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The impact of outdoor spaces on children's stress, attention and behaviour: investigating the differential effects of the educational environment

Gemma Goldenberg

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Abstract

Time outdoors in natural surroundings has been evidenced, by a wide body of research, to have a positive impact on a range of outcomes for children. Despite this, children's connection with the outdoors appears to be decreasing with each generation. Children are spending less time outdoors both during school hours and their free time. This thesis reviews the current evidence that nature has a positive impact on children's stress, attention and behaviour, looking in particular at differential effects and the potential pathways through which this 'nature-effect' might occur.

Many urban schools face budget and curriculum constraints as well as a lack of nature on the school site, which prevents children from accessing nature easily. For this reason, this thesis examines the impact of relocating 4-5 year-old children's (n=76) everyday learning activities to urban outdoor spaces on their school site. Wearable equipment such as head mounted cameras, microphones and ECG monitors were used to gather objective data detailing children's experiences of indoor and outdoor learning environments. Data collection took place across 8 indoor and 8 outdoor sessions, repeated across 7 classes of children within 4 different primary schools located in the London Borough of Newham, an ethnically diverse area with high rates of poverty and low levels of green space. Sessions were carefully matched across conditions in an attempt to isolate the specific impact of an urban outdoor environment.

Results reveal that children's noise levels and resting heart rates were significantly lower outdoors, suggesting lower physiological stress. Analyses of attentional capacity show that children who struggle the most with their attention indoors, show significantly better attention in an outdoor environment. Finally, data indicates that children behave more prosocially in an outdoor environment, and that children who display the most antisocial behaviour indoors, are significantly less antisocial when interacting with peers outside.

Throughout, individual differences are explored and noise, heart rate and the amount of natural features in outdoor areas are investigated as potential mediators of effects. The discussion focuses on how these findings can influence education.

Declaration

This thesis is based on the dataset from one large school-based research project, which was subsequently split into three separate studies for analysis. This project was funded by a UBEL DTP studentship. The ethical approval for this study is located in Appendix 5

I was solely responsible for writing the ethics application for this study, for school and participant recruitment, for the design of the study and for choosing and creating all of its measures for stress, attention and behaviour. I devised the coding protocol for the video coding for this project and wrote manuals to train video coders. Data collection was conducted by myself, student volunteers (detailed in section 3.2.3) and Molly Atkinson, a member of the Baby Development Lab who worked as a Knowledge Exchange Officer between UEL and Newham Learning (detailed in Chapter 7). I supervised and trained Molly Atkinson to carry out some of the data collection in schools, carry out video coding and to manage the research equipment (charging devices and uploading their data) due to delays created by the Covid Pandemic.

In chapter 1.1, some of the content has been rewritten based on an unpublished paper co-authored with Professor Sam Wass, 'Why does exposure to natural outdoor environments improve children's self-regulation of attention and behaviour? An examination of mediating mechanisms'.

In chapters 4,5 and 6 the preprocessing of the heart rate data, the violin plots generated using MatLab, and the PROCESS allocation of participants to baseline groups for analyses were conducted by Molly Atkinson. The linear mixed effects models, mixed ANOVA , moderation analyses and binomial logistic regression analyses in chapters 4, 5 and 6 were conducted together with Molly Atkinson when preparing manuscripts for the three co-authored papers as listed on page 8.

Otherwise, all of the work included in this thesis, including the formulation and testing of hypotheses, data analysis and written text, are entirely my own.

First author publications arising from this thesis:

Goldenberg, G., Atkinson, M., Wass, S., Dubiel, J. (2024) Outdoor learning in urban schools: Effects on 4-5 year-old children's noise and physiological stress (Under revision) *The Journal of Environmental Science*

Goldenberg, G. (2020) Child development: Smarter by Nature. *Early Years Educator*, *22*(4), 23-26.

Goldenberg, G. (2020). Making the link between mental and physical focus. *Early Years Educator*, *22*(5), 33-35.

Goldenberg, G. (2020). Natural force for good. *Early Years Educator*, *22*(3), 34-36.

Goldenberg, G. (2021). Risky Play: as safe as possible or as safe as necessary?. *Early Years Educator*, *23*(1), 37-39.

Goldenberg, G. (2022). Quiet please!. *Early Years Educator*, *23*(9), 20-21.

Goldenberg, G. (2022). Rest is not idleness. *Early Years Educator*, *23*(8), 18-19.

Goldenberg, G. (2022). Self-regulation and the learning environment. *Early Years Educator*, *23*(15), S7-S7.

Goldenberg, G. (2022) Forest schools: An approach in itself or outdoor learning?. *Early Years Educator*, *23*(16), 32-35.

Goldenberg, G. (2023). Do you have a gut feeling that being outdoors is healthy?. *Early Years Educator*, *23*(18), 20-22.

Goldenberg, G. (2023) The science behind outdoor play: Part 1 *The Voice of Early Childhood* https://thevoiceofearlychildhood.com/the-science-behind-outdoor-play-part-1/

Goldenberg, G. (2023) The science behind outdoor play: Part 2 *The Voice of Early Childhood* https://thevoiceofearlychildhood.com/the-science-behind-outdoor-play-part-2/

Goldenberg, G. (2023) Impact of the outdoors on children's behaviour and attention *The Voice of Early Childhood* https://thevoiceofearlychildhood.com/impacts-of-outdoors-on-childrens-behaviour-and-attention/

Goldenberg, G. (2023) Noise levels in classrooms: The science behind outdoor play series *The Voice of Early Childhood* https://thevoiceofearlychildhood.com/noise-levels-in-classrooms-the-science-behind-outdoor-play-series/

Other publications arising from this thesis (submitted and awaiting review):

Atkinson, M., Gemma. G, Wass, S. (2024) Differential effects of an urban outdoor environment on 4-5 year-old children's attention in school

Other publications arising from this thesis (in preparation):

Goldenberg, G., Wass, S. (2024) Why does exposure to natural outdoor environments improve children's self-regulation of attention and behaviour? An examination of mediating mechanisms

Goldenberg, G., Atkinson, M., Wass, S. (2024) Inside out: Comparing 4-5 year-old children's prosocial and antisocial behaviour across indoor and outdoor learning environments

Thesis Overview

Chapter 1 is an introductory exploration of how the physical environment can impact human health, wellbeing and performance.

Section 1.1 gives an overview of the impact of urban and natural environments on humans and how our relationship with nature is changing over time.

Section 1.2 looks at 'The Nature Effect' – the idea that nature has a positive impact on humans - and explores the pathways through which this effect might operate. Key theories and frameworks are explored and critiqued, providing a rationale for the focus of the literature review in Chapter 2.

Section 1.3 introduces the concept of learning environments and summarises the work of pioneers in early education who first emphasised the importance of the physical learning environment. It also outlines specific aspects of the environment such as noise and visual complexity which have been shown to impact children's learning and behaviour.

Chapter 1 concludes with section 1.4 which explores individual differences in how children respond to their environment and summarises research evidence regarding whether nature contact might be more impactful for some children than others, depending on factors such as gender and socio-economic status.

Chapter 2 introduces the literature reviews that follow, in sections 2.1-2.3. key terms are defined and the range of measures and methodology used in the research field are summarised.

Section 2.4 is the first of three literature review sections and looks specifically at nature's effect on stress.

Section 2.5 reviews the literature on nature and children's attention and Section 2.6 reviews the literature on nature and children's behaviour.

Chapter 3 introduces three empirical studies which were conducted for this thesis, each utilising the same participant sample recruited from schools in the London Borough of Newham.

Section 3.1 provides the rationale and aims for these studies, first considering the role and importance of research conducted in schools before introducing the topic of outdoor learning in urban schools and why this is important.

Section 3.2 outlines the methodology common to all three of the school studies including school and participant recruitment, apparatus and materials and data collection procedures and Section 3.3 describes the ethical considerations taken for these studies.

Chapter 4 reports the findings of School study 1. It examines whether moving learning activities outdoors at an urban primary school affects 4-5 year-old children's noise levels and physiological stress. Potential mediators and differential effects are explored.

Chapter 5 reports School study 2. It looks at the effect of learning outdoors on 4-5 year-old children's attention, using a wide range of measures including looking time, time spent on task and comprehension of a story.

Chapter 6 shares the findings from School study 3, it examines how children's prosocial and antisocial behaviour and the amount of time they spent playing and talking with peers differed between indoor and outdoor settings. Chapter 6 concludes with a summary of the findings from all three school studies.

Chapter 7 discusses the ethical issues involved in school-based research and summarises what has been learnt about researcher-school partnerships and knowledge dissemination throughout this project. It offers guidance for future school-based research.

Chapter 8 summarises and integrates the findings from all three studies and suggests future research directions.

Chapter 9 completes this thesis by making some final conclusions and discussing their implications for education.

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Abbreviations

ANS	Autonomic nervous system
ART	Attention restoration theory
BP	Blood pressure
BPM	Beats per minute
dB	Decibels
EAL	English as an additional language
ECG	Electrocardiogram (measure of heart activity)
EEG	Electroencephalogram (measure of electrical activity in the brain)
EYFS	Early Years Foundation stage (Statutory educational framework for 0-5 year-olds in England)
FSM	Free school meals (measure of SES)
HR	Heart rate
HRV	Heart rate variability
LMM	Linear mixed effects model
PPT	Self-directed peer play and talk
SES	Socioeconomic status
SDQ	Strengths and difficulties questionnaire
SEND	Special educational needs and disabilities
SRT	Stress reduction theory
VR	Virtual reality

Acknowledgements

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Contents

Chapter 1

General Introduction

1.1 Urban or Nature-rich environments – the impact on humans

"When a flower doesn't bloom, you fix the environment in which it grows, not the flower"
Alexander Den Heijer

Development involves complex interactions between children and their environment. It is known that the physical environment can have a significant effect on children's learning and behaviour (Evans, 2006), but for most families, the environment that children are growing up in is changing.

For the first time, Earth is now a majority urban planet. The urban population is growing by 80 million inhabitants every year, whilst the proportion of children growing up in rural areas is decreasing. Almost 70% of the world's children are expected to grow up in cities by 2050 (UNICEF, 2019).

In response to rapid urbanisation, recent decades have seen more research investigating how urbanisation affects individuals' mental and physical health, behaviour and cognition. However, there are difficulties in understanding causative pathways where urban living is concerned. Many changes to society have occurred alongside urbanisation over the course of the past century. These include rapid technological advancements, globalisation, commercialisation and increased pollution to name just a few. Disentangling the effects of one change from another is problematic.

Urban living can be positive. Living more closely together offers increased opportunities for social cohesion and shared resources. On average, urban households have higher incomes and better access to education and other services (termed 'the urban advantage') (UNICEF, 2019). The average country shows an urban advantage for all 10 of UNICEF's indicators of child survival and wellbeing

(UNICEF, 2019) and research suggests that urban living can make children more resilient (Wandersman et al., 1998) and may confer some cognitive strengths (Wass et al., 2019). However, if wealth is controlled for, often much of this urban advantage disappears (UNICEF, 2019), and more recent data from population studies suggests that over the course of the last 30 years, the benefits of urban living for children's growth and development have diminished in most high-income western countries (Zeglen, 2023).

There are also risks to living in urban environments, which are associated with nigher levels of noise, crowding and crime (Neilson et al., 2019). Urban populations have a higher prevalence of mental disorders, particularly depressive disorders. (Kovess-Masféty et al., 2005; Peen et al., 2010). In some societies, those living in cities have been found to have almost a 50% greater risk of developing anxiety and mood disorders, whilst the risk of developing schizophrenia was found to be 200% higher for children growing up in the most urban environments (Engemann et al., 2019). Living in these environments, especially at a young age, is associated with higher prevalence of childhood psychotic symptoms, even when neighbourhood-level deprivation and family SES and psychiatric history are controlled for (Newbury et al., 2016). Furthermore, studies have associated urban living with increased physiological stress and stress reactivity in infants (Wass et al., 2019).

One potential mediating factor in the relationship between the environment and developmental outcomes for children, is the level of nature that children are exposed to. Research suggests that exposure to natural outdoor environments during childhood may have a long-lasting protective impact, affecting a range of outcomes in adulthood including better mental health (Preuß et al., 2019) and lower blood pressure in later life (Bijnens et al., 2017; Jimenez et al., 2021).

A Danish study, which used satellite data to calculate the level of green space surrounding approximately one million people's places of residence, found that after controlling for other confounds, higher levels of green space during childhood (ages 0-10) were associated with lower levels of psychiatric disorders in later life. People with the lowest levels of green space growing up, were 15-55% more likely to develop mental illnesses later in life, than those with the highest levels (Engemann et al., 2019). Although this research suggests that early childhood may be a highly influential time when nature access should be prioritised, testing this experimentally by withholding nature contact presents ethical and logistical challenges, leaving researchers heavily reliant on correlational data.

The Covid-19 pandemic however, provided a unique opportunity to observe the impact of changing nature contact on an international level. Whilst the majority of schools and attractions were closed during lockdowns, many families found themselves spending more time in local nature instead. However, this nature access was polarised - whilst some people accessed nature more than ever before, others barely got outside at all. In England, 60% of children reported spending less time outdoors during the pandemic, whilst around 30% had increased their outdoor time (Armstrong et al., 2021). Adults who were unemployed, on lower incomes, with lower levels of education and living in more deprived areas were less likely to make visits to natural spaces (Armstrong et al., 2021).

Research suggests that whilst an increased nature connection during the pandemic was more common for affluent families, those who decreased their nature connection were more at risk of wellbeing problems (Friedman et al., 2021). Surveys of over 5,200 respondents from nine countries found that nature contact helped people cope with the impact of lockdowns and that those with nature views from home reported more positive emotions. People with restricted access to public outdoor spaces were more likely to show symptoms of mental health disorders (Pouso et al., 2020). This is supported by a study of over 500 adults which found that those who felt most 'nature deprived' during the pandemic showed significant declines in flourishing (Tomasso et al., 2021). Furthermore, survey data indicates that youths who participated in outdoor play and nature-based activities during the pandemic reported smaller declines in subjective wellbeing, indicating that outdoor time might bolster resilience to stressors (Jackson et al., 2021). Research conducted with teachers during the pandemic further supports this finding, revealing that educators found outdoor time to be an effective strategy to support students' wellbeing, engagement and motivation during periods of distance learning (Muller and Goldenberg, 2021). It is yet to be seen how reduced or increased nature access during lockdowns may have affected longer term outcomes for children who were born during the pandemic.

Even prior to the pandemic, data suggested that relationships with nature are changing across generations. Today's children from the UK spend less time playing in natural places than previous generations and are less likely to have nature near their homes. Around twice as many children today spend time playing at an indoor activity centre or after school club compared to their parents' generation when they were young (Natural England, 2009). In the UK, 5-7 year-old children, on average, watch more than 13 hours of television a week and spend over 17 hours a week online or gaming (Statista, 2018). Meanwhile, even prior to the pandemic, 12% of children in the UK had not been in a natural outdoor environment such as a park, forest or beach for over a year (Hunt et al., 2016).

The issue appears to be exacerbated for children growing up in urban environments. Children living in London are less likely to visit the natural environment than peers in more rural areas, and those from lower income households and ethnic minorities are least likely to access nature (Hunt et al., 2016). It has been suggested that this may be perpetuating wider health and educational inequalities (Browning & Rigolon, 2019). Research in the USA corroborates these findings, suggesting that poorer communities and ethnic minorities have less access to urban greenspaces (Dai, 2011).

These statistics have led to societal concerns about a growing disconnect between children and nature and the affect this has on both development and wellbeing. The term 'Nature deficit disorder' has been coined to describe "the human costs of alienation from nature, among them: diminished use of the senses, attention difficulties, and higher rates of physical and emotional illness.' (Louv, 2005, pg 34). Whilst this term did not exist pre-2004, today a search for it on google yields over 62 million results.

Despite children expressing that they want to spend more time outside (Thomas & Thompson, 2004), and 87% of children reporting that being outdoors in nature makes them 'very happy' (Natural England, 2023), as society becomes more risk averse, children are afforded less freedom to explore outdoor environments. Survey data shows that children today are granted permission to play outdoors unsupervised at an older age than their parents were allowed this freedom (Dodd et al., 2021). An increase in surveillance and regulation of public outdoor spaces, as well as decline in the number of children allowed to travel to and from school alone and to engage in unsupervised activities such as climbing trees and playing in parks has led to concern over 'the shrinking world of childhood' (Jack, 2010). It has been suggested that this disconnect from nature could be part of a negative feedback loop whereby each generation has less opportunity for direct nature experiences and so over time, our expectations and reference points for quality nature interaction are shifted and narrowed (Bratman et al., 2019).

Until recent decades, the long-held intuition that nature is beneficial for children, has not been backed up by robust research evidence. However more recently, in a rapidly growing body of research, nature exposure has been linked to improvements in attention and behaviour (Bikomeye et al., 2021; Faber Taylor & Kuo, 2009; Taylor & Butts-Wilmsmeyer, 2020; Mygind et al., 2021; Putra et al., 2020; Zare Sakhvidi et al., 2022), improved affect (Gaekwad et al., 2022) and reduced psychological (Corraliza et al., 2012; Feda et al., 2015; Wells & Evans, 2003) and physiological (Bijnens et al., 2017; Dettweiler et al., 2017; Dzhambov et al., 2022) stress, amongst other positive outcomes. However, methodological issues and theoretical complexities, which will be discussed in detail in subsequent sections of this thesis, have made it difficult for this field of research to meaningfully impact policy and practice.

With opportunities for nature contact decreasing, schools are well positioned, but often overlooked, as potential guarantors of outdoor provision - maintaining childhood connections with the natural world. Existing research points to a range of geographic and socio-demographic factors which are associated with children's likelihood to play outdoors outside of school hours (Dodd et al., 2021), thus schools are in a unique position to overcome potential barriers and 'level the playing field' by becoming a universal access point for nature, enabling equality of access for all children. 'The Nature Premium Campaign' calls on the UK government to make it a statutory requirement for schools to regularly take children into nature, with additional funding to enable this. However, it has not yet received government support.

In the UK, primary school-aged children spend 30-40 hours per week in the school environment, making this likely to be the single environment that they interact with the most. Despite this, there is relatively little research on how the physical environment impacts children's learning, and whether nature-access at school is an important factor to consider for both wellbeing and academic benefits.

Meanwhile, at school, as well as at home, children are spending less time outdoors. A study tracking how school playtimes have changed in over 1,000 schools over the last quarter of a century, reported that 11-16 years olds have seen a reduction of 65 minutes per week in breaktimes since 1995, whilst 5-8 year-olds have seen a 45 minute reduction per week (Baines & Blatchford., 2019). This is thought to be due to a changing educational climate, where the curriculum is more demanding and schools are under increased pressure to raise standards. 58% of surveyed primary schools also said they enforce policies of withholding break times as disciplinary action for poor behaviour, further reducing outdoor access (Baines & Blatchford., 2023), often for the children who may need it most of all.

97% of teachers surveyed believed that schools should utilise outdoor spaces effectively to support pupil's development, yet only 18% believe that their school is already doing this as much as they can (Dillon, 2010). Furthermore, less than a quarter of children report doing learning activities outdoors at school, except for PE (The Children's Society, 2023).

If nature exposure can improve cognition and wellbeing, then spending more of the school day learning outside in natural settings could have a significant impact on pupils' learning and mental health. This is particularly salient during a time when children's self-reported wellbeing has declined over the last decade (Department for Education, 2019). Between 2019 and 2022, the risk of a child aged 5-16 having a mental health problem increased by 50%. One in six children now meet this criterion (NHS Digital, 2022). Children's self-reported happiness with their lives is also significantly lower now than a decade ago, with school unhappiness driving this change (The Children's Society, 2023).

The London Borough of Newham, where this research study is conducted, has one of the lowest rates of access to green outdoor spaces in the country. Green space covers 13.1% of Newham, compared with 39% for London as a whole (Newham.gov). A nature deficit in many parts of the borough is likely to be exacerbated by an expected population increase of over 27% between 2022 and 2038, meaning publicly accessible greenspace provision will need to increase by 70 hectares to meet demand (Sheaff et al, 2022).

This is compounded by other risk factors including high rates of homelessness and poverty. Newham residents have the lowest average wages in London - more than half of residents are paid less than the London Living wage. Taking the high costs of housing into account, 49% of Newham residents are living in poverty, and the rate of households in temporary accommodation is almost three times the

London average (Trust for London, 2021). The empirical studies in this thesis, therefore, seek to explore whether spending more time outdoors at school, can support the learning and wellbeing of young children living in these challenging circumstances. Furthermore, as many Newham schools are lacking green space, this project aims to explore whether learning in outdoor urban environments is still beneficial, or whether natural elements are a prerequisite for success.

1.2 The 'Nature-Effect' and the pathways through which it might occur

"I firmly believe that nature brings solace in all troubles." –Anne Frank

1.2.1 The Nature-Effect

A huge variety of outcomes have been studied in relation to nature contact and exposure. These are summarised in Table 1 below, although not all of these outcomes have been studied in a child population.

Table 1

Researched outcomes in relation to nature contact and exposure

Cognitive outcomes	Physical health outcomes	Mental health outcomes	Behavioural outcomes	Academic outcomes	Social outcomes	Other
Executive functioning, attention, inattention, hyperactivity, working memory, inhibition, creativity	Cardiovascular health, physical development, sleep, obesity, physical activity levels, myopia, immunity, birth weight, wheezing and bronchitis	Mood, affect resilience, restorativeness, subjective wellbeing, stress, self esteem	Self-regulation, emotional and behavioural development, co-operation, self-discipline	Reading ability, standardised test scores in writing, reading and maths, speech and language use	Community cohesion, crime, environment-al attitudes, social behaviour	Self-confidence, imaginative play

Recent systematic reviews of research on the impact of nature on children have found supporting evidence for:

- Passive nature exposure promoting positive changes in attention, memory and mood (Norwood et al., 2019)
- Greater exposure to green spaces during childhood being associated with increased physical activity and lower risk of obesity and neurodevelopmental issues (Islam et al., 2020)
- Higher levels of 'green time' being associated with favourable psychological outcomes and possibly buffering the negative effects of high 'screen time' (Oswald et al., 2020)
- Cognitive benefits of nature interventions (Vella-Brodrick & Gilowska, 2022)
- Measurable socio-emotional, academic and wellbeing benefits associated with nature-specific outdoor learning (Mann et al., 2022)
- Beneficial associations between greenspace exposure and children's behaviour (Zare Sakhvidi et al., 2022)

These positive outcomes, brought about by exposure to nature will henceforth be referred to as the *'nature-effect'.* There is a growing body of evidence in support of the nature-effect on various academic, social and physical and mental health outcomes and some of this evidence will be explored in detail in the literature review that follows in Chapter 2. However, in order to choose specific areas of focus within this vast body of research evidence, it is first necessary to explore the theoretical frameworks which seek to explain the nature-effect and the potential pathways and mechanisms through which this effect occurs.

Identifying these specific pathways is problematic. There are multiple features of natural environments; including lower auditory and visual noise levels, presence of plants and trees, natural light, lower levels of air pollution and more space to move around - each of which could be a potential mechanism. Yet disentangling the individual effect of each environmental feature is almost impossible as most studies do not measure or control for such variables. However, evaluating and comparing the strength of the evidence in favour of each possible pathway is important, as outdoor environments differ in many ways. Understanding which aspects contribute to positive outcomes, allows these benefits to be provided more effectively in a range of settings. It is likely that the nature-effect operates via multiple pathways, which overlap and inter-relate. Nevertheless, for clarity, each pathway is explored separately here, in order to explore its theoretical basis and briefly summarise its supporting evidence. Further exploration of the research evidence supporting or challenging each pathway is provided in the 'Theories and frameworks' section of the literature review in Chapter 2.

We begin with Attention Restoration Theory, one of the most well-known frameworks in this field.

1.2.2 Attention Restoration Theory

The predominant theory which seeks to explain why nature has beneficial effects on cognition is Attention Restoration Theory or ART (Kaplan, 1995), which claims that natural environments decrease mental fatigue and increase attentional capacity.

ART builds on William James's (1982) concept of 'voluntary attention' which refers to choosing to pay attention to something which may not capture one's attention naturally. This attention requires effort, to maintain focus and inhibit potential distractions. Kaplan renamed this type of attention 'directed attention' and proposed that it is a limited resource, susceptible to fatigue after prolonged mental effort. Directed attention is thought to be crucial for effective cognitive and emotional functioning, playing a key role in both school success and short-term memory (Berman et al., 2008).

Kaplan proposed that in order to restore directed attention, an alternative mode of attention needs to be employed, which allows directed attention to rest and replenish. This alternative is 'involuntary attention', which requires no conscious effort (James, 1982). Kaplan replaced the term 'involuntary attention' with 'fascination' and used it to describe when one is intrinsically compelled to attend to something. Being fascinated is effortless and allows for the restoration of directed attention.

ART further sub-divides this into *hard* and *soft* fascination; *hard* fascination refers to attention being effortlessly held by something highly stimulating such as watching a boxing match. In these situations, one is so absorbed that there is no time for reflective thought. In contrast, *soft* fascination is when attention is held by something inherently interesting but less active and engaging, such as the view of a forest. *Softly* fascinating stimuli may afford opportunities for reflection which is thought to contribute to the benefits of directed attention restoration.

According to Kaplan (1995), fascination is not the only component required for recovering directed attention. In order to be restorative, environments also need to give the individual:

- A sense of 'Being away'. This involves feeling apart from everyday worries or distractions and away from the environment that's draining directed attention. This is a conceptual shift involving either being in a new or different environment or viewing an old environment in a new way.
- 'Extent'. The environment must offer enough scope to immerse the individual and engage their mind, so that there is enough to 'see, experience and think about, so that it takes up a substantial portion of the available room in one's head' (Kaplan, 1995, p. 173)
- 'Compatibility'. The environment needs to match the individual's preferences and needs and enable them to meet their aims. Therefore, in a compatible environment a person feels safe, comfortable and is able to behave naturally. The environment is not distracting and does not require much effort to engage with.

According to ART, these three environmental requirements, along with soft fascination, are likely to be found in nature and thus, natural environments have the potential to restore attention. Improved attentional capacity may subsequently benefit other cognitive processes such as inhibition and working memory as they are thought to be interlinked (Schutte et al., 2017).

There are several critiques of ART on both empirical and theoretical grounds. Whilst the concept of directed attention being a limited resource which is prone to fatigue is well established and has been demonstrated in a wide range of empirical studies throughout the last century (See Scalf et al, 2013 for a summary), proving that natural environments restore attention after fatigue, specifically because of the features listed above, is much more problematic. Whilst attention may be improved following exposure to nature, this could be due to a range of other environmental features and processes (as explored in the remainder of this chapter). Critics have suggested that central aspects of ART such as ‘soft fascination’ are too vague and undeveloped (Joye & Dewitte, 2018). Another fundamental issue is that there’s not a clear definition of ‘directed attention’ as a concept in relation to ART, making it difficult to determine the validity and reliability of measures used in studies which aim to support the theory. Nor is it clear which characteristics of a natural environment make it restorative and the relative importance of each. The four characteristics offered by Kaplan (1995): ‘soft fascination’, ‘being away’, ‘extent’ and ‘compatibility’ are difficult to define and measure operationally, making it impossible to manipulate them experimentally (Neilson et al., 2019). Furthermore, ART rests on the assumption that natural environments are less taxing of attention because they invite more bottom-up processing, whilst urban ones recruit top-down processing. However, there has been no verification that this is the case, in fact some studies suggest that soft fascination is a top-down process (Grassini et al., 2019).

A review and meta-analysis of 31 studies provided some support for nature improving attentional capacity but commented on the diversity of evidence regarding study design and outcomes, asserting that this has led to uncertainty about which aspects of attention might be affected by nature exposure (Ohly et al., 2016).

An alternative, but linked theory is that time in nature acts as an ‘incubation period’ during which conscious problem-solving stops, but the brain continues to work unconsciously; enabling improved performance after nature exposure (Williams et al., 2018). This is a less researched area but nonetheless may explain why in some studies, time in nature leads to improvements in subsequent cognitive tasks. Wakeful rest, whereby the brain is in ‘default mode’ has been argued as important for mental processing and cognitive abilities such as comprehension and divergent thinking (Immordino-Yang et al., 2012).

Given that a large proportion of existing research on the nature-effect is based on measuring attentional effects, and that attention is key to school performance, the research evidence in support of ART is explored fully in the literature review in section 2.5.

1.2.3 The Biophilia Hypothesis and Stress Reduction Theory (SRT)

The two other primary theoretical frameworks for understanding nature's beneficial effects are the Biophilia Hypothesis (Wilson, 1984) and Stress-Reduction Theory or SRT (Ulrich et al., 1991). Each of these are related to several other, interlinked theories.

According to the Biophilia Hypothesis (Wilson, 1984) humans have an innate, adaptive affinity with the natural world. Although we have transitioned from living outdoors in nature to inside buildings and cities, we have maintained our need to connect with nature and meeting this need brings about emotional wellbeing.

Support for the Biophilia hypothesis comes from studies which evidence people's preferences for natural environments over urban ones (K. Han, 2007), which are consistent cross-culturally (Meidenbauer et al., 2019), and from evidence that exposure to nature is associated with positive affect (Gaekwad et al., 2022). Recent reviews and meta-analyses report that walking or running in nature reduces anxiety and anger and improves vigour and positive affect significantly more so than doing the same exercise in an outdoor urban environment (Wicks et al., 2022; McMahan & Estes, 2015), whilst random experience sampling indicates that people are happier outdoors in green or natural habitats (MacKerron & Mourato, 2013). A more recent study seeking to provide global evidence of the Biophilia Hypothesis used social media and artificial intelligence to examine over 31,000 photographs across 185 countries. It reported that people are more likely to interact with nature during fun and relaxing moments, and countries with more nature in activity photographs had higher life satisfaction (Chang et al., 2020).

Some studies evidencing young children's preferences for natural environments (Margherita, 2015) suggest that nature preferences are innate. However, these findings are inconsistent, as other research has demonstrated that younger children prefer urban scenes and that nature preferences emerge with age (Meidenbauer et al., 2019).

Thus, it remains unclear whether nature preferences are adaptive and innate, or culturally and socially learnt. Furthermore, due to a lack of control over conditions we cannot be certain that Biophilia is the reason behind these nature preferences rather than the other theories and variables that are discussed throughout this section.

According to Stress Reduction Theory (SRT) (Ulrich et al., 1991), environments with water and vegetation which could provide shelter and food were important to our ancestors in terms of survival. Therefore, humans have evolved to have an unconscious positive response to such natural environments. This initial positive response is a physiological one, it involves decreased physical arousal (reduced blood pressure and lower levels of stress hormones) which creates a shift towards a more positive emotional state. This reduced stress could also explain other observed effects of natural environments including positive effects on behaviour and cognition.

Critics of SRT have questioned how all natural landscapes could trigger positive affect and/or reduce stress when historically, such landscapes would also have contained threats to survival such as predators and hazards (Joye & de Block, 2011, McMahan & Estes, 2015). Thus, the specific features of the natural environment may be important mediators of the nature-effect. According to Prospect-Refuge Theory (Appleton, 1975), (the most recent, expanded version of which incorporates aspects of Berlyne's (1951) arousal theory and Kaplan & Kaplan's (1989) information model), environments that offer both views and a sense of enclosure, trigger feelings of safety and pleasure (Dosen & Ostwald, 2016). Much like SRT, this has been explained in relation to survival instincts. However, Prospect-Refuge theory has been criticised for a lack of robust experimental evidence. A meta-analysis concluded that quantitative evidence in support of Prospect-Refuge theory was inconsistent (Dosen & Ostwald, 2016). In order to further examine the support for these theories, section 2.4 of the literature review looks specifically at the evidence that nature exposure has an impact on children's emotional and physiological stress.

The majority of research conducted on The Nature Effect is underpinned by one of the three theories described above. However, there are many other, less explored aspects of natural outdoor environments through which The Nature Effect could also operate. If humans' physiological functions have adapted to natural environments through the course of evolution, then living in an urban society, with a prevalence of artificial rather than natural features could be inherently stressful (Tsunetsugu et al., 2010). Thus, many studies which claim nature can reduce stress or improve cognition, do so by attempting to evidence the detrimental effects of an urban environment in comparison. Aspects of the physical environment such as noise, crowding and pollution are chronic stressors which some studies suggest can lead to depletion of individual's coping resources, and therefore result in mental health problems (Wandersman & Nation, 1998). This viewpoint is supported by research which evidences a link between urbanicity and higher risks of mental disorders (Bratman, Hamilton, et al., 2015; Kovess-Masféty et al., 2005).

Therefore, we will next look at how the nature-effect may occur from protecting individuals against harmful urban stressors.

1.2.4 Protection from harmful environmental stressors

Air pollution

Exposure to air pollutants is detrimental for health and development. Early exposure associates with adverse neurodevelopmental outcomes (Castagna et al., 2022) and evidence suggests that pollutants in schools adversely influence student performance and attendance (Grishkevich et al., 2005) and are associated with increased behavioural problems (Forns et al., 2016). Some studies suggest that air pollution might also affect ADHD: increases in specific air pollutants around children's home addresses raised the relative risk of ADHD, whilst increases in green space decreased the risk (Markevych et al., 2018). However, access to child psychiatrists was thought to be a confound here.

For these reasons, the association between greenness surrounding children's schools or homes and improved cognitive performance is thought to be partly mediated by reduced air pollution. In one study, this was thought to account for 20-65% of the nature-related gains made in cognitive development (Dadvand et al., 2015). In another, reduced levels of nitrogen dioxide in greener areas were thought to mediate over 97% of the association between lifetime exposure to residential greenspace and early childhood development, whilst fine particulate matter mediated 29.5% of the relationship (Jarvis et al., 2021). However, not all studies have replicated these findings. Some studies have shown that greenspace is associated with improved cognition in children, independent of traffic-related air pollution exposure (Saenen et al., 2023).

Air pollutants may also mediate the relationship between nature exposure and physiological stress. A study of over 9,000 children in China reported positive associations between blood pressure and four different air pollutants (Zeng et al., 2017). These findings are supported by a study of 4-5 years olds (n=4,279) which found that living in more harmful urban environments (those high in air pollution, traffic and noise and low in green space) is associated with higher blood pressure (Warembourg et al., 2021). Associations between newborn blood pressure and exposures to pollutants during the last four to five weeks of pregnancy have also been reported (Madhloum et al., 2019).

Excess noise

Environmental noise exposure has been associated with physiological markers of stress in children, (Evans, 2001; Bremmer et al, 2003) and also negatively impacts cognition and school performance (Connolly et al., 2019; Howard et al., 2010; Klatte et al., 2013; Shield & Dockrell, 2003; Woolner & Hall, 2010). Therefore, lower levels of noise in green spaces or outdoor learning environments compared to indoor ones, could be the mechanism behind the nature-effect. It is likely that more dense vegetation buffers road traffic noise and that residential and school areas with a higher proportion of green space are in quieter, less urban areas.

However, studies of The Nature Effect do not typically measure noise levels as a potential mediator, making this theory difficult to evidence. Studies which do use causal mediation analyses and incorporate noise as a covariate provide some support for noise as a key pathway. One study of over 27,000 children found associations between lifetime exposure to greenspace and early cognitive development. Reductions in noise were found to mediate 35.2% of this association (Jarvis et al., 2021). In another, greater noise exposure in classrooms was associated with increased ADHD symptoms (Forns et al., 2016).

Although research specifically on noise and the nature-effect is lacking, there is a large body of research to draw from which evidences the negative effect of noise on school performance, affecting a wide range of academic outcomes such as numeracy, reading, speech and language and overall achievement (Shield &

Dockrell, 2003), as well as affecting mental and physical health and cognitive development (Thakur et al, 2016).

A recently-updated systematic review and metanalysis of noise pollution and cognition (Thompson et al., 2022) concluded there is moderate evidence for an association between aircraft noise and both reading and language, and executive functioning in children and suggests that mitigating exposure to noise could not only improve cognitive performance but also provide wider health and wellbeing benefits. Conversely, natural soundscapes have been found to restore children's cognitive performance (Shu & Ma, 2019) and improve adults' mood recovery after watching an unsettling video (Benfield et al., 2014). Noise from background chatter in the classroom, which has been shown to be detrimental to learning (Lamotte et al., 2021; Visentin et al, 2023), is also likely to be lower in outdoor learning environments due to reduced reverberation from walls and ceilings.

Together, these findings suggest that being outside in nature could benefit attention due to noise reduction rather than the processes described in Attention Restoration Theory.

Noise has also been shown to affect emotions and behaviour; road traffic noise has been linked to peer problems, hyperactivity and inattention (Tangermann et al., 2022) and emotional symptoms (Tiesler et al., 2013) in children, whilst in adults, noise exposure has triggered annoyance and accentuated aggression, as well as suppressing altruistic behaviour (Evans, 2006).

However, it cannot be assumed that outdoor environments are always quieter, there may be increased traffic noise if school outdoor spaces are positioned close to roads and construction sites. Even in more natural areas, there may be noise from air traffic, birds, trees rustling etc which provides additional distractions which are not present in the indoor environment. Therefore, it is imperative that research which examines the impact of learning outdoors also considers whether auditory noise levels are increased or reduced in outdoor learning environments and how this might mediate effects.

Visual processing demands

Unlike natural environments which, according to ART, restore attentional capacities, urban environments are thought to deplete attention as they are more cognitively taxing (White & Shah, 2019). There are several studies which investigate the visual properties of urban and natural scenes and the amount of cognitive load they create. People have displayed more fixations (focussing on a greater number of different objects) and higher blink rates for images of urban environments compared to natural ones, suggesting greater cognitive load when processing urban environments (Valtchanov & Ellard, 2015). Urban scenes contain more red and blue whilst natural scenes are more green and luminous (Grassini et al, 2019). Features such as density of contrast changes and straight lines, average colour saturation and hue diversity have all been found to be most related to perceptions of 'naturalness' when adults rate images (Berman et al, 2014) and may affect how easily natural scenes can be processed.

Whilst some studies use eye-tracking software, others look at what's happening inside the brain to evidence variations when processing different environments. One such study used EEG and found different electrical activity in the brain when processing urban and natural images, which suggested lower attentional demand and less cognitive processing for natural images (Grassini et al., 2019). Another used haemodynamic response to conclude that some patterns found in urban images (such a repetitive stripes) are uncomfortable to view and are processed inefficiently (Le et al., 2017). Whilst a detailed description of these studies on visual processing is beyond the scope of this thesis, they do offer an alternative framework through which to understand observed associations between nature contact and improved cognitive performance.

Learning environments which place high visual processing demands on children have also been found to negatively impact learning. Classrooms for younger children commonly have visual displays on the walls such as posters, artwork and charts (Godwin, Leroux, Scupelli, et al., 2022) and often contain a multitude of colours, shapes and edges. Such processing demands which are not related to the learning task can be thought of as 'visual noise' or 'visual clutter'.

Evidence that visual clutter negatively impacts attention comes from a lab study which manipulated the visual environment, teaching three science lessons in a highly decorated 'lab classroom' and three science lessons in a 'streamlined' non cluttered 'lab classroom.' Results showed that 5-year-olds performed better in the classroom with blank walls. Over 85% of children spent more instructional time off-task in the decorated classroom, leading to lower learning outcomes, whilst reducing visual clutter reduced children's off-task behaviour (Fisher et al., 2014). In a follow up study, which looked at whether classroom decorations only provide distraction when they are novel to the children, it was found that these visual distractions continued to be a source of off-task behaviour even after two weeks - the children did not become completely habituated to them (Godwin et al., 2022). The effect is theorised to occur because visual attention is a competitive process, with multiple objects in the field of vision competing for representation in the visual cortex. Highly decorated environments may therefore create greater competition between the target for attention (the teacher and/or relevant learning material) and other classroom design elements (such as wall displays or non- relevant objects) (Godwin et al., 2022).

Furthermore, across 58 classrooms, children exhibited significantly less on-task behaviour in classrooms which had greater levels of colour variability and visual noise. On-task behaviour was highest in classrooms with an intermediate amount of wall displays (approximately 25% of wall coverage). In classrooms with less than 20% or greater than 30% of walls covered by displays, on-task behaviour was reduced (Godwin et al., 2022).

Other experiments have found similar results: Children with and without Autism were shown video-taped lessons, with half delivered against a plain background and the other with classroom displays in the background, then asked followup questions about the content. Children's gaze was measured using eye-tracking technology. Children spent more time looking at the teacher in the 'plain background' condition and had higher learning scores. The effect was stronger in children with Autism (Hanley et al., 2017).

In other research, children performed better in cognitive tasks of attention and memory in a low-load visual environment (cubicle with blank walls) than in a high-load environment (walls with visual displays) (Rodrigues & Pandeirada, 2018)

Together, this research suggests that the nature-effect may occur via reduced visual processing demands in outdoor environments.

1.2.5 Exposure to positive environmental factors

In addition to buffering negative environmental factors that are characteristic of urban environments, natural outdoor environments also offer positive factors which may operate as mechanisms through which The Nature Effect occurs.

Phytoncides

Phytoncides (the natural scent of trees) have been shown to contribute to reducing physiological stress. Certain smells, such as those of cedar and Taiwan cypress, have been found to reduce blood pressure in laboratory experiments (Tsunetsugu et al., 2010).

Although phytoncides may be one of the pathways through which The Nature Effect operates, we know they are not the sole mechanism as phytoncides cannot be responsible for the observed positive effects of observing images of nature (Brown et al., 2013; Mostajeran et al., 2021; Ulrich et al., 1991b), nature exposure based on virtual-reality experiences (Kort et al., 2006; Meara et al., 2020; Yu et al., 2018) and exposure to natural environments which do not contain trees (M. White et al., 2010).

Natural light

Spending time in natural outdoor spaces is also likely to increase the amount of natural daylight children are exposed to. Studies consistently show that people prefer daylight to artificial lighting and believe that it is better for their health (Van den Berg, 2005). Daylight tends to have a more balanced spectrum of colours than artificial light and is also often brighter (Van den Berg, 2005). Some research has demonstrated that exposure to natural light can improve a wide range of health outcomes including depression (Beauchemin & Hays, 1996), headaches (Wilkins et al, 1989) and stress (Walch et al, 2005), whilst flicker from indoor fluorescent lights can cause stress and headaches (Wilkins et al, 1989; Kuller & Laike, 1998). In addition, exposure to natural light, especially in the mornings, is thought to regulate circadian rhythms and improve sleep (Roenneberg et al, 2003). Further evidence for a link between daylight and sleep quality comes from a study using wearable light sensors and sleep actigraphy. Results suggested that children learning in classrooms receiving more daylight slept longer than children in classrooms with the lowest light (Boubekri et al, 2020).

Artificial bright light has been used successfully to treat both mood (Faulkner et al, 2019) and sleep disorders (Geoffroy et al, 2019). A metanalysis showed that in cases of severe depression, light therapy is as effective as prescribing antidepressants, and that combining both treatments improves efficacy (Faulkner et al, 2019). Light therapy is thought to affect emotion, mood and melatonin production by modulating dopamine, serotonin and adrenaline (Korman at al, 2022).

Thus, theoretically, natural light from being outdoors in nature could reduce stress and improve mood and attention via both physiological and psychological pathways; by improving mood, reducing eye strain and associated headaches and stress, and also by improving sleep quality and feelings of alertness due to improved circadian rhythms - which could have a knock-on effect on positive affect and brain functioning.

If increased natural light is a pathway through which The Nature Effect occurs, it is likely to be operating alongside other mechanisms, as otherwise we would expect all outdoor time to be equally beneficial - whereas multiple studies, as summarised in the literature review which follows, have demonstrated that time outdoors in natural environments reduces stress and improves attention and behaviour more so than an equivalent amount of time spent in urban outdoor environments. Furthermore, both images of nature and indoor plants have been shown to have a positive effect.

Gut microbiota

Exposure to more diverse microbiota in natural environments is thought to influence individuals' gut microbiota which regulates brain function and behaviour (Mu et al., 2016). This modulation could have downstream effects on other outcomes such as stress, behaviour and cognition.

A study of twins (n=2,443) found differences in gut microbiota according to whether participants lived in urban or green spaces (Bowyer et al., 2022), the microbiota signature of those living in the greenest places was distinct from other individuals and some pathogenic bacteria species were particularly associated with urban environments. Although the differences observed were modest, when comparing the relative variance explained by each variable in the study, surrounding green space accounted for almost as much variance as diet, and more than SES or health deficits.

Some research suggests that issues disrupting the development and composition of the gut microbiome during early life might be linked to central nervous system dysfunction and brain function (Clarke et al., 2014). It is now understood from animal studies that gut microbiota can shape mood and behaviour (Borrelli et al., 2016). This occurs via the gut-brain axis which allows an event in the brain to impact the gut and vice-versa. This bi-directional communication happens via several pathways including immune, endocrine and neurological systems (Clarke et al., 2014; Cryan & Dinan, 2012). Animal studies suggest that experimentally manipulating gut microbiota can affect behaviour; depleting microbiota made rats more reactive to stress (Collins et al., 2012) and created abnormality in social interactions which could be reversed by weaning (Clarke et al., 2014). Other research suggests that some functions of the vagus nerve may also be activated by gut microbiota (Cryan & Dinan, 2012).

There are fewer studies conducted on humans, although small studies have suggested that children with Autism Spectrum Disorder have a different composition of gut microbiota compared to neurotypical peers. Autistic children commonly report gastrointestinal symptoms. However, they have also been found to use antibiotics more often than neurotypical children and also differ in their diet, so it is difficult to distinguish between cause and effect (Cryan & Dinan, 2012). Similarly, some research suggests that gut microbes play a role in the development of ADHD and that some medicines which improve ADHD symptoms in rats also improve the structural composition of gut microbiota (Tang et al., 2022).

A 28-day intervention which enriched biodiversity at urban daycare centres by covering their outside play area with forest floor and sod (Roslund et al., 2020) was found to alter children's gut bacteria, making it more similar to peers who attended nature-oriented daycare centres which spend time daily in forest environments. Some initial research suggests that such changes may have a knock-on effect on behaviour. When 54 preschool children participated in a 10-week program promoting interaction with the natural outdoor world, their gut microbiota profiles changed and, according to teacher ratings, their prosocial behaviour frequency and anger frequency improved significantly in comparison to a control group (Sobko et al., 2020). However, such research is still in its infancy and as yet, causal mechanisms have not been evidenced robustly.

Thus, it is possible that the nature-effect could, in part, be due to increased diversity of gut microbiota. However, studies that show effects of nature even in cases where exposure occurs only via images, would naturally preclude gut microbiota as being the only pathway.

Increased physical activity

The final pathway explored here is that natural green spaces encourage more physical activity, which has downstream effects on other outcomes such as learning, stress and behaviour. Existing research suggests a link between nature and physical activity (McCurdy et al., 2010); natural spaces induce more physical activity than other types of outdoor space such as concrete playgrounds (Bikomeye et al., 2021; Boldemann et al., 2006; Dawn P. Coe et al., 2014; Pagels et al., 2014) and individuals living in greener areas are more likely to engage in exercise and have a lower BMI (Bell et al., 2008; Dadvand et al., 2014).

The physical activity undertaken in natural environments, often involving activities like climbing, balancing, jumping and den building affords children with opportunities to take risks, be creative and exploratory, and learn about mastery and control, all of which have been suggested as beneficial for brain development (Kahn and Kellert, 2002) and may impact other outcomes such as stress and attention.

Some studies have also found relationships between physical exercise and self-regulation (Oaten and Cheng, 2006) and physical activity and reduced stress (Hobson & Rejeski, 1993) and improved stress recovery (Peluso et al, 2005). Therefore, increased physical exercise may mediate relationships between greenspace exposure and behavioural and mental health outcomes.

One theory is that the cardiovascular efficiency associated with regular exercise enables people to recover (physiologically) more quickly from stressful events, i.e. their heart rate returns to a baseline level more quickly. This then leads to better psychological coping (Plante & Rodin, 1990).

However, as with adults, children who identify more symptoms of stress and depression are less likely to be physically active (Olive et al, 2016). Therefore, taking evidence from correlational studies which link physical activity to stress is problematic as we cannot specify the direction of effects - does exercise reduce stress in children, or are children who are already stressed less likely to exercise in the first place?

Furthermore, studies have shown that merely the presence of greenspace surrounding the home or school (whether or not children engage with that space) is associated with better behavioural outcomes and has an impact on stress (Corraliza et al., 2012; Feda et al., 2015; Wells & Evans, 2003), and that benefits can be gained from sitting still in natural outdoor spaces, viewing them through windows (Li & Sullivan, 2016;Kobayashi et al., 2015), or via photos and videos (Ulrich et al., 1991) suggesting there must also be other mechanisms in play. In one study, access to neighbourhood parks was found to predict perceived stress in adolescents even after controlling for physical activity (Feda et al, 2014).

1.2.6 Summary

There are multiple pathways and mechanisms through which the nature-effect may operate, and these are unlikely to be mutually exclusive. The majority of existing studies utilise Attention Restoration Theory, Stress Reduction Theory or The Biophilia Hypothesis as their underpinning theoretical framework, though there are many other features of natural environments which could mediate effects. These features, such as lower levels of noise, natural light and reduced visual processing demands are less researched and often not included as covariates in study designs.

Attention is one of the most commonly researched outcomes in regard to the nature-effect. Many of the aforementioned pathways, through which the nature-effect could occur would have a direct or indirect effect on attention. For example, natural environments may restore attention by providing wakeful rest or reduced processing demands, they may improve attentional capacity via reduced stress or increased physical activity, or exposure to natural light may improve sleep which has downstream effects on attention.

Similarly, stress (both psychological and physiological) is frequently measured in studies of the nature-effect and nature may impact stress via multiple pathways such as improving affect, improving gut microbiota or reducing blood pressure and heart rate.

An important concept related to both stress and attention is self-regulation. Self-regulation of attention allows individuals to engage in directed attention, resisting distractions and maintaining focus, whilst self-regulation of stress supports coping strategies and physiological stress recovery. The research discussed so far suggests that natural environments may support better self-regulation of both stress and attention. A third type of self-regulation is behavioural self-regulation- in this context, a child's ability to control their behaviour and emotions and the extent to which they can manage impulses in order to 'behave well'- for example to act pro-socially by sharing and taking turns, or to tolerate strong emotions without physically hurting others or damaging property.

Recent systematic reviews (Bikomeye et al., 2021; Mygind et al., 2021; Putra et al., 2020; Zare Sakhvidi et al., 2022) have indicated that access to natural, outdoor spaces may have a beneficial effect on various outcomes linked to behavioural self-regulation. This effect may operate through various pathways including increased physical activity, reduced stress and improved affect.

These three areas of self-regulation: attentional, physiological (stress) and behavioural are also all closely linked to school performance and success. This is explored further in the literature review that follows in Chapter 2. The literature review chapters of this thesis will therefore focus specifically on research evidencing nature's effect on the regulation of stress, attention and behaviour.

Before this, however, it is important first to return to the educational context of this study and consider the importance of the school environment. Many of the studies discussed in the literature review that follows were not conducted in school settings. However, the physical environment in which children learn, and the extent to which it influences outcomes is an important but often neglected area of study. In order to better understand the potential benefits of learning outdoors, it is important to also consider the features of the *indoor* classroom environment, and whether they comprise optimal conditions for children's learning and wellbeing.

Therefore, the next section of this introduction will briefly consider the significance of the learning environment in child development and learning, briefly summarising how the environment is incorporated into well-known pedagogical approaches as well as considering environmental variables and their impact on learning outcomes.

This is important because a broader understanding of how aspects of the learning environment influence learning and behaviour is helpful in beginning to disentangle why being outdoors might be effective, whether outdoor environments need natural elements to be beneficial, and which aspects of nature are most impactful. These areas are discussed below in section 1.3 before closing this introductory chapter by exploring differential susceptibility and whether children may differ in their sensitivity to environmental influences.

1.3 The significance of the learning environment in child development and learning

"Winston Churchill once said 'we shape our buildings and then they shape us'. If this is true… then there is no designed environment that needs immediate attention more than does the school facility"

(Conners, 1983)

Friedrich Froebel (1782-1852), who created the word 'kindergarten', was one of the first early childhood pioneers to write about the importance of the outdoor environment in children's early development, and the sensory experience of being outdoors in nature. He advocated for the importance of 'pure air, clear light, clear space' (Froebel, 1826, p30) and ensured each of his kindergartens had a garden area for playing outdoors, and a plot of land for each individual child to sow seeds, tend plants and harvest produce. He believed that this helped children to recognise their place in the natural world, respect living livings and also to learn how to take care of themselves (Tovey, 2014).

Maria Montessori (1869-1952) followed on from this, pioneering the idea of 'free flow' learning environments; providing open access from indoors to outside. In Montessori settings, children were encouraged to be self-directed and choose whether to be indoors or outside. She provided learning apparatus and mats so that children could move their learning outside and also asserted the importance of children being 'masters in their own houses' (Tovey, 2014, p18). To create this effect, Montessori ensured that early learning environments utilised child-sized furniture and resources and made these resources well organised and easily accessible for children.

More recently, the Reggio Emilia approach developed in the 1950s, in a region of Italy where early years settings coined an alternative approach to education based around key values (Thornton and Brunton, 2010). This approach, led by Loris Malaguzzi and influenced by the work of Maria Montessori and Jean Piaget, has influenced early years provision around the world, gaining international praise and recognition (Hall et al, 2014). One of the early developments in the Reggio movement was the recognition that the *space* and *place* in which children learnt was significant. Reggio collaborators invested significant time and energy in considering and planning the learning environment (Edwards, 1998). Famously, the Reggio Emilia approach considers there to be three educators in any learning situation; the teacher, the child and the environment (Strong-Wilson, 2007). The status of ‘third teacher’ afforded to the environment indicates its importance and relates to the necessity of the learning environment being well prepared and aesthetically pleasing, with great attention afforded to detail. A Reggio Emilia classroom should facilitate children’s learning by allowing them easy access to resources, providing places to encourage interaction, and having inviting materials which ‘enrich but do not dominate the environment’ (Hall et al, 2014, p46). Thus, Reggio classrooms commonly utilise neutral rather than bright colours, soft lighting, natural materials and indoor plants, and intentionally lack clutter. They are designed to offer multisensory experiences (Edwards, 1998). In many ways, this approach replicates the affordances of a natural outdoor environment.

However, whilst it is central to the three approaches described above, the learning environment is not awarded such attention in all discourses about education. Whilst the social and emotional environment in the classroom has been discussed more frequently, the physical environment has been largely neglected until more recent decades (C. S. Weinstein, 1979). In fact, a lack of available funding often means that school environments are unsatisfactory with inadequate lighting, heating, air quality and ventilation (Frumkin et al, 2006) as well as failing to provide optimum conditions for learning and socialisation. Indeed, despite vast societal and pedagogical changes, classrooms today look remarkably similar to those from a century ago.

Research on physical learning environments falls across multiple disciplines including architecture, urban planning and various sectors of psychology including environmental, educational and developmental. Perhaps for this reason, there appears to be no cohesive research-based guidance on classroom design which is used as part of initial teacher training. However, evidence suggests that some classroom variables have a significant impact on learning and behavioural outcomes. Assessments of 153 primary school classrooms across 57 schools found seven parameters that were identified together to explain 17% of the variation in children's learning performance; namely: light, temperature, air quality, ownership, flexibility, complexity and colour (Barrett et al., 2015). A curvilinear relationship was reported whereby students performed best in classrooms with intermediate levels of colour and visual complexity. This is in keeping with theories of physiological arousal and performance such as the Yerkes Dodson Law (Yerkes & Dodson, 1908) whereby being over or under aroused can negatively impact performance.

Consideration of environmental classroom factors is particularly pertinent in light of rising awareness of sensory processing disorders (SPD). A recent prevalence study estimated that over 26% of children have sensory processing difficulties, with around 15% meeting the threshold for diagnosis (Galiana et al., 2022). SPD can take many forms, including Sensory Modulation Disorder – being under or over responsive to sensory input (Wild & Steeley, 2018). Interventions to support SPD include increased opportunities for movement and sensory input, noise-reducing headphones and dimming lights (Wild et al, 2018). However, it is not only neurodivergent children who can benefit from such adjustments. Existing research has evidenced a number of factors that negatively impact neurotypical children in school environments including excess noise (Klatte et al., 2013; Massonnié et al., 2020), poor lighting (Winterbottom & Wilkins, 2009), lack of windows (Vásquez et al., 2019) and excess visual clutter (Fisher et al., 2014; Godwin et al., 2022).

Whilst an in-depth literature review on all physical aspects of learning environments is beyond the scope of this thesis, brief overviews of existing research on both auditory and visual noise have already been included in section 1.2.4, as they have been commonly studied in school settings and are pertinent to the effects of an outdoor learning environment. Excess auditory and visual noise could lead to sensory overload and overstimulation in young children, as well as taxing their attention regulation (Godwin, Leroux, Scupelli, et al., 2022). Noise and visual clutter are likely to be reduced in an outdoor learning environment compared to an indoor classroom, therefore these variables may act as mediators, playing a part in some of the observed effects of nature which are described in subsequent sections of this thesis.

1.4 Differential susceptibility to the environment

The literature reviewed thus far has examined the impact of a range of environmental variables. However, it is possible that such variables don't affect all children in the same way. Much existing research on learning treats children as one homogenous group and does not consider individual differences in the way children respond to their environment. Yet studies suggest that we do interpret and respond to environments differently.

Individual differences in environmental sensitivity

Outside of the realm of research specifically on nature, evidence seeking to explain why there is such great variation in psychological and physical health of children exposed to both high and low levels of adversity, posits that some children are more reactive to environmental influences (Kennedy, 2013).

Empirical research suggests there is significant variability in how individuals react to both positive and negative common experiences. These differential reactions relate to how sensitive a person is to their social and physical environment (Assary et al., 2023). Previous research has looked at genotypic variations, physiological reactivity and temperament as possible indicators of how susceptible or sensitive a child may be (Slagt et al., 2017), with these factors considered more like 'plasticity factors' than 'vulnerability factors' - some individuals are more malleable by environmental influences than others (Belsky & Pluess, 2009). This heightened sensitivity makes such individuals more receptive to the environment and more likely to experience sustained, developmental effects in response to environmental exposures (Ellis et al., 2011).

The concept of environmental sensitivity has also been studied from a personality perspective. The notion of a 'highly sensitive person' (HSP), has gathered interest in both academic and non-academic communities. Today, a Google search for 'highly sensitive person' yields over 480 million results, and new scales and frameworks of sensitivity are being developed across multiple fields in psychology (Pleuss et al., 2023).

Differential susceptibility theory (Belsky, 1997) proposes that more sensitive, or more 'reactive' people are more susceptible to *both* the positive *and* negative effects of their surrounding environment, indicating that children who are particularly vulnerable to negative environments may also experience the greatest benefits from positive ones.

The terms 'Dandelions' and 'Orchids' have been used to describe how people differ in their sensitivity, with dandelions being more resilient to environmental effects (and therefore able to 'grow' anywhere) and orchids being more sensitive to both positive and negative influences (and therefore thriving in some conditions but suffering in others) (Boyce and Ellis, 2005; Lionetti et al, 2018). Although these labels can be a helpful metaphor, in reality children are more likely to be somewhere along a sensitivity continuum rather than fitting into one of two neatly defined boxes.

Whether a child is an 'Orchid' or a 'Dandelion' has a neurobiological basis, relating to increased Autonomic Nervous System (ANS) reactivity. Existing research suggests that exposure to both high levels of stress, and high levels of support, in childhood environments upregulates biological sensitivity to the environment (creating Orchid children). In contrast, childhood environments that do not have extreme levels of either stress or support, downregulate biological sensitivity (creating Dandelion children) (Ellis et al., 2011). More recent research, based on over 900 adults, has advocated for the inclusion of a third group, 'Tulips' who are neither highly sensitive or low-sensitive individuals (Lionetti et al., 2018).

Both correlational and experimental studies suggest that children who are high in negative emotionality (more easily distressed) are more susceptible to environmental influences (Slagt et al., 2017), including the quality of childcare that they receive (Belsky & Pluess, 2012).

There have been a small number of studies applying differential susceptibility theory to the classroom context. One such study (n=712), exploring what mediates and moderates the relationship between classroom climate and achievement, found that more anxious children were more reactive to both positive and negative elements of the classroom environment (Hughes & Coplan, 2018). Other research on children's temperament, attributes children's differing responses to the same stimulus to differences in the sensitivity of various brain systems related to children's reactivity and self-regulation (Rothbart & Jones, 1998). Such research suggests that due to individual differences, children will process the same environment differently from one another– whilst some children are more easily overwhelmed by high levels of stimulation, others may cope better with it (Rothbart & Jones, 1998).

