, 1.12)	.262	1.29	(0.77, 2.17)	.339
2nd tertile x 4th quintile	0.72	(0.56, 0.93)	.011	0.72	(0.43, 1.21)	.215
2nd tertile x 5th quintile	0.76	(0.60, 0.98)	.034	0.92	(0.56, 1.49)	.727
2nd tetrile x income undisclosed	0.92	(0.69, 1.25)	.609	0.89	(0.49, 1.65)	.720
3rd tertile x 2nd quintile	1.10	(0.84, 1.43)	.488	1.83	(1.01, 3.31)	.055
3rd tertile x 3rd quintile	1.04	(0.80, 1.36)	.778	1.88	(1.08, 3.30)	.027
3rd tertile x 4th quintile	0.89	(0.76, 106)	.210	0.97	(0.55, 1.69)	.901
3rd tertile x 5th quintile	0.95	(0.73, 1.22)	.671	1.39	(0.82, 2.36)	.219
3rd tetrile x income undisclosed)	0.92	(0.67, 1.26)	.598	1.61	(0.86, 3.01)	.138
Nature Visits						
<once a week (ref)						
≥ once a week	0.91	(0.85, 0.98)	.009	1.14	(1.00, 1.30)	.061
Gender (female)	0.90	(0.84, 0.96)	.001	0.48	(0.42, 0.54)	<.001
Age						
18-29 (ref)						
30-39	1.24	(1.10, 1.39)	<.001	1.39	(1.04, 1.85)	.026
40-49	1.23	(1.10, 1.38)	<.001	1.61	(1.21, 2.13)	.001
50-59	1.24	(1.10, 1.39)	<.001	2.09	(1.59, 2.75)	<.001
60+	1.05	(0.92, 1.20)	.470	2.87	(2.17, 3.80)	<.001
Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	0.85	(0.79, 0.91)	<.001	1.08	(0.93, 1.24)	.306
Undisclosed	0.88	(0.73, 1.05)	.144	1.15	(0.78, 1.70)	.467
Higher education (yes)	0.77	(0.72, 0.82)	<.001	0.93	(0.82, 1.06)	.291

Table 10b cont.

Working status						
Unemployed (ref)						
Employed	1.12	(0.98, 1.27)	.105	0.87	(0.66, 1.15)	.327
In education	0.65	(0.53, 0.80)	<.001	0.50	(0.30, 0.84)	.009
Retired	0.75	(0.63, 0.89)	.001	1.21	(0.90, 1.64)	.211
Other	1.12	(0.96, 1.30)	.139	0.76	(0.55, 1.06)	.104
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.24	(1.09, 1.41)	.001
Disability (yes)	1.15	(1.08, 1.24)	<.001	1.17	(1.03, 1.33)	.014
Nature Connectedness (INS)	1.02	(1.00, 1.04)	.086	1.03	(0.99, 1.07)	.096
Urban	0.95	(0.88, 1.03)	.217	0.89	(0.77, 1.03)	.105
Intercept	0.25	(0.19, 0.33)	<.001	0.04	(0.02, 0.07)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.02)	
Nature visits	0.01	(0.00, 0.04)		0.03	(0.02, 0.08)	
Nature connectedness	0.00	(0.00, 0.02)		0.01	(0.00, 0.02)	
Intercept	0.09	(0.04, 0.18)		0.02	(0.01, 0.04)	
χ^2 (df)	466.38(34) ***			482.03(34) ***		
Log likelihood	-8770.91			-3.688.29		
Marginal R^2	.04			.04		
Conditional R^2	.16			.17		

Notes: All models use survey weights. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** *p* <.001

Appendix 11: Study 2: robustness check - co-occurrence between health (risk) behaviours

Table 11. Multilevel mixed-effects Poisson regression models, estimating the prevalence ratios (PR) and 95% CIs for health risk behaviours as a function of nature contact, covariates and other domains of health (risk) behaviours.

	Current Smoking (N = **14, 317**)			**Exceeding Recommended Alcohol Guidelines (N = 14, 317)**		
	PR	**95% CIs**	***p***	**PR**	**95% CIs**	***p***
Neighbourhood Greenspace						
1st Tertile (M = .31, ref)						
2nd Tertile (M = .52)	0.96	(0.88, 1.04)	.314	0.70	(0.60, 0.82)	<.001
3rd Tertile (M = .70, most green)	0.88	(0.80, 0.98)	.016	0.75	(0.63, 0.90)	.002
Nature Visits						
<once a week (ref)						
≥ once a week	0.92	(0.86, 0.99)	.018	1.16	(0.99, 1.32)	.543
Gender (female)	0.91	(0.86, 0.98)	.008	0.49	(0.43, 0.56)	<.001
Age						
18-29 (ref)						
30-39	1.23	(1.09, 1.38)	<.001	1.34	(1.01, 1.79)	.045
40-49	1.23	(1.10, 1.38)	<.001	1.55	(1.17, 2.06)	.002
50-59	1.22	(1.09, 1.37)	.001	2.03	(1.54, 2.67)	<.001
60+	1.02	(0.90, 1.17)	.727	2.91	(2.20, 3.84)	<.001
Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	0.84	(0.78, 0.90)	<.001	1.14	(0.99, 1.31)	.077
Undisclosed	0.87	(0.73, 1.04)	.137	1.22	(0.83, 1.80)	.318

Table 11 continued

Higher education (yes)	0.77	(0.72, 0.82)	<.001	0.96	(0.85, 1.09)	.547
Working status						
Unemployed (ref)						
Employed	1.13	(0.99, 1.29)	.081	0.84	(0.64, 1.11)	.229
In education	0.66	(0.54, 0.81)	<.001	0.53	(0.32, 0.89)	.016
Retired	0.75	(0.63, 0.89)	.001	1.23	(0.91, 1.67)	.169
Other	1.14	(0.98, 1.32)	.096	0.73	(0.53, 1.02)	.063
Household income						
1st quintile (lowest, ref)						
2nd quintile	0.95	(0.85, 1.06)	.327	0.92	(0.72, 1.18)	.507
3rd quintile	0.87	(0.78, 0.98)	.020	1.27	(1.00, 1.60)	.048
4th quintile	0.82	(0.73, 0.92)	.001	1.23	(0.97, 1.55)	.090
5th quintile (highest)	0.80	(0.71, 0.90)	<.001	1.40	(1.10, 1.77)	.006
Undisclosed	0.72	(0.64, 0.82)	<.001	1.09	(0.84, 1.42)	.522
Dog owner (yes)	1.38	(1.29, 1.48)	<.001	1.16	(1.02, 1.32)	.027
Disability (yes)	1.14	(1.06, 1.22)	<.001	1.15	(1.01, 1.30)	.035
Nature Connectedness (INS)	1.02	(1.00, 1.04)	.059	1.03	(0.99, 1.07)	.122
Urban (yes)	0.96	(0.88, 1.03)	.257	0.89	(0.78, 1.03)	.129
Current smoker (yes)	-	-	-	1.88	(1.65, 2.13)	<.001
Exceeds Alcohol Guidelines (yes)	1.58	(1.42, 1.76)	<.001	-	-	-
5 days + Physical Activity (yes)	0.89	(0.82, 0.97)	.008	1.03	(0.89, 1.19)	.688
Intercept	0.26	(0.21, 0.33)	<.001	0.03	(0.02, 0.05)	<.001
Random effects (country/region)	**Variance**	**95% CIs**		**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)		0.00	(0.00, 0.02)	
Nature visits	0.01	(0.00, 0.04)		0.03	(0.02, 0.08)	
Nature connectedness	0.00	(0.00, 0.02)		0.01	(0.00, 0.02)	
Intercept	0.09	(0.04, 0.18)		0.02	(0.01, 0.04)	

Table 11 cont.

χ^2 (df)	523.90(26) ***	553.82(26) ***
Log likelihood	-8712.34	-3652.27
Marginal R^2	.05	.06
Conditional R^2	.17	.18

Notes: All models use survey weights. χ^2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** *p* <.001

Appendix 12: Study 2: additional analyses - nature visits and dog ownership

Table 12. Adjusted modified Poisson regression models estimating prevalence ratio of current smoking as a function of nature contact/connectedness predictors and all covariates except dog ownership.

	Current Smoking (N=14,359)		
	PR	**95% CIs**	***p***
Neighbourhood Greenspace (NDVI)			
1st Tertile (M = .31, least green, ref)			
2nd Tertile (M = .52)	0.94	(0.87, 1.03)	.169
3rd Tertile (M = .70, most green)	0.87	(0.79, 0.97)	.008
Nature Visits			
<once a week (ref)			
≥ once a week	0.95	(0.88, 1.01)	.124
Nature Connectedness (INS)	1.03	(1.01, 1.05)	.013
Gender (female)	0.91	(0.85, 0.97)	.004
Age			
18-29 (ref)			
30-39	1.20	(1.07, 1.35)	.002
40-49	1.20	(1.07, 1.35)	.002
50-59	1.21	(1.08, 1.36)	.001
60+	1.01	(0.88, 1.15)	.928
Marital status			
Single/widowed/divorced (ref)			
Married/cohabiting	0.87	(0.81, 0.93)	<.001
Undisclosed	0.89	(0.74, 1.06)	.178

Table 12 continued

Higher education (yes)	0.75	(0.70, 0.80)	<.001
Working status			
Unemployed (ref)			
Employed	1.13	(0.99, 1.29)	.075
In education	0.66	(0.54, 0.81)	<.001
Retired	0.75	(0.63, 0.88)	.001
Other	1.13	(0.97, 1.31)	.115
Household income			
1st quintile (lowest, ref)			
2nd quintile	0.94	(0.84, 1.05)	.293
3rd quintile	0.89	(0.79, 1.00)	.042
4th quintile	0.83	(0.74, 0.93)	.002
5th quintile (highest)	0.82	(0.73, 0.92)	.001
Undisclosed	0.72	(0.63, 0.82)	<.001
Disability (yes)	1.18	(1.10, 1.26)	<.001
Urban (yes)	0.93	(0.86, 1.00)	.051
Intercept	0.29	(0.23, 0.37)	<.001
Random effects (country/region)	**Variance**	**95% CIs**	
Neighbourhood greenspace	0.00	(0.00, 0.04)	
Nature visits	0.01	(0.00, 0.04)	
Nature connectedness	0.00	(0.00, 0.02)	
Intercept	0.09	(0.04, 0.18)	
χ^2 (df)	363.18(23)***		
Log likelihood	-8824.2926		

Notes: All models use survey weights. PR χ2 (df) = Wald's Chi-Square Statistic (degrees of freedom). *** p <.001

Appendix 13: Study 3: sensitivity analyses comparing greenspace operationalisations.

Tables 13a and 13b present the results of linear regression models predicting pro-environmental behaviours with greenspace operationalised as a binary variable and in quartiles respectively.

Table 13a. Fully adjusted linear regression models predicting pro-environmental behaviours, as a function of nature contact, nature connectedness, controlling for individual, area and related-outcome covariates, with greenspace as a binary variable (based on a median split)

	Household PEB				**Nature Conservation PEB**			
	b	**95% CIs *b***	***β***	***p***	***b***	**95% CIs *b***	***β***	***p***
High greenspace (≥ 64.66%)	.0148	(-.0641, .0937)	.0051	.714	-.0188	(-.0570, .0194)	-.0150	.334
Nature visits (≥ once a week)	.3414	(.2690, .4137)	.1164	<.001	.0148	(-.0205, .0501)	.0116	.412
Nature media (Yes)	.6779	(.6057, .7501)	.2356	<.001	.0707	(.0346, .1068)	.0564	<.001
Nature connectedness (%, NC)	.0110	(.0097, .0122)	.2156	<.001	.0020	(.0013, .0026)	.0886	<.001
Individual-level controls								
Gender (female)	.1450	(.0731, .2169)	.0504	<.001	-.0278	(-.0626, .0071)	-.0222	.118
Age								
16-34 (ref)								
35-64	-.0113	(-.1038, .0813)	-.0039	.812	.0404	(-.0044, .0852)	.0318	.077
65+	-.1419	(-.3150, .0313)	-.0445	.108	.0184	(-.0655, .1022)	.0132	.668
Ethnicity (White British)	.1260	(.0387, .2133)	.0372	.005	-.0107	(-.0530, .0316)	-.0073	.620

Working Status								
Unemployed (ref)								
Full-time Employment	.1230	(.0113, .2347)	.0403	.031	-.0513	(-.1054, .0027)	-.0386	.063
Table 13a continued								
Part-time Employment	.1409	(.0105, .2713)	.0331	.034	-.0262	(-.0893, .0370)	-.0141	.416
In Education	.3012	(.1215, .4810)	.0525	.001	-.0338	(-.1209, .0533)	-.0135	.446
Retired	-.0245	(-.1945, .1456)	-.0078	.778	.0600	(-.0222, .1423)	.0441	.153
Marital Status								
(Married/Cohabiting)	.1199	(.0181, .2217)	.0414	.021	-.0062	(-.0555, .0431)	-.0049	.805
Household composition								
Alone (ref)								
With adults	-.0572	(-.1722, .0577)	-.0199	.329	-.0097	(-.0653, .0459)	-.0077	.733
With children	-.1317	(-.3224, .0590)	-.0186	.176	.0640	(-.0283, .1563)	.0207	.174
With adults and children	-.1518	(-.2972, -.0064)	-.0447	.041	-.0407	(-.1111, .0297)	-.0275	.258
Social Grade								
DE (ref)								
AB	.5258	(.4160, .6355)	.1396	<.001	.2064	(.1531, .2597)	.1258	<.001
C1	.2928	(.1961, .3895)	.0900	<.001	.0683	(.0213, .1152)	.0482	.004
C2	.1650	(.0636, .2664)	.0460	.001	.0221	(-.0270, .0712)	.0142	.378
Survey year (2017/18)	-.0800	(-.1578, -.0021)	-.0244	.044	.0131	(-.0246, .0508)	.0092	.496
Area-level controls								
Deprivation Index								
1st Quintile (Least deprived, ref)								
2nd Quintile	-.1601	(-.2694, -.0508)	-.0440	.004	-.0075	(-.0604, .0454)	-.0047	.781
3rd Quintile	-.1002	(-.2124, .0120)	-.0279	.080	-.0247	(-.0790, .0296)	-.0158	.372
4th Quintile	-.1594	(-.2753, -.0435)	-.0444	.007	-.0255	(-.0816, .0307)	-.0163	.374
5th Quintile (Most deprived)	-.3145	(-.4363, -.1927)	-.0874	<.001	-.0110	(-.0701, .0481)	-.0070	.715

Urbanicity (Rural)	.0585	(-.0485, .1654)	.0142	.284	.0919	(.0402, .1436)	.0513	<.001

Table 13a continued

Related outcome controls								
Household PEB	--	--	--	--	.1004	(.0871, .1138)	.2305	<.001
Nature Cons. PEB	.4288	(.3719, .4857)	.1868	<.001	--	--	--	--
Constant	.5565	(.3464, .7667)	--	<.001	-.1762	(-.2781, -.0743)	--	.001
N	4874				4874			
Adjusted R^2	.29				.13			

Note. PEB = pro-environmental behaviour

Table 13b. Fully adjusted linear regression models predicting pro-environmental behaviours, as a function of nature contact, nature connectedness, controlling for individual, area and related-outcome covariates, with quartiles of neighbourhood greenspace

	Household PEB				Nature Conservation PEB			
	b	**95% CIs *b***	***β***	***p***	***b***	**95% CIs *b***	***β***	***p***
Neighbourhood greenspace								
1st quartile (M = 39.83%)								
2nd quartile (M = 59.74%)	.0304	(-.0680, .1288)	.0091	.545	-.0301	(-.0777, .0176)	-.0208	.216
3rd quartile (M =69.76%)	.0057	(-.0970, .1084)	.0017	.913	-.0308	(-.0805, .0189)	-.0213	.224
4th quartile (M= 88.42%)	.0832	(-.0388, .2051)	.0250	.181	-.0452	(-.1042, .0139)	-.0312	.134
Nature visits (≥ once a week)	.3418	(.2694, .4141)	.1165	<.001	.0145	(-.0208, .0498)	.0114	.420
Nature media (Yes)	.6795	(.6073, .7518)	.2362	<.001	.0705	(.0344, .1067)	.0563	<.001
Nature connectedness (%, NC)	.0110	(.0097, .0123)	.2158	<.001	.0020	(.0013, .0026)	.0880	<.001
Individual-level controls								
Gender (female)	.1446	(.0727, .2165)	.0502	<.001	-.0277	(-.0626, .0071)	-.0221	.119
Age								
16-34 (ref)	-.0131	(-.1057, .0795)	-.0045	.781	.0413	(-.0035, .0861)	.0325	.071
35-64	-.1433	(-.3164, .0299)	-.0449	.105	.0194	(-.0644, .1033)	.0140	.649
65+								
Ethnicity (White British)	.1230	(.0352, .2108)	.0364	.006	-.0079	(-.0504, .0346)	-.0053	.717
Working Status								
Unemployed (ref)								
Full-time Employment	.1232	(.0115, .2349)	.0403	.031	-.0519	(-.1060, .0022)	-.0390	.060
Part-time Employment	.1416	(.0112, .2721)	.0333	.033	-.0269	(-.0900, .0363)	-.0145	.404
In Education	.3040	(.1241, .4839)	.0530	.001	-.0359	(-.1231, .0512)	-.0144	.419
Retired	-.0248	(-.1949, .1453)	-.0079	.775	.0593	(-.0230, .1416)	.0436	.158
Marital Status (Married/Cohabiting)	.1186	(.0168, .2204)	.0410	.022	-.0061	(-.0554, .0432)	-.0048	.809

Table 13b continued.

Household composition								
Alone (ref)								
With adults	-.0565	(-.1714, .0585)	-.0196	.336	-.0097	(-.0653, .0460)	-.0077	.734
With children	-.1300	(-.3207, .0607)	-.0184	.181	.0636	(-.0287, .1559)	.0206	.177
With adults and children	-.1507	(-.2962, -.0053)	-.0444	.042	-.0401	(-.1105, .0303)	-.0271	.265
Social Grade								
DE (ref)								
AB	.5241	(.4143, .6339)	.1392	<.001	.2063	(.1530, .2595)	.1257	<.001
C1	.2914	(.1947, .3881)	.0896	<.001	.0683	(.0214, .1153)	.0482	.004
C2	.1649	(.0636, .2663)	.0460	.001	.0222	(-.0270, .0713)	.0142	.377
Survey year (2017/18)	-.0814	(-.1593, -.0035)	-.0249	.041	.0133	(-.0244, .0510	.0093	.489
Area-level controls								
Deprivation Index								
1st Quintile (Least deprived, ref)								
2nd Quintile	-.1597	(-.2690, -.0504)	-.0439	.004	-.0082	(-.0612, .0447)	-.0052	.760
3rd Quintile	-.0956	(-.2079, .0168)	-.0266	.096	-.0263	(-.0807, .0281)	-.0168	.344
4th Quintile	-.1525	(-.2692, -.0357)	-.0424	.010	-.0300	(-.0865, .0266)	-.0192	.299
5th Quintile (Most deprived)	-.3029	(-.4262, -.1797)	-.0842	<.001	-.0172	(-.0770, .0426)	-.0110	.572
Urbanicity (Rural)	.0188	(-.1026, .1403)	.0046	.761	.0988	(.0401, .1575)	.0551	.001
Related outcome controls								
Household PEB	--	--	--	--	.1005	(.0872, .1139)	.2308	<.001
Nature Cons. PEB	.4292	(.3723, .4862)	.1870	<.001			--	--
Constant	.5385	(.3213, .7557)	--	<.001	-.1592	(-.2645, -.0540)	--	.003
N	4874				4874			
Adjusted R^2	.29				.13			

Note. PEB = pro-environmental behaviour

Appendix 14. Study 3: unadjusted and partially adjusted linear regression models.

Unadjusted regression models (nature contact/connectedness indicators only) are presented in Tables 14a- 14b and partially adjusted models (including individual-level covariates) are presented in Tables 14c -14d.

Table 14a: Initial models -unadjusted linear regression models predicting pro-environmental behaviours (PEB) as a function of nature contact and nature connectedness.

	Household PEB				Nature Conservation PEB			
	b	**95% CI *b***	**β**	***p***	***b***	**95% CI *b***	**β**	***p***
Neighbourhood greenspace (%)	.0050	(.0031, .0070)	.0653	<.001	.0015	(.0006, .0024)	.0448	.001
Nature visits (≥ once a week)	.4712	(.3973, .5451)	.1607	<.001	.0732	(.0379, .1084)	.0573	<.001
Nature media (Yes)	.7886	(.7151, .8621)	.2741	<.001	.1722	(.1372, .2073)	.1374	<.001
Nature connectedness (%)	.0125	(.0112, .0138)	.2453	<.001	.0034	(.0028, .0040)	.1527	<.001
Constant	.3196	(.1711, .4681)	-	<.001	-.1973	(-.2680, -.1265)	-	<.001
N	4875				4875			
Adjusted R^2	.22				.06			

Note. PEB = pro-environmental behaviour

Table 14b: Moderation models- unadjusted linear regression models predicting pro-environmental behaviours (PEB), as a function of nature contact, nature connectedness and their interaction terms

	Household PEB				**Nature Conservation PEB**			
	b	**95% CI *b***	**β**	***p***	***b***	**95% CI *b***	**β**	***p***
Neighbourhood greenspace (%)	.0031	(-.0015, .0076)	.0397	.192	.0005	(-.0017, .0026)	.0139	.676
Nature visits (≥ once a week)	.3728	(.2030, .5427)	.1271	<.001	-.0088	(-.0895, .0719)	-.0069	.831
Nature media (yes)	.5589	(.3852, .7325)	.1942	<.001	-.0426	(-.1251, .0399)	-.0340	.311
Nature connectedness (NCI)	.0077	(.0030, .0124)	.1509	.001	-.0002	(-.0024, .0021)	-.0073	.887
Greenspace x NC	.0000	(-.0000, .0001)	.0497	.362	.0000	(-.0000, .0000)	.0593	.319
Visits x NC	.0017	(-.0009, .0043)	.0443	.197	.0014	(.0002, .0026)	.0847	.024
Nature media x NC	.0038	(.0012, .0064)	.1003	.004	.0036	(.0023, .0048)	.2157	<.001
Constant	.5947	(.2879, .9016)		<.001	.0038	(-.1419, .1497)		.959
N	4875				4875			
Adjusted R^2	.22				.07			

Note: NC= Nature connectedness; PEB = pro-environmental behaviour

Table 14c: Initial models- partially adjusted linear regression models predicting pro-environmental behaviours (PEB) as a function of nature contact and nature connectedness, controlling for individual and area level covariates.

	Household PEB				**Nature Conservation PEB**			
	b	**95% CI *b***	**β**	***p***	***b***	**95% CI *b***	**β**	***p***
Neighbourhood greenspace (%)	.0009	(-.0015, .0033)	.0117	.470	-.0007	(-.0019, .0005)	-.0216	.227
Nature visits (≥ once a week)	.3633	(.2894, .4371)	.1239	<.001	.0513	(.0156, .0871)	.0402	.005
Nature media (yes)	.7401	(.6668, .8134)	.2572	<.001	.1450	(.1095, .1805)	.1157	<.001
Nature connectedness (NCI)	.0124	(.0111, .0136)	.2427	<.001	.0032	(.0026, .0038)	.1443	<.001
Individual-level controls								
Gender (female)	.1388	(.0653, .2123)	.0482	<.001	-.0137	(-.0492, .0219)	-.0109	.451
Age								
16-34 (ref)								
35-64	.0049	(-.0898, .0995)	.0017	.920	.0418	(-.0040, .0876)	.0329	.074
65+	-.1423	(-.3193, .0348)	-.0446	.115	.0052	(-.0804, .0909)	.0038	.905
Ethnicity (White British)	.1224	(.0327, .2120)	.0362	.007	.0038	(-.0396, .0471)	.0025	.865
Working Status								
Unemployed (ref)								
Full-time Employment	.1060	(-.0081, .2202)	.0347	.069	-.0408	(-.0960, .0144)	-.0307	.147
Part-time Employment	.1360	(.0027, .2693)	.0320	.045	-.0128	(-.0773, .0517)	-.0069	.698
In Education	.3021	(.1183, .4858)	.0527	.001	-.0045	(-.0934, .0845)	-.0018	.921
Retired	.0024	(-.1714, .1762)	.0008	.978	.0595	(-.0246, .1436)	.0437	.165
Marital Status (Married/Cohabiting)	.1225	(.0185, .2265)	.0423	.021	.0062	(-.0442, .0565)	.0049	.810

Table 14c continued.

Household composition								
Alone (ref)								
With adults	-.0645	(-.1820, .0529)	-.0224	.282	-.0161	(-.0729, .0408)	-.0128	.580
With children	-.1091	(-.3040, .0857)	-.0154	.272	.0530	(-.0413, .1473)	.0172	.271
With adults and children	-.1775	(-.3261, -.0289)	-.0523	.019	-.0583	(-.1302, .0137)	-.0394	.112
Social Grade								
DE (ref)								
C2	.1823	(.0787, .2859)	.0509	.001	.0404	(-.0097, .0906)	.0259	.114
C1	.3369	(.2382, .4356)	.1036	<.001	.1022	(.0544, .1499)	.0721	<.001
AB	.6419	(.5309, .7529)	.1705	<.001	.2712	(.2176, .3250)	.1654	<.001
Survey year (2017/18)	-.0775	(-.1571, .0021)	-.0237	.056	.0054	(-.0331, .0439)	.0038	.782
Area-level controls								
Deprivation Index								
1st Quintile (Least deprived, ref)								
2nd Quintile	-.1685	(-.2799, -.0571)	-.0463	.003	-.0246	(-.0785, .0293)	-.0155	.371
3rd Quintile	-.1107	(-.2246, .0033)	-.0308	.057	-.0369	(-.0920, .0182)	-.0236	.190
4th Quintile	-.1698	(-.2889, -.0506)	-.0472	.005	-.0461	(-.1038, .0115)	-.0295	.117
5th Quintile (Most deprived)	-.3215	(-.4484, -.1946)	-.0894	<.001	-.0494	(-.1108, .0120)	-.0315	.115
Urbanicity (Rural)	.0847	(-.0332, .2026)	.0206	.159	.1113	(.0543, .1684)	.0621	<.001
Constant	.0911	(.8156, 1.3666)		<.001	.1819	(.0486, .3153)		.007
N	4874				4874			
Adjusted R^2	.26				.09			

Note. PEB = pro-environmental behaviour

Table 14d: moderation models- partially adjusted linear regression models predicting pro-environmental behaviours (PEB) as a function of nature contact, nature connectedness and their interaction terms, controlling for individual and area level covariates.

	Household PEB				Nature Conservation PEB			
	b	**95% CI *b***	**β**	***p***	***b***	**95% CI *b***	**β**	***p***
Neighbourhood greenspace (%)	-.0012	(-.0059, .0035)	-.0151	.629	-.0013	(-.0036, .0009)	-.0400	.248
Nature visits (≥ once a week)	.2544	(.0877, .4210)	.0868	.003	-.0328	(-.1133, .0476)	-.0257	.424
Nature media (yes)	.4673	(.2980, .6365)	.1624	<.001	-.0733	(-.1550, .0084)	-.0587	.079
Nature connectedness (NCI)	.0070	(.0024, .0116)	.1378	.003	.0001	(-.0022, .0023)	.0023	.964
Greenspace x NC	.0000	(.0000, .0001)	.0524	.325	.0000	(.0000, .0000)	.0348	.555
Visits x NC	.0019	(-.0007, .0044)	.0840	.148	.0014	(.0002, .0027)	.0856	.021
Nature media. x NC	.0045	(.0020, .0071)	.1196	<.001	.0036	(.0024, .0049)	.2200	<.001
Individual-level controls								
Gender (female)	.1350	(.0615, .2084)	.0469	<.001	-.0167	(-.0522, .0187)	-.0134	.355
Age								
16-34 (ref)								
35-64	.0017	(-.0928, .0963)	.0006	.971	.0395	(-.0062, .0851)	.0310	.090
65+	-.1484	(-.3252, .0284)	-.0465	.100	.0006	(-.0847, .0860)	.0004	.989
Ethnicity (White British)	.1213	(.0317, .2110)	.0359	.008	.0019	(-.0414, .0452)	.0013	.931
Working Status								
Unemployed (ref)								
Full-time Employment	.1053	(-.0087, .2192)	.0345	.070	-.0413	(-.0963, .0137)	-.0311	.141
Part-time Employment	.1384	(.0053, .2715)	.0325	.042	-.0105	(-.0747, .0538)	-.0057	.749
In Education	.2975	(.1139, .4811)	.0519	.001	-.0068	(-.0954, .0819)	-.0027	.881
Retired	-.0013	(-.1748, .1723)	-.0004	.989	.0574	(-.0264, .1412)	.0422	.179
Marital Status								
(Married/Cohabiting)	.1226	(.0187, .2265)	.0423	.021	.0063	(-.0438, .0564)	.0050	.805

Table 13c continued.

Household composition								
Alone (ref)								
With adults	-.0617	(-.1792, .0558)	-.0214	.303	-.0136	(-.0703, .0431)	-.0109	.638
With children	-.1118	(-.3065, .0829)	-.0158	.260	.0512	(-.0427, .1452)	.0166	.285
With adults and children	-.1742	(-.3228, -.0256)	-.0513	.022	-.0558	(-.1276, .0159)	-.0378	.127
Social Grade								
DE (ref)								
C2	.1841	(.0801, .2875)	.0514	<.001	.0415	(-.0084, 0915)	.0266	.103
C1	.3370	(.2385, .4355)	.1036	<.001	.1025	(.0549, .1500)	.0723	<.001
AB	.6447	(.5338, .7555)	.1712	<.001	.2736	(.2201, .3271)	.1668	<.001
Survey year (2017/18)	-.0790	(-.1585, .0005)	-.0241	.051	.0046	(-.0337, .0430)	.0033	.813
Area-level controls								
Deprivation Index								
1st Quintile (ref)								
2nd Quintile	-.1709	(-.2822, -.0596)	-.0470	.003	-.0271	(-.0808, .0267)	-.0171	.324
3rd Quintile	-.1119	(-.2258, .0019)	-.0311	.054	-.0388	(-.0937, .0161)	-.0248	.166
4th Quintile	-.1738	(-.2929, -.0546)	-.0484	.004	-.0503	(-.1078, .0072)	-.0321	.086
5th Quintile (Most deprived)	-.3292	(-.4560, -.2024)	-.0915	<.001	-.0552	(-.1164, .0060)	-.0353	.077
Urbanicity (Rural)	.0800	(-.0378, .1978)	.0194	.183	.1086	(.0517, .1655)	.0605	<.001
Constant	1.4074	(1.0284, 1.7864)		<.001	.3682	(.1852, .5511)		<.001
N	4874				4874			
Adjusted R^2	.26				.10			

Note: NC= Nature connectedness

Appendix 15. Study 4: health risk behaviour scale

As continuous dependent variables are preferable for structural equation models, I had planned to create a composite health risk behaviour index (with engagement in each health risk behaviour coded as 1 *vs*. 0, resulting in a continuous scale with a possible range of 0-4). However, a principal components analysis with an orthogonal varimax rotation (*KMO* =.54; Bartlett's test of sphericity: $\chi 2$ (6) = 730.47., p < .001), revealed that only the two alcohol items had satisfactory loadings on the same factor.

Table 15: Factor Loadings for Health Risk Behaviour Items

Item	**Factor 1**
Current smoker	.25
Alcohol everyday	**.52**
>14 units of alcohol per week	**.52**
Poor diet	.00

Appendix 16. Study 4: sensitivity analysis comparing the two alcohol outcomes

Study 1 found that neighbourhood greenspace was unrelated to exceeding 2012 alcohol unit guidelines, but Study 2 observed an inverse association between greenspace and the prevalence of drinking every day. I had speculated that the inconsistent findings may relate to different operationalisations of exceeding alcohol guidelines between studies (Chapter 2, section 2.3.4). However, that appears not to be the case in Study 4, which included measures of the frequency of alcohol consumption (drinks everyday: no *vs*. yes), as well the amount of alcohol consumed (≤ 14 units *vs*. > units per week). As indicated in Appendix 15 above both items loaded onto the same factor. Table 16 (below) presents a summary of the fully adjusted Poisson regression models predicting the prevalence ratio (PR) of the two alcohol outcomes as a function of nature contact, nature connectedness (and their interaction terms). The associations between nature contact and connectedness variables and the two behaviours were largely consistent between models. An exception was the positive association with nature media was statistically significant for drinking every day (*PR* = 1.71, *95% CIs* = 1.30, 2.25, $p < .001$), but not for consuming more than 14 units of alcohol per week (*PR* = 1.14, *95% CIs* = 0.96, 1.36, $p = .126$). To reduce collinearity in the Structural Equation Models they were combined into a composite measure of exceeding alcohol guidelines.

Table 16. Summary of fully adjusted Poisson regression models predicting the prevalence ratio (PR) of drinking behaviours as a function of nature contact, nature connectedness (and their interaction terms), whilst controlling for covariates.

	Drinks Every Day			>14 units alcohol		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Initial Models						
Green view (%)	0.9871	(0.9769, 0.9974)	.014	0.9921	(0.9858, 0.9985)	.016
Nature visits (≥ once a week)	1.1013	(0.8257, 1.4689)	.511	1.0938	(0.9208, 1.2994)	.307
Nature media (≥ once a week)	1.7111	(1.3026, 2.2475)	<.001	1.1447	(0.9627, 1.3611)	.126
Nature connectedness (INS)	1.0518	(0.9703, 1.1402)	.219	0.9583	(0.9123, 1.0065)	.089
Constant	0.0306	(0.0135, 0.0692)	<.001	0.1924	(0.1197, 0.3092)	<.001
Pseudo R^2	.10			.05		
Moderation Models						
Green view (%)	1.0026	(0.9751, 1.0309)	.854	0.9902	(0.9745, 1.0061)	.224
Nature visits (≥ once a week)	1.0363	(0.4813, 2.2313)	.927	1.5100	(0.9784, 2.3305)	.063
Nature media (≥ once a week)	2.7849	(1.2976, 5.9769)	.009	1.1143	(0.7024, 1.7679)	.646
Nature connectedness (INS)	1.1966	(0.9930, 1.4418)	.059	0.9873	(0.8837, 1.1030)	.821
Green view x INS	0.9965	(0.9907, 1.0022)	.228	1.0004	(0.9969, 1.0039)	.814
Nature visits x INS	1.0128	(0.8623, 1.1896)	.876	0.9237	(0.8377, 1.0186)	.112
Nature media. X INS	0.8980	(0.7671, 1.0511)	.180	1.00760	(0.9128, 1.1122)	.881
Constant	0.0176	(0.0059, 0.0529)	<.001	0.1725	(0.0934, 0.3187)	<.001
Pseudo R^2	.10			.05		
Delta R^2	.00			.00		

Appendix 17. Study 4: sensitivity analysis comparing the inclusion vs exclusion of non-drinkers

Table 17. Sensitivity analysis: comparison of the association between nature contact and exceeding recommended alcohol guidelines, including/excluding non-drinkers

	Exceeds Alcohol Guidelines (including non-drinkers)			**Exceeds Alcohol Guidelines (excluding non-drinkers)**		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view	0.9936	(0.9876, 0.9997)	.040	0.9928	(0.9867, 0.9988)	.020
Nature visits (≥ once a week)	1.1184	(0.9489, 1.3181)	.182	1.0351	(0.8773, 1.2214)	.682
Nature media (≥ once a week)	1.2240	(1.0394, 1.4413)	.015	1.1419	(0.9688, 1.3460)	.114
Nature Connectedness (INS)	0.9648	(0.9206, 1.0111)	.135	0.9857	(0.9397, 1.0339)	.554
Female	0.6274	(0.5367, 0.7333)	<.001	0.6867	(0.5867, 0.8038)	<.001
Age						
18-29 (ref)						
30-39	1.0208	(0.8091, 1.2879)	.862	1.0526	(0.8314, 1.3327)	.670
40-49	1.0112	(0.7830, 1.3059)	.932	1.0928	(0.8436, 1.4155)	.502
50-59	1.2317	(0.9502, 1.5966)	.115	1.2828	(0.9867, 1.6676)	.063
60+	1.1155	(0.8074, 1.5411)	.507	1.2170	(0.8790, 1.6850)	.237
Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	0.9785	(0.8223, 1.1643)	.806	1.0036	(0.8424, 1.1956)	.968
Undisclosed	0.8325	(0.5124, 1.3526)	.459	0.8717	(0.5291, 1.4361)	.590
Higher education (yes)	0.9837	(0.8376, 1.1554)	.842	0.9340	(0.7945, 1.0980)	.408
Working status						
Unemployed (ref)						
Employed	0.9009	(0.6855, 1.1841)	.454	0.8555	(0.6482, 1.1291)	.270
In education	0.8343	(0.4926, 1.4132)	.501	0.8080	(0.4747, 1.3754)	.432
Retired	0.9438	(0.6403, 1.3914)	.770	0.8773	(0.5928, 1.2984)	.513

Table 17 continued

Other	0.6968	(0.4948, 0.9811)	.039	0.7388	(0.5216, 1.0464)	.088
Household income						
1st quintile (lowest, ref)						
2nd quintile	1.0597	(0.7999, 1.4037)	.686	0.9466	(0.7119, 1.2588)	.706
3rd quintile	1.1436	(0.8719, 1.5000)	.332	1.0114	(0.7695, 1.3294)	.935
4th quintile	1.2785	(0.9721, 1.6815)	.079	1.0919	(0.8275, 1.4409)	.534
5th quintile (highest)	1.4676	(1.1110, 1.9387)	.007	1.1890	(0.8978, 1.5746)	.227
Undisclosed	0.7876	(0.4885, 1.2698)	.327	0.8523	(0.5278, 1.3763)	.513
Disability						
No (ref)						
Yes	1.2679	(1.0728, 1.4985)	.005	1.2922	(1.0919, 1.5292)	.003
Undisclosed	1.4510	(0.8046, 2.6165)	.216	1.5794	(0.8318, 2.9989)	.162
Dog owner (yes)	1.1565	(0.9836, 1.3598)	.078	1.0792	(0.9170, 1.2700)	.359
Rec. physical activity (yes)	1.0903	(0.9239, 1.2866)	.306	1.1196	(0.9482, 1.3218)	.183
Covid-19 local lockdown (yes)	1.6095	(1.3516, 1.9167)	<.001	1.4963	(1.2545, 1.7847)	<.001
Carstairs deprivation						
1st quintile (most deprived, ref)						
2nd quintile	1.0785	(0.8512, 1.3664)	.532	1.0284	(0.8108, 1.3044)	.817
3rd quintile	0.8677	(0.6708, 1.1223)	.280	0.8205	(0.6329, 1.0638)	.135
4th quintile	1.0285	(0.7987, 1.3244)	.828	1.0224	(0.7928, 1.3184)	.865
5th quintile (most deprived)	1.0525	(0.8091, 1.3692)	.703	1.0560	(0.8098, 1.3769)	.688
Population density	1.0000	(0.9975, 1.0024)	.984	1.0005	(0.9982, 1.0029)	.662
Constant	0.1898	(0.1206, 0.2987)	<.001	0.2743	(0.1730, 0.4350)	<.001
N	3,811			2,851		
Wald's χ^2	165.69***			110.95***		
Pearson goodness of fit χ^2	3131.06			2172.89		
Pseudo R^2	.04			.03		

Note. *** *p* <.001

Appendix 18. Study 4: sensitivity analysis comparing operationalisations of green view

Tables 18a-18b present the results of the fully adjusted regression models operationalising green view as a binary variable and Tables 18c -18d contain regression models operationalising green view in quartiles.

Table 18a. Fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of nature contact, nature connectedness, whilst controlling for covariates with green view operationalised as a binary variable (based on a median split)

	Current Smoker			**Exceeds Alcohol Guidelines**			**Poor Diet**		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view									
Low (*M* = 17.74)									
High (*M* = 34.68)	0.6050	(0.5279, 0.6932)	<.001	0.6824	(0.5842, 0.7972)	<.001	0.8730	(0.7729, 0.9862)	.029
Nature visits (≥ once a week)	0.9675	(0.8414, 1.1126)	.643	1.1218	(0.9516, 1.3225)	.171	0.9069	(0.7964, 1.0327)	.140
Nature media (≥ once a week)	1.3081	(1.1380, 1.5037)	<.001	1.2164	(1.0328, 1.4327)	.019	0.8546	(0.7392, 0.9880)	.034
Nature Connectedness (INS)	1.0545	(1.0134, 1.0973)	.009	0.9677	(0.9234, 1.0141)	.169	0.9182	(0.8844, 0.9533)	<.001
Female	0.8187	(0.7170, 0.9348)	.003	0.6336	(0.5420, 0.7407)	<.001	1.1944	(1.0521, 1.3560)	.006
Age									
18-29 (ref)									
30-39	1.3198	(1.0931, 1.5934)	.004	1.0122	(0.8024, 1.2768)	.919	0.9188	(0.7639, 1.1051)	.369
40-49	1.2113	(0.9842, 1.4906)	.070	1.0069	(0.7801, 1.2997)	.958	1.0261	(0.8405, 1.2528)	.800
50-59	1.0148	(0.8121, 1.2682)	.897	1.2082	(0.9322, 1.5660)	.153	1.0724	(0.8788, 1.3085)	.491
60+	0.7702	(0.5676, 1.0451)	.094	1.1101	(0.8034, 1.5337)	.527	0.9753	(0.7584, 1.2542)	.845
Marital status									
Single/widowed/divorced (ref)									
Married/cohabiting	0.9738	(0.8413, 1.1273)	.723	0.9838	(0.8267, 1.1708)	.854	0.9000	(0.7850, 1.0319)	.131
Undisclosed	0.9986	(0.6913, 1.4424)	.994	0.8389	(0.5161, 1.3636)	.479	1.0057	(0.7185, 1.4078)	.974

Table 18a continued

Higher education (yes)	0.8088	(0.7016, 0.9324)	.003	0.9936	(0.8458, 1.1673)	.938	0.7845	(0.6873, 0.8955)	<.001
Working status									
Unemployed (ref)									
Employed	1.0902	(0.8691, 1.3676)	.455	0.9138	(0.6953, 1.2009)	.518	0.9306	(0.7571, 1.1440)	.495
In education	0.5338	(0.3071, 0.9280)	.026	0.8733	(0.5156, 1.4790)	.614	0.6407	(0.4218, 0.9732)	.037
Retired	0.7423	(0.5036, 1.0943)	.132	0.9635	(0.6530, 1.4217)	.851	0.8226	(0.6035, 1.1212)	.217
Other	1.0454	(0.8082, 1.3522)	.735	0.6967	(0.4947, 0.9812)	.039	0.9304	(0.7394, 1.1708)	.538
Household income									
1st quintile (lowest, ref)									
2nd quintile	0.8021	(0.6483, 0.9924)	.042	1.0563	(0.7974, 1.3993)	.702	0.8181	(0.6733, 0.9940)	.043
3rd quintile	0.8163	(0.6625, 1.0057)	.057	1.1407	(0.8695, 1.4963)	.342	0.8829	(0.7274, 1.0717)	.208
4th quintile	0.7697	(0.6162, 0.9615)	.021	1.2921	(0.9826, 1.6992)	.067	0.8181	(0.6625, 1.0104)	.062
5th quintile (highest)	0.6779	(0.5356, 0.8581)	.001	1.4485	(1.0963, 1.9139)	.009	0.8648	(0.6950, 1.0761)	.193
Undisclosed	0.5281	(0.3515, 0.7935)	.002	0.7872	(0.4884, 1.2689)	.326	0.8904	(0.6675, 1.1877)	.430
Disability									
No (ref)									
Yes	1.2370	(1.0718, 1.4278)	.004	1.2613	(1.0673, 1.4905)	.006	1.4470	(1.2689, 1.6500)	<.001
Undisclosed	1.2162	(0.7308, 2.0241)	.451	1.4633	(0.8112, 2.6398)	.206	1.1743	(0.7438, 1.8539)	.490
Dog owner (yes)	1.5687	(1.3704, 1.7956)	<.001	1.1458	(0.9742, 1.3476)	.100	1.0315	(0.9038, 1.1771)	.646
Rec. physical activity (yes)	0.9743	(0.8414, 1.1281)	.728	1.0855	(0.9199, 1.2810)	.331	0.7407	(0.6360, 0.8627)	<.001
Covid-19 local lockdown (yes)	1.0939	(0.9354, 1.2792)	.261	1.6051	(1.3481, 1.9111)	<.001	0.8343	(0.7096, 0.9810)	.028
Carstairs deprivation									
1st quintile (most deprived, ref)									
2nd quintile	1.0031	(0.8305, 1.2116)	.974	1.0775	(0.8504, 1.3654)	.537	0.9952	(0.8282, 1.1959)	.959
3rd quintile	0.9132	(0.7438, 1.1211)	.385	0.8781	(0.6787, 1.1360)	.322	0.9185	(0.7562, 1.1156)	.391
4th quintile	0.8606	(0.6946, 1.0663)	.170	1.0298	(0.7998, 1.3259)	.820	0.8445	(0.6881, 1.0365)	.106
5th quintile (most deprived)	0.7981	(0.6322, 1.0076)	.058	1.0750	(0.8264, 1.3984)	.590	0.7707	(0.6184, 0.9606)	.020
Population density	1.0004	(0.9984, 1.0024)	.695	0.9999	(0.9975, 1.0023)	.949	0.9972	(0.9950, 0.9994)	.012

Table 18a continued

Constant	0.2594	(0.1823, 0.3691)	<.001	0.1852	(0.1201, 0.2854)	<.001	0.7168	(0.5168, 0.9942)	.046
N	3811			3811			3811		
Wald's $\chi 2$	305.93***			185.23***			212.76***		
Pearson goodness of fit $\chi 2$	2799			3123			2677		
Pseudo R2	.07			.05			.04		

Note. *** p <.001

Table 18b. Fully adjusted linear regression models predicting pro-environmental behaviours as a function of nature contact, nature connectedness whilst controlling for covariates, with green view operationalised as a binary variable (based on a median split)