Similarly, children differ in how easily they become scared and excited, and in how easily they can regulate their attention. This poses clear issues for learning environments whereby a single classroom setting is usually required to meet the needs of multiple children with varying sensitivity and baseline levels of arousal.

Theories of temperament are also relevant here. Thomas and Chess (1977) coined the term 'goodness of fit' in thinking about how well a child's temperament and characteristics match the demands of the environment they're in. The classroom environment will be a better 'fit' for some children than others, affecting how they interact with the classroom and those within it.

Ultimately, what variation in neurobiological susceptibility to the environment means, is that even when a group of children experience the same environmental influences, some individuals' development and life outcomes will be affected more than others (both for better and for worse). Whilst this theoretical framework hasn't been directly applied to The Nature Effect before, in this thesis it provides a rationale for exploring whether nature has a differential effect on groups of individuals, and if so, the mechanisms through which this might operate.

Differential effects of nature contact

The limited existing research looking at individual differences has suggested that children who are already disadvantaged may reap the greatest benefits from nature. Those who are already suffering from higher levels of stress, experience greater stress-relieving benefits from nature contact (Morita et al., 2007; Wells & Evans, 2003), children who lived in the least nature to begin with, benefit most from a move to increased nature (Wells, 2000) and effects of nature on academic performance may be greatest for the schools who are in the most challenging circumstances (Sivarajah et al., 2018). Given this potential pattern, it is important to explore why nature might have differential effects, what underlies these differences and whether exploiting an understanding of this could enable nature access to improve inclusion and equity in education.

Socio-economic status

The term ‘equigenisis’ refers to when environmental factors disrupt the usual relationship between economic inequality and health inequality, narrowing the gap between more and less disadvantaged groups (Jordan, 2020). In the present context, equigenic effects of nature are those that disproportionately benefit disadvantaged people, and therefore may have the potential to improve equity in areas such as mental health, physical health and academic outcomes.

A study from 2015 explored relationships between neighbourhood environments and socioeconomic inequalities in mental wellbeing, across 34 European nations. Various neighbourhood characteristics were investigated but access to green space and recreational areas was the only one that associated with narrower socioeconomic inequalities in wellbeing (Mitchell et al, 2015). These equigenic effects have since been replicated in other studies. Frequency of recreational visits to nature moderated the effect of income-related wellbeing disparities in one study (Fian et al, 2024), and time in nature was associated with smaller socio-economic inequalities in wellbeing in another (Garrett et al, 2023). Furthermore, preschool and primary school children who were from disadvantaged families appeared to gain greater mental health benefits from nearby greenspaces compared to their peers. There were stronger associations between greenspace exposure and anxiety when looking at children from low education households (de la Osa et al, 2024).

Other research has reported that the relationship between neighbourhood natural space and prosocial behaviour is stronger in low-income families (McCrorie et al, 2021), this is theorised to be because neighbourhood green spaces encourage social interactions, a sense of community and place identity which support low-income households.

Some existing research also suggests that the link between nature and academic performance is moderated by the disadvantage level of students (M. Kuo, Browning, Sachdeva, et al., 2018) and that students who are most socio-economically challenged benefit the most from nature access (Sivarajah et al., 2018). Unpicking why this would be the case is important practically, so that outdoor interventions can be designed to support disadvantaged students.

However, although socioeconomic status has had significant moderation effects across a range of studies, the direction of these effects is somewhat unclear. Some research (Tuen Veronica Leung et al., 2019; Wu et al., 2014) evidenced that low SES schools benefitted *less* from green space, whereas other studies (Sivarajah et al., 2018) showed the opposite effect. Some studies have found that nature has equivalent effects on all students, regardless of sociodemographic characteristics (Tuen Veronica Leung et al., 2019).

One suggestion to explain these mixed results is that green space in educational settings may matter more for the achievement of low SES students who live in urban areas, than for those living in areas where green space is more available elsewhere (Browning & Rigolon, 2019). It has been reported that children from lower SES families and those from ethnic minorities are least likely to visit nature outside of school (Hunt et al., 2016). Other research has suggested that children from poorer backgrounds may be less interested in being outdoors in nature, however, this difference can be quickly overcome after having the opportunity to experience learning outside (Wildfowl and Wetlands Trust, 2017). Therefore, if low SES children live in urban settings without easy access to a garden or local park, green space in schools may be the only nature they are accessing.

Another possibility is the type of measures used for SES used affected results. Some studies use a single measure such as eligibility for free school meals (FSM) or family income, whereas other use a broader range of SES variables combined into one index.

As narrowing the achievement gap between lower and higher SES students is a key focus for schools, whether nature has equigenic effects is an important area to explore further. However, as yet research has not provided us with robust reasons as to why nature would affect children from low SES backgrounds differently to children from more affluent families.

Special educational needs and disabilities (SEND)

Research into the nature-effect on children with special educational needs and disabilities (SEND) is important to ascertain whether effects vary depending on children's cognitive, emotional and physical needs, and whether access to nature is an effective intervention to support children with SEND.

Although such research was lacking for a long time, it has seen an increase over the two decades, likely to due to increased awareness about neurodiversity, and the need for more inclusive practices now that more children with SEND are educated in mainstream schools in England.

A recent review and meta-analysis of 24 studies on nature-based interventions for autistic children (Fan et al., 2023) found positive short-term outcomes on sensory, social and behavioural functioning. The interventions did not have an effect, however, on emotional functioning. Significant effects were found on hyperactivity, inattention and distractibility, sensory seeking, social cognition, social communication and social motivation, suggesting impact across a wide range of functions. The quality of evidence however, was not robust – only six studies had control groups and studies commonly failed to consider participants' comorbid conditions. They also lacked follow up assessments which limits our understanding of longer-term outcomes. The meta-analysis also covered a broad range of interventions including horticultural therapy, outdoor art therapy and surfing, golfing and equine activities – making it problematic to distentangle which specific aspects of the interventions were impactful.

Studies have also investigated the impact of nature on children with ADHD, evidencing improved performance on concentration tasks in natural surroundings (Van den Berg & van den Berg, 2011), and after exposure to nature (Faber Taylor & Kuo, 2009). Research also suggests that nature may decrease levels of aggressive, impulsive and hyperactive behaviours and other symptoms of ADHD (Faber Taylor & Kuo, 2011; Kuo & Faber Taylor, 2004; Van den Berg & van den Berg, 2011).

However, there is less research comparing effects between children with ADHD and neurotypical populations.

Some existing research suggests that even within the ADHD population, effects are differential and may depend in part on children's preferences (Van den Berg & van den Berg, 2011).

Although positive effects have also been observed in children with a range of other SEND including Down's syndrome (Floresca, 2020) and emotional and behavioural difficulties (Price, 2015; Szczytko et al., 2018), as above, methodological issues sometimes prevent causal links from being made. These issues include small sample sizes, a lack of neurotypical participant samples to compare with, and inadequate control over confounding variables such as pedagogical style, activities and teachers.

Finally, although nature access has been found to benefit children with SEND both academically and behaviourally, as well as improving attendance rates for these children (Price, 2015), children with SEND may not have equal access to time outdoors in nature. A systematic review concluded that children with disabilities participate in less outdoor play than their typical peers (Sterman et al., 2016). Whilst some caregivers perceive outdoor play as important for children's development and are strongly motivated to provide outdoor opportunities, others report a lack of disability-friendly opportunities for outdoor play, inaccessible spaces, prohibitive costs and a lack of knowledge and training amongst staff supervising outdoor activities (Sterman et al., 2016).

Qualitative research with parents of children with SEND (D. Li, Larsen, et al., 2019) has identified a number of barriers that make accessing nature difficult for them, including safety concerns and inappropriate behaviours in public. They cite the need for advanced and extensive planning to access outdoor play, especially where there are concerns around medical and supervision needs such as toileting (Sterman et al., 2016). Normative discourses about the value of outdoor play have therefore been criticised for marginalising the experiences of families with disabled children, who are substantially less likely to visit and enjoy outdoor nature spaces than other local families, despite feeling disheartened about not being able to do so (Horton, 2017).

As different groups of children vary in their access to nature outside of school; their prior access and experiences, as well as their parents' attitudes towards nature, may also affect children's susceptibility to a natural outdoor learning environment and their motivation and interest in spending more time outside. This is currently underexplored in the existing literature on children with SEND and the nature-effect.

Gender

Being outdoors has been conceptualised by some researchers as a genderised phenomenon, where stereotypical gender roles are often reified rather than challenged. These discourses suggest that much of the current literature on outdoor education is located in male experience, with women's experiences of the outdoors poorly represented (Warren, 2015; MacBride-Stewart et al., 2016). Research suggests that in advertising, women are less often depicted as being involved in outdoor pursuits and in life, they are less likely to be leaders in outdoor careers (Warren, 2015). This seems counterintuitive given that women are generally considered to feel closer to nature and to be more environmentally friendly (MacBride-Stewart et al., 2016; Rosa et al., 2023). Women were also found to spend more time than men in public green spaces, to be more affected by the aesthetic qualities of outdoor spaces (such as green space quality and litter), and show greater sensitivity to factors such as perceived personal safety when outdoors (MacBride-Stewart et al., 2016). Safety concerns could potentially be one of the reasons why women are less likely to engage in nature-based recreation than men, although cultural norms and more constraints on leisure time have also been cited as relevant factors (Rosa et al., 2023).

If these gender differences are correct, they could affect how children of different genders feel about nature, and how they respond to natural, outdoor environments. It has been suggested that gendered norms of femininity may prevent girls from feeling encouraged, motivated and comfortable engaging in outdoor play which may involve physical activity, getting dirty, damaging clothes and possibly sustaining injuries (MacBride-Stewart et al., 2016). However, gender differences may not emerge until children are older or move into adulthood, as despite differences in nature-connectedness and time spent in nature reported for adults, some research with younger children reports no such differences (Basten et al., 2021).

Gender effects have, however been reported in studies of The Nature Effect (Taylor et al., 2002) but the direction of this relationship varies. Some studies suggest nature has a greater impact on boys (Lundy & Trawick-Smith, 2021; Markevych et al., 2014) whereas others find that girls are more affected (Taylor et al., 2002).

One study found that, compared to the traditional classroom, boys demonstrated significantly better scores for knowledge, attitudes, behaviour and comfort when learning outdoors. Whilst girls also showed some outdoor improvement, their score increases were smaller and did not reach significance (Carrier, 2009). However, pedagogy was not matched across conditions; the outdoor lessons were deliberately designed to incorporate more hands-on, active learning as this was theorised to be more ‘boy-friendly’. Thus, it is not possible to isolate the effect of the outdoor environment, from the between-condition differences in pedagogical approach.

Whilst some literature claims that boys and girls have distinct learning styles, with girls more suited to an indoor classroom environment and boys less likely to learn best from sitting still inside (Carrier, 2009), more recent thinking suggests that gender differences in learning have been over-stated, and that male and female brains are not meaningfully different (Eliot, Ahmed, Khan & Patel, 2021).

A further challenge of looking at gender in isolation from other aspects of identity, is that gender is likely to intersect with other factors including ethnicity, age and SEND, making it impossible to identify how gender specifically might mediate the nature-effect. Given the complexities outlined above, and the mixed findings regarding gender and nature, there is currently not enough robust evidence to draw conclusions.

Age

Some research has suggested that nature contact is most beneficial for the youngest children (Putra et al., 2020) yet outdoor provision for under-twos is currently thought to be lacking, with dominant narratives in early childcare settings excluding babies and toddlers from the outdoors (Kemp & Josephidou, 2021). There is a paucity of data on babies’ and toddlers’ access to nature and outdoor time. Only 21 papers referencing children under age two were found in a recent review of outdoor learning and none of these studies took place in the UK (Kemp et al, 2021). Experimental studies with this age group are currently non-existent.

It is thought that in the UK context, younger infants may have the least outdoor exposure. Survey data suggests that nurseries struggle with inadequate outdoor space which limits how many children can be outdoors and in some cases is unsafe for younger children (Davy, 2016). Lack of staff training in outdoor play and parental attitudes whereby they complain about their children being outside in cold and wet weather or getting dirty were also cited as barriers to taking young children outdoors (Davy, 2016). Unlike in Scandinavian countries where infants spend much of the day outside, in some cases even sleeping outdoors, in the UK outdoor-based nurseries and preschools are still very uncommon (Kemp et al, 2022).

Support for the importance of nature exposure early in the lifespan comes from a range of studies demonstrating long lasting positive effects of childhood exposure to green space (Abbasi et al., 2020; Dadvand et al., 2017, 2018; Preuß et al., 2019; V. Ulset et al., 2017) and negative effects of urban upbringing (Engemann et al., 2019; Lederbogen et al., 2011; Thygesen et al., 2020). Some studies have evidenced the nature-effect in children as young as three and four years old (V. Ulset et al., 2017). However, few studies compare the nature-effect across different age groups, whilst controlling for other confounding factors. Those that do, report no clear findings regarding whether nature has a greater impact on younger or older children (Anabitarte et al., 2022). A metanalysis of nature-effects on cognitive functioning concluded that exposure does not seem to differentially effect children of different age groups, however more studies with younger children are required to draw conclusions (Vella-Brodrick & Gilowska, 2022).

In addition, due to a lack of research on nature contact with babies and toddlers, little is known about whether the nature-effect is something inherent which is present from birth or is a social phenomenon that develops throughout the lifespan. This limits our understanding of how the nature-effect might occur and change over time. In conclusion, due to a lack of research on the nature-effect on babies, toddlers and those in the early years of school, and a lack of studies which compare effects across age groups, we do not yet know whether there are age-effects regarding nature exposure.

Sensitivity

As described in section 1.4 above, it is known that children differ in their sensitivity to environmental influences but there has not yet been any research looking specifically at how environmental sensitivity, or temperament might mediate or moderate the nature-effect. However, one experiment on adults (Ojala et al., 2019) found that noise sensitivity modified the restoration effects of nature. Both noise-sensitive and noise-insensitive groups perceived natural settings as more restorative than city settings, but only the noise-sensitive group experienced greater feelings of vitality after sitting in natural spaces.

More research is needed in this area.

1.5 Summary

In summary, there is ample evidence that exposure to nature and green spaces yields beneficial effects for a wide range of children, yet the planet is becoming increasingly urban and children's contact with nature is decreasing.

Whilst some approaches to child development value the role played by the physical learning environment, it has been neglected in other discourses. Although research is limited, existing studies suggest that intermediate levels of colour, complexity and stimulation best support children's attention and learning performance. High levels of auditory and visual noise can be detrimental to learning, so nature's positive effect may, at least in part, be due to the intermediate levels of visual complexity it offers and relatively low levels of auditory noise. However – these factors are rarely measured and included as covariates in existing research on nature contact, so the ways in which they interact with the nature-effect is underexplored.

An area which requires further research and attention is the extent to which children vary in their susceptibility to environmental influences and how this relates to the educational context - namely, are some children more impacted by their learning environment than others? And specifically, do some children benefit more from nature contact than others? Research suggests that disadvantaged children (those who are the most nature-deprived to begin with, those who have SEND and those who come from lower SES families and attend the most challenging schools) may reap the greatest benefits, but as these individual differences are commonly

only controlled for in studies, rather than being analysed in detail, there is not enough robust evidence to draw conclusions.

The exact mechanisms behind the nature-effect are not yet fully understood and are difficult to disentangle. However, the theoretical frameworks and potential mediators discussed in this chapter relate most closely to attention, stress and behaviour, all of which are underpinned by different aspects of self-regulation. With this in mind, these three areas form the basis of the literature review that follows in Chapter 2. Section 2.4 reviews the literature on nature's effect on stress, section 2.5 focusses on nature's impact on attention, and the final part of the literature reviews looks at nature's impact on behaviour in section 2.6.

Chapter 2

Literature review – The impact of natural outdoor spaces on children's stress, attention and behaviour

2.1 Terms and definitions

What constitutes 'nature' or 'greenness' varies across studies in the field and there is no clear consensus on features that must be included or excluded in order for an environment to be considered 'natural'. Some studies consider window views of trees on urban streets as nature exposure (D. Li & Sullivan, 2016), whereas others are more focussed on 'wilderness' and places with an absence of man-made features. Many correlational studies calculate how much 'green space' is around a child's home or school environment using satellite imagery. Yet in many papers it is unclear whether 'green space' includes private fields and farmland or only public land which is accessible to the children being studied.

One systematic review of the mental health benefits of nature comments on the "substantial diversity" of 'nature' under consideration. Terms used across studies included 'green space', 'water/blue space', 'vegetation' 'parks' and 'gardens' amongst others (Tillmann et al., 2018). Other research papers do not define the terms 'nature' and 'green' at all. This lack of clear criteria to define what constitutes a 'green' or 'natural' environment has led to a wide range of environments being included in such studies, this makes comparisons across studies and generalisability of findings problematic. Further work is needed to come to agreed terms and definitions for use across research projects.

This is important because where studies have distinguished between different types of natural spaces such as woodland compared to grassland or different amounts of nature in an outdoor space, differences in impact have been found. For example, in a Virtual Reality (VR) study, grassy environments were found to have a greater effect on positive affect than a courtyard with trees (Huang et al., 2020), whilst a study of stress recovery found that the percentage of tree cover in neighbourhood streets affected recovery times (Jiang et al., 2014).

Similarly, a correlational study found that children with ADHD managed hyperactivity symptoms more effectively in open grass areas compared to those with trees (Faber Taylor & Kuo, 2011).

For the purposes of this review, studies using the following types of nature have been included:

- Public green spaces e.g. parks, forests, fields
- Private green spaces e.g. gardens
- Outdoor areas at school or nursery
- Indoor green plants
- Window views of nature
- Images, videos and VR experiences of natural settings

Some studies have looked specifically at the effects of being near water, however this literature review has not included such studies.

2.2 Measures and methodology used in this field

There are high levels of heterogeneity in the methodology used across studies in this field of research. Studies differ in several areas, most commonly:

- The measures used to quantify greenness/nature (e.g. satellite imagery/ photographs/ observational scales and ratings)
- The type of exposure studied (e.g. outdoor learning/amount of time spent in public green spaces/amount of green space surrounding the home or school/window views/viewing images or videos of nature)
- Outcomes studied (wellbeing/academic/cognitive/behavioural/physical health etc)
- The measures used for each of these outcomes (self-report/teacher-report/cognitive tests/brain scans etc.)
- The timing and frequency of measurements (whilst the child is in nature/ immediately after nature exposure/longitudinal effects/one-off or repeated measures)

Measures to quantify greenness

Some research utilises objective measures such as tree density indexes, land use databases and satellite imagery (Dadvand et al., 2018) to calculate a percentage of 'greenness' in a person's residential neighbourhood or school, often using the Normalised Difference Vegetation Index (NDVI). This remote sensing measure quantifies vegetation based on how land areas reflect certain ranges of the electromagnetic spectrum. NDVI calculates the difference between near infrared (which is reflected by vegetation) and red light (which is absorbed by vegetation).

However, there is no universal consensus about the size of the area which constitutes a residential or school neighbourhood. Thus, the size of the 'buffer' distance used to calculate surroundings also varies across studies, ranging from 90m to 5km. Whilst some studies use several buffer distances, others use only one. Therefore, it is often unclear how close-by nature needs to be in order to yield beneficial effects, and how proximity affects the strength of those effects.

Other studies use observational scales which categorise how natural the surrounding area is, for example: non-natural/mixed/natural and very natural (Corraliza et al., 2012). To support this categorisation, some researchers have developed their own criteria to distinguish between settings which are 'very natural' (trees, shrubs and other natural elements with minimal evidence of human influence) 'mostly natural' (significant amounts of vegetation and some human influences such as walkways and buildings) and mostly built (majority of viewable landscape is due to human influence) (Beil & Hanes, 2013). These are often subjective ratings based on photographs of environments or site visits and such criteria can vary across studies.

Type of nature exposure:

The duration and intensity of participants' nature exposure also differs across studies.

One review categorised approaches using three key groups: accessibility, exposure and engagement (Tillmann et al., 2018). These headings will be utilised and expanded upon here to describe the variety of nature exposure across studies.

Accessibility studies

Studies based on nature accessibility look at how easily nature can be encountered by the child, often focussing on geographical proximity and how 'green' the area is around a child's home or school (Matsuoka, 2010; Wu et al., 2014). These measures are used in correlational analyses to examine how nearby levels of greenness relate to various outcomes. As accessibility to nature is not easily manipulated, these studies might identify associations but are unable to elicit whether nature access was the cause of specific outcomes.

Furthermore, accessibility studies usually do not explore whether children have actually *engaged* with the nature that they have access to. Thus, whilst a home or school may be in a green, natural area, the extent to which the child notices or visits those green surroundings and how much time they spend in local green environments remains unknown.

Exposure/intervention studies

In exposure/intervention studies, participants have experienced *contact* with nature. Therefore, unlike in accessibility studies, the nature encounter is guaranteed and often engineered by the researcher. The natural setting is a 'condition' within the experiment. Exposure studies can be further sub divided into laboratory studies, where nature exposure is indirect, for example being shown photographs or films of natural environments and field studies, where participants are taken to real-life environments and directly exposed to them.

Laboratory-based studies allow for greater control, enabling specific aspects of the natural environment to be isolated. For example, confounding factors such as temperature, noise and air pollution associated with each setting are eliminated. However, field-based studies offer greater ecological validity.

Direct exposure to nature in a field-based study can involve walking in the natural setting, sitting and viewing the environment, or taking part in tasks within the setting, for example completing cognitive tests. However, in these studies, nature exposure does not involve *actively engaging* with the nature itself (for example gardening or den building). Therefore, this is sometimes described in the literature as 'passive' nature exposure (Norwood et al., 2019b). Whilst in some study designs nature exposure lasts for less than an hour, in others the effects of nature are measured over days or weeks. Henceforth, these types of studies are referred to as 'nature-interventions'.

Engagement studies

Although exposure studies guarantee some level of contact between participants and nature - this is often a passive process and does not equate to engagement with nature. Thus, in nature-engagement studies, participants make direct use of the affordances of the natural environment. Here the interaction with the environment is sustained and intentional, e.g. studies of forest schools, wilderness therapies, therapeutic gardening and adventure. In this research, nature is not just the 'setting' but also affects activities, resources and pedagogies. These studies are sometimes described as 'active' nature interventions (Norwood et al., 2019).

In engagement-based interventions it is usually impossible to isolate the effect of the natural environment itself from the activities which are being carried out. 'Forest school' for example has its own values, aims and set of pedagogical principles which differ from those used in mainstream indoor schools. Therefore, any benefits of forest school could be attributable to the different curriculum that is taught, differences in equipment, resources and activities or to the different pedagogy used. A review of empirical evidence regarding children and nature, commented that factors such as free play, exploration and child-initiated learning were all associated with various benefits (Gill, 2011). It could be that these factors are creating the positive effects seen during engagement studies, rather than the outdoor environment itself.

Many nature-engagement studies fall under the umbrella of research on 'outdoor learning'. Drawing generalised conclusions from this research is problematic as approaches to outdoor learning vary substantially and can include fieldwork, workshops, school trips, outdoor free-play, residential visits, gardening and adventurous activities such as mountaineering, as well as a range of other activities. Due to this diversity of approaches, studies use a wide range of measures and evaluations to determine effects. In addition, studies are spread across a range of age groups, educational settings and subject areas (Fiennes et al., 2015), making it difficult to replicate findings, make comparisons and synthesise a coherent picture of the effectiveness of outdoor learning as a whole.

Furthermore, the methodological quality of research in this field is often rated as only moderate or low, most commonly because participants were not selected at random, and data presentation and statistical techniques were not carried out appropriately. In a review of over 7,800 studies on outdoor learning, only 13 were deemed to have met reasonable research standards (Becker et al., 2017). Studies usually lack control groups and there is a scarcity of research using experimental or quasi-experimental designs. Much of the data is based on small case studies, which although they may offer some insight, may lack criticality (Waite et al., 2015).

Due to these methodological issues, and the fact that disentangling the specific impact of the environment is so problematic in engagement studies, the existing evidence compiled in this literature review is drawn from accessibility and intervention studies only and does *not* include engagement studies.

Outcomes studied

This literature review focusses only on evidence related to children's stress, attention and behaviour, in line with the rationale outlined in the summary in section 1.5. However, even within these three specific domains, a wide range of outcomes have been measured. These are summarised in Table 2 below and explored in more detail in each section of the literature review.

Table 2

Outcomes studied relating to stress, attention and behaviour

Stress outcomes	Attention outcomes	Behaviour outcomes
Heart rate, skin conductivity, salivary cortisol, changes in brain structure and activity, amygdala activation, self-reported stress	Executive functioning, attention, inattention and hyperactivity, working memory, inhibition, off-task behaviour	Self-regulation, emotional and behavioural development, co-operation, self-discipline, conduct disorders, prosocial behaviour

Types of measures

Further heterogeneity comes in the range of measures used to assess each outcome. For example, to measure attention, studies choose from a diverse range of cognitive tasks and tests as well as parent and teacher-report scales. To account for this, prior to each section of the literature review that follows, the range of measures used across the literature is described and summarised.

Timing of measurement/data collection

At which point differential effects of environments can be detected, and how long they last for is an issue of contention which makes it difficult for researchers to choose when and how often measures should be taken. Study designs vary regarding whether measures are taken before, after or during nature exposure and whether there is any follow up to ascertain longer-term effects.

Therefore, repeated or continuous measures are often necessary to gain a full picture, as some effects may be immediate whereas others take longer to emerge. However, many studies do not take multiple measurements, or where multiple measures are taken, only averages are reported. This may obscure patterns of change in environmental effects and prevent studies from showing the full impact of natural environments including whether effects increase or attenuate over time.

2.3 Inclusion and exclusion criteria

Table 3 below summarises the inclusion and exclusion criteria for research included in the following literature reviews.

Table 3

Inclusion and exclusion criteria for studies included in literature review

	Included	Excluded
Nature type	Surrounding greenness Garden access Direct access to fields, parks, forests Urban nature e.g. urban parks Window views of nature Indoor plants	Use of natural materials and resources 'Blue spaces' – ponds, lakes, oceans, water features
Exposure type	Nature access Nature exposure (both direct and indirect e.g. via video footage in a lab and via walking in nature)	Engagement based interventions e.g. gardening, forest school, wilderness therapy
Outcomes	Physiological stress Psychological stress (including measures of anxiety and negative affect) Measures of attention and cognitive control Prosocial behaviour Antisocial behaviour	All other outcomes e.g. measures of vitality and positive mood, academic outcomes, physical health outcomes
Measures	All quantitative and qualitative measures related to the outcomes listed above	None
Timing of measurements	Studies which take measures either before, during or after nature exposure, or which utilise repeated measurements	None
Participant age	0-18 years old	Studies conducted with adults – unless this forms part of a wider review/meta-analysis or comprises the only available evidence in this area

The next three sections of this thesis comprise three separate literature reviews, one for each of the aforementioned key areas; stress, attention and behaviour and the evidence suggesting that nature has an effect on this area of self-regulation.

2.4 Nature's effect on stress

2.4.1 Introduction and rationale

When the body is under stress, it activates the sympathetic nervous system, producing hormones such as adrenaline and cortisol which prepare the body for a fight-flight response. However, in the short term, these hormones can affect anxiety, concentration and sleep, whilst chronic exposure to stress hormones can affect the brain structures involved in learning and mental health.

Reducing chronic stress in children whose brains are still developing is key. Whilst the hippocampus develops during early childhood, the pre-frontal cortex undergoes major development in adolescence. These are thought to be key windows of vulnerability when the development of these regions can be slowed due to stress, leading to reduced volume in that area (Lupien et al., 2009). However, the relationship between stress and learning is complex.

Early studies (cited in Arnsten & Goldman-Rakic, 1998) showed that stress impairs performance in complex tasks involving the PFC, but may enhance performance on simpler, well-rehearsed tasks. More recently, both animal and human studies suggest that acute mild stress can actually improve amygdala and hippocampus functioning (Arnsten, 2009). Experiments conducted on rhesus monkeys have found that whilst acute mild stress, induced by noise, impairs PFC function - in some cases it improves memory function (Arnsten & Goldman-Rakic, 1998).

Research investigating the links between physiological stress in urban environments, and human infants' attention and cognitive engagement found that, compared to infants living in lower density housing environments, urban infants had weaker sustained attention and increased stress reactivity. However, they did have some cognitive advantages such as better retention (Wass et al., 2019). This study replicated previous findings that infants with elevated psychological stress have superior recognition memory (De Barbaro, Clackson, & Wass, 2016).

These results point towards a more complicated relationship between stress and learning than the simple assumption that learning is always more effective in a quiet, low-stress environment. More recent thinking about stress and learning suggests that stress can have both positive and negative outcomes and that optimal amounts of stress can enhance performance (Rudland et al., 2020). It may be the case that low-stress environments are beneficial for some types of learning but not others. Given this information, it is important to explore the effect that different environments have on stress and how this might in turn affect learning and health outcomes for children.

Population studies suggest that higher levels of green space in neighbourhoods are associated with significantly lower levels of symptomology for stress in adults (Beyer et al., 2014), it is possible that this has downstream effects on the stress levels of children living with those adults. A plethora of other correlational and experimental research also indicates that natural environments have stress-reducing effects (Yao et al., 2021; Zhang et al., 2020; Zhao et al., 2022). This chapter reviews this literature in detail.

2.4.2 Definitions, inclusion criteria and measures

Although the previous introduction has acknowledged that stress can both enhance and impair learning performance and is not necessarily indicative of 'distress', within this literature review the studies cited commonly quantify stress without considering both positive and negative effects. Therefore, the research summarised in this review is concerned with reducing stress in order to improve mental wellbeing and learning.

Due to the complex psycho-physiological nature of stress, using one single measure of stress is problematic. Therefore, the majority of research uses both subjective psychological measures such as self-report questionnaires and more objective physiological stress markers. The various measures used in these studies are summarised in Table 4 below. Where possible, research has only been included in this review if it has used specific measures of stress. However, in the case of reviews and meta-analyses, some studies using more generalised measures of affect and wellbeing have been incorporated.

Table 4

Overview of stress measures

Measure	Description	Examples of nature studies using this measure
Psychological measures		
Cohen's perceived stress scale (1983)	Asks participants to rate on a scale of 0-4 how often during the last month they felt or thought a certain way, for example 'How often have you found that you could not cope with all the things that you had to do?'	Feda et al., 2015
Visual analogue scale (VAS)	A scale used for subjective ratings of mood, emotion or distress whereby participants rate the intensity of the sensation on a scale from 0-100	D. Li & Sullivan, 2016
Ethnographic observations and interviews	Questions which asked children to reflect on how they felt in natural places.	Chawla et al., 2014
The profile of mood states (POMS)	A questionnaire which assesses mood states over a period of time. Includes six different dimensions: Tension/anxiety, anger/hostility, vigour/activity, fatigue/inertia, depression/dejection and confusion/bewilderment	Tsunetsugu et al., 2013a
Multiple mood scale	A self-report instrument to measure multiple mood states. Adjectives on a list are rated on a four-point intensity scale to assess eight momentary mood states.	Morita et al., 2007
The Oldenburg Burnout Inventory (OLBI) and The Mini-Z questionnaire	Questionnaires related to workplace stress and burnout	Kavanaugh et al., 2022
Physiological measures		
Heart rate	Pulse rate – the number of times the heart beats per minute	D. Li & Sullivan, 2016; Gidlow et al., 2016

Heart rate variability	The extent to which time between heart beats fluctuates (Explained in detail in section below)	Brown et al., 2013a; Gidlow et al., 2016; Kobayashi et al., 2015
Blood pressure	A measure of the force the heart uses to pump blood around the body	Kobayashi et al., 2015
Skin conductance rate	A measure of how easily low voltage electricity is conducted through the skin. Greater conductivity is associated with more skin secretions, a sign of higher stress.	D. Li & Sullivan, 2016; Jiang et al., 2014
Respiratory rate and depth	The speed, pattern and depth of breaths can indicate responses to stress. Stress can increase respiratory rate and depth.	Brown et al., 2013; Galdwell et al., 2012
Cortisol/adrenaline noradrenaline/alpha amylase/dopamine	The amount of stress hormone(s) in the urine or saliva	Beil & Hanes, 2013; Dettweiler et al., 2017; Gidlow et al., 2016
Immunoglobulin concentration in saliva	Immunoglobulin levels signify the antibodies in the blood. Stress is thought to suppress immunoglobulin production.	Tsunetsugu et al., 2007
EEG	Measurements of brain electrical activity as a measure of cortical arousal	Ulrich et al., 1991
Body temperature	Acute and chronic stress can elevate body temperature	D. Li & Sullivan, 2016
Muscle tension	The extent to which muscles remain semi contracted for a prolonged period– usually measured through electromyography	Ulrich et al., 1991b
Amygdala activity	fMRI measures changes in blood flow that occur with brain activity. As the amygdala processes threatening stimuli and releases	Costa e Silva & Steffen, 2019;

	stress hormones, activity in the amygdala is thought to indicate stress.	Lederbogen et al., 2011
MRI scans to look at changes in brain structure/maturity	Some areas of the brain such as the hippocampus and amygdala are scanned to track longitudinal changes	Dettweiler et al., 2023

How physiological markers relate to stress

Physiological stress markers are determined by autonomic nervous system (ANS) functioning. The ANS regulates internal organs automatically, controlling processes such as heart rate and breathing without an individual's conscious awareness. The ANS is partitioned into two subsystems: the sympathetic and parasympathetic nervous systems.

The sympathetic nervous system is activated when an individual is under stress. In the face of perceived threat, the sympathetic nervous system mobilises defensive behaviours by increasing heart rate, blood pressure and blood sugar levels, increasing blood flow throughout the body to support movement and provide energy. Sympathetic arousal also stimulates the release of adrenaline, noradrenaline and cortisol and activates the sweat glands. Therefore higher resting heart rate and blood pressure, along with higher levels of sweating, cortisol, adrenaline and noradrenaline are all indicators of stress.

In contrast to the sympathetic system's fight or flight response, the parasympathetic system conserves energy by slowing heart rate and also controls the digestive system, promoting homeostasis and calming the body. Parasympathetic arousal suggests that the individual is emotionally regulated.

Heart rate variability (HRV) is a way of measuring individual differences in people's autonomic balance between sympathetic and parasympathetic activation. Vagal regulation of the heart can be measured by looking at respiratory sinus arrhythmia (RSA) which is the natural increase and decrease in heart rate that accompanies breathing. This creates a rhythmic, stable heart rate pattern of repetitive, evenly spaced rises and falls. High frequency heart rate variability (HF-

HRV) corresponds to RSA and indicates modulation by the parasympathetic nervous system.

Low-frequency heart rate variability (LF-HRV) is an indicator of sympathetic nervous system modulation and is characterised by less coherent heart rhythms, with unpredictable rises and falls. When used as a measure in studies of stress, more sympathetic functioning and LF-HRV are associated with greater levels of stress.

2.4.3 Reviews and meta-analyses

Associations between nature and stress have been evidenced in a range of recent reviews and meta-analyses. One such review found the relationship between nature and stress to be one of the strongest observed, with four out of five findings identifying a significant effect (Tillmann et al., 2018). Another (Zhang et al., 2020), reported beneficial associations between green space exposure and reduced stress, however only four studies incorporated measures of stress specifically, the majority used more generalised wellbeing measures.

These findings are consistent with a subsequent systematic review reporting that five out of six studies showed that nature exposure decreased levels of perceived stress and seven out of seven studies found an inverse relationship between nature exposure and physiological markers of stress (Shuda, Bougoulias & Kass, 2020). Further evidence comes from a meta-analysis of 52 analyses involving over 5.2 million participants (Zhao et al., 2022), results showed decreased blood pressure and hypertension for people living in greener environments, with higher levels of greenspace within 500m of people’s homes significantly associated with lower blood pressure. However, only eight out of the 52 studies were conducted with children.

Studies with children less commonly use physiological markers of stress. In a recent review of the literature on nature’s effect on children’s psychological wellbeing (Liu & Green, 2023), a call was made for studies to use more effective evaluation methods, including bio-monitoring.

In other reviews involving adults and older adolescents, exposure to natural environments has been associated with decreased salivary cortisol, anxiety, self-reported stress and blood pressure, and with heart rate variability (Yao et al., 2021) and both walking and sitting in natural environments enhanced heart rate variability more than the same activities in control conditions (Mygind et al., 2019). Not all results, however, have been consistent. A systematic review and meta-analysis of randomised controlled studies found that whilst forest therapy (visiting forests or conducting forest-based treatment activities) significantly reduces depression, it does *not* have a significant effect on adults' blood pressure (Yi et al., 2022). Effects of nature on cortisol have also been inconsistent (Mygind et al., 2019).

In conclusion, whilst reviews and meta-analyses provide strong support for a relationship between nature and stress, there are some inconsistencies regarding which measures of stress are affected. The existing research base is also dominated by adult studies. Looking in more detail at specific studies conducted with children provides more information about how nature might affect stress during early life. In the section that follows, individual studies are described and summarised and these are categorised into accessibility and intervention studies, with intervention studies further sub-categorised into laboratory-based and field-based experiments.

2.4.4 Nature accessibility studies

Psychological stress

Data from several studies suggests that access to nature might have a protective effect against psychological stress in children. A study (Wells & Evans, 2003) conducted with 337 rural children (m = 9.2yrs) asked participants about the frequency of stressful events in their lives. A behaviour questionnaire and self-worth scale were also utilised to measure psychological distress. A naturalness scale (used to measure levels of green-ness in children's residential environment) considered the view from windows, the yard and how many live plants were inside the house. After controlling for household income, regression analysis showed there was a significant interaction between nearby nature and stressful life events. Furthermore, the impact of stressful life events on psychological distress was mediated by the level of nature children were exposed to at home, suggesting that nature can buffer the effects of childhood stress. Interestingly, the buffering effects were greatest for children experiencing the highest levels of stress.

These findings were echoed in a later study where 172 children aged 10-13 were asked to complete a perceived stress scale, a perceived nature questionnaire and a stressful events questionnaire. An observational scale quantified the amount of nature in home and school environments. Results suggested that children who had greater nature access coped better with adversity than those who didn't. There was a significant inverse correlation between the amount of nearby nature, and the child's perceived stress level (Corraliza et al., 2012).

Other research has evidenced an association between neighbourhood parks and perceived stress in adolescents, suggesting that even after controlling for physical activity levels and socio economic status, access to parks may buffer young people against perceived stress (Feda et al, 2014), whilst natural landscapes in the residential area were also positively associated with better emotional states in a longitudinal study which tracked 172 children for three years as they moved into adolescence (Van Aart et al., 2018).

Physiological stress

Experimental studies using Functional Magnetic Resonance imaging (fMRI) to measure brain activity have shown a link between social stress processing and urban living (Costa e Silva & Steffen, 2019; Lederbogen et al., 2011). In one study, adult participants without mental illnesses completed stress-inducing tasks in a laboratory experiment. Current urban living was correlated with amygdala activity, which was lowest for participants living in the country, and higher for those living in small towns, it increased further still for city dwellers suggesting a dose-response relationship. Growing up in an urban environment was also associated with changes to activity in the perigenual anterior cingulate cortex, which regulates amygdala activity. Again, activation increased according to the level of urbanicity during childhood, with the highest activity seen in participants who were brought up entirely in cities and lower activity in those who lived in a combination of urban and rural environments (Lederbogen et al., 2011).

Longitudinal research has also explored whether greenspace exposure during childhood might influence blood pressure during adulthood (Bijnens et al., 2020). Significant associations were found between residential greenness exposure during early life and nighttime blood pressure. No associations, however, were found between blood pressure and the distance to major roads in childhood, suggesting effects are not due to noise or traffic pollution. The study postulated instead that the underlying mechanism could be maternal stress which has a knock-on effect on children's blood pressure and then persists into adulthood. These findings are supported by another study of over 500 participants which evidenced that living further from green space at birth was associated with higher blood pressure in adulthood, suggesting that the perinatal period may be a critical time to access nature (Jimenez et al., 2020).

There are several studies investigating correlations between children's blood pressure and their access to natural environments. As their methodologies are similar, they are summarised in Table 5 below. Studies are organised chronologically, with newer research listed first. They are also colour coded to indicate whether studies found a positive effect of nature on stress (green), had inconsistent findings (yellow) or found no effect, or a negative effect of nature on stress (orange).

Table 5

Studies of nature and blood pressure

N	Age	Greenspace measure/s	Findings	Reference
1251	8-12yrs	Presence of a home garden Land cover (NDVI) and tree canopy cover within 100 and 1000m of home and school Naturalness indicator 'distance to nature'	Higher NDVI and tree cover in home and school surroundings were associated with lower BP Presence of a home garden weakly associated with more outdoor play and in turn with lower BMI and lower BP	Dzhambov et al., 2022
12340	7-18yrs	Subjective proximity to green space – children answered questionnaires about whether they lived within 15min walk of green spaces (defined as	No significant associations reported between proximity to green spaces and blood pressure	Abbasi et al., 2020

		parks, fields, gardens and land covered with trees)		
2302	12ys and 16yrs	NVDI in 300m and 3000m buffers around residential address	No consistent patterns of associations between green space access, pollution and traffic noise and cardiometabolic risk measures including blood pressure.	Bloemsma et al., 2019
2078	10yrs	NVDI in 500m buffers around residential address	Lower residential greenness was positively associated with higher BP in children. Associations were significant in urban but not rural areas.	Markevych et al., 2014

2.4.5 Nature Intervention studies

Field studies

Psychological stress

In adults, spending time in the forest has been found to impact acute emotions, including decreasing feelings of hostility and depression and increasing positive emotions. Psychological effects were particularly strong for those who reported feeling chronically stressed (Morita et al, 2007). These studies are summarised in Table 6 on page 83 below.

Unfortunately, there are fewer stress-related studies conducted with children, and those that do exist tend to examine wellbeing more generally rather than looking at stress as a specific outcome measure or investigating whether baseline stress mediates effects. Some reviews have also focused on nature engagement activities such as forest schooling or therapeutic gardening which are excluded from this review as the impact of the environment cannot be disentangled from the activities themselves.

Ethnographic observations and open-ended interviews of over 100 children, exploring how they experienced natural areas at their school, found that young children more often chose to play in wooded areas and spoke frequently about feeling calm and peaceful there. Teens described gardens as a place for reflection and centring and felt that gardening helped them to relax. The researchers concluded that green schoolyards, with opportunities for nature interaction, can enable students to reduce and escape stress, acting as a safe haven (Chawla et al., 2014).

Physiological stress

Redesigning a schoolyard to incorporate more nature impacted children's physiological stress in a quasi-experimental study of 133 children (Kelz et al., 2015). Children's blood pressure decreased after the schoolyard greening intervention, more so than pupils in a control school. Pinpointing exactly what caused this change however is problematic, as the schoolyard redesign, as well as adding more shrubs and pot plants, also involved adding more seating and sports equipment. Thus, it is not possible to attribute effects solely to nature contact.

Another study looked at the effects of secondary school students having one full school day a week spent in the forest learning their curriculum outdoors. The outdoor intervention lasted for a full school year and the researchers found differences in diurnal cortisol rhythms between the intervention and control group. After controlling for differences in physical activity between indoor and outdoor learning, children in the outdoor curriculum group had a significantly greater decline in cortisol throughout the school day, as measured by three salivary samples taken throughout the day. The effect was constant throughout the school year and suggested that children in the intervention group had a healthy diurnal rhythm. However, salivary analyses were only conducted on three days throughout the study. More data would be needed to understand patterns in greater detail (Dettweiler et al., 2017).

A follow up study (Dettweiler et al, 2023) repeated a similar procedure but also used Magnetic Resonance Imaging (MRI) scans at the start and end of the year-long intervention to track changes in brain maturation. Cortisol levels, taken three times throughout the school year replicated previous findings that cortisol decreased throughout the day for children in the outdoor intervention group but increased for children in the control group. Increased physical activity was found to drive the cortisol decline. Children in the intervention group with lower cortisol levels also showed lower levels of amygdala activation when under stress, suggesting better stress regulation. Longitudinal differences in brain structure were less clear; hippocampus and amygdala maturation were similar across intervention and control groups and contra to expectations, anterior cingulate cortex (ACC) maturation was higher in the control group.

Lower stress in outdoor learning environments was also reported in a later study which measured children's heart rate variability during rest and mental load, in indoor classrooms compared to natural environments (Mygind et al., 2018). Tonic vagal tone was higher in the natural environment, suggesting lower stress. However, effects were only found during rest periods and not during cognitively demanding activities.

Even green views from classroom windows correlated with recovering significantly faster from a stressful experience, in a study of 94 high school students (D. Li & Sullivan, 2016) who were randomly assigned to classrooms with either no windows, windows with views onto built space, or windows with green views. To stimulate classroom activities and induce mild stress, participants engaged in 30 minutes of activities including a proof-reading task, giving a speech and completing a subtraction task. Subjective stress was measured using a Visual Analogue Scale (VAS) questionnaire and physiological stress using skin conductance level, body temperature and using wrist and finger receivers of electrocardiography and blood volume pulse. These were combined to create a standardised summary physiological score. Classroom window view was found to predict stress recovery, explaining 17% of the variance in stress reduction at the end of the break period.

The largest body of field-based research on nature and stress has taken place in forest settings in Asian countries, predominantly Japan, where over 54% of the population aged 12 years and above consider their stress levels to be 'very high' or 'relatively high' (Wen, Tan, Pan & Liu, 2019). This has led to significant financial investment in research to assess the effects of *Shinrin-yoku* or 'forest bathing' where participants relax by laying, sitting or walking in forest environments to reduce stress and improve wellbeing. Although thus far, studies have been categorised as investigating either psychological or physiological stress, much research in this area acknowledges that these two constructs cannot be separated as they interrelate and influence one another. Thus, many studies of *Shinrin-yoku* incorporate measures of both physiological and psychological markers of stress. There have been hundreds of studies in this field, making the literature too vast to detail every study. Instead, the results of recent reviews and meta-analyses have been summarised below, and a selection of studies is presented in Table 6, focussing specifically on experiments which incorporated measures of stress and control or comparison groups. Such studies are commonly conducted with adults and in many cases, earlier studies were only conducted with men.

Recent reviews and meta-analyses suggest that forest bathing can be effective in reducing mental health symptoms, however longer-term follow up with participants from a range of countries, and further examination of potential mechanisms is required in order to make robust conclusions (Kotera, Richardson & Sheffield, 2020). Physiological outcomes and self-report measures provide the most convincing report for nature's stress reducing effects (Kondo et al, 2018) but some biomarkers of stress have a stronger evidence base than others. Reviews and meta-analyses have concluded that forest bathing has a significant impact on cortisol levels (Antonelli, Barbieri & Donelli, 2019) and blood pressure (Ideno, Hayashi, Abe, Ueda, Iso, Noda & Suzuki, 2017).

One study of forest bathing (Hohashi and Kobayashi, 2013) compared the salivary amylase of 12-14 year-old girls in two conditions; walking in a forest and walking in a city environment. Whilst mood and relaxation measures suggested positive effects of the forest environment on wellbeing more broadly, the salivary amylase was not significantly different across conditions, suggesting there was not an impact on physiological stress. The remainder of the studies in this field have used adult participants but have been included in Table 6 below as there is a paucity of such research that has been conducted with children. Studies are organised chronologically, with newer research listed first. Studies are colour coded to indicate whether they found beneficial nature-effects on stress (green), had mixed findings (yellow) or found no effect, or a negative effect of nature on stress (orange).

Table 6

Impact of a forest environment on physiological and psychological stress

N	Intervention	Physiological stress measures	Psychological measures	Findings	Reference
11	1 hr of walking and 20 minutes of seated gazing in forest and urban environments	Blood pressure, pulse, heart rate variability	'Profile of Mood States'	Forest bathing increased high frequency HRV and decreased blood pressure and pulse. It also enhanced parasympathetic and decreased sympathetic nervous system activity, particularly in women Negative mood state scores were reduced in the forest condition and positive mood states were increased.	Wen et al, 2023
56	A 3 hr forest bathing intervention (grounding and centring exercise, walk and seated viewing) conducted by forest bathing guides	/	The Oldenburg Burnout Inventory (OLBI), The Mini-Z questionnaire Subjective feedback and comments collected from participants in the intervention group	No significant differences between pre and post-test questionnaires for the intervention or control groups. Subjective feedback from participants reported decreased feelings of stress and improved wellbeing after the forest experience.	Kavanaugh et al., 2022

38	30 min walk in 3 different environments: urban/green/blue	Salivary cortisol, heart rate, heart rate variability	Abbreviated version of the ‘Profile of Moods States’ - BRUMS.	Walks in both environments reduced salivary cortisol and improved mood.	Gidlow et al, 2016
625	15 min seated, viewing a forest or urban environment	Heart rate variability	/	80% of participants showed increased parasympathetic activity in forest environments. 20% showed decreased parasympathetic activity.	Kobayashi et al., 2015
48	15 minutes seated viewing of an urban or forest landscape	Blood pressure, heart rate	3 questionnaires: subjective ratings of levels of comfort, sedation and naturalness and the state of being refreshed. The profile of mood states (POMS).	Viewing the forest landscape: Increased parasympathetic activity Blood pressure and heart rate were lower than when viewing the urban landscape/ Forest environment was rated as sig. more comfortable, soothing, natural and refreshing. Urban landscape increased ratings of tension-anxiety, fatigue and confusion.	Tsunetsugu et al., 2013
15	20 mins observing four settings ranging from very natural to very built	Salivary cortisol and alpha amylase	Self-reported measure of stress experienced during the past week	Salivary cortisol reductions were largest after exposure to the natural settings.	Beil & Hanes, 2013

			Self-reported current stress level (taken at start and end of exposure to each environment)	Alpha amylase was significantly higher in the 'very built' setting. Changes in subjective stress were largest for the very natural setting	
16	Day trip to forest park or urban environment- 2 hrs walking in morning, 2 hrs walk in afternoon in each environment.	Blood pressure, urinary noradrenaline and dopamine	/	The forest walk sig. reduced blood, noradrenaline and dopamine levels in urine Urban environment did not reduce blood pressure, adrenaline and noradrenaline levels but did sig. decrease dopamine.	Q.Li et al., 2011
280	Walk in a forest vs city walk	Salivary cortisol, pulse rate, blood pressure, heart rate variability	/	In the forest area: Pulse rate, blood pressure, cortisol sig. lower. HRV higher compared to the city	Park et al.,2010
498	Walking in the forest	/	Multiple Mood Scale-Short form State-Trait Anxiety Inventory	Mood significantly improved on the day of the forest visit, compared to a control day.	Morita et al.,2007

				Individuals experiencing chronic stress were those who gained the most benefits	
12	20 min walking followed by 20 min sitting viewing scenery in a forest or city environment.	Salivary cortisol, cerebral activity (absolute haemoglobin concentrations)	Self-report ratings of 'comfort' and 'calm' on 13-point scales.	In the forest environment: salivary cortisol was sig. lower before and after watching the forest scenery compared to the city condition. Participants felt sig. more comfortable in the forest	Park et al, 2007
12	15 minutes sitting watching scenery, followed by 15 minutes walking, and 15 minutes watching scenery again. Forest vs city environment	Salivary cortisol, pulse rate, blood pressure, heart rate variability (HRV), immunoglobulin concentration in saliva.	Self-report ratings of 'comfort' and 'calm' on 13-point scales. Self-reported feelings of being 'refreshed' using the 'Stress-Refresh feeling test'.	Pulse rate, blood pressure, cortisol sig. lower than in the city. HRV suggested parasympathetic activity was more dominant in the forest environment. Participants felt sig. more comfortable, calm and refreshed in the forest.	Tsunetsugu et al, 2007
112	Sitting in a room with tree views or in a windowless room Walking in a nature reserve and in an urban setting	Systolic and Diastolic blood pressure	ZIPERS to measure pre and post-walk positive affect, attentiveness, fear arousal, sadness and anger/aggression	Sitting in a room with tree views promoted a significantly steeper decline in blood pressure than sitting in a windowless room	Hartig et al., 2003

			10 minutes into the walks, blood pressure declined in the natural environment but increased in the urban environment. However, these effects did not persist after 30 minutes. Positive affect increased in the nature walk and decreased in the urban walk.

As conditions are difficult to control when in outdoor environments, it is problematic to isolate which aspect of the environment is affecting stress. Factors such as temperature, weather and air quality in each setting could affect physiological stress markers, as could sounds, smells and other emotional triggers or connotations in the environment. Laboratory based studies offer the opportunity to control conditions more carefully in order to isolate some of these confounding variables.

Laboratory studies

Laboratory studies have utilised images and video footage of natural environments to examine effects on stress, and more recently have incorporated virtual reality (VR) technology. Whilst some experimental studies find that real-life, direct nature contact is more beneficial than indirect nature exposure (Browning et al., 2020; Sprague et al, 2022), a plethora of recent evidence suggests that indirect nature exposure is still beneficial for affect change and stress reduction in adults (Abdullah et al., 2021; Bolouki, 2024; Kaplan Mintz et al., 2021; Mostajeran et al., 2023; Schebella et al., 2020; Suseno & Hastjarjo, 2023) and may even have comparable effects to direct nature contact (Gaekwad et al., 2023; H. Li et al., 2023; Reese et al., 2022). In addition, indirect experiences offer access for people who may otherwise have struggled to reach natural sites, such as those with physical disabilities, people who live far from nature and children whose parents may not have the time, resources or capacity to take them outdoors.

One small study (n=14) compared children's physiological and psychological responses to cycling whilst viewing a film of a forest setting compared to cycling with no visual stimulus. Although there were no significant differences in heart rate or mood across conditions, systolic blood pressure 15 minutes post-exercise was significantly lower in the forest condition (Duncan et al., 2014). 14-18 year-olds (n=30) also reported finding a virtual reality (VR) nature experience relaxing and helpful with stress after using an Oculus headset to spend time in natural environments three times each week (Björling et al., 2022). A larger experiment (Cha, 2023), conducted with 144 children aged 5-7 used VR to explore whether classroom window views of nature or a built environment affected children's physiological stress, but no significant effects were found.

There is currently a paucity of experimental laboratory research exploring nature's effects on stress that has been conducted with children, therefore the following studies have all been conducted with adults.

Stress recovery experiments

Some experiments involve exposing participants to an initial stressor and observing stress recovery. The initial stressor serves to increase baseline stress so that stress changes are easier to measure. In one such study, adults watched a stressful film, followed by a ten-minute video of either a natural or urban environment. Measures of muscle tension, heart rate and skin conductance were taken at baseline and continually throughout exposure to the stimuli. Physiological recovery from the stressful film was found to be faster and more complete when watching the natural environment video rather than the urban environment (Ulrich et al., 1991).

An experiment which induced stress in 160 subjects and then randomly assigned them to watch one of ten different videos of neighbourhood streets, found that the level of tree density in the video was related to their stress recovery - but only for men. In male participants, stress recovery (measured through salivary cortisol and skin conductance) improved as tree density increased, but only up to a certain point. When tree density increased beyond 24% there was no effect on stress recovery, and when it exceeded 34%, recovery slowed down. For women, there was no relationship between the two variables (Jiang et al., 2014).

In both of these studies, nature exposure took place during the recovery period. However, in another study (Brown et al., 2013), nature exposure took place *prior* to the stressor to see whether it would have a protective effect on ANS functioning during recovery. Adult participants (n=23) rested for 15 minutes to allow HR and BP measures to stabilise, then viewed a ten-minute slideshow of either natural or built environments. Following this, participants took part in a five-minute mental stressor. Throughout the experiment and for five minutes after the stressor ended, heart rate, blood pressure, respiration frequency and depth and heart rate variability were measured. A week later the experiment was repeated with participants viewing the alternate slideshow. Viewing natural scenes was found to alter autonomic function during recovery from the stressor. Parasympathetic activity was significantly higher during recovery when nature scenes had been viewed beforehand, this was evidenced by significantly higher levels of heart rate variability in the nature condition. These were higher during recovery than at baseline. This study suggests that nature exposure could potentially act as a buffer against acute stress.

Experiments which did not induce stress

29 adult participants watched slideshows of natural and urban scenes and were asked to imagine that they were in the environment pictured. Heart rate and blood pressure were measured along with respiratory rate and depth. Combined measurements of heart rate variability and blood pressure were used as indicators of sympathetic and parasympathetic nervous system activity. Mean HR, systolic and diastolic blood pressure and breathing depth and cycle duration did not vary significantly according to whether natural or built scenes were viewed. However, indices of vagal outflow suggested that parasympathetic activity increased during views of nature, indicating that the natural images may have induced relaxation (Gladwell et al., 2012). A more recent study, however, found that walking in nature for five minutes in a VR experience affected cardiovascular activity (Chan et al., 2023). Inter-beat intervals were significantly reduced from baseline in the nature condition compared to the urban VR environment, suggesting lower stress. Heart rate variability also increased in the nature condition, although this did not reach statistical significance.

EEG data also supports the idea that viewing images of nature is more relaxing than viewing urban scenes (Ulrich et al., 1991). In a study (n=19) where subjects viewed 60 slides of either nature with water, nature with vegetation or urban environments, alpha activity (signifying relaxed wakefulness) was significantly higher during vegetation slides and lowest for urban environments. Supporting this idea that some natural environments are more stress reducing than others, a VR experiment exposed participants to one of seven different forest parks. Each park had different landscape features; some natural and some manmade. Although all seven forest environments had some stress reducing effects, analyses revealed significant differences in blood pressure and heart rate, depending on the forest type (Wang et al., 2019). Forests with more structural and artificial features such as platforms and benches reduced physiological stress less than forests with more natural features such as waterfalls and pools. Grass and tree environments were also found to be more stress reducing than a concrete courtyard in another VR study which used skin conductance levels as a measure of physiological stress (Huang et al., 2020).

More recent research (Luo & Jiang., 2022) suggests that feeling of 'oppressiveness' in the environment are linked to stress. In this online study, adults (n=1396) viewed images of urban streets and after each image, reported their feelings of oppressiveness, environmental quality and acute mental stress. Perceived oppressiveness was a major mediator linking urban streetscapes to mental stress, explaining over 50% of the relationship. Conversely, natural features in the city environments such as tree canopy and sky associated with lower levels of stress whilst billboards and vehicles were associated with higher stress levels.

2.4.6 Individual differences

Many studies have treated participants as one homogenous group and have not explored individual differences. However, some research suggests that nature has the greatest effect on individuals who were already suffering from the most stress prior to exposure (Morita et al., 2007). Other studies suggest that people are more susceptible to the stress relieving effects of nature during the perinatal period (Bijnens et al., 2020; Jimenez et al., 2020) and that access to green space is more important during early childhood than in adulthood. However, there are not enough studies which look at age as a mediator to be able to draw conclusions on whether age effects occur.

There may also be other differential effects. Research conducted with adults points towards stronger nature-effects for lower SES individuals, people who are more physically active (James et al., 2015) and urban dwellers (Markevych et al, 2014). However, there are not enough studies to evidence this robustly. Furthermore, the mechanisms behind such differential effects are not yet fully understood.

2.4.7 Theories and frameworks for understanding nature's impact on stress

Various theories and frameworks which seek to explain the nature-effect have already been described fully in the pathways chapter of this thesis in Chapter 1.2. However, in addition to these theories, there are others which are specific to effects on stress. Some research suggests that nature exposure could modulate activity in specific brain regions involved in stress-responses. Neuroimaging studies comparing brain activity in urban compared to natural environments have reported differences in pre-frontal cortex activity (Park et al., 2007; Tost, 2019). Following on from this work, a later study which tried to unpick which aspects of nature had this effect (Chang et al., 2021) found that the green-space density in different environments corresponded with changes in the human posterior cingulate (a brain region which forms part of the emotional-regulating limbic system) and that these changes in turn correspond with changes in participant's stress ratings. This research suggested that green landscapes (including urban ones) moderate stress-related responses by engaging the ventral posterior cingulate cortex (vPCC), and that the vPCC is engaged earlier when viewing green landscapes, possibly triggering a cascade affecting other brain regions involved in attention.

Other research suggests that urban upbringing affects the way people process stress, citing the perigenual anterior cingulate cortex (pACC) as a key region which is affected. According to such research (Lederbogen et al., 2011), fMRI imaging of adults during a stressful task or situation suggests those currently living in urban environments showed more amygdala activity than those living in the country, whilst urban living earlier in life was associated with differential activity in the pACC. These studies need to be interpreted with caution as it may be over simplistic to attribute stress responses and certain cognitive functions to specific brain regions. In reality, multiple regions of the brain are likely to be involved, with patterns of overlap and inter-relation which may not easily be detected using neuroimaging.

Nevertheless, although it remains unclear exactly which aspects of natural environments trigger differences in brain activity and a clear theory or framework has not yet been conceptualised, these studies provide an alternative pathway through which the nature-effect might operate; assuming that differences in brain activity trigger a cascade, leading to other observed effects on stress.