	Household PEB				Nature Conservation PEB			
	b	**95% *CI b***	***β***	***p***	***b***	**95% *CI b***	***β***	***p***
Green view								
Low (*M* = 17.74)								
High (*M* = 34.68)	.1011	(.0178, .1844)	.0354	.017	.0226	(-.0284, .0737)	.0134	.384
Nature visits (≥ once a week)	.3885	(.2991, .4778)	.1358	<.001	.0258	(-.0289, .0805)	.0152	.356
Nature media (≥ once a week)	.1562	(.0614, .2511)	.0498	.001	.2674	(.2093, .3255)	.1438	<.001
Nature Connectedness (INS)	.1906	(.1643, .2168)	.2252	<.001	.0865	(.0705, .1026)	.1724	<.001
Female	.2261	(.1398, .3125)	.0787	<.001	-.0216	(-.0745, .0313)	-.0127	.423
Age								
18-29 (ref)								
30-39	-.0668	(-.1947, .0612)	-.0203	.306	-.1593	(-.2376, -.0809)	-.0817	<.001
40-49	.0361	(-.1044, .1766)	.0096	.615	-.1982	(-.2843, -.1122)	-.0892	<.001
50-59	.2309	(.0859, .3760)	.0599	.002	-.2210	(-.3098, -.1322)	-.0966	<.001
60+	.3133	(.1359, .4908)	.0862	.001	-.2492	(-.3579, -.1405)	-.1156	<.001
Marital status								
Single/widowed/divorced (ref)								
Married/cohabiting	-.0703	(-.1655, .0250)	-.0244	.148	.0366	(-.0218, .0949)	.0214	.219
Undisclosed	-.2630	(-.5094, -.0167)	-.0320	.036	.0206	(-.1302, .1715)	.0042	.789
Higher education (yes)	.3445	(.2556, .4334)	.1203	<.001	.1492	(.0948, .2036)	.0878	<.001
Working status								
Unemployed (ref)								
Employed	-.0122	(-.1668, .1424)	-.0042	.877	.0459	(-.0488, .1406)	.0266	.342
In education	.0490	(-.2220, .3201)	.0062	.723	.1822	(.0162, .3481)	.0390	.031
Retired	-.0478	(-.2668, .1712)	-.0113	.669	-.0360	(-.1701, .0981)	-.0143	.599
Other	-.0487	(-.2266, .1293)	-.0122	.592	-.0303	(-.1393, .0787)	-.0128	.586

Table 18b continued

Household income								
1st quintile (lowest, ref)								
2nd quintile	.1469	(.0020, .2918)	.0373	.047	-.0340	(-.1227, .0547)	-.0146	.452
3rd quintile	.1540	(.0115, .2965)	.0426	.034	-.0185	(-.1058, .0688)	-.0086	.678
4th quintile	.2280	(.0797, .3764)	.0625	.003	.0381	(-.0528, .1289)	.0176	.411
5th quintile (highest)	.3589	(.2058, .5119)	.1045	<.001	.0293	(-.0644, .1230)	.0144	.540
Undisclosed	-.0409	(-.2498, .1679)	-.0064	.701	-.0992	(-.2270, .0287)	-.0262	.129
Disability								
No (ref)								
Yes	-.0684	(-.1640, .0271)	-.0222	.160	.1623	(.1038, .2208)	.0886	<.001
Undisclosed	-.4995	(-.8316, -.1674)	-.0446	.003	-.0314	(-.2348, .1720)	-.0047	.762
Dog owner (yes)	-.0069	(-.0986, .0847)	-.0023	.882	.1175	(.0614, .1736)	.0657	<.001
Rec. physical activity (yes)	.2038	(.1090, .2985)	.0634	<.001	.0416	(-.0165, .0996)	.0218	.160
Covid-19 local lockdown (yes)	-.1179	(-.2265, -.0094)	-.0329	.033	.1423	(.0758, .2088)	.0669	<.001
Carstairs deprivation								
1st quintile (most deprived, ref)								
2nd quintile	.1381	(.0046, .2716)	.0386	.043	-.0006	(-.0823, .0812)	-.0003	.989
3rd quintile	.2397	(.1018, .3775)	.0672	.001	.0173	(-.0671, .1017)	.0082	.687
4th quintile	.2811	(.1386, .4235)	.0790	<.001	.0063	(-.0809, .0935)	.0030	.887
5th quintile (most deprived)	.2972	(.1481, .4462)	.0833	<.001	.0673	(-.0240, .1585)	.0318	.149
Population density	.0010	(-.0004, .0024)	.0233	.174	.0014	(.0005, .0022)	.0556	.002
Constant	.9110	(.6701, 1.1518)	.	<.001	-.1388	(-.2863, .0087)	.	.065
N	3811				3811			
Pseudo R2	.18				.12			

Note. PEB = pro-environmental behaviours

Table 18c. Fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of nature contact, nature connectedness, whilst controlling for covariates with green view operationalised in quartiles.

	Current Smoker			Exceeds Alcohol Guidelines			Poor Diet		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view									
1st quartile (*M* = 10.57 , ref)									
2nd quartile (*M* = 24.77)	1.0132	(0.8644, 1.1875)	.872	1.5109	(1.2453, 1.8332)	<.001	0.8788	(0.7497, 1.0301)	.111
3rd quartile (*M* = 31.52)	0.5204	(0.4321, 0.6267)	<.001	0.8093	(0.6519, 1.0047)	.055	0.8654	(0.7410, 1.0106)	.068
4th quartile (*M* = 40.73)	0.7759	(0.6345, 0.9488)	.013	0.9415	(0.7350, 1.2059)	.633	0.7262	(0.5932, 0.8892)	.002
Nature visits (≥ once a week)	0.9669	(0.8408, 1.1118)	.637	1.1172	(0.9477, 1.3169)	.187	0.9085	(0.7978, 1.0346)	.148
Nature media (≥ once a week)	1.3044	(1.1347, 1.4996)	<.001	1.2218	(1.0378, 1.4386)	.016	0.8556	(0.7400, 0.9893)	.035
Nature Connectedness (INS)	1.0520	(1.0110, 1.0946)	.012	0.9688	(0.9244, 1.0154)	.186	0.9190	(0.8852, 0.9542)	<.001
Female	0.8200	(0.7181, 0.9364)	.003	0.6379	(0.5456, 0.7457)	<.001	1.1871	(1.0455, 1.3478)	.008
Age									
18-29 (ref)									
30-39	1.3104	(1.0849, 1.5827)	.005	0.9788	(0.7755, 1.2356)	.857	0.9256	(0.7695, 1.1133)	.412
40-49	1.1900	(0.9665, 1.4652)	.101	0.9707	(0.7513, 1.2542)	.820	1.0415	(0.8528, 1.2719)	.690
50-59	1.0134	(0.8106, 1.2669)	.907	1.1743	(0.9056, 1.5227)	.226	1.0803	(0.8853, 1.3182)	.447
60+	0.7616	(0.5615, 1.0331)	.080	1.0843	(0.7855, 1.4968)	.623	0.9801	(0.7619, 1.2608)	.876
Marital status									
Single/widowed/divorced (ref)									
Married/cohabiting	0.9767	(0.8438, 1.1305)	.752	0.9850	(0.8281, 1.1716)	.864	0.9009	(0.7857, 1.0331)	.135
Undisclosed	1.0117	(0.7002, 1.4616)	.951	0.8292	(0.5103, 1.3476)	.450	1.0084	(0.7203, 1.4117)	.961
Higher education (yes)	0.8066	(0.6998, 0.9298)	.003	1.0033	(0.8540, 1.1787)	.968	0.7844	(0.6871, 0.8955)	<.001
Working status									
Unemployed (ref)									
Employed	1.0964	(0.8738, 1.3757)	.426	0.9310	(0.7080, 1.2243)	.609	0.9230	(0.7510, 1.1346)	.447
In education	0.5488	(0.3157, 0.9542)	.033	0.8867	(0.5233, 1.5025)	.655	0.6329	(0.4165, 0.9618)	.032
Retired	0.7381	(0.5009, 1.0878)	.125	0.9819	(0.6655, 1.4487)	.927	0.8193	(0.6010, 1.1168)	.207

Table 18c continued

Other	1.0446	(0.8076, 1.3512)		0.7021	(0.4983, 0.9891)	.043	0.9295	(0.7387, 1.1695)	.533
			.740						
Household income									
1st quintile (lowest, ref)					(0.7935, 1.3935)				
2nd quintile	0.7990	(0.6458, 0.9886)		1.0515	(0.8587, 1.4787)	.727	0.8207	(0.6755, 0.9972)	.047
3rd quintile	0.8103	(0.6575, 0.9986)	.039	1.1269	(0.9679, 1.6752)	.389	0.8886	(0.7321, 1.0785)	.232
4th quintile	0.7695	(0.6161, 0.9610)	.048	1.2734	(1.0621, 1.8541)	.084	0.8221	(0.6656, 1.0154)	.069
5th quintile (highest)	0.6719	(0.5307, 0.8508)	.021	1.4033	(0.4697, 1.2218)	.017	0.8737	(0.7020, 1.0875)	.227
Undisclosed	0.5225	(0.3476, 0.7853)	.001	0.7575		.255	0.9015	(0.6757, 1.2027)	.481
			.002						
Disability									
No (ref)					(1.0776, 1.5041)				
Yes	1.2350	(1.0701, 1.4253)		1.2731	(0.8147, 2.6579)	.005	1.4434	(1.2655, 1.6463)	<.001
Undisclosed	1.2560	(0.7543, 2.0914)	.004	1.4715		.200	1.1651	(0.7380, 1.8396)	.512
			.381		(0.9692, 1.3398)				
Dog owner (yes)	1.5631	(1.3654, 1.7894)		1.1395	(0.9170, 1.2772)	.114	1.0317	(0.9039, 1.1775)	.644
Rec. physical activity (yes)	0.9705	(0.8381, 1.1237)	<.001	1.0822	(1.3950, 1.9798)	.350	0.7432	(0.6381, 0.8656)	<.001
Covid-19 local lockdown (yes)	1.0950	(0.9361, 1.2810)	.689	1.6619		<.001	0.8262	(0.7023, 0.9720)	.021
			.257						
Carstairs deprivation									
1st quintile (most deprived, ref)					(0.8549, 1.3728)				
2nd quintile	1.0120	(0.8378, 1.2224)		1.0833	(0.6881, 1.1523)	.508	0.9893	(0.8232, 1.1889)	.909
3rd quintile	0.9159	(0.7459, 1.1246)	.901	0.8905	(0.8003, 1.3266)	.378	0.9157	(0.7539, 1.1122)	.374
4th quintile	0.8702	(0.7023, 1.0782)	.402	1.0304	(0.8379, 1.4169)	.817	0.8402	(0.6846, 1.0312)	.096
5th quintile (most deprived)	0.7985	(0.6325, 1.0080)	.204	1.0896		.522	0.7682	(0.6164, 0.9575)	.019
			.058		(0.9975, 1.0023)				
Population density	1.0004	(0.9985, 1.0024)		0.9999		.943	0.9972	(0.9950, 0.9994)	.012
			.666		(0.0941, 0.2299)				
Constant	0.2614	(0.1819, 0.3755)		0.1470		<.001	0.7624	(0.5441, 1.0684)	.115
N	3811		<.001	3811			3811		
Wald's $\chi 2$	318.13***			204.43***			218.25***		
Pearson goodness of fit $\chi 2$	2805.96			3121.27			2672.71		
Pseudo R2	.07			.05			.05		

Note. *** $p < .001$

Table 18d. fully adjusted linear regression models predicting pro-environmental behaviours as a function of nature contact, nature connectedness whilst controlling for covariates with green view operationalised in quartiles

	Household PEB				Nature Conservation PEB			
	b	**95% *CI b***	***β***	***p***	***b***	**95% *CI b***	***β***	***p***
Green view								
1st quartile (*M* = 10.57 , ref)								
2nd quartile (*M* = 24.77)	.0329	(-.0818, .1477)	.0102	.574	-.0420	(-.1123, .0283)	-.0218	.242
3rd quartile (*M* = 31.52)	.0975	(-.0130, .2080)	.0317	.084	.0031	(-.0646, .0708)	.0017	.928
4th quartile (*M* = 40.73)	.1567	(.0254, .2881)	.0406	.019	-.0020	(-.0825, .0784)	-.0009	.961
Nature visits (≥ once a week)	.3880	(.2986, .4773)	.1356	<.001	.0259	(-.0288, .0806)	.0153	.354
Nature media (≥ once a week)	.1557	(.0608, .2506)	.0497	.001	.2672	(.2091, .3253)	.1437	<.001
Nature Connectedness (INS)	.1903	(.1641, .2165)	.2249	<.001	.0865	(.0704, .1025)	.1722	<.001
Female	.2275	(.1411, .3139)	.0791	<.001	-.0225	(-.0754, .0304)	-.0132	.405
Age								
18-29 (ref)								
30-39	-.0697	(-.1978, .0584)	-.0212	.286	-.1577	(-.2361, -.0793)	-.0809	<.001
40-49	.0309	(-.1099, .1717)	.0083	.667	-.1960	(-.2822, -.1098)	-.0882	<.001
50-59	.2288	(.0836, .3740)	.0593	.002	-.2192	(-.3081, -.1303)	-.0958	<.001
60+	.3106	(.1330, .4881)	.0854	.001	-.2487	(-.3574, -.1399)	-.1153	<.001
Marital status								
Single/widowed/divorced (ref)								
Married/cohabiting	-.0700	(-.1653, .0253)	-.0243	.150	.0368	(-.0216, .0951)	.0215	.217
Undisclosed	-.2629	(-.5093, -.0164)	-.0320	.037	.0225	(-.1285, .1734)	.0046	.770
Higher education (yes)	.3442	(.2553, .4331)	.1202	<.001	.1487	(.0943, .2031)	.0876	<.001
Working status								
Unemployed (ref)								
Employed	-.0100	(-.1648, .1447)	-.0035	.899	.0446	(-.0501, .1393)	.0259	.356
In education	.0543	(-.2170, .3257)	.0069	.695	.1817	(.0156, .3479)	.0390	.032
Retired	-.0475	(-.2665, .1716)	-.0112	.671	-.0372	(-.1713, .0969)	-.0148	.587

Table 18d continued

Other	-.0488	(-.2268, .1292)	-.0123	.591	-.0305	(-.1395, .0785)	-.0129	.583
Household income								
1st quintile (lowest, ref)								
2nd quintile	.1462	(.0013, .2911)	.0371	.048	-.0340	(-.1228, .0547)	-.0146	.452
3rd quintile	.1523	(.0097, .2949)	.0422	.036	-.0178	(-.1051, .0695)	-.0083	.689
4th quintile	.2269	(.0785, .3753)	.0622	.003	.0391	(-.0517, .1300)	.0181	.399
5th quintile (highest)	.3563	(.2032, .5095)	.1037	<.001	.0314	(-.0624, .1251)	.0154	.512
Undisclosed	-.0440	(-.2530, .1649)	-.0069	.679	-.0969	(-.2248, .0311)	-.0256	.138
Disability								
No (ref)								
Yes	-.0682	(-.1638, .0274)	-.0221	.162	.1615	(.1030, .2200)	.0882	<.001
Undisclosed	-.4951	(-.8275, -.1628)	-.0442	.004	-.0306	(-.2341, .1729)	-.0046	.768
Dog owner (yes)	-.0079	(-.0995, .0838)	-.0026	.866	.1178	(.0616, .1739)	.0658	<.001
Rec. physical activity (yes)	.2029	(.1082, .2977)	.0631	<.001	.0419	(-.0161, .0999)	.0220	.157
Covid-19 local lockdown (yes)	-.1159	(-.2248, -.0071)	-.0323	.037	.1394	(.0728, .2061)	.0656	<.001
Carstairs deprivation								
1st quintile (most deprived, ref)								
2nd quintile	.1395	(.0060, .2730)	.0390	.041	-.0009	(-.0827, .0808)	-.0004	.983
3rd quintile	.2409	(.1030, .3788)	.0676	.001	.0163	(-.0682, .1007)	.0077	.706
4th quintile	.2832	(.1407, .4257)	.0796	<.001	.0056	(-.0817, .0928)	.0026	.900
5th quintile (most deprived)	.2983	(.1492, .4474)	.0836	<.001	.0662	(-.0251, .1576)	.0313	.155
Population density	.0010	(-.0004, .0024)	.0235	.171	.0014	(.0005, .0022)	.0553	.002
Constant	.8959	(.6471, 1.1447)	.	<.001	-.1163	(-.2687, .0360)	.	.135
N	3811				3811			
Pseudo R2	.18				.12			

Note. PEB = pro-environmental behaviours

Appendix 19. Study 4: calculation of area-level covariates

As outlined in Chapter 4 (section 4.2.2.3), area-level covariates were derived by linking respondents' partial postcodes (i.e. all but the last two digits of their full postcode) to 2011 census data by postcode sector (England and Wales, Office for National Statistics, 2011) and detailed characteristic postcode sectors[12] (Scotland, National Records for Scotland, 2011). The census data used to derive the area-level covariates is summarised in Table 19.

Table 19. Summary of data used to calculate Carstairs deprivation and population density

Variable	Numerator England & Wales	Denominator England & Wales	Numerator Scotland	Denominator Scotland
Carstairs Deprivation				
Proportion male unemployment: Males unemployed 16-74/ Economically active males 16-74	KS602EW0005	KS602EW0002+ KS602EW0003+ KS602EW0004+ KS602EW0005+ KS602EW0006	KS602SC005	KS602SC002+ KS602SC003+ KS602SC004+ KS602SC005+ KS602SC006
Proportion overcrowded households: (Over 1 and up to 1.5 persons per room + Over 1.5 persons per room) / All households	QS409EW0004+ QS409EW0005	QS409EW0001	QS409SC004+ QS409SC0005	QS409SC001
Proportion no car/vans ownership: No Cars or vans in household / All households	QS416EW0002	QS416EW0001	KS404SC002	KS404SC001
Proportion low social class: (L11.2+L12.2+L12.4+L12.5+L12.7+L13.1+L13.2+L13.4+L13.5) / All persons	QS607EW0035+ QS607EW0038+ QS607EW0040+ QS607EW0041+ QS607EW0043+ QS607EW0045+ QS607EW0046+ QS607EW0048+ QS607EW0049	QS607EW0001	QS607SC034+ QS607SC037+ QS607SC039+ QS607SC040+ QS607SC042+ QS607SC044+ QS607SC045+ QS607SC047+ QS607SC048+	QS607SC001
Population density (No. people per hectare)	QS102EW		QS102SC	

[12] In the Scottish census, detailed characteristic postcode sectors that cross council areas are split (e.g. PA11 3 includes Inverclyde and Renfrewshire), but are identifiable in the census output by the suffix 'part'. As a result there were a number of areas in Scotland (N =225) without unique partial postcodes. All detailed characteristic postcode sectors were included in the national Carstairs deprivation scores calculations, but respondents whose partial postcodes did not match a unique partial postcode where excluded from the analysis (N = 19).

Consistent with Wheeler (2014), Carstairs deprivation scores were calculated for all areas with available data (N = 9046) by standardising each of the fours variables to have a population-weighted mean of zero and a variance of one (z-score method). The sum of the four standardised values constitutes the overall Carstairs score (*M* = .00, *SD* = 3.04, range = -6.26 – 16.12), with higher values indicating high levels of material deprivation. The two area-level variables (population density and Carstairs score) were then merged with individual-level respondent data on partial postcode. Consistent with prior work (Morgan & Baker, 2006; Wang et al., 2019), population density was operationalised as a continuous variable (*M = 34.56*, *SD* = 34.37) and Carstairs deprivation in quintiles (*M* = .78, *SD* = 2.96).

Appendix 20. Study 4: unadjusted regression models

Unadjusted regression models (nature contact/connectedness indicators) are presented in Tables 20a -20d.

Table 20a. Unadjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of nature contact and nature connectedness.

	Current Smoker			Exceeds Alcohol Guidelines			Poor Diet		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view	0.9897	(0.9844, 0.9949)	<.001	0.9913	(0.9853, 0.9975)	.006	0.9932	(0.9882, 0.9982)	.007
Nature visits (≥ once a week)	0.9463	(0.8274, 1.0823)	.420	1.1903	(1.0165, 1.3937)	.030	0.7876	(0.6945, 0.8932)	<.001
Nature media (≥ once a week)	1.4481	(1.2635, 1.6598)	<.001	1.4249	(1.2159, 1.6699)	<.001	0.8453	(0.7324, 0.9756)	.022
Nature Connectedness (INS)	1.0315	(0.9916, 1.0730)	.124	0.9565	(0.9135, 1.0015)	.058	0.9118	(0.8785, 0.9463)	<.001
Constant	0.2558	(0.2065, 0.3167)	<.001	0.2220	(0.1738, 0.2835)	<.001	0.5773	(0.4785, 0.6966)	<.001
N	3811			3811			3811		
Wald's χ2	49.00***			34.59***			76.95***		
Pearson goodness of fit χ2	2867.64			3125.37			2725.14		
Pseudo R2	.01			.01			.02		

Notes.*** *p* <.001

Table 20c. Unadjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of nature contact, nature connectedness and their interaction terms.