Linking back to the other potential pathways outlined in Chapter 1.2, the evidence summarised in this literature review provides support for some pathways and presents challenges for others. Although there is ample evidence that natural environments can reduce both psychological and physiological stress, ascertaining specifically why this is and which aspects of nature are stress reducing is more problematic.

According to Stress Reduction Theory (Ulrich, 1991), natural environments are stress-reducing for evolutionary reasons. Although multiple studies cited in this review support that natural environments down-regulate several physiological markers of stress, and participants self-report reduced feelings of stress when in nature, there is no empirical evidence which suggests that this can be specifically attributed to an adaptive, evolutionary response. In fact, proving this experimentally would be extremely difficult. It would be expected, however, that if SRT was correct, then finding nature stress-reducing would be innate and consistent both cross-culturally and throughout the lifespan. Observing this effect in babies, who have not yet developed emotional connotations about natural environments would support that they are inherently stress-reducing. However, there are no such studies conducted with very young infants, making this difficult to prove. The study conducted with the youngest children (5-7 year-olds) reported no effects (Cha, 2023) whilst other research suggests that the nature preferences observed in adults don't exist in children aged 4-11 (Meidenbauer et al., 2019). Given a lack of empirical evidence for an evolutionary pathway, other mechanisms must also be considered.

It is possible that natural environments are stress reducing because of exposure to positive aspects of the physical environment such as phytoncides, natural light, reduced air pollution, more space to move around and diverse microbiota. However, evidence from laboratory studies which show that even videos and photographs of nature can reduce stress or improve stress recovery, preclude these pathways from being the sole mechanisms behind the stress-reducing effects of nature.

If natural light was a key mechanism, it would stand to reason that urban outdoor areas would be equally as beneficial as natural ones, as long as they had an equal amount of natural light. In fact, although some studies report that *both* urban and natural outdoor areas reduce stress (Gidlow et al, 2016) the majority of research reports that natural environments are *more* stress reducing than urban outdoor environments (Park et al., 2007; Q.Li et al., 2007; Tsunetsugu et al., 2013; Wen et al., 2023). If light mediated the relationship between natural environments and stress, a dose-response relationship would also be predicted, whereby the greatest levels of natural light in outdoor areas would associate with the lowest levels of stress, and being in natural outdoor spaces at night would confer little to no effect on stress. As yet, however, this research has not been conducted.

Regarding physical activity as a pathway, whilst one study found it mediated the relationship between learning outdoors and reduced stress (Dettweiler et al., 2023), most studies do not incorporate measures of physical activity, therefore supporting evidence is scarce. Furthermore, studies which show that window views (D.Li et al, 2010) and seated observation of nature (Tsunetsugu et al., 2013) still have effects on stress, suggest that there must be other mechanisms in play.

Similarly, one study has evidenced a relationship between natural spaces and reduced stress, which appears to exist independently from noise and air pollution (Bijnene et al., 2020). However, noise and air pollution are rarely incorporated as potential mediators in studies, meaning little is known about how these factors interact with measures of psychological and physiological stress.

To demonstrate that natural outdoor spaces reduce stress by reducing overall noise levels, noise measures would need to be taken in both indoor and outdoor environments and compared during matched activities, alongside stress measures. If it is noise, rather than the presence of nature, which reduces stress when forest bathing outdoors for example, then quiet indoor environments should provide the same stress reducing benefits as a forest environment. However, existing studies do not include indoor relaxation strategies as a comparison.

In line with the Biophilia hypothesis (Wilson, 1984), the presence of natural features such as plants and trees would associate with improved mood and lower levels of stress. The research presented thus far does provide support for this idea -

many studies which have compared urban and natural environments incorporate measures of both physiological stress and mood and report positive effects on both, suggesting that the two are related (Beil & Hanes, 2013; Hartig et al., 2003; Park et al., 2007; Tsunetsugu et al., 2013). However, determining the direction of influence is not possible from the existing research base. Do natural environments improve affect, which in turn reduces stress? Or does nature reduce physiological stress which has downstream effects on emotion?

Furthermore, in studies which compare specific features of outdoor environments; natural features are associated with lower levels of stress, whilst more manmade features associate with higher levels of stress (Beil & Hanes, 2013; Huang et al, 2020; Luo et al, 2022; Wang et al., 2019). This offers support for the Biophilia hypothesis, suggesting that natural features such as trees and plants are key, but again, these studies do not provide empirical evidence for why this is the case. It could be that stress reduction is due to natural features being easier to process visually (Grassini et al, 2019; Le et al, 2017; Valtchanov et al 2015; White et al, 2019) rather than there being an innate human connection with the natural world which triggers reduced stress. However, the research cited in this literature review did not compare the visual complexity of indoor and outdoor environments, making this impossible to explore as a potential mediator.

2.4.8 Limitations of existing research

Whilst a small number of accessibility studies suggest that nearby nature is related to lower blood pressure and lower perceived stress in children and may act as a buffer to stressful life events, there are not yet enough studies to draw conclusions. Furthermore, these studies' correlational design means they cannot imply causation. Most of these studies use remote sensing to measure nature in the nearby area, yet such crude measures cannot fully capture the complexity of nature access. For example, measuring the amount of vegetation nearby using satellite imagery does not account for whether a child actually spends time in the green spaces nearby or even has access to them (they may include private land, farmland etc).

Although some confounds such as socio-economic status are included in regression analyses for accessibility studies, others are often neglected. As physical activity has been shown to buffer chronic stress and reduce stress reactivity in children (Feda et al., 2015), this could mediate the relationship between school/neighbourhood green space and stress levels. Children spending time in areas with more green space such as public parks may be more likely to engage in physical exercise. However, this has not been explored fully in the existing literature.

Similarly, community noise has been linked to stress in children. Children living in areas with more road and rail traffic noise were found to have higher blood pressure and urinary cortisol. They also rated themselves higher in perceived stress symptoms (Evans et al, 2001). Mediation analyses are commonly lacking in such research but, as discussed in section 2.4.7, future research designs should factor in these potential mediators and confounds.

Overall, there is a lack of research conducted with children examining nature's effect on stress. The studies that do exist tend to use subjective measures such as self-report scales and have low participant numbers, thereby lacking statistical power. Physiological measures are rarely used in studies with children and there appear to be no experimental studies at all on younger infants regarding nature exposure and stress, despite early life being the period when the brain is most vulnerable to environmental effects (Dadvand et al., 2018). Given that childhood is an important time during which to target interventions for future mental health, further research with younger children is required.

There are several further limitations to the existing research base. Some adult field studies of physiological stress only recruited male participants (Gidlow et al., 2016; Kobayashi et al., 2015; Q. Li et al., 2011; Park et al., 2007; Tsunetsugu et al., 2007, 2013), limiting the generalisability of findings. Given that gender differences have been observed in other nature studies (Jiang et al., 2014) this also misses an opportunity to explore how gender may mediate nature's effects on stress.

Heterogeneity in the measures used (the range of which can be seen in Table 4) make it difficult to synthesise results across studies and report statistical power. Study design and quality in this area is also considered weak to moderate - mainly due to methodological issues such as sampling bias, lack of blinding procedures and inadequate background information on participants to allow consideration of confounds (Corazon et al., 2019).

2.4.9 Summary

Together, this research suggests that both direct nature access and indirect experiences via images, videos or VR can have an impact on both individuals' physiological stress markers and psychological feelings of stress. Whilst there are consistent findings which evidence that short amounts of time spent walking or sitting in natural environments can reduce adult males' blood pressure, heart rate, and levels of salivary cortisol as well as increase levels of parasympathetic functioning, less is known about nature's impact on physiological stress in women and children. It is also unclear how long these physiological effects last for and whether they accumulate or attenuate over time.

There are multiple explanations as to why and how nature could have this effect on stress. Further research which incorporates these variables as mediators would be required in order to draw conclusions.

Limitations of the current literature, including a lack of experimental research conducted with younger children, paucity of studies using physiological measures of stress with a child population and a lack of exploration of differential effects and potential mediators provide the rationale for the stress study conducted as part of this thesis.

2.5 Nature's effect on attention

2.5.1 Introduction and rationale

In everyday life we encounter a huge volume of competing demands for our attention. Our ability to manage these demands effectively is dependent upon a collection of skills which develop throughout childhood and are thought to be essential for school success and effective functioning later in life. Worse outcomes for children who struggle with attention have been indicated by large scale longitudinal cohort studies, implicating a cascade pathway between attention deficits, academic attainment, peer relations and subsequent challenges in adult life (Kuriyan et al., 2013; Powell et al., 2020).

As attention skills in early childhood have been correlated with later school success and even college completion (McClelland et al, 2013) it is important to consider under which conditions children are best able to develop and display optimal attention skills. As explored already in section 1.2.2, attention is one of the most commonly researched outcomes in relation to nature contact and much of this work has been designed to provide supporting evidence for Attention Restoration Theory (Kaplan, 1995). The literature review that follows compiles the existing evidence regarding nature's impact on children's attention.

2.5.2 Definitions, inclusion criteria and measures

Attention is a notably difficult construct to define and measure because it intersects with other cognitive processes such as inhibition and memory in complex ways (Barger et al., 2021). Some research suggests that there are three key aspects of attention: orienting (looking at a visual point of interest), alertness (maintaining sustained attention) and selection-executive function (being able to ignore one stimulus whilst attending to another) (Berger et al., 2007), whilst other frameworks suggest different distinctions, citing four or five aspects of attention instead. Despite the lack of a general consensus, various attentional tasks and tests have been developed to measure individual aspects of attention. However, the extent to which these distinctions exist, and what they are, remains an area of debate.

Various studies have explored associations between nature access or nature interventions and general school achievement, such as school grades or results in standardised national tests. As this review is focussed on attention specifically, these studies have not been included.

Research conducted with children (under 16 years old) is the focus of this review. Studies with adult participants have only been included where there is a lack of such research conducted with children.

The studies reviewed encompass a wide range of measures of attention, both objective and subjective. Some are cognitive tasks administered in a structured setting whilst others outcomes are observed more naturalistically. It is important to acknowledge the heterogeneity of measures used and how this may have affected results. Therefore, these measures are listed and described in Table 7 below.

Table 7

Overview of attention measures

Measure	Description	Example of studies using this measure
Standardised cognitive tasks		
Digit Span tasks	Backward and forward digit span tasks involve hearing sequences of digits which increase in length each time and repeating them back. In the case of a backward digit span task, they are repeated in reverse order. This task utilises directed attention because participants need to hold information in mind and move it in and out of attentional focus	(Berman et al., 2008; D. Li, Chiang, et al., 2019)
Attentional Network Test (ANT)	A computer based reaction test designed to test three attentional networks simultaneously: alternating, orienting and executive control. Participants see a row of horizontal arrows pointing left or right and have to identify the direction of the centre arrow, which requires them to focus on one fixation point for the entire task.	(Berman et al., 2008)

Posner's attention orienting task	This paradigm is designed to assess a person's ability to shift attention by measuring the time it takes to reorient attention from one side of the visual field to another, when a misleading cue is given.	(Laumann et al., 2003)
Skysearch	A sub-scale from the 'Test of everyday attention for children' designed to measure selective attention by requiring participants to attend to relevant stimuli whilst ignoring irrelevant stimuli	(van den Berg et al., 2017a)
Bells test	A paper and pencil test consisting of four sheets each containing figures of 35 black bells among other distracting stimuli. Children have two minutes to find as many bells as possible one each sheet. Scores on sheet 1 are used as a measure of selective attention, with scores from sheet 2 used as a measure of sustained attention.	(Mason et al., 2022)
The Sustained Attention to Response Task (SART)	This task, used as a measure of attentional control, requires participants to withhold a behavioural response to a target, for example, hitting the arrow key on a keyboard for every digit that is displayed on screen, except for the digit '3'.	(K. E. Lee et al., 2015)
The Standardised Attention Test (SAAT)	An iPad-based sub test which measures attention and impulsivity by asking participants to tap or inhibit tapping on a screen depending on the moving location of a symbol	(Faber Taylor et al., 2022)
The continuous performance test (CPT)	A pencil and paper task with three sub tests containing long strings of characters. Participants are asked to find given letters in the string.	(Margherita, 2015)
Visual sustained attention test and auditory sustained attention test– Becker's 'Find animals' task	In the auditory test, children hear an animal name and a non-animal name, when children hear the target animal name, they must report it or raise their hand. In the visual test, a series of pictures are presented on screen including target (animal) pictures and non-targets. When target pictures are seen, the child must say the name of the animal immediately.	(Luo et al., 2023)
D2 revision test	A pencil and paper task designed to test concentrated attention over a short period of time. Measures visual scanning speed and accuracy by	(Lindemann-Matthies et al., 2021)

	requiring participants to identify targets and ignore distractors in rows of letters.	
Necker cube	The Necker Cube Pattern Control Test (NCPC) is an image of a wire cube that can be viewed from two different perspectives. It is designed to measure ability to purposefully direct attention by requiring participants to inhibit one response (seeing one view) in favour of another (seeing the alternative view).	(Hartig et al., 2003)
Digit letter substitution test (DLST)	A speed-dependent task which asks participants to match particular signs (digits or letters) with other signs.	(van den Berg et al., 2017; van Dijk-Wesselius et al., 2018)
Symbol digit modalities test (SDMT)	This is a screening for cognitive impairment. It involves pairing specific numbers with geometric figures.	(Tennessen & Cimprich, 1995)
Trailmaking test (TMT)	Tests skill in perceiving visual and spatial stimuli and in changing between numerical and alphabetical characters. Participants complete tasks such as connecting scattered numbers in the correct order.	(Mancuso et al., 2006)
Other measures		
Strengths and difficulties questionnaire (SDQ)	This parent/teacher reported questionnaire involves responding on a three-point scale ranging from 'true', 'somewhat true' and 'not true' to describe a child's behaviour over the last few months related to statements such as 'restless, overactive, cannot keep still'. Statements around inattentiveness and hyperactivity form part of the questionnaire which means it is sometimes used as a measure of attention.	(Dockx et al., 2022; Ulset et al., 2017a)
The Attention and Deficit Disorders Evaluation Scale (ADDES)	This parent-report scale gives scores on three areas: inattention, hyperactivity-impulsivity and an age-based percentile score. In some studies, it is used as a measure of directed attention capacity.	(Wells, 2000)
Parent questionnaire about ADD symptoms and functioning	Researcher-created questionnaire which asked parents to report their children's functioning and ADD symptoms following leisure activities.	(Faber, 2001)

Number of teacher redirects	A count of how many times the teacher needs to redirect student behaviour in order to keep them focussed on their task	(M. Kuo, Browning, & Penner, 2018)
Visual attention – eye tracking	Measuring look duration has been used as a measure of young children's visual attention	(Fadda et al., 2023)
Brain imaging	A few studies have used brain scans to evidence differences in brain volume associated with cognitive performance	(Dadvand et al., 2018)

Many studies attempt to fatigue participant's attention before exposure to nature (Berman et al., 2008) in order to elicit whether nature can replenish attentional capacity. Fatigue tasks include directed forgetting tasks which require participants to suppress information in short term memory (Berman et al., 2008), the Trier social stress test (D. Li & Sullivan, 2016) and proofreading tasks (Laumann et al., 2003).

Some studies (Li, Dongying, 2016) utilise self-report questionnaires to assess attention depletion. These include Visual Analogue Scale (VAS) questionnaires where participants are asked to report how mentally fatigued they feel by placing an (x) along a horizonal line which is marked 'Not all all' at one end and 'Extremely' on the other.

2.5.3 Reviews and meta-analyses

Nature-effects on children's attention are complex to interpret due to the range of measures used across studies (Barger et al., 2021). Although reported associations between green space and attention have grown over the last decade, meta-analyses are often impossible to conduct due to diverse outcome measures and their questionable congruence. There have, however, been several systematic reviews of effects on cognition more generally. The most recent (Díaz-Martínez et al., 2023) reported mixed evidence based on 28 studies but suggested that re-naturalising school environments could improve children's neurodevelopment.

Another review (Vella-Brodrick & Gilowska, 2022) of 12 studies (10 of which were rated as strong methodologically) found substantial support for children and adolescents gaining cognitive benefits from nature exposure, including improvements in sustained and selective attention. The most consistent attentional benefits were reported in studies using short-term nature exposure, but effects varied depending on the attentional measures used. None of the studies, however, included children under the age of six, and the majority were conducted with children aged nine and over.

A systematic review of green space exposure on children's mental health (Vanaken & Danckaerts, 2018) also found effects on attention; reporting that when studies used the SDQ as a measure, strongest results were most often reported for the hyperactivity and inattention domain. Five out of six studies reported significant associations between hyperactivity and inattention problems and less exposure to green space. This is supported by a review of six studies of young people which reported that passive nature exposure promotes positive changes in attention (Norwood et al., 2019). However, it did caution that it was unclear how these effects translate to real-world outcomes for children.

Reviews based on both child and adult studies (predominantly adults) have also provided some support for Attention Restoration Theory (Ohly et al., 2016), stating that whilst working memory and cognitive flexibility are the cognitive domains most likely to be affected by nature, exposure to natural environments also has shown low to moderate sized effects on attentional control (Stevenson et al., 2018).

2.5.4 Nature accessibility studies

The following studies look at how much green space surrounds a child's home or school.

A small longitudinal study of 17 children aged 7-12 years, (Wells, 2000) assessed children before and after moving house, using a parent-reported attention deficit disorders evaluation scale (ADDES). A housing scale was used to compare the level of 'greenness' in the area around their home. Moving to a greener area was associated with improvements in directed attention, and children living in the least nature to begin with made the greatest gains. The change in 'greenness' of the home environment accounted for 19% of the variance in attentional capacity. This study is supported by more recent research which found significant associations between surrounding greenness and better attentional performance (Saenen et al., 2023) and reduced odds of hyperactivity (Dockx et al., 2022) in children. A study (Dadvand et al., 2018) of schoolchildren in Barcelona (n=253) used 3D MRI brain scans to assess whether lifelong exposure to residential greenspace affected regional differences in brain volume and also measured cognitive performance using the Attentional Network Test (ANT) repeated four times over a 12-month period. Results suggested that being raised in greener neighbourhoods was associated with beneficial effects on brain development and cognitive performance, as evidenced by more grey and white matter volume in brain areas associated with cognitive test scores. Results from two sub-studies suggested that the brain areas associated with greenspace exposure were particularly related to working memory and attentiveness.

However, there have been mixed findings regarding whether *residential* greenness or green space around a child's *school* is more impactful. Greenness around children's home and school were calculated in a study of over 2500 7–10 year-old schoolchildren (Dadvand et al., 2015). Computerized cognitive tests measuring working memory, superior working memory and inattentiveness were taken every three months over a one-year period. After controlling for confounders such as individual and neighbourhood socio-economic status, the study found improvements in all three cognitive areas, associated with greenness around the school. Yet in contrast to the aforementioned Wells study (2000), residential greenness did not associate with cognitive development.

Although most accessibility studies look only at the amount of green space which is accessible to a child and do not record how much time the child actually spends in those green spaces, there has been some research which records direct contact with green spaces. A correlational study (Ulset et al., 2017) of over 560 preschool children, (m= 52.45 months old) tested children's attention skills over the course of four years using a digit span test and teacher report of inattentiveness and hyperactivity symptoms (SDQ). Measures were taken annually along with information from daycare managers about how many hours the children spent outside.

Outdoor hours were significantly negatively correlated with inattention and hyperactivity symptoms at ages four, five and six and positively associated with digit span scores at ages five, six and seven. Daycare quality, as a likely confound, was controlled for in these correlations. Growth curve analyses revealed an inverse dose-response relationship between daily outdoor hours and hyperactivity/inattentiveness and a positive dose-response relationship between outdoor hours and attention skills.

A later, 10-year longitudinal study conducted with 555 children (Ulset et al., 2023) found a direct positive association between time spent outdoors at daycare and self-reported attentional control in adolescence. Associations were also found between outdoor time and later academic achievement, with working memory capacity believed to be the pathway through which this effect occurs.

Children with ADHD (n=421) who spend more time playing in outdoor green settings have also been found to have milder symptoms (as assessed by a parent questionnaire) than those who spend more time indoors and in more manmade outdoor areas (Faber Taylor & Kuo, 2011). Areas of open grass were associated with the mildest symptoms. Similar findings were reported in a study (Kuo & Faber Taylor, 2004) which asked parents to rate their child's ADHD symptoms following various after school activities. Green outdoor activities were associated with reduced symptoms significantly more than activities in other settings, even when the activity type was matched for example comparing football in a field to football in a concrete playground.

There is a body of other evidence which has not measured attention directly but has explored other cognitive functions such as executive functioning and processing speed which are likely to impact attention. Such research has not been included in this review, except for one study (Ward et al., 2016) due to its methodological implications. This study measured time spent in greenspace by fitting participants with a GPS receiver and using locational data over the course of seven days. 108 children aged 11-14 took part in the study which involved a battery of tests including those on visual and verbal memory, processing speed, reaction time, cognitive flexibility and executive function.

The study found no significant relationships between greenspace exposure and cognitive development. However, data showed that participants spent less than 2% of their monitored time in greenspace (under 16.5 minutes per day). The study's authors noted that this calculation may have underestimated actual exposure as the parks dataset was not able to categorise back gardens, school yards or accessible vacant land as greenspace. This study illustrates the importance of evidencing how much time is actually spent in greenspace, and also the methodological difficulties in doing so.

There is also a wide body of research evidencing links between both greenspace and levels of tree cover around the school and academic performance as measured by results on state-wide exams (Hodson & Sander, 2017; Kweon et al., 2017; Li et al., 2019; Matsuoka, 2010; Sivarajah et al., 2018; Tallis et al., 2018; Wu et al., 2014). This literature is not explored in detail here, as these studies do not specifically measure attention. However, it's possible that attentional capacity may mediate the observed relationship between nature and school performance.

2.5.5 Nature intervention studies

Greening schoolyards and classrooms

A body of research has looked at the impact of adding more nature to school playgrounds and classrooms. One such longitudinal study (van Dijk-Wesselius et al., 2018) examined the impact of changing schoolyards from paved to green areas. Data was collected from 700 school children (aged 7-11) at baseline and during two follow ups taking place over the next two years. Digit letter substitution tests and a sky search task were administered both before and after recess as objective measures of attention. At the first follow up, pupils at schools with greened schoolyards and at control schools both showed improvements in attentional performance after recess. There was no significant difference between the groups in terms of the schoolyard's attention-improving effect, suggesting that outdoor time and physical activity may benefit attention rather than nature-access. However, at the second follow up, children in the intervention condition showed greater improvement in scores, suggesting that a greened schoolyard gradually improved attentional capacity over a longer time period. As attentional performance (measured by the ANT) was not impacted by schoolyard greening in a different study which measured attention six to seven weeks after greening took place, it is possible that these effects take months rather than weeks to develop (Kelz et al., 2015).

This notion is supported by other research including a study which introduced greening inside the classroom environment (van den Berg et al., 2017). Green walls, made from living plants, were introduced into the classrooms of 7-10 year-olds (n=170). Measurements of cognitive performance including a digit letter substitution test and skysearch were taken at baseline and repeated after two and four months. Results showed that children in the green wall classrooms showed greater improvements on the test for selective attention, compared to controls. The difference in progress between the intervention and control groups was greater at the second follow up, suggesting effects may increase over time.

A series of studies which added greenery to lecture halls found no effects on students' attention after attending a single lecture in the greened space (van den Bogerd et al., 2020), raising questions about whether effects would have been observed if the study had utilised a longer-term intervention.

Other studies found that indoor plants had a positive effect on 10-12 year-olds' (n=360) performance in standardised tests in spelling and maths (Daly et al., 2010) and increased visual attention in 4-5 year-olds (Fadda et al., 2023) – although eye tracking data revealed that only children's *first* fixations at a stimuli were significantly higher when plants were present, plants did not extend their overall looking time.

These effects were not found, however, in a study which asked students to rate the naturalness of their classroom using a seven-step scale and then measured their attention using the D2 revision test. Classrooms with more indoor plants were rated as more natural but test performance was not associated with levels of naturalness (Lindemann-Matthies et al., 2021). Interestingly however, test performance *was* associated with children's perceived level of stress in class, and some of the questions asked as part of the stress questionnaire related to distractibility and concentration during lessons, suggesting possible collinearity between stress and attention measures.

Outdoor interventions

A study of 48 children aged 9-11 implemented the continuous performance task across three different conditions: inside the classroom after mindful silence, in the playground after play time and in an alpine forest. Children answered more items correctly and also performed the test more quickly in the forest condition (Margherita, 2015). They also considered the forest environment to be the most appealing and restorative. However, the confounding effect of different activities taking place in each condition (mindfulness vs playtime) make these results difficult to disentangle. Other studies have addressed this by matching activities across both conditions, for example completing the same attention task indoors and outside in nature or looking at the impact of walking in both natural and urban settings. Results from such studies have been mixed.

Children performed better on a standardised test of selective attention after being taught a single lesson outdoors as opposed to in their usual indoor classroom in a study of 65 primary school children (Mason et al., 2022). Whilst other pupils (n=80) significantly improved the speed at which they completed the Trail making test, when completing it in their school garden as opposed to their indoor classroom. This effect occurred despite the indoor classroom being quiet and the garden being exposed to road noise (Mancuso et al., 2006).

Other studies evidencing a nature-effect include an experimental study of 4-5 year-olds (n=33) and 7-8 year-olds (n=34) where participants' attention was fatigued by completing jigsaw puzzles, then they walked for 20 minutes in either a nature or urban condition, before completing assessments of working memory, attention and inhibitory control. Children of both ages performed better on the attention task following a walk in nature rather than an urban walk (Schutte et al., 2017).

A walk in nature was also linked to improved attention performance for 7-12 year-old children with ADHD. 17 children experienced walking for 20 minutes in three different environments in blind controlled trials (Faber Taylor & Kuo, 2009). Following each walk, attentional performance was measured using a backwards digit span task. Whilst the two less natural settings did not significantly affect task performance, a walk in the park was found to significantly affect children's scores. The effect of the nature walk was comparable to the peak effects of two typical ADHD medicines.

Studies which did not replicate such effects include a study where 14 children completed a digit span forward and digit span backward task to deplete their attention. They then took part in a child-appropriate version of the ANT, walked for 30 minutes in either a natural or built environment and completed the ANT again. Exposure to the natural environment did *not* lead to improvements in executive attention or accuracy, however, it was associated with faster reaction times and more stable performance (Stevenson et al., 2019).

Similarly, whether children took a break outdoors in a natural, or concrete environment didn’t impact their performance on the ANT (Anabitarte et al., 2021) and a controlled comparison of teaching science lessons outdoors compared to inside did not lead to significant differences in student performance (Faber Taylor et al., 2022).

Several walking intervention studies have also taken place with adults and produced mixed results. Whilst some evidenced that walks in nature but not in urban settings improved performance on attentional tasks (Berman et al., 2008) others found that both types of walks are beneficial (Gidlow et al., 2016). In many studies, effects varied depending on the cognitive tasks used and the specific domains they assessed (Bratman et al., 2015).

Nature’s positive effects on attention were also evidenced in an experimental study whereby different classes of children received matched lessons, some of which took place after an outdoor lesson and some of which took place after an indoor lesson. The experiment was repeated across 10 different lesson topics and weeks, and children’s attention was measured during a 20-minute observation period during which the number of teacher redirects were counted and student engagement was rated using photographs. Classroom engagement was significantly better following lessons in nature. Students were more on-task and required almost half the number of redirects as after indoor lessons (Kuo, Browning, & Penner, 2018). The implications of this study are important as they suggest that effects on attention are detectable not only whilst the child is in a natural environment but continue to be observed after they have returned indoors.

Window views of nature

Views of nature from indoors may also be effective in supporting attention, though results are inconsistent. A study of university students (n=72) found that those with more natural views from their dormitory windows scored better on tests of directed attention (Tennessen & Cimprich, 1995). These findings were later replicated in a study where 94 high school students were randomly allocated to one of three classrooms: one with no windows, one with a window overlooking a built space, and one with a window overlooking green space. Attentional capacity (measured by digit span tests) was over 14% higher in the green window condition than in the other two conditions (D. Li & Sullivan, 2016). However, a later study with younger children, found that naturalness of window views was not correlated with children's performance on a standardised attention and concentration task (Lindemann-Matthies et al., 2021).

Laboratory nature interventions

Nature-effects on attention were identified in a study of 4-6 year-olds (n=152) which compared the effects of various combinations of four minutes of physical activity and watching natural environment videos using VR glasses (Luo et al., 2023). Results showed that engaging in physical activity first, followed by watching a four minute nature video second, conferred the greatest benefits for visual attention (as measured by a visual sustained attention test). Improvements were stronger in this condition than when children had only the video or only the physical activity intervention, or when the video was presented before the physical activity.

There has been very little laboratory-based research which specifically examines the impact of nature on children's attention. Therefore, adult studies have been summarised here.

A within-subjects experiment on 12 adults administered a backwards digit span test and attentional network test. Participants then viewed images of either nature or urban scenes for 10 minutes and repeated the attentional tests. One week later, they returned to the lab to repeat the procedure, viewing the alternative set of images. Participants only improved their backward digit span and ANT performance after viewing the nature images. Furthermore, the only aspect of the ANT which was affected was the executive control section which is thought to be the one which most involves directed attention (Berman et al., 2008). Participants were asked to rate how much they liked each individual picture and also completed a mood scale (PANAS) before and after viewing the collection of images. Whilst the nature images were rated as more enjoyable, there was no reliable change in mood when participants viewed nature instead of urban images, suggesting that changes in attentional capacity operated independently of emotional affect.

Several other studies (Berto, 2005) have corroborated these findings, reporting that images of natural environments are more restorative and lead to greater performance gains in attentional tasks and tests. In one such study (n=150) effects on attentional control were observed after just a 40-second exposure to an image of urban nature. (Lee et al., 2015). Participants completed a baseline Sustained attention to response task (SART), were given a 40-second microbreak, during which they were asked to look freely at the view on screen (a computer simulation of a city scene with either a flowering green roof or a bare concrete roof) and then completed the SART again. Despite no significant differences at baseline, those who viewed the flowering green roof made significantly fewer errors on the task and gave more consistent responses in the post-break SART test when compared with those who viewed the concrete roof image.

However, not all such studies report nature-effects. In a study of 28 female undergraduates (Laumann et al., 2003), students were randomly allocated to watch either a natural or urban environment video. Participants first sat in a chair for a 10-minute baseline relaxation period, then mental load was induced with a series of proofreading tasks. Afterwards, the Posner attention orienting task was administered. After this, either the nature or urban video was shown, and then the attention-orienting task was repeated. Reaction times from the attention-orienting task showed that the nature video did not improve attentional performance compared to the urban video. Conversely, the urban video condition elicited faster reaction times on valid trials, and there was no significant difference between conditions for invalid trials.

2.5.6 Theories and frameworks for understanding nature's effects on attention

Having reviewed the existing research literature on the nature-effect and attention, it is important to return to the pathways discussed in section 1.2, and the extent to which this literature provides support for them. Whilst there is ample evidence that natural environments are associated with improved attention – does the current literature point towards any specific mechanisms which underpin this relationship?

In order to evidence Attention Restoration Theory, any improvements to attention would have to be attributed specifically to the restorative effects of natural environments. In order to do this, children would need to report how restorative they found different environments, and these levels of restoration would be expected to associate with attention outcomes. This is problematic with young children as restoration is a complex concept to understand and therefore difficult to measure with self-report scales which may be unreliable with young children. Therefore, it is unsurprising that many studies conducted with children do not include measures of restoration. Some of the aforementioned studies conducted with adults do provide evidence that natural environments are rated as more restorative by participants, and in turn, seem to improve attentional capacity more so than non-natural environments (Berto, 2005). However, such research with children is lacking.

Furthermore, in line with Attention Restoration Theory, one would expect natural environments to provide benefits immediately after attention had been depleted and then restored. However, many studies evidence longer term effects on attention, improving performance weeks or months later, rather than immediately after spending time in the environment (Kelz et al, 2015; Van Dijk- Wesselius et al, 2018). It is also unclear how short-term restoration processes could explain longitudinal associations between residential green space in early childhood and attention outcomes in adolescence and adulthood for example (Ulset et al, 2023).

Attention Restoration Theory also does not allow for the possibility that the more someone's directed attention skills are taxed, the more their capacity for attention improves over time. If the nature-effect on attention is to be attributed solely to ART, it would suggest that people who spend the most time in restorative environments which reduce demands on their attention would have superior attention skills over the course of the lifespan, compared to people whose attention is regularly taxed, for example, those who spend time in busy, highly stimulating environments or who are engaged in careers which require long periods of sustained focus. However, there appears to be no such direct evidence that placing increased long term demands on attention control associates with poorer long term attention skills.

If ART cannot solely account for nature's effect on attention, then other pathways may also be responsible. Some argue that improvements in attentional capacity following nature exposure are actually linked to stress reduction. In this aspect, research on both attention and stress begin to overlap somewhat. In many situations, resource deficiencies and stress happen concurrently; fatiguing activities which take place before nature exposure are often stressful for participants. Kaplan (1995) suggests that directed attention is the resource lacking when psychological stress occurs.

Whilst existing research does suggest that stress and attention are linked, this is rarely studied in relation to urban and natural environments. One study, however, did directly examine adults' stress recovery and attention in natural and urban settings (Hartig et al., 2002) and found that both diastolic blood pressure and self-regulation of attention benefitted more from walking in natural compared to urban settings. However, changes in attention correlated only weakly with blood pressure changes, possibly because the timescales of effects did not converge: environmental effects of attention were observed during the walk and persisted after it, whereas environmental effects on blood pressure dissipated more quickly.

Another study examined physiological stress and self-regulation of attention in infants, compared between children from high-density urban and low-density rural environments (Wass et al., 2019). Overall, average physiological stress (respiratory sinus arrhythmia) was higher in urban infants, and urban infants also showed impaired sustained attention.

As it's difficult to ascertain whether stress causes attention fatigue or vice versa, and the role that nature plays in this - further research is needed to explore how these variables may interact. Kaplan proposes that theories of both stress and attention should be integrated into one framework about nature restoration (Kaplan, 1995).

Higher levels of physical activity outdoors could also support attention, and some studies suggest that it does mediate effects (Luo et al., 2023), but studies which have matched activities in natural and non-natural settings and still report more beneficial effects from natural environments (Kuo & Faber-Taylor 2004; Schutte et al., 2017) suggest that physical activity is unlikely to be a key mediator. However, given that most studies do not incorporate activity levels, future research should measure activity levels indoors compared to outside, or in urban environments compared to natural environments and correlate these with measures of attention.

As previously mentioned in section 2.4.7, research which demonstrates that even viewing pictures and videos of nature can benefit attention (Berman et al., 2008; Berto 2005; Lee et al., 2015) also precludes other aspects of natural outdoor environments such as natural light, diverse microbiota, air quality and phytoncides as being the sole cause of attention effects.

It remains possible that lower levels of noise and lower levels of visual complexity in natural environments could support attention improvements, however, studies rarely incorporate these variables as potential mediators and thus, the extent to which these impact environmental effects on attention remains unknown.

Finally, it is well established that in adults, exposure to nature is associated with positive mood (Gaekwad et al., 2022; MacKerron & Mourato, 2013; Wickes et al., 2022). Similar findings have been reported with children, albeit often from less controlled studies (Liu et al., 2023). Whether improvements in affect underpin improvements in attentional performance is unclear, as the studies cited in this review did not commonly include measures of affect. It is unknown whether moment-by-moment changes in affect would influence attention performance in the short term.

2.5.7 Individual differences

Historically, not all studies have considered individual differences and whether effects vary according to children's characteristics. Those that do, tend to control for demographic variables as covariates but do not analyse them in detail. However, newer research is beginning to explore whether individual differences might moderate relationships between the environment and attentional performance.

In the aforementioned study (Mason et al., 2022) which compared children's attention performance after a single indoor or outdoor lesson, children's self-reported emotional difficulties were found to have moderate effects. Students who reported higher levels of emotional difficulties benefitted most from lessons outdoors in nature.

It is possible that children with existing attention deficits may also confer greater benefits from nature, however most studies either focus exclusively on clinical populations or exclude children with ADHD from their analyses. Furthermore, many study designs do not incorporate baseline measures of attention, or where they are included, this is only to show whether there is a pre/post improvement in attention following nature exposure, rather than to carry out between-participant comparisons. This makes it difficult to explore how baseline attentional capacities might impact children's susceptibility to nature's effects.

Most of the studies summarised thus far do not report gender effects, although some suggest that greenspace has more of an effect on hyperactivity (Yang et al., 2019) and on-task behaviour (Lundy & Trawick-Smith, 2021) for boys than it does for girls.

Some studies have suggested that children who are exposed to higher levels of nature in everyday life may be less affected by nature interventions. This reason was used to explain null results in some experiments (Anabitarte et al., 2021). In the aforementioned body of literature based on nature exposure and school test results, some studies evidenced greater nature-effects for urban schools (Tallis et al., 2018) and schools with more deprived students (Kuo et al., 2018; Sivarajah et al., 2018). – i.e. greenspace surrounding the school was more impactful in settings whereby children may not access as much nature outside of school hours. However, as yet there is not enough experimental evidence to support this hypothesis.

It is also possible that nature-effects vary depending on children's age and stage of development. However, few studies have been conducted on children from a range of ages and there is not enough research conducted with younger children to draw conclusions.

2.5.8 Limitations of existing research

Despite cognitive capacities developing rapidly during early childhood, indicating that this could be a key developmental stage within which to explore nature's potential impact on cognition, studies rarely focus on younger children and there is a complete lack of research evidence on toddlers and babies.

Heterogeneity in measurements used across studies has made it difficult to synthesise results from a range of research. Attention performance has been measured using a wide range of tasks, often interchangeably, which makes it difficult to perform meta-analyses and often impossible to disentangle specific cognitive processes utilised by each test, for example, the digit letter substitution test has been used as an attention measure in some studies, but arguably involves a range of cognitive processes including visual scanning, mental flexibility, psychomotor speed and speed of information processing, all of which could interfere with obtaining a 'pure' measure of attention. Other measures of attention appear to measure vigilance processes, requiring participants to stay focused and avoid shifting attention to distractions, whilst some rely more heavily on working memory (Ohly et al., 2016). Arguably, all of these cognitive performance tests are very different to real-world learning experiences, limiting the ecological validity of many studies. Most studies look at participants' attention in isolation, when they are performing a task alone within a quiet and structured setting, whereas real world situations requiring attention are more likely to incorporate interactions with peers and teachers and tasks which rely on prior knowledge. Little is known about the effect of nature on children's attention performance in naturalistic school tasks.

This has been a criticism of psychological research more broadly; that there is a lack of integrative theory development and testing, with theories becoming siloed and over-specialised because they are based on specific tasks rather than being situated within the broader literature and looking at the constructs associated with these tasks and how they relate to real world outcomes (Eisenberg et al., 2019). Whilst in a controlled experimental task, the participant is usually passive while the researcher controls what is presented, how, when and for how long; in real-world attention, children's interactions with their environment and what they find relevant determine what they pay attention to (Wass & Goupil, 2022).

In studies attempting to provide support for Attention Restoration Theory, for example, ADHD scales and objective attention measures are often used. However, it has been noted that there is no evidence that such measures are comparably sensitive to green space, nor is it clear whether these measures meaningfully relate to restoration (Barger et al., 2021).

Furthermore, studies vary in terms of when measurements are taken. Some research suggests that benefits to cognitive function do not consistently occur during the first 15-20 minutes of nature exposure and take longer to manifest (Laumann et al, 2003). This has implications for studies which did not take measures at multiple intervals, including after participants had left the natural environment. In the context of school learning, it may be the case that cognitive performance is improved during the lessons that follow outdoor nature exposure, rather than for the tasks completed whilst in the natural environment. Very few studies include longer term follow ups to see whether effects last for hours or even days. Tracking these changes longitudinally would provide more detailed information about the rate and longevity of improvement effects.

A further limitation of attention studies is that many fatigue or deplete subjects' attention prior to nature exposure to make restoration effects easier to detect. This limits the scope of findings as without a non-fatigued control group, it is not possible to ascertain whether nature can enhance attention as well as restore it to baseline. Additionally, due to individual differences, participants may not be equally fatigued by the same tasks, which could affect results, yet studies rarely incorporate measures to quantify how fatigued participants attention is.

In addition, conceptualising ‘natural environments’ as one broad category, as many studies do, may obscure important distinctions between different types of natural features and which are most beneficial. Forests and coastal environments have been associated with greater restoration than environments such as urban playing fields (M. P. White et al., 2013), and whether greenspace was open grass area, or grass with trees was found to impact symptoms in a study of 421 children with ADHD or ADD (Faber Taylor & Kuo, 2011). For children with ADD (and no hyperactivity), the mildest symptoms were associated with playing in both areas of open grass, and grass with trees, whereas for children with hyperactivity, only open grass areas without trees were significantly associated with milder symptoms. Thus, further research of this kind is needed which isolates different aspects of the natural environment to see which affect attention and which specific cognitive and biological processes are involved. Digitally manipulating the features in the natural environment, for example by adjusting the amount of tree cover or open space in a VR nature experience, is a new opportunity to explore such variables.

2.5.8 Summary

Collectively, the research summarised in this literature review suggests that surrounding greenness in both residential and school areas is associated with better attention performance and reduced risk of hyperactivity and inattention. However, in many of these studies it is unclear how much time children spend engaging with surrounding nature.

Field-based intervention studies have yielded mixed results. There is some evidence that interventions such as schoolyard greening, nature views from windows and plants in classrooms have small to medium effects on cognitive performance, but the specific aspects of cognition affected (attentional control, spatial memory, inhibitory control and reaction times) vary across studies. There is also evidence to suggest that when natural features such as plants are experimentally added to indoor or outdoor environments, beneficial effects may take time to appear and may increase over time (van den Berg et al., 2017b; van Dijk-Wesselius et al., 2018).

Walking in nature was found to have beneficial effects on attention deficits for children with ADHD but there is not enough evidence to corroborate these findings with a non-clinical population of children. Findings also vary in adult studies of walking in nature. Whilst some found that directed attentional capacity improved after a walk in nature, others did not replicate this finding.

Laboratory-based research conducted with adults suggests that viewing images of nature may also have beneficial effects on attention, however a study using video footage of nature did not find a positive association between nature and attentional performance.

Limitations of the current literature, including a lack of ecologically valid attention measures and a paucity of research with younger children provide the rationale for the attention study conducted as part of this thesis.

2.6. Nature's effect on behaviour

2.6.1 Introduction and rationale

Behaviour is a key issue for schools, commonly cited as one of the most challenging aspects of teaching (Moore et al., 2019). In the academic year 2022/23 there were over 3,100 permanent exclusions and over 247,000 temporary suspensions in English schools (Gov.uk) and suspension rates in primary schools are increasing, over 4,600 of the suspensions issued in 2022/23 were for children aged six or under.

'Persistent disruptive behaviour' is the most common reason, accounting for around 50% of all suspensions and exclusions (DfE, 2023). This disruptive behaviour has led to significant issues with teacher recruitment and retention. Two thirds of teachers report thinking of leaving the profession due to poor pupil behaviour (Williams, 2018). Boys have around twice as many exclusions as girls, and children who are eligible for free school meals are over four times more likely to be suspended than their peers (DfE, 2023).

Rates of suspensions and permanent exclusions tend to increase as children's age increases, peaking around age 14, but are often the culmination of behaviour issues which begin in early childhood. Thus, supporting children, early in life, to develop behavioural self-regulation skills and providing an environment which fosters more prosocial behaviours may help prevent serious behaviour incidents in the future, as well as maintaining the teaching workforce.

Some existing research suggests that natural, outdoor environments are associated with reduced problem behaviours and increased prosocial behaviour in children (Zare Sakhvidi et al., 2022). This chapter will summarise this existing research evidence. However, first it will define the types of behaviour which are examined in such research and the ways in which these behaviours are measured.

2.6.2 Definitions, inclusion criteria and measures

Self-regulation

Self-regulation is one of the key aspects of children's behaviour which has been researched in relation to nature access. Self-regulation is the ability to control one's own feelings, thoughts and impulses, usually in the pursuit of longer-term goals. This self-control allows individuals to conform to social expectations and relate positively with others (Jenkin et al., 2018). Sometimes referred to as self-control or self-discipline, self-regulation is thought to underlie both executive functioning and emotional intelligence, as well as being linked to motivation and wellbeing. It is commonly viewed as a sign of good socio-emotional development.

Children with good self-regulation skills are able to delay gratification, manage frustrations and control their emotions and behaviour. Poor self-regulation in children has been linked to obesity and poor academic outcomes (Baumeister and Heatherton, 1996). In adulthood, this inability to control and discipline oneself has been linked to alcohol and drug addiction, crime, gambling and a range of other individual and societal problems (Baumeister and Heatherton, 1996).

After controlling for intelligence and socio-economic status, one longitudinal study (n=1,000) found that levels of self-control in childhood, predicted physical health, substance dependence, personal finances and criminal behaviour in later life (Moffitt et al., 2011). Early development of self-regulation is associated with myriad short and long-term positive outcomes such as academic achievement and mental health (Mueller & Flouri, 2020)

Fortunately, self-regulation is a skill that can be improved and developed with intervention (Pandey et al., 2018). As a result, it has attracted a lot of attention in the education sector and if there are particular interventions and learning environments which can foster the development of self-regulation skills, these are important to explore. Research suggests that natural, outdoor environments may have this effect. According to one systematic review (Gill, 2011), the claims that spending time in nature improves emotional self-regulation are well supported.

Antisocial behaviour, aggression and behaviour/conduct problems

Persistent antisocial behaviour is one of the most common mental health problems in childhood (Romeo et al., 2006). The cost of supporting a child with severe antisocial behaviours is almost £6,000 per annum (Romeo et al., 2006), a significant challenge in the current climate where mental health support is underfunded. Yet early intervention is key, as antisocial behaviour and conduct problems in childhood increase the risk of violence, crime and mental health problems in later life (Hill and Maughan, 2001 cited in Romeo et al, 2006).

Antisocial behaviour has been defined as that which causes or is likely to cause harassment, alarm or distress to others (Met.police.uk) and is one of the symptoms of conduct disorder. Conduct disorders, affecting around 5% of children aged 5-16 in the UK (NICE, 2013) are characterised by repetitive and persistent patterns of behaviours which violate societal rules or norms, or the basic right of others (DSM-5). Aggressive behaviour is one example of such behaviour.

Aggression refers to behaviour that's aimed at harming others (dictionary.apa.org). It can be subdivided into physical aggression, which causes bodily harm, and verbal aggression. Physical aggression is thought to appear around 12-17 months of age and decrease throughout childhood into adolescence (Tremblay et al., 1999).

Prosocial behaviour

Prosocial behaviour is considered that which benefits others or promotes harmony. In children such behaviours may include sharing, comforting and helping (Putra et al., 2020). Such behaviours are important in a classroom setting where children are expected to learn and play alongside others, co-operating and building friendships. Prosocial behaviour has been linked with a wide range of positive outcomes including academic success and wellbeing (Putra et al., 2020).

All of these types of behaviour have been studied in relation to nature access, and various measures have been used to quantify such behaviour.

Inclusion criteria:

Studies have been included for review if they specifically measure any of the aforementioned aspects of behaviour - namely: self-regulation, prosocial behaviour, antisocial behaviour, socioemotional development, aggression and behavioural/conduct difficulties.

Some studies of nature's impact on behaviour use diagnosis rates or criteria from ADHD assessments as a measure. Such studies have been included in this section as ADHD involves behavioural difficulties such as self-regulation. However, study findings which refer specifically to the attentional dimensions of ADHD have been included in the attention section of this literature review instead.

The prime focus of this review is studies conducted with children of pre-school, primary or secondary school age (2-16 years old). Where participant samples span an age range including the school years and into an older age range e.g. 12-18 year-olds, the study has been included. Occasionally studies with older adolescents or adults may have been included if they add a new theoretical dimension to the evidence base and no such research has been conducted with children.

Measures of behaviour used in existing research

Existing research on the nature-effect has used a wide range of tools to measure the types of children's behaviour described above, these are listed and described in table 8 below.

Table 8

Overview of behaviour measures

Measure	Description	Examples of nature studies using this measure
Delayed gratification tasks	Tasks require children to choose between an immediate small reward, or a greater reward after a delay. For example one study (Jenkin et al., 2018) asked children to make a series of delay of gratification choices such as 'would you choose to be given 20 pence now, or 50 pence in a week's time?'	(Jenkin et al., 2018; Taylor et al., 2002)
Attention tasks	Attention or concentration is seen as a cognitive facet of self-regulation. Therefore, tasks mentioned in the previous section on attention (Table 7) such as the Symbol Digit Modalities test, forward and backward digit span and Necker Cube pattern have also sometimes been used in self-regulation studies	(Taylor et al., 2002).
Inhibition tasks	Inhibition tasks require subjects to restrain or block a behaviour or impulse. Examples include: Stroop Colour-Word test Matching familiar figures test Category matching In all of these tasks, the participant needs to inhibit their initial response in order to reach the correct answer.	(Taylor et al., 2002)
Head-Toes-Knees-Shoulders task	A behavioural assessment of the executive function aspects of self-regulation (working memory, attentional flexibility, inhibition and concentration) which involves firstly following instructions e.g. 'touch your toes' and secondly, doing the opposite to what has been instructed	(Faber-Taylor & Butts-Wilmsmeyer, 2020)

	e.g. touching head when told ‘touch your toes’.	
Live or video observations coded for incidents of behaviour	Researchers have coded the number of teacher redirects(to keep children focussed on their learning task) during lessons as well as the number of times children are off-task .	(Kuo, Browning, & Penner, 2018; Largo-Wight et al., 2018)
DSM Scales for ADHD symptoms	The Diagnostic and statistical manual of mental disorders scales are used to measure 18 ADHD symptoms (8 inattention and 9 hyperactivity symptoms).	(Yang et al., 2019b)
The strengths and difficulties questionnaire (SDQ)	A behavioural screening questionnaire for 3-16 years olds, commonly used as a measure of social, emotional and behavioural difficulties. It consists of five scales; emotional symptoms, conduct problems, hyperactivity and inattention, peer relationship problems and prosocial behaviour. It is commonly completed by parents and sometimes by teachers.	(Flouri et al., 2014; Mueller & Flouri, 2020)
Behavioural Assessment System for Children (BASC-2)	A behavioural and emotional screening system which facilitates diagnosis and classification of a variety of behavioural and emotional disorders. It consists of parent and teacher rating scales covering a range of areas including aggression, hyperactivity, social skills and behavioural symptoms.	(Madzia et al., 2019)
Child Social Behaviour Questionnaire (CSBQ)	A parent questionnaire. Two Specific scales from this questionnaire have been used to measure self-regulation: Independence and Emotional Dysregulation	(Mueller & Flouri, 2020)
Achenbach Child Behaviour	A parent checklist of 100 questions which assesses the extent of behavioural and emotional problems in the following areas: anxious/depressed, somatic complaints,	(Bijnens et al., 2020; Lee et al., 2019)

Checklist (CBCL)	social problems, thought problems, attention problems, rule breaking behaviour and aggressive behaviour.	
Child behaviour rating scale (CBRS)	10 items assessing classroom behavioural self-regulation using a five-point scale (1= child never displayed these behaviours, 5= always displayed).	(Faber-Taylor & Butts-Wilmsmeyer, 2020)
Cognitive emotion regulation questionnaire (CERQ-k)	A questionnaire with 9 sub-scales, each of which are scored on a 5-point likert scale (1= never, 5=always). Children consider a negative event experience to respond to each statement.	(Bakir-Demir et al., 2019)
Emotion regulation questionnaire for children and adolescents (ERQ-CA)	A 10 item questionnaire designed to measure emotional regulation ability. Children respond on a 5 point scale (from strongly disagree to strongly agree) regarding their tendency to regulate their emotions in 2 ways: 1) Cognitive reappraisal and 2) Expressive suppression	(Bakir-Demir et al., 2019)
Childhood executive functioning inventory (CHEXI)	A 26 item parent reported questionnaire designed to measure executive control. The inhibition sub-scale of this inventory has been used as a measure of behavioural self-regulation whilst the regulation, planning and working memory sub scales have been used to measure cognitive regulation.	(Bakir-Demir et al., 2019)
Barratt impulsiveness scale-11 (BIS-11)	A child version of this scale was developed to assess childrens self-regulation skills. The child version has 16 items which cover both emotional and behavioural self-regulation.	(Bakir-Demir et al., 2019)
Heart rate variability (HRV)	Heart rate variability is a measure of the time interval between each heart beat. It can be measured using ECG. High frequency heart rate variability indicates	(Beute & de Kort, 2014)

	that the parasympathetic nervous system is modulating the heart and suggests that an individual is self regulated.	
System for observing children's activity and relationships during play (SOCARP)	An observational system for concurrently observing social interactions, activity type, group sizes and physical activity during play times in school. Each child is observed for 10 seconds, then observations are recorded for 10 seconds.	(Bates et al., 2018)
Social orientation choice cards (SOCC)	Children were given a scenario where they had to choose how to share a reward with another child, their choice was categorised as prosocial, individualistic or competitive.	(Van Dijk-Wesselius 2018)
Behavioural Observations	Live observations, video coding and behavioural mapping have been used to track incidences of prosocial behaviour and misbehaviour.	(Brussoni et al., 2017)
Devereux Early Childhood Assessment (DECA) Preschool Programme	A strengths based assessment consisting of a standardised, norm referenced behaviour rating scale to assess socioemotional resources, including self-regulation and attachment in children aged 2-5	(Scott et al., 2018)
Punishment /misbehaviour records	The number of times misbehaviour has been logged in school, or punishments such as detentions have been given.	(Han, 2009)
Windfall task (Richins and Dawson, 1992)	Children were asked to imagine they had won $100 and were asked to choose how to spend it 1) Buy things they want 2) Give to charity 3) Buy gifts for others 4) Save for the future	(Dopko et al., 2019)

	Allocating more money to choices 2) and 3) was considered to represent higher pro-sociality	
Tangram task (Gentile et al, 2009)	Children were asked to choose 11 tangrams to assign to someone else in the class to solve. Tangrams were rated as easy, medium and hard. Assigning more easy and medium tangrams and fewer hard tangrams was considered to represent prosocial behaviour.	(Dopko et al., 2019)

2.6.3 Reviews and meta-analyses

There are four systematic reviews on nature/greenspace and children's behaviour that have been conducted within the last four years (Bikomeye et al., 2021; Mygind et al., 2021; Putra et al., 2020; Zare Sakhvidi et al., 2022). The findings from these reviews are summarised here before moving onto the details of specific studies below.

The most recent systematic review of greenspace exposure and children's behaviour concluded there are indications that green space is beneficial and that evidence in this area is accumulating (Zare Sakhvidi et al., 2022). This review of 29 studies found an association between green space exposure and eight different behavioural outcomes including prosocial behaviour, peer relationship problems, total behavioural difficulties and emotional symptoms. However, a relationship was not found with conduct problems. Due to the diversity of measures and methodology, it was not possible for the review's authors to do a metanalysis of these findings.

In the 29 studies reviewed, total behavioural difficulties (TBD) was the most frequently researched outcome. 16 studies, 81% of which were rated as fair or good quality, reported an association between greenspace exposure and TBD. 13 of these used the SDQ to do so. Five different greenspace measures were used across these 16 studies, though over half of them used NVDI. 25 out of 30 associations reported that greenspace exposure had a protective role on the TBD score, but only three of these were statistically significant (Zare Sakhvidi et al., 2022).

This review also contained 10 studies which reported nature's effect on prosocial behaviours, again, the vast majority of these used the SDQ. 13 out of 18 associations between green space and prosocial behaviour suggested a positive effect, however only 3 of these associations were significant. Unexpectedly, four associations from one study reported that green space had a negative effect.

Bikomeye et al's (2021) systematic review was specifically of quasi-experimental studies which looked at the impact of schoolyard greening (adding more greenery and natural elements to school playgrounds). Six articles were included and a range of measures were used across studies, including physical and verbal conflict rates, % of children engaged in prosocial behaviour and scores from SDQ. Two studies used video footage of student's play sessions to analyse social behaviour and interactions. All of the studies reviewed which looked at positive behaviours and interactions reported a positive or mixed association between prosocial behaviour and schoolyard greening. In two studies there were age effects whereby younger children appeared to benefit from greening whilst older children had a negative effect or no effect.

Mygind et al (2021) conducted a systematic review of evidence for associations between children's exposure to nature and their socioemotional development. Exposure to nature included access to nature, passive exposure to nature and direct engagement with nature. 43 of the texts reviewed related to socioemotional outcomes. Although a considerable amount of positive associations were found, the review concluded that findings are inconsistent and empirical evidence is limited.

Finally, Putra et al (2020) conducted a systematic review of the relationship between green space and children's prosocial behaviour. They reviewed 63 associations from 15 studies, finding 44 positive associations, 18 of which were statistically significant ($p < 0.05$). The review concluded that there was insufficient evidence to draw conclusions on causality, but that there is preliminary evidence that exposure to green space may possibly increase prosocial behaviour. More significant associations were found when studies used in-person observation to measure children's nature exposure, compared to studies that used area-level green space measurements such as NDVI. None of the reviewed studies investigated potential mediators.

In conclusion, these reviews suggest that there may be an association between children's behaviour and access to green space. However, few studies found statistically significant results and there is a lack of experimental research which can evidence direct causation. Experimental studies which do exist often involve a risk of bias (Mygind et al., 2021).

Some of the reviews suggest that certain groups of children might benefit more from nature contact than others. Across different studies, children's age, gender, SES and whether they lived in urban areas were found to mediate nature's impact on behavioural outcomes. However, the direction of these relationships were mixed, often depending on which greenspace measures and behavioural measures were used, this is explored further in the 'individual differences' section below.

A multitude of different measures, instruments and research designs used across various studies made meta-analyses impossible and meaningful comparisons problematic. The following sections of this literature review will explore specific studies in more detail, firstly looking at correlational studies of area-level green space and behavioural outcomes, before moving onto more controlled quasi experimental and experimental studies.

2.6.4 Nature accessibility studies

As accessibility studies tend to employ similar methodology, they have been summarised in the table below and are ordered according to the date they were conducted and colour coded according to their findings (Green = positive associations found between nature and behaviour, yellow = mixed findings, orange = null fundings or negative associations between nature and behaviour). Studies have not been included if their only behavioural measure was an ADHD diagnosis.

Table 9

Studies of greenspace accessibility and children's behaviour

N	Age	Behaviour measures	Measures of nature accessibility	Control variables/co-variates	Main findings	Reference
3568	9-15 year-olds	SDQ – Total difficulties score	Mapping of urban natural environments in 50, 100m, 250m and 500m buffers around the school and home. Natural environments sub-categorised into: Green/blue space Woodland/grassland	Age Ethnic background Gender Parental occupation Type of school	Higher exposure to woodland (but not grassland) was associated with a lower risk of emotional and behavioural problems.	(Maes et al., 2021)
908	0-7 year-olds	SDQ completed by teacher and Mother – total difficulties score, externalizing and internalizing subscales	Residential greenness at birth, 'early' and 'mid-childhood' and 'early adolescence' using NDVI buffers of 90m around the home (directly accessible greenness) 270m and 1230m (walkable areas of greenness)	Mother's characteristics: age, IQ, smoking during pregnancy, education, marital status Child's characteristics: age, sex, ethnicity, season of birth Household income	Residential greenness did not associate with behaviour outcomes in mid childhood or early adolescence. Maximum greenness in early childhood associated with mid childhood SDQ.	Jiminez et al, 2021

				Population density Screen time		
1489	4-6 year-olds	SDQ	NDVI – residential greenness Time spent in the nearest city park	Maternal characteristics SES Child characteristics: sex, age, birth order, birth weight, breastfeeding Health characteristics	Higher greenness exposure within 100m of the home was associated with reduced risk of parent reported mental difficulties (including conduct problems, hyperactivity and peer relationship problems) Lower greenness exposure and <5hrs per week spent in city parks were associated with increased risk of hyperactivity and total mental difficulties.	Andrusaityte et al, 2020
620	7-15 year-olds	CBCL – Total behavioural score, internalizing and externalizing subscales	Residential green space during pregnancy and childhood – measured using land cover databases.	Gestational age, weight and birth Parental education Household income Neighbourhood SES Air pollution (residential	Higher residential green space was associated with a reduction in behavioural problems for urban but not rural children.	Bijnens et al, 2020

				distance to nearest main road)		
13,774	At ages 3, 5 and 7	CSBQ – Independence and emotional dysregulation scales	Neighbourhood greenspace – measured using data from the Multiple Environmental Deprivation index (based on land use databases and satellite imagery)	Neighbourhood air pollution and deprivation Urbanicty Home physical environment Family background Maternal education and depression Child-level covariates (sex, ethnicity, IQ)	After adjusting for covariates, no association was found between neighbourhood greenspace quantity and self-regulation in children.	(Mueller & Flouri, 2020)
299	8-11 years old	CHEXI BIS-11	NDVI – residential greenness	Nature connectedness Perceptions of nearby nature Child's temperament Sex of child Age of parents and child Education level of parents	More greenery around the home was positively associated with nature connectedness, which in turn predicted emotional regulation skills and cognitive regulation skills. However, the direct effects of greenery on emotional and cognitive regulation were not significant. No significant associations were found between	Bakir-Demir et al, 2019

					greenness and behavioural regulation.	
1817	7-17 years old	CBCL	MSAVI (Modified soil-adjusted vegetation index) calculated for a 1.6km radius of child's residence. MASVI values categorized into low, moderate and high greenness.	Age Sex Physical activity BMI Family income Exposure to second hand smoke Exposure to NO2 Blood lead level	Children living in the greenest areas had significantly lower total problems scores compared to children living in areas with the lowest greenness. The inverse relationship between greenness and problematic behaviour was strongest for externalizing behaviours, specifically attention problems and aggressive behaviours.	Lee et al, 2019
6039	5-6 years old	CBCL	NDVI (100m buffer around home and school)	Maternal age and education Gestational age Birth outcomes Residential address at birth Sex Age whether child was breastfed	Decreases in problem behaviours (including aggression, hyperactivity and anxiety) were associated with higher levels of greenspace around the kindergarten. Associations were stronger in boys than in girls.	Liao et al, 2019

562	7 and 12 year-olds	BASC-2	NDVI based on 200, 400 and 800m buffers around children's residential address at 7 and 12 years.	Child's sex and race Maternal education level Community level deprivation	At age seven years, more residential greenness within a 200m buffer was associated with decreased conduct problems. There were no significant associations between NDVI at age 12 and BASC-2 scores for hyperactivity, aggression or conduct problems.	Madzia et al, 2019
59,754	2-17years old	DSM-IV scales for ADHD – completed by parent	NDVI used to measure greenness surrounding each child's school	Age Sex Parental education level Annual household income Dog ownership Smoking during pregnancy Alcohol during pregnancy Breastfeeding Pre-term birth Number of siblings Birth weight	More greenness surrounding the school was associated with lower odds of ADHD symptoms.	(Yang et al., 2019)

2594	4 year-olds	SDQ (parent reported)	NDVI for residential green space in 100m, 300m and 500m buffers Distance to nearest major green space.	Ethnicity Mother's educational status Subjective poverty (self report) Index of multiple deprivation Mother's age Mother's smoking behaviour Child's age Mother's cohabitation status Household size Mother's mental health	More green space was associated with fewer total behavioural difficulties and greater prosocial behaviour but only in south Asian children. No such associations were found for white British children.	McEachan et al, 2018
1551	4-5 year-olds	DECA	Park access (proportion of homes within ½ mile of a park) Proportion of impervious surfaces (manmade materials that water cannot pass through e.g. concrete) Tree canopy around the home and school.	Home covariates: median income, violent crime rate, population density No school or individual covariates were reported.	Students with high levels of tree canopy at home or school showed greater development in emotional and behavioural regulation skills. Students at schools with lower levels of impervious surfaces developed better social skills.	(Scott et al., 2018)

172	6.7-12.2 years old	SDQ	Land cover data used to calculate the landscape in a 100m-5km radius around children's home Distance to the nearest major road Traffic density	Age Sex SES	Hyperactivity problem scores were lower in more agricultural areas and higher in areas with more residential traffic density.	(van Aart et al., 2018)
2650	4-6 year-olds	SDQ	% of natural space and parks within 500m of the child's home – calculated using Scotland's greenspace map. Private garden access	Child's sex, age and hours of screen time per day. Household highest educational attainment, annual income, carer's mental health, neighbourhood level disadvantage.	Private garden access was most strongly related to SDQ scores but this depended on household education level. Neighbourhood green space was related to more prosocial behaviour. There was no evidence that neighbourhood natural space or garden access influenced the trajectory of change in SDQ scores between ages four and six, suggesting that any	Richardson et al, 2017

					benefits occur before the age of four.	
1287	9-18 years	Parent reported child behaviour checklist	Residential green space measured by NDVI (amount of greenspace within 1000m of home)	Age Gender Ethnicity Household SES Perceived neighborhood quality Neighborhood noise Maternal risk factors – smoking during pregnancy and maternal depression Temperature	Exposure to green space was associated with reduced aggressive behaviours.	Younan et al, 2016
1468	4-6 year-olds	SDQ	NDVI – residential greenness Distance to the nearest city park	Child's age and gender Mother's level of education and employment status Parenting stress	There was a significant relationship between proximity to city parks and children's peer problems and hyperactivity, only in the lower maternal education group.	Balseviciene et al, 2014

					Proximity to parks and residential greenness were significantly related to prosocial behaviour. Residential greenness did not significantly impact peer problems. Proximity to parks and residential greenness did not significantly impact emotional problems	
6384	Measures taken at ages 3, 5 and 7	SDQ	Neighbourhood green space measured using the Generalised land use database to calculate % of green space (excluding domestic gardens) within the LSOA. LSOA =Lower layer super output areas. - These are used as 'neighbourhoods' they are built from groups of census outputs and have on average 1500 residents.	Family socio-economic disadvantage (a summary of 4 indicators: overcrowding, not owning the home, in receipt of means tested income support, below the poverty line) Life adversity (self report measure)	Access to parks, playgrounds and gardens related to lower incidences of conduct, peer and hyperactivity problems. Poorer children aged 3-5 who lived in greener areas had fewer emotional problems than their counterparts in less green neighbourhoods.	Flouri et al, 2014

				Neighbourhood disadvantage Child covariates: age, sex and ethnicity		
2111	7-10 year-olds	SDQ and DSM-IV	Residential surrounding greenness - Average NDVI in buffers of 100m, 250m and 500m around the child's home address. Proximity to green space - defined as living within 300m of a major green space (0.05km2 or larger) Time spent playing in green spaces – parent report of the average times per week and hours per week their child spent playing in green spaces across four different time periods	Child's sex School level Ethnicity Pre-term birth Breastfeeding Exposure to tobacco smoke Maternal smoking during pregnancy Responding person Parental education Parental employment status Parental marital status Neighbourhood SES	Statistically significant inverse associations between green space playing time and SDQ total difficulties, emotional symptoms and peer relationship problems. Statistically significant inverse associations between residential surrounding greenness and SDQ total difficulties. Inconclusive results for proximity to major green spaces.	Amoly et al, 2014

2.6.5 Nature intervention studies

A study of 250 kindergarten students (Taylor & Butts-Wilmsmeyer, 2020) compared children's self-regulation before and after a nature intervention lasting one semester. One group of children had a limited amount of outdoor lessons in their green schoolyard, whilst the comparison group had a greater amount of outdoor lessons. Girls in the intervention which offered greater outdoor access improved their self-regulation significantly more than girls in the lower access intervention. However, the same effect was not observed in boys. A dose-response relationship was also identified whereby the more total time girls spent outdoors, the greater their self-regulation improvements (as measured by the child behaviour report scale).

Environmental effects on behaviour were also observed in a non-randomised controlled trial (n=437) which examined the effects of greening a school playground (replacing asphalt areas with grass, trees, mulch and plant borders). This study found that physical and verbal conflict rates initially increased post-greening but then reduced 4 months after the greening took place, ending up lower than a control group (Raney et al., 2019). This may have occurred as a result in changes to play behaviour after greening; researchers observed that activity levels increased immediately after greening took place and that standardised playground equipment was used less, as more children chose to engage in creative free play and non-sport activities such as tag and climbing. Children also spent more time playing in small groups after greening took place which may have increased prosocial behaviours. The study suggests that children may initially need time to adapt and learn how to navigate new play areas with peers but that longer term exposure may benefit prosocial behaviour.

Another study (Kuo, Browning, & Penner, 2018), previously summarised in the review of attention literature in section 2.5.5, reported improved classroom engagement after children returned from outdoor lessons. The greatest effect was seen in the number of teacher redirects, which was significantly lower during lessons following outdoor learning. As well as being a measure of attention, redirects could also be considered a measure of self-regulation as children are managing to keep themselves on task and resist distractions.

Similar effects were reported in an experimental crossover design study of 18 children, aged 5-6 years old (Largo-Wight et al., 2018). Children were taught their daily writing lesson in either their usual classroom, or in an outdoor classroom. Researchers observed the daily lesson and collected data on 33 days. There was a significant reduction in teacher redirections of behaviour in the outdoor classroom, suggesting that children may have been better able to self-regulate behaviour in the outdoor environment. The researchers noted that the effects of the outdoor environment also seemed to become increasingly beneficial over time. Throughout the 6-week study, teacher redirections decreased more quickly over time in the outdoor condition than they did in the indoor classroom.

A small longitudinal study (n=13) in Denmark (E. Mygind, 2009) used student questionnaires to examine the impact of moving traditional lessons into the forest every Thursday for a three-year period. Children used Likert scales to report their thoughts and experiences learning in both the indoor classroom and the forest environment. Questionnaires were completed eight times throughout the three-year period and included 10 statements specifically about social relations with their peers. Children experienced the forest environment as a less noisy place to be and there was a slight trend towards more quarrelling in the classroom compared to outdoors, however this relationship did not meet statistical significance.

Effects on prosocial behaviour were observed in a preliminary investigation (n=80) comparing a four-hour nature experience with a trip to an indoor museum (Dopko et al., 2019). Tangram and Windfall tasks were used to measure children's prosocial tendencies and showed that children were more likely to act prosocially following the nature trip. However, the order of the trips was not counterbalanced, and observations suggest that the children had difficulty in understanding the task instructions. Activities and pedagogical approaches were also not consistent across the two conditions making it impossible to disentangle the specific impact of nature.

A quasi-experimental study of two classes in a Taiwanese high school (Han, 2009) evidenced positive effects after placing six plants at the back of one classroom, whilst the other classroom acted as a control group. Measures were taken throughout a 1.5 month baseline period and a 2.5 month intervention period. The experimental group had fewer incidence of misbehaviour and stronger feelings of friendliness, as measured by punishment records and self-report questionnaires which were administered approximately every 14 days.

One study of pre-schoolers (aged 2-5) looked at the effect of introducing more nature-based play to uninspiring outdoor areas at children's centres by using natural elements such as sand, water, boulders and plants as sources of play. These were introduced into existing outdoor play areas and children's play and behaviour was tracked and observed over several months using coded video observations, behavioural mapping, questionnaires and accelerometers. The intervention reported that two weeks after the introduction of natural play materials (measures were taken after this time to eliminate novelty effects), children displayed improved prosocial play and independent play, problem-solving, focus and self-regulation and reduced stress, boredom and injury (Brussoni et al., 2017). However, the study did not incorporate an indoor control.

In an experiment on views of nature and self discipline in inner-city children (Taylor et al., 2002), 169 children aged 7-12 years were randomly assigned to live in one of 12 high rise buildings on the same estate in Chicago, which were architecturally identical but differed in their levels of nearby nature. Parents were asked to rate the naturalness of the view from home and these ratings were used to predict performance on tests of concentration, impulse inhibition and delay of gratification. For girls, performance in all three tests of self discipline were positively related to views of nature, accounting for 20% of variance in their combined scores. For boys however, there were no significant relationships between nature and performance in concentration, impulse inhibition or delay of gratification. The researchers suggested this could be because boys spend less time in and around the home, and tend to play further afield, thus would be less affected by nature close to home. This conclusion is based on previous studies which mapped children's play and found that boys play further from home than girls.

Laboratory studies

An experimental study (Jenkin et al., 2018) with 8-11 year-olds (n=79) gave children a delay of gratification task before and after they watched a three minute video of either an urban or natural environment, or a control display. Measures of mood and selective attention were also taken to investigate possible mechanisms behind self-regulation effects. The study found that delay of gratification scores were significantly better after exposure to a natural environment compared to an urban environment. However, this was thought to be due to the depleting effect of the urban environment rather than any restorative properties in the nature condition, as there were no significant differences in self-regulation effects between the nature and control conditions, and pre and post video regulation scores in the nature condition were not significantly different.

Other studies have used photographs of urban and nature scenes, inhibition tasks and physiological measures (Heart rate variability and pulse transit time) to explore relationships between exposure to nature and self-regulation in adults (Beute & de Kort, 2014). Viewing nature scenes led to quicker reaction times on the task when compared to urban scenes and heart rate data suggested that the nature condition was associated with lower stress levels and less exertion of self-regulation. Similarly, a series of experiments (Zelenski et al., 2015) showed that watching nature videos led to more prosocial and cooperative behaviour in subsequent scenario-based tasks, when compared to watching videos of built environments. Interestingly, this effect did not depend on the nature videos being 'pleasant' – the relationship between nature exposure and more positive behaviour outcomes still held true even when the nature videos were of floods and wolves hunting. Together these studies suggest that indirect nature exposure might have an impact on both physiological and behavioural self-regulation. However, these studies were conducted with adults and no comparable research has yet been conducted with children.

2.6.5 Individual differences

Gender effects are unclear. Whilst some studies report greater effects of nature on girls' behaviour (Faber-Taylor & Butts-Wilmsmeyer, 2020; Faber-Taylor et al., 2002; Richardson et al., 2017;), others have found that green space has a larger effect on boys (Markevych et al., 2014).

A longitudinal study found that the greenspace measures used (postcode green spaces vs access to a private garden) might mediate gender effects. In this study, prosocial behaviours in girls were positively associated with postcode green space but this was not the case for boys. Whereas conduct problems were lower in boys who had access to a private garden but this relationship was not found for girls (Richardson et al., 2017).

There was a similarly mixed pattern regarding whether children from high or low education households were more affected by greenspace. The measures of greenspace used seem to further differentiate effects. Private garden access was associated with fewer conduct, hyperactivity and inattention problems in lower, but not higher education families whereas postcode green space associated positively with prosocial behaviours in highly educated families but not those from low education households (Richardson et al., 2017). Shorter distances from home to urban green spaces were also associated with increased prosocial behaviour and decreased conduct problems for preschoolers whose mothers had lower levels of education, but did not affect the behaviour of children with highly educated mothers, whereas residential vegetation showed the opposite pattern of effects (Balseviciene et al., 2014).It is unclear why children from lower and higher education homes may benefit from different types of greenspace and as patterns are inconsistent, more research is required to draw conclusions.

Urbanicity may also modify the relationship between nature and behaviour. A recent review reported that associations between green space and problem behaviour were more frequently reported in samples of children living in urban areas (Mygind et al., 2021). In some studies, a higher percentage of residential greenness has been associated with fewer behavioural problems in urban but not rural children (Bijnens et al., 2020; Lee et al., 2019)

Some research also suggests age effects. In one study, younger children's behaviour benefitted most from having access to a private garden and living a shorter distance from a local green space, whereas for older children, associations were found more consistently when using average measures of green space in the local area and the quality of green spaces. This suggests that older children are affected by nature across a wider geographical area, likely because they are more able to access those spaces independently (Vanaken & Danckaerts., 2018).

Another suggested that early childhood may be a particularly sensitive period for greenness exposure, finding that more greenspace during early childhood associated with fewer behavioural difficulties in mid-childhood, whereas greenspace exposure in later periods did not (Jimenez, Aris, et al., 2021). One study (Madzia et al., 2019) found that increased neighbourhood greenspace within 200m of the home was linked to decreased conduct problems in seven year-olds. However, when data was collected from the same children at age 12, more green space was associated with decreased risk of depression, anxiety and somatization related problems but not conduct problems. This suggests that nature may affect different behavioural outcomes depending on the child's age.

Less is known about whether nature disproportionately affects the behaviour of children with existing behaviour issues or children from particular ethnicities. Fewer studies have incorporated these variables into their analyses. One study (McEachan et al., 2018) found associations between residential green space and children's behavioural difficulties and prosocial behaviour, observed only in children of South Asian origin and not for White British children. This research also found that South Asian children faced 'a triple count of inequity' in relation to their residential green space; they spent less time playing outside than their White British peers, had less green residential areas and their parents rated lower satisfaction with their local green spaces compared to white British families in the study. However, no evidence was found for racial differences in associations between residential green space and children's total SDQ scores. Overall, more research is required to establish mediating and moderating factors.

2.6.7 Theories and frameworks for understanding nature's effect on behaviour

There are several mechanisms through which nature exposure may affect children's behaviour, these may operate via emotional, cognitive or physical pathways and are likely to overlap. These pathways have previously been described in Chapter 1.2 of this thesis. However, there are some theories relating specifically to behaviour which are explored here.

Nature may impact behaviour via physiological routes such as heart rate modulation. Heart rate variability (a measure of how much heart rate varies from minute to minute) is an indicator of autonomic nervous system functioning with low frequency heart rate variability suggesting that the sympathetic system is activated whilst high frequency heart rate variability indicates that the parasympathetic system is activated and an individual is more calm and regulated. The vagus is the primary part of the parasympathetic nervous system, connecting the brainstem to several organs and regulating the heart as well as muscles in the face and head which are related to our social engagement system. According to polyvagal theory (Porges & Furman, 2011), when individual's autonomic balance is shifted towards parasympathetic activity, there is increased synchronisation and harmony in physiological systems which leads to increased emotional stability, but when children display low frequency heart rate variability, they are in a state of stress and defence which prevents them from being able to act pro-socially and regulate emotions effectively (Porges, 2011).

Studies, albeit with adults, have shown that viewing a natural environment such as a forest can affect heart rate variability and increase parasympathetic functioning (Tsunetsugu et al., 2013). Therefore, ANS functioning might mediate the relationship between natural environments and an individual's ability to engage in more self regulated and prosocial behaviour.

Nature may also affect behaviour via emotional pathways. The Biophilia Hypothesis, described fully in section 1.2.3, suggests that being in natural environments is satisfying and pleasurable, and because of this, these environments promote a sense of connection (Weinstein et al., 2015). According to self-determination theory (Ryan & Deci, 2000) a sense of connection with other people and the world around oneself is a universal, psychological need. Thus, some researchers have suggested that time in nature promotes feelings of connection to the environment, and this in turn can extend to a sense of connection with other people (Weinstein et al., 2015).

Neighbourhood greenspaces such as shared parks might encourage more social ties and community networks which have a positive effect on behaviour. This relationship is supported by research showing that crime is lower in greener areas due to increased community cohesion (Weinstein et al., 2015) and that social exclusion impairs adult's self-regulation (Baumeister et al., 2005) whilst social support enables it (Zelenski et al., 2015).

In pulling apart these competing explanations, it is important to look at the predictions they would make and how they differ. The Biophilia Hypothesis, which rests on the assumption that humans have an innate affinity with the natural world, would predict that outdoor spaces would only support self-regulation of behaviour if they contained natural features such as plants and trees. Whereas if social ties and community are the mechanism behind the nature-effect, this effect could hold true in any indoor or urban space where social interaction is facilitated. Unfortunately, there is not enough research which looks at these factors as a dose-response relationship. For example, by measuring levels of social interaction in a controlled comparison of various environments with differing levels of nature. Therefore, these hypotheses have not been thoroughly tested.

Qualitative research suggests that self-regulation occurs in places where children feel secure, private and in control – and that natural environments afford children more opportunities to be alone, escape from social demands, clear their minds and regain perspective (Korpela et al, 2002). Waite et al (2013) assert that outdoor spaces offer more opportunity for children to be self-directed, because classroom-activities tend to be more 'adult directed' and 'outcome-dominated'. When children are outside, they are more likely to initiate their own experiences and play without adult interruption – and are therefore, more likely to engage in playful interactions which are important for social and emotional development (Samborski, 2010). Although one study looked at children's level of autonomy when learning outdoors, and found that compared to a control group, children learning outside in nature had greater perceived autonomy and choicefulness (Detweiler et al, 2023), as yet, no other research has scientifically tested this idea, and the impact on prosocial and antisocial behaviour has not been explored.

Affect has also been linked to self-regulation. Stress is thought to negatively affect self -regulation whilst being in a better mood is thought to improve children's capacity to delay gratification (Leith & Baumeister, 1996). Therefore, if natural environments promote better moods, as suggested by Stress Reduction Theory and the Biophilia Hypothesis, self-regulation capacities would be enhanced.

One study conducted with high school students used images of environments with varying degrees of naturalness and urbanicity as primes before presentations of facial expressions. It found that as natural elements in the images increased, the speed at which happy faces were recognised increased, and the recognition of disgusted faces slowed down (Hietanen et al., 2006). This study suggests that perceptions of the physical environment might interact with perceptions of social stimuli - if natural and urban environments trigger automatic affective responses, these may affect the way in which children perceive and interact with others.

An alternative theory is that nature could influence cognition, which in turn affects behaviour. Directed attention is considered a key resource in self-regulation as it involves inhibiting distractions. Therefore, Attention Restoration Theory (ART) which was explored fully in section 1.2.2, might also apply to studies on behaviour, as restored attentional capacity would enhance an individual's ability to self-regulate behaviour (Kaplan & Berman, 2010). Evidence that executive functioning and self-regulation share a common resource comes from studies which demonstrate that heavy demands in either domain reduce performance in the other. For example, in one study, after participants resisted eating cookies and ate radishes instead, they were less persistent and effective at solving puzzles than a control group who had not had to exert self-regulation (Baumeister at al., 1998). Such studies, in which executive functioning and self-regulation tasks interact, assert that self-control is a limited resource which is subject to depletion through a process called ego-depletion (Baumeister, 1998). However, ego-depletion studies tend to focus on self-regulation as the ability to inhibit behaviours and resist temptations, rather than conceptualising self-regulation more broadly and including other types of emotional and behavioural self-control.

Different theories have developed regarding ego depletion: one analogises that that self-regulation is like a muscle which can become fatigued, but exercising that muscle helps to strengthen it. Another theory suggests that self-regulation is not a limited resource, but instead that individuals are less motivated to exert self-control after it has already been exerted in a previous task. According this theory people *do* have the capacity to exert self-control following depletion, but they choose not to (Beute & de Kort, 2014). Therefore, self-regulation capacities may decline and be restored in a similar way to directed attention (Taylor et al., 2002) and is posited that natural environments may support this restoration (Beute & de Kort, 2014). However, it remains unclear whether being self-regulated in one instance, harms or bolsters self-regulation in a subsequent situation.

Closer examination of these pathways suggests that they are likely to interrelate and overlap. Whilst this thesis has been organised into three separate literature reviews, examining nature's impact on stress, attention and behaviour, in reality these domains cannot be considered in isolation from one another as they interlink and influence one another in multiple ways. This makes understanding the mechanisms behind the nature-effect particularly challenging.

2.6.8 Limitations of existing evidence on behaviour

One limitation of existing evidence is the prevalence of subjective measures. Most studies utilise parent reports such as the SDQ to measure children's behaviour rather than direct observations of behaviours or professional judgements from teachers or clinicians. It is unclear whether parent's judgements are accurate and unbiased. Their assessments also tend to reflect the child's behaviour in the home and not in other social settings such as school, where their behaviour may not be seen by the parent. Combining both teacher and parent scores could address this limitation but this is not common practice.. Alternatively, more objective measures such as computerised tests could be used to quantify aspects of behavioural self-regulation such as inhibition.

However, where more objective measures of self-regulation, such as standardised cognitive tasks, are used in place of questionnaire-based scales, it is difficult to ascertain whether it is self-regulation specifically which is being examined and to what degree this is inter-related with other cognitive functions such as executive control, memory and attention. Some of these tasks also have low ecological validity and their findings may not be transferable to a real-life scenario.

A further limitation of studies utilising the SDQ is that the five sub-scales (emotional symptoms, peer problems, hyperactivity and inattention, conduct problems and prosocial behaviour) covered by the questionnaire are not always reported separately in studies' results (Vanaken & Danckaerts, 2018). Thus, even where a correlation is found between green space exposure and overall difficulties, it is not always possible to unpick exactly which aspects of behaviour are affected.

Previous studies have also differed substantially in their design, participant sample and measures. For example, some studies use parent or self-report questionnaires to assess children's exposure to nature rather than measuring it directly. This matters because the method for measuring nature exposure has been found to significantly moderate effects; in a meta-analysis of the effects of nature on children's self-regulation, stronger associations were found when parent reports were used as opposed to a less subjective measure such as a vegetation index (Weeland et al., 2019). This suggests that more rigorous experimental designs using validated measures to quantify green space exposure would be helpful in yielding more conclusive results. However, even where measures such as satellite imagery and NDVI are used, results appear to vary depending on the type of greenspace measured. Stronger associations with SDQ scores have been reported from studies measuring residential distance to the nearest public green space and garden access than studies measuring the percentage of greenspace in the local are (Vanaken & Danckaerts, 2018).

In addition, there are many potential covariates involved in relationships between nature access and self-regulated behaviour which need to be carefully controlled for. For example, a study exploring links between residential greenspace and adolescent aggression (Younan et al., 2016) found that Caucasians, higher SES families and children born to non-smoking mothers and mothers with fewer baseline depressive symptoms were all more likely to live in greener areas.

Complicating the matter even further, the direction in which these confounds affect observed associations is not even universal cross culturally. For example, in some cities or countries, such as Kaunas in Lithiania, children from lower SES families are *more* likely to live closer to green spaces, whereas in other locations, such as Scotland, lower SES children are *less* likely to have greenspace access

(Vanaken & Danckaerts, 2018). Although studies control for some demographic characteristics, not all studies control for wider variables such as family history of behaviour problems which could be a significant confound. Measures of SES also tend to be taken at the household level (parental education, income and employment status) rather than also looking at neighbourhood SES (Zare Sakhvidi et al., 2022).

Finally, prosocial and antisocial behaviours are often used as indicators of self-regulation, but these terms can be problematic to define and may differ cross culturally. In some neurodivergent children it may be difficult to distinguish antisocial behaviours from purposeful ways of self regulating. For example, in a neurotypical child, ignoring a peer or putting their hands over their ears whilst being spoken to, may be considered antisocial, however in a child with Autism this may be a way of self regulating by reducing over stimulation. Thus, what looks like poor self-regulation for one child may represent good self-regulation for another. This makes using standardised measures of behaviour problematic as they do not account for contextual factors and individual differences.

2.6.9 Summary

Collectively, accessibility studies suggest that higher levels of residential greenspace, as well as access to nearby nature such as parks and gardens are associated with improved behavioural outcomes, however these effects may differ between children according to their age, gender and socioeconomic status as well as whether they reside in urban or rural area.

Quasi-experimental studies provide some evidence that nature exposure may improve children’s behaviour but there have not been enough studies consistent in measures and methodology to draw conclusions. Experimental laboratory studies using photographs or video footage of nature offer opportunities to evidence causation more robustly but these are rare and not commonly conducted with children.

Several questions remain unanswered such as: how much exposure to nature is required to yield effects on behaviour? For how long do these effects last? And which measures most accurately reflect behavioural changes? The exact pathways through which nature affects children's behaviour are also, as yet, unknown. Existing research suggests a wide range of potential mechanisms.

Chapter 3

School based research

3.1 Study introduction, aims and objectives

3.1.1 Educational research

Over the past decade, great strides have been taken in making the education sector more research-informed. Correlational data suggests that using research as part of training is related to higher teacher and school performance, and that evidence- informed practice can lead to improvements in pedagogy and confidence (Brown, 2016). Thus, teachers are increasingly expected to engage with research evidence to inform their practice. In the UK this has been championed by organisations such as The Education Endowment Foundation (EEF) and The Chartered College of Teaching (CCT) and is discussed in more detail in Chapter 7.

However, there are many challenges involved in bridging the gap between research and teaching practice. Teachers can be resistant to engage with research (Brown, 2016) and feel that it doesn't reflect their experiences and knowledge (Hedges, 2010). A common issue is that much of the research that teachers are expected to base their practice on was not conducted in settings which reflect their teaching context. Some of the cognitive load research, for example, which was incorporated into Ofsted's new inspection framework (TES, 2019), was conducted on undergraduate participants and involved laboratory tasks related to material which does not reflect the curriculum taught in schools. The extent to which this should be used to inform pedagogy for young children is arguable.

Teachers can find themselves faced with using research evidence which doesn't reflect the age or demographic of the children they teach, the setting they work within, or the material they teach. What works in a research study often simply cannot be replicated within the existing structures, policies and routines of the school setting.

An EEF review of cognitive science approaches in the classroom (Perry et al, 2021) found that although these approaches had recently been incorporated into the Early Career Framework (a government-produced set of entitlements for early career teachers to learn about during their professional development), and were utilised by a majority of teachers, evidence for their application in everyday classrooms was limited. Even research which is conducted within a school classroom as opposed to a laboratory or university, often doesn't reflect the reality of everyday teaching due to factors such as:

- Activities being delivered by a researcher instead of the teacher
- Activities being scripted and therefore not mirroring a lesson's usual content
- Approaches focussing on a very particular learning objective over a very short period of time
- Measuring outcomes which are very close/specific to the intervention
- Only looking at a very small group of pupils in one particular school, which may not be representative of all pupils
- Participating teachers having a vested interest in the area of study (Summarised from Perry et al, 2021)

Although written about cognitive science, these issues can apply to any area of educational research. The present study aimed to address these limitations and its methodology was designed with them in mind. For research to be as useful and applicable as possible for teachers, it needs to reflect everyday teaching as closely as possible. As mentioned in earlier sections of this report, the methodological standards of outdoor learning studies are frequently rated as poor. In a review of over 7800 studies, only 13 were rated as reasonable (Becker et al., 2017).This makes such research findings problematic to inform teaching practice.

The book 'High Quality Outdoor learning' (Jucker & von Au, 2022) details the key methodological issues with the majority of existing research on outdoor learning which are summarised and listed below in Table 10

Table 10

Key methodological issues in existing outdoor learning research

Key methodological issues in existing outdoor learning research
Duration of interventions is short
Low number of participants
Studies reflect 'special' teaching situations rather than 'everyday' teaching
Not randomised
Not reproducible (a lack of methodological detail is reported)
Circular design, prone to researcher bias (They validate initial hypotheses with subjective self reports by the participants)
Lack of objective measuring tools
Conclusions often not linked to the data

Note. Summarised from *High Quality Outdoor learning* (2022)

Although there has been an increase in quasi-experimental and experimental studies in recent years, this research rarely reaches educators working in schools. The Early Career Framework details 43 pages of information about teaching and learning that all educators should learn and there is no mention of outdoor learning, or the impact of the learning environment more generally.

Lack of access to high-quality research on learning environments leaves teachers with a paucity of reliable evidence on which to base their decisions about whether to engage in outdoor learning, and how best to implement this. Approaches such as 'Forest School' have rapidly gained popularity. Established in the UK in the 1990s, by 2017, over 10,000 forest schools were operating in the region (Waite & Goodenough, 2018). Yet for such a prolific educational approach, empirical research is lacking. It remains unclear which aspects of forest school are beneficial, whether effects can be evidenced robustly, and whether this approach is more or less impactful than other types of outdoor learning (Goldenberg, 2022).

The empirical research which forms the remainder of this thesis aimed to address this gap in the research base and the methodological issues listed above. Each of the issues listed in Table 10, which were addressed through the research design are detailed below:

Duration of interventions is short

The study conducted for this thesis took part across eight indoor and eight outdoor sessions.

Low number of participants

Seven different classes of children were recruited for this study, comprising a total of 76 participants.

Studies reflect 'special' teaching situations rather than 'everyday' teaching

The study was planned so that data collection sessions were as naturalistic as possible, limiting the extent to which the research interfered with the usual routines, structure and content of learning sessions so that 'everyday' teaching was well represented. For this reason, all sessions were led by the children's usual class teacher, conducted on the school site and using the school's own resources. All activities were those that would usually take place according to the school's planned curriculum.

Not reproducible (a lack of methodological detail is reported)

All equipment and measures have been described in detail allowing for easy reproduction.

Circular design, prone to researcher bias (They validate initial hypotheses with subjective self reports by the participants)

The study was not designed to provide evidence in support of one particular theoretical framework, instead, a range of possible mechanisms through which the nature-effect might occur were considered, and measures and controls were incorporated to explore which aspects of the outdoor environment were impactful. For example, the physical amount of space available to children was matched across indoor and outdoor setting, noise levels were measured and the amount of nature in each outdoor space was quantified.

Lack of objective measuring tools

Central to the study design was the rejection of self-report measures which can be unreliable with young children, due to shortcomings with internal reliability and validity (Cremeens et al, 2006). Instead, more objective tools and processes were employed such as physiological measures, objective measuring equipment such as decibel meters and blinded video coding.

3.1.2 Outdoor learning in urban schools

All of the schools recruited for this study were located in urban areas. Specific school and local area statistics are detailed later on in section 3.2.1. At each school, whatever outdoor space was available on-site was used for the outdoor sessions. This is important because most existing research on outdoor learning utilises forest land or other natural sites which are not available to most urban schools. It is imperative to find out whether outdoor benefits can also occur in more manmade urban environments such as concrete school playgrounds.

Existing research suggests that nature quality and quantity is higher in more socioeconomically advantaged neighbourhoods, and that less advantaged groups are less likely to visit natural sites such as parks (Shanahan et al., 2015). Therefore, for disadvantaged communities, nature access at school may be even more important. However, current research also suggests that urban schools located in wealthier neighbourhoods are likely to be greener and organise more nature-based activities than schools in poorer urban communities (Baro et al., 2021). Thus, children from deprived urban areas may be doubly disadvantaged - experiencing less nature access both within the school day, and outside of school hours.

Whether or not outdoor areas need to be nature-rich in order to provide benefits remains unclear. The use of urban outdoor spaces has been shown to have a positive impact on children's physical (Akpinar, 2007; Peacock et al., 2021; Raney et al., 2019) and mental (Birch et al.2020; Flouri et al., 2014; Markevych et al., 2014) , health as well as their cognitive development and behaviour (Perez-del-Pulgar et al., 2021). However, often these studies do not report how natural or man-made these urban outdoor spaces were. It is possible that utilising any outdoor space in school, even if it isn't natural, could still be beneficial. However, there are several barriers to making better use of outdoor spaces in urban schools, including a lack of pupil and teacher awareness of the existence and benefits of outdoor spaces on-site

(Zhang et al., 2021) and a lack of understanding that even small ‘in-between spaces’ outdoors can be enjoyed by children (Aminpour et al., 2020).

3.1.3 Overview of study aims and objectives

This project was comprised of three studies, each of which used wearable equipment to capture and analyse children’s everyday experiences in both indoor and outdoor environments. The aim was to investigate whether children might learn and behave differently outdoors, and whether this effect is homogenous or varies between individuals. The project also hoped to shed light on the mechanisms behind the nature-effect. For this reason, potential mediators such as noise levels were also measured.

The project looked specifically how an outdoor learning environment affected children in three areas:

1.) Stress

2.) Attention

3.) Behaviour

Thus, this research is broken down into three individual empirical studies, each focussing on one of the aforementioned areas.

The schools and participants recruited for each of the studies were all from the same sample, and the data for each of the three studies were collected from the same data collection sessions. Therefore, the studies share some common methodology. For this reason, this chapter describes the overarching methodology and procedures which pertain to all three studies. Where there are study-specific differences in methodology, these are described in detail in the individual study chapters that follow.

3.2 Methodology

3.2.1 School recruitment and selection

This research was conducted in the Reception classes of four different state-funded urban primary schools in the borough of Newham, East London. Reception is the first year of primary school in England and the final year of the Early Years Foundation Stage (EYFS). It is often considered the 'bridge' between preschool and the more formal learning that begins in Year One. Children join Reception in the September after they turn four years old and therefore children in Reception are aged 4-5 years. Unless there are exceptional circumstances, children attend Reception five days per week for approximately 6.5 hours per day.

4-5 year-old children were chosen as the participant sample for several reasons:

1) There is currently a lack of research evidence regarding whether time outdoors reduces physiological stress and improves attention and prosocial behaviour for this age group
2) If learning outdoors does confer benefits for children, it makes sense to begin this at the start of children's school career so that benefits can be reaped for as long as possible; and
3) For practical reasons, namely:

- Most reception classes in English primary schools have access to a specific outdoor area exclusively for their use which could be utilised during this study.
- The timetable tends to be more flexible for this age group making it logistically easier to collect data during the school day without disrupting planned learning
- The learning activities in reception tend to be more play-based and flexible. With older children, who learn various subjects and have a more prescriptive curriculum, it would have been difficult to match learning activities across indoor and outdoor environments whilst avoiding repetition and practice effects.

All schools were recruited from a wider partnership of 40 schools in Newham called ‘Newham Learning’. Having made contact with the director of Newham Learning, the headteachers from all 40 schools were invited to an online information session about the project. Following this session, eight headteachers expressed an interest in their schools taking part in the research.

Further online meetings were offered to early years staff from all eight of these schools, whereby further details of the project were given and discussions took place around whether the schools were able to commit to the requirements of the project. Two schools withdrew at this stage, leaving six remaining potential participant schools. Time constraints allowed only four of the schools to be included in the project. The four schools were chosen based on their capacity to host the project, namely:

-Did they have an outdoor area that could be utilised for the project?

-Were the reception teachers willing to take part?

- Were staff in the right position to take part in a research project? (Some schools had newly qualified teachers or those new to teaching in EYFS, who felt it would be too much to take on board during that particular term).

The headteachers of each school, and the teachers from each class, gave their written consent to take part in the project.

Before commencing piloting and data collection at each school, a minimum of two visits to the school took place:

Visit 1

Meet Early years leader, clarify details and requirements of the project

Gather information about the class timetable and how the data collection could fit around existing routines

Observe indoor and outdoor environments, discuss how the outdoor classroom could be resourced and furnished

Visit 2

Meet the class teacher and children

Clarify plans and details for the project

Read a ‘social story’ about the research project to the children

Show children the equipment and demonstrate it using a soft toy

Distribute information and consent letters for children to take home

Participating schools

Newham is one of the most diverse local authorities in the UK. Over 72% of residents are from an ethnic minority, with no single ethnic group predominating. The borough also has high levels of poverty, the highest rate of households in temporarily accommodation in London and low levels of access to public greenspaces (Newham.gov).

Although geographically located within the same London borough, the four participating schools varied in size and their student population differed with regards to their SEND status, ethnicity, socio-economic status and attainment. Demographic information for each participating school is summarised in Table 11 below.

Table 11

Participating School Characteristics

School	Pupils on roll	Pupils with SEN support (%)	Pupils with EAL (%)	Pupils eligible for FSM-6 (%)
1	1002	14	93	24
2	380	21	50	28
3	632	13	57	30
4	636	10	56	28
Combined	2650	12.48	69.37	25.53

SEN = Special Educational Needs, EAL = English as Additional Language, FSM-6 = eligibility for Free School Meals currently or in the past six years

Each of the schools also differed in terms of their indoor and outdoor learning environments. Whilst some schools had access to natural areas for outdoor learning, others had only tarmacked or concrete areas outdoors. In each case, to avoid the amount of space available being a confounding variable, the outdoor area was demarcated to replicate the same size as the indoor classroom. The indoor and outdoor environments for each school are displayed in the Table 12 below. The procedure for rating each school's nature-level is described in section 3.2.4.

Table 12

Participating schools and their learning environments

School	Indoor classroom	Outdoor classroom	Level of nature outdoors	Data collection period
1			Low	February 2022-April 2022 (1 participating class)
2			Medium	April 2022 – July 2022 (2 participating classes)
3			High	October 2022-March 2023 (3 participating classes)
4			Low	April 2023- July 2023 (1 participating class)

3.2.2 Participant recruitment

After schools had been recruited, researchers visited the reception classes in participating schools to meet the children and tell them about the project. Children were shown the project equipment and read a ‘social story’ about what the project involved (Appendix 1). Following their visit from the researchers, all children from participating classes were given a parent information and consent letter to take home (Appendix 2). Parents were invited to an information session where they could ask questions and find out more about the project.

Student participants

From across the four schools, 76 participants aged 4-5 took part in this study. In order to explore potential covariates, schools were asked to provide demographic information for each participant and complete a Strengths and Difficulties Questionnaire for each child. Further information is provided in section 3.2.4

Table 13 below summarises the demographic details of the participant sample.

Table 13

Demographic breakdown of participating sample

School	1	2	3	4	Average
N	**8**	**17**	**38**	**13**	**19**(11.40)
Class groups recruited	1	2	3	1	**1.75**
Sessions Recorded	98	165	317	177	**189.25** (79.70)
Female (%)	87.5	70.6	42.1	46.2	**53.2** (18.50)
Age (years)	4.99(0.35)	5.02(0.22)	4.90(0.38)	5.33(0.35)	**4.97**(0.36)

SEN (%)	12.5	11.8	2.6	0	**6.7**(5.51)
EAL (%)	100	35.3	60.5	46.2	**60.5**(24.5)
FSM-6 (%)	25	17.6	10.5	7.7	**15.2**(6.71)
SDQ	7.9(7.1)	4.5(3.4)	8.3(5.1)	6(6.3)	**6.2**(5.2)

N/M(SD)/%. *N* = 76. Sessions Recorded = number of observable testing sessions run in each school. SEN = Special Educational Needs, EAL = English as Additional Language, FSM-6 = eligibility for Free School Meals currently or in the past six years (measure of socioecomonic status), SDQ = Strengths and Difficulties Questionnaire total score

Estimating the required sample size for this study was challenging given the large number of different analyses proposed. At the time of preregistering the study, it was known that each of the different analyses detailed in Chapters 4, 5 and 6 would have different effect sizes and thus will require differently powered samples.

No existing papers in this field had implemented the same measures in a comparable way. Nevertheless, to give a rough estimate, Amicome et al's 2018 study was used for comparison. This study reported an effect size of 0.4-0.68 for the effect of nature on performance in attention and memory tasks (Amicome et al., 2018). The statistical tests used in this study included repeated measures ANCOVA and t-tests. Based on this effect size, and a required significance level of 0.05, it was estimated using an online calculator (https://powerandsamplesize.com/Calculators/) that a sample size of 75 would give a 0.99 chance of replicating an effect of the same magnitude. Sample sizes in the aforementioned study ranged from 71-75 across hypotheses reporting significant relationships between nature and attention, memory and perceived restorativeness.

3.2.3 Data collection procedures

Data was collected simultaneously for each of the three studies described in the following chapters. This data was used to examine the impact of relocating everyday learning activities to urban outdoor spaces on children's school site.

Wearable equipment such as head mounted cameras, microphones and ECG monitors were used to gather objective data detailing children's experiences of indoor and outdoor learning environments and the impact on their stress, attention and behaviour.

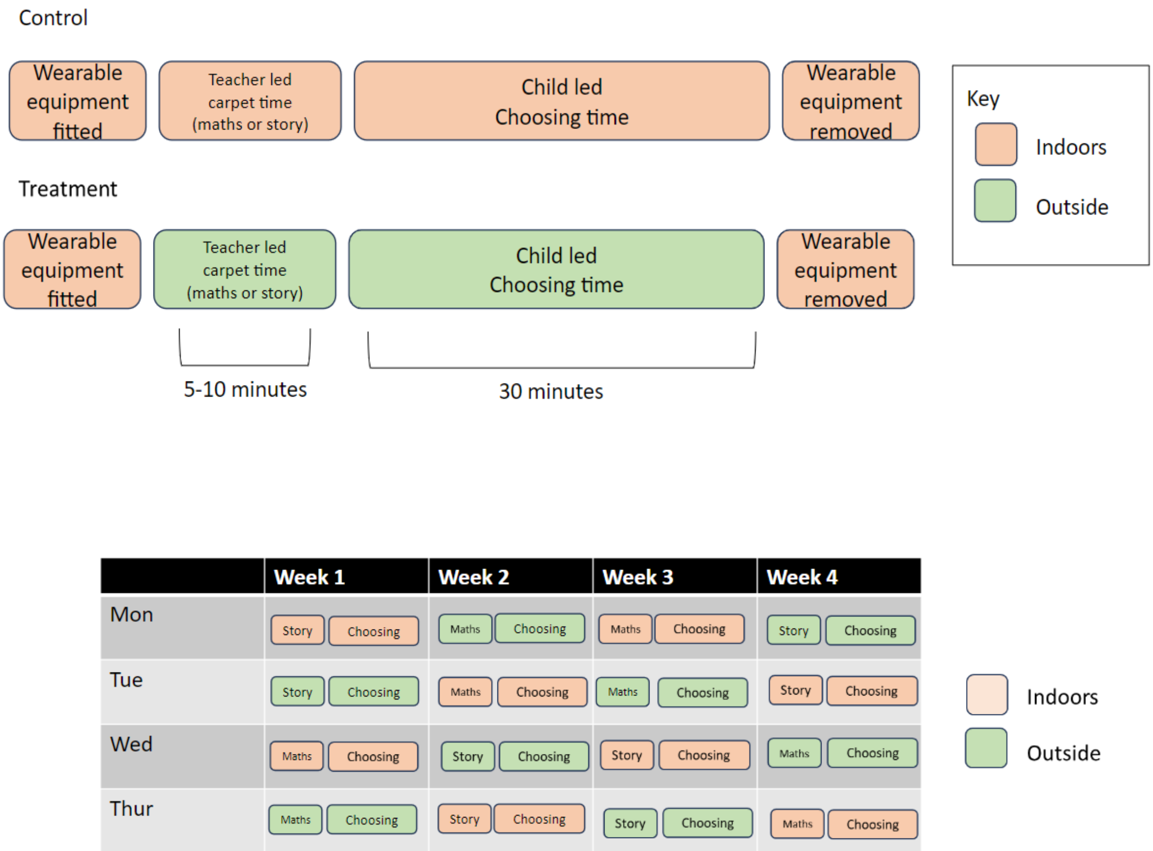
Data was collected from different class groups, taking a total of two school years. Therefore data collection took place during each season of the school year which runs from September to July. In each participating class of children, data took place over a period lasting approximately four weeks. The time period spent at each school can be seen in the final column of Table 12.

Approximately 40 minutes of data was collected each day, for four days per week. (16 x 40minute sessions in total). Of these data collection sessions, half took place outside and half took place indoors in the children's usual classroom.

All sessions consisted of a five to ten minute 'carpet time' session led by the class' usual teacher. This was followed by a 30 minute 'choosing time'. These components of the session are described in more detail below. The schematics below in Figure 3 demonstrate how data collection sessions were structured at an individual session level, and organised across a four-week data collection period.

Figure 3

Data collection schematics



These timescales were chosen because existing research suggests that stress reducing benefits of urban nature are greatest after being outdoors for 20-30 minutes (Hunter et al., 2019). It was also felt that spending a 40 minute period outdoors daily was more achievable for schools than a longer session, both for the duration of the project, and thereafter if they chose to maintain their outdoor practice in the long term.

Wherever possible, allowing for the weather, sessions alternated between indoors and outside rather than completing a two-week block inside followed by a two- week block outdoors. This was to take into account that children may vary from one two- week block to another in terms of how settled they are (at the start of a new school year), their overall development and due to other extraneous factors such as feeling generally unwell, or going through a phase of being upset, stressed or distracted. Having a mixture of both indoor and outdoor sessions each week aimed to reduce the effect of some of these time sensitive variables.

The structure of data collection sessions: 'Carpet time' and 'Choosing time'

Carpet time

'Carpet time' refers to teacher directed, whole class time where all of the children are seated on the ground in front of the teacher, who leads the learning activity. 'Carpet time' was common practice in all of the school settings and was thus part of the everyday teaching routine and not implemented specifically for this study.

In the present study, carpet time consisted of either a story time, where the teacher read a story selected by the researcher, or a maths session. Sessions were counterbalanced so that each class of children experienced four indoor and four outdoor maths sessions and four outdoor and four indoor stories during carpet time.

Measures were taken during the first ten minutes of carpet time.

Choosing time

'Choosing time' sessions are periods of time when the children can choose what to engage with, and move freely between a selection of resources and activities set up by the teaching staff. Commonly, these include a wide range of table top and floor based activities covering several areas of learning, for example; maths and literacy activities, role play, construction and creative arts. Table 15 below details the full list of activity types which were on offer during choosing time throughout this study. These activities were categorised and noted so that activities and resources could be matched across indoor and outdoor sessions.

In order to avoid repetition effects, the exact content of the activity did not need to be matched across sessions, as long as the activity was within the same category and of equal difficulty and appeal. For example, if during the indoor session one of the activities was to cut out butterfly shapes, the outdoor session activity could be cutting out snail shapes. Activities were planned and matched in collaboration with the class teacher.

Table 15

List of Choosing time activities

Choosing time activities
Reading without an adult
Literacy activity (phonics, writing)
Maths activity
Drawing/painting
Sticking/junk modelling
Small world play
Messy/sensory play including water and sand
Fine motor (cutting/tweezers/threading)
Music/instruments
Puzzles
Card or board games
Vehicle play
Soft toys
Play doh/plasticine
Role play
Construction
Teacher assessment

The specific activities and resources offered to the children were not standardised across different schools so that the research project did not interfere with teachers' planned curriculum or approach, or require schools to purchase specific resources.

Although choosing time commonly lasted for between one and two hours in the participating schools, due to storage capacity and battery life on the head mounted cameras, data for the present study was only collected during 30 minute periods of choosing time.

Outdoor classroom

In order to compare children's experiences in indoor and outdoor learning environments, an outdoor classroom had to be created. This was achieved by choosing an outdoor area on the school premises, where disturbance would not be created for, or by, other groups of children in the school. This area was measured and marked so that it was the same approximate size in square footage as the indoor classroom.

Wherever possible, furniture and resources were moved from the indoor classroom to the outdoor classroom in order to maintain consistency across the two environments. All outdoor classrooms replicated the same key areas as the indoor classroom e.g. role play area, reading corner, construction area, table top activities etc. This was achieved by mapping these areas for each school.

Children were given an introductory session in the outdoor classroom to remove novelty effects and allow them to assimilate to the outdoor environment. The introductory sessions also allowed children to get used to the rules and expectations of the outdoor classroom. It was explained that although they were outside, it was not a playground, and therefore the same rules applied as if they were indoors, for example they were not allowed to run, scream or climb in the outdoor classroom. These rules were implemented to reduce extraneous variables between the two conditions.

Piloting

Prior to beginning data collection, a two-week piloting period was conducted to test the devices and familiarise the children with them, and to test that the measures being used were appropriate and practically possible. During these piloting sessions, several issues were identified and troubleshooted, these are detailed in Appendix 3.

Thereafter, each time the study was conducted with a new group of children, a period of familiarisation with the equipment was completed again before data collection began. This time was used to:

- Let children try out wearing the equipment for short periods of time
- Identify any challenges or obstacles with particular children wearing the equipment e.g. sensory issues, SEND
- Finalise a stable participant list of children who were comfortable to wear the equipment daily
- Observe the everyday routines and structures in the class
- Allow the children and teacher to become familiar with the researchers
- Introduce the children to the outdoor classroom

If a child refused to wear their equipment on three or more consecutive occasions during the piloting phase, they were removed from the study. In some cases, piloting identified children who were happy to wear the head mounted cameras but not the ECG monitor. In such cases, children remained in the project but were excluded from the stress study and any analyses requiring heart rate data.

Daily procedure

The daily procedure for data collection was as follows:

1) Researcher sets up the outdoor classroom if it is an outdoor session that day
2) Researcher makes a note of all activities and areas on offer to the children that day to enable counterbalancing in subsequent sessions
3) Researcher completes the daily log (Appendix 4) to make a note of the weather and temperature that day, and any other events which may affect results e.g. if the class teacher was absent
4) Wearable devices are switched on and left outdoors to connect to GPS
5) Wearable devices are inserted into belts ready for fitting
6) Children arrive in school and give verbal consent to take part for that day
7) Children are fitted with the wearable devices
8) Teacher takes the register and begins the carpet session. Researcher takes dB readings and counts teacher redirects throughout the carpet session

9) After the carpet session, children engage in 30 minutes of choosing time. Researcher takes dB readings throughout the choosing time session and conducts the literacy task if a story has been read at carpet time.
10) Equipment is removed from the children
11) Any resources and furniture brought outside are returned to the classroom
12) Data collection session concludes
13) Devices are returned to the laboratory for uploading data and charging

3.2.4 Apparatus and materials

Wearable devices

Each participant wore a specially designed device made by Harkwood industries consisting of: a heart rate (electrocardiogram) monitor with three Ag-Cl electrodes attached in a modified lead II position; a microphone which attached to the child's lapel; and an actigraph. This was contained within a rectangular plastic box measuring approximately 7cm x 5cm. The device also had GPS connectivity which allowed recorded data and events to be linked to real time. These devices were worn underneath clothing in an elasticated belt around the child's middle, half-way between the waist and chest (see Figure 1). The belts were made by a seamstress according to a specific design created by the BabyDevLab at the University of East London. The strap was made from thick elastic material with Velcro to fasten and incorporated a cotton pouch with a press stud to close, which the device could slip into and would be held securely in place.

Participants also wore a head mounted video camera, the Babyeyes HD smart camera, which was attached to an elasticated headband using a plastic clip as shown in Figure 1.

For hygiene reasons, each child was assigned their own device, strap and headband to be worn daily and these were washed in between data collection sessions in different schools.

Figure 1

Images of wearable devices

Note. Images of participants wearing the heart rate monitoring device and the Babeyes head mounted camera and frames of raw video footage taken from indoor and outdoor testing sessions.

Measures used across all three studies:

Heart rate data

Heart rate was measured using an ECG monitor, incorporated into the wearable device outlined above. To pre-process the ECG data, the signal was first detrended before performing R peak identification using the in-built MATLAB function ‘findpeaks’. The minimum peak height was defined as a simple amplitude threshold. Minimum peak distance was set at 270ms (corresponding to a maximum heart rate of 130 BPM for children aged 4-5) and used to improve the performance of ‘findpeaks’. Following this, automatic artefact rejection was performed. A maximum temporal threshold was applied to exclude those R peaks occurring within more than 1200ms since the previous R peak (corresponding to a minimum heart rate of 75 BPM for children aged 4-5). Data sets where more than 50% of ECG data was unusable after filtering or incomplete cable connection were not included in analysis.

Noise

Noise levels indoors and outside were monitored using a sound level meter from RS components (model RS PRO RS-95). This is a handheld instrument with a microphone, the diaphragm of which responds to changes in air pressure caused by sound waves. It is recommended for measuring ambient sound levels. The sound level meter was positioned at the middle point of the indoor and outdoor classrooms.

To allow for the fact that sound levels may vary throughout the course of a 10minute carpet time session or a 30-minute choosing time session (carpet time and choosing time are defined in section 3.2.5 below), and that children may become louder towards the end of sessions when they feel more restless and bored, multiple noise readings were taken throughout each session. Nine instant readings were taken at equally spaced intervals during the beginning, middle and end of each carpet time and choosing time session as detailed in table 14 below. These noise readings were collapsed to a single average per session for analyses.

Table 14. *Schedule for noise readings taken during each session*

Carpet time	Beginning	Middle	End
Readings taken at (mins)	03:00, 03:20, 3:40	06:00, 06:20, 6:40	09:00, 09:20, 9:40
Choosing time			
Readings taken at (mins)	03:00, 06:00, 09:00	13:00, 16:00, 19:00	23:00, 26:00, 29:00

Video and audio footage

Head mounted cameras recorded the children's point of view during data collection sessions and also recorded their verbal interactions using an in-built microphone. Video footage was recorded at 30 frames per second and outputted as a series of five minute MKV video clips which were later appended using a Python script into a continuous recording of the session.

On each day of data collection, video files from the Babyeyes cameras were downloaded to a password protected laptop, and uploaded to password protected folders on 'p-cloud', secure encrypted cloud storage. Videos were labelled and saved with participant numbers on p-cloud, before being deleted from the laptop and recording devices. They were later analysed according to the relevant coding protocols for each study, which are described in each of the empirical chapters that follow.

Individual differences Data

Schools were asked to provide the following information about each participant: whether they had a pre-existing preference for being inside or outdoors at school; the child's Special Educational Needs (SEN) status and type; entitlement for Free School Meals currently or in the past six years (FSM-6) (a measure of socio-economic status in the UK which is based on a household receiving any of the following government benefits: income support, income-based Jobseeker's Allowance, income-related Employment or Support Allowance); indication of English as an additional language (EAL); admission date to the school and prior school/childcare experience; age; previous and current level of academic attainment in relation to national expectations. This data was anonymised and stored with the child's participant number.

Strengths and Difficulties Questionnaire

The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) was completed by the participants' usual class teacher. This is a 25-item emotional and behavioural screening tool comprising of five subscales (emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, prosocial behaviour), and designed for use with children aged 3-17.

Nature level rating

A rating scale (Figure 2) was created to quantify the level of nature in each outdoor area. These ratings considered the space occupied by the children during data collection, as well as a 10 meter buffer around this space, from which natural features might be visible to the children.

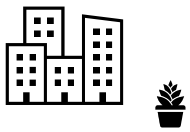
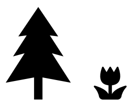
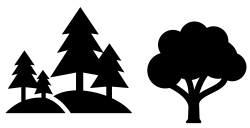
Given that this project was located on school grounds within an urban borough of London, and wild spaces such as forests and meadows were not used within this study, ratings are adjusted with this context in mind. Thus, some areas were rated as having ‘high levels of nature’ even if they were located near to buildings or roads, as long as they met the criteria listed below. This is because these areas do represent ‘high levels of nature’ within an urban context. The level of nature for each school was rated on-site by a researcher and then double coded by someone blinded to the study, using photographs to check for rater-consistency.

Additional resources

The project utilised tarpaulins as well as individual circular mats for sitting outdoors on damp ground. Further materials which are specific to a particular one of the three studies are detailed in subsequent chapters.

Figure 2

Rating scale used to measure levels of nature in outdoor environments

Rating the level of nature in outdoor learning environments	
Low levels of nature 	• Predominantly man-made materials used for ground and borders • 1 or zero trees or large shrubs within the outdoor learning area itself • Limited greenery visible within 10m perimeter outside the learning area (fewer than 3 trees or large shrubs).
Medium levels of nature 	• A mixture of man-made and natural features • At least 2 trees or large shrubs within the outdoor learning area itself. • Greenery visible within 10m perimeter outside the learning area (at least 2 trees or large shrubs)
High levels of nature 	• Natural ground underfoot e.g. lawn/bark/soil • At least 3 trees or large shrubs within the outdoor learning area itself • At least 3 trees or large shrubs visible within 10m perimeter outside the learning area.

3.2.5 Volunteer research assistants

Due to the large volume of data to be collected and analysed as part of this project, it was necessary to recruit volunteer research assistants to help with the following tasks:

- Fitting the wearable equipment during data collection sessions
- Moving furniture and resources to create the outdoor classroom
- Coding video footage

These volunteers were either interns working at the BabyDevLab at the University of East London, or were recruited as volunteers from the MSc Psychology course at the University of East London, with the offer of providing a work experience opportunity. These students were informed about the project by recording a narrated powerpoint which was shared with all students on the course via the MS Teams page.

Volunteers were required to have a Disclosure and barring service (DBS) check and were fully trained by the PhD researcher and added to the study's ethics application. All volunteers were accompanied at all times during data collection.

This project also utilised a Knowledge Exchange Officer, as detailed in Chapter 7 of this thesis, who supported the dissemination of project findings and helped build collaborative relationships between the schools in the Newham Learning Partnership and researchers at UEL.

3.2.6 Ethics

This study met the requirements to gain ethical approval from The University of East London Research Ethics Committee. The ethics application and approval letter are provided in Appendix 5. As part of this ethics application, a data management plan was created, detailing how participant data would be anonymised and protected. This plan is provided in Appendix 6. There were specific ethical considerations when conducting research of this kind in school and these are discussed further in chapter 7.

The headteachers for all participating schools provided a written letter consenting to take part in this research study. In addition, written consent was obtained from all teachers and parents. Children gave their verbal consent on each day of data collection.

Chapter 4

School study 1 – The impact of an outdoor learning environment on children's noise and physiological stress

4.1 Introduction and rationale

Children's mental wellbeing is declining. Over the past three years, the risk of a child aged 5-16 having a mental health problem has increased by 50% (NHS digital, 2022) and children's happiness with their lives is significantly lower now than 10 years ago, largely driven by unhappiness with school (The Children's Society, 2023). In many ways this is unsurprising, the life of a modern child can be very stressful. Today, 29% of children in the UK live in poverty (Child Poverty Action Group, 2023) and are increasingly growing up in cities (Unicef, 2019). Urban living has been strongly associated with higher risk of mental health disorders in adulthood (Engemann et al., 2019; Kovess-Masféty et al., 2005; Peen et al., 2010) and increased physiological stress and stress reactivity in infants (Wass, S., Smith, C., Stubbs, L., Clackson, K., & Mirza, 2019).