	Current Smoker			**Exceeds Alcohol Guidelines**			**Poor Diet**		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view	0.9903	(0.9765, 1.0043)	.174	0.9908	(0.9756, 1.0063)	.244	1.0043	(0.9924, 1.0163)	.483
Nature visits (≥ once a week)	1.1474	(0.7927, 1.6610)	.466	1.4157	(0.9408, 2.1303)	.095	0.8526	(0.6142, 1.1835)	.341
Nature media (≥ once a	1.9224	(1.3150, 2.8103)	.001	1.4867	(0.9688, 2.2814)	.070	0.7991	(0.5502, 1.1606)	.239
week)	1.0865	(0.9922, 1.1898)	.073	0.9783	(0.8788, 1.0891)	.689	0.9831	(0.9038, 1.0693)	.691
Nature Connectedness (INS)									
	0.9998	(0.9969, 1.0028)	.895	1.0000	(0.9967, 1.0034)	.983	0.9970	(0.9942, 0.9998)	.037
Green view x INS	0.9564	(0.8833, 1.0355)	.271	0.9608	(0.8761, 1.0537)	.396	0.9815	(0.9097, 1.0589)	.630
Nature visits x INS	0.9399	(0.8681, 1.0176)	.126	0.9910	(0.9038, 1.0867)	.848	1.0108	(0.9315, 1.0970)	.796
Nature media x INS									
Constant	0.2082	(0.1384, 0.3131)	<.001	0.2048	(0.1296, 0.3237)	<.001	0.4371	(0.3105, 0.6154)	<.001
N	3,811			3,811			3,811		
Wald's $\chi2$	53.49(7)***			37.05(7)***			44.83(7)***		
Pearson goodness of fit $\chi2$	2867.23			3157.90			2771.03		
Pseudo R2	.01			.01			.02		

Notes.*** *p* <.001

Table 20c. Unadjusted linear regression models predicting pro-environmental behaviours as a function of nature contact and nature connectedness

	Household PEB				Nature Conservation PEB			
	b	**95% *CI b***	***β***	***p***	***b***	**95% *CI b***	***β***	***p***
Green view	.0064	(.0029, .0099)	.0543	<.001	-.0013	(-.0034, .0009)	-.0181	.247
Nature visits (≥ once a week)	.4827	(.3938, .5716)	.1687	<.001	.0745	(.0201, .1288)	.0439	.007
Nature media (≥ once a week)	.1302	(.0342, .2263)	.0415	.008	.3207	(.2620, .3795)	.1724	<.001
Nature Connectedness (INS)	.2107	(.1842, .2371)	.2490	<.001	.0768	(.0606, .0929)	.1530	<.001
Constant	1.3696	(1.2270, 1.5122)	.	<.001	.0423	(-.0449, .1295)	.	.342
N	3,811				3,811			
Pseudo R2	.12				.07			

Note. PEB = pro-environmental behaviours

Table 20d. Unadjusted linear regression models predicting pro-environmental behaviours as a function of nature contact, nature connectedness and their interaction terms

	Household PEB				Nature Conservation PEB			
	b	**95% *CI b***	***β***	***p***	***b***	**95% *CI b***	***β***	***p***
Green view	.0067	(-.0023, .0157)	.0565	.147	-.0050	(-.0105, .0005)	-.0714	.075
Nature visits (≥ once a week)	.2701	(.0272, .5129)	.0944	.029	-.0858	(-.2342, .0626)	-.0506	.257
Nature media (≥ once a week)	.2243	(-.0465, .4952)	.0715	.104	.2401	(.0746, .4056)	.1291	.004
Nature Connectedness (INS)	.1948	(.1334, .2563)	.2302	<.001	.0302	(-.0073, .0677)	.0602	.115
Green view x INS	.0000	(-.0020, .0019)	-.002	.961	.0009	(-.0003, .0021)	.0766	.138
Nature visits x INS	.0503	(-.0032, .1038)	.0911	.065	.0383	(.0056, .0710)	.1170	.022
Nature media x INS	-.0219	(-.0781, .0342)	-.0364	.444	.0170	(-.0173, .0513)	.0476	.330
Constant	1.4271	(1.1579, 1.6963)		<.001	.2275	(.0630, .3920)		.007
N	3, 811				3, 811			
Pseudo R2	.13				.07			

Note. PEB = pro-environmental behaviours

Appendix 21. Study 4: fully adjusted regression models

Table 21a. Fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of nature contact and nature connectedness whilst controlling for covariates

	Current Smoker			Exceeds Alcohol Guidelines			Poor Diet		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view	0.9925	(0.9873, 0.9977)	.005	0.9936	(0.9876, 0.9997)	.040	0.9946	(0.9896, 0.9997)	.037
Nature visits (≥ once a week)	0.9583	(0.8336, 1.1017)	.550	1.1184	(0.9489, 1.3181)	.182	0.9074	(0.7968, 1.0334)	.143
Nature media (≥ once a week)	1.3179	(1.1467, 1.5146)	<.001	1.2240	(1.0394, 1.4413)	.015	0.8562	(0.7405, 0.9898)	.036
Nature Connectedness (INS)	1.0519	(1.0109, 1.0946)	.013	0.9648	(0.9206, 1.0111)	.135	0.9182	(0.8843, 0.9533)	<.001
Female	0.8108	(0.7101, 0.9257)	.002	0.6274	(0.5367, 0.7333)	<.001	1.1923	(1.0503, 1.3536)	.007
Age									
18-29 (ref)									
30-39	1.3320	(1.1032, 1.6083)	.003	1.0208	(0.8091, 1.2879)	.862	0.9206	(0.7654, 1.1073)	.380
40-49	1.2219	(0.9924, 1.5044)	.059	1.0112	(0.7830, 1.3059)	.932	1.0386	(0.8505, 1.2682)	.710
50-59	1.0358	(0.8289, 1.2943)	.757	1.2317	(0.9502, 1.5966)	.115	1.0806	(0.8856, 1.3186)	.445
60+	0.7772	(0.5731, 1.0539)	.105	1.1155	(0.8074, 1.5411)	.507	0.9762	(0.7591, 1.2554)	.851
Marital status									
Single/widowed/divorced (ref)									
Married/cohabiting	0.9648	(0.8337, 1.1166)	.631	0.9785	(0.8223, 1.1643)	.806	0.8986	(0.7838, 1.0303)	.126
Undisclosed	0.9935	(0.6883, 1.4342)	.972	0.8325	(0.5124, 1.3526)	.459	1.0128	(0.7236, 1.4177)	.941
Higher education (yes)	0.7951	(0.6899, 0.9164)	.002	0.9837	(0.8376, 1.1554)	.842	0.7833	(0.6863, 0.8941)	<.001
Working status									
Unemployed (ref)									
Employed	1.0733	(0.8558, 1.3461)	.541	0.9009	(0.6855, 1.1841)	.454	0.9271	(0.7543, 1.1394)	.472
In education	0.5108	(0.2938, 0.8881)	.017	0.8343	(0.4926, 1.4132)	.501	0.6353	(0.4183, 0.9649)	.033
Retired	0.7213	(0.4900, 1.0617)	.098	0.9438	(0.6403, 1.3914)	.770	0.8195	(0.6014, 1.1166)	.207
Other	1.0511	(0.8128, 1.3593)	.704	0.6968	(0.4948, 0.9811)	.039	0.9282	(0.7377, 1.1679)	.525

Table 21a continued

Household income									
1st quintile (lowest, ref)									
2nd quintile	0.8027	(0.6488, 0.9930)	.043	1.0597	(0.7999, 1.4037)	.686	0.8181	(0.6733, 0.9940)	.043
3rd quintile	0.8206	(0.6662, 1.0108)	.063	1.1436	(0.8719, 1.5000)	.332	0.8863	(0.7302, 1.0756)	.222
4th quintile	0.7621	(0.6101, 0.9521)	.017	1.2785	(0.9721, 1.6815)	.079	0.8183	(0.6626, 1.0107)	.063
5th quintile (highest)	0.6897	(0.5452, 0.8725)	.002	1.4676	(1.1110, 1.9387)	.007	0.8705	(0.6995, 1.0832)	.214
Undisclosed	0.5335	(0.3551, 0.8015)	.002	0.7876	(0.4885, 1.2698)	.327	0.8942	(0.6704, 1.1927)	.447
Disability									
No (ref)									
Yes	1.2430	(1.0770, 1.4346)	.003	1.2679	(1.0728, 1.4985)	.005	1.4442	(1.2663, 1.6471)	<.001
Undisclosed	1.1989	(0.7207, 1.9943)	.485	1.4510	(0.8046, 2.6165)	.216	1.1722	(0.7426, 1.8503)	.495
Dog owner (yes)	1.5820	(1.3824, 1.8105)							
Rec. physical activity (yes)	0.9816	(0.8477, 1.1366)	<.001	1.1565	(0.9836, 1.3598)	.078	1.0326	(0.9048, 1.1783)	.635
Covid-19 local lockdown (yes)	1.1024	(0.9426, 1.2892)	.804	1.0903	(0.9239, 1.2866)	.306	0.7429	(0.6378, 0.8653)	<.001
			.222	1.6095	(1.3516, 1.9167)	<.001	0.8263	(0.7024, 0.9721)	.021
Carstairs deprivation									
1st quintile (most deprived, ref)									
2nd quintile	1.0044	(0.8316, 1.2130)	.964	1.0785	(0.8512, 1.3664)	.532	0.9937	(0.8269, 1.1941)	.946
3rd quintile	0.8956	(0.7297, 1.0991)	.291	0.8677	(0.6708, 1.1223)	.280	0.9145	(0.7530, 1.1106)	.367
4th quintile	0.8603	(0.6942, 1.0661)	.169	1.0285	(0.7987, 1.3244)	.828	0.8408	(0.6851, 1.0320)	.097
5th quintile (most deprived)	0.7775	(0.6159, 0.9815)	.034	1.0525	(0.8091, 1.3692)	.703	0.7626	(0.6119, 0.9504)	.016
Population density	1.0004	(0.9984, 1.0024)	.676	1.0000	(0.9975, 1.0024)	.984	0.9971	(0.9949, 0.9993)	.010
Constant	0.2632	(0.1814, 0.3818)	<.001	0.1898	(0.1206, 0.2987)	<.001	0.7773	(0.5504, 1.0976)	.152
N	3,811			3, 811			3, 811		
Wald's $\chi 2$	259.28(31)***			165.69(31)***			212.36(31)***		
Pearson goodness of fit $\chi 2$	2836.10			3131.06			2678.37		
Pseudo R2	.06			.04			.04		

Notes.*** *p* <.001

Table 21b. Fully adjusted linear regression models predicting pro-environmental behaviours as a function of nature contact and nature connectedness whilst controlling for covariates

	Household PEB				**Nature Conservation PEB**			
	b	**95% *CI b***	***β***	***p***	***b***	**95% *CI b***	***β***	***p***
Green view	.0046	(.0012, .0081)	.0391	.009	-.0005	(-.0026, .0016)	-.0072	.641
Nature visits (≥ once a week)	.3876	(.2982, .4769)	.1354	<.001	.0268	(-.0279, .0815)	.0158	.337
Nature media (≥ once a week)	.1553	(.0605, .2501)	.0495	.001	.2665	(.2085, .3246)	.1433	<.001
Nature Connectedness (INS)	.1906	(.1643, .2168)	.2252	<.001	.0870	(.0709, .1031)	.1733	<.001
Female	.2277	(.1414, .3141)	.0792	<.001	-.0211	(-.0739, .0318)	-.0123	.435
Age								
18-29 (ref)								
30-39	-.0690	(-.1970, .0589)	-.0210	.290	-.1589	(-.2372, -.0805)	-.0815	<.001
40-49	.0275	(-.1132, .1681)	.0073	.702	-.1971	(-.2832, -.1109)	-.0887	<.001
50-59	.2250	(.0800, .3701)	.0583	.002	-.2214	(-.3102, -.1325)	-.0967	<.001
60+	.3114	(.1339, .4888)	.0856	.001	-.2488	(-.3574, -.1401)	-.1154	<.001
Marital status								
Single/widowed/divorced (ref)								
Married/cohabiting	-.0692	(-.1644, .0261)	-.0240	.155	.0375	(-.0208, .0958)	.0219	.208
Undisclosed	-.2658	(-.5121, -.0194)	-.0324	.034	.0211	(-.1298, .1720)	.0043	.784
Higher education (yes)	.3449	(.2561, .4337)	.1205	<.001	.1503	(.0959, .2047)	.0885	<.001
Working status								
Unemployed (ref)								
Employed	-.0086	(-.1633, .1460)	-.0030	.913	.0459	(-.0488, .1406)	.0266	.342
In education	.0570	(-.2138, .3278)	.0072	.680	.1857	(.0199, .3516)	.0398	.028
Retired	-.0456	(-.2646, .1733)	-.0108	.683	-.0353	(-.1694, .0988)	-.0141	.606
Other	-.0466	(-.2246, .1313)	-.0117	.607	-.0318	(-.1408, .0772)	-.0135	.567

Table 21b continued

Household income								
1st quintile (lowest, ref)								
2nd quintile	.1482	(.0033, .2930)	.0376	.045	-.0337	(-.1224, .0551)	-.0144	.457
3rd quintile	.1511	(.0086, .2936)	.0419	.038	-.0177	(-.1050, .0696)	-.0083	.691
4th quintile	.2280	(.0797, .3763)	.0625	.003	.0398	(-.0510, .1306)	.0184	.391
5th quintile (highest)	.3543	(.2013, .5074)	.1031	<.001	.0300	(-.0637, .1237)	.0147	.530
Undisclosed	-.0440	(-.2528, .1649)	-.0069	.680	-.0979	(-.2258, .0300)	-.0258	.133
Disability								
No (ref)								
Yes	-.0666	(-.1622, .0290)	-.0216	.172	.1612	(.1027, .2198)	.0881	<.001
Undisclosed	-.4978	(-.8299, -.1657)	-.0445	.003	-.0306	(-.2340, .1728)	-.0046	.768
Dog owner (yes)	-.0092	(-.1008, .0824)	-.0030	.845	.1171	(.0610, .1732)	.0655	<.001
Rec. physical activity (yes)	.2011	(.1063, .2959)	.0626	<.001	.0420	(-.0161, .1000)	.0220	.156
Covid-19 local lockdown (yes)	-.1103	(-.2191, -.0015)	-.0308	.047	.1400	(.0734, .2067)	.0659	<.001
Carstairs deprivation								
1st quintile (most deprived, ref)								
2nd quintile	.1402	(.0067, .2737)	.0392	.040	-.0011	(-.0828, .0807)	-.0005	.980
3rd quintile	.2433	(.1055, .3812)	.0683	.001	.0176	(-.0669, .1020)	.0083	.684
4th quintile	.2852	(.1428, .4277)	.0801	<.001	.0060	(-.0813, .0932)	.0028	.893
5th quintile (most deprived)	.3051	(.1560, .4541)	.0855	<.001	.0680	(-.0232, .1593)	.0321	.144
Population density	.0010	(-.0004, .0024)	.0243	.157	.0014	(.0005, .0022)	.0550	.002
Constant	.8355	(.5824, 1.0887)	.	<.001	-.1185	(-.2735, .0365)	.	.134
N	3, 811				3, 811			
Pseudo R2	.18				.12			

Note. PEB = pro-environmental behaviours

Table 21c. Fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of nature contact, nature connectedness and their interaction terms whilst controlling for covariates

	Current Smoker			**Exceeds Alcohol Guidelines**			**Poor Diet**		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view	0.9952	(0.9817, 1.0088)	.486	0.9920	(0.9770, 1.0072)	.301	1.0074	(0.9955, 1.0195)	.225
Nature visits (≥ once a week)	1.2070	(0.8343, 1.7463)	.318	1.3852	(0.9129, 2.1018)	.126	0.9423	(0.6778, 1.3101)	.724
Nature media (≥ once a week)	1.5766	(1.0777, 2.3064)	.019	1.1987	(0.7722, 1.8607)	.419	0.7773	(0.5346, 1.1300)	.187
Nature Connectedness (INS)	1.1144	(1.0200, 1.2174)	.016	0.9819	(0.8827, 1.0923)	.737	0.9929	(0.9127, 1.0801)	.868
Green view x INS	0.9993	(0.9965, 1.0022)	.642	1.0004	(0.9970, 1.0037)	.834	0.9967	(0.9939, 0.9995)	.021
Nature visits x INS	0.9478	(0.8758, 1.0258)	.184	0.9491	(0.8644, 1.0421)	.273	0.9903	(0.9180, 1.0682)	.800
Nature media x INS	0.9620	(0.8888, 1.0413)	.338	1.0057	(0.9158, 1.1044)	.906	1.0223	(0.9423, 1.1091)	.595
Female	0.8089	(0.7083, 0.9237)	.002	0.6253	(0.5348, 0.7310)	<.001	1.1924	(1.0502, 1.3538)	.007
Age									
18-29 (ref)									
30-39	1.3350	(1.1055, 1.6122)	.003	1.0225	(0.8104, 1.2901)	.851	0.9180	(0.7632, 1.1043)	.364
40-49	1.2347	(1.0025, 1.5207)	.047	1.0168	(0.7872, 1.3134)	.898	1.0383	(0.8500, 1.2682)	.713
50-59	1.0393	(0.8316, 1.2988)	.735	1.2361	(0.9535, 1.6023)	.109	1.0760	(0.8818, 1.3130)	.471
60+	0.7782	(0.5736, 1.0557)	.107	1.1176	(0.8087, 1.5444)	.500	0.9676	(0.7520, 1.2450)	.798
Marital status									
Single/widowed/divorced (ref)									
Married/cohabiting	0.9627	(0.8319, 1.1141)	.610	0.9774	(0.8214, 1.1630)	.796	0.8960	(0.7813, 1.0274)	.116
Undisclosed	0.9889	(0.6847, 1.4282)	.952	0.8342	(0.5132, 1.3559)	.465	0.9995	(0.7139, 1.3993)	.998
Higher education (yes)	0.7972	(0.6918, 0.9186)	.002	0.9838	(0.8377, 1.1555)	.843	0.7842	(0.6870, 0.8951)	<.001
Working status									
Unemployed (ref)									
Employed	1.0738	(0.8563, 1.3464)	.538	0.9041	(0.6880, 1.1881)	.469	0.9181	(0.7469, 1.1285)	.417
In education	0.5120	(0.2945, 0.8902)	.018	0.8391	(0.4953, 1.4216)	.514	0.6261	(0.4121, 0.9511)	.028
Retired	0.7255	(0.4927, 1.0683)	.104	0.9458	(0.6414, 1.3947)	.779	0.8166	(0.5990, 1.1131)	.200
Other	1.0502	(0.8119, 1.3586)	.709	0.6990	(0.4963, 0.9844)	.040	0.9210	(0.7318, 1.1592)	.483

Table 21c continued

Household income									
1st quintile (lowest, ref)									
2nd quintile	0.8000	(0.6465, 0.9898)	.040	1.0609	(0.8009, 1.4054)	.680	0.8146	(0.6704, 0.9898)	.039
3rd quintile	0.8174	(0.6636, 1.0069)	.058	1.1444	(0.8725, 1.5011)	.330	0.8851	(0.7292, 1.0744)	.217
4th quintile	0.7643	(0.6117, 0.9550)	.018	1.2847	(0.9765, 1.6901)	.073	0.8151	(0.6598, 1.0069)	.058
5th quintile (highest)	0.6893	(0.5448, 0.8722)	.002	1.4719	(1.1138, 1.9450)	.007	0.8621	(0.6925, 1.0732)	.184
Undisclosed	0.5362	(0.3569, 0.8057)	.003	0.7952	(0.4931, 1.2823)	.347	0.8932	(0.6694, 1.1918)	.443
Disability									
No (ref)									
Yes	1.2373	(1.0716, 1.4286)	.004	1.2677	(1.0720, 1.4992)	.006	1.4508	(1.2721, 1.6546)	<.001
Undisclosed	1.1677	(0.7010, 1.9453)	.551	1.4287	(0.7916, 2.5786)	.236	1.1660	(0.7384, 1.8410)	.510
Dog owner (yes)	1.5814	(1.3817, 1.8100)	<.001	1.1549	(0.9822, 1.3580)	.081	1.0361	(0.9078, 1.1825)	.599
Rec. physical activity (yes)	0.9779	(0.8444, 1.1324)	.765	1.0892	(0.9228, 1.2855)	.312	0.7453	(0.6399, 0.8681)	<.001
Covid-19 local lockdown (yes)	1.1011	(0.9412, 1.2882)	.229	1.6121	(1.3536, 1.9201)	<.001	0.8326	(0.7077, 0.9795)	.027
Carstairs deprivation									
1st quintile (most deprived, ref)									
2nd quintile	1.0083	(0.8348, 1.2179)	.931	1.0813	(0.8533, 1.3702)	.518	0.9886	(0.8227, 1.1881)	.903
3rd quintile	0.8977	(0.7315, 1.1018)	.302	0.8684	(0.6714, 1.1233)	.283	0.9164	(0.7546, 1.1128)	.378
4th quintile	0.8578	(0.6921, 1.0631)	.161	1.0292	(0.7992, 1.3254)	.824	0.8406	(0.6850, 1.0316)	.097
5th quintile (most deprived)	0.7741	(0.6130, 0.9775)	.031	1.0516	(0.8082, 1.3684)	.708	0.7686	(0.6166, 0.9580)	.019
Population density	1.0005	(0.9985, 1.0025)	.654	1.0000	(0.9975, 1.0024)	.987	0.9972	(0.9950, 0.9994)	.011
Constant	0.2093	(0.1272, 0.3443)	<.001	0.1781	(0.0987, 0.3213)	<.001	0.5821	(0.3740, 0.9060)	.017
N	3, 811			3, 811			3, 811		
Wald's $\chi2$	262.98(34)***			166.93(34)***			218.12(34)***		
Pearson goodness of fit $\chi2$	2832.95			3123.81			2683.60		
Pseudo R2	.06			.04			.05		

Notes.*** *p* <.001

Table 21d. Fully adjusted linear regression models predicting pro-environmental behaviours as a function of nature contact, nature connectedness and their interaction terms, whilst controlling for covariates

	Household PEB				**Nature Conservation PEB**			
	b	**95% *CI b***	***β***	***p***	***b***	**95% *CI b***	***β***	***p***
Green view	.0041	(-.0048, .0129)	.0344	.367	-.0035	(-.0089, .0019)	-.0503	.202
Nature visits (≥ once a week)	.1816	(-.0560, .4191)	.0635	.134	-.1309	(-.2763, .0144)	-.0772	.077
Nature media (≥ once a week)	.3107	(.0453, .5761)	.0991	.022	.1677	(.0053, .3302)	.0902	.043
Nature Connectedness (INS)	.1753	(.1151, .2354)	.2071	<.001	.0435	(.0067, .0803)	.0866	.021
Green view x INS	.0001	(-.0017, .0020)	.0067	.891	.0007	(-.0004, .0019)	.0627	.215
Nature visits x INS	.0487	(-.0035, .1008)	.0881	.067	.0378	(.0059, .0697)	.1154	.020
Nature media x INS	-.0353	(-.0901, .0196)	-.0585	.207	.0211	(-.0125, .0546)	.0589	.218
Female	.2302	(.1439, .3166)	.0801	<.001	-.0195	(-.0724, .0334)	-.0114	.470
Age								
18-29 (ref)								
30-39	-.0704	(-.1984, .0576)	-.0214	.281	-.1588	(-.2371, -.0805)	-.0814	<.001
40-49	.0241	(-.1166, .1649)	.0064	.737	-.2024	(-.2885, -.1162)	-.0911	<.001
50-59	.2230	(.0779, .3680)	.0578	.003	-.2226	(-.3114, -.1338)	-.0973	<.001
60+	.3129	(.1354, .4904)	.0861	.001	-.2489	(-.3576, -.1403)	-.1154	<.001
Marital status								
Single/widowed/divorced (ref)								
Married/cohabiting	-.0676	(-.1628, .0277)	-.0234	.164	.0396	(-.0187, .0979)	.0232	.183
Undisclosed	-.2626	(-.5090, -.0161)	-.0320	.037	.0281	(-.1228, .1789)	.0058	.715
Higher education (yes)	.3446	(.2558, .4335)	.1204	<.001	.1490	(.0946, .2033)	.0877	<.001
Working status								
Unemployed (ref)								
Employed	-.0067	(-.1613, .1480)	-.0023	.933	.0454	(-.0493, .1400)	.0263	.347
In education	.0623	(-.2087, .3332)	.0079	.652	.1859	(.0201, .3517)	.0398	.028
Retired	-.0443	(-.2633, .1746)	-.0105	.692	-.0363	(-.1702, .0977)	-.0144	.596
Other	-.0449	(-.2229, .1331)	-.0113	.621	-.0306	(-.1395, .0783)	-.0130	.582

Table 21d continued

Household income								
1st quintile (lowest, ref)								
2nd quintile	.1478	(.0029, .2926)	.0375	.046	-.0346	(-.1232, .0541)	-.0148	.445
3rd quintile	.1511	(.0085, .2936)	.0418	.038	-.0170	(-.1042, .0702)	-.0079	.702
4th quintile	.2264	(.0780, .3748)	.0621	.003	.0372	(-.0536, .1281)	.0172	.421
5th quintile (highest)	.3556	(.2025, .5087)	.1035	<.001	.0301	(-.0636, .1238)	.0148	.529
Undisclosed	-.0519	(-.2608, .1571)	-.0081	.627	-.1016	(-.2295, .0263)	-.0268	.119
Disability								
No (ref)								
Yes	-.0698	(-.1655, .0259)	-.0226	.153	.1630	(.1044, .2216)	.0890	<.001
Undisclosed	-.4862	(-.8185, -.1539)	-.0434	.004	-.0180	(-.2214, .1854)	-.0027	.862
Dog owner (yes)	-.0095	(-.1011, .0821)	-.0031	.839	.1168	(.0608, .1729)	.0653	<.001
Rec. physical activity (yes)	.1998	(.1050, .2946)	.0622	<.001	.0417	(-.0163, .0997)	.0219	.159
Covid-19 local lockdown (yes)	-.1136	(-.2225, -.0047)	-.0317	.041	.1384	(.0717, .2050)	.0651	<.001
Carstairs deprivation								
1st quintile (most deprived, ref)								
2nd quintile	.1396	(.0061, .2730)	.0390	.040	-.0029	(-.0846, .0787)	-.0014	.944
3rd quintile	.2415	(.1036, .3793)	.0677	.001	.0165	(-.0679, .1008)	.0078	.702
4th quintile	.2830	(.1406, .4255)	.0795	<.001	.0067	(-.0805, .0939)	.0032	.880
5th quintile (most deprived)	.3030	(.1539, .4521)	.0849	<.001	.0700	(-.0213, .1612)	.0330	.133
Population density	.0010	(-.0004, .0024)	.0247	.149	.0014	(.0005, .0022)	.0552	.002
Constant	.8930	(.5580, 1.2280)	.	<.001	.0531	(-.1519, .2581)	.	.612
N	3,811				3,811			
Pseudo R^2	.18				.12			

Note. PEB = pro-environmental behaviours

Appendix 22. Study 4: robustness check – moderation by socio-economic status

Moderation models by education (Tables 22a-22b), income (Tables 22c- 22d), and neighbourhood deprivation (Tables 22e-22f) are presented below.