During childhood, the brain is particularly sensitive to stress. Chronic exposure to stress during early life can have enduring effects on brain architecture, which may make individuals more likely to experience stress in adulthood (Lupien et al., 2009). It is also thought that at various stages of childhood, whilst specific areas of the brain are developing, exposure to stress may slow the development of those regions, leading to reduced brain volumes (Lupien et al., 2009).

Stress can impair cognitive ability, particularly affecting tasks involving the pre-frontal cortex. Yet structural changes (which can occur to the dendrites in the pre-frontal cortex after just one week of stress) gradually reverse when stress subsides (Arnsten, 2009). This makes the identification and reduction of stress imperative for preventing long term negative effects.

However, there is also evidence which suggests that stress can benefit certain types of learning. Whilst stress has been linked to reduced educational performance, it has also been associated with improved memory, faster brain processing, increased motivation and working harder (Rudland et al., 2020). Therefore it is important not to oversimplify the relationship between environments, stress and learning but to understand which learning environments are more or less stressful for a child and why, and explore the environmental variables which affect stress so that an optimum level of arousal can be achieved to best support learning and behaviour.

Studies on mice have investigated the relationship between levels of arousal (stress) and rates of learning. These suggest an inverted U-shaped relationship whereby as physiological stimulation increases, so does learning - however this is true only until the point whereby the stimulation, or stress, becomes too much, and then learning performance begins to decrease (Rudland et al., 2020). Generalising the results of these studies to human learning is problematic as human learning situations are complex, involving the motivation, mindset and personality of the learner, their existing coping and learning strategies, and contextual and situational factors such as the type of learning taking place. However, they do raise important questions about how stimulating learning environments should be for optimal performance, and whether it's possible that a single indoor classroom can be the ideal environment for all of the children inside it.

Potential sources of stress and discomfort shown to negatively impact children in school environments include excess noise (Klatte et al., 2013; Massonnié et al., 2020), poor lighting (Winterbottom & Wilkins, 2009), lack of windows (Vásquez et al., 2019) and excess visual clutter (Fisher et al., 2014; Godwin et al., 2022). These effects may be particularly acute for the 26% of children estimated to have sensory processing difficulties (Galiana et al., 2022).

As explored in detail in chapter 2.4, Systematic reviews and meta-analyses have evidenced that being outdoors in nature associates with reduced physiological stress in adults and children (Tillmann et al., 2018; Yao et al., 2021; Zhang et al., 2020; Zhao et al., 2022) but economically disadvantaged children tend to have less nature contact (Mears et al., 2019; Natural England 2009) and are more likely to report low wellbeing and to be unhappy at school (The Children's Society, 2023). Children from disadvantaged backgrounds are also thought to be disproportionately affected by swapping 'green time' for 'screen time' (Oswald et al., 2020).

Therefore, providing outdoor time within the school day could be an important way of ensuring equality of access and reducing existing mental health disparities. Yet time spent outdoors at school has decreased, too (Baines & Blatchford, 2019). Currently less than a quarter of children engage in outdoor activities at school that are not physical education (Natural England, 2023).

As yet, the exact reasons why learning in natural outdoor settings affects physiological stress in children remain largely unknown. One likely but under-investigated potential mediator is noise. Environmental noise exposure associates with increased physiological stress in children, (Bremmer et al., 2003; Evans et al., 2001), and negatively impacts cognition and school performance (Connolly et al., 2019; Howard et al., 2010; Hygge, 2003; Klatte et al., 2013; Norlander et al.,2007; Shield & Dockrell, 2003; Woolner & Hall, 2010). Several components of noise have been shown to impact preschoolers' perception of soundscapes (Dellve et al., 2013; McAllister et al., 2019), with levels of 'pleasantness' and 'peacefulness' significantly affecting which soundscapes young children prefer (Ma et al., 2022).

Outdoor environments may be quieter, as without walls and ceilings they have less reverberation than an indoor classroom, allowing noise to dissipate more quickly. Therefore, lower noise levels in outdoor spaces could be the mechanism mediating nature's stress reducing effect. However, existing research (McAllister et al., 2019) suggests that children's opinions differ regarding whether it is noisier indoors or outside at preschool. No existing studies have measured noise levels across matched indoor and outdoor preschool sessions to make this comparison objectively.

The goal in the present study was to address the following research questions. First, how does physiological stress differ between indoor and outdoor learning sessions? Second, how does noise differ during indoor and outdoor learning? Third, to what extent are these two things related? And finally, are particular groups of children – such as children from lower income families and children who speak English as an additional language - more likely to experience these effects than others?

4.2 Hypotheses

This study tested the following predictions:

1) On average, children will have a lower mean resting heart rate outdoors than they do indoors

2) Noise levels will be lower during outdoor sessions

3) The relationship between indoor/outdoor environments and resting heart rate will be mediated by noise levels

4) Reductions in noise and heart rate will be greater in outdoor areas with a higher proportion of nature, compared to more urban outdoor areas with fewer natural features

5) Children will have differential susceptibility to the learning environment – most children will show a decrease in resting heart rate outdoors, but the magnitude of effect will vary across different groups of children

6) Specific groups of children (those eligible for Free School meals (FSM), children with existing behavioural and emotional difficulties (SDQ score) and children who speak English as an additional language (EAL) will be more likely to experience heart rate reductions outdoors

4.3 Methodology

This research was conducted in the Reception year classrooms of four state-funded primary schools in the London Borough of Newham. Details of the schools recruited and the participant sample were outlined previously in sections 3.2.1 and 3.2.2. Details of the equipment and measures used, and the data collection procedures for collecting noise and heart rate data have also been outlined in sections 3.2.3 through to 3.2.5 and therefore are not repeated here.

Sample Characteristics

From across the four schools, a total of 76 participants aged 4-5 were enrolled to take part in this study (as detailed previously in Table 13 in section 3.2.1). In order to be included in analyses examining heart rate, children needed to have completed a minimum of two indoor and two outdoor sessions wearing the ECG monitor. 32 children did not meet this criteria, therefore the sample size for the heart rate analyses in this study was a sub-sample of the participants described in Chapter 3. This subsample consisted of 45 children who completed a total of 350 observational sessions. The characteristics of this sample of 45 children are summarised in Table 16 below

Table 16

Sample characteristics for heart rate analyses

Demographic breakdown of participating sample (n=45)

School	1	2	3	4	Mean
N	**8**	**11**	**16**	**10**	11.25
Sessions Recorded	123				
Female (%)	87.5	72.7	31.3	50	69.38
Age (years)	4.99(0.35)	5.02(0.22)	4.90(0.38)	5.33(0.35)	
SEN (%)	12.5	9.1	6.3	0	
EAL (%)	100	27.3	50	40	
FSM-6 (%)	25	27.3	12.5	10	
SDQ	7.9(7.1)	4.5(3.4)	8.3(5.1)	6(6.3)	

N/M(SD)/%. *N* = 45. SEN = Special Educational Needs, EAL = English as Additional Language, FSM-6 = eligibility for Free School Meals currently or in the past six years, SDQ = Strengths and Difficulties Questionnaire total score

The drop out rate was high (from 76 participants to 45) due to resistance to wearing the ECG monitor which was attached to the skin with stickers which some children found uncomfortable. As the project progressed, drop-out rates improved dramatically due to strategies employed by the research team which put children at ease and made removal of the ECG stickers easier. Further detail of drop-out statistics per school can be found in Appendix 7 and suggested recommendations for using ECG equipment with children are made in chapter 7.

4.4 Results

4.4.1 Overview of analyses

The results presented below are based on 7 areas of analyses.

Analysis 1 examined whether participants' resting heart rates differed between indoor and outdoor conditions by conducting a paired samples t test and a linear mixed effects model (LMM) with a fixed effect of condition and a random effect of participant. Further analyses using a mixed ANOVA examined any effect of class group or school on heart rate, compared to the effect of condition.

Analysis 2 examined differences in *carpet time* noise levels between the indoor and outdoor conditions using a paired samples t test, and mixed ANOVA to examine any effect of class group or school on noise, compared to the effect of condition

Analysis 3 examined differences in *choosing time* noise levels between the indoor and outdoor conditions using the same procedure as Analysis 2.

Analysis 4 examined the relationship between noise levels and resting heart rate during carpet time by running a Spearman's rank-order correlation in each condition.

Analysis 5 examined whether the amount of nature in the outdoor condition affected participant's resting heart rates and noise levels. A one way ANOVA was used to compare children's mean difference between indoor and outdoor resting heart rate, according to the level of nature in their school's outdoor area.

Analysis 6 repeated the same procedure to compare differences in indoor and outdoor noise levels across different nature levels.

Analysis 7 examined whether specific groups of children were more likely to have a lower resting heart rate when outdoors. Binomial logistic regressions were performed to ascertain whether EAL, FSM, SEN, SDQ or Gender significantly predicted whether children experienced lower heart rates outdoors.

4.4.2 The impact of an outdoor environment on mean resting heart rate

A paired samples t-test was used to determine whether there was a statistically significant mean difference between children's resting heart rates in the indoor and outdoor conditions. No extreme outliers were detected and assumptions of normality were not violated within this data set, as evidenced by visual inspection of box plots and Shapiro-Wilk's test (p= >.05).

T test results confirmed that participants' mean resting heartrates were lower during outdoor carpet time sessions (M= 103.0, SD = 7.82) than during indoor ones (M=105.8 ,SD=8.99) as shown in Figure 3 below. This was a statistically significant mean difference 95% CI [1.122, 4.311] $t(44)$= 3.435, p <.001, d = .512.

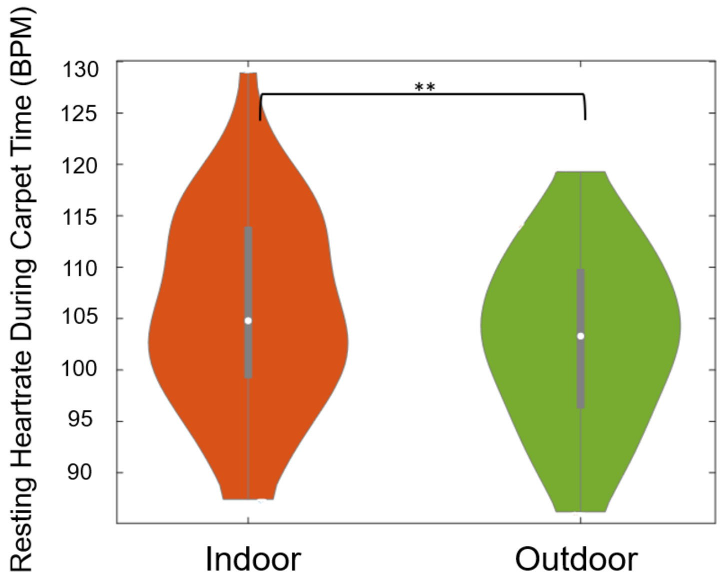
However, using a paired samples t-test to compare indoor and outdoor heart rates was problematic with this dataset as not all participants had an equal amount of heart rate data collected from each condition (i.e. in many cases children had missing data points from one condition, so they did not have paired samples of heart rate data). Removing data points to equalise across conditions, or removing participants who didn't have a full dataset would have reduced the sample size too much, whilst weighting the data would potentially lead to issues with pseudo replication. Therefore, a Linear mixed effects model (LMM) was used to confirm t test results and examine whether the environmental condition had a significant effect on heart rate. A Linear mixed model was appropriate here as the LMM copes well with missing data and dependency between repeated measurements (Magezi, 2015) and it is also possible to specify random effects.

Assumption testing through visual inspection of residual and predicted value plots confirmed homogeneity of variance within each of the following linear mixed effect model (LMM) datasets. Q-Q plots confirmed normality in random effect variables. Linearity was not tested as fixed effects tested in each model fit were categorical (i.e fixed effect of condition or test session number).

The LMM was run through MatLab R2022a using the fitlme function. Resting heart rate was included as the dependent variable and condition as the fixed effect. Participant number was specified as a random effect to account for individual differences between participants. A significant main effect of condition was observed (beta = -1.79 , t= -2.58, *p* = .010).

Figure 3

Indoor and outdoor resting heart rates during carpet time



Note. Violin plot comparing children's heart rate during indoor and outdoor carpet times. Median denoted by white marker.

Further, mixed-ANOVA did not yield significant interactions between condition and school, *F*(3,41) = .830, *p* = .485, 95% CI [-9.874, 14.598], partial η^2 = .057 or condition and class group, *F*(6,38) = 1.008, *p* = .435, 95% CI [-32.008, 16.416], partial η^2 = .137 on resting heart rate. This indicated that during carpet time, condition alone affected resting heart rate significantly, despite the data being collected from various class groups and from different participating schools which were visited across different seasons, and whose indoor and outdoor classrooms varied. These results supported Hypothesis 1, that children would have a lower mean resting heart rate outdoors than they do indoors.

4.4.3 The impact of an outdoor environment on noise

Unlike heart rate data (where individual datapoints were available for each child, in each session) for noise levels only one mean reading was used per session for the whole group. Therefore, paired samples t-tests were used to determine whether there was a statistically significant mean difference between noise levels across each condition during both carpet and choosing times. Prior to conducting these, exploratory analyses were carried out to test assumptions for each statistical test including normality, outliers, sphericity, homogeneity of variance and covariance and linearity in the session level noise data. The assumption for normality was not violated for either carpet time or choosing time noise data, as assessed by Shaprio-Wilk's test (*p* > .05) and inspection of studentized residuals.

Effect of condition on carpet time noise

A paired samples t-test confirmed a significant mean difference between noise levels recorded during indoor carpet times (*M*=62.3, *SD*= 4.7) and outdoor carpet times (*M*=59.5, *SD*=4.2), 95% CI [-4.58, -.707], *t*(36) = -2.770, *p* =.004, *d* =-.455. Carpet time noise levels (when children were seated, listening to the teacher), were 2.8dB quieter outdoors as seen in Figure 4 below.

Again, mixed ANOVA analyses did not yield significant interactions between condition and school, *F*(2,34) = .171, *p* = .844, 95%CI[-6.407, 1.584], partial η^2 =

.010 or condition and class group, $F(5,31) = .200$, $p = .960$, 95% CI [-8.577, 2.516], partial $\eta^2 = .031$. This indicated that during carpet time, outdoor sessions were consistently quieter than indoor sessions, even when participant groups changed and data was collected across different schools.

Effect of condition on choosing time noise

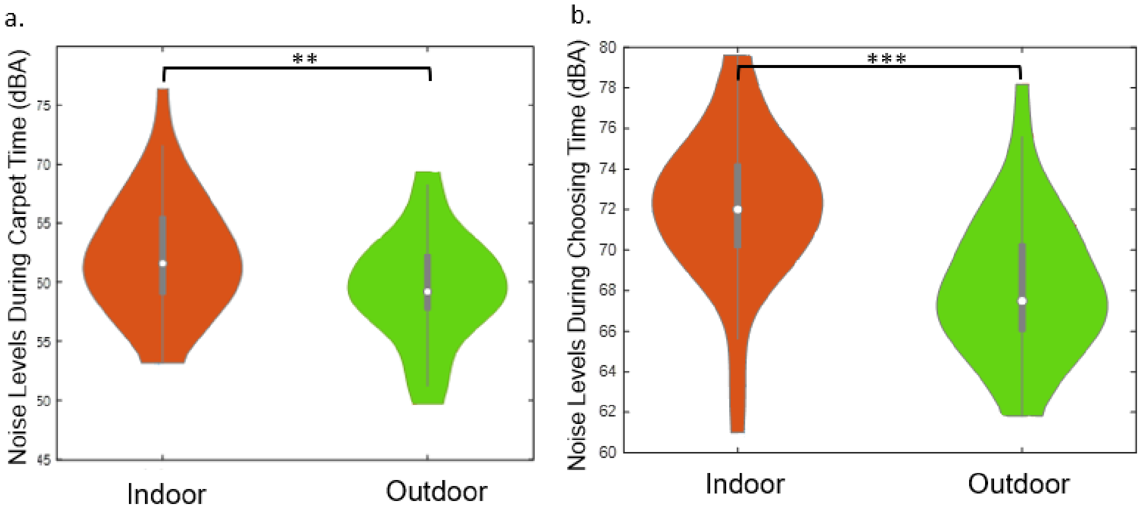
A paired samples t-test also confirmed there was a significant difference between noise levels recorded during indoor choosing times (M=72.0, SD= 3.7) and outdoor choosing times (M=68.2., SD= 3.4). A mean decrease of 3.8dB was observed outdoors, 95%CI [2.2, 5.3] ,$t(39) = 4.818$, $p < .001$, d =1.064. Noise levels indoors and outside are compared in Figure 4 below.

Further analyses using mixed ANOVAs also indicated there were no significant interactions between condition and the class group $F(5, 32) = 1.782$, $p = .145$, 95%CI[-.80789, 6.67873], partial $\eta^2 = .218$, or school, $F(2, 35) = 1.846$, $p = .173$, 95%CI[-1.0917, 3.8947], partial $\eta^2 = .095$ on choosing time noise levels.

These analyses supported Hypothesis 2, that noise levels would be lower during outdoor sessions.

Figure 4

Difference in noise levels during indoor and outdoor carpet time and choosing time



Note.a) violin plot comparing noise levels during indoor and outdoor carpet times. Median denoted by white marker b) violin plot comparing noise levels during indoor and outdoor choosing times. Median denoted by white marker.

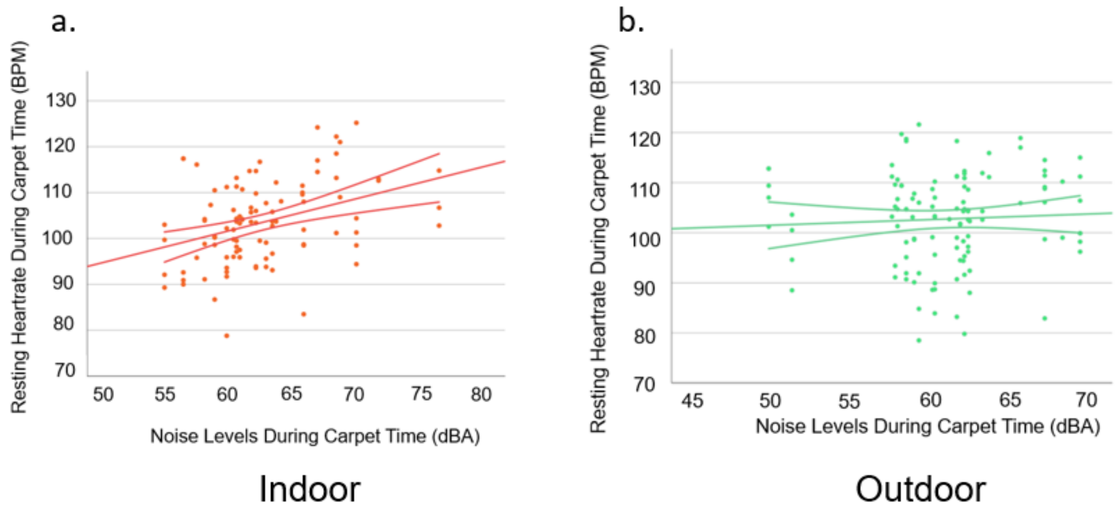
4.4.4 The relationship between noise and resting heart rate

Correlational analyses were conducted to explore the relationship between noise levels and resting heart rate during carpet time in the indoor and outdoor conditions. A non-normal distribution of noise level data paired with heart rate data at a participant level violated the assumptions for a parametric correlation, and so a Spearman's rank-order correlation was conducted. A significant positive correlation was observed between carpet time noise and resting heart rate r_s (210)= .198, *p*= .002.

To explore whether the same relationship between noise and resting heart rate was observed in both the indoor and outdoor conditions, two separate Spearman rank correlations were conducted (see Figure 5). Indoors, there was a significant positive correlation between noise during carpet time and resting heart rate, r_s(98)= .364, *p* < .001. However, outdoors, no significant relationship between noise and resting heart rate, r_s (112)= .048, *p*=.309 was observed.

Figure 5

Relationship between resting heart rate and noise levels during indoor and outdoor carpet time sessions



4.4.5 Effect of nature-level on noise and heart rate

Although all participant schools were in urban, densely populated areas, they each had a different outdoor area, with varying degrees of nature. Some had grass underfoot and several trees and shrubs, whereas others were concrete playgrounds surrounded with buildings on all sides. To quantify these differences, the outdoor areas were rated on a 3-point scale (Low, medium or high nature), as detailed previously in Table 12 and Figure 1 in chapter 3.2.

Having only four schools to compare across three different nature-level groups was not conducive to producing reliable and generalisable data in these analyses and this is discussed further in section 4.5. However, these analyses have been included as they provide an illustration of how nature-level could be explored as a potential mediator in future research.

Effect of nature-level on children's heart rate

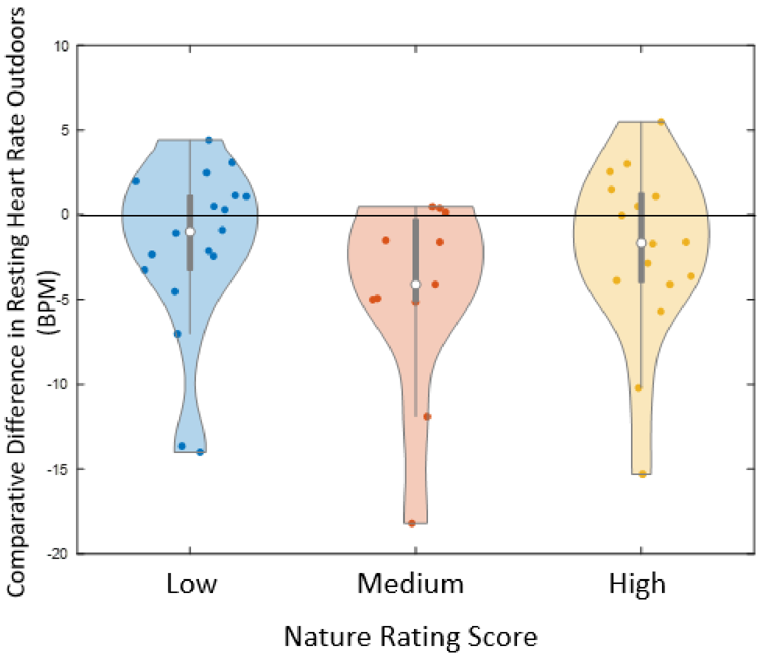
A one-way ANOVA compared children's mean difference between indoor and outdoor resting heart rate, according to the level of nature in their school's outdoor area. Prior to conducting the ANOVA, normality was assessed by visually inspecting histograms of heart rate data and was considered to be approximately normal.

In the school rated as having a 'high-level' of nature in their outdoor area, the mean reduction in children's resting heart rate when outdoors was 2.17bpm. In schools with a 'low-level' of nature outdoors, there was a smaller mean reduction in heart rate of 2.01bpm. However, contrary to Hypothesis 4, the greatest mean reduction in heart rate was observed in the school which was rated as having a 'medium-level' of nature (4.67bpm). However, the ANOVA results indicated that differences in heart rate data between the low/medium/high nature groups were non significant $F(2,42) = 0.986$, $p=.381$.

Figure 6 below compares the effect of the outdoor environment on children's resting heart rate, in each of the different nature conditions (high, medium, low level nature). As can be seen, in both the high and low nature conditions, several children experienced an *increase* in heart rate when outdoors, but in the medium nature condition, almost all children experienced a decrease in heart rate.

Figure 6

Differences in outdoor heart rate, across 3 nature levels



Note Violin plot comparing change in resting heart rate during carpet time (values below 0 indicate a decrease in the outdoor condition) across different levels of nature in the outdoor condition. Each dot represents one child's mean HR change. White dots represent the median.

Effect of nature-level on noise

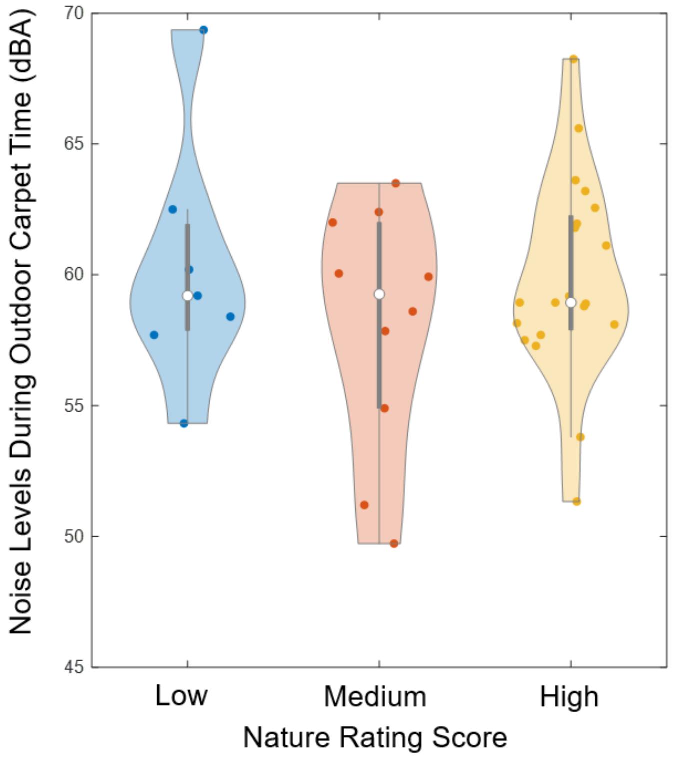
A one way ANOVA was conducted to compare noise levels in the outdoor environment, according to the level of nature in each school's outdoor area.

Carpet time noise

In schools rated as having a 'high-level' of nature in their outdoor area, the mean noise level during outdoor carpet times was 59.8dB. In schools with a 'low-level' of nature outdoors, as predicted, the mean noise level was the loudest at 60.2dB. However, contrary to Hypothesis 4, the quietest mean level of noise was recorded from carpet time sessions in the outdoor area with a 'medium-level' of nature (57.6dB). Figure 7 below shows the comparative noise levels in each outdoor area type. However, ANOVA results indicated that differences in carpet time noise between the low/medium/high nature groups were non-significant $F(2,34) = 1.126$, $p = .336$ as demonstrated by the similar medians in the figure below.

Figure 7

Outdoor carpet time noise across three nature levels

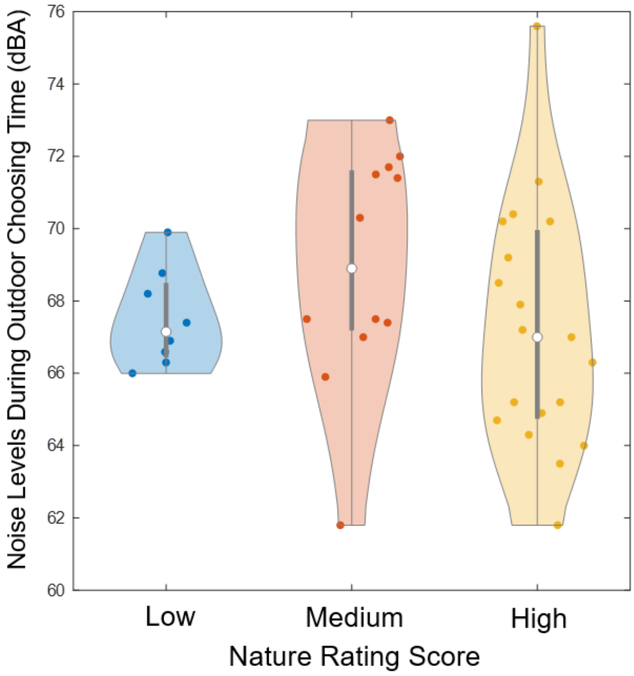


Choosing time noise

The same procedure was repeated to look at outdoor choosing time noise across different nature levels. In schools rated as having a 'high-level' of nature in their outdoor area, as predicted, the mean noise level during outdoor choosing times was the quietest at 67.22B. In schools with a 'low-level' of nature outdoors, the mean noise level was slightly louder at 67.64dB. The loudest mean level of noise was recorded from choosing time sessions in the outdoor area with a 'medium-level' of nature (68.92dB), as demonstrated in Figure 8 below. Once again, ANOVA results indicated that there was not a significant difference in choosing time noise between the low/medium/high nature groups $F(2,35) = 1.117$, $p = .339$

Figure 8

Outdoor choosing time noise across 3 nature levels

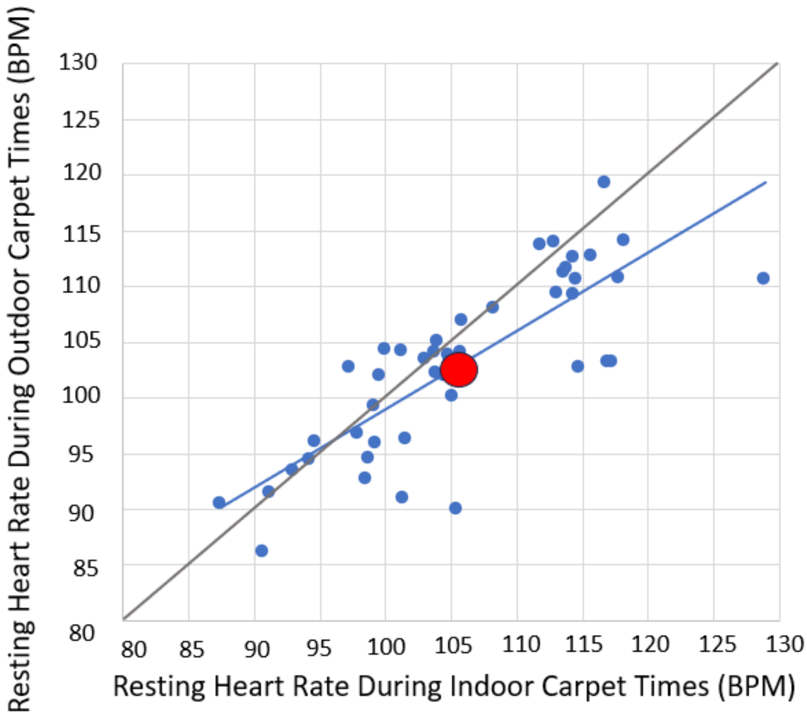


4.4.6 Individual differences

As predicted, the majority of children experienced a lower resting heart rate outdoors compared to inside. However, in line with Hypothesis 5, heterogenous effects were observed. Of the 45 participants, 28 experienced a decrease in resting heart rate when seated outdoors, whereas 17 children experienced an increased resting heart rate in this condition. These heterogenous effects are demonstrated in Figure 9 below.

Figure 9

Differential effects of condition on resting heart rate



Note. Scatter plot comparing each child's average heart rate across the indoor sessions (x axis) with each child's average heart rate across the outdoor sessions (y axis) The 1:1 equivalence is drawn in grey. Data points below this line indicate a child whose average heart rate was lower outdoors than indoors. The red dot shows the group mean heart rate. In addition, a linear best fit line is drawn in blue.

To identify whether specific groups of children were more likely to experience a decrease in heart rate outdoors, a binomial logistic regression was performed to ascertain the effect of: Special Educational Needs; Free School Meals; English as an Additional Language; scores on the Strengths and Difficulties Questionnaire; and Gender. The dependent variable was the condition in which the participant experienced a decrease in average resting heart rate. Linearity of SDQ score, (as the only continuous variable) was assessed via the Box-Tidwell (1962) procedure.

The logistic regression model was statistically significant, $\chi^2(5) = 16.315$, p = .006. and explained 41.4% (Nagelkerke R Square) of the variance in which condition decreases in resting heart rate were observed. It correctly classified 66.7% of cases. Sensitivity was 75.0%, specificity was 52.9%, positive predictive value was 72.4% and negative predictive value was 56.3%. Of the 5 predictor variables, only two were statistically significant: gender and FSM (as shown in Table 17).

Table 17

Logistic Regression Predicting Likelihood of Decrease in Heart Rate in Indoor or Outdoor Condition based on EAL, FSM, SEN, SDQ and Gender

	N	*B*	SE	Wald	*df*	*p*	Odds Ratio	95%CI of Odds Ratio	
								Lower	Upper
a. EAL	23	.239	.773	.096	1	.757	1.271	.279	5.785
b. FSM	8	-3.543	1.378	6.605	1	.010	.029	.002	.431
c. SEN	3	2.937	1.992	2.175	1	.140	18.860	.380	935.053
d. SDQ	-	-.038	.070	.299	1	.584	.963	.839	1.104
e. Gender	25	2.241	.902	6.180	1	.013	9.400	1.607	55.002
Constant		.063	.819	.006	1	.939	1.065		

*Not*e: Gender is for females compared to males

Girls were significantly more likely than boys to present with lower heart rates outdoors, which may relate to the fact that girls' mean indoor heart rates (*M*=106.3, *SD*=9.6) were higher than boys' (*M*=105.2, *SD*=8.5) providing greater capacity for decrease. Girls were 9.4 times more likely to present with lower heart rates outdoors than boys. Contrary to expectations, children eligible for free school meals (FSM) were *less* likely to show lower heart rates outdoors than their non-FSM peers. All other variables (EAL, SDQ and SEN) did not significantly predict in which condition participants would experience a decrease in resting heart rate.

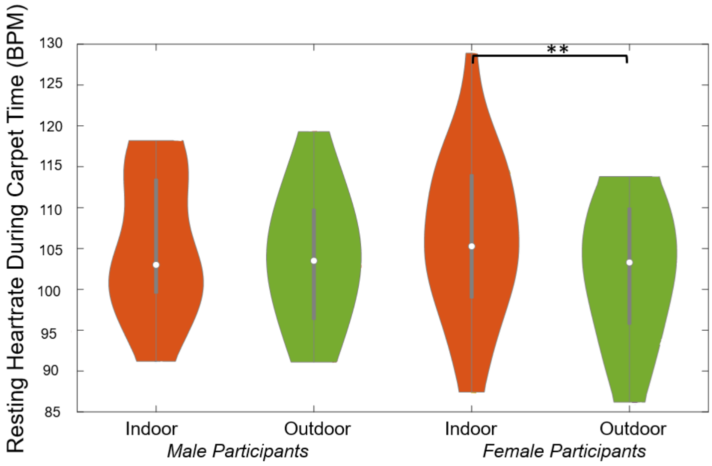
As can be seen in Figure 10a, a paired samples t-test confirmed that there was a significant difference between resting heart rates indoors (*M*=106.3, *SD*=9.6), and outdoors (*M*= 102.4), *SD* = 7.8) for girls 95% CI [1.43695,6.10545], *t*(24) = 3.334, *p* <.001, *d* =.667. However, boys resting heart rates indoors (*M*= 105.2, *SD*= 8.5) and outdoors (*M* = 103.9, *SD* = 8.0) were not significantly different 95% CI[-.77250,3.57150], *t*(19) = 1.349, *p* = .097, *d* =.302.

A paired samples t-test also confirmed that there was a significant difference between resting heart rates indoors (*M*= 107.0, *SD*= 8.8), and outdoors (*M*= 103.6, *SD* = 7.7) for children who were *not* eligible for FSM 95% CI [1.53812, 5.20891], *t*(36) = 3.728, *p* <.001, *d* =.613. However, children who *were* eligible for FSM did not show significant differences in resting heart rates indoors (*M*= 100.1, *SD*=8.0) and outdoors (*M* =100.4, *SD* = 8.3) 95% CI [-2.73802, 2.10052],*t*(7) = -.321 *p* = .381, *d* = -.110. This is demonstrated in Figure 10b.

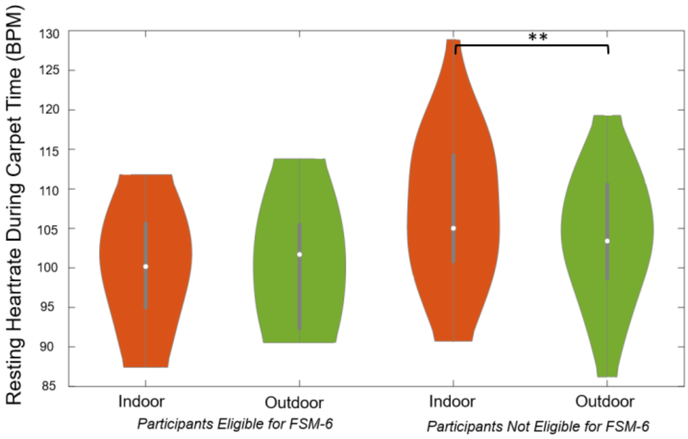
Figure 10

Comparing indoor and outdoor heart rates for male and female participants and children eligible and not eligible for Free school meals

a.



b.



Note. (a) Violin plot comparing resting heart rates of male and female participants during carpet time in the indoor and outdoor condition and (b) violin plot comparing resting heart rates of children eligible for free school meals (FSM) and those not eligible during carpet time in the indoor and outdoor condition.

** denotes a significant difference between conditions.

4.5 Discussion and conclusions

The primary findings of this study were as follows: firstly, when eight indoor and eight outdoor sessions were matched within an urban school setting, noise levels were significantly lower outdoors, both during carpet time and choosing time. Secondly, it was found that during carpet time (when children were seated listening to a teacher reading a story or teaching a maths lesson), resting heart rates were significantly lower outdoors compared with indoors. And thirdly, it was found that whereas noise and heart rate were significantly associated indoors, no significant relationship was observed in outdoor environments, suggesting that being outdoors may have buffered children from the stressful effects of excess noise.

These measures have not been compared across matched indoor and outdoor settings in any other research, therefore it is not possible to compare these findings directly with existing literature. However, increased noise in educational settings has been associated with a range of negative effects on children, particularly influencing language and literacy outcomes (Evans, 2001; Bremmer et al, 2003; Connolly et al., 2019; Howard et al., 2010; Klatte et al., 2013; Shield & Dockrell, 2003; Woolner & Hall, 2010; Wålinder et al., 2007). These results confirm that noise levels are reduced significantly outdoors and thus, spending more time learning outside may have academic and developmental benefits.

Previous studies have evidenced lower physiological stress in children when they are exposed to nature, using cortisol (Dettweiler et al 2017; 2023) or blood pressure (Duncan et al, 2014) as measures. The present results add to this body of research, replicating the finding that nature is associated with lower levels of physiological stress in children but adding to the literature by evidencing this with a different physiological measure and studying a younger age group.

Short-term physiological stress has well-documented short- and medium-term effects on childrens' learning (Whiting et al., 2021), and there are well-evidenced relationships between short-term and long-term physiological stress (Evans et al., 2001, 2005), with associated adverse mental health (Conway et al., 2018) and cognitive outcomes (Evans & Schamberg, 2009). The present finding that lower resting heart rates can be detected during just a five minute period outdoors, suggests that even short periods of time outside can be beneficial and may help reduce stress after particularly noisy or stimulating parts of the school day. However, further research needs to ascertain how long stress reducing effects last for, whether there is a dose-response relationship and whether this effect increases or attenuates as children get older (Whiting et al., 2021).

Existing evidence suggests that children experience environments differently (Aykan et al., 2020) meaning that learning outdoors may have heterogeneous effects. The results of the present study confirmed this partially. Although differential effects on heart rate were observed, identifying specific group differences was more problematic. Within the binomial logistic regression model, two out of five individual differences variables (Gender and Free School Meals) were found to significantly predict children's change in heart rate between indoor and outdoor settings. Girls were more likely to present with lower heart rates outdoors, possibly because on average, girls' mean indoor heart rates were higher than boys', suggesting a greater capacity for a decrease. Contrary to expectations, and to existing literature which suggests that economically disadvantaged children may reap the greatest benefits from nature contact (de la Osa et al, 2024; Fian et al, 2024; Garrett et al, 2023; Mitchell et al, 2015) in this study, the children who were eligible for free school meals (FSM) were *less* likely to show lower heart rates outdoors.

FSM eligibility was used as a proxy for SES in this study (Gorard, 2012; Hobbs et al, 2007) because FSM data was readily available from the schools recruited. However, this was a problematic indicator of SES in this study's location, as in Newham all children are eligible for Free school meals due to a Mayoral policy. Therefore, many low SES families do not complete the paperwork required to identify them as a low-income family. As a result, many low SES children will have been missing from the FSM-eligible sample and the number of qualifying children was low (n=8), therefore, these findings await replication with a larger sample.

The reason why FSM-eligible children were less likely to have decreased heart rates outdoors, compared to their non-FSM counterparts is unclear. However, it should be noted that the FSM sample had lower mean heart rates than their non-

FSM peers (M_{in} = 106.98 , SD_{in}= 8.82, M_{out}= 103.61, SD_{out} = 7.71) both indoors (M_{FSM} = 100.1 BPM, SD = 7.98) and outside (M_{FSM} = 100.4 BPM, SD = 8.33). This is in contradiction to previous literature which has asserted that low income is associated with higher resting heart rates (McGrath, 2006; Boylan et al., 2019).

The other measures that were examined - Special Educational Needs, English as an Additional Language and scores on the Strengths and Difficulties Questionnaire - were not found to be significant predictors of children's change in resting heart rate between indoors and outside. This may be because this experimental design, with a relatively small number of children who each took part in up to 16 sessions, was not well set up to detect individual differences.

Although this sample contained high proportions of students who spoke English as an additional language (51%) and who were eligible for Free School Meals (18%), these numbers were nevertheless slightly below the average levels in the schools where data collection took place (69%/26% respectively), indicating some small sampling bias. Similarly, the proportion of children in the sample with Special Educational Needs (6.7%) was lower than across the schools studied (12.5%). This is likely to be due to the age of the children - this study was conducted during the first year of primary school, whereas most SEND diagnoses do not take place until later in the child's school years. However, children with SEND may also be less likely to consent to being fitted with the wearable equipment due to sensory sensitivities or difficulties in understanding the study aims and instructions.

When analyses were conducted to examine differences in the strength of the effects observed between schools, effects were found to be consistent across schools. No evidence was found suggesting that outdoor settings rated as containing more natural elements associated with significantly greater reductions in physiological stress and noise than less natural outdoor settings. This suggests that even when schools do not have access to natural spaces, it is still worthwhile to use whatever urban outdoor space they have available. However, as this study consisted of only four schools, larger scale studies with multiple schools in each nature category are recommended to perform such comparisons. Nevertheless, the fact that effects were observed consistently even in urban outdoor settings suggests that noise, rather than exposure to nature per-se may be an important mediating pathway. This suggests that there may be an ‘outdoor-effect’ rather than a ‘nature-effect.’

This is the first study to compare children’s physiological stress in outdoor and indoor learning environments, whilst controlling for extraneous variables such as activity type, resources and the size of space available, and examining the potential mediating effect of noise. Strengths of this study include its ecological validity (achieved by utilising the children’s usual classrooms, teachers and outdoor environments and keeping resources and activities consistent with the school’s usual curriculum and timetable), within-subjects design which controlled for child characteristics, repeated sessions in each condition, and its use of objective measures for noise and stress.

With these strengths naturally come limitations. The scale used to quantify the level of nature in each school’s outdoor area was created for this study, therefore its reliability and validity has not been verified. Findings from the nature-level analyses cannot be generalised as there were not enough schools in each ‘nature-level’ group, making it impossible to ascertain whether observed differences were due to nature levels or other between-school differences. Future research should aim to objectively measure and/or control the amount of nature in outdoor conditions and to compare across multiple schools, in order to isolate the effects of different natural features and proportions of nature. This has already begun in research that uses virtual reality (Wang et al., 2019) to assess the stress relieving effects of different types of natural environments. However, this could be replicated more ecologically in school settings, for example by adding different amounts of potted trees or shrubs to urban spaces with no natural features.

In addition, heart rate was used as the sole measure of physiological stress in this study and there was a high level of missing data due to children’s reluctance to wear the heart rate monitoring equipment consistently. Incorporation of other stress measures such as salivary cortisol or skin conductivity alongside a self-report psychological measure would have been preferable.

A further limitation to interpreting the results of this study is that it was not possible to reliably separate sound that was caused by the children in the group from ambient/background noise. Thus, it may be that increased noise levels caused increased physiological stress, or that children first experienced physiological stress, which made them increase the noise they were making. Or, it may be a combination of the two. Of note, however, increased noise and physiological stress were both observed during carpet time, when the teacher was speaking and the pupils were quiet for the majority of the time, indicating that the noise was not entirely self-generated by the children. In future, it would be informative to track changes in physiological stress and noise continuously, in order to examine relationships between these variables over time. Future studies should also take noise readings when the learning environments are not populated by children, to capture levels of traffic noise and other background noise.

Given children's decreasing connection with the outdoors and rises in children's unhappiness with school and mental health problems, spending more time outdoors at school may help alleviate some of the stressful effects of urban living and could support children's learning and mental health. The results from this study should encourage educators to make more use of outdoor environments for curriculum learning, including for short activities such as story time and circle times.

Teacher training programmes should raise awareness of the ways in which the physical learning environment can impact children's learning and wellbeing, drawing attention to the potential of outdoor environments in reducing noise and stress. Moving everyday learning activities outdoors costs nothing, requires minimal additional training and resources and does not create substantial additional workload for teachers. In fact, many teachers have reported increased wellbeing and job satisfaction when spending time teaching outdoors (Deschamps et al., 2022; Marchant et al., 2019; Waite et al., 2016). Thus, it is an avenue worthy of more exploration and attention.

In conclusion, this study has examined the impact of outdoor learning in urban settings and with disadvantaged populations. Its findings suggest that decreases in physiological stress are observed outdoors even in urban outdoor areas, and point to noise as an important pathway that may mediate indoor/outdoor differences. This study was designed to address criticisms of existing outdoor learning research including methodological issues such as subjective measures, a lack of control groups, and reflecting ‘special’ teaching situations rather than ‘everyday teaching’. Previous reviews have recommended conducting more quasi-experimental studies with a strong focus on higher methodological quality (Becker et al, 2017; Jucker & von Au, 2022; Tillman et al., 2018). To build on these attempts, future research should continue using empirical methods and objective, reproducible measures, not only to measure outcomes but also to explore which aspects of outdoor learning environments mediate effects. For example, by replicating the noise measures used in this study and building on this by incorporating additional variables such as children’s movement levels, and the air quality and visual complexity in various indoor and outdoor environments.

Chapter 5

School study 2 – The impact of an outdoor learning environment on children's attention

5.1 Introduction and rationale

Existing research, explored in detail in chapter 2.5 suggests that attentional capacity may be enhanced by exposure to natural, green spaces. Correlational studies using satellite imagery to quantify greenspace around the home or school, as well as brain scans (Dadvand et al., 2018) and attentional tests (Dadvand et al, 2015) or scales (Wells, 2000), suggest positive associations between green space and attention performance.

Spending more time playing outdoors was associated with better memory and attention and lower odds of inattention and hyperactivity in preschoolers (Ulset et al, 2017), whilst for children with ADHD, time outside in nature is reported to associate with milder ADHD symptoms (Faber Taylor & Kuo, 2011) and lead to improvements in attentional performance (Faber Taylor & Kuo, 2009).

Neurotypical children have also demonstrated better long term knowledge retention of material taught outdoors (Fagerstrom & Blom, 2013), better performance in attention tests in their school garden compared to their indoor classroom (Mancuso et al, 2006) and improved spelling and maths scores after plants were placed in their classroom (Daly et al, 2010). Furthermore, children were more on-task and required almost half the number of teacher redirects in an indoor lesson following time spent outside (Kuo et al, 2018) whilst another study showed that 3-5 year-olds boys and children from lower income families were more on-task in class after playing outdoors, especially when play was active (Lundy et al, 2021). There are multiple possible reasons for these effects on attention which were explored previously in sections 1.2 and 2.5.6.

However, several barriers prevent these promising research findings on attention and outdoor time from having an impact on school policy and practice.

Firstly, many of the measures used in such studies are cognitive tests such as the ANT and digit span test. These are not familiar measures to educators and are thus not meaningful in school contexts. There is a lack of research evidencing whether children pay better attention to everyday school activities when outside compared to indoors. The few studies which have looked at curriculum learning are often unable to match activities across conditions due to practice effects.

Additionally, existing research has tended to focus on nature vs urban comparisons, yet many schools are situated in urban contexts without access to natural sites. It remains unclear whether spending time outdoors at school in urban environments can still benefit attentional performance.

Finally, some teachers are resistant to taking classes outdoors due to the belief that children are more likely to misbehave outside (Van Dijkk-Wesselius et al., 2020) and that their teaching practice may suffer without the structure and familiarity of the indoor classroom (Dillon et al., 2006, Waite et al., 2016). Thus, despite evidence that nature contact might support attention, and children reporting that being outside makes them happy (Natural England, 2023), the vast majority of learning activities in school take place indoors (Dillon, 2010).

The present study used a range of attentional measures in a naturalistic school-based quasi-experiment. Footage from wearable cameras and microphones were used to investigate whether moving teaching and learning activities into outdoor spaces at school affects the attentional performance of 4-5 year old children.

5.2 Hypotheses

Based on the existing literature on greenspace and attention, the hypotheses for this study were as follows:

1. The class, as a whole, will be more attentive and therefore require fewer teacher redirects during outdoor carpet time sessions

2. Most children will attend better to a story that takes place in an outdoor learning environment, as evidenced by a greater percentage of looking time at the teacher/story book during carpet time outside compared to indoors.

3. Most children will show better recall and comprehension of a story that has been read to them in an outdoor environment, as evidenced by higher composite literacy task scores.

4. The majority of children will spend a greater percentage of their time on-task at teacher prepared activities when in an outdoor environment for choosing time.

5. Most children will spend longer engaged and involved at a single activity (‘peak focus’) when in an outdoor environment for choosing time.

6. Attention effects will be associated with noise levels, whereby better attention will occur in quieter environments

7. Attention effects will be associated with heart rate, whereby better attention will occur when children’s resting heart rates are lower. This will be demonstrated by a negative correlation between looking time and heart rate during carpet time.

8. Attention effects will vary between individuals, with an outdoor learning environment benefiting some children’s attention more than others.

In addition, the study sought to investigate the following research questions, for which there is very little existing evidence

1. Who will gain the greatest attentional benefits from an outdoor learning environment? For example, are children with existing attentional difficulties and behaviour issues more likely to show improved attention in an outdoor environment? Will other individual characteristics such as SES, ethnicity,

gender and SDQ scores have an impact on how the learning environment affects attention?

2. Will the amount of nature vs manmade features in the outdoor learning environment mediate effects on attention? For example, will greener and more natural environments be associated with greater improvements in attention than more urban outdoor environments?

3. Will children be more likely to engage with certain types of activities in an outdoor environment? For example, might outdoor learning encourage greater involvement with creative activities but make children less likely to engage with more formal learning tasks such as numeracy and literacy-based tasks?

5.3 Methodology

5.3.1 Participants

The recruitment of schools and participants for this study is described in detail in chapter 3. From across four schools, 76 participants aged 4-5 took part and a total of 1216 observational sessions were conducted (up to 8 indoor/8 outdoor per child). The demographic breakdown for this sample is included in Table 13 in Chapter 3. For inclusion in attention measure analyses, children needed to have participated in a minimum of two indoor sessions and two outdoor sessions wearing a head mounted camera. All 76 children met this criteria.

5.3.2 Equipment and Measures

This study utilised the head-mounted cameras described in Chapter 3. In addition to the heart rate and noise measures also aforementioned in Chapter 3, this study utilised six measures of attention:

1. Redirects: The number of teacher redirects during instructional time (carpet time)

2. Looking time: The % of instructional time during which the child was looking at the intended target (*teacher/resources)
3. Composite literacy task score: Children's scores on a literacy task (sequencing, comprehension and retelling of a story that was read to them during carpet time)
4. % Time on task: The percentage of time children spent at teacher-prepared tasks during a 30 minute choosing time session
5. Peak Focus: The longest amount of time children spent focussed at one particular task during a 30 minute choosing time session
6. Activity choice: The amount of time children spent engaged with each activity category in total (literacy, maths, creative, imaginative)

Each of these measures is described in more detail below

1. Teacher redirects

Teacher redirects are defined as times when the teacher has had to tackle off-task or inattentive behaviour from an individual, group or the whole class, either verbally or non-verbally during carpet time. For example, by shaking a tambourine to regain attention when the class is too chatty, by 'sshhhhing', clapping hands for attention, or prompting 'Who is listening nicely?' Teacher redirects have been used previously as a measure of children's attention and engagement in existing research (Kuo et al., 2018).

A coding manual (Appendix 7) was created to explain how to recognise and code teacher redirects which were tallied live during each carpet session. In order to reduce the risk of bias, the teacher was blinded to this measure and 10% of the carpet sessions were double coded by members of the research team.

2. Looking time

Looking time has been used as a measure of directed attention in several existing studies (Noris at al., 2011; Smith et al., 2015; Slone et al., 2018). In this study, looking time was calculated during carpet time sessions whilst the teacher read a story to the whole class. A Python script was written to extract one frame from every 150 frames of the head mounted video camera footage during story time (one frame every 5 seconds). These extracted frames for each child were displayed on screen and a coder clicked each frame in which the child was looking ‘on target’ (cases where the teacher or story book were visible in the frame). This was used to calculate the percentage of time that the child was looking at the target. The coders were student volunteers who were blinded to the study’s aims and hypotheses in order to reduce the risk of bias.

Figure 11

Examples of ‘on-target’ and ‘off target’ video frames

Note. ‘On-target’ frames are indicated by a red ring.

3. Literacy Task

To account for the possibility that some children may be looking in the right direction but not attending to what is being said and shown, or may use gaze aversion as a way of helping with their thinking (Phleps et al., 2006), it was important not to depend exclusively on looking time as a measure of children’s attention to a story. Therefore, a literacy task was devised to elicit children’s comprehension of the story they had been read, and their memory of key events, as an indicator of their directed attention during the carpet session.

The literacy task was comprised of three parts

1. The child was asked to sequence three events from the story using picture cards made from the story illustrations
2. The child was asked three comprehension questions about the story (the format of these questions were matched across all stories in each condition and can be viewed in Appendix 8)
3. The child was asked to re-tell the story in their own words, using the picture cards as prompts

These re-tellings were transcribed and scored in three areas:

1. Mean utterance length
2. Total words spoken during the retelling
3. Clarity and accuracy of the retelling

Clarity and accuracy were scored using assessment criteria (Appendix 9). Children's scores for sequencing, retelling, and comprehension were totalled to give a final composite score for the literacy task.

Children's focus and engagement with activities during choosing time

During the 30 minute choosing time, the head mounted camera footage from each child was used to record which activities participants chose to engage with and how long for. Four videos from each condition were randomly selected for analysis for each participant. A coding manual was created to support with video coding (Appendix 10) and all activity choices and durations were recorded in an excel spreadsheet for analysis (Appendix 11). From this data, the following measures of attention and engagement were calculated:

4. Percentage of time on-task

The percentage of the 30-minute session that the child was 'on task' was calculated. Being 'on-task' was defined as engaging with the activities and resources prepared by the teacher. An average percentage on-task was taken across each individual session in each condition and used to calculate mean percentage on-task values for each participant indoors and outdoors.

5. Peak Focus

The child's 'peak focus' was defined as the longest amount of time that the child remained focussed at a single activity before moving onto something else. Peak focuses coded across each individual session were averaged to give the mean peak focus for each participant, indoors and outdoors.

6. Activity choice

The total amount of time spent at each category of activity during choosing time (Literacy, Maths, Creative and Imaginative activities) was calculated for each session and averaged to create a mean duration of engagement for each of these categories. The type of activities included in each category are listed Table 18 below.

Table 18

Categories of choosing time activity

Category	Types of activities included
Literacy	Independent reading, writing tasks, phonics activities
Maths	Number based tasks/games, shape based tasks/games
Creative	Drawing, painting, sticking, play-doh, construction
Imaginative	Small world play, role-play

Procedure

The data collection procedure and structure of each session have been described previously in Chapter 3. In addition, this study followed the procedure below for the literacy task component of the data collection.

5.3.2 Procedure for literacy task

After the teacher had read the story to the class during carpet time, children were called over to the researcher one by one to complete a literacy task which was based on the story they had heard. This took place during the 30min choosing time session and took 3-4 minutes to administer with each child.

The order in which children were called over to do the task was recorded and counterbalanced. This was to allow for the possibility that being called over to complete the task first may confer an advantage, as the story would have been read recently and be fresh in the child's mind, therefore they may achieve a higher score than if they were called to do the task last.

The children completed the literacy task in the following order

1. Sequence the images from the story
2. Re-tell the story in their own words
3. Answer the comprehension questions

Scores for components 1 and 3 were recorded live in each session by the researcher. Scores for component 2 were given post-data collection after the retellings had been transcribed for analysis and scoring. The following materials were used as part of the literacy task:

Story books

The same group of texts were used for story time in each school. These were carefully chosen to be age appropriate, previously unseen by the children, and to be based on content which was relevant to the EYFS curriculum so that the inclusion of these books within the daily timetable supported, rather than detracted from the curriculum. The books chosen were a selection of eight picture book stories from the 'Our emotions and behaviour' and 'Behaviour Matters' series published by Franklin Watts.

Each story was a school or community-based scenario where a key character was challenged by their own or someone else's feelings or behaviour, for example feeling left out or not wanting to share. These were chosen so that despite being unseen stories, the contexts and language would be familiar to children, thus making them more equally accessible to all participants.

The books were already banded by the publishers according to reading level which facilitated matching stories of equal complexity across conditions. In addition, the researcher read each book aloud and timed its duration. This meant that pairs of books could be matched in terms of difficulty and length, with one book in each matched pair being presented indoors and one outdoors.

Sequencing cards

From each story, three illustrations were photocopied and made into sequencing cards (one from the start, middle and end of each narrative) for children to place in the correct order, demonstrating their recall of the story.

Comprehension questions

In addition, three comprehension questions were created about each story. To maintain consistency in difficulty across texts, the comprehension questions for each story followed the same structure and content:

Question 1 – 'What's happening here?' question, which requires the child to describe/explain a key event using an illustration from the story as a prompt.

Question 2 – 'Why' question, which asks the child to infer why a character is feeling a certain way, using their knowledge of the story.

Question 3 – 'Who' question, which asks the child to identify a character from the story by saying their name or pointing them out in a picture.

The final question, which could be answered just by pointing, was included to allow non-verbal children and those at early stages of English language acquisition to demonstrate their recall and understanding.

Task manual

A script to use when administering the literacy tasks was created along with assessment guidelines (Appendix 12) to ensure consistency in prompting/supporting children when they did not answer a question, and offer guidance in deciding whether to record the children's responses as correct or incorrect. For example, this guidance explained that in order to be awarded a mark, children’s responses may need to include specific key words from the text, or demonstrate knowledge from listening to the story, rather than just giving answers that could be inferred from the illustration alone.

Comprehension questions and marking criteria were created in collaboration with qualified teachers to ensure their consistency and that they were pitched appropriately for the age group. These were piloted beforehand.

5.4 Results

5.4.1 Overview of analyses

The results below are presented based on 5 areas of analysis.

Analysis 1 - First, differences between attention in the indoor and outdoor conditions were explored by conducting paired samples t-tests, Mann Whitney U tests and Linear Mixed Effects models (LMM), depending on the data-type, amount of missing data and whether assumptions were met for parametric tests. Multiple comparisons were corrected for using Fisher’s least significant difference (LSD) procedure to adjust p-values.

Analysis 2 - To identify whether specific groups of children were more likely to show improved attentional capacity when outdoors, binomial logistic regressions were performed to ascertain whether Gender, FSM, EAL, SDQ and having an outdoor preference predicted in which condition children showed improved attention.

Analysis 3 - To determine whether children who already struggled with their attention in typical indoor settings showed greater outdoor improvements than their peers, the sample was split into three groups (low, medium and high baseline attention) based on baseline levels of attention in the indoor classroom. Paired samples t tests and moderation analyses were then used to compared effects across different baseline attention groups.

Analysis 4 – Correlational analyses were performed to explore the relationship between noise levels and attention outcomes, and resting heart rate and attention outcomes in each condition.

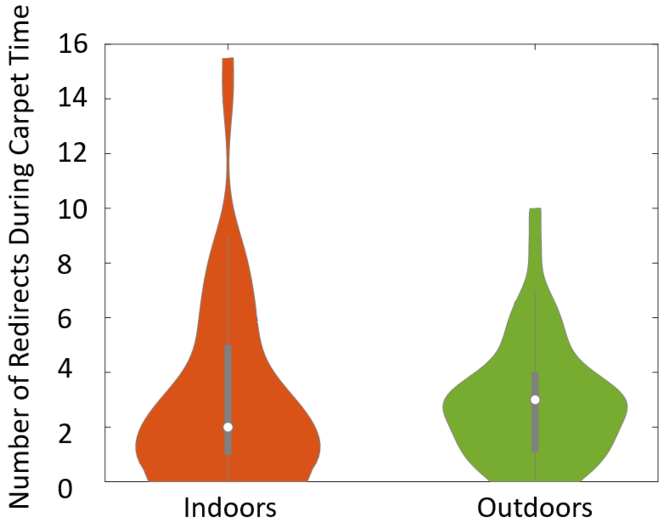
Analysis 5 examined whether the amount of nature in the outdoor condition affected participant's attention. T-tests compared differences between indoor and outdoor attention, across 3 different nature levels. An ANOVA was then used to investigate whether there were significant differences between children's indoor and outdoor attention, according to the level of nature in their school's outdoor area.