Table 22a. Fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of green view, education and their interaction terms whilst controlling for covariates

	Current Smoker			Exceeds Alcohol Guidelines			Poor Diet		
	PR	**95%** ***CI***	***p***	***PR***	**95%** ***CI***	***p***	***PR***	**95%** ***CI***	***p***
Green view	0.9946	(0.9878, 1.0014)	.120	0.9919	(0.9834, 1.0004)	.062	0.9942	(0.9879, 1.0005)	.072
Nature visits (≥ once a week)	0.9563	(0.8318, 1.0994)	.530	1.1352	(0.9638, 1.3370)	.129	0.9104	(0.7999, 1.0362)	.155
Nature media (≥ once a week)	1.3179	(1.1468, 1.5147)	<.001	1.2251	(1.0413, 1.4414)	.014	0.8475	(0.7332, 0.9797)	.025
Nature Connectedness (INS)	1.0513	(1.0103, 1.0939)	.014	0.9630	(0.9192, 1.0090)	.113	0.9164	(0.8828, 0.9514)	<.001
Higher education (yes)	0.9006	(0.6710, 1.2088)	.486	0.9263	(0.6611, 1.2978)	.656	0.7757	(0.5804, 1.0368)	.086
Green view x higher education (yes)	0.9949	(0.9845, 1.0055)	.345	1.0031	(0.9911, 1.0152)	.615	1.0001	(0.9898, 1.0105)	.980
Female	0.8096	(0.7091, 0.9244)	.002	0.6278	(0.5375, 0.7331)	<.001	1.1882	(1.0469, 1.3486)	.008
Age									
18-29 (ref)									
30-39	1.3316	(1.1028, 1.6077)	.003	1.0490	(0.8334, 1.3205)	.684	0.9151	(0.7616, 1.0995)	.344
40-49	1.2227	(0.9931, 1.5054)	.058	1.0145	(0.7863, 1.3091)	.912	1.0314	(0.8453, 1.2584)	.761
50-59	1.0343	(0.8276, 1.2924)	.767	1.2286	(0.9485, 1.5914)	.119	1.0737	(0.8807, 1.3090)	.482
60+	0.7788	(0.5743, 1.0561)	.108	1.1203	(0.8115, 1.5466)	.490	0.9742	(0.7581, 1.2519)	.838
Marital status									
Single/widowed/divorced (ref)									
Married/cohabiting	0.9645	(0.8334, 1.1162)	.628	0.9810	(0.8251, 1.1663)	.828	0.8983	(0.7839, 1.0294)	.123
Undisclosed	0.9942	(0.6888, 1.4351)	.975	0.9320	(0.5925, 1.4661)	.761	0.9931	(0.7122, 1.3846)	.967

Table 22a continued

Working status									
Unemployed (ref)									
Employed	1.0762	(0.8580, 1.3500)	.525	0.8935	(0.6820, 1.1706)	.414	0.9209	(0.7497, 1.1312)	.433
In education	0.5093	(0.2929, 0.8855)	.017	0.8246	(0.4877, 1.3943)	.472	0.6471	(0.4284, 0.9772)	.038
Retired	0.7241	(0.4919, 1.0658)	.102	0.9324	(0.6339, 1.3714)	.722	0.8160	(0.5990, 1.1114)	.197
Other	1.0543	(0.8152, 1.3635)	.687	0.6940	(0.4952, 0.9727)	.034	0.9342	(0.7433, 1.1741)	.559
Household income									
1st quintile (lowest, ref)									
2nd quintile	0.8047	(0.6504, 0.9956)	.045	1.0315	(0.7811, 1.3622)	.827	0.8206	(0.6759, 0.9965)	.046
3rd quintile	0.8224	(0.6676, 1.0131)	.066	1.1115	(0.8499, 1.4537)	.440	0.8859	(0.7303, 1.0748)	.219
4th quintile	0.7644	(0.6118, 0.9549)	.018	1.2442	(0.9485, 1.6321)	.115	0.8248	(0.6682, 1.0180)	.073
5th quintile (highest)	0.6905	(0.5459, 0.8734)	.002	1.4137	(1.0736, 1.8615)	.014	0.8812	(0.7093, 1.0947)	.253
Undisclosed	0.5359	(0.3567, 0.8052)	.003	0.7711	(0.4833, 1.2302)	.275	0.8812	(0.6633, 1.1706)	.383
Disability									
No (ref)									
Yes	1.2431	(1.0771, 1.4346)	.003	1.2705	(1.0760, 1.5003)	.005	1.4421	(1.2652, 1.6439)	<.001
Undisclosed	1.1918	(0.7164, 1.9827)	.499	1.4286	(0.8084, 2.5246)	.219	1.1494	(0.7354, 1.7965)	.541
Dog owner (yes)	1.5834	(1.3836, 1.8122)	<.001	1.1641	(0.9911, 1.3674)	.064	1.0357	(0.9080, 1.1815)	.601
Rec. physical activity (yes)	0.9806	(0.8469, 1.1355)	.794	1.0907	(0.9250, 1.2860)	.302	0.7388	(0.6344, 0.8603)	<.001
Covid-19 local lockdown (yes)	1.1025	(0.9427, 1.2893)	.222	1.5871	(1.3340, 1.8881)	<.001	0.8228	(0.7001, 0.9671)	.018
Carstairs deprivation									
1st quintile (most deprived, ref)									
2nd quintile	1.0050	(0.8322, 1.2138)	.958	1.0837	(0.8567, 1.3707)	.503	0.9890	(0.8237, 1.1875)	.906
3rd quintile	0.8937	(0.7282, 1.0969)	.282	0.8634	(0.6678, 1.1164)	.263	0.9127	(0.7519, 1.1078)	.355
4th quintile	0.8585	(0.6928, 1.0639)	.163	1.0353	(0.8047, 1.3321)	.787	0.8425	(0.6868, 1.0337)	.100
5th quintile (most deprived)	0.7765	(0.6151, 0.9802)	.033	1.0576	(0.8142, 1.3737)	.675	0.7666	(0.6162, 0.9538)	.017

Table 22a continued

Population density	1.0004	(0.9984, 1.0024)	.684	0.9999	(0.9974, 1.0023)	.912	0.9972	(0.9950, 0.9994)	.011
Constant	0.2505	(0.1703, 0.3686)	<.001	0.2011	(0.1258, 0.3217)	<.001	0.7963	(0.5574, 1.1374)	.211
N	3,811			3,811			3,811		
Wald's χ^2	260.17(32)†			165.59(32)†			216.10(32)†		
Pearson goodness of fit χ^2	2840.42			3171.76			2711.58		
Pseudo R^2	.06			.04			.04		

Note. † *p* <.001

Table 22b. Fully adjusted linear regression model predicting household pro-environmental as a function of green view, education and their interaction terms whilst controlling for covariates

	Household Pro-Environmental Behaviours			
	b	**95% *CI b***	***β***	***p***
Green view	.0027	(-.0020, .0074)	.0229	.258
Nature visits (≥ once a week)	.3889	(.2995, .4783)	.1359	<.001
Nature media (≥ once a week)	.1550	(.0601, .2498)	.0494	.001
Nature Connectedness (INS)	.1907	(.1645, .2169)	.2254	<.001
Higher education (yes)	.2380	(.0389, .4370)	.0831	.019
Green view x higher education (yes)	.0041	(-.0027, .0110)	.0448	.239
Female	.2286	(.1423, .3149)	.0795	<.001
Age				
18-29 (ref)				
30-39	-.0691	(-.1970, .0589)	-.0210	.290
40-49	.0264	(-.1142, .1671)	.0071	.712
50-59	.2258	(.0808, .3709)	.0585	.002
60+	.3104	(.1330, .4879)	.0854	.001
Marital status				
Single/widowed/divorced (ref)				
Married/cohabiting	-.0689	(-.1641, .0264)	-.0239	.156
Undisclosed	-.2651	(-.5114, -.0187)	-.0323	.035
Working status				
Unemployed (ref)				
Employed	-.0116	(-.1663, .1431)	-.0040	.883
In education	.0592	(-.2116, .3300)	.0075	.668
Retired	-.0492	(-.2683, .1698)	-.0116	.660
Other	-.0494	(-.2275, .1286)	-.0124	.586

Table 22b continued

Household income				
1st quintile (lowest, ref)				
2nd quintile	.1464	(.0015, .2913)	.0372	.048
3rd quintile	.1509	(.0084, .2935)	.0418	.038
4th quintile	.2272	(.0790, .3755)	.0623	.003
5th quintile (highest)	.3545	(.2015, .5075)	.1032	<.001
Undisclosed	-.0481	(-.2570, .1609)	-.0075	.652
Disability				
No (ref)				
Yes	-.0669	(-.1625, .0287)	-.0217	.170
Undisclosed	-.4910	(-.8232, -.1587)	-.0438	.004
Dog owner (yes)	-.0100	(-.1016, .0816)	-.0033	.830
Rec. physical activity (yes)	.2015	(.1068, .2963)	.0627	<.001
Covid-19 local lockdown (yes)	-.1111	(-.2199, -.0022)	-.0310	.045
Carstairs deprivation				
1st quintile (most deprived, ref)				
2nd quintile	.1403	(.0068, .2737)	.0392	.039
3rd quintile	.2453	(.1074, .3831)	.0688	<.001
4th quintile	.2865	(.1440, .4290)	.0805	<.001
5th quintile (most deprived)	.3056	(.1566, .4546)	.0856	<.001
Population density	.0010	(-.0004, .0024)	.0246	.151
Constant	.8844	(.6185, 1.1502)		<.001
N	3,811			
Pseudo R^2	.18			

Table 22c. Fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of green view, income and their interaction terms whilst controlling for covariates

	Current Smoker			**Exceeds Alcohol Guidelines**			**Poor Diet**		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view	0.9961	(0.9856, 1.0066)	.465	0.9810	(0.9656, 0.9967)	.018	0.9908	(0.9809, 1.0008)	.072
Nature visits (≥ once a week)	0.9585	(0.8338, 1.1020)	.552	1.1184	(0.9490, 1.3180)	.182	0.9063	(0.7957, 1.0322)	.138
Nature media (≥ once a week)	1.3244	(1.1522, 1.5223)	<.001	1.2224	(1.0377, 1.4398)	.016	0.8569	(0.7411, 0.9909)	.037
Nature Connectedness (INS)	1.0477	(1.0067, 1.0904)	.022	0.9675	(0.9230, 1.0141)	.168	0.9188	(0.8848, 0.9541)	<.001
Household income									
1st quintile (lowest, ref)									
2nd quintile	0.7406	(0.4616, 1.1881)	.213	1.0470	(0.5958, 1.8400)	.873	0.5871	(0.3779, 0.9122)	.018
3rd quintile	1.0397	(0.6779, 1.5948)	.858	0.7173	(0.4090, 1.2582)	.247	0.7912	(0.5239, 1.1948)	.265
4th quintile	0.8713	(0.5532, 1.3723)	.552	0.7875	(0.4514, 1.3738)	.400	0.7099	(0.4528, 1.1130)	.135
5th quintile (highest)	0.8762	(0.5601, 1.3708)	.563	1.2041	(0.7165, 2.0234)	.483	0.8168	(0.5261, 1.2680)	.367
Undisclosed	0.3298	(0.1445, 0.7527)	.008	0.2224	(0.0825, 0.5998)	.003	1.1916	(0.6529, 2.1748)	.568
Green view x Q1 income, ref									
Green view x Q2 income	1.0034	(0.9861, 1.0209)	.705	1.0008	(0.9782, 1.0239)	.946	1.0139	(0.9975, 1.0306)	.098
Green view x Q3 income	0.9903	(0.9748, 1.0060)	.224	1.0204	(0.9991, 1.0422)	.061	1.0049	(0.9898, 1.0202)	.530
Green view x Q4 income	0.9947	(0.9785, 1.0110)	.520	1.0209	(1.0001, 1.0422)	.049	1.0060	(0.9898, 1.0225)	.472
Green view x Q5 income	0.9904	(0.9750, 1.0061)	.228	1.0097	(0.9904, 1.0293)	.328	1.0029	(0.9876, 1.0185)	.710
Green view x income undisc.	1.0175	(0.9923, 1.0433)	.176	1.0474	(1.0177, 1.0780)	.002	0.9882	(0.9655, 1.0115)	.318
Female	0.8154	(0.7141, 0.9311)	.003	0.6295	(0.5384, 0.7359)	<.001	1.1916	(1.0496, 1.3527)	.007
Age									
18-29 (ref)									
30-39	1.3302	(1.1016, 1.6062)	.003	1.0179	(0.8068, 1.2843)	.881	0.9204	(0.7653, 1.1071)	.379
40-49	1.2228	(0.9928, 1.5060)	.058	1.0018	(0.7753, 1.2944)	.989	1.0448	(0.8556, 1.2759)	.667
50-59	1.0380	(0.8306, 1.2972)	.743	1.2204	(0.9414, 1.5821)	.133	1.0811	(0.8860, 1.3193)	.443
60+	0.7818	(0.5766, 1.0602)	.113	1.1126	(0.8049, 1.5380)	.518	0.9695	(0.7536, 1.2473)	.810

Table 22c continued

Marital status									
Single/widowed/divorced (ref)									
Married/cohabiting	0.9596	(0.8291, 1.1107)	.581	0.9851	(0.8275, 1.1727)	.866	0.8981	(0.7831, 1.0299)	.124
Undisclosed	0.9971	(0.6905, 1.4397)	.987	0.8525	(0.5244, 1.3857)	.520	0.9982	(0.7129, 1.3976)	.991
Higher education (yes)	0.7941	(0.6889, 0.9155)	.001	0.9721	(0.8274, 1.1420)	.730	0.7812	(0.6843, 0.8918)	<.001
Working status									
Unemployed (ref)									
Employed	1.0733	(0.8553, 1.3468)	.541	0.8851	(0.6730, 1.1640)	.383	0.9259	(0.7531, 1.1383)	.465
In education	0.5083	(0.2923, 0.8839)	.017	0.8183	(0.4829, 1.3866)	.456	0.6412	(0.4221, 0.9740)	.037
Retired	0.7215	(0.4900, 1.0626)	.098	0.9162	(0.6205, 1.3529)	.660	0.8222	(0.6029, 1.1212)	.216
Other	1.0546	(0.8151, 1.3643)	.686	0.6958	(0.4939, 0.9802)	.038	0.9230	(0.7334, 1.1615)	.494
Disability									
No (ref)									
Yes	1.2362	(1.0712, 1.4268)	.004	1.2608	(1.0666, 1.4902)	.007	1.4497	(1.2713, 1.6532)	<.001
Undisclosed	1.1813	(0.7098, 1.9662)	.521	1.4528	(0.8054, 2.6206)	.215	1.1886	(0.7528, 1.8765)	.458
Dog owner (yes)	1.5766	(1.3774, 1.8047)	<.001	1.1540	(0.9815, 1.3568)	.083	1.0315	(0.9038, 1.1773)	.645
Rec. physical activity (yes)	0.9868	(0.8521, 1.1428)	.859	1.0867	(0.9207, 1.2826)	.325	0.7444	(0.6390, 0.8672)	<.001
Covid-19 local lockdown (yes)	1.0970	(0.9379, 1.2832)	.247	1.5903	(1.3349, 1.8946)	<.001	0.8282	(0.7039, 0.9744)	.023
Carstairs deprivation									
1st quintile (most deprived, ref)									
2nd quintile	1.0027	(0.8302, 1.2111)	.978	1.0730	(0.8468, 1.3596)	.560	0.9978	(0.8303, 1.1992)	.982
3rd quintile	0.8948	(0.7289, 1.0986)	.288	0.8500	(0.6569, 1.0999)	.217	0.9157	(0.7539, 1.1122)	.374
4th quintile	0.8615	(0.6952, 1.0675)	.173	1.0216	(0.7933, 1.3154)	.869	0.8415	(0.6855, 1.0329)	.099
5th quintile (most deprived)	0.7768	(0.6153, 0.9807)	.034	1.0472	(0.8051, 1.3622)	.731	0.7606	(0.6101, 0.9482)	.015
Population density	1.0004	(0.9984, 1.0024)	.704	1.0000	(0.9976, 1.0025)	.978	0.9971	(0.9949, 0.9993)	.009

Table 22c continued

Constant	0.2458	(0.1597, 0.3781)	<.001	0.2567	(0.1481, 0.4449)	<.001	0.8488	(0.5708, 1.2623)	.418
N	3, 811			3, 811			3, 811		
Wald's χ2	265.59(36)†			178.59(36)†			217.60(36)†		
Pearson goodness of fit χ2	2833.87			3126.95			2676.03		
Pseudo R2	.06			.05			.05		

Note. † *p* <.001

Table 22d. Fully adjusted linear regression model predicting household pro-environmental as a function of green view, education and their interaction terms whilst controlling for covariates

	Household Pro-Environmental Behaviours			
	b	**95% *CI b***	***β***	***p***
Green view	-.0003	(-.0083, .0077)	-.0026	.941
Nature visits (≥ once a week)	.3881	(.2987, .4774)	.1356	<.001
Nature media (≥ once a week)	.1529	(.0580, .2479)	.0488	.002
Nature Connectedness (INS)[a]	.1922	(.1659, .2185)	.2271	<.001
Household income				
1st quintile (lowest, ref)				
2nd quintile	.0999	(-.2293, .4291)	.0254	.552
3rd quintile	-.0778	(-.3908, .2352)	-.0215	.626
4th quintile	.1627	(-.1609, .4862)	.0446	.324
5th quintile (highest)	.0889	(-.2273, .4051)	.0259	.581
Undisclosed	-.0352	(-.5015, .4311)	-.0055	.882
Green view x Q1 income, ref				
Green view x Q2 income	.0020	(-.0100, .0140)	.0141	.745
Green view x Q3 income	.0090	(-.0020, .0201)	.0736	.110
Green view x Q4 income	.0028	(-.0086, .0141)	.0224	.633
Green view x Q5 income	.0103	(-.0006, .0211)	.0895	.063
Green view x income undisc.	.0000	(-.0161, .0161)	.0000	<.001
Female	.2258	(.1394, .3121)	.0785	<.001
Age				
18-29 (ref)				
30-39	-.0657	(-.1937, .0623)	-.0200	.314
40-49	.0264	(-.1143, .1671)	.0071	.713
50-59	.2250	(.0800, .3701)	.0583	.002
60+	.3130	(.1354, .4905)	.0861	.001
Marital status				
Single/widowed/divorced (ref)				

Table 22d continued

Married/cohabiting	-.0654	(-.1607, .0299)	-.0227	.178
Undisclosed	-.2659	(-.5123, -.0194)	-.0324	.034
Higher education (yes)	.3454	(.2565, .4344)	.1206	<.001
Working status				
Unemployed (ref)				
Employed	-.0111	(-.1659, .1438)	-.0038	.889
In education	.0572	(-.2138, .3283)	.0073	.679
Retired	-.0509	(-.2704, .1686)	-.0120	.649
Other	-.0524	(-.2306, .1258)	-.0132	.564
Disability				
No (ref)				
Yes	-.0652	(-.1608, .0304)	-.0211	.181
Undisclosed	-.4915	(-.8236, -.1594)	-.0439	.004
Dog owner (yes)	-.0099	(-.1015, .0817)	-.0033	.832
Rec. physical activity (yes)	.2005	(.1057, .2954)	.0624	<.001
Covid-19 local lockdown (yes)	-.1083	(-.2172, .0006)	-.0302	.051
Carstairs deprivation				
1st quintile (most deprived, ref)				
2nd quintile	.1395	(.0061, .2730)	.0390	.040
3rd quintile	.2419	(.1040, .3799)	.0679	.001
4th quintile	.2818	(.1393, .4243)	.0792	<.001
5th quintile (most deprived)	.3032	(.1542, .4522)	.0849	<.001
Population density	.0010	(-.0003, .0024)	.0253	.141
Constant	9512	(.6413, 1.2612)		<.001.
N	3,811			
Pseudo R2	.18			

Table 22e. Fully adjusted Poisson regression models predicting the prevalence ratio (PR) of health risk behaviours as a function of green view, neighbourhood deprivation and their interaction terms whilst controlling for covariates

	Current Smoker			**Exceeds Alcohol Guidelines**			**Poor Diet**		
	PR	**95% *CI***	***p***	***PR***	**95% *CI***	***p***	***PR***	**95% *CI***	***p***
Green view	0.9983	(0.9881, 1.0087)	.754	0.9954	(0.9822, 1.0087)	.492	0.9938	(0.9831, 1.0048)	.268
Nature visits (≥ once a week)	0.9569	(0.8323, 1.1002)	.536	1.1093	(0.9411, 1.3077)	.216	0.9069	(0.7963, 1.0329)	.141
Nature media (≥ once a week)	1.3167	(1.1455, 1.5135)	<.001	1.2239	(1.0391, 1.4416)	.016	0.8571	(0.7413, 0.9910)	.037
Nature Connectedness (INS)	1.0522	(1.0112, 1.0950)	.012	0.9665	(0.9222, 1.0130)	.155	0.9178	(0.8839, 0.9530)	<.001
Carstairs deprivation									
1st quintile (most deprived, ref)									
2nd quintile	1.2972	(0.8618, 1.9526)	.212	1.4890	(0.8954, 2.4762)	.125	1.0179	(0.6745, 1.5359)	.933
3rd quintile	1.0563	(0.6831, 1.6334)	.805	0.8017	(0.4610, 1.3943)	.434	0.9573	(0.6291, 1.4567)	.839
4th quintile	0.9213	(0.5910, 1.4362)	.717	0.8676	(0.5189, 1.4507)	.588	0.8181	(0.5309, 1.2606)	.363
5th quintile (most deprived)	1.0360	(0.6401, 1.6766)	.886	1.2409	(0.7341, 2.0975)	.420	0.6261	(0.3856, 1.0167)	.058
Green view x Carstairs Dep.									
Green view x 1st quintile									
Green view x 2nd quintile	0.9894	(0.9746, 1.0045)	.168	0.9863	(0.9674, 1.0055)	.161	0.9990	(0.9839, 1.0144)	.900
Green view x 3rd quintile	0.9933	(0.9780, 1.0088)	.393	1.0031	(0.9836, 1.0229)	.759	0.9982	(0.9831, 1.0135)	.816
Green view x 4th quintile	0.9972	(0.9816, 1.0131)	.729	1.0066	(0.9888, 1.0247)	.468	1.0012	(0.9856, 1.0169)	.883
Green view x 5th quintile	0.9884	(0.9716, 1.0055)	.182	0.9933	(0.9750, 1.0120)	.482	1.0078	(0.9908, 1.0251)	.372
Female	0.8127	(0.7118, 0.9280)	.002	0.6314	(0.5401, 0.7381)	<.001	1.1924	(1.0502, 1.3537)	.007
Age									
18-29 (ref)									
30-39	1.3338	(1.1045, 1.6108)	.003	1.0206	(0.8087, 1.2881)	.863	0.9202	(0.7650, 1.1069)	.377
40-49	1.2237	(0.9936, 1.5071)	.057	1.0109	(0.7825, 1.3059)	.934	1.0420	(0.8532, 1.2726)	.687
50-59	1.0393	(0.8315, 1.2990)	.735	1.2404	(0.9566, 1.6085)	.104	1.0821	(0.8868, 1.3205)	.437
60+	0.7762	(0.5722, 1.0528)	.103	1.1149	(0.8067, 1.5409)	.510	0.9772	(0.7599, 1.2566)	.857
Marital status									
Single/widowed/divorced (ref)									
Married/cohabiting	0.9659	(0.8346, 1.1178)	.641	0.9790	(0.8227, 1.1651)	.811	0.8990	(0.7840, 1.0308)	.127

Table 22e continued									
Undisclosed	1.0041	(0.6954, 1.4497)	.983	0.8431	(0.5186, 1.3704)	.491	1.0109	(0.7221, 1.4151)	.950
Higher education (yes)	0.7962	(0.6907, 0.9179)	.002	0.9876	(0.8407, 1.1601)	.879	0.7830	(0.6860, 0.8939)	<.001
Working status									
Unemployed (ref)									
Employed	1.0757	(0.8575, 1.3495)	.528	0.9052	(0.6887, 1.1899)	.475	0.9252	(0.7528, 1.1372)	.460
In education	0.5145	(0.2959, 0.8946)	.019	0.8474	(0.5001, 1.4359)	.538	0.6339	(0.4173, 0.9628)	.033
Retired	0.7245	(0.4921, 1.0666)	.102	0.9484	(0.6431, 1.3986)	.789	0.8178	(0.6002, 1.1141)	.202
Other	1.0500	(0.8118, 1.3581)	.710	0.6984	(0.4958, 0.9836)	.040	0.9297	(0.7389, 1.1697)	.534
Household income									
1st quintile (lowest, ref)									
2nd quintile	0.7994	(0.6461, 0.9890)	.039	1.0549	(0.7963, 1.3976)	.709	0.8196	(0.6745, 0.9959)	.045
3rd quintile	0.8191	(0.6647, 1.0093)	.061	1.1332	(0.8636, 1.4869)	.367	0.8875	(0.7312, 1.0772)	.227
4th quintile	0.7585	(0.6071, 0.9477)	.015	1.2702	(0.9657, 1.6707)	.087	0.8205	(0.6643, 1.0135)	.066
5th quintile (highest)	0.6882	(0.5439, 0.8707)	.002	1.4616	(1.1062, 1.9312)	.008	0.8719	(0.7005, 1.0852)	.219
Undisclosed	0.5349	(0.3559, 0.8037)	.003	0.7870	(0.4883, 1.2685)	.325	0.8996	(0.6743, 1.2002)	.472
Disability									
No (ref)									
Yes	1.2456	(1.0793, 1.4375)	.003	1.2643	(1.0697, 1.4944)	.006	1.4445	(1.2664, 1.6476)	<.001
Undisclosed	1.2035	(0.7232, 2.0028)	.476	1.4476	(0.8025, 2.6114)	.219	1.1819	(0.7485, 1.8660)	.473
Dog owner (yes)	1.5886	(1.3878, 1.8184)	<.001	1.1588	(0.9851, 1.3630)	.075	1.0329	(0.9050, 1.1789)	.631
Rec. physical activity (yes)	0.9823	(0.8482, 1.1375)	.811	1.0881	(0.9219, 1.2843)	.318	0.7429	(0.6378, 0.8653)	<.001
Covid-19 local lockdown (yes)	1.0993	(0.9400, 1.2857)	.236	1.6052	(1.3476, 1.9120)	<.001	0.8253	(0.7015, 0.9710)	.021
Population density	1.0004	(0.9984, 1.0024)	.674	1.0000	(0.9976, 1.0024)	.991	0.9972	(0.9950, 0.9994)	.011
Constant	0.2267	(0.1464, 0.3511)	<.001	0.1807	(0.1051, 0.3106)	<.001	0.7908	(0.5194, 1.2040)	.274
N	3,811			3, 811			3,811		
Wald's $\chi 2$	262.19(35)†			171.39(35)†			213.81(35)†		
Pearson goodness of fit $\chi 2$	2835.17			.05			2674.89		
Pseudo R2	.06						.04		

Note. † *p* <.001

Table 22f. Fully adjusted linear regression model predicting household pro-environmental as a function of green view, neighbourhood deprivation and their interaction terms whilst controlling for covariates

	Household Pro-Environmental Behaviours			
	b	**95% *CI b***	***β***	***p***
Green view	.0086	(.0011, .0162)	.0732	.026
Nature visits (≥ once a week)	.3887	(.2993, .4781)	.1359	<.001
Nature media (≥ once a week)	.1535	(.0586, .2484)	.0490	.002
Nature Connectedness (INS)	.1907	(.1644, .2169)	.2253	<.001
Carstairs deprivation				
1st quintile (most deprived, ref)				
2nd quintile	.1927	(-.1146, .5000)	.0538	.219
3rd quintile	.5002	(.1941, .8063)	.1403	.001
4th quintile	.3872	(.0813, .6930)	.1088	.013
5th quintile (most deprived)	.4024	(.0774, .7274)	.1127	.015
Green view x Carstairs Dep.				
Green view x 1st quintile				
Green view x 2nd quintile	-.0020	(-.0129, .0089)	-.0162	.714
Green view x 3rd quintile	-.0099	(-.0205, .0007)	-.0824	.066
Green view x 4th quintile	-.0040	(-.0145, .0066)	-.0329	.460
Green view x 5th quintile	-.0038	(-.0149, .0073)	-.0313	.501
Female	.2266	(.1402, .3130)	.0788	<.001
Age				
18-29 (ref)				
30-39	-.0682	(-.1962, .0598)	-.0207	.296
40-49	.0314	(-.1093, .1722)	.0084	.662
50-59	.2271	(.0820, .3722)	.0589	.002
60+	.3138	(.1364, .4913)	.0863	.001

Table 22f continued				
Marital status				
Single/widowed/divorced (ref)				
Married/cohabiting	-.0679	(-.1631, .0274)	-.0236	.162
Undisclosed	-.2619	(-.5083, -.0155)	-.0319	.037
Higher education (yes)	.3431	(.2542, .4320)	.1198	<.001
Working status				
Unemployed (ref)				
Employed	-.0083	(-.1630, .1464)	-.0029	.916
In education	.0584	(-.2125, .3293)	.0074	.673
Retired	-.0455	(-.2645, .1735)	-.0108	.684
Other	-.0459	(-.2239, .1321)	-.0115	.613
Household income				
1st quintile (lowest, ref)				
2nd quintile	.1489	(.0040, .2938)	.0378	.044
3rd quintile	.1566	(.0139, .2992)	.0434	.031
4th quintile	.2296	(.0813, .3780)	.0630	.002
5th quintile (highest)	.3546	(.2016, .5077)	.1032	<.001
Undisclosed	-.0384	(-.2473, .1706)	-.0060	.719
Disability				
No (ref)				
Yes	-.0645	(-.1601, .0311)	-.0209	.186
Undisclosed	-.4976	(-.8299, -.1653)	-.0444	.003
Dog owner (yes)	-.0066	(-.0983, .0851)	-.0022	.888
Rec. physical activity (yes)	.2037	(.1089, .2985)	.0634	<.001
Covid-19 local lockdown (yes)	-.1117	(-.2205, -.0028)	-.0312	.044
Population density	.0010	(-.0004, .0024)	.0250	.145
Constant	.7257	(.4167, 1.0346)	.	<.001
N	3, 811			
Pseudo R^2	.18			

Appendix 23. Study 4: robustness check – ever smoking and smoking cessation

Table 23: Fully adjusted modified Poisson regression models estimating prevalence ratio of smoking outcomes for neighbourhood greenspace, neighbourhood deprivation and their interaction terms, controlling for other individual and area-level covariates

	Ever Smoking			**Smoking Cessation**		
	PR	***95% CIs***	***p***	***PR***	***95% CIs***	***p***
Green view	0.9938	(0.9911, 0.9965)	<.001	1.0012	(0.9978, 1.0046)	.484
Nature visits (≥ once a week)	0.9659	(0.9016, 1.0347)	.323	1.0037	(0.9109, 1.1059)	.941
Nature media (≥ once a week)	1.0933	(1.0209, 1.1707)	.011	0.8194	(0.7345, 0.9141)	<.001
Nature Connectedness (INS)	1.0460	(1.0258, 1.0666)	<.001	0.9929	(0.9642, 1.0224)	.632
Female	0.8090	(0.7582, 0.8631)	<.001	1.0269	(0.9337, 1.1295)	.584
Age						
18-29 (ref)						
30-39	1.2952	(1.1700, 1.4339)	<.001	0.9778	(0.8224, 1.1625)	.799
40-49	1.2682	(1.1357, 1.4161)	<.001	1.0556	(0.8779, 1.2693)	.565
50-59	1.2180	(1.0842, 1.3683)	.001	1.2096	(1.0099, 1.4487)	.039
60+	1.3237	(1.1557, 1.5161)	<.001	1.5372	(1.2760, 1.8519)	<.001
Marital status						
Single/widowed/divorced (ref)						
Married/cohabiting	1.0260	(0.9553, 1.1018)	.482	1.0618	(0.9536, 1.1822)	.274
Undisclosed	1.0035	(0.8233, 1.2231)	.973	0.9805	(0.6982, 1.3769)	.909
Higher education (yes)	0.8797	(0.8208, 0.9429)	<.001	1.1033	(1.0018, 1.2151)	.046
Working status						
Unemployed (ref)						
Employed	1.0616	(0.9471, 1.1899)	.305	1.0134	(0.8367, 1.2276)	.891
In education	0.6531	(0.4787, 0.8911)	.007	1.3556	(0.9208, 1.9959)	.123
Retired	0.9233	(0.7840, 1.0873)	.339	1.1309	(0.9157, 1.3966)	.253
Other	1.0152	(0.8913, 1.1562)	.821	0.9668	(0.7780, 1.2015)	.761

Table 23 continued

Household income						
1st quintile (lowest, ref)						
2nd quintile	0.9415	(0.8484, 1.0447)	.256	1.2124	(1.0285, 1.4290)	.022
3rd quintile	0.9635	(0.8704, 1.0667)	.474	1.2075	(1.0243, 1.4236)	.025
4th quintile	0.9234	(0.8289, 1.0287)	.148	1.2304	(1.0375, 1.4591)	.017
5th quintile (highest)	0.7960	(0.7068, 0.8965)	<.001	1.2005	(0.9954, 1.4478)	.056
Undisclosed	0.6614	(0.5347, 0.8180)	<.001	1.2905	(1.0067, 1.6544)	.044
Disability						
No (ref)						
Yes	1.2854	(1.2012, 1.3754)	<.001	1.0209	(0.9257, 1.1260)	.679
Undisclosed	1.0209	(0.7427, 1.4034)	.899	0.7857	(0.4663, 1.3238)	.365
Dog owner (yes)	1.3065	(1.2229, 1.3957)	<.001	0.8107	(0.7279, 0.9029)	<.001
Rec. physical activity (yes)	0.9830	(0.9149, 1.0562)	.639	1.0172	(0.9162, 1.1295)	.749
Covid-19 local lockdown (yes)	1.1259	(1.0449, 1.2133)	.002	1.0290	(0.9115, 1.1617)	.644
Carstairs deprivation						
1st quintile (most deprived, ref)						
2nd quintile	1.0102	(0.9236, 1.1049)	.824	0.9901	(0.8535, 1.1485)	.895
3rd quintile	0.8689	(0.7839, 0.9632)	.008	0.9643	(0.8223, 1.1307)	.654
4th quintile	0.8631	(0.7765, 0.9594)	.006	1.0079	(0.8600, 1.1812)	.923
5th quintile (most deprived)	0.8945	(0.8013, 0.9985)	.047	1.1388	(0.9730, 1.3328)	.106
Population density	1.0006	(0.9997, 1.0015)	.220	1.0001	(0.9986, 1.0016)	.894
Constant	0.4090	(0.3385, 0.4943)	<.001	0.3555	(0.2632, 0.4803)	<.001
N	3,811			1838		
Wald's $\chi 2$	213.90***			79.47***		
Pearson goodness of fit $\chi 2$	1950.28			939.09		
Pseudo R2	.03			.03		

Appendix 24: robustness check – nature visits and alcohol consumption

Respondents who indicated that they had visited natural spaces within the last month were presented with an additional question: 'How many of these visits involved the consumption of alcohol?' Response options were (1. none; 2. alcohol consumed on some visits; 3. alcohol consumed on most visits; 4. alcohol consumed on every visit). The item was dichotomised according to whether respondents consumed alcohol on nature visits (N = 686; Response options 2 - 4) *vs*. those who did not (N= 2474, Response option 1). Table 24 presents the results of an additional Poisson regression model estimating the prevalence of exceeding alcohol limits as a function of nature visits, the tendency to consume alcohol on nature visits and their interaction term (plus covariates), amongst the sub-sample of individuals who had visited nature at least once in the last month (N =3,160). The interaction term is depicted in Figure 1, for individuals who did not consume alcohol on nature visits there was little difference in prevalence of exceeding alcohol guidelines as a function of visit frequency. However, for individuals who reported consuming alcohol on visits to natural spaces, the prevalence of exceeding alcohol guidelines was higher amongst those than visited at least once a week, compared to those that visited less than weekly.

Table 24. Poisson regression model estimating the prevalence of exceeding alcohol limits as a function of nature visits, the tendency to consume alcohol on nature visits and their interaction term whilst controlling for covariates

	Exceeds Alcohol limits		
	PR	***95% CIs***	***p***
Green view	0.9872	(0.9762, 0.9984)	.025
Nature visits (≥ once a week)	1.0233	(0.6775, 1.5456)	.913
Nature media (≥ once a week)	1.6575	(1.2152, 2.2609)	.001
Nature Connectedness (INS)	1.0708	(0.9772, 1.1734)	.143
Regularly drinks on nature visits (yes)	1.3000	(0.6711, 2.5182)	.437
Visits once a week x drinks (yes)	2.2533	(1.1039, 4.5995)	.026
Female	0.6103	(0.4452, 0.8366)	.002
Age			
18-29 (ref)			
30-39	1.3181	(0.7961, 2.1823)	.283
40-49	1.6155	(0.9278, 2.8130)	.090
50-59	2.1718	(1.2235, 3.8549)	.008
60+	3.8548	(2.0465, 7.2611)	<.001
Marital status			
Single/widowed/divorced (ref)			
Married/cohabiting	1.1577	(0.8102, 1.6541)	.421
Undisclosed	0.4325	(0.1034, 1.8092)	.251
Higher education (yes)	1.1730	(0.8551, 1.6090)	.323
Working status			
Unemployed (ref)			
Employed	0.6757	(0.3929, 1.1622)	.157

Table 24 continued			
In education	0.3626	(0.0805, 1.6335)	.187
Retired	0.9907	(0.4999, 1.9633)	.979
Other	0.7180	(0.3644, 1.4145)	.338
Household income			
1st quintile (lowest, ref)			
2nd quintile	0.7054	(0.3864, 1.2876)	.256
3rd quintile	0.9199	(0.5295, 1.5983)	.767
4th quintile	1.0150	(0.5957, 1.7293)	.956
5th quintile (highest)	1.2185	(0.7077, 2.0980)	.476
Undisclosed	1.0456	(0.4597, 2.3781)	.915
Disability			
No (ref)			
Yes	1.4064	(1.0249, 1.9298)	.035
Undisclosed	3.2086	(1.2450, 8.2692)	.016
Dog owner (yes)	1.1250	(0.8175, 1.5481)	.470
Rec. physical activity (yes)	0.8986	(0.6546, 1.2335)	.508
Covid-19 local lockdown (yes)	1.9540	(1.3888, 2.7493)	<.001
Carstairs deprivation			
1st quintile (most deprived, ref)			
2nd quintile	1.0015	(0.6017, 1.6668)	.995
3rd quintile	0.7972	(0.4591, 1.3843)	.421
4th quintile	1.2748	(0.7779, 2.0892)	.335
5th quintile (most deprived)	1.5344	(0.9267, 2.5407)	.096
Population density	1.0008	(0.9963, 1.0052)	.730
Constant	0.0173	(0.0066, 0.0456)	<.001
N	3160		
Wald's χ^2	219.69***		
Pearson goodness of fit χ^2	2506.13		
Pseudo R^2	.07		

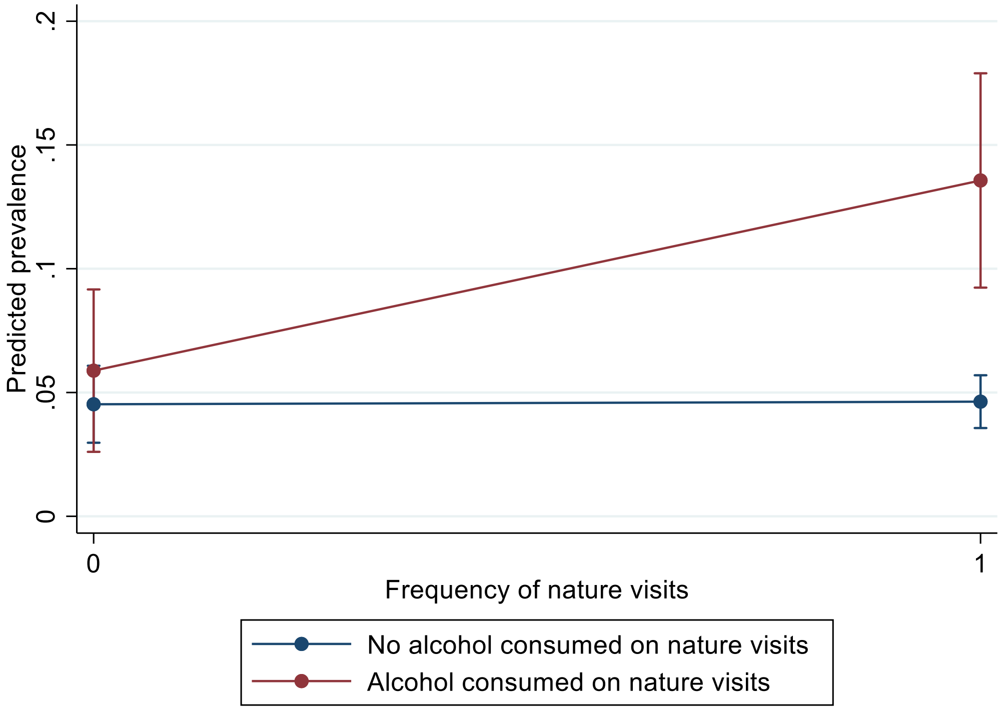
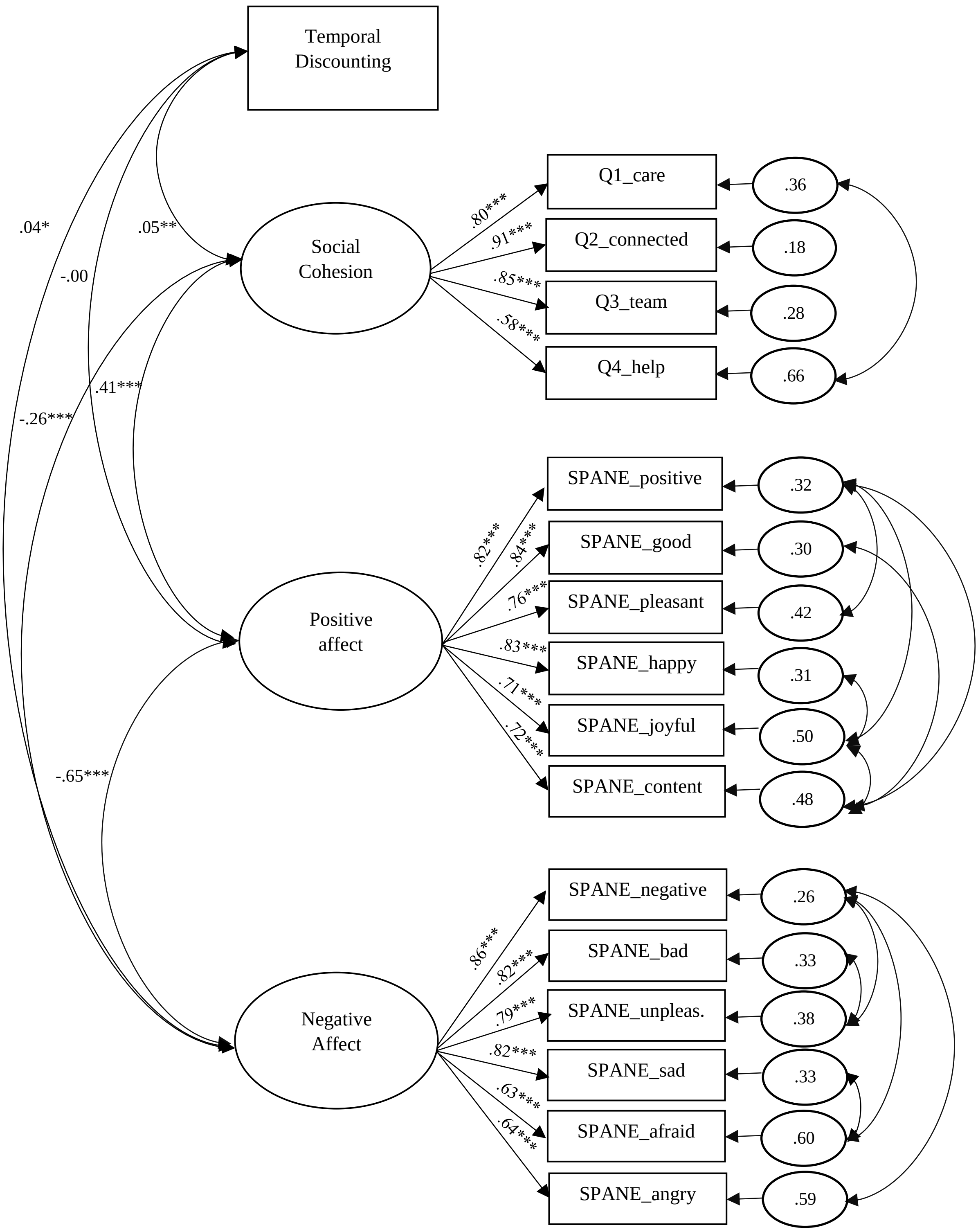


Figure 1. Predicted prevalence of exceeding alcohol guidelines as a function of tendency to consume alcohol on nature visits and visit frequency

Appendix 25. Study 4: measurement model (CFA)



Appendix 26. Study 4: structural model

Covariates were entered into the SEM to predict mediator and outcome variables. Covariate operationalisation was consistent with the regression models. Notably, the following dummy variables were entered into the model: gender (female, male = reference); age (18-29 = reference, 30-39, 40=49, 50-59, 60+); long-term limiting illness or disability (no = reference, yes, undisclosed); completed higher education (yes, no = reference); working status (unemployed= reference, employed, in education, retired, other); marital status (married/cohabiting, single/widowed/divorced = reference, undisclosed); dog ownership (yes, no = reference); recommended physical activity (yes, no = reference); Covid-19 local lockdown (yes, no = reference) population density (continuous variable); quintiles of Carstairs deprivation score (1st quintile = reference).