5.4.2 The impact of an outdoor environment on the number of 'teacher redirects'

From visual inspection of histograms, the distribution of redirects data was not normally distributed in either condition, however visual inspection of histograms confirmed that the distributions were the same shape in both conditions. Therefore, a Mann-Whitney U test was conducted to determine if there were differences in the number of redirects in each condition. Contrary to Hypothesis 1, results showed that the number of redirects per minute was not significantly different between the indoor condition (mean rank= 46.24) and outdoor condition (mean rank = 58.04), $U = 1120$, $z = -1.652$, $p = .099$. The violin plots in Figure 12 below compare the number of redirects in each indoor and outdoor session. Whilst the median was slightly higher outdoors, some indoor sessions reached up to 15 redirects whereas outdoor sessions did not exceed 10 redirects.

Figure 12

Number of teacher redirects in each condition

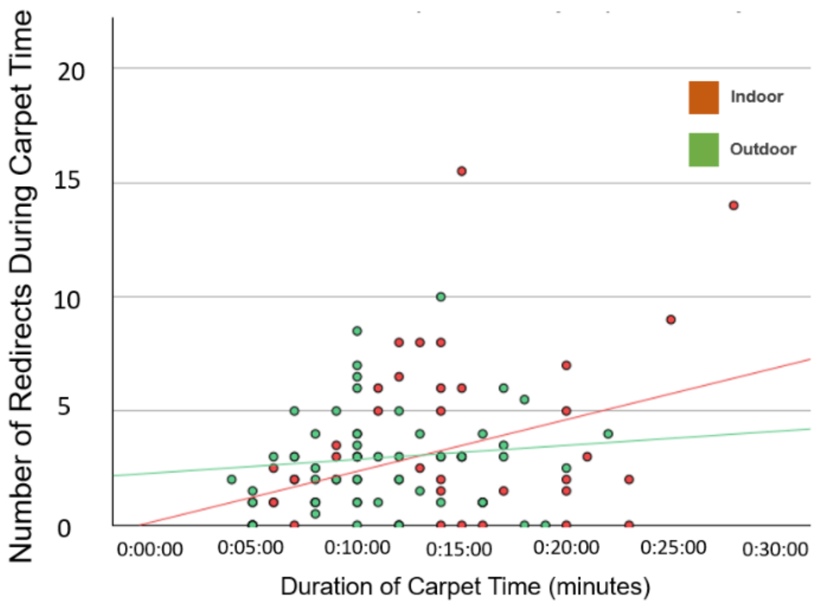


Note. *White dot denotes the median.*

A Spearman's rank correlation was run to explore whether there was a relationship between the duration of carpet time and the number of times the children were redirected by their teacher. As expected, a moderate correlation was observed between the duration of carpet time and number of redirects in the indoor condition $r_s(54) = .260$, $p = .058$, such that the longer the children were seated on the carpet, the more times the teacher had to redirect them. However, a comparatively weaker correlation between carpet time duration and redirects was observed in the outdoor condition $r_s(51) = .144$, $p = .313$, suggesting that children may cope better with maintaining attention levels over longer time periods outdoors. These relationships are displayed in Figure 13 below.

Figure 13

Scatterplot showing correlations between carpet time duration and teacher redirects in each condition



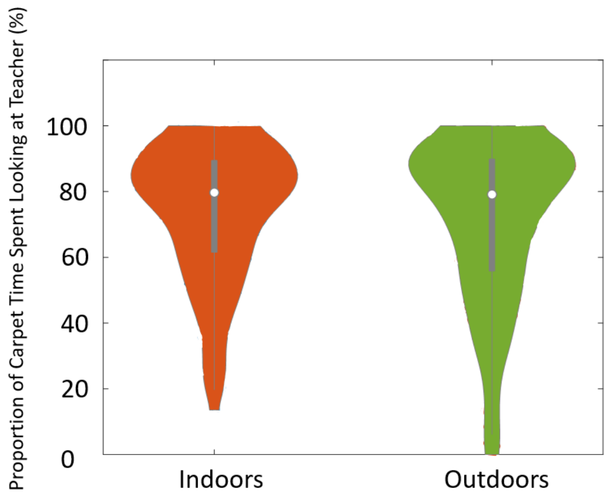
5.4.3 The impact of an outdoor environment on children's directed attention (looking time during a story)

The Linear Mixed Effects Model (LMM) was run through MatLab R2022a using the fitlme function. Looking time was included as the dependent variable and condition as the fixed effect. Participant number was specified as a random effect to account for individual differences between participants. A non-significant main effect of condition was found for looking time (beta = -0.04 , t= -1.47, *p* = .14).

Looking times outdoors (*M* = 71.4%, *SD* = .24) and indoors (*M* = 73.2%, *SD*= .20) were not significantly different (*p* = .540) (see Figure 14). Contrary to Hypothesis 2, on average, children looked 'on-target' slightly more in the indoor condition.

Figure 14

Violin plots comparing looking time during indoor and outdoor story times.



Note: Median denoted by white marker

Individual differences

The majority of children (n=43) showed an increase in looking time indoors. 25 children looked on-target more when they were outside and for two children the condition had no effect on looking time. These heterogenous effects are detailed in Table 19 below and explored further in regard to group differences in section 5.4.8.

Table 19

Descriptive statistics detailing effect of the outdoor/indoor condition on looking time

	N	Min	Max	Range	Mean (SD)
Increase in looking time outdoors (%)	25	1	54	53	16.48(13.85)
Increase in looking time indoors (%)	43	1	39	38	17.00(10.45)

5.4.4 The impact of an outdoor environment on children's comprehension and recall of a story

A series of paired samples t-tests were carried out to compare children's indoor and outdoor performance in the literacy task. Composite literacy task scores (combined score for clarity and accuracy of retellings and comprehension tasks) were compared as well as children's mean utterance length and total words spoken during retellings. No significant differences between these scores were observed across conditions (see Table 20 below) so Hypothesis 3 was not confirmed.

Table 20

Effect of condition on performance in components of the literacy task

Task Component	Indoor		Outdoor		df	t	p	Cohen's d
	M	SD	M	SD				
a.Mean utterance length during retelling	14.9	10.0	15.1	12.2	60	-.230	.409	-.029
b.Mean total words spoken during retelling	27.3	13.7	26.6	14.0	61	.630	.266	.080
c.Clarity and accuracy of retelling	2.2	.63	2.2	.61	65	.594	.277	.073
d.Comprehension task*	7.9	1.2	7.9	1.0	74	.219	.828	.025
e.Composite literacy task score**	10.3	1.3	10.1	1.4	64	1.425	.080	.175

Note: *Comprehension task was comprised of sequencing events and answering questions about the story. ** Composite literacy task score is c+d

Individual differences

Although t-tests confirmed that indoor and outdoor performance on the literacy task was not significantly different (p >.05) when analysing data from the whole group, heterogenous effects were observed on children's literacy task performance, with some children scoring over 30% higher outdoors as demonstrated in Table 21 below. These differences are explored further in section 5.4.8

Table 21

Differential effects of the outdoor/indoor condition on literacy task performance

	N	Min	Max	Range	Mean (SD)
Increase in utterance length outdoors	28	0.2	25.2	25	5.82 (6.65)
Increase in utterance length indoors	33	0.1	14.5	14.4	4.53 (3.58)
Increase in total words outdoors	28	0.3	23.5	23.2	6.78 (5.60)
Increase in total words indoors	34	0.2	21	20.8	6.90 (5.35)
Increase in clarity and accuracy of retelling outdoors (Marked out of 4)	23	0.2	1.5	1.3	0.56 (0.32)
Increase in clarity and accuracy of retelling indoors (Marked out of 4)	32	0.2	1.3	1.2	0.50 (0.28)
Increase in comprehension task outdoors (Marked out of 9)	28	0.1	5.0	4.9	1.04 (0.37)
Increase in comprehension task indoors (Marked out of 9)	38	0.2	3.2	3.0	0.83 (0.63)
Increase in composite literacy task score outdoors (Marked out of 13)	19	0.1	4.5	4.4	1.14 (1.06)

Increase in composite literacy task score indoors (Marked out of 13)	44	0.1	3.7	3.6	0.81 (0.75)

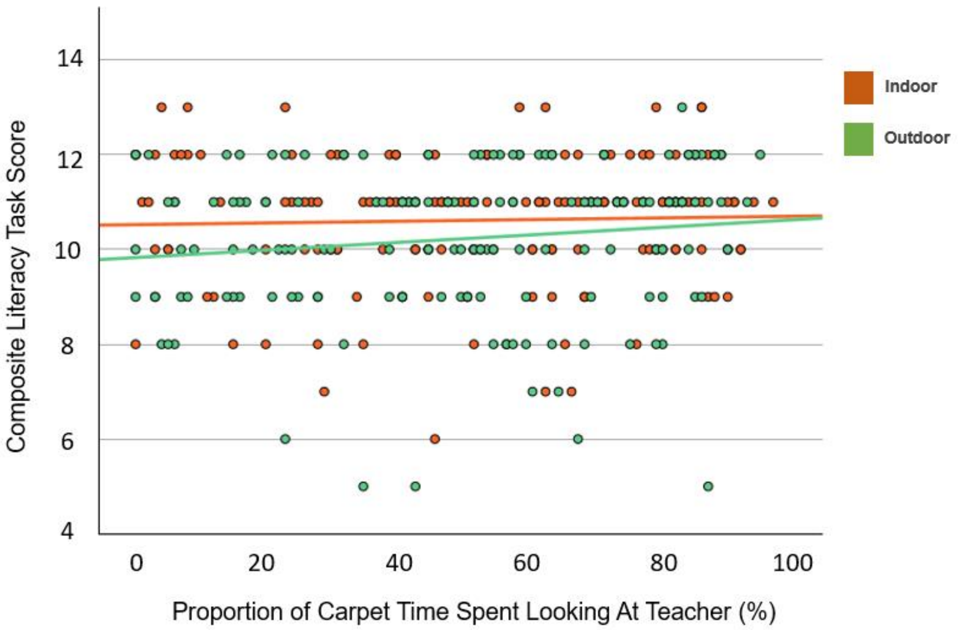
Relationship between looking time and literacy task performance

In order to explore whether looking time was a reliable measure of attention, further analyses were conducted to explore whether looking time and literacy task performance were related. Specifically– when a child is looking at a story, does this necessarily mean that they are listening to that story?

A non-normal distribution of looking time data paired with literacy task score at a participant level violated the assumptions for a parametric correlation so a Spearman's rank-order correlation was conducted. Looking time and composite literacy task scores from indoor and outdoor sessions were analysed separately, revealing that there was a significant relationship between looking time and literacy task scores in the outdoor condition r_s(157)= .181, *p* =.012) but not the indoor condition r_s (157)= .020, *p* =.401).

Figure 15

Relationships between looking time and literacy task scores in each condition



5.4.5 The impact of an outdoor environment on children's percentage of time on task

A linear mixed effects model (LMM) was used to analyse the fixed main effect of condition on the percentage of choosing time that children spent 'on-task', with a random effect of participant number. An LMM was chosen to enable inclusion of all data collected, even where some children didn't have an equal number of sessions collected from each condition.

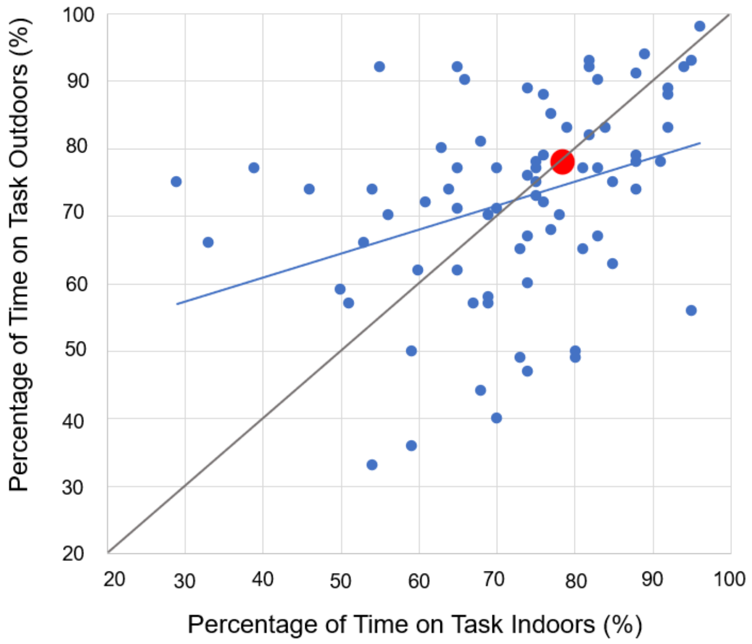
Assumption testing through visual inspection of residual and predicted value plots confirmed homogeneity of variance. Q-Q plots confirmed normality in random effect variables. Linearity was not tested as the fixed effect tested was categorical (i.e fixed effect of condition).

The LMM was run through MatLab R2022a using the same procedure as described previously. On-task behaviour was included as the dependent variable, condition as the fixed effect and participant number as the random effect. A non-significant main effect of condition was found for on-task behaviour, (beta = -0.01 , t= -0.61, p = .54). The percentage of time spent on task during outdoor choosing time (M = 72.5%, SD = 14.8%) and indoor choosing time (M = 72.8%, SD= 14.0%) were not significantly different.

A comparison of children's indoor and outdoor percentage of time on task is shown in Figure 16 below.

Figure 16

Average % time on task indoors and outside



Note. Red dot denotes group mean time on task in each condition. Grey line denotes the 1:1 line, data points above this line represent children who were more on task in the outdoor condition. A linear best fit line is drawn in blue.

Contrary to the hypothesised outcome, a small majority of children actually spent a greater percentage of their time on-task in the indoor condition. 51% (39) of children spent increased time on-task indoors, whereas 49% (37) children were more on task outdoors. To explore whether these differences were significant, further analyses were conducted.

Individual differences

Although no overall significant effect was found, some children did stay on task for up to 46% longer outdoors. Heterogeneous effects are detailed in Table 22 below and explored further in terms of group differences in section 5.4.8.

Table 22

Descriptive statistics detailing heterogenous effect of the outdoor/indoor condition on percentage of time spent on-task

	N	Min	Max	Range	Mean (SD)
Increase in % on-task behaviour outdoors	37	1.0	46.0	45.0	12.5 (11.2)
Increase in % on-task behaviour indoors	39	0.0	39.0	39.0	12.5 (9.99)

Note. On task behaviour was calculated and averaged across 4 sessions in each condition

5.4.6 The impact of an outdoor environment on children's 'peak focus'

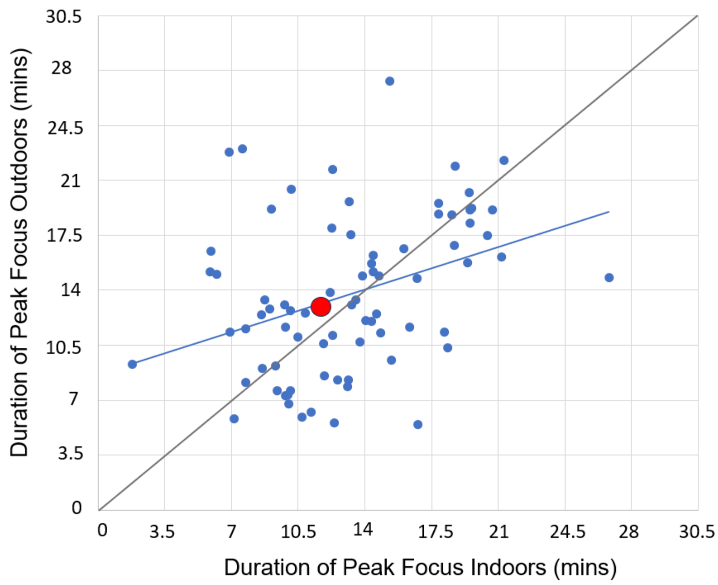
An LMM was conducted using the same procedure as described previously. Peak focus was included as the dependent variable, condition as the fixed effect and participant number as the random effect. A non-significant main effect of condition was found for peak focus, (beta = 0.00 , t= 0.31, p = .754).

The duration of peak focus during outdoor choosing time (M = 0:13:08, SD = 0:00:32) and indoor choosing time (M = 00:12:42, SD= 0:00:29) were not significantly different. A comparison of children's peak focus indoors and outside is displayed in Figure 17 below.

Approximately half of the sample (37 children) displayed a longer peak focus in the outdoor condition, whilst the remainder of the sample (38 children) displayed a longer peak focus indoors. These differential effects are summarised in Table 23 below.

Figure 17

Average peak focus indoors and outside



Note. Red dot denotes group mean time on task in each condition.

Grey line denotes the 1:1 line, data points above this line represent children who were more on task in the outdoor condition. A linear best fit line is drawn in blue.

Table 23

Descriptive statistics detailing heterogenous effect of the outdoor/indoor condition on peak focus duration

	N	Min increase	Max increase	Range	Mean (SD)
Increase in peak focus outdoors	37	0:00:13	0:15:09	0:14:56	0:04:15 (0:04:11)
Increase in peak indoors	38	0:00:05	0:11:24	0:11:19	0:03:17 (0:02:39)

Note. Peak focus was calculated and averaged across 4 sessions in each condition

5.4.7 The impact of an outdoor environment on children's activity choice

Paired samples t-tests were performed to explore whether children spent longer at certain activity types in one condition compared to the other. Activities were categorised into 'literacy', 'maths', 'creative' and 'imaginative'. Creative activities were those in which children created something for example, doing drawing, painting, play doh and Lego. Imaginative activities were those where the child engaged in an imaginary scenario such as playing in the role-play area, or using small-world resources to enact a scene with characters. T-test results are summarised in Table 24 below.

Participants engaged in 'imaginative' activities for significantly longer in the outdoor condition (*M* = 0:04:36, *SD* = 0:04:56) compared to the indoor condition (*M*= 0:03:24, *SD* = 0:03:40), 95% CI [-0:03:39, 0:02:25], $t(74) = -3.425$, $p = .001$, d = -.396. No other category of activity saw a significant difference in engagement length across conditions.

Table 24

Comparison of activity engagement across conditions

Activity Category	Indoor		Outdoor		df	t	*p*	Cohen's d
	M	SD	M	SD				
Literacy	0:02:02	0:02:28	0:01:24	0:01:59	74	1.983	.104	.229
Maths	0:01:31	0:02:08	0:01:15	0:02:21	74	.739	.924	.085
Creative	0:11:05	0:06:14	0:11:26	0:07:24	74	-.444	1.00	-.051
Imaginative	0:02:48	0:03:08	0:04:36	0:04:56	74	-3.425	**.001***	-.396

Note. Mean duration of activity engagement is presented in minutes and seconds, per 30 minute session.

5.4.8 Individual differences

Percentage of time on task

To identify whether specific groups of children were more likely to show improved time on task outdoors, a binomial logistic regression was performed to ascertain whether Gender, FSM, EAL, SDQ Total score and whether children had an existing indoor/outdoor preference would predict in which condition participants were more on-task. The linearity of SDQ scores were assessed via the Box-Tidwell (1962) procedure.

The logistic regression model was statistically significant, $\chi^2(5) = 14.490$, $p =$ .013. and explained 23.1% (Nagelkerke R Square) of the variance in which condition children were more on task and correctly classified 68.4% of cases. Sensitivity was 67.6%, specificity was 69.2%, positive predictive value was 67.6% and negative predictive value was 69.2%. Of the five predictor variables, only gender (p=.049) and indoor/outdoor preference (*p*=.006) were statistically significant. Compared to children with an indoor preference or no preference, children with a preference for the outdoor condition were 5.83 times more likely to exhibit an increase in on-task behaviour in the outdoor condition. Furthermore, boys were 3.27 times more likely than girls to exhibit an increase in on-task behaviour outdoors.

There was some overlap between these two variables, namely that boys were more likely than girls to exhibit a preference for being outdoors. From the total sample of 76, nine girls and 19 boys had an outdoor preference. In contrast, 19 girls and only eight boys showed a preference for being indoors. The remaining 21 children did not show a preference for either condition.

Table 25

Logistic regression predicting likelihood of more on-task behaviour in either indoor or outdoor condition based on EAL, FSM, indoor/outdoor preference, SDQ and Gender

	N	*B*	SE	Wald	*df*	*p*	Odds Ratio	95% CI of Odds Ratio	
								Lower	Upper
a. EAL	43	-.471	.532	.783	1	.376	.624	.220	1.772
b. FSM	8	-.236	.815	.084	1	.772	.760	.160	3.905
c.Indoor/ outdoor preference	28	1.763	.645	7.482	1	.006	5.830	1.648	20.619
d. SDQ	-	-.104	.060	2.997	1	.083	.901	.801	1.014
e. Gender	41	-1.185	.603	3.866	1	.049	.306	.094	.996
Constant		.754	.540	1.9	1	.162	2.126		

Note: Gender is for females compared to males, indoor/outdoor preference is for outdoor preference compared to indoor/no preference.

Peak Focus

The same logistic regression procedure was repeated for Peak Focus, the model was statistically significant $\chi^2(5) = 13.786$, $p = .017$. It explained 22.4% (Nagelkerke R Square) of the variance in which condition children had a longer peak focus and correctly classified 69.3% of cases. Sensitivity was 70.3%, specificity was 68.4%, positive predictive value was 68.4% and negative predictive value was 70.2%. Of the five predictor variables only preference for being indoors or outdoors was statistically significant ($p = .003$). Compared to children with an indoor preference, or no preference, children with a preference for the outdoor condition were 6.74 times more likely to exhibit an increase in peak focus in the outdoor condition.

Table 26

Logistic regression predicting likelihood of increase in Peak Focus in either the indoor or outdoor condition based on EAL, FSM, indoor/outdoor preference, SDQ and Gender

	N	*B*	SE	Wald	*df*	*p*	Odds Ratio	95% CI of Odds Ratio	
								Lower	Upper
a. EAL	43	-.667	.542	1.442	1	.218	.513	.177	1.484
b. FSM	8	-1.007	.838	1.516	1	.230	.365	.071	1.889
c.Indoor/ outdoor preference	28	1.907	.631	9.140	1	.003	6.735	1.956	23.191
d. SDQ	-	-.045	.055	.676	1	.411	.956	.856	1.065
e. Gender	41	-.753	.583	1.666	1	.197	.471	.150	1.478
Constant		.424	.529	.643	1	.423	1.528		

Note: Gender is for females compared to males, indoor/outdoor preference is for outdoor preference compared to indoor.

Looking time

For looking time, the logistic regression model was non significant $\chi^2(5) = 2.008$, $p = .848$ and all 5 predictor variables were non significant. The individual difference variables did not predict in which condition children would spend more time looking ‘on-target.

Literacy task scores

For composite literacy task scores, the model was statistically significant $\chi^2(5) = 12.332$, $p = .031$. The model explained 25.2% (Nagelkerke R Square) of the variance in which condition children scored higher in the literacy task and correctly classified 76.2% of cases. Sensitivity was 31.6%, specificity was 95.5%, positive predictive value was 75% and negative predictive value was 76.4%. Of the 5 predictor variables, only FSM was statistically significant (p=.009). Compared to children who were not eligible, children eligible for Free School Meals (FSM) were 14.53 times more likely to have higher composite literacy scores in the outdoor condition. Table 27 below summarises the statistics for each predictor variable in the model.

Together, these analyses support Hypothesis 8, that attention effects will vary between individuals.

Table 27

Logistic regression predicting likelihood of increase in composite literacy task score in either indoor or outdoor condition based on EAL, FSM, indoor/outdoor preference, SDQ and Gender

	N	*B*	SE	Wald	*df*	*p*	Odds Ratio	95%CI of Odds Ratio	
								Lower	Upper
a. EAL	43	1.078	.681	2.506	1	.113	2.939	.774	11.166
b. FSM	8	2.676	1.029	6.769	1	.009	14.525	1.935	109.040
c.Indoor/ outdoor preference	28	.265	.696	.145	1	.704	1.303	.333	5.097
d. SDQ	-	-.003	.069	.002	1	.966	.997	.871	1.141
e. Gender	41	-.981	.724	4.955	1	.175	.375	.091	1.547
Constant		-1.535	.689	4.955	1	.026	0.216		

Note: Gender is for females compared to males, indoor/outdoor preference is for outdoor preference compared to indoor.

Effect of condition on children with pre-existing attentional deficits

To determine whether children who already struggled with their attention indoors showed greater outdoor improvements than their peers, the sample was split into three groups (*low*, *medium* and *high* baseline attention).

Baseline levels of attention were determined by averaging z-scored composite measures of attention. These composite measures of attention were calculated by combining children’s peak focus and percentage of time on task data from across their eight indoor sessions. Indoor attention was considered a baseline measure as this represented how the children paid attention when in their typical learning environment.

These composite indoor baseline attention scores were z-scored at the school group level rather than the entire sample to account for between-school differences and the varying stages of the academic year at which different schools were visited for data collection. Allocation of children to their baseline level of attention groups was based on PROCESS v.4.2 (Hayes, 2017) moderation output (model 1) which determined the *low/medium/high* groupings based on 16th, 50th and 84th percentiles and was used to run the moderation analyses in this section.

% time On-Task

Paired samples t-tests indicated differential effects of condition between children from different baseline attention groups as seen in Table 28 and Figure 18 below. Children with the lowest baseline attention made the most significant gains in on-task behaviour outdoors (p = <.001), whereas children from the highest baseline attention group did not experience a significant difference between conditions (p = .093) as can be seen in Figure 18 below.

Figure 18

Violin plots comparing indoor and outdoor % time on task across different baseline attention groups

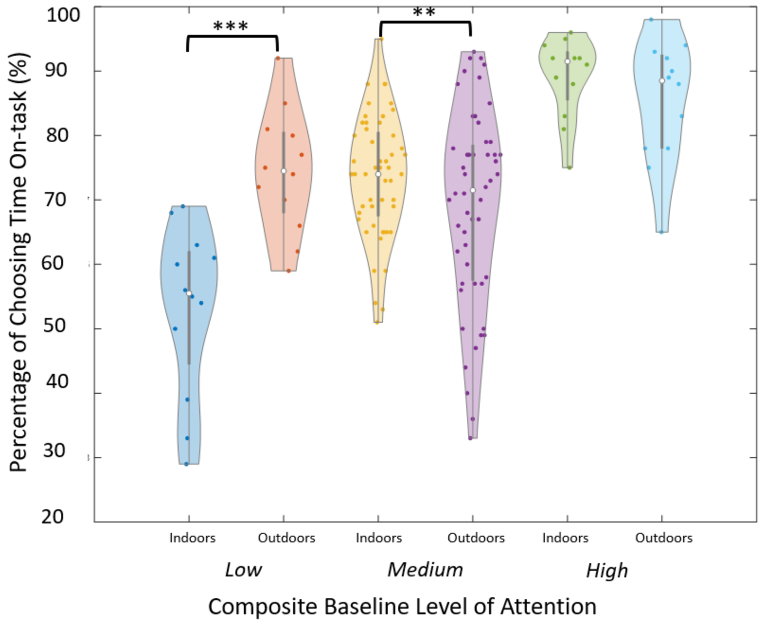


Table 28

Effect of condition on time-on-task, across different baseline attention groups.

Baseline Attention Group	N	On-Task Behaviour (%)				df	t	p	Cohen's d
		Indoor		Outdoor					
		M	SD	M	SD				
Low	12	53.1	13.1	74.4	9.5	11	-5.384	<.001	-1.554
Medium	52	73.3	10.1	69.0	15.2	51	2.030	.049	.280

		On-Task Behaviour (%)							
High	12	89.0	6.3	85.3	9.6	11	1.840	.093	.531

A moderation analysis was run using SPSS to explore the predictive effect of ‘percentage of time on-task indoors’ on ‘percentage of time on-task outdoors’ with a moderating variable of participant’s composite baseline level of attention.

The interaction between percentage of time on-task indoors and outdoors and composite baseline level of attention was significant (b = 0.333, SE = 0.0963, *t* = 3.461, *p* = .0009), indicating that the relationship between percentage of time on-task indoors and outdoors was moderated by participant’s composite baseline level of attention. The simple slope of percentage of time on-task indoors and outdoors was significant at a low (b = .6404, SE = .2329, t = 2.7491, *p* = .008) medium (b = .9090, SE = 0.2525, t = 3.6138, *p* =.0006) and high levels of composite baseline level of attention (b = 1.2093, SE = 0.2960, t = 4.0858, *p* = .0001).

Peak Focus

The same analyses were run to examine whether levels of baseline attention affected whether children experienced a significant increase in peak focus outdoors. Paired samples t-tests indicated differential effects, with children from the low baseline attention group experiencing a statistically significant increase in peak focus outdoors (*p* = .005), whereas children with medium and high-level baseline attention had a non-significant increase indoors, as detailed in Table 29.

Table 29

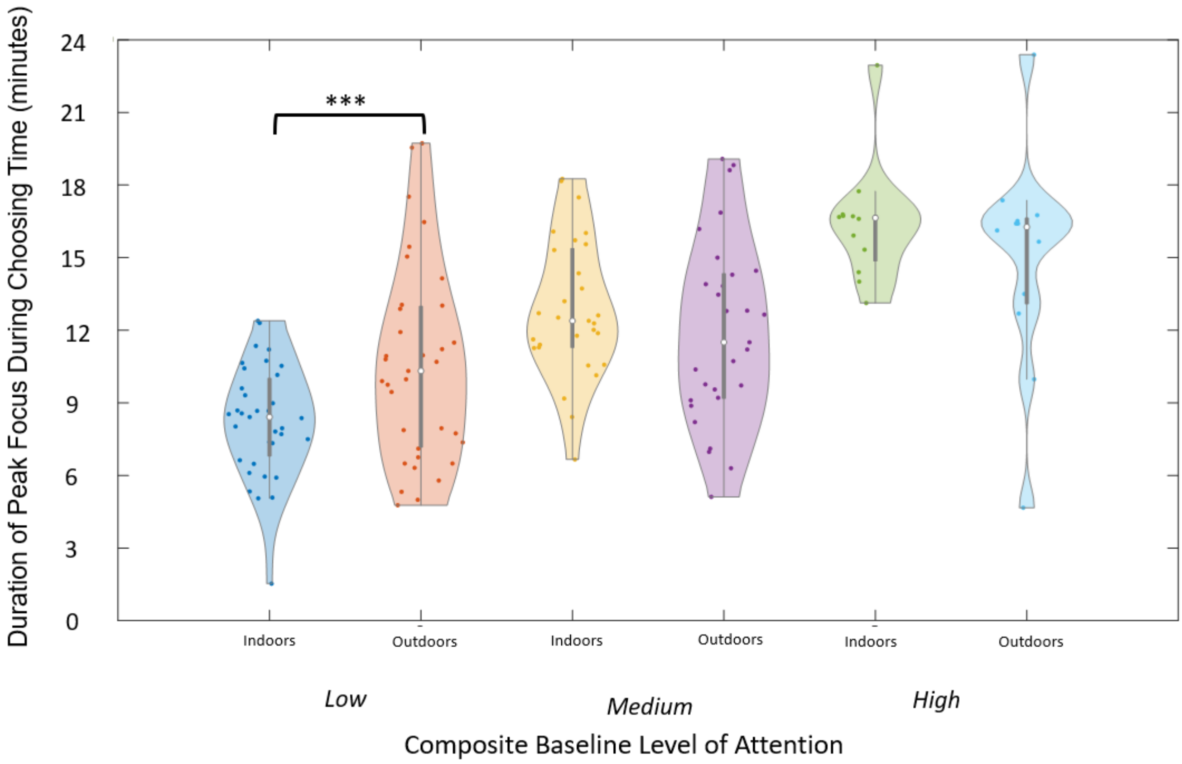
Effect of condition on duration of peak focus across different baseline attention groups.

		Duration of Peak Focus							
		Indoor		Outdoor		df	t	p	Cohen's d
Baseline Attention Group	N	M	SD	M	SD				
Low	35	0:09:11	0:02:33	0:11:43	0:04:28	34	-2.756	.005	-.455
Medium	29	0:14:17	0:03:09	0:13:16	0:04:13	28	1.556	.065	.289
High	12	0:18:14	0:02:44	0:16:37	0:05:02	11	.951	.181	.274

Following the same pattern of effects as described for 'percentage of time on task', the outdoor condition narrowed the gap in 'peak focus' between children with low baseline attention, and their higher-attention peers, as can be seen in Figure 19.

Figure 19

Violin plots comparing indoor and outdoor Peak Focus across different baseline attention groups



A moderation analysis was run on the predictive effect of indoor peak focus on outdoor peak focus with a moderating variable of participant's composite baseline level of attention.

The interaction between peak focus indoors and peak focus outdoors and baseline indoor attention was significant (b = 0.413, SE = 0.1638, t = 2.525, p = .0138), indicating that the relationship between peak focus indoors and peak focus outdoors was moderated by participant's composite baseline level of attention.

The simple slope of peak focus indoors and peak focus outdoors was not significant at a low (b = .0365, SE = .3119, t = .1170, p = .907) or medium (b = .3585, SE = .2542, t = 1.4106, p = .1629) levels of composite baseline attention, although it was significant at high levels of composite baseline attention (b = .7125, SE = .2573, t = 2.7691, p = .0072).

Literacy Score

Paired samples t-tests indicated that condition did not have a significant effect on children's literacy scores, even when analyses were run separately for low, medium and high baseline attention groups (p>.05)

Looking time

Paired samples t-tests indicated that condition also did not have a significant effect on children's looking time, even when analyses were run separately for low, medium and high baseline attention groups (p>.05)

5.4.9 Relationships between noise and attention

Noise and attention during carpet time

Analyses explored whether noise levels during carpet time affected children's attention during carpet time (their looking time and their literacy task score).

Visual inspection of histograms confirmed that looking time and literacy score data were both not normally distributed, and Shapiro Wilk testing confirmed non normality (p<.001), therefore Spearman's rank-order correlations were run to determine the relationships between carpet time noise and looking time and carpet time noise and literacy task scores.

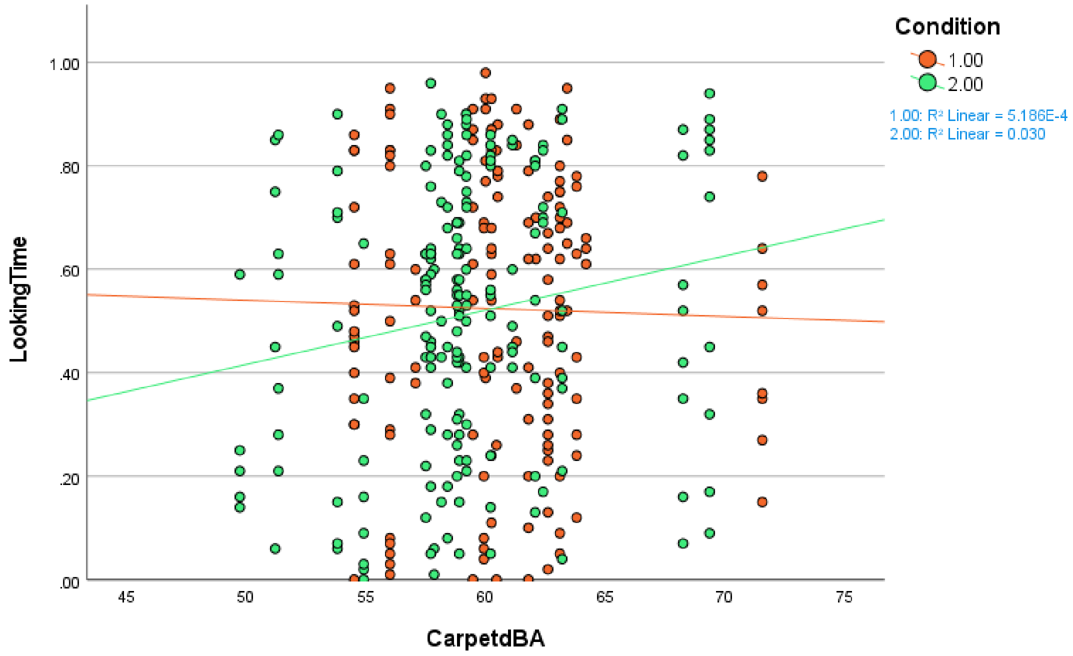
Looking time

There was a statistically significant, small positive correlation between noise during carpet time and children's looking time, $r_s(349) = .111$, $p = .019$. This was in the opposite direction to hypothesised, whereby children's looking time increased as noise increased.

When associations were explored for each condition separately, a significant correlation remained in the outdoor condition $r_s(193) = .190$, $p = .004$ but there was not a significant correlation between looking time and noise indoors $r_s(154) = .010$, $p = .451$. These correlations are displayed in Figure 20 below.

Figure 20

Relationships between noise and looking time in each condition



Literacy task score

There were no statistically significant correlations between carpet time noise and children's literacy task score, neither when the data were analysed as a whole group $r_s(329) = .031$, $p = .288$ or when correlations were run separately for the indoor $r_s(145) = -.010$, $p = .452$ and outdoor condition $r_s(182) = .085$, $p = .125$.

Noise and attention during choosing time

Further correlational analyses explored the relationship between noise and attention during choosing time.

Percentage of time on task

A Spearman's rank-order correlation was run to assess the relationship between noise during choosing time and children's percentage of time spent on task.

Preliminary analysis showed the relationship to be monotonic, as assessed by visual inspection of a scatterplot. There was a statistically significant, small positive correlation between noise and time on task, $r_s(389) = .088$, $p = .040$ such that the noisier it was, the more time children spent on task.

When each condition was analysed separately, correlations no longer reached significance in either the indoor $r_s(177) = .068$, $p = .184$ or the outdoor $r_s(210) = .092$, $p = .091$ condition

Peak focus

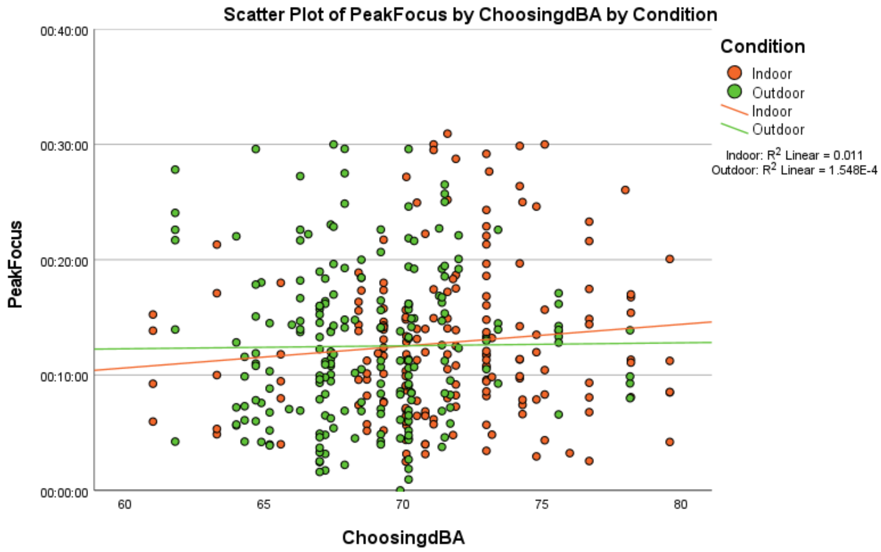
A Spearman's rank-order correlation was run to assess the relationship between noise during choosing time and children's peak focus. Preliminary analysis showed the relationship to be monotonic, as assessed by visual inspection of a scatterplot. There was a statistically significant, small positive correlation between noise and peak focus, $r_s(389) = .095$, $p = .030$ such that the noisier it was, the longer children remained focussed on a task.

When each condition was analysed separately, correlations no longer reached significance in either the indoor $r_s(177) = .096$, $p = .102$ or the outdoor $r_s(210) = .084$, $p = .111$ condition.

Together, these analyses did not support Hypothesis 6. Contrary to expectations, better attention performance during choosing time was not associated with quieter conditions.

Figure 21

Relationships between noise and Peak Focus in each condition



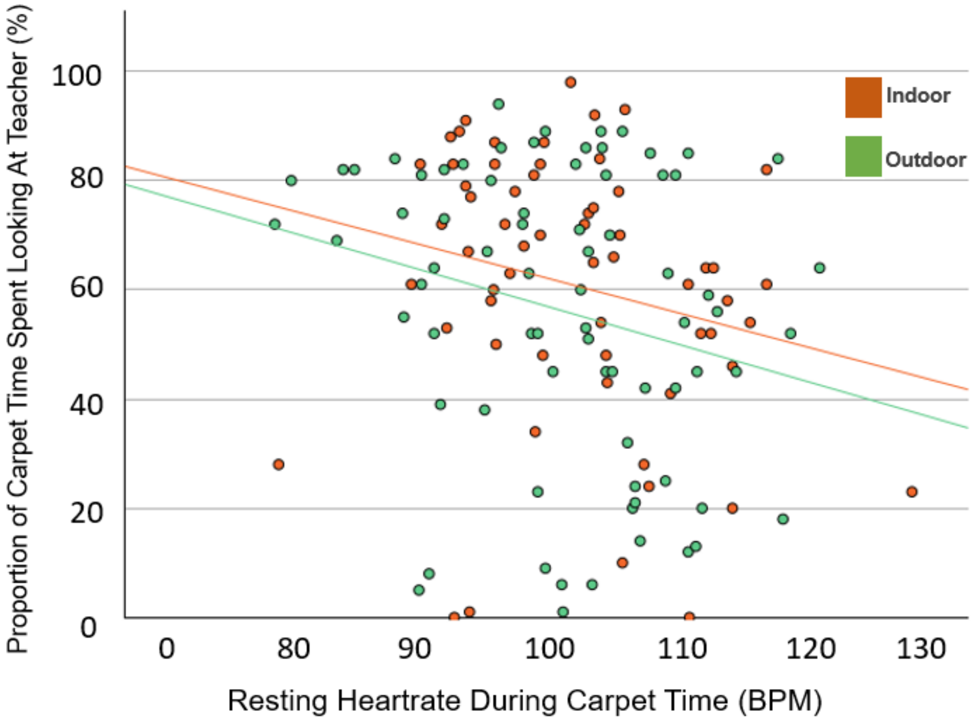
5.4.10 Relationships between heart rate and attention

As visual inspection of histograms confirmed that looking time data was not normally distributed, a Spearman's rank order correlation was performed to examine the relationship between participants' heart rate during carpet time, and their looking time during the session. There was a significant negative correlation between resting heart rate and looking time, such that lower heart rates were associated with longer looking durations $r_s(150) = -.263$, $p < .001$.

When analyses were run separately for each condition, the significant, negative relationship between resting heart rate and looking time remained in both the indoor $r_s(70) = -.290$, $p = .007$ and outdoor $r_s(78) = -.244$, $p = .015$ conditions. These results supported Hypothesis 7, that lower resting heart rates would be associated with spending more time looking on target.

Figure 22

Relationships between resting heart rate and looking time in each condition



Heart rate analyses were not conducted for any other attentional outcomes as children's physical movement during activities would have confounded results.

5.4.11 Effect of nature level on attention outcomes

Each participating school had a different outdoor environment used as the outdoor condition, some of these were very urban with no natural features, whereas others had lawn, shrubs and trees. Each area was rated in terms of its level of nature as detailed in Chapter 3.

Much of the literature detailed in chapter 2.5 suggests that natural environments in particular have a positive impact on attention, more so than outdoor urban environments without natural features. Therefore, it was important to explore whether the school outdoor areas with more natural features had a greater positive impact on participants' attention.

Schools were grouped into those with *low*, *medium* or *high* levels of nature in their outdoor condition and paired samples t-tests were conducted to compare participants' indoor and outdoor attention performance for all measures used in the present study and make comparisons across nature levels.

Results confirmed that whilst for some attention measures, the difference between indoor and outdoor attention was closer to significance in high nature areas than in low ones, however overall the area with a medium level of nature elicited the most significant effect of condition. The results of these t-tests are summarised in Table 30 below.

Table 30

Effect of Nature level on differences between indoor and outdoor attention measures

		Paired Samples T-tests comparing indoor and outdoor attention		
Nature level	Attention measure	t	DF	p
Low	% time on task	-0.28	20	.489
	Peak focus	.217	20	.415
	Looking time	.423	19	.339
	Composite literacy task score	.709	17	.244
Medium	% time on task	-1.168	16	.130
	Peak focus	-1.334	16	.100

	Looking time	3.974	16	**<.001***
	Composite literacy task score	-2.199	15	**.022***
High	% time on task	.819	37	.209
	Peak focus	-.538	37	.297
	Looking time	.394	32	.348
	Composite literacy task score	-1.731	30	**.047***

A series of one-way ANOVAs were conducted and analysis confirmed there were no significant between-nature level group differences for percentage of time on task (*F* 1.168, p=3.17) peak focus (*F*.445, *p*=.643), looking time (*F* 2.441, *p* = .095) or composite literacy score (*F* 1.771, *p* = .179) .

5.5 Discussion and conclusions

The primary findings of this study were as follows: Firstly, when eight indoor and eight outdoor sessions were matched within an urban school setting, the outdoor environment did not have a significant effect on children's attention when data was analysed at a whole group level. However, this methodology obscured effects on individual groups. When children were split into groups according to their baseline attention in the indoor condition, those with the lowest baseline attention indoors showed the greatest improvements in their attentional capacity while outdoors for choosing time. This meant that when outdoors, the gap between the children who struggled with their attention indoors and their higher performing peers was narrowed.

Secondly, children's gender, eligibility for free school meals, and whether they had an existing outdoor or indoor preference predicted whether they would pay better attention outdoors, with boys being more likely to show more on task behaviour outdoors, children with an outdoor preference being more likely to display longer peak focus and more on task behaviour outdoors, and children eligible for FSM being more likely to score higher on the literacy task outside. It is notable that teacher reports indicated that boys were more likely than girls to have an outdoor preference (19 boys compared to only nine girls preferred being outside).

Thirdly, whilst positive effects of being outdoors on 'low-baseline attention' children were observed consistently for attention measures taken during choosing time (when children were allowed to move freely between a range of different activities), no significant improvements were observed for attention measures taken during carpet time (when children were seated, listening to a teacher). Children with low baseline attention did not significantly improve their looking time or literacy task scores outdoors.

Fourthly, children spent significantly more time engaged in imaginative play during choosing time when in the outdoor condition, but there were no effects of condition on other activity durations.

And finally, the level of nature in the outdoor areas did not appear to have a significant effect on children's attention outcomes, nor did noise mediate effects as expected.

The lack of an observed nature-effect on carpet time attention may be because distracting movements are more common outdoors (such as planes or birds flying overhead and leaves falling from trees) but these may only have been distracting to children during times when they were asked to sit still and be quiet. Or, it may be that children required longer to get used to the unusual experience of sitting still on the ground outdoors whilst at school. It should be noted that during choosing time sessions, children were either on their feet, or seated at chairs, whereas for carpet time they were seated on a tarpaulin on the ground. Some children were resistant to this, complaining that it felt wet or cold. This sensory discomfort may have counteracted any potential positive impacts on attention.

Interestingly, however, looking time and children's literacy scores were correlated in the outdoor condition but not when the children were indoors. This suggests that when children were able to look at the story being read outdoors, they were genuinely paying attention and absorbing the information. However, during the indoor sessions, even if they were looking at the story, this did not associate with being able to score well when assessed on their recall and understanding of the story. This means that it may be more difficult to tell whether children are paying attention indoors. It is possible that increased stimulation indoors (visual clutter, noise etc) leads to children being more likely to ‘zone out’ (i.e. looking in the right direction but not paying attention.)

The results from this study corroborated some previous findings and stood in contrast to others. The finding that boys were more likely than girls to show improved on task behaviour outdoors is consistent with previous literature which evidenced that access to greenspace affected hyperactivity (Yang et al, 2019) and on task behaviour (Lundy & Trawick-Smith, 2021) more for boys than girls. However, an unexpected aspect of the study’s results was a failure to observe overall group differences between indoor and outdoor settings. Previous research has found whole group effects, whereby children pay better attention when given access to the outdoors (Mancuso et al, 2006; Mason et al, 2022), yet the present study only found significant effects for certain groups such as children who struggled the most with their attention indoors.

This finding supports previous research which has evidenced that time outdoors in natural settings can support the attentional performance of children with ADHD (Faber Taylor & Kuo 2011; Kuo & Faber Taylor 2004). Whilst previous research has shown fewer teacher redirects after exposure to outdoor learning (Kuo et al, 2018), the present study found no significant difference in teacher redirects between the indoor and outdoor conditions. However, this may be due to methodological differences. The present study counted redirects whilst the children were in each condition whereas the aforementioned study only counted redirects in the indoor classroom, to measure lasting effects after the children had been learning outdoors. Finally, previous research has suggested that higher levels of nature confer greater attentional advantages, for example in studies which compared attentional performance after walks in urban and natural settings, nature walks elicited better attention than urban ones (Berman 2008; Faber Taylor & Kuo, 2009; Schutte et al, 2017). This suggests that it is nature exposure which is influential rather than generic outdoor time. However, the present study found that nature levels did not mediate effects; urban outdoor areas with minimal nature appeared to be equally beneficial as natural sites. However, this may be because all of the outdoor areas were situated in inner-city schools and there was not enough contrast between high and low nature conditions. Some previous literature has also found that time outdoors in urban and natural environments are equally beneficial (Gidlow et al, 2016).

Taken together, the results from this study suggest that there is not one optimal environment for all children, and that some children attend better indoors, whilst others attend better outside. A possible explanation for this finding may be that children have different underlying levels of baseline physiological stress, and all children perform best at intermediate stress (Wass, 2021; Whiting et al., 2021). So for some children (who naturally have lower baseline stress), noisy and stimulating indoor environments actually improve attention overall because they increase stress to an optimal intermediate level; whereas for other children (who have higher baseline stress) outdoor environments improve attention because they reduce stress to an optimal intermediate level, thus cancelling out the overall group-level effect. This hypothesis requires, however, additional testing to support it.

Contrary to expectations, and to existing research which evidences that noise is detrimental to learning and attention (Lamotte et al., 2021; Visentin et al, 2023), noise did not have the predicted effect on attention in this study. Conversely, when carpet time sessions were louder, children looked more at the teacher and story, not less. This is likely to be because louder sessions comprised more interaction and questioning around the story which kept children engaged. Similarly, during choosing time, noise was positively correlated with children's percentage of time on-task and peak focus. Again, this may be because when engaged at an activity, children are more likely to converse with peers which generates noise. Future research should aim to distinguish between children's self generated noise and background noise (e.g road traffic) in the learning environment.

Positive effects of being outdoors were observed in 'low baseline attention' groups consistently, even in urban outdoor areas with minimal or no natural features and in some cases, with noise from road and air traffic. This suggests that Attention

Restoration Theory was not the key mechanism behind this effect, as the outdoor spaces utilised in this study did not match the theory's descriptions of being 'restorative' places or providing 'softly fascinating' stimuli (Kaplan, 1995). However, it is possible that for children of this age, even a small urban outdoor area could be restorative compared to a busy indoor classroom.

The study provides some clear implications for early years practice. Firstly, analyses also showed that whether children have an existing indoor or outdoor preference significantly predicted where children would perform better in attention measures – children who prefer to be outside, pay better attention outside. The implications of this are clear; that teachers should seek out children's preferences and offer opportunities for them to learn in their preferred environment as children may intuitively know which environment suits them best. In order to give children this autonomy, a full provision must be on offer both indoors and outside. Whilst outdoor play is common in Early Years settings, many settings do not replicate the full range of activities on offer indoors, in their outdoor environment. In particular, activities which are considered to comprise more 'formal learning' (for example the literacy task used in this study), are almost always conducted exclusively indoors. Yet this study showed that overall, children did not perform worse in the literacy task outdoors compared to inside, and that some children performed significantly better on comprehension and recall tasks outside. Thus, teachers should be open minded about the type of activities that are appropriate for outdoor contexts, including literacy and numeracy-based tasks and assessments.

In addition, this study revealed a further positive effect of the outdoor environment - that children engage for longer in imaginative play outside compared to indoors. The reasons for more sustained imaginative play in the outdoor condition could be linked to lower stress and noise levels, as reported in chapter 4 of this thesis. These results suggest that outdoor time may help support the development of children's imagination and language.

Finally, despite teachers reportedly having concerns about children's behaviour being harder to manage outdoors, results from this study confirmed that children did not require significantly more teacher redirects during outdoor carpet time sessions, suggesting that there was no increased need for behaviour management.

A strength of this study's design was its incorporation of individual differences, and an aim to explore these important between-student variables rather than ignore them by only analysing whole group means. Other key strengths were the careful matching and counterbalancing of activities, resources and procedures across conditions, the repeated measures design which ensured that each participant took part in multiple indoor and outdoor sessions, and the range of attention measures used, which aimed to replicate the different types of attentional performance that are important to early years educators as well as building on previous literature in this field, for example by replicating the redirects measure. Attempts were also made to identify mechanisms behind the nature-effect.

However, the study also had some limitations and areas of weakness. The main limitation was that only 30 minutes of choosing time was recorded per session due to battery life and data storage issues with the head mounted cameras. This did not allow the study to explore how children's attention might increase or attenuate over a longer time period in each condition. In addition, the analyses comparing the levels of nature in each outdoor area were unreliable as there were only four schools to allocate across three different nature levels. This limitation was described previously in section 4.5.

The study may also have been vulnerable to some selection bias – more sensitive children and those with SEND were not always able to tolerate having the wearable equipment on, thus they may have been less likely to consent to taking part, or may not have met the minimum requirements for inclusion in analyses.

Although the study had good ecological validity as it did not interfere with the school's usual curriculum and approach, this did mean that there were slight between-school differences. For example, it was observed when counting teacher redirects, that the teacher's approach affected the number of redirects. At one particular school, teachers were more likely to accept children's contributions and encourage them to call out comments and questions throughout the story, whereas in another school this behaviour was considered more disruptive and was redirected. Although this was consistent across both conditions, it raised issues regarding whether counting redirects was a true measure of attention. For example, in some cases teachers redirected behaviour as children were calling out, but in many cases the children were engaged in the story and calling out relevant comments, suggesting that they were actually paying good attention to the story. Therefore the ability to sit quietly and not 'call out' may have been measuring behavioural self-regulation more than attention.

Finally, there were issues with the literacy task being too easy for some children. Although the retelling aspect of the task was added to address this, by providing an open-ended opportunity for children to show the full extent of their comprehension, there was still a ceiling effect regarding how high children could score on the comprehension questions. These were tested with children during piloting and deemed to be at an age-appropriate level. However, the year-round data collection procedure was overlooked – when data was collected from classes during the Autumn, this was the start of the school year and the literacy task was at an appropriate level of challenge for children who have just started school. However, some classes participated in the summer term, when the children were almost a year older and had experienced many months of learning in school, by this point of the year, the activity had become too easy for many of the children.

In conclusion, this study has examined the impact of outdoor learning on 4-5 year-olds' attention across a range of measures. Results revealed the differential effect of the outdoor environment on these children, namely that children who prefer being outdoors, and those who struggle with their attention indoors, confer the greatest benefits from being outside. These effects held true across various schools, regardless of the amount of nature in their outdoor area. The results from this study suggest that outdoor time could be a valuable way of supporting children who struggle with their attention, and that even urban outdoor environments with a lack of nature can still be effective. Although noise was predicted to mediate the relationship between the learning environment and children's attention performance, the results of this study did not support noise as a key mediator. Therefore, future research should aim to explore other mediators in order to elicit the specific features of outdoor environments which make them beneficial.

Chapter 6

School study 3 – The impact of an outdoor learning environment on children's behaviour

6.1 Introduction and rationale

Antisocial behaviour is a significant social and economic challenge, both in educational settings and in wider society - but when investigating the reasons for disruptive behaviour, the physical learning environment is often neglected. The majority of children in England are educated in an indoor classroom for all lessons except for Physical Education (Natural England, 2023), yet there is a paucity of research examining whether a crowded, often noisy and highly stimulating indoor environment might contribute to poor behaviour. Much of the existing literature on environmental influences on behaviour in the classroom focuses on the impact of external sources of noise, such as road (Bao et al., 2022; Tangermann et al., 2022) and air traffic (Clark et al., 2021; Stansfeld et al., 2009). The former has been associated with increased conduct problems and the latter with hyperactivity and impulsivity. Yet little research has examined how the impact of noise in an outdoor classroom may compare to the impact of noise indoors.

A range of correlational and experimental evidence (Bikomeye et al., 2021; Mygind et al., 2021; Putra et al., 2020; Zare Sakhvidi et al., 2022) suggests that exposure to natural green spaces at home and school has an impact on children's pro and antisocial behaviour. A review of quasi-experimental studies investigating the impact of schoolyard greening (adding more greenery and natural elements to school playgrounds) found evidence of positive effects on children's prosocial behaviour (Bikomeye et al, 2021), whilst large-scale correlational studies have reported that children attending school or kindergarten in greener areas, or in places with more tree cover have fewer behavioural problems (Luque-García et al., 2022) and better emotional and behavioral regulation (Scott et al, 2018). Higher levels of greenspace around children's homes has been also associated with reduced risk of conduct and peer relationship problems (Andrusaityte et al, 2020), lower levels of behaviour problems (Lee et al, 2019; Maes et al, 2021) and reduced aggressive behaviour (Younan et al, 2016) and increased prosocial behaviour (Balseviciene et al, 2014; Richardson et al, 2017). Some studies have reported heterogenous effects, suggesting that green spaces have a greater impact on behaviour for urban children (Bijnens et al, 2020) and for boys (Markevych et al, 2014). However, this field of research is far from conclusive, with many studies reporting mixed results, or no effect of greenspace exposure on children's behaviour (Jimenez et al, 2021; Mueller & Flouri, 2020; Bakir-Demir et al, 2019).

The mostly commonly cited reasons why being outside in nature may have this effect are the Biophilia Hypothesis (Wilson, 1986) and Stress Reduction Theory (Ulrich et al, 1991). According to the Biophilia Hypothesis (Wilson, 1986), humans have an innate, adaptive affinity with the natural world. Although we have transitioned from living outdoors in nature to inside buildings and cities, we have maintained our need to connect with nature and meeting this need brings about emotional wellbeing. According to Stress Reduction Theory (SRT) (Ulrich et al., 1991), environments with water and vegetation which could provide shelter and food were important to our ancestors in terms of survival. Therefore, humans have evolved to have an unconscious positive response to such natural environments. This initial positive response is a physiological one, it involves decreased physical arousal (reduced blood pressure and lower levels of stress hormones) which creates a shift towards a more positive emotional state. This reduced stress could then have downstream effects on behaviour and self-regulation. Polyvagal theory supports this idea that shifting autonomic balance towards more parasympathetic functioning enables humans to connect and behave prosocially (Porges., 2011).

It has also been posited that natural outdoor environments may help children to feel more connected to their surroundings, and in turn to other people around them, and that outdoor areas promote social interaction and forming social ties (Weinstein et al., 2015). As yet, the exact mechanisms behind nature's effect are not yet fully understood and it is likely that the nature-effect operates through multiple pathways.

Current evidence also does not provide us with an understanding of how much nature is needed to have a positive effect on behaviour. Inner city schools commonly lack access to natural outdoor spaces such as fields and woodland but it is unclear whether utilising smaller urban outdoor spaces could yield the same behavioural benefits as greener spaces. This study therefore sought to compare the frequency of urban children's prosocial and antisocial interactions with their peers in their indoor classroom compared to an urban outdoor learning environment, in order to explore whether being outside can support children's behavioural regulation. Footage from wearable cameras and microphones were coded from across 8 indoor and 8 outdoor sessions, where activities, resources and children were matched across conditions. A decibel meter was used to record noise levels in each condition and explore whether noise mediated effects.

6.2 Hypotheses

The hypotheses for this study were as follows:

1. The majority of children will be involved in more prosocial incidents outdoors compared to indoors.

2. The majority of children will be involved in fewer antisocial incidents outdoors compared to indoors

3. Children will spend a greater percentage of their choosing time engaging in self directed play and talk with peers (PPT) outdoors, compared to indoors

4. Noise will be associated with behaviour in both conditions; noise levels will be positively correlated with antisocial incidents and negatively correlated with prosocial incidents

5. Heart rate will be associated with behaviour in both conditions, whereby heart rate will correlate with antisocial incidents. It is predicted that children's mean resting heart rates during carpet time will correlate with the number of antisocial events occurring in the 5 minutes immediately after carpet time.

6. The outdoor environment will have differential effects on children's behaviour. Effects may be mediated by individual differences such as gender, SES, SEND, SDQ scores and whether children have an existing indoor/outdoor preference.

6.3 Methodology

6.3.1 Participants

The recruitment of schools and participants for this study, and the demographic details for the sample of 76 children participating have previously been outlined in chapter 3.

6.3.2 Equipment and measures

The wearable equipment outlined in chapter 3 was also used in this study. In addition to the heart rate and noise measures, Strength and Difficulties Questionnaire and demographic information aforementioned in chapter 3,

This study utilised four measures of behaviour:

1. The number of anti social incidents taking place within 5 minute windows
2. The number of pro social incidents taking place within 5 minute windows
3. The amount of time children spent in self-directed play and talk with peers (PPT)
4. Children's heart rate during choosing time

Children were fitted with head mounted cameras, heart rate monitors and microphones whilst learning and playing indoors and outside for 16 sessions across a period of 4 weeks. The footage from these cameras was then analysed to determine whether their behaviour differed across the 2 settings. The procedures for fitting the wearable equipment, measuring noise levels and the schedule for data collection sessions is explained in the general methodology section in chapter 3.

6.3.4 Procedure for coding for prosocial and antisocial behaviour

For each participant, two indoor and two outdoor choosing time sessions were chosen randomly from each child's bank of video data. From each of these 30 minute choosing time sessions, 2x 5-minute segments were coded for incidents of pro and anti social behaviour. One of these 5 minute segments was taken from the start of choosing time (minutes 5-10) and the other was from the end of choosing time (minutes 25-30). This was to account for the fact that children may behave more antisocially towards the end of a session once they become less engaged in the activities offered.

As detailed in the general methodology section in Chapter 3, activities and resources were counterbalanced across both conditions to avoid confounding variables.

Incidents of pro and anti social behaviour were only coded if they directly involved the participant, any incidents involving non participating peers which were captured in the background of video footage were not coded or included in any analyses.

A manual for coding pro and anti social incidents was created and used to train any coders (Appendix 13). This manual detailed how to identify and categorise pro and anti social incidents.

Prosocial incidents were categorised as *physical* (for example hugging a peer), *verbal* (for example making a kind comment) or *combined* (for example asking a child if they are ok, whilst simultaneously holding their hand). Incidents were only considered prosocial if they had a benefit to a peer and did not only serve the child themselves, for example, asking 'where is the blue pen?' did not count as instigating social conversation as it was functional and served a purpose only for the child themselves.

Antisocial incidents were categorised using the same headings. The full list of incident types used for categorisation are listed in Table 31 below

Table 31

Categorising prosocial and antisocial incidents

	Prosocial	Anti social
Verbal	Kind comment to peer Invite peer to play Verbal encouragement Playful laughing/joking together Instigate or join social conversation	Angrily shouting at peers Verbally refusing to share/take turns Insulting/teasing Excluding verbally e.g 'You can't play with us'
Physical	Play together with a peer/join play Build/create something with a peer Hold hands/hug/other affection Helping a peer Taking turns/sharing resources	Physically refusing to share/take turns by snatching/moving resources Excluding physically e.g. by walking away from a child intentionally Intentionally breaking or ruining a peer's creation Physical altercation e.g. push, hit, kick, scratch
Combined	Any simultaneous combination of verbal/physical from the lists above	Any simultaneous combination of verbal/physical from the lists above

Each incident was coded using a spreadsheet with drop down menus to select the type and category of incident that took place (Appendix 14). Coders also made a note on the spreadsheet to describe each incident in context, for example *'pulling tray of pegs towards self so other child couldn't reach them'* and to record the time at which it occurred.

Procedure for coding self directed play and talk with peers (PPT)

Coding for PPT was done as part of the 'activity choice' coding for Study 2 in Chapter 5 of this thesis (Coding manual in Appendix 10). When children were not at a teacher-prepared task during choosing time, coders noted when the off-task activity they engaged in involved self directed play and talk with peers. The start and end time of each session of 'PPT' was noted on the spreadsheet so that totals could be calculated. Examples of behaviour considered to be PPT are included in Figure 22 below.

Figure 22 Examples of Self directed peer play and talk (PPT)

Self directed play and talk with peers (PPT)
Sustained chatting with a peer Making up a song or dance with a peer/s Making up/playing a game with a peer/s Playing collaboratively with resources children had sourced themselves/using provided resources in a new/unintended way

Eight x 30 minute choosing sessions (four indoors and four outside) were coded for the amount of time spent in PPT and then totalled to find the mean duration spent in PPT in each condition.

6.4 Results

6.4.1 Overview of analyses

The results from this study are based on five areas of analysis:

1) Firstly, Wilcoxon signed ranks tests and paired samples t-tests were conducted to compare the number of prosocial and antisocial events, and the amount of peer play and talk (PPT) in each condition and determine whether

there were significant mean differences between conditions at a whole-group level.

2) Further analyses explored relationships between behaviour and noise, and behaviour and resting heart rate, by conducting Spearman's Rank Order correlations and Pearson's correlations.

3) To explore whether the amount of nature outdoors had an effect on behaviour, a one-way ANOVA was performed to compare the difference between indoor and outdoor behaviour across each nature-level.

4) A series of binomial logistic regressions were performed to explore whether specific groups of children were more likely to show improved behaviour outdoors. Demographic variables including gender, SDQ score and indoor/outdoor preference were included in regression models.

5) In the final stage of analysis, participants were split into sub-groups. Based on their baseline behaviour indoors, children were categorised as 'High antisocial' or 'Rest of sample' and 'High prosocial' or 'Rest of sample'. An exact sign test was then conducted to determine whether there was a significant difference in indoor/outdoor antisocial behaviour for children who were 'high antisocial' and children who were not. The same procedure was then repeated for prosocial behaviour.

6.4.2 The impact of an outdoor environment on antisocial behaviour

Visual inspection of histograms suggested that antisocial incidents data was not normally distributed. This was confirmed by a Shapiro Wilk test (p<.001). Therefore, a Wilcoxon signed ranks test was performed to examine whether there were significant mean differences in the amount of antisocial events taking place indoors, compared to outside.

The difference scores were approximately symmetrical, as assessed by a histogram with superimposed normal curve. Of the 76 participants recruited to the study, the outdoor condition elicited a decrease in antisocial behaviour in 26 participants and the indoor condition elicited a decrease in 25 participants. There were 25 cases of no change in antisocial behaviour between conditions.

Contrary to Hypothesis 2, there was no statistically significant median increase in the number of antisocial behaviour events when children were indoors (two events) compared to outdoors (1 event) $z = -.217$, $p = .828$. However, some children engaged in up to eight fewer antisocial incidents in the outdoor condition compared to inside, and vice versa. These differential effects of the learning environment on behaviour are detailed in Table 32 below.

Table 32

Differential effects of condition on antisocial behaviour

	N	Min decrease	Max decrease	Range	Mean (SD)
Fewer antisocial incidents indoors	25	-1	-8	7	-2.64 (1.95)
Fewer antisocial incidents outdoors	26	-1	-8	7	-2.54 (1.61)

Note. Antisocial incidents were totalled across 4 sessions in each condition

6.4.3 The impact of an outdoor environment on prosocial behaviour

Prosocial incidents were normally distributed, as identified by visual inspection of histogram and Q-Q plots and there were no extreme outliers. Therefore, a paired samples t-test was conducted to compare the number of prosocial incidents that took place indoors and outside.

Contrary to Hypothesis 1, there was not a significant mean difference in the amount of prosocial behaviour children displayed indoors (M=8.82, SD 4.72) and outdoors (M=9.68, SD 4.83), 95% CI [-2.002, .2655], t (75) = -1.526, p = .066, d= -.175.

However, effects of condition were heterogenous. These differential effects of the learning environment on prosocial behaviour are detailed in Table 33 below.

Table 33

Differential effects of condition on prosocial behaviour

	N	Min increase	Max increase	Range	Mean (SD)
More prosocial incidents indoors	29	1	12	11	4.10 (3.11)
More prosocial incidents outdoors	43	1	11	10	4.30 (2.88)

Note. Prosocial incidents were totalled across 4 sessions in each condition

6.4.4 The impact of an outdoor environment on children's self directed peer play and talk (PPT)

The distribution of children's self-directed peer play and talk (PPT) with peers did not meet the normality assumptions for a t-test. However, visual inspection of histograms confirmed approximately symmetrical distribution of difference scores, therefore a Wilcoxon signed-rank test was conducted to compare the amount of PPT children engaged in outdoors compared to inside.

Of the 75 children included in analyses, 44 participants engaged in more PPT in the outdoor condition. 25 children engaged in more PPT indoors, and for 6 children the condition had no effect.

There was a statistically significant increase in time spent in PPT outdoors (*Mdn* = 0:02:24) compared to indoors (*Mdn* = 0:01:18), z= -2.167, p = .030. These results support Hypothesis 3.

6.4.5 Relationships between noise and behaviour

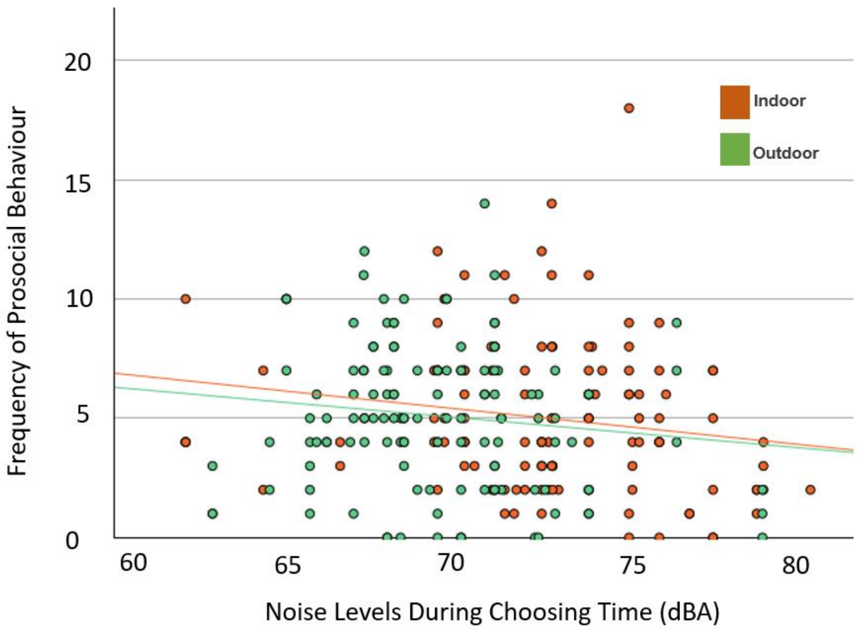
Data from Study 1 had previously confirmed that noise levels during indoor choosing times (*M*=72.0, *SD*= 3.7) were significantly higher compared to outdoor choosing times (*M*=68.2., *SD*= 3.4), 95% CI [2.2, 5.3], $t(37) = 4.818$, $p < .001$, $d = 1.064$.

Further analysis implementing mixed ANOVA also indicated there were no significant interactions between condition and the class group $F(5, 32) = 1.782$, $p = .145$, 95% CI [-.80789, 6.67873], partial $\eta^2 = .218$, or school, $F(2, 35) = 1.846$, $p = .173$, 95% C I[-1.0917, 3.8947], partial $\eta^2 = .095$ on choosing time noise levels (i.e. outdoor sessions were consistently quieter than indoor sessions even when participant groups changed and outdoor areas differed across schools e.g. more traffic noise/fewer natural features).

Analyses were conducted to explore whether noise levels might mediate effects on prosocial behaviour. A non-linear relationship between noise levels during choosing time and prosocial behaviour was indicated via a scatter plot. Therefore, a Spearman's correlation was carried out to assess relationships between noise and prosocial behaviour in each condition. A small but statistically significant, negative correlation between noise levels and prosocial events was identified in the indoor condition, $r_s(117) = -.198$, $p = .016$. However, there was not a significant correlation between noise levels and prosocial behaviour in the outdoor condition, $r_s(129) = -.116$, $p = .095$, as demonstrated in the scatterplot in Figure 23 below.

Figure 23

Relationships between noise and prosocial behaviour in each condition



The same analysis was conducted to explore whether noise levels were associated with antisocial behaviour. Contrary to Hypothesis 4, the Spearman's correlation revealed no significant correlations between noise levels and antisocial events in either the indoor condition, r_s (117) = .014, *p* = .442 or the outdoor condition, r_s (129) = .103, *p* = .123.

Finally, analyses explored whether noise was associated with the amount of time children engaged in self-directed play and talk with a peer (PPT). Visual inspection of scatter plots confirmed there was a linear relationship between noise and PPT outdoors but not indoors. Therefore a Spearman's correlation was conducted for indoor PPT and a Pearsons correlation for outdoor PPT. No significant correlations were found in either condition. There was a small negative correlation between noise and PPT indoors r_s(205) = .-.055, *p* = .214 and a small positive correlation between noise and PPT outdoors, which almost reached significance *r*(241) = .103, *p* = .055.

6.4.6 Relationships between heart rate and behaviour

In order to explore whether heart rate was associated with childrens antisocial and prosocial behaviour, children's resting heart rates during carpet time were correlated with the number of antisocial and prosocial events taking place in the first 5 minutes following carpet time.

A Pearson's correlation confirmed that there was no significant correlation between prosocial incidents during the first five minutes after carpet time, and resting heart rate during carpet time indoors r_s (56) = -1.36, *p* = .154 and a Spearman's rank correlation confirmed there was also no significant relationship outdoors r_s (62) = -.058, *p* = .326

Further Pearson's correlations were conducted and found no significant correlation between antisocial incidents during the first 5 minutes after carpet time, and resting heart rate during carpet time indoors r_s (56) = .145, *p* = .139 or outdoors r_s (62) = .074, *p* = .281. Taken together, these results did not support Hypothesis 5.

6.4.7 Effect of nature-level on behaviour

In order to explore whether school outdoor areas with more natural features had a more beneficial impact on participants behaviour, schools were grouped into low, medium or high levels of nature using the criteria described in Chapter 3.

Nature level and antisocial behaviour

A one-way ANOVA was performed to compare the difference between indoor and outdoor antisocial behaviour across the three nature levels. Compared to indoors, there was a decrease in antisocial behaviour incidents in the low-nature outdoor condition (*M* =.67, *SD*= 3.11) and an increase in antisocial behaviour incidents in the medium-nature (*M* =.18, *SD*= 2.21) and high-nature (*M* =.29, *SD*= 2.39) conditions. However, these differences between nature levels were not statistically significant *F* (2, 73) = .982, *p*= .379 suggesting that the naturalness of the environment did not significantly affect antisocial behaviour.

Nature level and prosocial behaviour

The same procedure compared the difference between indoor and outdoor prosocial behaviour across each nature level. There was an increase in prosocial behaviour incidents outdoors, across all three nature-levels: high-nature (*M* =.76, *SD*= 5.15) medium-nature (*M* =.53 *SD*= 4.71) and low-nature (*M* =1.33, *SD*= 5.02). The differences between nature levels were not statistically significant F (2, 73) = .137, p= .872 suggesting that the outdoor environment may support more prosocial behaviour, regardless of the level of nature.

Nature level and self-directed play and talk with peers (PPT)

A one-way ANOVA compared the difference between time spent in PPT in the indoor and outdoor conditions, across each nature level. There was an increase in time spent in PPT across all three nature-levels: high-nature (*M* = 0:01:02, *SD*= 0:02:40) medium-nature (*M* = 0:01:33, *SD*= 0:03:32) and low-nature (*M* = 0:01:23, *SD*= 0:02:55.) The differences between nature levels were not statistically significant F (2, 72) = .206, p= .814 suggesting that the naturalness of the environment does not significantly affect how much time children spend in PPT.

6.4.8 Individual differences

To identify whether specific groups of children were less likely to show antisocial behaviour when outdoors, a series of binomial logistic regressions were performed to ascertain whether gender, having an existing indoor/outdoor preference and children's z-scored SDQ total score would predict whether participants were less antisocial in the outdoor condition

The logistic regression models were not significant for gender, $\chi^2(1) = .224$, $p = .636$), indoor/outdoor preference $\chi^2(1) = 1.714$, $p = .190$ or SDQ total score $\chi^2(1) = 1.444$, $p = .229$, suggesting that none of these individual differences significantly influenced whether a child displayed less antisocial behaviour outside.

The same procedure was repeated for prosocial behaviour and again, the models for gender $\chi^2(1) = .310$, $p = .578$, indoor/outdoor preference $\chi^2(1) = 3.397$, $p = .065$ and SDQ score $\chi^2(1) = 1.014$, $p = .314$ were not statistically significant, suggesting that none of these individual differences significantly influenced whether a child displayed more prosocial behaviour outside.

Finally, the logistic regression was used to examine whether the same three variables would predict whether participants spent more time engaged in PPT outdoors. Only the model for gender was statistically significant $\chi^2(1) = 3.923$, $p = .048$, explaining 7.6% (Nagelkerke R Square) of the variance in which condition children engaged in more PPT and correctly classified 63.8% of cases. Boys were almost three times as likely as girls to show increased PPT in the outdoor condition.

Effect of condition on children with high baseline antisocial behaviour

In order to examine whether children who were the most antisocial in their indoor classroom, were more likely to experience improved behaviour outdoors, children were split into two groups - ‘High antisocial’ and ‘Rest of sample’.

To determine whether children were ‘High antisocial’ or not, their behaviour data from the eight indoor sessions were used. Indoor behaviour was considered a baseline measure as this represented how the children behaved when they were in their typical learning environment.

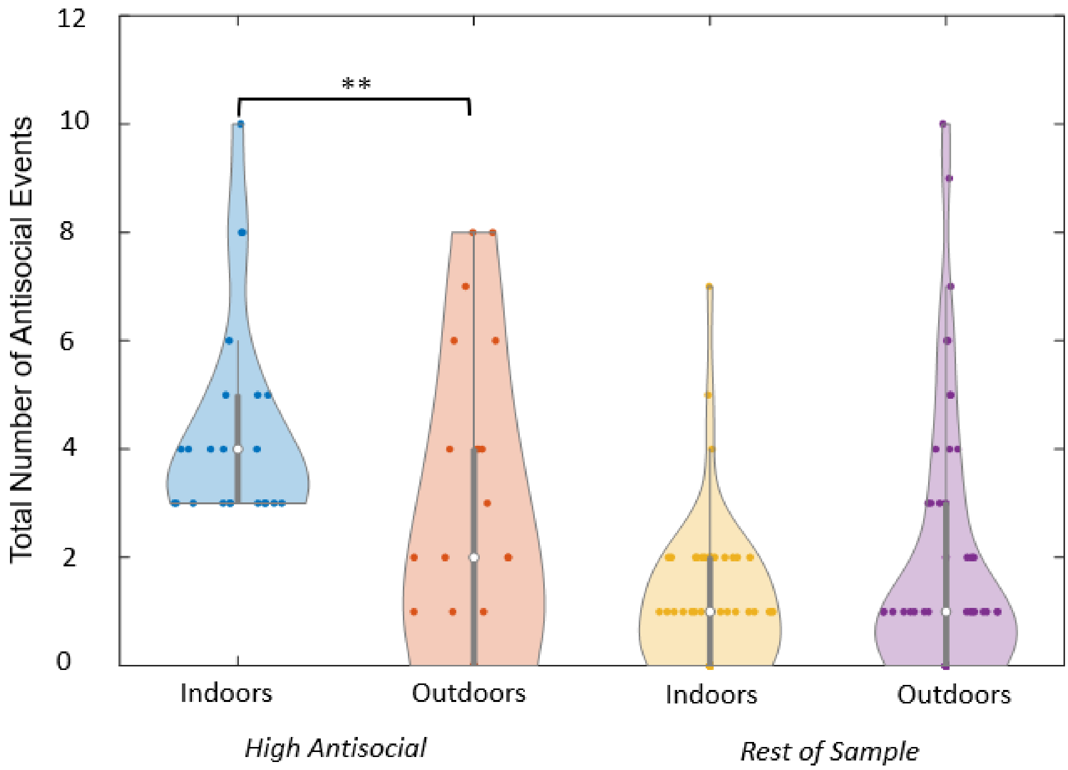
Children were identified as ‘High antisocial’ if they were >0.5 SD higher in their number of indoor antisocial events than the group mean for their school. The ‘rest of sample’ group were those who were did not meet this criteria. Of the 76 children, 24 were determined to be ‘High antisocial’ and 52 were not.

Due to non-normal distribution of the indoor and outdoor antisocial datasets and a non-symmetrical distribution of difference scores, normality tests were not met for either t-tests or Wilcoxon signed rank. Therefore, an exact sign test was conducted to determine the effect of condition on children’s anti social behaviour. Of the ‘High antisocial’ children, 16 children were more antisocial indoors than outside, 5 children were more antisocial outdoors and there was no difference between conditions for 3 children. There was a statistically significant median increase in antisocial behaviour (*Mdn* = 2.5) when the ‘high antisocial’ children were indoors (*Mdn* = 4) compared to outdoors (*Mdn* = 2), z = -2.390, *p* = .027, r= -0.30.

Of the ‘Rest of sample’ children, 10 children were more antisocial indoors than outside, 20 children were more antisocial outdoors and there was no difference between conditions for 22 children. There was not a statistically significant median increase in antisocial behaviour (*Mdn* = 0.0) when the ‘Rest of sample’ children were indoors (*Mdn* = 1) compared to outdoors (*Mdn* = 1), z = -1.643, *p* = .100, r = -0.18.

In other words, the most antisocial children were significantly *less* antisocial in the outdoor condition, whereas their non-antisocial peers did not show this effect. These differential effects of condition, according to whether participants were categorised as ‘high antisocial’ or not, are illustrated in the violin plots in Figure 24 below.

Figure 24 *Violin plots comparing indoor and outdoor antisocial behaviour across 2 different baseline antisocial behaviour groups*



Note. Each dot represents the total number of antisocial events for one child (totalled across 4x 5minute segments). White dots denote the median. ** denotes a significant difference between conditions.

Effect of condition on children with low baseline prosocial behaviour

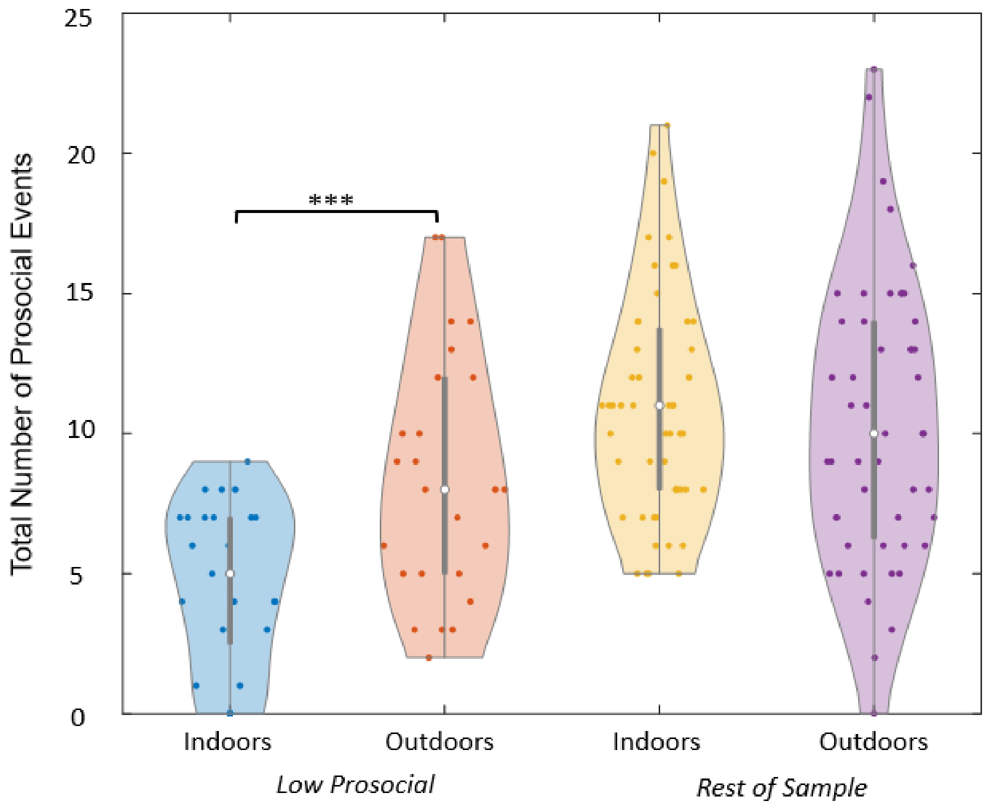
The same procedure was repeated to determine the effect of condition on children's prosocial behaviour. Children were split into two groups - 'Low prosocial' and 'Rest of sample'. 'Low prosocial' children were determined by being >0.5 SD lower in their number of indoor prosocial events (calculated across eight indoor sessions) than their school group mean. The 'rest of sample' group were those who were did not meet this criteria. Of the 76 children, 25 were determined to be 'Low prosocial' and 51 were not.

In the ‘Low prosocial’ sub-group, only three children were more prosocial indoors than outside, 21 children were more prosocial outdoors and there was no difference between conditions for one child. There was a statistically significant median increase in prosocial behaviour (*Mdn* = 3) when the ‘low prosocial’ children were outdoors (*Mdn* = 8) compared to indoors (*Mdn* = 5), z = -3.682, p <.001, r = -0.42.

In the ‘Rest of sample’ sub=group, 26 children were more prosocial indoors than outside, 22 children were more prosocial outdoors and there was no difference between conditions for three children. There was not a statistically significant median increase in prosocial behaviour (*Mdn* = 1) when the ‘Rest of sample’ children were outside (*Mdn* = 10) compared to indoors (*Mdn* = 11) z = -.433, p = .665, r = -0.05.

In summary, the least prosocial children were significantly *more* prosocial in the outdoor condition, whereas their more prosocial peers did not show this effect. These differential effects of condition, according to whether participants were categorised as ‘high prosocial’ or not, are illustrated in the violin plots in Figure 25 below.

Figure 25 *Violin plots comparing indoor and outdoor prosocial behaviour across 2 different baseline prosocial behaviour groups*



Note. Each dot represents the total number of prosocial events for one child (totalled across 4x 5minute segments). White dots denote the median. *** indicates a statistically significant effect

6.5 Discussion and conclusions

The primary findings of this study were as follows: Firstly, when eight indoor and eight outdoor sessions were matched within an urban school setting, the outdoor environment did not have a significant effect on children's antisocial or prosocial behaviour when data was analysed at a whole group level. However, when children were split into groups according to their behaviour indoors, those with the highest levels of indoor antisocial behaviour, engaged in significantly less antisocial behaviour outside. Being outdoors reduced antisocial behaviour for 67% of the children who were categorised as being highly antisocial.

Secondly, following a similar pattern of effects, children who were the least prosocial indoors displayed significantly more prosocial behaviour outside. More prosocial behaviour was observed outdoors for 84% of the children categorised as being least prosocial indoors.

Thirdly, results revealed that even when analysed as a whole group, on average children engaged in significantly more self-directed talk and play with their peers (PPT) when in the outdoor condition, regardless of the amount of nature in the outdoor environment.

And finally, noise and heart rate did not appear to mediate relationships between the environment and children's behaviour. Nor were any individual differences variables (such as gender, SDQ scores and socio-economic status) able to significantly predict which children would show more prosocial behaviour and less antisocial behaviour outdoors.

Taken together, these findings suggest that utilising an urban outdoor environment can effectively support the behaviour of children who struggle the most with their behaviour indoors. Given the statistics cited in the introduction to this study and in the literature review in section 2.6, which describe the social and economic costs of antisocial behaviour and school exclusions and suspensions, this is a promising finding which suggests that making more use of outdoor spaces in school could support struggling students to self-regulate their behaviour. The outdoor environment also elicited more self-directed peer play and talk which could have a positive impact on other areas of learning and development. Future research could explore whether this increase in PPT has downstream positive effects on other outcomes such as children's imagination, speech and language and social skills.

This study's results build on previous literature which evidences that access to outdoor spaces, especially natural ones, benefits children's behaviour and social skills (Bikomeye et al., 2021; Mygind et al., 2021; Putra et al., 2020; Zare Sakhvidi et al., 2022). Much of this prior literature is correlational and no previous studies have compared children's prosocial and antisocial behaviour quantitively across matched indoor and outdoor settings. The originality of this study makes direct comparisons to prior literature impossible. However, some existing literature suggests that children's language and communication is better outdoors (Richardson et al, 2019; 2023) and the findings reported here, regarding increased PPT in the outdoor condition, are consistent with this literature.

An unexpected aspect of this study's findings was a failure to find what mediates the learning environment's effects on behaviour. Analyses showed that, although outdoor sessions were significantly quieter than indoor sessions, across all participating schools, noise was not consistently correlated with prosocial or antisocial behaviour. There are several potential reasons for this, but the most likely is that noise levels were related to overall levels of interaction between the participants. In other words, high levels of noise were not necessarily a source of stress which could lead to poor behaviour, but could also signify high levels of positive engagement with children talking and playing together. A key limitation of this study was that it did not distinguish between child-generated noise and background environmental noise such as road traffic. Future research should address this by taking noise readings in unpopulated learning environments. In addition, noise analyses were only conducted on the group as a whole and the impact of noise on sub- groups of children was not analysed. Future research could incorporate children's noise sensitivity as a variable, and also analyse whether noise was associated with behaviour for the 'high antisocial' and 'low prosocial' subgroups specifically.

Heart rate was also investigated as a possible mediator, but no significant relationships were found between heart rate during carpet time and behaviour in the five minutes thereafter. This is likely to be because of the time-lag between the heart rate and behaviour measures, which was necessary due to the confounding effect of physical movement. Heart rate during choosing time (when behaviour was measured) was not used as children were physically active during this period and their levels of movement would have confounded results. This could be tackled in future research by examining children's prosocial and antisocial behaviour whilst they are seated, so that heart rate and behaviour can be measured concurrently. In addition, as stated above, further analyses could explore whether heart rate was associated with behaviour for specific sub-groups of children including those who struggled most with their behaviour indoors, and those with the highest resting heart rates in their usual indoor classroom.

This study controlled for the size of the space available, keeping this consistent across indoor and outdoor conditions. Therefore, having more space to physically move around cannot be cited as the reason why outdoor environments supported self-regulated behaviour for children who struggled indoors. There must, therefore, be other features of the outdoor environment which made it beneficial. Future research should continue to explore which aspects of the outdoor environment support behavioural self-regulation, so that this information can be used to create more optimal environments for children who struggle with their behaviour in school.

The fact that this study found significant effects of the environment on the groups of children who struggle most with their behaviour, but not on the rest of the sample, suggests that there are differential effects which warrant further exploration. Further analysis could be conducted to examine these groups and try to ascertain why some children are ‘high antisocial’ or ‘low prosocial’ and which other features these children have in common. Contrary to expectations, children’s SDQ scores did not predict whether their behaviour was better outdoors. It is possible that the SDQ was not a reliable measure in this context, as anecdotally many teachers reported that they were unsure how to answer some of the items, as they related to situations that they had not observed the child in before.

Previous research has suggested that outdoor environments may have differential effects on the behaviour of specific groups of children. Whilst some studies report that nature affects girls’ behaviour more than boys’ (Taylor & Butts-Wilmsmeyer 2020; Taylor et al, 2002) others report the opposite effect (Liao et al, 2029; Markevych et al., 2014). However, across almost all analyses in the present study, gender effects were not found. The only reported gender effect was that boys were almost three times as likely as girls to increase the amount of time they spent in PPT in the outdoor condition. In earlier literature, differences have also been reported in how nature impacts the behaviour of children from high and low income families (Richardson et al., 2017) and children of different ethnicities (McEachan et al., 2018). However, the present study did not replicate these findings either.

Regression analyses confirmed that none of the other demographic variables collected significantly predicted whether children’s prosocial and antisocial behaviour improved outdoors. As discussed previously in Chapters 4 and 5, this may be because this experimental design was not well set up to detect individual differences, and because some of the demographic measures used (FSM and SEND) were problematic to collect with this sample.

A key limitation of this study, was that due to the labour intensive nature of the coding protocol, only eight x five-minute segments of choosing time were coded for each child which prevented exploration of how the outdoor environment affects behaviour over longer time periods. Future research should aim to observe behavioural effects over longer time scales, exploring whether effects attenuate over time, or build longitudinally as children spend more and more time outdoors. However, the results of this study hopefully provide a helpful foundation upon which further research into this important area can be built.

Conclusion

In conclusion, this study has examined the impact of outdoor learning on 4-5 year old children from an urban population in a deprived setting. Its results showed differential effects of the outdoor environment, namely that children who struggle with their behaviour the most indoors, confer the greatest benefits from being outside. The outdoor environment also elicited significantly more self-directed talk and play with peers, for the group as a whole. These effects held true across various schools, regardless of the amount of nature in their outdoor area and provide a strong rationale for using outdoor environments to support challenging behaviour in schools.

Crucially, unlike other outdoor approaches such as forest school, the outdoor condition in the present study involved making no changes to the school's typical pedagogy, curriculum and resources. Children engaged in the same activities as they would in their usual indoor classroom. This gave opportunities to disentangle the specific impact of the outdoor environment aside from other potential confounds. This methodological decision is also pertinent because it means the outdoor intervention involved no cost to the school, both in terms of financial costs and teacher time and workload. As the outdoor sites utilised were spaces on the urban school's own grounds, no travel was required to nature sites and no specific resources or training were required. This study's results suggest that all outdoor areas, even those with low levels of nature, can be beneficial in supporting children's behaviour, making this intervention accessible even to settings with limited funding.

6.6 Summary of findings across all three school-based studies

Bringing together the results from all three studies allows for exploration of the inter-relationship between different measures and the effects of individual differences. Results are summarised briefly here and discussed further in Chapters 8 and 9.

Appendix 15 contains a summary table which combines the results from all three studies. This was generated to enable comparisons to be made more easily across multiple outcome variables.

Nature-level did not significantly mediate effects for any of the outcome variables studied, whilst noise and heart rate were associated with some outcomes but not others.

Higher levels of noise were associated with higher resting heart rates in the indoor condition only. Unexpectedly, higher levels of noise also associated with more looking time in the outdoor condition and with a greater percentage of time on-task and longer peak focus in both conditions. Finally, higher levels of noise were associated with less prosocial behaviour in the indoor condition.

Heart rate was associated with looking time but no other outcome variables.

In terms of demographic differences and the extent to which they predicted who would be most likely to benefit from an outdoor learning environment, EAL and SDQ score were not significant predictors for any of the outcome variables across studies.

Gender effects were observed for both time on-task and self-directed peer play and talk, whereby boys were significantly more likely than girls to show improved outcomes when outdoors. Girls, however were more likely to show decreased heart rates in the outdoor condition.

Children eligible for free school meals were significantly more likely to score higher in the literacy task when outdoors, yet slightly less likely to have lower resting heart rates when outdoors.

Finally, children with a pre-existing preference for being outdoors (the majority of whom were boys) were significantly more likely to be more on task outdoors and have a longer peak focus in the outdoor condition, yet an outdoor preference does not appear to influence their levels of prosocial and antisocial behaviour outdoors.

The strongest and most significant effects observed across the three studies were the differences in noise levels and resting heart rates outdoors compared to inside, and the impact of the outdoor environment on peak focus and time on task for low baseline attention children.

Chapter 7

School based research – what can be learnt from this project about collaboration, knowledge mobilisation and dissemination.

7.1 The importance of bridging the gap between research and practice in schools

Teachers and schools are increasingly expected to be research-informed in their pedagogy and practice. This is evident through Ofsted's research review series (2021) as well as the inclusion of key research from cognitive psychology, such as cognitive load theory, in their guidance to teachers. In addition, there are multiple organisations set up to support schools and education systems in using research evidence to improve school and pupil outcomes such as The Chartered College of Teaching, the Centre for the Use of research and Evidence in Education (CUREE), The Education Endowment Foundation (EEF) and the National Foundation for Educational Research (NFER) to name just a few. There has been a huge increase in randomised controlled trials (RCTs) conducted in the field of education over the last 15 years (Connolly et al., 2018).

However, this evidence-informed approach is not without contention. Some claim that RCTs, whilst considered the 'Gold standard' are not as applicable to education as they are to clinical research, explaining that the education system is too complex, and procedures like tightly controlling variables and blinding students and teachers to the aims of the study are often unethical or even impossible in a school environment (Sullivan, 2011). Others point out that educational RCTs commonly find small and uninformative effects and question whether conducting them is worth the time and financial cost (Lortie-Forgues & Inglis, 2019).

Calls have been made for greater engagement with a diverse range of research methodologies to inform educational practice, in order to generate richer understandings, cautioning that without this, research could create a narrow and oversimplified view, which underplays the complexity of educational practice (Burnett & Coldwell, 2020).

One solution is for researchers and teachers to work more closely together, ensuring that research designs and measures are more relevant to teachers and can be practically conducted in school settings rather than in laboratories or under tightly controlled conditions which don't reflect everyday teaching. It has been suggested that educational research needs to move on from 'what works' towards 'what works for whom, under what conditions and in what circumstances.' (Connolly et al, 2019 p 290).

This project aimed to work towards this goal, working in partnership with teachers to design the research project and ensure it worked for them and their students without detracting from the school's planned curriculum in any way. The aim was to be robust methodologically, whilst retaining enough flexibility to account for the intricacies of the educational environment.

This chapter outlines the special considerations taken to ensure that this research project was as non-intrusive for teachers as possible and had high ecological validity to maximise its applicability and usefulness to school settings. Approaches used and steps taken are described in the hope that they may prove useful to others conducting school-based research.

7.2 Special considerations when working in schools

Pupil consent and comfort

As explored in literature on school-based research and consent (David, 2001; Kirby, 2020; Kraftl et al., 2021) there are specific issues to consider when gaining children's permission to take part in a research study which takes place on school premises. Children are used to conforming to adult's expectations and instructions in a school setting and may feel less able to dissent than they would at home, or in more power-neutral settings. Children may feel reluctant to say 'no' to a researcher in a school setting if they equate researchers with teachers, as they may perceive this to be ‘naughty’. Several actions were taken to try and mitigate this and ensure that children felt informed about the project, and able to refuse participation or withdraw their consent at any time.

A social story was created for the project (Appendix 1) and shared with children. A social story (Gray,1991) is a social learning tool, often used with autistic children. It is a description of a specific situation or activity which explains what children can expect in that situation. A slideshow version of the social story, with photographs to accompany it, was presented to each participating class. It was felt that, despite being developed as a tool for autistic children, in this context it would be beneficial for all children as it introduced the project in an accessible way, as well as key concepts and vocabulary such as what it means to do research and experiments, and what a scientist is. Given that many of the children in the sample spoke English as a second language, it was important to inform them about the project using pictures and physical demonstrations rather than relying solely on spoken information. Buring the recruitment process, class teachers were asked whether any of the children were non-verbal, had other special educational needs or were new to learning English and whether this might affect children’s ability to express their consent or dissent. If required, children were provided with picture cards to indicate if they wanted to cease participation.

To further support children in understanding that they were able to dissent, they were explicitly reminded that when their name was called to put the equipment on, it was fine to say ‘no’ and that this was not a problem. Children were provided with phrases to help them feel more comfortable in doing this. “You can say ‘no thank you’ or, ‘not today’ if you don’t want the equipment on this time.” Providing children with the words to dissent can support less confident speakers and provide a framework which shows that it is acceptable to dissent. Children were also reassured that they would still be able to join in next time if they wanted to.

Participants were asked to come to the researcher if any of the equipment was uncomfortable or bothering them. On these occasions, the researchers would adjust any equipment as required and then check ‘Are you happy with that now?’ Equipment was removed during testing if children asked for it to be removed at any point. Throughout data collection sessions, children were observed and if any appeared to be uncomfortable or agitated by the equipment, adults checked in with them and asked if they were ok and whether they needed help with their equipment. Non-verbal signs of dissent such as pushing the equipment away during fitting, trying to pull it off or shaking their head were taken as requests to withdraw. Children who did participate were not rewarded in any way, for example by giving them a sticker or special praise – as this may have made others feel coerced into participating.

Furthermore, researchers were careful to distinguish themselves as non-teachers so that children did not transfer teacher-student power dynamics across to the research situation. Steps to distinguish themselves from teachers included using their first names instead of Ms/Mr and a surname, wearing less formal clothes, and not engaging in any teacherly behaviour/duties such as behaviour management or leading learning tasks in the classroom. On occasions when children asked for support with learning activities, researchers redirected them to their teacher.

Use of head mounted video data

Using head mounted cameras worn by children created additional ethical issues to consider. Unlike a fixed camera on a tripod, whereby the researcher is in control of who and what is filmed, when children are fitted with wearable cameras it is often not possible to control what, and who, is captured on the footage. Children moved around the learning environments, sometimes into corridors or other classrooms, as well as visiting the bathroom.

To protect the children's privacy and also the privacy of adults and children who were not active participants in the project, children's head mounted cameras were removed whenever they left the designated data collection area, for example if they visited another classroom or went to speak to a member of staff in their office. All equipment was also removed before a child went to the bathroom.

Parents with children in participating classes were informed about the project and signed a consent form if they were happy for their child to be fitted with the wearable equipment. It was explained that all children would still take part in the indoor and outdoor sessions, even if they were not wearing the project equipment.

This inevitably meant that children whose parents had not consented for them to wear the equipment, may still be captured on the video footage.

For this reason, it had to be made very clear that all video footage would be used only for the purposes of this research study and would only be accessed by the research team. Video footage would not be used to report back to teachers on children's development and attainment or general behaviour. In the case of misbehaviour being captured on film, this was not reported to the participating schools and teachers unless there was a safeguarding concern.

Parents were given the opportunity to withdraw their child from the data collection sessions if they did not want them to be present when video footage was being collected. In this circumstance, the child would have joined another reception class in the school for the duration of the data collection session. In this project, no parents withdrew their children and all students were allowed to remain present for the data collection sessions. This was important for maintaining ecological validity; the sessions would not have represented everyday lessons well if only half of the children in the class were present. However, for future research it is worth considering carefully how to ensure that parents feel comfortable with their child being captured in video footage. If parents are concerned that their child's behaviour or learning may be judged in an unfavourable way which might disadvantage their child in the future, they are unlikely to agree to them being captured on film. To this end, the following messages were communicated with both parents and teachers as well as any members of the research team:

- Video footage will only be shared within the research team and will not be shown to teachers, parents or students
- Incidents captured on camera will not be reported to teachers or parents unless there is a safeguarding concern
- Only the prosocial and antisocial behaviour of participating children will be analysed. If prosocial and antisocial incidents involved non participating children are captured in the video footage, these incidents will not be coded
- All data arising from the project will be anonymised using participant numbers

Barriers to data collection

Day to day life in schools can be unpredictable and there are myriad events and variables which make data collection problematic or even impossible.

For this project, before starting data collection at each school, there was a meeting between the researcher, teacher and EYFS leader to discuss any potential barriers or timetabling issues which may disrupt data collection. This information informed the planning and timetabling of sessions in each class. Such issues included:

- Upcoming INSET days when children would not be present
- Lessons taught by supply teachers or specialist teachers e.g. Music, PE, Forest school (These were avoided as different lesson content and teaching staff may confound results)
- Upcoming special events which may interfere with the children's usual timetable e.g. Performances, assemblies, Christmas parties, transition days etc

Despite this planning, there were still unforeseen events which delayed or cancelled data collection or meant that participant numbers were lower for some sessions than others. These included:

- Outbreaks of chicken pox and Covid which affected student attendance
- Teachers on leave for illness
- Ofsted inspections
- Teacher strikes
- Technical issues with equipment
- School closures due to heat waves
- Other inclement weather including heavy rain, snow and strong winds

To allow for such barriers, this project planned to collect data on twice as many days as were needed for analysis. At each school there were 8 indoor and 8 outdoor sessions planned, even though all analyses could be run using just 4 indoor and 4 outdoor sessions. This ensured that unforeseen events did not prevent thresholds being met for analyses.

7.3 Recruiting schools and children in challenging circumstances

Gaining the time and cooperation of school leaders and teachers who work in areas of high deprivation can be difficult. These professionals are working in extremely challenging circumstances and this pressure can result in schools feeling as if they do not have the time to participate in research, nor can they afford the risk that it may detract from more pressing matters such as covering the school curriculum and meeting increasingly high standards in national assessments.

Parents can also be reluctant to give consent for their children to participate in research projects. Those for whom English is not their first language, or who have low levels of literacy, may not understand the information given to them about the project. Others may feel distrustful of researchers. Families living in challenging circumstances may simply not have the time to respond to a letter or consider their child's participation.

Furthermore, the data collection for this project took place shortly after schools had re-opened after Covid lockdowns. Schools could have understandably withdrawn their participation from the project, over concerns about 'Covid-catch up' and the need to return to normal routines as quickly as possible. Similarly, parents may not have wanted researchers fitting equipment onto their child at a time when some people were still trying to distance socially.

Despite these potential challenges, this research project was successful in recruiting several schools from areas of high deprivation, where teachers were under considerable pressure, and was successful in recruiting its target number of participant children. This was the result of a carefully planned strategy to build relationships with participating schools and their children and parents. The following section details how these schools were recruited and brought on board with the study's aims, and how consent was gained from parents and children. Suggestions are made as to how other researchers may engage with such schools in future.

School recruitment

After making contact with the Newham Learning group and gaining some initial interest in participation, an online presentation was delivered to headteachers from the schools, to outline the background to the research, what the project would involve and what schools might gain from taking part. Benefits to the schools were clearly outlined to encourage participation. These included:

- Insights into their student's behaviour, learning and wellbeing
- The opportunity to take part in new, cutting-edge research with specialist equipment and technology
- Opportunities to partner with researchers and psychologists and learn more about how research is conducted (CPD opportunities for staff)
- The opportunity to co-design the project and help research become more school-relevant and contextual
- A detailed report about the data collected in each class
- Invitations to attend a series of webinars detailing the project's results and any implications for classroom practice

Schools indicated an expression of interest via email, and following this, the early years teachers and school leaders from interested schools were asked to attend an online meeting where they could find out more about the project and ask any questions. During this meeting, logistical information was collected about each school for example:

- What is the ethos and approach to learning at the school and how does this fit with the data collection procedures for the project
- Did the schools have accessible outdoor areas which could be utilised for the project?
- Were there particular times of the school year during which it would be problematic or preferable to collect data for individual schools?

Schools were also asked about their own development priorities and targets to see whether there was any overlap with the project aims which could be utilised. At each stage, the needs and pressures of schools were considered when planning sessions and timelines.

The headteachers of each school who wanted to participate then completed an online survey outlining what they were being asked to commit to and any potential inconveniences this could cause. Headteachers had to confirm that they understood and agreed to these, and that they had also shared the project information with the reception teachers from whose classes data would be collected. The aim of this was to reduce the risk of schools dropping out at a later stage, due to any misunderstandings about what was required from participation. It is important to gain the understanding and agreement of not just school leaders, but those teachers whose day-to-day work in the classroom is directly impacted by the research project. A researcher and class teacher meeting prior to data collection was a compulsory requirement for participation in this project.

These strategies enabled a diverse participant sample to be recruited from across several schools in challenging circumstances. Whilst recruiting schools in deprived areas can be difficult, it is vital that such schools are represented in educational research. Investing time and thought in how to form strong partnerships with schools enabled this to happen.

Participant recruitment

Teachers and school leaders were asked for their input on how pupil participation rates could be maximised, suggesting strategies such as:

- Having researchers available during school drop off and pick up times, to demonstrate equipment and chat to parents
- Putting project information on school platforms such as the Tapestry app or school website, as well as in the school newsletter
- Utilising bilingual school staff to translate information letters and consent forms

Parents who could not attend the school site to hear more about the project were communicated with online. Zoom meetings were offered and a video about the project was recorded and uploaded to the school’s communication platforms.

Children were also familiarised with the research team via preliminary visits where they also got to see and play with some of the wearable equipment. Time was spent in each class, getting to know the children and interacting with them before the project began. This sparked children's interest in the research, many of whom went home and asked their parents to give consent for them to take part.

Using ECG equipment with young children

One of the most challenging aspects of data collection in these studies, was using the ECG equipment with young children. The ECG monitor was attached to the child's skin using electrode stickers with a metal stud. These were unfamiliar to the children and many of them were nervous about wearing them. Furthermore, the stickers were sometimes difficult to remove, which caused some minor discomfort. Initially, drop-out rates were high as a result of children's reluctance to wear the ECG monitor. However, several strategies were employed which enabled children to feel more comfortable with the ECG equipment. These reduced drop out rates significantly and are listed below:

- The use of a medical adhesive remover spray made removing the ECG stickers painless and easy
- Children were asked if they would like to attach and remove the stickers themselves or whether they would prefer an adult to help
- During the fitting and removal of ECG equipment, researchers chatted to the children to help them feel at ease.

7.4 The role of a Knowledge Exchange Officer in building school-researcher partnerships

This project aimed to help bridge the gap between research theory and practice, and to provide opportunities for researchers and teachers to enhance one another's practice. To this end, additional Knowledge Exchange funding was sought to create a partnership between The University of East London and Newham Learning, in order to fund the employment of a Knowledge Exchange Officer who would be the main point of contact between the partnership of 40 schools, and various departments at The University of East London.

UEL and Newham Learning each contributed 50% of the costs of a two-year position. The Knowledge Exchange Ofifcer’s role throughout the two-year contract involved the following:

- Liasing with Newham Learning schools to see how research and expertise at the Baby Development lab at UEL could support and develop what they were doing in school e.g. offering CPD opportunities for teachers and undertaking mini projects e.g. measuring noise levels in the school lunch hall to inform decisions on soundproofing

- Sharing the results of the present study by working alongside the researcher to produce reports for each school, providing project updates for Newham Learning newsletters and presenting emerging findings at Newham Learning Conferences

- Developing strong working relationships with schools in the partnership in order to provide further opportunities for them to participate in other research projects and grant applications. For example, a PhD position was funded to look at how outdoor learning could support students in a Pupil Referral Unit in Newham, and Newham learning were recruitment partners for bids to ERSC and Wellcome Trust.

- Meeting with various university and school departments such as the Educom and Psychology departments at UEL and school leaders from Newham Learning in order to improve collaboration and communication.
- Co-designing and presenting a series of webinars for Newham Learning schools, which shared the results of this study and summarised the existing literature in associated areas (the impact of noise in schools, how attention develops etc), and offering practical tips and suggestions for how to apply this information to everyday teaching practice.
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7.5 Engaging a wider audience in the findings of this study

In addition to the work of the Knowledge Exchange Partnership, findings from the present project, as well as summaries of the existing evidence base were disseminated by the researcher amongst the wider community in several other ways,

An Instagram account was created to share research summaries and project updates in simple, accessible language. Posts were made at least once each week throughout the 4.5 year duration of this project which shared findings from other research on outdoor learning as well as updating followers on the design and progress of the studies reported in this thesis. This account amassed over 5400 followers throughout the course of the project and both parents and educators from across the globe were engaged in asking questions and posting comments. During the early stages of the project design, the account was used to ask questions and post polls to ask for teachers' input on project design ideas.

Additionally, multiple articles on the topics of noise, learning environments, research in early years settings and the impact of outdoor learning were published in teacher and EYFS practitioner-friendly publications such as *Early Years Educator* and *Nursery World* magazines, *Impact*, the journal from The Chartered College of Teaching, *The Childcare Professional* and the *PACEY* (Professional association for childcare and early years) newsletter. This was an important method for disseminating research that could influence practice, as articles in scientific journals are not frequently accessed by teachers due to paywalls and workload.

For the same reason, presentations were delivered at several free online and face to face events to reach teacher and parent audiences including The Nursery World Show, The Centre for Educational Neuroscience webinar and The Outdoor Learning Conference.

7.6 Future recommendations for collaborative research between schools and academics

On the basis of the work undertaken as part of this research project, the following recommendations may help others who wish to conduct research in school settings:

1. Make links with a partnership or network of schools so that via one point of contact, you can access multiple schools who may share a particular focus or ethos pertinent to your project.
2. Clearly outline at the start of the project, the commitments expected from the school and teachers involved, and the commitments they can expect in return from the researchers. Be clear from the start about any potential impact on the school timetable, curriculum and planned activities.
3. Wherever possible, collaborate and co-plan with teachers to avoid disruption to planned curriculum activities. Time which detracts from the teachers' planned input may have a detrimental impact on children's learning and progress.
4. Consider having a teacher to act as an advisor on the research team and offer a school-perspective, particularly at the design and planning stage, to improve awareness of logistical issues which may arise.
5. Consider having someone in a Knowledge Transfer role who can maximise opportunities for researchers to learn from teaching staff and vice versa, and who can disseminate project results and their implications for teaching practice.
6. Learn about the development priorities and key challenges for the schools you are recruiting and consider how your research project addresses these. If possible, incorporate measures or aspects of research design which enable the school to work toward their own aims. This will help get more schools on board.
7. Consider how children can be put at ease throughout the process and how to enable them to give consent or dissent within a structured school setting where they may not be used to saying 'no' to what an adult would like them to do.

8. Plan for a large number of contingency sessions and collect in the region of 50%-100% more data than is needed to meet minimum thresholds for analyses.
9. Keep a daily log of any potential confounding variables e.g. unusual events, unexpected interruptions, extreme weather etc and the times that these occurred, so that these can be considered alongside future analyses and referred back to if outliers occur in the data.
10. Think about how best to share project findings beyond the academic community, so that they reach people at the front line of education and are presented in a way which is accessible for educators and parents. Examples include utilising social media, speaking at free events and publishing articles in popular print and online publications. Using school networks to contribute to newsletters and parent apps is also a good way to keep the local community updated about project progress and outcomes.

The author of this thesis had prior experience as a teacher and school leader and this enabled a lot of the aforementioned strategies to take place. Having insight into the school system and an understanding of the local community was a significant advantage in this situation.

Teachers and ex-teachers are well placed to conduct educational research because they understand the contextual complexities of the educational environment. If research is going to inform future education policy it is also important that those working in education have been co-collaborators in the design and implementation of this research, to ensure that it is meaningful and provides useful insights that can be applied and generalised to the teaching context.

It would be welcomed to see funding allocated to provide teachers with training in research strategies and to promote more cross-disciplinary research which is codesigned with teachers. At a time when teacher recruitment and retention is a challenge, career pathways into educational research could help attract and retain teaching staff, as well as enhance their practice.

Chapter 8

Summary and integration of findings

In summary, this thesis aimed to synthesise the existing literature on nature's effect on children's stress, attention and behaviour, paying particular attention to any differential effects of nature and exploring the mechanisms behind the nature-effect, as well as adding new findings for each of these outcomes.

Although the literature reviews were categorised into three sections; exploring evidence of effects on stress, attention and behaviour separately, understanding the way in which these three areas inter-relate is important in advancing our understanding of the nature-effect. Although many of the studies, theories and pathways discussed in this thesis artificially separate physiological from psychological stress, attention from emotions, or even one aspect of attention from another, there are no strict boundaries at a neural level which support these distinctions (Wass et al., 2022). Whilst cognitive tests or studies using brain scans might assert that self-regulation of attention or stress utilises one specific part of the brain, or can be measured with one specific activity, the reality is much more complex and multifaceted. Concepts such a self-regulation cannot be neatly measured or viewed in silo, separate from other factors such as environmental influences, individual differences, motivations and preferences. Stress, attention and behaviour interact and overlap with one another and future exploration of the mechanisms behind this and how they are influenced by outdoor environments is key.

The empirical studies that formed Chapters 4, 5 and 6 were designed to provide robust evidence of the impact of learning environments, and to isolate the specific influence of being outdoors, whilst controlling for other variables. This was to ascertain whether even urban primary schools, with limited nature and outdoor space, could reap some of the reported benefits of the nature-effect. With emerging studies on equigenisis highlighting the potential for nature access to narrow the disadvantage gap, this study also sought to investigate whether disadvantaged children show greater gains from learning outdoors.

At the heart of the project, was a drive to acknowledge the complexities of school contexts, and to respect that there is no 'one-size-fits-all' approach to education. Children's individual differences were incorporated and analysed throughout, rather than being obscured by only analysing data at a whole-group-mean level. It was vital to explore who the outdoor environment benefitted most, why this might be, and what these 'outdoor-gain' children might have in common. It is only by understanding these differential effects, that truly inclusive learning environments can be designed and provided.

Whilst some of the data analyses didn't reach statistical significance, the results from individual children were in some cases, quite staggering. For some students, being in the outdoor environment was transformative – leading to individual children scoring 140% higher on the literacy task, being on task for over 45% longer or speaking in much longer utterances when retelling a story. The project provided an opportunity for their teachers to observe these students in a new light. This was doubtless the most rewarding aspect of this project, and an example of how some data can be meaningfully, if not statistically, significant. However, it is important not to 'cherry pick' the most extreme results from the study. Although eight data collection sessions were conducted for each group of children, it is still possible that these results reflected sampling error. Further research with larger numbers of children and a larger number of sessions would be needed to check reliability.

It was important to systematically identify patterns and find generalisable results, as school-based research should ideally inform policy and practice. For these studies to make a compelling case for schools to utilise their outdoor spaces more often, they had to be rigorous. These studies did report several statistically significant findings which held true across multiple class and school groups. If replicated with larger samples of children from a range of localities, these findings could provide robust evidence that learning outdoors can benefit children's stress, attention and behaviour.

School study 1 was the first study of its kind, to compare noise levels indoors and outside across a series of matched lessons. It found that outdoor sessions were significantly quieter, across all classes and schools, and for both carpet time and choosing time - adding to the body of existing literature on noise levels in early years settings. Future research could explore this further, identifying why outdoor sessions are quieter, even in settings close to road and air traffic noise. More detailed analysis of soundscapes, predictability of noise, student-generated noise, signal to noise ratios and reverberation times would add more to our understanding of whether outdoor learning could help mitigate some of the detrimental effects of excess classroom noise.

Results from across Studies 1 and 3 showed that noise associates with heart rate and prosocial behaviour in the indoor condition only, suggesting that noise impacts children differentially depending on the environment that they are in. It is possible that high levels of noise feel more intense in the indoor environment, which is an enclosed space with more reverberation, and thus, it is more stress-inducing and has a knock-on effect on children’s ability to engage their parasympathetic systems and exhibit in prosocial behaviour. Qualitative information would further add to these investigations, exploring how children perceive noise levels in indoor and outdoor environments and how it affects their mood, perceived stress and behaviour.

School study 2 revealed significant improvements in outdoor attention during choosing time for the children who struggled the most with their attention indoors. ‘Low-baseline attention’ children spent more time on-task outdoors and also increased their ‘peak focus’, indicating that children were not just flitting from one activity to another, but stayed engrossed at an activity for more sustained amounts of time, suggesting higher levels of involvement and deeper learning. When previous studies have incorporated a baseline attention measure, this tends to be a single attention task or battery used only to assess pre- and post-intervention attention. In this study, baseline attention was determined by multiple measures, taken on several different occasions.

Despite other studies evidencing nature’s equigenic effects, this study did not find that learning outdoors had stronger positive effects on children from lower income families. In general, being eligible for free school meals did not predict whether children would show improved outcomes outdoors across a range of measures and in fact, children eligible for FSM did not show significant decreases in heart rate outdoors, unlike their non-eligible peers. For one outcome measure (the literacy task) low SES children did perform significantly better when outdoors, however, the small sample size for children eligible for free school meals (n=8) precludes this result from being generalisable. The lack of evidence for equigenic effects may have occurred for several reasons. Firstly, the levels of nature in the outdoor learning environments may not have been high enough to elicit these effects. Secondly, as discussed previously in section 4.5, eligibility for FSM is not a perfect proxy for being economically disadvantaged, especially in Newham where this study was located. Future research should look at composite measures of SES and also explore whether 'disadvantage' should be conceptualised more broadly in analyses. For example, by looking at children who are at higher risk of mental health issues, who have less adult support at home, and who have poorer access to greenspace outside of school.

Significant differences were found between baseline attention groups, indicating that whilst for 'high-baseline attention' children, the outdoor environment did not lead to significant improvements in attention, for 'low-baseline attention' children, it did. This finding has important implications for narrowing the gap between high and low achieving children and for supporting children with attentional difficulties. However, it also has methodological implications for future research, namely that attention studies should investigate whether baseline levels of attention mediate intervention effects.

Whilst it was predicted that higher levels of noise would associate with worse attention, in the present study, the opposite was true for most of the attention measures. This could be because higher levels of noise signified more engagement with peers and activities, and therefore more time focussed on-task. In the context of a reception classroom, learning is commonly play-based and interactive. Children are not expected to sit quietly whilst engaging in learning activities. Therefore, in future research it would be interesting to see how noise associates with attention in classrooms for older children where learning tasks are often quieter and more sedentary.