Table 26. Full Structural Equation Model including covariates

Outcome	Predictor	β	*SE*	95% *CIs*	*p*
Positive affect	Green view	.0411	.0172	(.0074, .0747)	.017
R^2 = .142	Nature visits	.0986	.0173	(.0647, .1324)	<.001
	Nature media	.0103	.0164	(-.0219, .0424)	.531
	Nature connectedness	.1577	.0181	(.1221, .1933)	<.001
	Female	-.0436	.0166	(-.0762, -.0111)	.009
	Age 30-39	.0117	.0210	(-.0294, .0528)	.577
	Age 40-49	-.0287	.0212	(-.0704, .0129)	.176
	Age 50-59	.0061	.0215	(-.0361, .0482)	.778
	Age 60+	.1083	.0265	(.0563, .1603)	<.001
	Marital status- married/cohabiting	.1105	.0181	(.0750, .1459)	<.001
	Marital status- undisclosed	.0124	.0169	(-.0207, .0454)	.463
	Higher education (yes)	.0237	.0170	(-.0095, .0570)	.162
	Work status- employed	.1217	.0296	(.0637, .1797)	<.001
	Work status -in education	.0624	.0187	(.0257, .0990)	.001
	Work status -retired	.1476	.0289	(.0910, .2042)	<.001
	Work status -other	.0721	.0250	(.0232, .1211)	.004

	Income- 2nd quintile	.0114	.0204	(-.0285, .0513)	.576
	Income- 3rd quintile	.0174	.0223	(-.0263, .0611)	.435
	Income -4th quintile	.0498	.0227	(.0054, .0942)	.028
	Income- 5th quintile (highest)	.0893	.0248	(.0406, .1380)	<.001
	Income- undisclosed	.0367	.0180	(.0015, .0719)	.041
	Disability- yes	-.1784	.0169	(-.2116, -.1452)	<.001
	Disability- undisclosed	-.0404	.0166	(-.0729, -.0080)	.015
	Dog owner (yes)	.0061	.0215	(-.0361, .0482)	.778
	Rec. physical activity (yes)	.0454	.0161	(.0138, .0770)	.005
	Covid-19 local lockdown (yes)	.0240	.0168	(-.0090, .0570)	.154
	Carstairs - 2nd quintile	-.0042	.0202	(-.0439, .0355)	.836
	Carstairs -3rd quintile	-.0107	.0203	(-.0505, .0291)	.598
	Carstairs - 4th quintile	.0008	.0205	(-.0394, .0409)	.970
	Carstairs -5th quintile	-.0133	.0204	(-.0533, .0266)	.513
	Population density	.0498	.0227	(.0054, .0942)	.028
Negative Affect	Green view	-.0241	.0174	(-.0582, .0101)	.167
R^2 = .173	Nature visits	-.0372	.0166	(-.0697, -.0047)	.025
	Nature media	.0242	.0163	(-.0077, .0561)	.138
	Nature connectedness	-.0687	.0178	(-.1036, -.0339)	<.001
	Female	.0802	.0162	(.0484, .1120)	<.001
	Age 30-39	-.0559	.0202	(-.0956, -.0162)	.006
	Age 40-49	-.0853	.0198	(-.1241, -.0464)	<.001
	Age 50-59	-.1367	.0204	(-.1766, -.0968)	<.001
	Age 60+	-.2638	.0254	(-.3135, -.2141)	<.001
	Marital status- married/cohabiting	-.0430	.0176	(-.0774, -.0086)	.014
	Marital status- undisclosed	-.0125	.0160	(-.0440, .0189)	.435
	Higher education (yes)	.0230	.0163	(-.0090, .0550)	.158
	Work status- employed	-.1538	.0284	(-.2094, -.0982)	<.001
	Work status -in education	-.0715	.0170	(-.1048, -.0381)	<.001
	Work status -retired	-.1913	.0276	(-.2454, -.1371)	<.001
	Work status -other	-.0990	.0241	(-.1463, -.0517)	<.001
	Income- 2nd quintile	.0105	.0196	(-.0279, .0489)	.592
	Income- 3rd quintile	.0169	.0216	(-.0255, .0593)	.434
	Income -4th quintile	-.0349	.0215	(-.0771, .0072)	.104
	Income- 5th quintile (highest)	.0024	.0238	(-.0442, .0490)	.920
	Income- undisclosed	-.0026	.0169	(-.0357, .0305)	.879
	Disability- yes	.2466	.0160	(.2152, .2781)	<.001
	Disability- undisclosed	.0137	.0176	(-.0207, .0481)	.435
	Dog owner (yes)	-.0383	.0160	(-.0697, -.0070)	.017

	Rec. physical activity (yes)	-.0169	.0155	(-.0474, .0135)	.276
	Covid-19 local lockdown (yes)	.0453	.0163	(.0133, .0774)	.006
	Carstairs - 2nd quintile	-.0108	.0198	(-.0497, .0280)	.585
	Carstairs -3rd quintile	-.0181	.0200	(-.0574, .0212)	.366
	Carstairs - 4th quintile	.0084	.0202	(-.0312, .0480)	.679
	Carstairs -5th quintile	-.0042	.0198	(-.0431, .0346)	.830
	Population density	-.0235	.0172	(-.0572, .0103)	.173
Community Cohesion	Green view	.0074	.0168	(-.0255, .0403)	.659
R^2 = .117	Nature visits	.0964	.0175	(.0622, .1307)	<.001
	Nature media	.1176	.0170	(.0843, .1508)	<.001
	Nature connectedness	.1608.	.0184	(.1247, .1970)	<.001
	Female	0342	.0170	(.0009, .0675)	.044
	Age 30-39	.0390	.0218	(-.0038, .0818)	.074
	Age 40-49	.0241	.0214	(-.0178, .0660)	.260
	Age 50-59	.0324	.0212	(-.0090, .0739)	.125
	Age 60+	.1187	.0286	(.0626, .1748)	<.001
	Marital status- married/cohabiting	.0717	.0187	(.0350, .1083)	<.001
	Marital status- undisclosed	-.0117	.0167	(-.0445, .0211)	.483
	Higher education (yes)	.0128	.0174	(-.0214, .0470)	.463
	Work status- employed	.0715	.0292	(.0141, .1288)	.015
	Work status -in education	.0013	.0183	(-.0345, .0371)	.944
	Work status -retired	.1034	.0291	(.0464, .1604)	<.001
	Work status -other	.0521	.0253	(.0025, .1018)	.040
	Income- 2nd quintile	-.0029	.0209	(-.0438, .0380)	.890
	Income- 3rd quintile	-.0280	.0225	(-.0721, .0161)	.213
	Income -4th quintile	-.0136	.0230	(-.0586, .0315)	.555
	Income- 5th quintile (highest)	.0242	.0249	(-.0247, .0731)	.331
	Income- undisclosed	.0026	.0187	(-.0340, .0392)	.891
	Disability- yes	-.0400	.0176	(-.0745, -.0055)	.023
	Disability- undisclosed	.0043	.0182	(-.0314, .0399)	.814
	Dog owner (yes)	.0715	.0292	(.0141, .1288)	.015
	Rec. physical activity (yes)	.0104	.0169	(-.0227, .0434)	.539
	Covid-19 local lockdown (yes)	.1120	.0171	(.0786, .1454)	<.001
	Carstairs - 2nd quintile	-.0307	.0212	(-.0722, .0108)	.147
	Carstairs -3rd quintile	-.0127	.0209	(-.0537, .0283)	.543
	Carstairs - 4th quintile	.0323	.0209	(-.0087, .0733)	.123
	Carstairs -5th quintile	.0169	.0209	(-.0241, .0578)	.420
	Population density	.0148	.0168	(-.0182, .0478)	.379
Temporal Discounting	Green view	-.0606	.0178	(-.0955, -.0257)	.001

R^2 = .035	Nature visits	-.0247	.0174	(-.0589, .0095)	.157
	Nature media	.0693	.0173	(.0353, .1032)	<.001
	Nature connectedness	.0329	.0200	(-.0063, .0721)	.100
	Female	-.0164	.0161	(-.0481, .0152)	.309
	Age 30-39	.0315	.0218	(-.0112, .0742)	.148
	Age 40-49	.0112	.0207	(-.0292, .0517)	.587
	Age 50-59	-.0042	.0212	(-.0458, .0373)	.842
	Age 60+	-.0415	.0253	(-.0912, .0081)	.101
	Marital status- married/cohabiting	.0280	.0190	(-.0092, .0652)	.140
	Marital status- undisclosed	-.0112	.0161	(-.0428, .0204)	.488
	Higher education (yes)	-.0555	.0160	(-.0868, -.0242)	.001
	Work status- employed	.0334	.0278	(-.0212, .0879)	.230
	Work status -in education	-.0120	.0176	(-.0465, .0225)	.497
	Work status -retired	.0153	.0267	(-.0370, .0675)	.567
	Work status -other	.0629	.0259	(.0121, .1136)	.015
	Income- 2nd quintile	-.0229	.0228	(-.0677, .0218)	.315
	Income- 3rd quintile	-.0685	.0227	(-.1129, -.0240)	.003
	Income -4th quintile	-.1006	.0224	(-.1446, -.0566)	<.001
	Income- 5th quintile (highest)	-.1417	.0234	(-.1876, -.0959)	<.001
	Income- undisclosed	-.0163	.0205	(-.0565, .0238)	.425
	Disability- yes	-.0166	.0171	(-.0502, .0170)	.332
	Disability- undisclosed	.0199	.0203	(-.0198, .0597)	.326
	Dog owner (yes)	.0315	.0218	(-.0112, .0742)	.148
	Rec. physical activity (yes)	.0034	.0164	(-.0288, .0355)	.838
	Covid-19 local lockdown (yes)	.0035	.0173	(-.0304, .0375)	.838
	Carstairs - 2nd quintile	-.0163	.0205	(-.0565, .0238)	.425
	Carstairs -3rd quintile	-.0535	.0213	(-.0953, -.0118)	.012
	Carstairs - 4th quintile	-.0506	.0213	(-.0924, -.0088)	.018
	Carstairs -5th quintile	-.0440	.0221	(-.0873, -.0006)	.047
	Population density	-.0771	.0210	(-.1182, -.0359)	<.001
	Intercept	.2133	.0791	(.0583, .3683)	.007
Current smoker	Green view	.1065	.0175	(.0722, .1407)	<.001
R^2 = .093	Nature visits	-.0368	.0264	(-.0885, .0150)	.164
	Nature media	.0967	.0194	(.0587, .1346)	<.001
	Nature connectedness	.0328	.0261	(-.0183, .0839)	.208
	Positive affect	-.0475	.0161	(-.0790, -.0160)	.003
	Negative affect	-.0126	.0168	(-.0457, .0204)	.453
	Community cohesion	.0590	.0172	(.0254, .0927)	.001
	Temporal discounting	.0339	.0179	(-.0012, .0690)	.059

	Female	-.0668	.0163	(-.0987, -.0349)	<.001
	Age 30-39	.0698	.0217	(.0273, .1122)	.001
	Age 40-49	.0429	.0210	(.0018, .0840)	.041
	Age 50-59	.0058	.0208	(-.0350, .0466)	.782
	Age 60+	-.0415	.0251	(-.0907, .0076)	.098
	Marital status- married/cohabiting	-.0131	.0177	(-.0478, .0216)	.458
	Marital status- undisclosed	.0016	.0166	(-.0309, .0341)	.925
	Higher education (yes)	-.0627	.0163	(-.0946, -.0307)	<.001
	Work status- employed	.0127	.0294	(-.0449, .0703)	.666
	Work status -in education	-.0428	.0160	(-.0742, -.0114)	.008
	Work status -retired	-.0412	.0262	(-.0925, .0102)	.116
	Work status -other	.0046	.0251	(-.0446, .0538)	.855
	Income- 2nd quintile	-.0473	.0206	(-.0876, -.0069)	.022
	Income- 3rd quintile	-.0385	.0219	(-.0814, .0043)	.078
	Income -4th quintile	-.0513	.0219	(-.0943, -.0083)	.019
	Income- 5th quintile (highest)	-.0757	.0235	(-.1217, -.0297)	.001
	Income- undisclosed	-.0633	.0156	(-.0938, -.0327)	<.001
	Disability- yes	.0599	.0173	(.0259, .0939)	.001
	Disability- undisclosed	.0051	.0163	(-.0268, .0371)	.753
	Dog owner (yes)	.1248	.0171	(.0913, .1583)	<.001
	Rec. physical activity (yes)	-.0069	.0155	(-.0373, .0236)	.659
	Covid-19 local lockdown (yes)	.0216	.0172	(-.0120, .0552)	.208
	Carstairs - 2nd quintile	.0112	.0210	(-.0299, .0522)	.594
	Carstairs -3rd quintile	-.0212	.0211	(-.0625, .0202)	.316
	Carstairs - 4th quintile	-.0333	.0219	(-.0761, .0096)	.128
	Carstairs -5th quintile	-.0436	.0223	(-.0874, .0001)	.050
	Population density	.0179	.0183	(-.0180, .0539)	.328
	Intercept	.6406	.0804	(.4831, .7982)	<.001
Exceeds alcohol guidelines	Temporal discounting	.0453	.0174	(.0113, .0793)	.009
R^2 = .064	Positive affect	.0443	.0284	(-.0114, .1001)	.119
	Community cohesion	.0319	.0195	(-.0063, .0700)	.102
	Negative affect	.1352	.0279	(.0806, .1899)	<.001
	Green view	-.0379	.0172	(-.0716, -.0042)	.027
	Nature visits	.0289	.0173	(-.0049, .0627)	.094
	Nature media	.0408	.0171	(.0074, .0743)	.017
	Nature connectedness	-.0328	.0173	(-.0667, .0012)	.058
	Female	-.0899	.0164	(-.1220, -.0578)	<.001
	Age 30-39	.0085	.0195	(-.0297, .0468)	.662
	Age 40-49	.0249	.0188	(-.0120, .0617)	.186

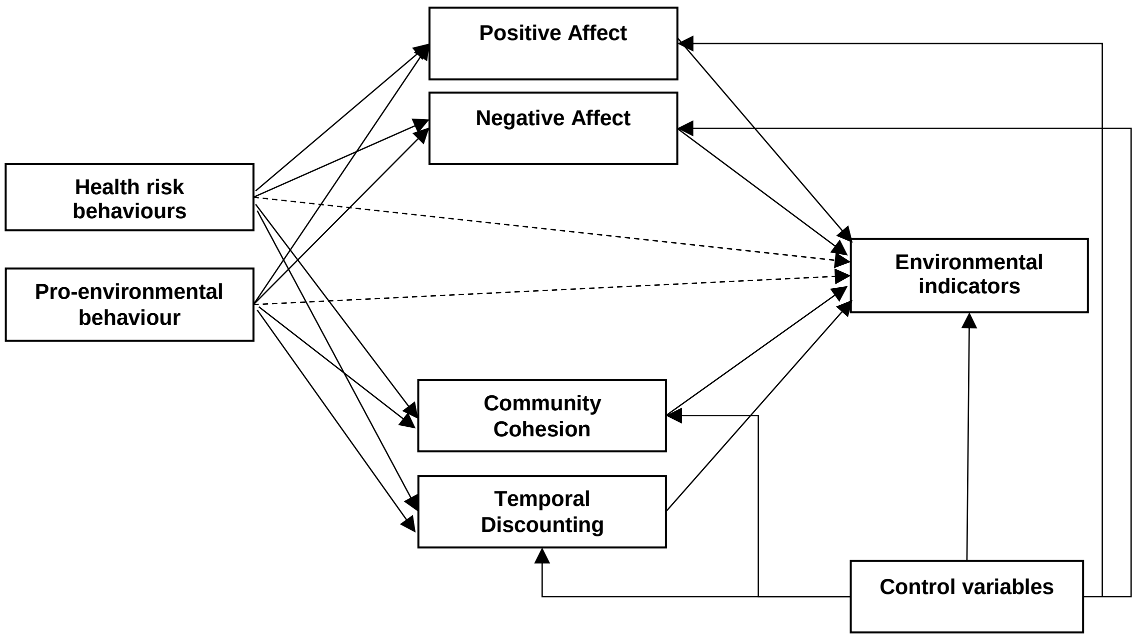
	Age 50-59	.0600	.0207	(.0195, .1005)	.004
	Age 60+	.1079	.0284	(.0523, .1635)	<.001
	Marital status- married/cohabiting	.0285	.0179	(-.0067, .0636)	.112
	Marital status- undisclosed	-.0098	.0119	(-.0331, .0134)	.408
	Higher education (yes)	.0412	.0172	(.0075, .0750)	.017
	Work status- employed	-.0371	.0298	(-.0955, .0213)	.213
	Work status -in education	-.0160	.0131	(-.0417, .0097)	.221
	Work status -retired	.0115	.0319	(-.0509, .0740)	.717
	Work status -other	-.0232	.0247	(-.0716, .0251)	.347
	Income- 2nd quintile	-.0270	.0181	(-.0624, .0084)	.135
	Income- 3rd quintile	-.0023	.0214	(-.0442, .0397)	.915
	Income -4th quintile	.0115	.0222	(-.0321, .0551)	.604
	Income- 5th quintile (highest)	.0346	.0253	(-.0149, .0842)	.171
	Income- undisclosed	-.0050	.0171	(-.0386, .0285)	.769
	Disability- yes	.0377	.0190	(.0006, .0749)	.047
	Disability- undisclosed	.0329	.0184	(-.0032, .0690)	.074
	Dog owner (yes)	.0118	.0158	(-.0190, .0427)	.452
	Rec. physical activity (yes)	-.0146	.0159	(-.0457, .0166)	.360
	Covid-19 local lockdown (yes)	.0713	.0172	(.0375, .1051)	<.001
	Carstairs - 2nd quintile	.0076	.0197	(-.0310, .0461)	.700
	Carstairs -3rd quintile	-.0116	.0189	(-.0487, .0255)	.542
	Carstairs - 4th quintile	.0299	.0213	(-.0118, .0716)	.160
	Carstairs -5th quintile	.0547	.0234	(.0089, .1005)	.019
	Population density	.0018	.0187	(-.0350, .0385)	.926
	Intercept	.1011	.0735	(-.0430, .2451)	.169
Poor diet	Temporal discounting	.0248	.0156	(-.0057, .0553)	.111
R^2 = .130	Positive affect	-.1659	.0242	(-.2133, -.1184)	<.001
	Community cohesion	-.0881	.0189	(-.1251, -.0510)	<.001
	Negative affect	.0730	.0224	(.0291, .1169)	.001
	Green view	-.0329	.0157	(-.0636, -.0022)	.036
	Nature visits	-.0087	.0167	(-.0414, .0241)	.605
	Nature media	-.0286	.0155	(-.0591, .0019)	.066
	Nature connectedness	-.0513	.0165	(-.0836, -.0191)	.002
	Female	.0422	.0157	(.0113, .0730)	.007
	Age 30-39	-.0125	.0210	(-.0536, .0286)	.551
	Age 40-49	.0118	.0204	(-.0282, .0517)	.564
	Age 50-59	.0307	.0210	(-.0103, .0718)	.142
	Age 60+	.0400	.0262	(-.0113, .0912)	.127
	Marital status- married/cohabiting	-.0121	.0177	(-.0468, .0226)	.494

	Marital status- undisclosed	.0015	.0160	(-.0299, .0329)	.925
	Higher education (yes)	-.0689	.0164	(-.1010, -.0368)	<.001
	Work status- employed	.0099	.0297	(-.0483, .0682)	.738
	Work status -in education	-.0362	.0177	(-.0708, -.0016)	.041
	Work status -retired	.0028	.0277	(-.0515, .0572)	.919
	Work status -other	.0111	.0252	(-.0383, .0605)	.660
	Income- 2nd quintile	-.0546	.0207	(-.0951, -.0141)	.008
	Income- 3rd quintile	-.0420	.0218	(-.0848, .0008)	.054
	Income -4th quintile	-.0455	.0219	(-.0884, -.0026)	.038
	Income- 5th quintile (highest)	-.0220	.0240	(-.0691, .0251)	.359
	Income- undisclosed	-.0146	.0176	(-.0491, .0200)	.408
	Disability- yes	.0678	.0177	(.0332, .1024)	<.001
	Disability- undisclosed	.0030	.0161	(-.0285, .0346)	.850
	Dog owner (yes)	.0103	.0159	(-.0209, .0415)	.518
	Rec. physical activity (yes)	-.0669	.0147	(-.0957, -.0380)	<.001
	Covid-19 local lockdown (yes)	-.0350	.0163	(-.0669, -.0030)	.032
	Carstairs - 2nd quintile	.0001	.0200	(-.0392, .0393)	.997
	Carstairs -3rd quintile	-.0227	.0208	(-.0634, .0180)	.274
	Carstairs - 4th quintile	-.0406	.0212	(-.0822, .0009)	.055
	Carstairs -5th quintile	-.0641	.0219	(-.1070, -.0212)	.003
	Population density	-.0545	.0166	(-.0870, -.0220)	.001
	Intercept	.9663	.0821	(.8053, 1.1273)	<.001
Household PEB	Temporal discounting	-.0842	.0165	(-.1166, -.0519)	<.001
R^2 = .188	Positive affect	.1058	.0251	(.0566, .1550)	<.001
	Community cohesion	.0168	.0183	(-.0190, .0527)	.358
	Negative affect	.0876	.0244	(.0397, .1355)	<.001
	Green view	.0299	.0148	(.0009, .0588)	.043
	Nature visits	.1277	.0160	(.0963, .1590)	<.001
	Nature media	.0508	.0155	(.0204, .0812)	.001
	Nature connectedness	.2137	.0165	(.1813, .2460)	<.001
	Female	.0753	.0154	(.0452, .1054)	<.001
	Age 30-39	-.0155	.0205	(-.0557, .0247)	.449
	Age 40-49	.0183	.0197	(-.0204, .0570)	.354
	Age 50-59	.0690	.0195	(.0307, .1073)	<.001
	Age 60+	.0924	.0246	(.0442, .1406)	<.001
	Marital status- married/cohabiting	-.0303	.0169	(-.0635, .0028)	.073
	Marital status- undisclosed	-.0330	.0168	(-.0659, -.0001)	.049
	Higher education (yes)	.1122	.0156	(.0816, .1428)	<.001
	Work status- employed	-.0011	.0267	(-.0534, .0512)	.967