Finally, school study 3 revealed a similar pattern of effects regarding prosocial and antisocial behaviour; the children who struggled with behaviour the most, were the ones for whom the outdoor environment had the most significant impact. Contrary to expectations, higher heart rates and higher levels of noise did not associate with higher levels of antisocial behaviour, suggesting that other aspects of the environment outdoors must have supported the behaviour of children who struggle indoors.

These findings provide a rationale for reframing thoughts around children who are deemed as having problem behaviour or attention problems. In some cases, children may have diagnosed conditions and neurological differences. However, in others the problem may not necessarily be situated ‘within the child’ and may instead be a problem with a learning environment that isn’t compatible with the child and the task at hand. The results of study 2 and 3 demonstrated that in an outdoor environment, many of the children who struggled with attention or behaviour indoors, were able to attend and behave in equally as well as their non-struggling peers. In this way, the outdoor environment was an equaliser, reducing differences between baseline groups. Even for children who do have specific additional needs, previous research demonstrates that access to nature in an outdoor environment may have a positive impact on the strength and frequency of their symptoms (Faber Taylor & Kuo, 2009, 2011; Kuo & Faber Taylor, 2004).

In addition to these findings, the studies also revealed that children spend significantly longer engaged in self-directed play and talk with their peers when outdoors and spend significantly longer engaging with imaginative activities. This effect occurred even though resources and pedagogy were matched across settings. Eliciting the mechanisms behind this effect would enable early years settings to promote more social and imaginative play which is known to be beneficial for children’s learning and development (Mguidich et al, 2023, Singer et al., 2006).

Levels of nature did not significantly influence effects in any of the measures used across the three studies, although these results may be unreliable due to the small number of schools in each nature category, and the unstandardised method for rating nature levels. There was also a ceiling effect regarding the amount of nature present across schools as all of the settings were in urban locations. Comparing these urban outdoor areas with more rural and natural settings might have yielded different results.

Therefore several questions remain, what is it specifically about being outdoors that enabled children struggling with their attention to be more on task and engage with single activities for longer when they were outside? And why were children who struggle with their behaviour less antisocial and more prosocial when they were outside? Future research should incorporate other ways of differentiating between children such as sensitivity and temperament measures, as well as qualitative discussions with children to try and elicit why some children benefit more from the outdoors than others. In addition, more features of the outdoor environment need to be isolated in studies to disentangle what is having an effect. These features could include visual complexity, predictability, air quality, levels of light, and temperature.

Chapter 9

Overall conclusions

This thesis has contributed new understandings about the differential effect of the learning environment on children's stress, attention and behaviour. The use of wearable technology has enabled new insights into children's experiences in both indoor and outdoor environments.

Much existing research on the impact of learning environments has involved presenting participants with standardised tasks or tests in a controlled setting. Such tests can only offer insights into children's performance in a controlled and specific situation and bear no resemblance to any real-world outcomes which occur in dynamic and continuous environments (Wass et al., 2022). Research suggests that such tasks, such as those claiming to measure self-regulation don't predict real-world outcomes (Eisenberg et al., 2019). Furthermore, whilst such tasks often claim to extrapolate performance in a particular domain, as previously discussed, this is often over simplistic and fails to acknowledge the significant interaction and overlap between different cognitive processes and brain regions.

For this reason, this study aimed to measure and analyse children's stress, attention and behaviour as naturalistically as possible, utilising objective measures which were conducted during, or based on, children's everyday learning in the classroom. Throughout, data collection procedures allowed for interactions between the children, their peers and their environment to take place organically.

It was also important that the outdoor intervention tested in these studies, was realistic for schools to implement after the research project had concluded. Many educational interventions are costly in terms of money or time; requiring investment in specific training, materials or equipment, or relying on additional staff to deliver the intervention. This is especially challenging in current times, when 70% of English state schools have faced 14 years of real-terms cuts to their funding (Ofori, 2024). Some interventions may also have unwanted side effects such as taking time away from the planned curriculum which can leave some children falling behind on other developmental or curriculum goals which weren't targeted by the intervention.

However, spending more time teaching the planned curriculum outdoors does not face any of these barriers. The studies conducted for this thesis evidenced that short periods of time outdoors, even in urban areas with limited nature, can be extremely beneficial for some children and implementing this does not require significant additional resources.

For over a century, both early childhood pioneers such as Froebel and Montessori as well as individual practitioners and settings have advocated for more time outdoors for children, feeling instinctively that being outside in nature is good for them. This may be even more important as the planet becomes increasingly urbanised and we disconnect further with the natural world. Until more recent years however, research which robustly evidences the importance of outdoor time, especially in school settings, has been lacking. The study results presented here provide evidence of the tangible benefits that learning outdoors has on some children, particularly those who struggle most indoors. It is hoped that they will support practitioners in advocating for more outdoor access at school and draw attention to outdoor time as a viable strategy to support children's stress, attention and behaviour.

Importantly though, the results from these studies did not suggest that outdoor environments are inherently better than indoor ones for all children. Whilst indoor environments were consistently noisier, some children still performed better indoors. Instead, these studies have shown that the learning environment has heterogeneous effects, the optimal environment for one child, is not necessarily the optimal environment for another. Given that there is still much to learn about why this is the case; which specific aspects of the environment affect which aspects of children's learning and behaviour and the pathways through which this operates, the best practical advice that can be taken from this thesis is to offer children choice and autonomy where possible.

Providing a full provision both indoors and outside gives children the opportunity to experience all aspects of their learning and development in both environments. Free-flow settings, which enable children to move from indoors to outside as and when they choose are ideal in supporting children to manage their self-regulation by moving between more and less stimulating environments. Where this isn't possible, providing quieter, less stimulating areas within the indoor classroom and using indoor plants, window views of nature and natural soundscapes or slideshows may also help.

The results from these studies suggest that children's preferences often significantly affect where they pay attention best, indicating that children may instinctively know which environment is optimal for them. Opening up discussions about the learning environment and encouraging children to express preferences and reflect on how factors such as noise, clutter and fresh air might help or hinder their learning and behaviour, would enable children to have a better understanding of self-regulation and how this can be influenced by the environment around them.

Giving children the autonomy to choose where to learn, and whether they prefer to be in quiet or noisier spaces, indoors or outside, could also help settings improve inclusivity, enabling educators to better meet the diverse needs and preferences of their learners.

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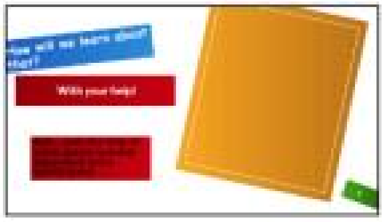
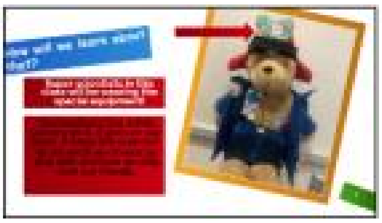
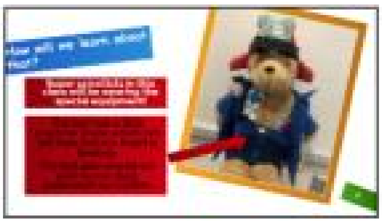
Appendices

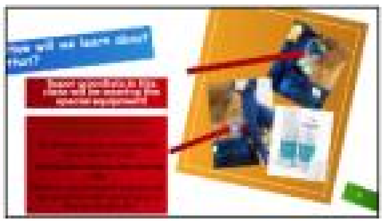
Appendix 1 – Social story

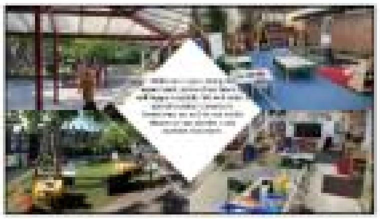
Social story read to participants prior to data collection sessions











Appendix 2 – Parent information and consent letter

Parent permission form

University of East London Research Project

XXX School recently formed a partnership with the University of East London so that we can become more involved in the research that they are doing and use it to inform our approach to teaching and learning. The first project that we are taking part in, along with 5 other primary schools in Newham, is research about learning environments.

This project is being run by Professor Sam Wass, who worked as a child psychologist on the Channel 4 programme 'The Secret life of 4 year-olds" and Gemma Goldenberg, who used to work as an Assistant Headteacher and is now doing a Phd. The research is looking at how children's learning, behaviour and wellbeing might vary depending on whether they play and learn ***inside*** or ***outdoors***.

To understand how children experience indoor and outdoor environments, special wearable devices have been made which include a microphone, actigraph (which measures movement) and an ECG monitor which measures heart rate using sticky pads which are placed on the ribs and collar bone. These have been designed for use with babies and children and used in other projects at the University of East London. Children will also wear a small camera on a head band, which has been designed for children to wear. This technology will allow the researchers to explore how children might learn, behave and feel in different environments.

We are looking for some children in the class to wear this equipment in school for around 1hr per day, for a few weeks. Your child will be allowed to take the equipment off at any time that they wish.

Further information about the project is overleaf. If you give your consent for your child to take part in this project, please tick the box and sign the slip below, writing yours and your child's name on the form. If you do not consent for your child to wear the equipment, they will still participate in the indoor and outdoor sessions, unless you choose to withdraw them. Please see overleaf for more information.

If you would like more information about this project, or to ask any questions, you can email Gemma, the researcher at u1538988@uel.ac.uk. You can also request an online or telephone meeting to find out more, by emailing this address.

....
....

Please tick the box below to give permission for your child to take part in this project, and return it to your child's class teacher.

☐ Yes I ....(insert your name) give permission for my child ....(insert child's name) To take part in this research project.

Further information

Research Integrity

The University adheres to its responsibility to promote and support the highest standard of rigour and integrity in all aspects of research; observing the appropriate ethical, legal and professional frameworks. The University is committed to preserving your dignity, rights, safety and wellbeing and as such it is a mandatory requirement of the University that formal ethical approval, from the appropriate Research Ethics Committee, is granted before research with human participants or human data commences.

Project Description

This project investigates whether children learn and behave differently in indoor and outdoor environments. This information will be gathered using observations and video/audio recordings of tasks and activities. The study involves children wearing a heart rate monitor (ECG), a microphone, and a small head mounted camera (similar to a 'go-pro') during some of their learning sessions in the classroom and outside.

This research has been approved by the University of East London School of Psychology Research Ethics Committee. This means that the research follows the standard of research ethics set by the British Psychological Society. The researcher for this project has worked as a teacher and has passed appropriate Disclosure and Barring Service checks. Your child will be with school staff for the duration of this project, the researcher will be in attendance as an additional adult.

Teacher and pupil's privacy and safety will be respected at all times. If children want to stop wearing any of the devices at any time they will be allowed to do so.

If your child does not have consent to wear the equipment, they will still take part in the indoor and outdoor sessions and may be captured on the footage from other children's cameras. This footage will be stored confidentially and will only be accessed by the research team. Footage of non-participating children will not be used as part of the analyses and any details from this footage will not be shared beyond the research team unless there is safeguarding concern. If you do not want your child to be part of these sessions, they can join another reception class for these periods. To arrange this, please speak to your child's class teacher.

Confidentiality of the Data
If your child participates in the project, the research team will ask the school for the following information about your child: whether they have any special educational needs, whether they receive free school meals, their date of birth, the date they joined the school and their overall level of attainment. All of this information will be anonymised.

Children will be allocated a participant number so that their name will not be recorded as part of the data collection. Any data related to the study will be stored securely and anonymously on password protected devices. Recordings will only be accessible to members of the research team, or school staff upon request for training purposes. Where possible, participants' confidentiality will be maintained unless a disclosure is made that indicates that the participant or someone else is at serious risk of harm. Such disclosures may be reported to the relevant authority. All data generated in the course of the research will be retained in accordance with the University's Data Protection Policy

Disclaimer
Giving your consent for your child to participate in this study is entirely voluntary, and you are free to withdraw your consent at any time during the research. Should you choose to withdraw your child from the programme you may do so without disadvantage to yourself and without any obligation to give a reason. . Participation in the research will have no impact on the school's assessment, treatment and support of your child. Their education will not be disadvantaged if you choose for them not to take part.

Please note that your child's data can be withdrawn up to the point of data analysis – after this point it may not be possible.

If you have any concerns regarding the conduct of the research in which you are being asked to participate, please contact:
Dr Sam Wass. School of Psychology, University of East London, Water Lane, London E15 4LZ,
Email: s.v.wass@uel.ac.uk

Appendix 3 – Troubleshooting details

Issue type	Issue	Solution/action
Fitting ECG monitors	Multiple layers of clothes making it difficult to place ECG stickers	Ensure wires go underneath all layers and not between them to reduce pulling. Ask girls to wear skirts and tops instead of dresses.
	Some children reporting that removing ECG stickers is sore	Offer children to remove the stickers themselves if they prefer Try alternative brand of stickers Using an adhesive removal spray before removal
	ECG stickers sliding off of child's skin due to body lotion	Use wipes to clean the area before placing the sticker.
	Children refusing to wear ECG monitors	Offer for children to participate wearing the camera but not the ECG monitor
Fitting head mounted cameras	Head bands sliding up/down child's forehead	Purchase new headbands with silicone strip inside for grip. Use hair slides to clip headband in place as needed
	Cameras were mounted sideways to be more in line with children's eye level, but rotating the videos was very time consuming	Adjusted camera mounting so that it was the correct way up
	Headbands too tight to accommodate some hairstyles	Purchased some headbands with a Velcro fastening which can be adjusted to size.

Using wearable devices	Fault with wearable devices switching themselves off	Contacted manufacturer who identified a formatting error to correct
	Head mounted cameras switching themselves off	Contacted manufacturer who replaced with new cameras
Uploading data	Video data taking too long to upload to computer for analysis	Used a different cable to connect to computer
Classroom management	Child from another class interrupted outdoor learning session	Ensure that other staff know when the project is taking place and do not allow children to wander into the teaching area outdoors
	Children wanting to run, jump etc on outdoor equipment during learning sessions	Put rules in place from the start, discuss with the children that the outdoor learning space has the same rules as the indoor classroom. Allow children a session to get used to this and become familiar with the outdoor area before data collection begins.

Appendix 4 Daily log used during data collection

Date	Weather	Temp	Indoor/ outdoor	Attendance	Table top activities for choosing	Maths/story	Observable Sessions	Technical issues	Events	Other notes	Carpet time decibels minute 1	Carpet time decibels minute 5	Carpe decib 10
25/04/2022	Cloudy	8C	Outdoor		Small world, kitchen role play, reading corner, drawing table, snack table, maths (counting), playdough, construction and vehicle play	Story 'I'm not happy'	5	Pt 2 stickers fell off (use tape tomorrow).		This column has been redacted for privacy reasons [redacted]			
26/04/2022	Sunny	7C	Outdoor		Small world, kitchen role play, tea party role play, reading corner, drawing table, snack table, maths (counting), playdough, construction and vehicle play.	Story 'I want to win'	6			[redacted]	49.5	52.9	N/A
27/04/2022	Cloudy	8C	Indoor		Messy play, reading corner, mark making, teacher led phonic, drawing and construction, role play and kitchen, snack table, counting, small world	Maths	7	Pt 2 stickers and tape fell off. Use wipe and tape tomorrow.		[redacted]	56.2	60.8	
28/04/2022	Overcast	11C	Indoor		Messy play, reading corner, TA led construction, small world, drawing table, shop role play, construction corner, snack table.	Maths	6	Pt 14 camera not working, switched for 15. Pt 6 opted out of wearing camera 10.00AM.		[redacted]	65.8	65.4	
03/05/22	Overcast	11C	Indoor	18/30	Mendhi pattern drawing, making get well soon cards/pics, farm shop role play, play doh, small world farm, ladybird counting, maths activites, snack table, construction	Maths	7	Pt 14 camera not working, switched for 16.	Sustained role play/social play between 2 participants in chossing time (farm shop role play)	[redacted]			
04/05/22	Overcast	12C	Indoor	19/30	Playdough, writing, drawing and cutting, small world, reading corner, construction, maths and counting, snack table, kitchen tole play.	Story 'Monkey Needs to Listen'	7			[redacted]	59.8	61.9	
05/05/22	Sunny	12C	Outdoor	24/30	Counting ladybirds, Spelling, Drawing and Cutting, Construction, Small World, Reading, Playdough	Story 'Elephant Learns To Share'	8	Camera 6 stopped working before CT. Pt cables fell of before carpet time. No ecg data.		[redacted]	57.1	67.7	
06/05/22	Sunny	17C	Outdoor	25/30	Role play, drawing/cutting, poster paper drawing, counting, playdough, small world, construction, snack table.	Maths	7	Camera 14 did not work, swapped for 6. Device 3 did not swtich on, swapped for device 2. Camera 5 did not record past prior to carpet time, have debugged.		[redacted]			
09/05/22	Sunny	9C	Indoor	27/30	Writing/drawing/cutting, reading, construction, role play, small world, snack table, shaped and screws, carpet drawing.	Story 'I don't want to play nicely'	7			[redacted]			
					Construction, small world, maths (shapes and screws), playdough, snack			Camera 5 stopped recording after 10mins. Did not need debugging. Possibly turned off		[redacted]			

Appendix 5 ethical approval

Dear Gemma,

Application ID: ETH2324-0216

Original application ID: ETH2324-0179

Project title: The impact of outdoor spaces on children's stress, attention and behaviour: investigating the differential effects of the educational environment

Lead researcher: Mrs Gemma Goldenberg

Your application to Ethics and Integrity Sub-Committee (EISC) was considered on the 29th April 2024.

The decision is: **Approved**

The Committee’s response is based on the protocol described in the application form and supporting documentation.

Your project has received ethical approval for 4 years from the approval date.

If you have any questions regarding this application please contact your supervisor or the administrator for the Ethics and Integrity Sub-Committee.

Approval has been given for the submitted application only and the research must be conducted accordingly.

Should you wish to make any changes in connection with this research/consultancy project you must complete 'An application for approval of an amendment to an existing application'.

The approval of the proposed research/consultancy project applies to the following site.

Project site: **In 6 Primary schools across Newham**

Principal Investigator / Local Collaborator: Mrs Gemma Goldenberg

Approval is given on the understanding that the UEL Code of Practice for Research and the Code of Practice for Research Ethics is adhered to.
Any adverse events or reactions that occur in connection with this research/consultancy project should be reported using the University’s form for Reporting an Adverse/Serious Adverse Event/Reaction.
The University will periodically audit a random sample of approved applications for ethical approval, to ensure that the projects are conducted in compliance with the consent given by the Ethics and Integrity Sub-Committee and to the highest standards of rigour and integrity.

Please note, it is your responsibility to retain this letter for your records.

With the Committee's best wishes for the success of the project.

Yours sincerely,

Fernanda Da Silva Hendriks

Research Ethics Support Officer

Appendix 6 Data management plan

UEL Data Management Plan

Completed plans **must** be sent to researchdata@uel.ac.uk for review

If you are bidding for funding from an external body, complete the Data Management Plan required by the funder (if specified).

Research data is defined as information or material captured or created during the course of research, and which underpins, tests, or validates the content of the final research output. The nature of it can vary greatly according to discipline. It is often empirical or statistical, but also includes material such as drafts, prototypes, and multimedia objects that underpin creative or 'non-traditional' outputs. Research data is often digital, but includes a wide range of paper-based and other physical objects.

Administrative Data	
PI/Researcher	Sam Wass Gemma Goldenberg
PI/Researcher ID (e.g. ORCiD)	
PI/Researcher email	u1538988@uel.ac.uk
Research Title	The impact of outdoor spaces on children's stress, attention and behaviour: investigating the differential effects of the educational environment
Project ID	ETH1920-0184
Research start date and duration	Sept/Oct 2020 - 4 years

Research Description	This study seeks to examine the effect of the learning environment on children's learning and behaviour and how this effect differs between children. In this study, each child's physiological stress, attention and social behaviour will be analysed at a micro-level. A series of 16x 1.hr sessions will take place with children aged 4-5 and their usual teacher. These sessions will take place over a period of 5-6 weeks (dependent on school term length). 6 consecutive sessions will take place in the class' usual indoor learning environment, for the other 6 sessions they will take place in an outdoor environment on the school site. Sessions include the reading of a story or a maths session, a sequencing/comprehension task and a session of free play.
Funder	UBEL DTP
Grant Reference Number (Post-award)	
Date of first version (of DMP)	05/05/2020
Date of last update (of DMP)	26/04/2024
Related Policies	Research Data Management Policy
Does this research follow on from previous research? If so, provide details	This is new research
Data Collection	
What data will you collect or create?	Physiological data: Autonomic monitoring: electrocardiogram (recorded at 150Hz); accelerometer (30Hz Behavioural: camcorder videos from head mounted cameras and wide angled camera. SDQ scores Academic: Scores on comprehension activity, school based EYFS assessment of progress e.g. GLD scores (good level of development), early learning goals Participants will be recruited from primary schools Prior to the study, the parents of each participant will be asked to provide baseline information including socio-economic status and current frequency of contact with nature. Teachers will be asked

	to fill out a strengths and difficulties questionnaire about their child. With permission from parents, participating schools will be asked to indicate the pupil's current levels of attainment, any special educational needs and any behaviour issues known to the School. Video data will be in .mp4 format. Physiological data will be stored as comma separated values files. Attention and social behaviour will be coded by a member of the research team, using the video recording of each session. These scores will be recorded in a spreadsheet saved on a password protected computer. At this point they will be anonymised and labelled with a participant number rather than name. Scores on the comprehension task will be recorded on paper live by a member of the research team, during the sessions. At the end of the session, these scores will be transferred to a password protected spreadsheet which will be saved on a password protected laptop. At this point they will be anonymised and labelled with a participant number rather than name. Paper copies of any scores will be destroyed as soon as the data has been transferred to the spreadsheet. The device will be used to video record the sessions will be a Babeyes camera For each 'round' of the study, all aforementioned data will be collected for approximately 20 children, across 16 sessions. Over the course of 2 years, the aim is to run these sessions with 150 children. The total volume of data collected will therefore be c.1-10TB. Baseline data such as the strengths and difficulties questionnaire and access to nature questionnaire, as well as information provided by the school on levels of attainment, special needs status and behaviour issues will be personal identifying at the point of collection. However, as soon as this data has been given to the researcher, participants will be allocated a participant number which will replace names on all documentation. Video data will also be personally identifying.
How will the data be collected or created?	Sessions will be video recorded and children will wear individual head mounted cameras, microphones and physiological stress monitors. Both video coding and Leuven scales of engagement will be used to measure children's level of engagement throughout each session.
Documentation and Metadata	

What documentation and metadata will accompany the data?	Blank consent form Information sheet Blank strengths and difficulties questionnaire Blank access to nature survey Examples of materials used for vocabulary and comprehension tasks Session plans for indoor and outdoor activities Readme file containing a description of the shape and format of the physiological and video data.
Ethics and Intellectual Property	
Identify any ethical issues and how these will be managed	All participants will be assigned unique ID numbers. Participants' ID number will be used at all times when managing the research data
Identify any copyright and Intellectual Property Rights issues and how these will be managed	None, to our knowledge.
Storage and Backup	
How will the data be stored and backed up during the research?	All video data will be stored on UEL's OneDrive for Business Only one file will be kept in which participant numbers are linked to personally identifiably information (names and addresses). This will be stored on a separate computer and kept in a locked office, on a password-protected computer, in an encrypted file. Data will be backed-up onto OneDrive for Business.
How will you manage access and security?	Immediately after recording, all video data will be transferred to a dedicated, encrypted hard disks that have been purchased specially for this purpose. Recordings will be securely deleted from the device that was used to make the recording. All data collected will only be accessible to members of the research team. It will be stored only on encrypted hard disks, in password-protected format. Between recording sessions, recording devices will be stored in a locked secure location.
Data Sharing	

How will you share the data?	5.1 Suitability for sharing As described above some of the raw data we collect (audio and camera recordings) will be impossible to anonymise so that participant's identity can be protected. As part of the consent procedure for the study we shall specify that any data collected that contains recognisable information will not be distributed outside of the immediate research team. For this reason, we shall not share these identifiable raw data with others. We may, however, share data in anonymised, unrecognisable formats - such as time-series of how different childrens' heart rate fluctuates over time. And we shall also share the equipment (hardware and firmware) that we have developed with others 5.2 Discovery by potential users of the research data Sharable data will be uploaded onto university web pages . It will not be possible to store identifying information (video data) on the repository. However, it will be possible to store information that can be safely de-identified – i.e. physiological data and processed questionnaire data – on the repository. , and links to these pages will be shared with interested parties. Availability of the data will be flagged during presentations of the research findings, which will take place in academic papers and at conferences. 5.3 Governance of access Given that all data will be anonymised and that no sensitive decisions will be required, decisions about data sharing will be made by PI Wass. In cases of doubt he will consult the university research ethics committee, the Sponsor, and the Project Partners. 5.4 The study team's exclusive use of the data Data will be made available for sharing on the publication of the first written article arising from the research.
Are any restrictions on data sharing required?	All participants will need parental consent for the data to be collected and stored. It will not be possible to store identifying information (video data) on the repository. However, it will be possible to store information that can be safely de-identified – i.e. physiological data and processed questionnaire data – on the repository. Only limited data will be sharable, in order to maintain participant confidentiality.
Selection and Preservation	

Which data are of long-term value and should be retained, shared, and/or preserved?	All data will be destroyed within 12 months of the completion of the study. This is following standard protocols.
What is the long-term preservation plan for the data?	All data will be destroyed within 12 months of the completion of the study. This is following standard protocols. During these 12 months data will be stored on a password protected UEL OneDrive account as mentioned above. Data suitable for sharing via the UEL repository will be reviewed at the end of the project and every 5 years until data is transferred or deleted in line with UEL's Research Data Management Policy
Responsibilities and Resources	
Who will be responsible for data management?	Gemma Goldenberg Sam Wass Gemma will be responsible for storing and implementing data management plan. Sam will oversee it.
What resources will you require to deliver your plan?	
Review	
	Please send your plan to researchdata@uel.ac.uk **We will review within 5 working days and request further information or amendments as required before signing**
Date: 26/04/2024	Reviewer name: Joshua Fallon Assistant Librarian Research Data Management

Guidance

Brief information to help answer each section is below. Aim to be specific and concise.

For assistance in writing your data management plan, or with research data management more generally, please contact: **researchdata@uel.ac.uk**

Administrative Data

Related Policies

List any other relevant funder, institutional, departmental or group policies on data management, data sharing and data security. Some of the information you give in the remainder of the DMP will be determined by the content of other policies. If so, point/link to them here.

Data collection

Describe the data aspects of your research, how you will capture/generate them, the file formats you are using and why. Mention your reasons for choosing particular data standards and approaches. Note the likely volume of data to be created.

Documentation and Metadata

What metadata will be created to describe the data? Consider what other documentation is needed to enable reuse. This may include information on the methodology used to collect the data, analytical and procedural information, definitions of variables, the format and file type of the data and software used to collect and/or process the data. How will this be captured and recorded?

Ethics and Intellectual Property

Detail any ethical and privacy issues, including the consent of participants. Explain the copyright/IPR and whether there are any data licensing issues – either for data you are reusing, or your data which you will make available to others.

Storage and Backup

Give a rough idea of data volume. Say where and on what media you will store data, and how they will be backed-up. Mention security measures to protect data which are sensitive or valuable. Who will have access to the data during the project and how will this be controlled?

Data Sharing

Note who would be interested in your data, and describe how you will make them available (with any restrictions). Detail any reasons not to share, as well as embargo periods or if you want time to exploit your data for publishing.

Selection and Preservation

Consider what data are worth selecting for long-term access and preservation. Say where you intend to deposit the data, such as in UEL's data repository (https://repository.uel.ac.uk) or a subject repository. How long should data be retained?

Appendix 7 Coding manual for redirects

<u>Measuring children's attention and focus during the maths carpet sessions by counting the number of 'teacher redirects'</u>

This is a measure that can be live coded during the lesson.

To reduce demand characteristics, the teacher is not aware that this coding is taking place, so try to be discrete when doing it.

Each session will be coded by multiples observers and the mean score taken.

Keep a tally of how many times the teacher (not any support staff/teaching assistants) has to redirect the children's behaviour to keep them on task.

Below is a guide as to what does and doesn't count as a redirect.

You should count it whether it is aimed at an individual or a whole class.

A long string of redirects spoken all together as one sentence would count as 1 redirect e.g. "Ok who is listening? I would like you all looking this way, please show me your hands so I know you're listening" would count as 1, not 3.

Do not count instructions which are based around needing to move the children physically, which are unrelated to attention/focus e.g. 'Can you move to the right you look squashed' or 'Everyone move back into the circle'. However, if a child is moved because of misbehaviour/not listening then this would count.

Yes – count this as a redirect	**No – do not count this type of comment**
Saying a child's name to get their attention/indicate that they are misbehaving or saying the whole class name "4D!"	Sit on your bottom
Moving a child into a different place because they are misbehaving/not paying attention	Put your hand up, don't call out
Clapping hands to get the classes attention	Move back, you're too close
Counting down from 5 to settle the class down if they are being too noisy/unfocussed	Spread out, you're squashed
Using an instrument e.g. tambourine/shaker or clapping to bring the children back to a listening/calm state	Move over here if you can't see properly
Asking the children to do something to refocus e.g. deep breaths	Go and get a tissue
Praising one child to make it clear that others are not paying attention e.g. "I am really happy with how X is doing good listening, who else can do that?"	
"Sssshhhhh"	
"Stop talking"	
"Calm down"	

Appendix 8 – Comprehension questions

Book	Pictures for sequencing	Page number and Question 1	Page number and Question 2	Page number and Question 3
I'm not happy Read time: 1min 51 Indoor book 1	13, 21, 25	Pg 15 – What are they doing? 1 point for any reference to searching/looking for the dog	Pg 17 – Why is Ben sad? 1 point for any reference to not liking the jumper/it being too big/scratchy	Pg 12/13 – Which one is Ben?
I want to win! Read time: 2min 12 Outdoor book 1	15, 21, 25	Pg 9, why is she cross? 1 point for any reference to her wanting to win/be the best	Pg 14 What are they doing? 1 point for any reference to building a den/tent	Pg 22 Which one is Bella?
Monkey needs to listen (Band 6 – orange) Read time: 5min13 Indoor 2	7, 17, 20	Pg 12 – What are they doing? 1 point for using specific term 'go kart' or referring to making/building a kart/car	Pg 21 –Why are they sad? 1 point for any reference to monkey going too fast/not listening/skidding/not building the kart properly/falling in the swamp. Don't give a point for something that could be inferred just from the picture, has to show some evidence that the story was listened to.	Pg 21 – Which one is the teacher? 1 point for saying crocodile/Mr Croc or pointing to crocodile
Elephant learns to share (Band 6 – orange) Read time: 5min13 Outdoor 2	13, 19, 27	Pg 4 - What's happening here? 1 point for any reference to elephant won't share his sweets/toys/he's being selfish/he won't let them have any Don't give a point for something that could be	Pg 25 – Why are they all happy? 1 point for any reference to sharing/taking turns/playing together/playing with the new bat and ball	Pg 26 – Which one is Gran? 1 point for pointing to correct character

		inferred just from the picture, has to show some evidence that the story was listened to.		
I don't want to play nicely Read time: 2min33 Indoor 3	6, 17, 23	Pg 11 – Which one is Finn?	Pg 7 Why is she sad? 1 point for any reference to he's pushed her/knocked her/he's not being kind/not playing nicely	Pg 24 – What happened in the end? 1 point for any reference to he's playing nicely now/he's a good buddy/they are all friends/he's kind
I didn't do it! Outdoor 3 Read time:	5, 17, 25	Pg 7 – what happened? 1 point for any reference to She broke the window (not him!), she is blaming him/saying its him	Pg 15 – Why is she sad? 1 point for reference to her being left out, they don't want her to play because she lied etc	Pg 24/25 Which one is Miss Plum?
Flamingo is brave Indoor 4	11, 13, 21	Pg6/7 who gets scared a lot? 1 point for saying flamingo or pointing to flamingo	Pg 23 – why is he happy? 1 point for saying he isn't scared/he's brave now/he's got the torch	Pg 26 – what happened in the end? 1 point for any reference to he's being brave/he's no scared/they are at the sleepover/the y heard a noise/it was the tractor/it wasn't scary
Tiger has a tantrum Outdoor 4	16, 21, 26	Pg 27 – what happened in the end? 1 point for any reference to he's being good/nice now, he's not angry/cross/having a tantrum, he shared the book	Pg 25 – Why is tiger sad? 1 point for reference to him wanting the tractor book/wanting a turn/he got told off	Pg 27- Which one is the teacher? 1 point for saying bird/Miss Bird or pointing to the bird wearing glasses

Turtle comes out of her shell Additiona l Indoor 5	7,20,25	pg 4 - What's Turtle doing here? 1 point for reference to being kind/nice/helpful/sharing/givin g her pencil/helping Lion feel better	pg 6 - Why is turtle hiding? 1 point for reference to feeling shy/not wanting to answer a question	pg 8/9 Which friend helped turtle? 1 point for bear (could also accept the teacher)
Croc needs to wait Additiona l Outdoor 5	13,18,23	pg 9 - why did Croc get all her sums wrong? 1 point for reference to she rushed/she did them too fast/she wasn't careful/she wasn't patient	pg 17- What's happening here? 1 point for reference to croc didnt wait for the pot to dry/she painted it before it was ready or dry/all the paint ran off and made a mess	pg 20 - who did Croc make the boat with? 1 point for Rhino/pointin g to Rhin o

Appendix 9 – Assessment criteria for assessing accuracy and clarity of story retellings

Video coding - Story re-telling

What?

We are coding the section of the literacy task where the child is asked to re-tell the story in their own words

Why?

Because we want to see whether the environment might affect how much detail children recall from the story they were read and how confident they feel to speak unprompted when retelling.

How?

For each child we'll find the retelling section of the video and record coding information on a document like this one: (linked removed for data protection)

The table at the top is to keep track of which sessions have been coded and if there are some missing, why this is.

The more detailed tables underneath are for transcribing the retelling and counting how many words and utterances were spoken.

Tips and guidance for coding retelling

Before coding, look at an example of an existing transcription here (link removed for data protection)

Make a note of the time of the retelling in case we want to further analyse this section at a later date

Transcribe all words spoken during the retelling by both adult (a) and (c) - beginning AFTER the adult has finished giving instructions.

However, if a child says something after the instructions which is not part of the retelling e.g. 'I can't read those words' ''I don't understand' or 'Can I play after this?' Do not transcribe this or count it as part of the retelling

If the child says a word but you cannot understand what the word was, add it to the transcript as a '?' and count it as a word. E.g. 'The turtle was ? and then he went to the ?' (11 words)

When counting how many adult prompts were given, adult prompts include non-word based prompts like 'Mmmm hmmm?' but only count as a prompt if the adult needed to encourage the child to continue, if the prompt is given at the same time as the child is speaking, e.g. in agreement, do not count it.

If at the very start of the retelling, after the adult has given instructions, the child remains silent and the adult says something like 'What was happening?' do not count this as a prompt. This may be the child unsure of when to start their retelling. However, if later on in the retelling the adult has to ask again 'what's happening here?' then it does count as a prompt.

Do not count repetition/stutter or non-words (Urm… errrr..) in the word total when counting up e.g. 'Then errrr then errrr then she went home' should be counted as 4 words (then she went home) if they repeat a phrase, you also only count it once e.g. 'Then he was sad, he was sad' would only count as 4 words' (Then he was sad).

If the child begins to talk more generally after the retelling e.g. 'I made a den once' or 'I liked this story' do not transcribe this or include it in the word total. Stop transcribing once they have finished retelling the story (even if they are still talking about the story)

Mean length of utterance is total words divided by number of utterances

An utterance is an uninterrupted chain of spoken language - e.g. the total amount a child speaks in one go without an adult prompt/question

When counting adjectives, don't count repeats, e.g. if they use the word 'small' in 3 different utterances, it only counts as 1 adjective.

Each retelling is given score for its overall coherence and detail, using the guide below:

Scoring guide for coherence and accuracy:

1 - No sense of a beginning, middle or end of the story or the problem-resolution/lesson that's been learned by the character, several elements from the 3 pictures have not been understood/included, retelling might be disjointed/not make sense or may not reflect the actual story that was read

2 - Main gist of the story has been understood and retelling generally makes sense but might lack detail or miss out some events, may be some repetition of words/phrases, events might be in slightly wrong order or not linked together clearly

3 - A clear beginning/middle/end or problem-resolution structure with events in correct order/linked together, all key elements from the 3 pictures included, retelling makes sense

4 - Detailed and clear retelling with a good level of structure, includes all key events from 3 pictures along with additional information beyond these 3 pictures

Appendix 10- Coding manual for activity choice and duration

Activity choice coding

What?

We are coding the first 30min of choosing time to see which activities the child chooses to engage with during the choosing time, and how long they stay at each activity for before moving on.

We are also making a note of when they are chatting/socialising in an unstructured way with peers (e.g. not at a task/activity which the adults have set up but creating their own games/singing/dancing/chatting together etc)

We need to code an equal number of indoor and outdoor sessions for each child.

Why?

Because we want to see whether the learning environment affects how long children stay focussed at a task for, this might be a measure of their attention, self control or autonomy.

The tasks children choose might also be affected by the environment e.g. are children more likely to choose a creative task in one environment compared to another?

We are also interested in how children interact in different environments, some environments may better enable prosocial interaction.

How?

For each child we'll watch the 'choosing time' section of the footage. This 30min period will be pre decided so that the coder knows at exactly what time it begins and ends.

Each time the child starts an activity, we will log the time they started and the time they moved onto something else.

Starting
The child has 'started' an activity once they have moved to an area/table and chosen to be there. They do not have to have picked up the resources/started actively participating to have 'started' - merely sitting or standing at the specific activity area counts.

Remaining at the activity
If the child stops actively partaking but remains at the activity area/table e.g. watching others or talking to peers, this counts as still being 'at' the activity. If they leave the activity area to look for resources, seek adult help, or play with something they've just created as part of the activity/show it to someone else, this all still counts as being 'at' the activity even though they may have moved from the location.

Ending the activity

If the child physically moves away from the activity and is no longer doing anything to try and continue with the purpose of the activity, their time at that activity has ended. If they come back to this activity at a later point, restart it as a new activity log.

Not at task but chatting/playing with peers
If a child is chatting/playing whilst doing an activity e.g in the construction area, or at the art table, this counts as an activity.

Only log something as '*Not at task but chatting/playing with peers'* if the child/ren are not engaging with the resources set up by the teacher but are 'doing their own thing' in an unstructured, child-led way e.g.
Wandering around chatting
Talking in the book area
Making up a song/dance/game together
Playing in the wigwams
Playing with resources which were not set up by the teacher e.g. stones they found on the ground, equipment they got out themselves etc.

Selecting which activity from the dropdown menu

You will select which activity the child is engaged in from a drop down of activity options. Below is clarification for which each activity means:

Reading - Looking at books alone or with peers - does not matter if they cannot read and are just looking at pictures. Does NOT include reading to an adult.

Teacher assessment - Use this for whenever a child has been called over to do some academic learning with an adult 1:1 this includes: reading aloud to an adult, taking part in a maths assessment, 1:1 phonics, doing the comprehension task which is part of this project etc

Literacy table/phonics activity - Anything which is on the designated 'literacy table' and/or writing of any kind, reading task e.g. flashcards/reading words from whiteboards or grids

Maths activity - Anything which is on the designated 'maths table' and/or number/shape/measures activities of any kind including number and counting games, making repeating patterns etc

Drawing/painting - Any art based activity

Sticking/junk modelling - 3D ART/DT (making something)

Small world play - Playing with miniaturised people/animals/buildings etc - this is often set up on the black 'tuff tray'

Messy/sensory play - Sand/water/shaving foam etc

Fine motor skills - includes threading, using tweezers to pick up/move things, cutting activities

Music/instruments - dancing/listening to music provided by the teacher, playing instruments

Puzzles

Card/board game

Vehicle play - play with any vehicle toys (can be classed as 'small world play' if a 'scene' has been created e.g. cars and toy garage with figures/road mat etc. If just playing with a car, without a 'scene' count it as vehicle play.

Soft toys - Playing

Play doh/clay/plasticine

Role play - Pretend/role play using resources provided/set up by the teacher e.g. dressing up/pretend shop/cafe/home corner

Construction Playing with any sort of building/construction toy e.g. blocks, lego, kinex, shapes that clip together, magnetic shapes

Q&A

What if the child isnt at an activity or chatting/playing with peers e.g. what if they're just staring into space or wandering around alone?
Just don't code this time at all. Not every minute has to be 'accounted for' it's fine to have gaps of time between activities. We will be able to total up this 'off-task' time later on.

Do I have to watch the whole 30min video?
No, you can fast forward through sections if you can see that the child is still at the same activity you've already logged, just make sure you capture the specific end time of each activity and keep an eye on the footage to make sure it hasn't frozen (when watching online, if the video has not fully loaded you may find that when you fast forward, the audio continues to run but the image stays frozen. If this happens, download the video to watch (delete it after!) or wait and let the video fully load before playing.

Appendix 11 – Coding spreadsheet for activity choice and durations

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Participant Number											Summary Data	
2		session 1	session 2	session 3	session 4	session 5	session 6	session 7	session 8				
3	Link for Video:	https://e.pcloud	https://e.pcloud	https://e.pcloud	https://e.pcloud	https://e.pcloud	https://e.pcloud	https://e.pcloud	https://e.pcloud.link/publink/show?code=XZb5jjZNi4q98l35KBPupYeypYf2mnUoqok				
4	Date:	06/02/2023	08/02/2023	07/02/2023	25/01/2023	02/02/2023	20/03/2023	29/03/2023	31/01/2023		Peak focus	Indoor	Outside
5	30min segment start	0:25:35	0:25:53	0:38:08	0:28:35	0:35:46	0:35:54	0:26:07	0:38:58		1	0:14:09	0:20:00
6	30min segment end	0:55:35	0:55:53	1:08:08	0:58:35	1:05:46	1:05:54	0:56:07	1:08:58		2	0:05:58	0:14:08
7	Indoor/Outdoor	INDOOR	INDOOR	INDOOR	INDOOR	OUTSIDE	OUTSIDE	OUTSIDE	OUTSIDE		3	0:10:08	0:13:17
8	**Activity 1 chosen**	literacy table	literacy table	reading with	puzzles	teacher asse:	drawing/pair	teacher asse:	drawing/pair		4	0:06:55	0:02:27
9	**Start time**	0:25:53	0:26:18	0:40:35	0:32:18	0:35:46	0:37:18	0:27:00	0:39:14		Mean	0:09:18	0:12:28
10	**End time**	0:40:02	0:29:08	0:50:43	0:37:26	0:38:40	0:43:07	0:28:36	0:41:18				
11	**Duration**	0:14:09	0:02:50	0:10:08	0:05:08	0:02:54	0:05:49	0:01:36	0:02:04				
12	**Activity 2 chosen**	teacher asse:	literacy table	teacher asse:	teacher asse:	literacy table	drawing/pair	drawing/pair	literacy table		Time spent @ literacy (reading, phonics, writing)	Indoor	Outside
13	**Start time**	0:40:12	0:29:56	0:52:36	0:39:20	0:40:17	0:44:28	0:28:41	0:42:17		1	0:14:09	0:20:00
14	**Finish time**	0:42:44	0:35:54	0:54:21	0:42:15	1:00:17	0:58:36	0:34:21	0:44:10		2	0:08:48	0
15	**Duration**	0:02:32	0:05:58	0:01:45	0:02:55	0:20:00	0:14:08	0:05:40	0:01:53		3	0	0
16	**Activity 3 Chosen**	maths activit	teacher asse:	soft toys	construction	maths activit	drawing/pair	drawing/pair	small word p		4	0	0:01:53
17	**Start time**	0:51:36	0:35:54	0:54:26	0:43:03	1:00:17	1:00:37	0:34:51	0:44:58		Mean	0:05:44	0:05:28
18	**Finish time**	0:53:30	0:38:43	1:00:10	0:49:58	1:02:05	1:03:56	0:42:21	0:45:52				
19	**Duration**	0:01:54	0:02:49	0:05:44	0:06:55	0:01:48	0:03:19	0:07:30	0:00:54				
20	**Activity 4 chosen**	puzzles	card/board g	maths activit	construction		teacher asse:	drawing/pair	teacher asse:		Time spent @ maths	Indoor	Outside
21	**Start time**	0:54:08	0:40:25	1:00:10	0:50:46		1:04:28	0:42:50	0:46:17		1	0:01:54	0:01:48
22	**Finish time**	0:54:46	0:41:28	1:00:41	0:54:28		1:05:54	0:56:07	0:48:44		2	0	0
23	**Duration**	0:00:38	0:01:03	0:00:31	0:03:42	0:00:00	0:01:26	0:13:17	0:02:27		3	0:03:00	0
24	**Activity 5 chosen**			soft toys					puzzles		4	0	0
25	**Start time**			1:00:41					0:49:09		Mean	0:01:14	0:00:27
26	**Finish time**			1:01:31					0:50:15				
27	**Duration**	0:00:00	0:00:00	0:00:50	0:00:00	0:00:00	0:00:00	0:00:00	0:01:06				
28	**Activity 6 chosen**			maths activit							Time spent @ chatting/playing	Indoor	Outside

Appendix 12 – Literacy task script and assessment guidance

Where possible, always conduct these assessments in the same indoor or outdoor location, seated at a table, slightly away from the main group

Which stories are read indoors and which outdoors is important - these have been counterbalanced across schools. See here for which stories should be read in which location.

Call children over one at a time, make a note of the order in which they are called over so that this can be matched between indoor/outdoor pairs but alternated across the course of the 4 weeks (see sheets in ring binder or this spreadsheet for this info)

Procedure

1. Lay 3 images from the book in the incorrect order on the table.

"I've got some pictures here from the story and I would like you to put them in order for me. So you're going to think about what happened first, what happened next and what happened last.

Have a look at the pictures. (Pause for 5 seconds for them to look at them)

Which one happened first?"

As the child selects a picture, move it down in front of them, into the first position in a line

"Ok and what happened next?"

"And what happened last?"

As they select each picture, move them into a line in front of them

If the child does not select any picture, pause for 5 seconds for them to think, then repeat

"Which one of these pictures happened first in the story?'

If the child still doesn't respond, point to the pictures one by one

"Did this one happen first? Did this one?" etc until they nod/say yes for the first picture. Then repeat for the other 2 pictures *'Did this one happen next or did this one happen next?"*

If they don't respond, suggest *"Are you not sure? That's ok, you can say 'I don't know'*

Do not give any indication to the child if they have got it wrong.

If they will not sequence the pictures, record it as '0' and move into the questions

2. After they have finished sequencing the pictures, rearrange them into the correct order if they git them incorrect and then gesture to the pictures and say

Now can you use the pictures to tell me what happened in the story? Point to first picture What happened?

The child might re-tell the story using all 3 pictures, if they stop after the first picture, point to the next one and ask *And then what happened in this one?*

You don't need to mark/code their retelling, we will do this later from the video data.

3. "Now we're going to look at some pages from the story"

Use the question sheet to turn to each relevant page and ask the questions. Always ask the questions in the order that they're written on the sheet.

<u>Do not point to the pictures</u> when asking the questions, the child needs to know which part of the picture/story the question relates to without you indicating this to them.

If the child does not respond to the question where they have to identify a character, you can point to all characters on the page asking one by one e.g. *'Is this one Max?'*

If the child does not respond to either of the other questions you can rephrase in the following ways:

'What's happening here/what happened?' can be replaced with 'What's going on?' and vice versa

'Why is he/she happy/sad/cross' can be replaced by pointing to the character in question and saying 'Look, he/she is happy/sad/cross. Why?'

If the child doesn't respond, suggest *"Are you not sure? That's ok, you can say 'I don't know'*

Appendix 13 – Coding manual for prosocial and antisocial behaviour

Video coding - Pro and antisocial behaviour with peers

What?

We are coding 2x 5min segments of choosing time, one near the start of the session and one towards the end, to see how children interact with one another, the number of prosocial and antisocial behaviour the child displays and which type of behaviours these are.

Why?

Because we want to see how children interact in different environments, some environments may better enable prosocial interaction whilst some are more likely to trigger antisocial behaviours. Or, children may behave very similarly across both environments.

How?

For each child we'll find the start of choosing time on their video, fast forward to min 5 of choosing time and watch the 5 minute segment of 'choosing time' from the video footage.

Pause the video whenever the child engages in a prosocial or antisocial behaviour. While the video is paused, we record the behaviour that takes place and the time it happened. We record the time in case we want to go back at a later point and analyse this event in more detail.

You log each behaviour, categorising it as pro or anti social and verbal, physical or combined (both verbal and physical.) Then use the drop down list to catergorise in more detail. Always use the 'notes' section to briefly explain what was happening e.g. "Singing together with friend" or "snatched a toy"

After logging any behaviours within the 5min segment, use the totals section at the bottom to count how many of each behaviour took place.

Deciding whether or not something is anti social or pro social can be difficult, see guidance on this below.

We then repeat this for min 15-20 of the same video.

Occasionally the 5-10min or 15-20min segments may fall at a 'bad' time e.g. when the child was doing a task with a teacher, going to the toilet or when their camera wasnt working. If this happens, adjust the time to a different 5min segment, write the actual time you coded on the spreadsheet and add a comment to the spreadsheet to explain why a different time was used.

It takes approx 8-10min to code each 5min segment, including the time it takes to find the start of choosing time and work out the correct 5min windows to code.

What if there are no anti or pro social interactions at all in the segment?

If there are none, type ‘no interactions’ in the notes box and add zeros to the totals row below (so its clear that the video has been coded and not accidentally missed out)

If there are no interactions in **both** 5 minute segments **and** this is the case for **both an indoor and an outdoor session**, then select a new indoor and outdoor video and re-code them. If there are still no interactions, label as above.

If there are no interactions in only one condition, do not search for another video to code (as this would give that condition an ‘unfair advantage’ as you would have given ‘more chances’ of finding interactions in that condition than you did in the other one.

Tips and guidance for coding antisocial and prosocial behaviours

For each session, only code 2 x 5min segments, as detailed on the spreadsheet. Before starting, type in the start and end time of the segment as this will help ensure you locate the right section of video and that you remember to stop coding at the right time. It also helps avoid errors with calculating the segments times.

When noting the time of an incident, it can be hard to get an exact time because when pausing the video, the white circular marker has a range of about 50 seconds depending on whether you hover your cursor over the left or right hand side of the circle. When pausing the video to log a behaviour, aim to hover over the centre of the circle to get a time to note on the spreadsheet.

When coding behaviours, remember to only code the behaviour of the child wearing the camera, not the other children you can hear/see around them.

At first it can be hard to tell who is speaking. If you listen to a video for a few moments, you will hear that the participant child’s voice sounds noticeably louder than the surrounding children’s voices. Always listen to a clip and locate the participant’s voice first so you can recognise it better when coding.

We are only looking at behaviours between peers, you do not need to record any interactions with adults.

Prosocial behaviours can be harder to spot when watching the videos. Look and listen carefully to try and notice:
Is the child willingly sharing resources or taking turns?
Incorporating someone else into their play?
Actively being helpful to someone?
Laughing together?
Encouraging someone?
Hugging or holding hands?

We are only counting something as prosocial if it has a benefit to another child. For example, one option on the drop down list is ‘instigate/join social conversation’. This would not include a child starting a conversation by asking a question like ‘Where is the blue pen?’ as this conversation is functional, serving only themselves. However, if they ask a child about the picture they’re drawing and begin chatting together about it, this would be a prosocial behaviour.

Another option on the dropdown list is ‘play together with peer’. Again, only count it as prosocial play if the child is actively joining in and playing together with someone, not simply joining the same activity but playing independently, alongside someone else. Are they actually engaging with one another, either verbally or physically?

A ‘combined’ antisocial or prosocial behaviour is one which incorporates both verbal and physical aspects within the same interaction e.g.
Saying ‘No!’ when someone asks for a turn, and also pulling the equipment away from them
Saying something kind whilst also hugging the person
Shouting at someone and pushing them
Asking someone to play and offering them a toy

If children are playing together, only count it as ‘combined’ if they are doing something physically prosocial as well (which benefits the other child) e.g. taking turns with a resource, dancing together. E.g. if playing with dinosaurs and verbally creating a narrative ‘My dinosaur is coming to eat yours!” This would be a verbal prosocial interaction. Even though the children are physically playing by holding the dinosaurs, this holding of the toys is not a prosocial act in itself.

If, however, children were in the role play area, acting as Mother and son, and chatting in role as well as the ‘Mother’ pretending to feed the child dinner, brush their hair etc, this would be a combined prosocial behaviour.

When recording something as ‘combined’ count it as both verbal and physical when adding up the totals at the end, so this behaviour would count as 2 in the total.

Knowing whether to record something as one behaviour or a series of individual behaviours can be tricky, especially if they all take place at the same activity. If there is a break between incidents of 10 seconds or more, or different children or resources are involved, or a different type of behaviour e.g. snatching vs pushing, count these as separate behaviours.

For example:

Scenario 1:
Participant 4 is playing with marbles and paint. A child tries to use the marble she is using and participant 4 shouts “No!” at them. The other child moves away and participant 4 continues to paint. 30 seconds later the same child comes and asks “Can I have a turn?” Participant 4 says “No” and pushes them away.

This would be recorded as one verbal antisocial behaviour (shouting) and one combined antisocial behaviour (shouting and pushing). It would be recorded as 2 behaviours/incidents as there were 2 separate interactions with a break in between.

Scenario 2:
Participant 4 is playing with marbles and paint. A child tries to use the marble she is using and participant 4 shouts “No!” at them. The other child tries to take it again and Participant 4 shouts “No”. This happens back and forth 3 times immediately one after the other.

The other child snatches the marble and participant 4 shouts “No” again and snatches the marble back. Participant 4 pushes the other child to the ground and shouts “I’m not your friends, I’m telling Miss of you!”

This would be recorded as:
1 verbal antisocial behaviour (the shouting ‘No’ which happened 3 times but is recorded as one behaviour as it was the same verbalisation within the same context and timeframe

1 combined antisocial behaviour (the shouting and the snatching)- the shouting is recorded as a ‘new’ behaviour here as the context has changed, they are responding to the snatching
1 combined antisocial behaviour (the pushing and the ‘I’m not your friend’ comment)
So this would be recorded as 3 entries for behaviour on the spreadsheet and totalled as 5 at the end (as 2 were combined).

Appendix 14 – Coding spreadsheet for prosocial and antisocial behaviour

	A	B	C	D	E	F	G	H	I
1		Session1: Segment a (mins 5-10)	Session1: Segment b (mins 25-30)	Session2: Segment a (mins 5-10)	Session2: Segment b (mins 25-30)	Session3: Segment a (mins 5-10)	Session3: Segment b (mins 25-30)	Session4: Segment a (mins 5-10)	Session4: Segment b (mins 25-30)
2	Date of session	5/12/22		23/11/22		21/02/2023 - no dBA		28/11/22	
3	Start of choosing time	0:41:45		0:00:19		0:35:00	0:35:00	0:53:25	
4	Start of this segment	0:46:45	1:04:45	0:05:19	0:20:00	0:41:00	0:52:00	0:58:25	1:17:25
5	End of this segment	0:51:45	1:09:45	0:10:19	0:25:00	0:46:00	0:57:00	1:03:25	1:22:25
6	Indoors/outside?	INDOORS	INDOORS	INDOORS	INDOORS	OUTSIDE	OUTSIDE	0	OUTSIDE
7	Behaviour 1	prosocial verbal	prosocial verbal	prosocial verbal	antisocial verbal	prosocial physical	prosocial combined	prosocial combined	prosocial combined
8	Type	instigate or join social conv	play together with peer/jo	Kind comment	angrily shouting	play together with peer/join ir	play together with peer/join	play together with peer/join in pl	play together with peer/join in pl
9	Time	0:47:40	1:05:11	0:09:03	0:22:25	0:44:47	0:55:57	0:58:31	1:19:07
10	Notes	"No food!" Instigates conversation with peer, showing there's no food in the role play shop. "Come with me!"	Pretending to be a dog, "I want an ice cream!" approaches peers and joins in their role play game	Joins peers at peg boards, says "Thank you" to peer who passes a board	Screaming/shouting - incoherent but sounds angry	Attempts to join in small world play by joining other children, taking dog figure and barking	Joins peers to play, joins countdown for rocket, plays with vehicles together	Playing with multilink with peers, chatting and asking questions "What is this number?"	Playing dinosaurs with peer, chasing each other around
11	Behaviour 2	prosocial combined	antisocial verbal	prosocial verbal		prosocial verbal			
12	Type	play together with peer/join in play	angrily shouting	instigate or join social conversation		instigate or join social conversation			
13	Time	0:49:03	1:07:14	0:09:55		0:45:36			
14	Notes	Role play shops with peer	"Ice cream! This is mine!"	Chats with peers whilst doing peg boards		Approaches peer and says hello and name			
15	Behaviour 3	antisocial verbal	prosocial combined						
16	Type	refusal to share/give turns	play together with peer/join in play						
17	Time	0:50:39	1:08:33						
18	Notes	Growling angrily at child who takes xylophone	Sustained role play game with peers pretending to be a dog eating ice creams						
19	Behaviour 4	prosocial combined							
20	Type	invite peer to play/instigate play							
21	Time	0:50:53							
22	Notes	Uses a hand puppet to approach peers and instigate play							
23	Behaviour 5								

Appendix 15 – Summary table of results from all three studies

Summary of findings across all three school-based studies

Outcome variable	Did the outdoor environment have significant effect? (At a whole-group level)	Did the outdoor environment have significant effect on baseline sub-groups?	Did noise significantly associate with the outcome variable?	Did heart rate significantly associate with the outcome variable?	Did nature-level significantly mediate effects?	Demographic/individual differences variables – did they significantly predict which environment would be most beneficial to the child?				
						Gender	**FSM**	**EAL**	**SDQ score**	**Indoor/ outdoor preference**
Carpet time attention (looking time)	No	No	Yes – a small positive correlation in the outdoor condition only *p* = .004 r = .190	Yes – a negative correlation *p* = .015 r = .244	No	No	No	No	No	No
Carpet time attention	No	No	No	n/a	No	No	Children eligible for FSM were	No	No	No

(literacy task)							14.53 times more likely to have higher literacy task scores in the outdoor condition *p* = .009			
Choosing time attention (% time on task)	No	Children with the lowest baseline attention made the most significant improvement in on-task behaviour outdoors *p* = < .001 *d* = 1.55 Children in the medium baseline groups also showed significant improvements outdoors	Yes - a small positive correlation *p* = .040 r = .088	n/a	No	Boys were 3.27 times more likely than girls to be more on task outdoors *p* = .049	No	No	No	Children with an outdoor preference were 5.83 times more likely to be more on task outdoors *p* = .006

		p = .049 *d* = .280								

	Did the outdoor environment have significant effect? (At a whole-group level)	Did the outdoor environment have significant effect on baseline sub-groups?	Did noise significantly associate with the outcome variable?	Did heart rate significantly associate with the outcome variable?	Did nature-level significantly mediate effects?	Did any demographic/individual differences variables significantly predict which environment would be most beneficial to the child?				
						Gender	**FSM**	**EAL**	**SDQ score**	**Indoor/ outdoor preference**
Choosing time attention peak focus)	No	Children with the lowest baseline attention had significantly longer peak focus outdoors *p* = .005 *d* = .455	Yes - a small positive correlation *p* = .030 r = .095	n/a	No	No	No	No	No	Children with an outdoor preference were 6.47 times more likely to have a longer peak focus outdoors *p* = .003
Antisocial behaviour	No	Children with the most antisocial behaviour indoors displayed significantly	No	No	No	No	No	No	No	No

		less antisocial behaviour outdoors *p* = .027 *r* = .30								
Prosocial behaviour	No	Children with the least prosocial behaviour indoors displayed significantly more prosocial behaviour outdoors *p* = < .001 *r* = .425	Yes - a small negative correlation in the indoor condition only *p* = .016 r = -.198	No	No	No	No	No	No	No
Self-directed peer play and talk (PPT)	Yes *p* = .030 *r* = .25	n/a	No	n/a	No	Boys were 2.88 times more likely than girls to engage in more PPT outdoors *p* = .048	No	No	No	No

Noise levels	Yes Carpet time *p* = .004 *d* = .455 Choosing time *p* = .001 *d* = 1.064	n/a	n/a	n/a	n/a	No	n/a	n/a	n/a	n/a
Resting heart rate	Yes *p* = <*.001* *d* = .512	n/a	Yes - a positive correlation in the indoor condition only *p* = <.001 *r* = .364	n/a	No	Girls were 9.4 times more likely than boys to have lower heart rates outdoors *p* = .013	Children eligible for FSM were slightly (.029) less likely to have lower resting heart rates in the outdoor condition *p* = .029	No	No	No

Note. n/a indicates that this specific analysis was not conducted for this outcome variable