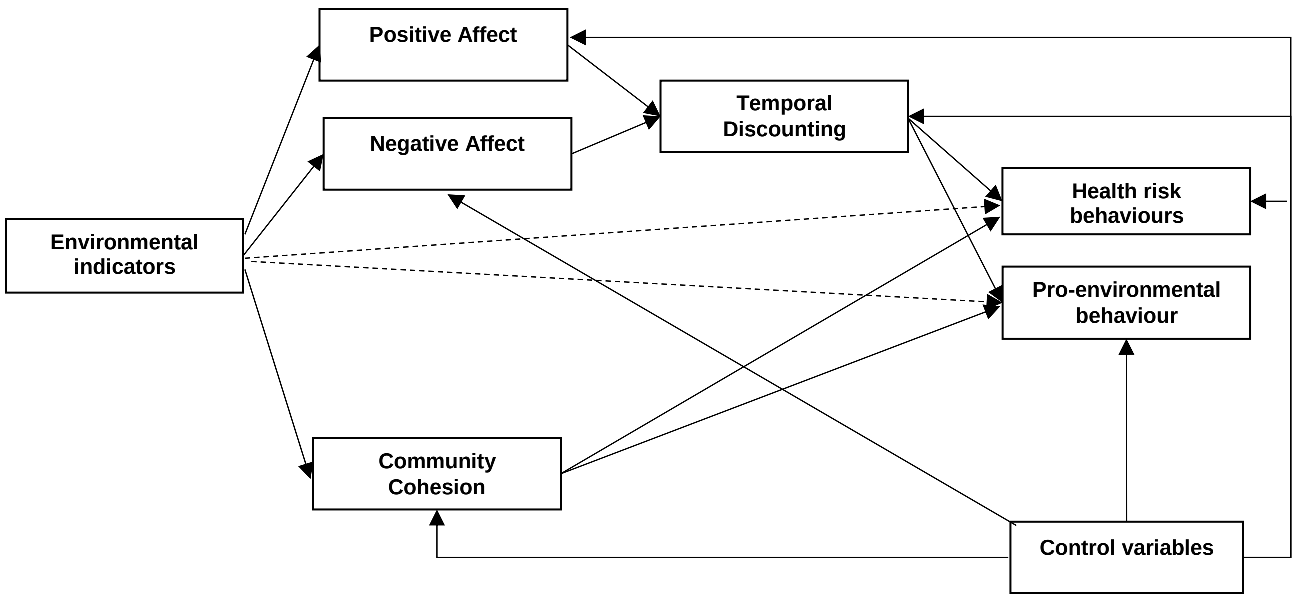
	Work status -in education	.0061	.0176	(-.0284, .0405)	.731
	Work status -retired	-.0103	.0254	(-.0601, .0394)	.684
	Work status -other	-.0070	.0226	(-.0513, .0374)	.758
	Income- 2nd quintile	.0339	.0187	(-.0028, .0706)	.070
	Income- 3rd quintile	.0337	.0201	(-.0057, .0732)	.094
	Income -4th quintile	.0530	.0205	(.0129, .0932)	.010
	Income- 5th quintile (highest)	.0826	.0234	(.0368, .1283)	<.001
	Income- undisclosed	-.0118	.0176	(-.0463, .0226)	.500
	Disability- yes	-.0249	.0163	(-.0568, .0070)	.126
	Disability- undisclosed	-.0401	.0175	(-.0744, -.0057)	.022
	Dog owner (yes)	-.0035	.0154	(-.0338, .0267)	.819
	Rec. physical activity (yes)	.0600	.0149	(.0308, .0891)	<.001
	Covid-19 local lockdown (yes)	-.0391	.0157	(-.0698, -.0084)	.012
	Carstairs - 2nd quintile	.0362	.0190	(-.0012, .0735)	.057
	Carstairs -3rd quintile	.0660	.0201	(.0267, .1054)	.001
	Carstairs - 4th quintile	.0741	.0206	(.0337, .1146)	<.001
	Carstairs -5th quintile	.0792	.0216	(.0369, .1216)	<.001
	Population density	.0211	.0182	(-.0145, .0567)	.245
	Intercept	-.6292	.0744	(-.7750, -.4833)	<.001
Nat. conservation PEB	Temporal discounting	-.0217	.0162	(-.0535, .0101)	.181
R^2 = .137	Positive affect	.0697	.0282	(.0144, .1249)	.013
	Community cohesion	.1131	.0189	(.0760, .1503)	<.001
	Negative affect	.1116	.0275	(.0577, .1655)	<.001
	Green view	-.0103	.0157	(-.0410, .0205)	.513
	Nature visits	.0046	.0158	(-.0263, .0356)	.769
	Nature media	.1286	.0174	(.0946, .1626)	<.001
	Nature connectedness	.1528	.0176	(.1184, .1873)	<.001
	Female	-.0219	.0161	(-.0533, .0096)	.173
	Age 30-39	-.0809	.0214	(-.1227, -.0390)	<.001
	Age 40-49	-.0800	.0211	(-.1212, -.0387)	<.001
	Age 50-59	-.0854	.0208	(-.1261, -.0448)	<.001
	Age 60+	-.1075	.0259	(-.1582, -.0568)	<.001
	Marital status- married/cohabiting	.0133	.0170	(-.0199, .0465)	.433
	Marital status- undisclosed	.0064	.0182	(-.0293, .0422)	.725
	Higher education (yes)	.0822	.0161	(.0507, .1137)	<.001
	Work status- employed	.0282	.0266	(-.0240, .0805)	.289
	Work status -in education	.0432	.0200	(.0039, .0825)	.031
	Work status -retired	-.0147	.0246	(-.0629, .0335)	.551

	Work status -other	-.0126	.0214	(-.0545, .0293)	.555
	Income- 2nd quintile	-.0166	.0191	(-.0540, .0208)	.384
	Income- 3rd quintile	-.0094	.0208	(-.0502, .0314)	.651
	Income -4th quintile	.0194	.0221	(-.0239, .0627)	.380
	Income- 5th quintile (highest)	.0035	.0246	(-.0448, .0518)	.888
	Income- undisclosed	-.0295	.0153	(-.0595, .0005)	.054
	Disability- yes	.0783	.0176	(.0438, .1129)	<.001
	Disability- undisclosed	-.0037	.0130	(-.0292, .0217)	.774
	Dog owner (yes)	.0563	.0160	(.0249, .0878)	<.001
	Rec. physical activity (yes)	.0213	.0163	(-.0106, .0532)	.190
	Covid-19 local lockdown (yes)	.0469	.0178	(.0119, .0818)	.009
	Carstairs - 2nd quintile	.0037	.0194	(-.0344, .0418)	.849
	Carstairs -3rd quintile	.0117	.0196	(-.0267, .0500)	.551
	Carstairs - 4th quintile	-.0022	.0204	(-.0421, .0378)	.916
	Carstairs -5th quintile	.0306	.0224	(-.0132, .0745)	.171
	Population density	.0554	.0188	(.0185, .0923)	.003
	Intercept	-.2184	.0719	(-.3594, -.0774)	.002

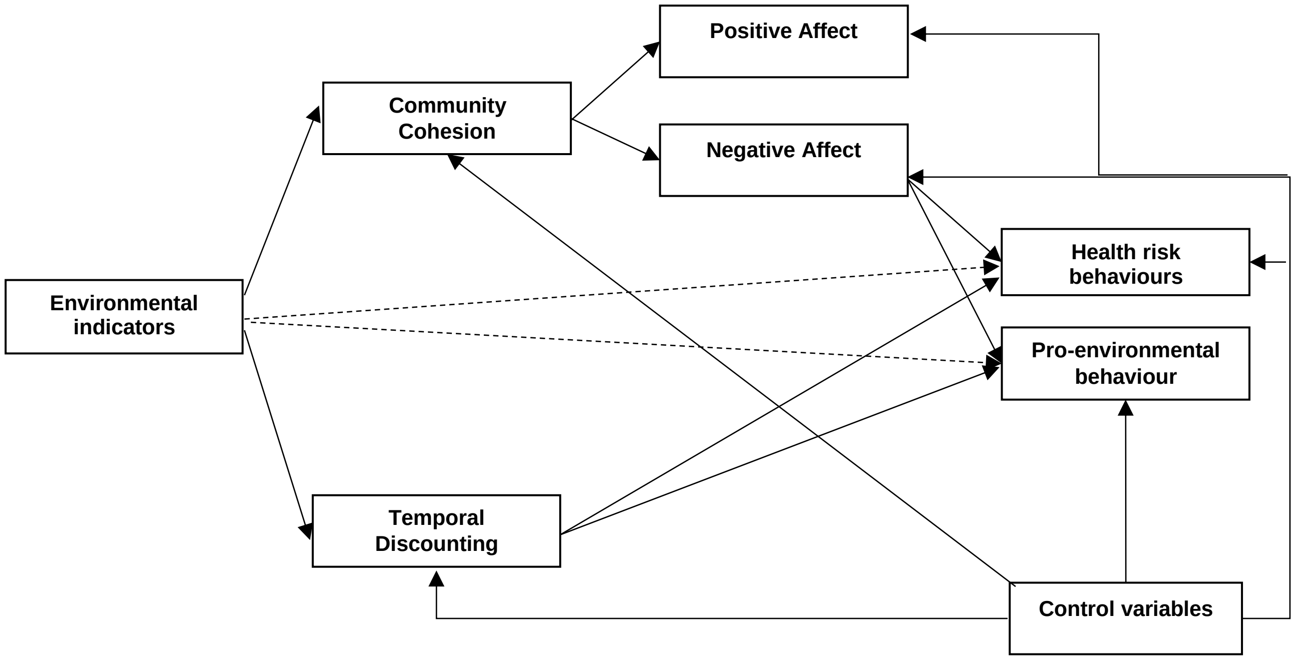
Appendix 27. Study 4: Alternative path models



Alternative Model A: Reverse casual pathway depicting the relationships between behavioural predictors and environmental indicators, mediated by positive affect, negative affect, community cohesion and temporal discounting.



Alternative Model B: serial mediation model depicting the relationships between environmental indicators and behavioural outcome, sequentially mediated via affect, then temporal discounting, as well through via community cohesion.



Alternative Model C. Serial mediation model depicting the relationships between environmental indicators and behavioural outcomes, sequentially mediated via community cohesion, then affect, as well through via temporal discounting

Table 27. Model fit comparison of the original and alternative path models of the associations between environmental indicators, proposed mediators and behavioural outcomes.

Model Fit	**Acceptable Level**	**Original Model**	**Alternative Model A (convergence failure)**	**Alternative Model B**	**Alternative Model C**
RMSEA	<.06	.03	--	.07	.05
CFI	>.95	.97	--	.91	.92
TLI	>.95	.96	--	.89	.90
SRMR	<.08	.02	--	.14	.10

Appendix 28. Study 4: additional analysis- diet and pro-environmental behaviour items

Table 28. Correlations between diet quality and individual pro-environmental behaviour items

	Diet quality[a]	
	r	***p***
Purchased eco-friendly products and brands	.14	<.001
Brought seasonal or locally grown food	.13	<.001
Recycled items rather than throw them away	-.02	.292
Chosen to walk/ cycle or instead of using my car	.08	<.001
Conserved water or energy in my home	.02	.198
Encouraged other people to protect the environment	.08	<.001
Been a member of an environmental/conservation organisation	.09	<.001
Volunteered to help care for the environment	.09	<.001
Donated money to support an environmental/conservation organisation	.07	<.001
Donated my time to an environmental /conservation organisation	.07	<.001

Note: [a] Self-rated diet quality: 1= Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent

Appendix 29. False Discovery Rate Adjustment

Table 29. False Discovery Rate (FDR) adjustment for multiple comparisons

Study	Outcome	Predictor	Unadjusted p	Adjusted p*	FDR = .05	FDR = .10	FDR = .25
Study 1	Current smoker	2^{nd} greenspace quartile	.158	.309	-	-	-
		3^{rd} greenspace quartile	.121	.290	-	-	-
		4^{th} greenspace quartile	.017	.068	Non-significant	Significant	Significant
	Ever smoker	2^{nd} greenspace quartile	.180	.309	-	-	-
		3^{rd} greenspace quartile	.922	.922	-	-	-
		4^{th} greenspace quartile	.447	.536	-	-	-
	Smoking cessation	2^{nd} greenspace quartile	.495	.540	-	-	-
		3^{rd} greenspace quartile	.012	.068	Non-significant	Significant	Significant
		4^{th} greenspace quartile	.016	.068	Non-significant	Significant	Significant
	Exceeds alcohol limits	2^{nd} greenspace quartile	.219	.327	-	-	-
		3^{rd} greenspace quartile	.120	.290	-	-	-
		4^{th} greenspace quartile	.245	.327	-	-	-
Study 2	Current smoker	2nd greenspace tertile	.150	.360	-	-	-
		3rd greenspace tertile	.008	.112	Non-significant	Non-significant	Significant
		Nature visits (once a week)	.033	.202	Non-significant	Non-significant	Significant
		Nature connectedness (INS)	.157	.360	-	-	-
		2nd Tertile X INS	.881	.914	-	-	-
		3rd Tertile X INS	.159	.360	-	-	-
		≥ once a week X INS	.654	.704	-	-	-
	Ever smoker	2nd greenspace tertile	.309	.484	-	-	-
		3rd greenspace tertile	.093	.324	-	-	-
		Nature visits (once a week)	.371	.484	-	-	-
		Nature connectedness (INS)	.319	.484	-	-	-
		2nd Tertile X INS	.644	.704	-	-	-
		3rd Tertile X INS	.058	.271	-	-	-
		≥ once a week X INS	.531	.646	-	-	-
	Smoking cessation	2nd greenspace tertile	.170	.360	-		
		3rd greenspace tertile	.104	.324	-	-	-
		Nature visits (once a week)	.103	.324	-	-	-
		Nature connectedness (INS)	.379	.484	-	-	-
		2nd Tertile X INS	.572	.667	-	-	-

		3rd Tertile X INS	.976	.976	-	-	-
		≥ once a week X INS	.354	.484	-	-	-
	Exceeds alcohol limits	2nd greenspace tertile	.000	.000	Significant	Significant	Significant
		3rd greenspace tertile	.016	.149	Non-significant	Non-significant	Significant
		Nature visits (once a week)	.380	.484	-	-	-
		Nature connectedness (INS)	.265	.464	-	-	-
		2nd Tertile X INS	.180	.360	-	-	-
		3rd Tertile X INS	.036	.202	Non-significant	Non-significant	Significant
		≥ once a week X INS	.255	.464	-	-	-
Study 3	Household PEB	Neighbourhood greenspace	.320	.407	-	-	-
		Nature visits (≥ once a week)	.000	.000	Significant	Significant	Significant
		Nature media (yes)	.000	.000	Significant	Significant	Significant
		Nature connectedness (NC)	.000	.000	Significant	Significant	Significant
		Greenspace x NC	.378	.441	-	-	-
		Visits x NC	.319	.407	-	-	-
		Nature media. x NC	.019	.038	Significant	Significant	Significant
	Nature Conservation PEB	Neighbourhood greenspace	.165	.257	-	-	-
		Nature visits (≥ once a week)	.411	.443	-	-	-
		Nature media (yes)	.000	.000	Significant	Significant	Significant
		Nature connectedness (NC)	.000	.000	Significant	Significant	Significant
		Greenspace x NC	.690	.690	-	-	-
		Visits x NC	.040	.070	Non-significant	Significant	Significant
		Nature media. x NC	.000	.000	Non-significant	Significant	Significant
Study 4 Regressions	Current smoker	Green view	.005	.013	Significant	Significant	Significant
		Nature visits (≥ once a week)	.550	.628	-	-	-
		Nature media. (≥ once a week)	.000	.000	Significant	Significant	Significant
		Nature connectedness (INS)	.013	.030	Significant	Significant	Significant
		Green view x INS	.642	.692	-	-	-
		Nature Visits x INS	.184	.255	-	-	-
		Nature media x INS	.338	.420	-	-	-
	Ever smoker	Green view	.000	.000	Significant	Significant	Significant
		Nature visits (≥ once a week)	.323	.412	-	-	-
		Nature media. (≥ once a week)	.011	.027	Significant	Significant	Significant
		Nature connectedness (INS)	.000	.000	Significant	Significant	Significant

Smoking Cessation	Green view	.484	.573	-	-	-
	Nature visits (≥ once a week)	.941	.941	-	-	-
	Nature media. (≥ once a week)	.000	.000	Significant	Significant	Significant
	Nature connectedness (INS)	.632	.691	-	-	-
Exceeds alcohol limits	Green view	.040	.075	Non-significant	Non-significant	Non-significant
	Nature visits (≥ once a week)	.182	.255	-	-	-
	Nature media. (≥ once a week)	.015	.034	Significant	Significant	Significant
	Nature connectedness (INS)	.135	.211	-	-	-
	Green view x INS	.834	.861	-	-	-
	Nature Visits x INS	.273	.353	-	-	-
	Nature media x INS	.906	.915	-	-	-
Poor diet	Green view	.037	.069	Non-significant	Significant	Significant
	Nature visits (≥ once a week)	.143	.217	-	-	-
	Nature media. (≥ once a week)	.036	.068	Non-significant	Significant	Significant
	Nature connectedness (INS)	.000	.000	Significant	Significant	Significant
	Green view x INS	.021	.043	Significant	Significant	Significant
	Nature Visits x INS	.800	.834	-	-	-
	Nature media x INS	.595	.671	-	-	-
Household PEB	Green view	.009	.022	Significant	Significant	Significant
	Nature visits (≥ once a week)	.000	.000	Significant	Significant	Significant
	Nature media. (≥ once a week)	.001	.009	Significant	Significant	Significant
	Nature connectedness (INS)	.000	.000	Significant	Significant	Significant
	Green view x INS	.891	.910	-	-	-
	Nature Visits x INS	.067	.114	-	-	-
	Nature media x INS	.207	.280	-	-	-
Nat Con PEB	Green view	.641	.692	-	-	-
	Nature visits (≥ once a week)	.337	.420	-	-	-
	Nature media. (≥ once a week)	.000	.000	Significant	Significant	Significant
	Nature connectedness (INS)	.000	.000	Significant	Significant	Significant
	Green view x INS	. 215	.286	-	-	-

		Nature Visits x INS	.020	.042	Significant	Significant	Significant
		Nature media x INS	.218	.286	-	-	-
SEM	Negative Affect	Green view	.167	.242	-	-	-
		Nature visits	.025	.050	Significant	Significant	Significant
		Nature media	.138	.212	-	-	-
		Nature connectedness	.000	.000	Significant	Significant	Significant
	Positive Affect	Green view	.017	.037	Significant	Significant	Significant
		Nature visits	.000	.000	Significant	Significant	Significant
		Nature media	.531	.613	-	-	-
		Nature connectedness	.000	.000	Significant	Significant	Significant
	Community Cohesion	Green view	.659	.702	-	-	-
		Nature visits	.000	.000	Significant	Significant	Significant
		Nature media	.000	.000	Significant	Significant	Significant
		Nature connectedness	.000	.000	Significant	Significant	Significant
	Temporal Discounting	Green view	.001	.009	Significant	Significant	Significant
		Nature visits	.157	.234	-	-	-
		Nature media	.000	.000	Significant	Significant	Significant
		Nature connectedness	.100	.164	-	-	-
	Current Smoker	Green view	.000	.000	Significant	Significant	Significant
		Nature visits	.164	.241	-	-	-
		Nature media	.000	.000	Significant	Significant	Significant
		Nature connectedness	.208	.280	-	-	-
		Positive affect	.003	.008	Significant	Significant	Significant
		Negative affect	.453	.542	-	-	-
		Community cohesion	.001	.009	Significant	Significant	Significant
		Temporal discounting	.059	.104	-	-	-
	Exceeds alcohol guidelines	Temporal discounting	.009	.022	Significant	Significant	Significant
		Positive affect	.119	.189	-	-	-
		Community cohesion	.102	.165	-	-	-
		Negative affect	.000	.000	Significant	Significant	Significant
		Green view	.027	.053	Non-significant	Significant	Significant

	Nature visits	.094	.157	-	-	-
	Nature media	.017	.037	Significant	Significant	Significant
	Nature connectedness	.058	.104	-	-	-
Poor diet	Temporal discounting	.000	.000	Significant	Significant	Significant
	Positive affect	.000	.000	Significant	Significant	Significant
	Community cohesion	.001	.009	Significant	Significant	Significant
	Negative affect	.036	.068	Non-significant	Significant	Significant
	Green view	.605	.675	-	-	-
	Nature visits	.066	.114	-	-	-
	Nature media	.002	.006	Significant	Significant	Significant
	Nature connectedness					
Household PEB	Temporal discounting	.000	.000	Significant	Significant	Significant
	Positive affect	.000	.000	Significant	Significant	Significant
	Community cohesion	.358	.440	-	-	-
	Negative affect	.000	.000	Significant	Significant	Significant
	Green view	.043	.079	Non-significant	Significant	Significant
	Nature visits	.000	.000	Significant	Significant	Significant
	Nature media	.001	.009	Significant	Significant	Significant
	Nature connectedness	.000	.000	Significant	Significant	Significant
Nat. Conservation PEB	Temporal discounting	.181	.255	-	-	-
	Positive affect	.013	.030	Significant	Significant	Significant
	Community cohesion	.000	.000	Significant	Significant	Significant
	Negative affect	.000	.000	Significant	Significant	Significant
	Green view	.513	.600	-	-	-
	Nature visits	.769	.812	-	-	-
	Nature media	.000	.000	Significant	Significant	Significant
	Nature connectedness	.000	.000	Significant	Significant	Significant

Note. * Adjusted p values obtained using the Benjamini-Hochberg procedure.